Silicon Graphics Inc.

IRIS

IRIS

User's Guide

Version 2.1

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Preface

The IRIS is a powerful tool for interactive computer graphics. It is ideal for a variety of graphics applications, including CAD/CAM, simulation, VLSI design, and document preparation. The IRIS Graphics Library is the set of graphics commands that provides high- and low-level support for graphics on the IRIS. The *IRIS User's Guide* describes the Graphics Library and consists of four major sections.

I. The *Programming Guide* discusses the Graphics Library commands in a narrative style. The first chapter is an IRIS System Overview and the succeeding chapters are a topically organized discussion of the commands.

II. The *Window Manager* section describes *Multiple Exposure,* the window manager for the IRIS workstation.

III. The *Programming Examples* section contains ten programs which illustrate the use of various Graphics Library commands.

IV. The *Reference Manual* presents the Graphics Library commands in alphabetical order. Each entry contains a specification of the command in C, FORTRAN, and Pascal, a description of what the command does, and references to related commands.

The glossary defines graphics and IRIS-related terminology and the index identifies where key terms are discussed in the *Programming Guide.*

Finally, we welcome your comments and suggestions on the IRIS documentation. These will be a valuable source of ideas for improvement of the *IRIS User's Guide.* For this purpose, a postage-paid Reader Comment form is provided at the end of the guide.

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1. Introduction

The IRIS (Integrated Raster Imaging System) is a high-performance, high-resolution color computing system for 2D and 3D computer graphics. It provides a powerful set of graphics primitives in a combination of custom VLSI circuits, conventional hardware, firmware, and software.

The heart of the IRIS is a custom VLSI chip called the *Geometry Engine*™. A pipeline of ten or twelve Geometry Engines accepts points, vectors, polygons, characters, and curves in user-defined coordinate systems and transforms them to screen coordinates, with rotation, clipping, and scaling. In addition to the Geometry Pipeline, an IRIS system consists of: a general purpose microprocessor, a raster subsystem, a high-resolution color monitor, a keyboard, and graphics input devices.

1.1 IRIS System Overview

Conceptually, the graphics hardware of the IRIS is divided into three pipelined components, as shown in Figure 1.1: the applications/graphics processor, the Geometry Pipeline, and the raster subsystem. The applications/graphics processor runs the applications program, and controls the Geometry Pipeline and the raster subsystem. Graphics commands issued by the applications program either are sent immediately through the pipeline, or are compiled into *graphical objects* (display lists of graphics commands) which can be called later.

Graphics commands are expressed in 2D or 3D user-defined coordinates. These commands are sent through the Geometry Pipeline, which performs matrix transformations on the coordinates, clips the coordinates to normalized coordinates, and scales the transformed, clipped coordinates to screen coordinates. The output of the Geometry Pipeline is then sent to the raster subsystem. The raster subsystem fills in the pixels between the endpoints of the lines, fills in the interiors of polygons, converts character codes into bit-mapped characters, and performs shading, depth-cueing, and hidden surface removal. A color value for each pixel is stored in the system's *bitplanes*. The values contained in the bitplanes are then used to display an image on the monitor.

1.2 The Graphics Library

The IRIS Graphics Library is a set of graphics and utility commands that provide high- and low-level support for graphics on the IRIS. The IRIS system software is written in C, but the commands in the Graphics Library are callable in C, FOR-

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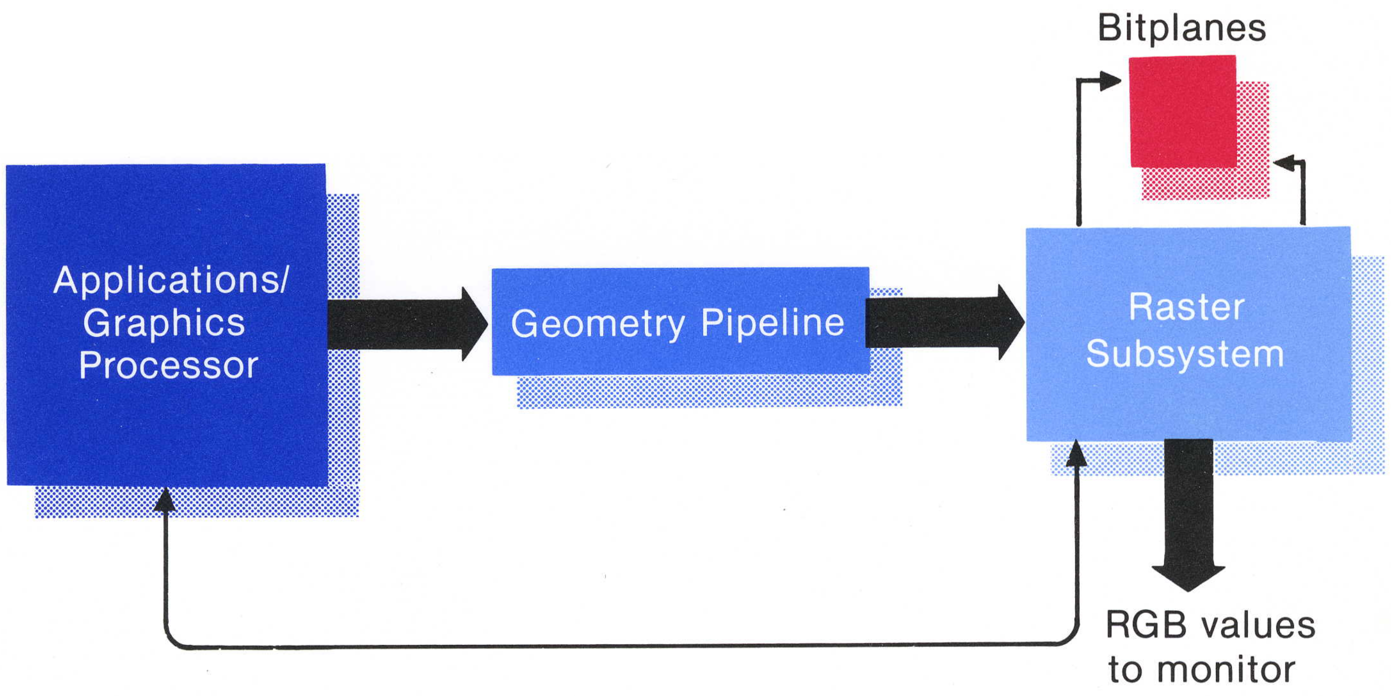


Figure 1.1

The IRIS consists of three subsystems: the **Applications/Graphics Processor**, the **Geometry Pipeline**, and the **Raster Subsystem**.

TRAN, and Pascal. The graphics commands can be broken into the following categories:

- *Global state* commands initialize the hardware and control global state variables.
- *Primitive drawing* commands draw points, lines, polygons, circles, arcs, and text strings on the screen.
- *Drawing attribute* commands select characteristics for drawing lines, filling polygons, and writing text strings.
- *Coordinate transformation* commands perform manipulations on coordinate systems, including mapping user-defined coordinate systems to screen coordinate systems.
- *Display mode and color* commands determine how the bitplane image memory is used and how objects are colored on the screen.
- *Input/output* commands initialize and read input/output devices.
- *Object creation and editing* commands provide the means to create hierarchical structures of graphics commands.
- *Picking and selecting* commands identify the commands that draw to a specified area of the screen.
- *Geometry Pipeline feedback* commands provide access to the computing capabilities of the geometry hardware.
- *Curve and surface* commands draw complex curved lines and surfaces.
- *Hidden surface* commands activate z-buffer mode, in which hidden lines and surfaces are removed from an image, and backface mode, in which backfacing polygons are removed from an image.
- *Shading* commands draw Gouraud-shaded polygons.
- *Depth-cue* commands draw points, lines, curves, and surfaces with intensities that vary as a function of depth.
- *Textport* commands allocate an area of the screen for writing text.

Each of the above categories is discussed in a separate chapter of the Programming Guide. Additional material is covered in the appendices:

- Appendix A contains header files for IRIS programs.
- Appendix B shows the computations performed by the Geometry Engines to transform, clip, and scale coordinate data.
- Appendix C gives the transformation matrices for the coordinate transformation commands in the Graphics Library.
- Appendix D discusses a feedback parser which simplifies the use of the Geometry Engines in feedback mode.

1.3 Documentation Conventions

The IRIS Graphics Library is accessible from three programming languages: C, FORTRAN, and Pascal. Specifications for the commands in the library are separated from the text by horizontal lines. The C specification is given first, the FORTRAN second, and the Pascal last. For example,

```
move(x, y, z)
Coord x, y, z;

subroutine move(x, y, z)
real x, y, z

procedure move(x, y, z: Coord);
```

Each command has a root name, like `move`. The default world space is 3D with floating-point coordinates. Suffixes are added to some commands to indicate 2D, integer (24 bits), and short integer (16 bits) arguments. Here are examples of the `move` variations:

```
move (1.0, 2.0, 3.0)   move2(1.0, 2.0)
movei (1, 2, 3)        move2i(1, 2)
moves(1, 2, 3)         move2s(1, 2)
```

The command names are unique to six characters to conform to standard FORTRAN naming conventions. Commands are referred to by their full C or Pascal name in the text.

While FORTRAN programs are constrained to a small set of predefined data types, both C and Pascal allow user-defined data types. Data types have been defined wherever it improves readability and reliability of the code. Appendix A gives the data type definitions used for the C and Pascal libraries.

Most important constants have been given symbolic names, such as XMAXSCREEN. Their values can be found in Appendix A. Other constants are often given in hexidecimal. The C syntax is used: the hexidecimal digits are preceded by "0x".

Sample programs are written in C, with the objective of making the programs clear rather than efficient. FORTRAN versions of the following programs have also been included in the text: the picking example in Chapter 9, the curve and the surface patch examples in Chapter 11, and examples #2 and #7 in the Programming Examples section.

2. Global State Commands

This chapter tells how to initialize an IRIS program, exit an IRIS program, and control the global state variables.

2.1 Initialization

The first Graphics Library command in every IRIS program is `ginit` or `gbegin`. These commands initialize the hardware, allocate memory for symbol tables and display list objects, and set up default values for global state variables. They have no arguments and should be called only once (before any other library command).

```
ginit()

subroutine ginit

procedure ginit;
```

`gbegin` performs all the same tasks as `ginit`, except it does not alter the color map.

```
gbegin()

subroutine gbegin

procedure gbegin;
```

State Variable	Initial Value	Section #
available bitplanes	all bitplanes[1]	6.1
backface mode	off	12.2
color	undefined	6.3
color map mode	one map	6.2
cursor	0 (arrow)[2]	6.4
depthcue mode	off	13.2
display mode	single buffer	6.1
font	0 [3]	5.3
linestyle	0 (solid)	5.1
linestyle backup	off	5.1
linestyle repeat	1	5.1
linewidth	1 pixel	5.1
monitor type	monitor supplied[4]	2.1
pattern	0 (solid)	5.2
picking size	10×10 pixels	9.2
reset linestyle	on	5.1
RGB color	undefined	6.3
RGB writemask	undefined	6.3
shaderange	0,7,0,1023	13.2
viewport	entire screen	4.4
writemask	all planes enabled[1]	6.3
zbuffer mode	off	12.1

Table 2.1: Initial values of global state variables

(1) If there are more than three bitplane boards installed, available planes = twelve.

(2) The color and writemask of the cursor are set to 1.

(3) Rasterfont 0 is a Helvetica-like font.

(4) A PROM on the graphics processor tells the IRIS which monitor it has.

Index	Name	RGB Value		
		Red	*Green*	*Blue*
0	BLACK	0	0	0
1	RED	255	0	0
2	GREEN	0	255	0
3	YELLOW	255	255	0
4	BLUE	0	0	255
5	MAGENTA	255	0	255
6	CYAN	0	255	255
7	WHITE	255	255	255
all others	unnamed	undefined		

Table 2.2: Initial color map values

greset returns the global state variables to their initial values, and can be called at any time. The global state variables are listed in Table 2.1. The color map is initialized by **greset** to the values shown in Table 2.2. **greset** also performs the following tasks (which are discussed in more detail throughout the Programming Guide):

- sets up a two-dimensional orthographic projection transformation that maps user-defined coordinates to the entire area of the screen (see Section 4.3);
- turns on the cursor and ties it to MOUSEX and MOUSEY (see Sections 6.4 and 7.3);
- unqueues each button, each valuator, and the keyboard (see Chapter 7);
- sets each button to FALSE (see Chapter 7);
- sets each valuator (except MOUSEY) to XMAXSCREEN/2, with a range of 0 to XMAXSCREEN (see Chapter 7);
- sets MOUSEY to YMAXSCREEN/2, with range 0 to YMAXSCREEN (see Chapter 7).

```
greset()

subroutine greset

procedure greset;
```

When the IRIS is used as a terminal, most graphics commands are buffered at the host by the communication software for efficient block transfer of data from the host to the IRIS. **gflush** causes all buffered yet untransmitted graphics data to be delivered to the IRIS. Certain graphics commands (notably those which return values) cause the host buffer to be flushed when they are executed. On the IRIS workstation, **gflush** does nothing.

```
gflush()

subroutine gflush

procedure gflush;
```

The final graphics command in an IRIS program is **gexit**. **gexit** flushes communication buffers and waits for the graphics pipeline to empty.

```
gexit()

subroutine gexit

procedure gexit;
```

The **setmonitor** command selects one of three types of monitors: HZ30 = 30hz interlaced, HZ60 = 60hz non-interlaced, and NTSC = NTSC (television standard encoding).

```
setmonitor(type)
short type;

subroutine setmon(type)
integer*4 type

procedure setmonitor(type: Short);
```

The **getmonitor** command returns the monitor type currently selected.

```
long getmonitor()

integer*4 function getmon()

function getmonitor: longint;
```

2.2 Saving Global State

The pushattributes command saves the current global state. The IRIS maintains a stack of attributes, and pushattributes copies each of the following attributes onto the stack: color or RGB color, writemask or RGB writemask, font, linestyle, linestyle backup, reset linestyle, linewidth, pattern, front and back buffers. These attributes are discussed in Chapters 5 and 6.

```
pushattributes()

subroutine pushat

procedure pushattributes;
```

popattributes restores the most recently saved values of the global state variables.

```
popattributes()

subroutine popatt

procedure popattributes;
```

3. Drawing Primitives

The IRIS Graphics Library includes commands for drawing points, lines, rectangles, polygons, circles, arcs, curves, and surfaces. It also includes commands for shading surfaces, for drawing text strings, and for writing and reading pixels. These commands take positioning arguments that may be integers (24 bits), short integers (16 bits), or floating-point numbers. Points, lines, polygons, and text can be positioned in two or three dimensions. Rectangles, circles, and arcs are defined in 2D, but can be translated to 3D using the modeling commands described in Chapter 4. Curves are always specified in 3D, although the z coordinate can be zero. Surface patches are specified in 3D.

3.1 Current Drawing Positions

The IRIS maintains two current drawing positions which determine where drawing takes place when a drawing command is executed.

The *current graphics position* is specified in 3D with floating-point coordinates and is updated by all drawing commands, except text, pixel, and clear commands. The current graphics position has meaning during streams of **move**, **draw**, and **pnt** commands. These commands can be interwoven with attribute-setting commands. (See Chapters 5 and 6 for a discussion of attributes.) Most other commands leave the graphics position undefined.

The *current character position* is specified in 2D with screen coordinates and has meaning during streams of **cmov**, **charstr**, and the four routines that read and write pixels. In general, only the attribute commands leave the character position intact.

The **getgpos** command returns the current graphics position, after transformation and before clipping and scaling. (The fourth coordinate, **fw**, is used for clipping and perspective division.)

```
getgpos(fx, fy, fz, fw)
Coord *fx, *fy, *fz, *fw;

subroutine getgpo(fx, fy, fz, fw)
real fx, fy, fz, fw

procedure getgpos(var fx, fy, fz, fw: Coord);
```

The getcpos command returns the current character position in screen coordinates.

```
getcpos(ix, iy)
Screencoord *ix, *iy;

subroutine getcpo(ix, iy)
integer*2 ix, iy

procedure getcpos(var ix, iy: Screencord);
```

3.2 Clearing the Viewport

The clear command sets the screen area within the current viewport to the current color using the current writemask and texture. (See Chapter 4 for a discussion of viewports and Chapters 5 and 6 for descriptions of the color, writemask, and texture attributes.) clear leaves the current graphics position and the current character position undefined.

```
clear()

subroutine clear

procedure clear;
```

3.3 Points

The pnt command draws a point. If the point is visible on the screen, it is shown as one pixel using the current color. pnt updates the current graphics position to its specified location.

```
pnt(x, y, z)
Coord x, y, z;

subroutine pnt(x, y, z)
real x, y, z

procedure pnt(x, y, z: Coord);
```

The following program draws 100 points in a square area of the screen:

```
#include "gl.h"

main()
{
        int i,j;
        ginit();
        cursoff(); /* turn off cursor so it doesn't interfere with drawing */
        color(BLACK); /* make BLACK the current drawing color */
        clear(); /* clear the screen (to black) */
        color(BLUE); /* make BLUE the current drawing color */

        for (i=0; i<10; i=i+1) {
                for (j=0; j<10; j=j+1)
                        pnti(i*5,j*5,0);
                }
        sleep(5);
        gexit();
}
```

3.4 Lines

The `move` and `draw` commands draw lines. The `move` command sets the current graphics position to the point specified by its arguments.

```
move(x, y, z)
Coord x, y, z;

subroutine move(x, y, z)
real x, y, z

procedure move(x, y, z: Coord);
```

The **draw** command draws a line from the current graphics position to the point specified by its arguments. The appearance of the line is determined by the current linestyle, linewidth, linestyle repeat, linestyle backup, color, and writemask (see Chapters 5 and 6). **draw** updates the current graphics position to the point specified by its arguments.

```
draw(x, y, z)
Coord x, y, z;

subroutine draw(x, y, z)
real x, y, z

procedure draw(x, y, z: Coord);
```

The following program draws a blue box on the screen using **move** and **draw** commands. For simplicity, a 2D integer world space is assumed.

```
#include "gl.h"

main()
{
    ginit();
    cursoff();
    color(BLACK);
    clear();
    color(BLUE);

    move2i(200,200);
    draw2i(200,300);
    draw2i(300,300);
    draw2i(300,200);
    draw2i(200,200);
    sleep(10);  /* sleep for ten seconds before returning
```

```
                    to textport */
        gexit();
    }
```

Relative drawing

The *relative drawing* commands interpret their arguments using the current graphics position as an origin. For example, the command

```
rmv(a,b,c)
```

changes the current graphics position from (x,y,z) to (x+a,y+b,z+c). The command

```
rdr(a,b,c)
```

draws a line from the current graphics position (x,y,z) to (x+a,y+b,z+c), and sets the current graphics position to (x+a,y+b,z+c).

```
rmv(dx, dy, dz)
Coord dx, dy, dz;

subroutine rmv(dx, dy, dz)
real dx, dy, dz

procedure rmv(dx, dy, dz: Coord);
```

```
rdr(dx, dy, dz)
Coord dx, dy, dz;

subroutine rdr(dx, dy, dz)
real dx, dy, dz

procedure rdr(dx, dy, dz: Coord);
```

3.5 Rectangles

A rectangle is determined by two points specifying opposite corners. The sides of the rectangle are parallel to the x and y axes; the z coordinate is zero. **rect** outlines a rectangle and **rectf** draws a filled rectangle. Since a rectangle is a two-dimensional shape, these commands take only 2D arguments, and set z to zero.

`rect` takes four arguments: `x1`, `y1`, `x2`, and `y2`. As shown in Figure 3.1, a rectangle is outlined by four line segments using the current linestyle, linewidth, linestyle repeat, linestyle backup, color, and writemask.

```
rect(x1, y1, x2, y2)
Coord x1, y1, x2, y2;

subroutine rect(x1, y1, x2, y2)
real x1, y1, x2, y2

procedure rect(x1, y1, x2, y2: Coord);
```

`rectf` takes the same arguments as `rect` and produces a filled rectangular region. The currently selected texture pattern, color, and writemask are used. An example is shown in Figure 3.1.

Both `rect` and `rectf` set the current graphics position to `(x1, y1)`.

```
rectf(x1, y1, x2, y2)
Coord x1, y1, x2, y2;

subroutine rectf(x1, y1, x2, y2)
real x1, y1, x2, y2

procedure rectf(x1, y1, x2, y2: Coord);
```

The `rectcopy` command copies a rectangular array of pixels defined in screen coordinates to another position on the screen. The lower left corner of the new rectangle is defined by `newx` and `newy`.

```
rectcopy(x1, y1, x2, y2, newx, newy)
Screencoord x1, y1, x2, y2, newx, newy;

subroutine rectco(x1, y1, x2, y2, newx, newy)
integer*4 x1, y1, x2, y2, newx, newy

procedure rectcopy(x1, y1, x2, y2, newx, newy: Screencoord);
```

3.6 Polygons

poly outlines a polygonal area; polf fills a polygonal area. A polygon is represented by an array of points. The first and last points are automatically connected to close the polygon.

poly takes two arguments: the number of points in the polygon and an array of coordinates. Points can be expressed in 2D or 3D, using integers, shorts, or floating-point numbers. The polygon is drawn using the current linestyle, linestyle repeat, linestyle backup, linewidth, color, and writemask.

```
poly(n, parray)
long n;
Coord parray[][3];

subroutine poly(n, parray)
integer*4 n
real parray(3,n)

procedure poly(n: longint; var parray: Coord3array);
```

polf takes the same arguments as poly, but fills the polygon using the current texture pattern, color, and writemask. All filled polygons must be convex. Although no errors are reported if concave polygons are specified, they produce unpredictable results.

```
polf(n, parray)
long n;
Coord parray[][3];

subroutine polf(n, parray)
integer*4 n
real parray(3,n)

procedure polf(n: longint; var parray: Coord3array);
```

Figure 3.1 shows a polygon drawn with both poly and polf. A solid linestyle and solid texture pattern are shown.

poly and polf set the current graphics position to the first point in array.

Filled polygons can also be drawn by specifying one vertex at a time. The pmv command specifies the first point in a polygon. A sequence of pdr commands

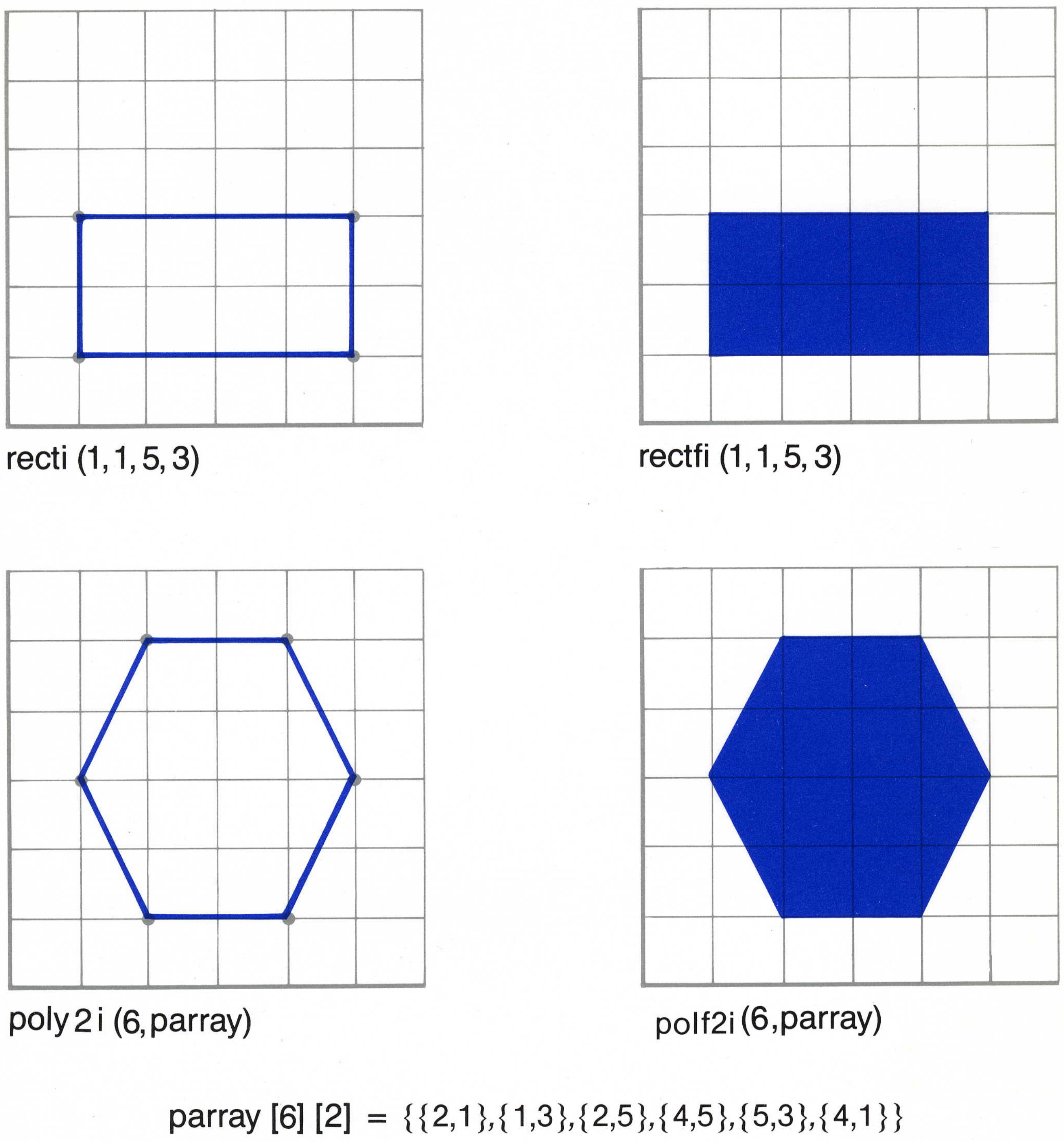


Figure 3.1

Rectangles are specified by opposite corners. A polygon is defined by an array of points. Both rectangles and polygons can be drawn as outlined or filled areas.

then draws lines to each of the subsequent points in the polygon (using the current linestyle, linewidth, linestyle repeat, linestyle backup, color, and writemask). The `pclos` command connects the last point with the first. The results of the `pmv`, `pdr`, and `pclos` commands are undefined if the polygon is not convex.

```
pmv(x, y, z)
Coord x, y, z;

subroutine pmv(x, y, z)
real x, y, z

procedure pmv(x, y, z: Coord);
```

```
pdr(x, y, z)
Coord x, y, z;

subroutine pdr(x, y, z)
real x, y, z

procedure pdr(x, y, z: Coord);
```

The `rpmv` command specifies the first point in a polygon using the current graphics position as an origin. The `rpdr` command draws a line to a point in the polygon using the previous point (the current graphics position) as an origin.

```
rpmv(dx, dy, dz)
Coord dx, dy, dz;

subroutine rpmv(dx, dy, dz)
real dx, dy, dz

procedure rpmv(dx, dy, dz: Coord);
```

```
rpdr(dx, dy, dz)
Coord dx, dy, dz;

subroutine rpdr(dx, dy, dz)
real dx, dy, dz

procedure rpdr(dx, dy, dz: Coord);
```

After a sequence of `pdrw` or `rpdr` commands, the `pclos` command connects the last point in the polygon with the first.

```
pclos()

subroutine pclos

procedure pclos;
```

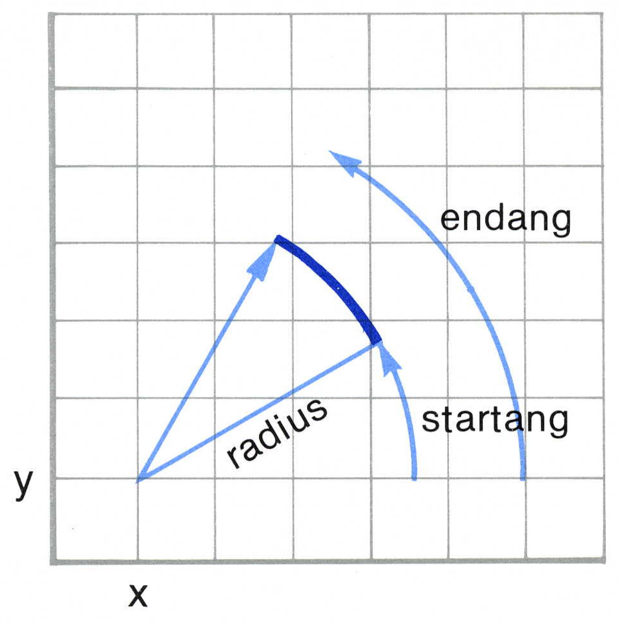
3.7 Circles and Arcs

`circ` and `circf` draw outlined and filled circles. A circle is defined by a center point and a radius, in the x-y plane, with $z = 0$. Circles are drawn using the current linestyle, linewidth, linestyle repeat, linestyle backup, color, and writemask.

```
circ(x, y, radius)
Coord x, y, radius;

subroutine circ(x, y, radius)
real x, y, radius

procedure circ(x, y, radius: Coord);
```

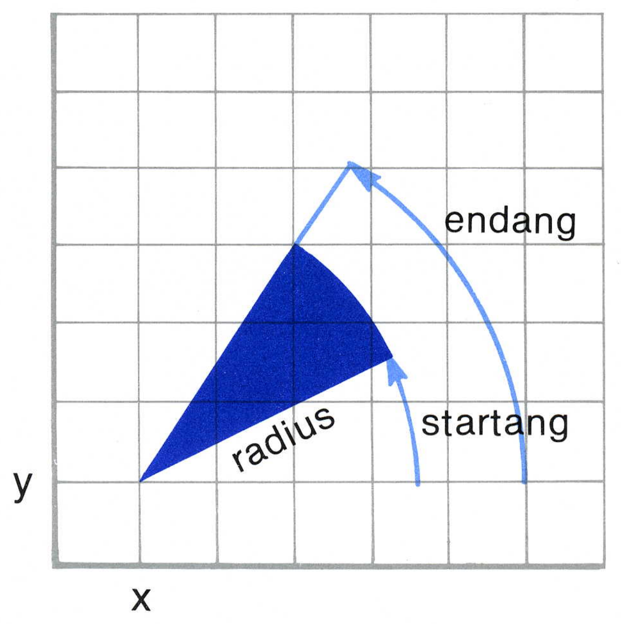
Filled circles are drawn with `circf`. The current color, texture pattern, and writemask are used to fill the circle with center `(x,y)` and radius `radius`. `circ` and `circf` set the current graphics position to `(x+radius, y)`.

(a)



arci(x,y,radius,startang,endang)

(b)



arcfi(x,y,radius,startang,endang)

Figure 3.2
Circular arcs are defined by a center point, radius, start angle, and end angle. They are drawn counterclockwise, with angles measured from the **x**-axis.

```
circf(x, y, radius)
Coord x, y, radius;

subroutine circf(x, y, radius)
real x, y, radius

procedure circf(x, y, radius: Coord);
```

`arc` and `arcf` draw circular arcs. Arcs are defined by a center point, a radius, a starting angle, and an ending angle. The angles are measured from the x axis and are specified in integral *tenths* of degrees; positive angles describe counter-clockwise rotations. The arc is drawn using the current color, linestyle, linestyle repeat, linestyle backup, linewidth, and writemask. Figure 3.2 shows an arc and the parameters that define it.

```
arc(x, y, radius, startang, endang)
Coord x, y, radius;
Angle startang, endang;

subroutine arc(x, y, radius, stang, endang)
real x, y, radius
integer*4 stang, endang

procedure arc(x, y, radius: Coord; startang, endang: Angle);
```

`arcf` produces filled arcs. The current texture pattern, color, and writemask are used. An example is shown in Figure 3.2. `arc` and `arcf` set the current graphics position to the endpoint of the arc.

```
arcf(x, y, radius, startang, endang)
Coord x, y, radius;
Angle startang, endang;

subroutine arcf(x, y, radius, stang, endang)
real x, y, radius
integer*4 stang, endang

procedure arcf(x, y, radius: Coord; startang, endang: Angle);
```

3.8 Text

The current character position (see Section 3.1) determines where text is drawn on the screen. The `cmov` command sets the current character position. Its arguments specify a point in 2D or 3D, which is transformed into screen coordinates and becomes the new character position.

```
cmov(x, y, z)
Coord x, y, z;

subroutine cmov(x, y, z)
real x, y, z

procedure cmov(x, y, z: Coord);
```

`charstr` draws a string of characters. The origin of the first character in the string is placed at the current character position. After the string is drawn, the current character position is updated to the pixel to the right of the last character in the string. (Character strings are null-terminated in C.) The text string is drawn in the currently selected font and color. (See Section 5.3 for a discussion of fonts.)

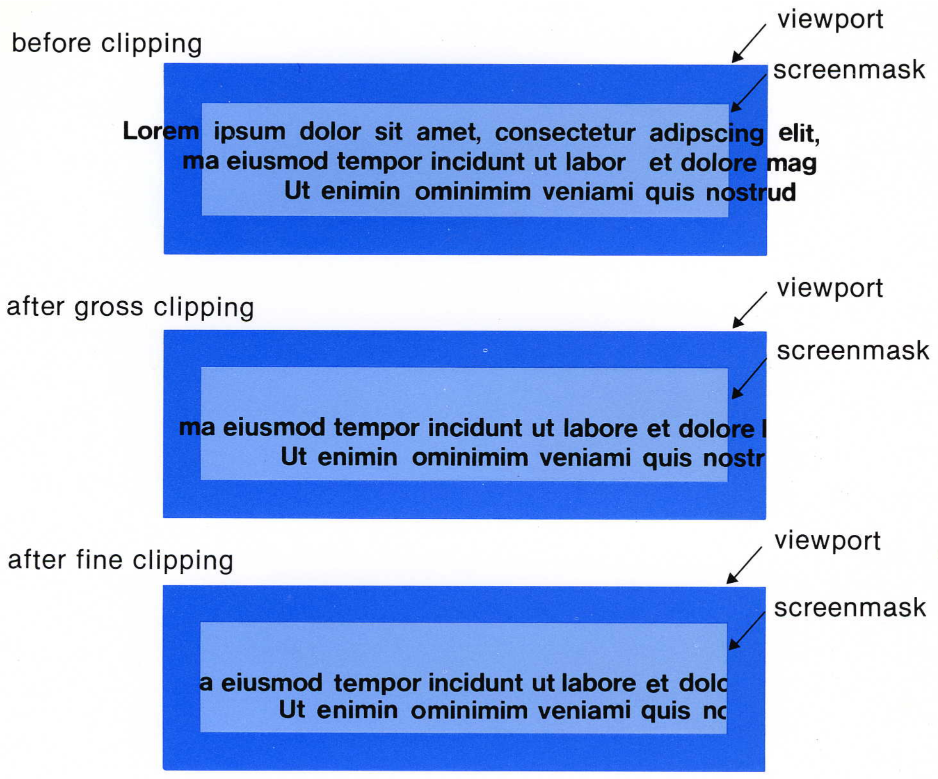

before clipping
viewport
screenmask
Lorem ipsum dolor sit amet, consectetur adipscing elit,
ma eiusmod tempor incidunt ut labor et dolore mag
Ut enimin ominimim veniami quis nostrud
after gross clipping
viewport
screenmask
ma eiusmod tempor incidunt ut labore et dolore l
Ut enimin ominimim veniami quis nostr
after fine clipping
viewport
screenmask
a eiusmod tempor incidunt ut labore et dolc
Ut enimin ominimim veniami quis nc

Figure 3.3

Gross clipping removes all strings that start outside the viewport. Fine clipping trims individual characters to the screenmask.

```
charstr(str)
String str;

subroutine charst(str, length)
character*(*) str
integer*4 length

procedure charstr(str: pstring);
```

If the origin of a character string lies outside the viewport, none of the characters in the string are drawn. If the origin is inside the viewport, however, the characters will be individually clipped to the screenmask. (Viewports and screenmasks are discussed in the next chapter.) Although the screenmask is normally set equal to the viewport, it can be set smaller than the viewport to enable two kinds of clipping. As shown in Figure 3.3, *gross clipping* removes all strings that start outside the viewport. *Fine clipping* trims individual characters to the screenmask.

The following example draws two lines of text. The program assumes the currently selected font is less than twelve pixels high.

```
#include "gl.h"

main()
{
    ginit();
    cursoff(); /* turn the cursor off so it won't interfere
                  with the text */
    color(BLACK);
    clear();
    color(RED);
    cmov2i(300,380);
    charstr("The first line is drawn ");
    charstr("in two parts. ");
    cmov2i(300, 368);
    charstr("This line is 12 pixels lower. ");
    sleep(5); /* pause for five seconds before returning
                 to textport */
    curson(); /* turn the cursor back on */
    gexit();
}
```

3.9 Writing and Reading Pixels

The `writepixels` and `writeRGB` commands paint one or more pixels on the screen. The commands specify the number of pixels to paint and a color for each pixel. The current character position is the starting location; it is updated to the pixel that follows the last one painted. The current character position becomes undefined if the next pixel position is greater than XMAXSCREEN. Pixels are painted from left to right and are clipped to the current screenmask (see Chapter 4). These commands do not automatically wrap from one line to the next.

`writepixels` supplies the number of pixels to be painted and a color index for each pixel. (See Chapter 6 for an explanation of color maps.)

```
writepixels(n, colors)
short n;
Colorindex colors[];

subroutine writep(n, colors)
integer*4 n
integer*2 colors(n)

procedure writepixels(n: Short; var colors: Colorarray);
```

`writeRGB` supplies a 24-bit RGB value (eight bits each for red, green, and blue) for each pixel. It is written directly into the bitplanes. (See Chapter 6 for an explanation of RGB mode.)

```
writeRGB(n, red, green, blue)
short n;
RGBvalue red[], green[], blue[];

subroutine writeR(n, red, green, blue)
integer*4 n
character*(*) red, green, blue

procedure writeRGB(n: Short; var red, green, blue: RGBarray);
```

It is also possible to read pixel values from image memory. `readpixels` attempts to read up to `n` pixel values, starting from the current character position and moving along a single scan line (constant y) in the direction of increasing x. `readpixels` returns the number of pixels actually read. The values of pixels read outside the current viewport are undefined. The current character position is updated to the pixel to the right of the last one read, or is undefined if the new position is outside the viewport. `readpixels` will not wrap to the next line of pixels when the edge of the screen is encountered.

```
long readpixels(n, colors)
short n;
Colorindex colors[];

integer*4 function readpi(n, colors)
integer*4 n
integer*2 colors(n)

function readpixels(n: Short; var colors: Colorarray): longint;
```

`readRGB` attempts to read up to `n` pixel values from the bitplanes. They are read into the `red`, `green`, and `blue` arrays starting from the current character position along a single scan line (constant y) in the direction of increasing x. `readRGB` returns the number of pixels actually read. The values of pixels read outside the current viewport are undefined. The current character position is updated to the pixel to the right of the last one read, or is undefined if the new position is outside the viewport.

```
long readRGB(n, red, green, blue)
short n;
RGBvalue red[], green[], blue[];

integer*4 function readRG(n, red, green, blue)
integer*4 n
character*(*) red, green, blue

function readRGB(n: Short; var red, green, blue: RGBarray): longint;
```

4. Coordinate Transformations

Chapter 3 discussed commands for drawing points, lines, circles, arcs, rectangles, and polygons. These commands are the primitives for drawing images. However, they can also be thought of as primitives for building models. For example, a sequence of drawing commands can be used to define a 3-dimensional shape. Such a sequence of commands is called a *graphical object*, and can be used to define a geometric model. Graphical objects can be manipulated as single entities – they can be moved, scaled, rotated, or combined with other objects into more complex objects. The coordinate transformation commands discussed in this chapter perform those manipulations. In addition, they map objects onto the screen so they can be displayed.

The process of displaying images of complex models can be broken into two subprocesses:

- building and manipulating models, and
- projecting models onto the screen.

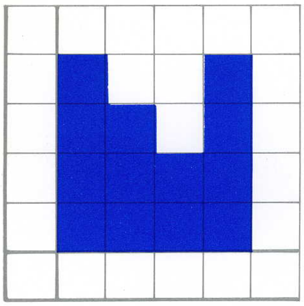
A model is built from graphical objects. It is convenient to define each object in terms of its own origin. For example, a planet might be drawn using the center of the planet as the origin for each drawing command in the object. An object is said to be defined in *object space* when a convenient point is chosen as the object's origin, and component parts are placed relative to it. Several objects may be combined to form a composite object by mapping their individual coordinate systems to a coordinate system based on a new origin. The new composite object and its subobjects are defined in the new object space.

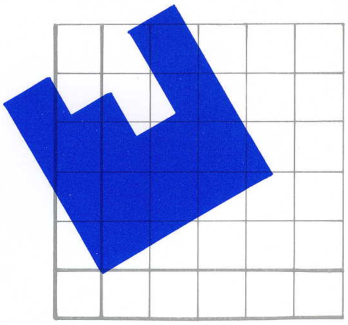
When a group of objects is to be displayed, it is defined in terms of one final object coordinate system, which is then called *world space*. In order to display the "world", a point of view must be specified. This point of view becomes the origin for a third coordinate system called *eye space*, and determines how the "world" is viewed. All the objects to be displayed are then defined in terms of the new coordinate system with origin at the view point.

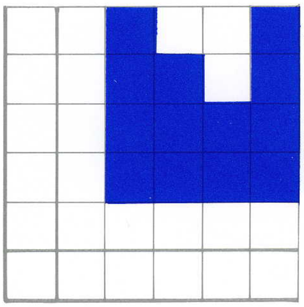
Finally, the eye-space coordinate system must be mapped to a two-dimensional coordinate system that can be projected on the screen. This coordinate system is called *screen space*, and its origin is the lower left corner of the image.

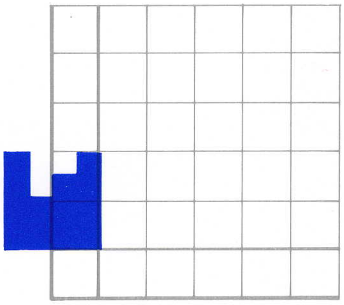
The coordinate transformation commands perform the mappings from object space to world space to eye space and finally to screen space. There are four types of transformation commands:

- *Modeling transformation commands* transform the coordinate systems of objects. These commands include `rotate`, `translate`, and `scale`.
- *Viewing transformation commands* specify a viewing position, and


(a) original object


(b) rotate (300.,'Z')


(c) translate (1.,1 .,0.)


(d) scale (–.5,.5,1.)

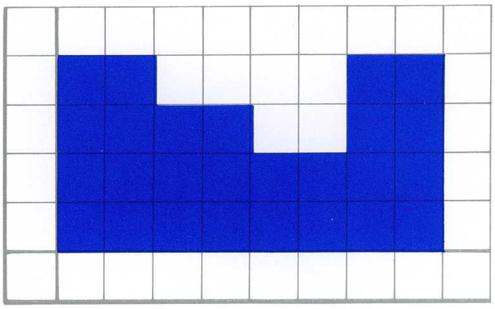

(e) scale (2.,1.,1.)

Figure 4.1
The modeling commands are *rotate, translate,* and *scale*. The object shown in (a) is rotated in (b), translated in (c), and scaled in (d) and (e).

transform a world coordinate system to an eye coordinate system. These commands include `polarview` and `lookat`.

- *Projection transformation commands* transform an eye coordinate system to a screen coordinate system. These commands include `perspective`, `window`, `ortho`, and `ortho2`.
- *Viewport commands* define a rectangular region of the screen for displaying an image (one screen coordinate system is transformed into another). These commands include `viewport` and `scrmask`.

After a coordinate transformation command is executed, all subsequent commands are interpreted through the new frame of reference. For example, if a `translate` command is executed, subsequent commands act on a translated coordinate system. If the `perspective` command has been executed, all subsequent objects will be projected on the screen with the specified perspective.

The coordinate transformation commands should be issued in the following order: a projection transformation command, a viewing transformation command, and finally any number of modeling commands. Each coordinate transformation is incorporated into the *current transformation matrix*, which reflects the cumulative effect of all the transformations. The coordinates of every drawing command are multiplied by the current transformation matrix. The current transformation matrix is the top matrix in a stack of eight 4x4 floating-point matrices. (The matrix stack can be extended in software to thirty-two matrices.) There are five commands for manipulating the matrix stack: `loadmatrix`, `getmatrix`, `multmatrix`, `pushmatrix`, and `popmatrix`.

4.1 Modeling Transformations

Each graphical object, or geometric model, is defined in its own coordinate system (object space). The entire object can be manipulated using the modeling transformation commands: `rotate`, `translate`, and `scale`. By combining or concatenating these primitives, more complex modeling transformations can be generated to express relationships between different parts of a complex object.

The `rotate` command specifies an angle and an axis of rotation. The angle is given in tenths of degrees according to the right-hand rule – as you look down the positive rotation axis to the origin, positive rotation is counterclockwise. The axis of rotation is defined by a character, either 'x', 'y', or 'z' (the character can be upper or lower case). For example, the object shown in Figure 4.1(a) is rotated 30 degrees with respect to the y-axis in Figure 4.1(b). All objects drawn after the `rotate` command is executed are rotated. `pushmatrix` and `popmatrix`, described later in this chapter, preserve and restore an unrotated world space.

```
rotate(a, axis)
Angle a;
char axis;

subroutine rotate(a, axis)
integer*4 a
character axis

procedure rotate(a: Angle; axis: char);
```

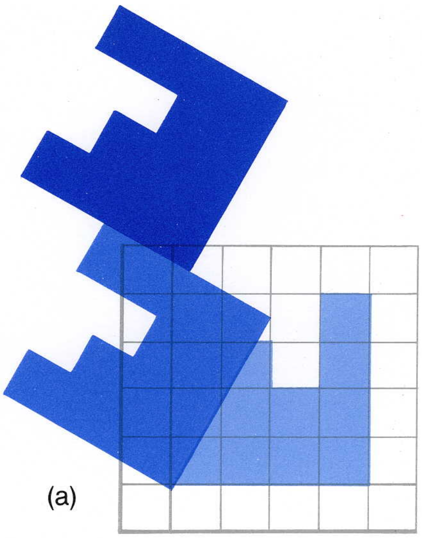
The `translate` command places the object space origin at a given world coordinate point. The object in Figure 4.1(a) is translated in Figure 4.1(c). All objects drawn after execution of the `translate` command will be translated. Again, `pushmatrix` and `popmatrix` may be used to limit the scope of the translation.

```
translate(x, y, z)
Coord x, y, z;

subroutine transl(x, y, z)
real x, y, z

procedure translate(x, y, z: Coord);
```

The `scale` command shrinks, expands, and mirrors objects. Its three arguments specify scaling in each of the three coordinate directions. Values with magnitude of 1 or more expand the object; values with magnitudes of less than 1 shrink it. Negative values cause mirroring.

All objects drawn after the `scale` command is executed are scaled; `pushmatrix` and `popmatrix` can be used to limit the scope of `scale`. The object shown in Figure 4.1(a) is shrunk to one quarter of its original size and mirrored about the y axis in Figure 4.1(d). It is scaled only in the x direction in Figure 4.1(e).

(a)



(b)

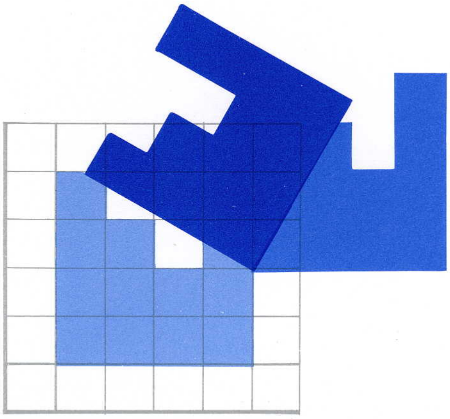


Figure 4.2

The modeling commands are not commutative. Frame (a) shows the rotated and translated object; in (b), the object has been translated and rotated.

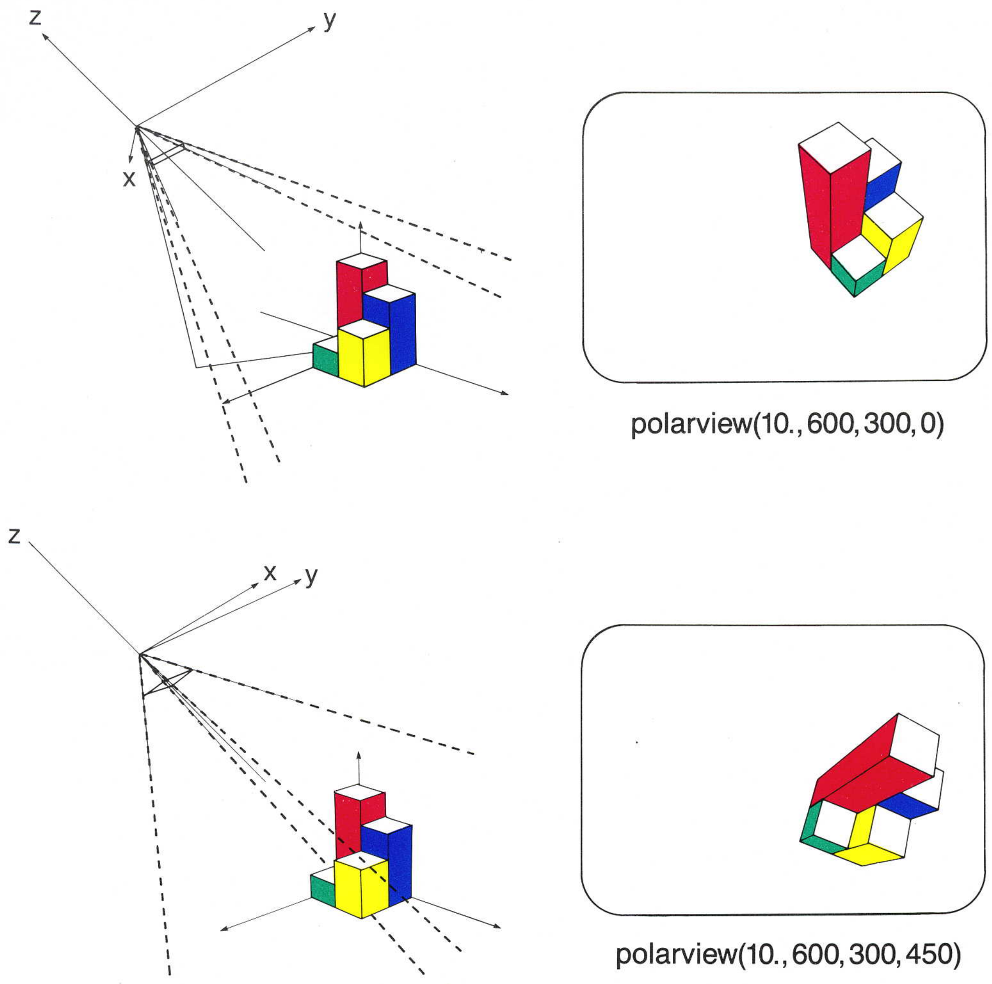


Figure 4.3
Polarview has four arguments: the viewing **distance** from the origin, an **incidence** angle measured from the **z**-axis in the **y-z** plane, an **azimuthal** angle measured from the **y**-axis in the **x-y** plane, and a **twist** around the line of sight. Each frame shows the viewpoint and viewed image as additional arguments to polarview are supplied.

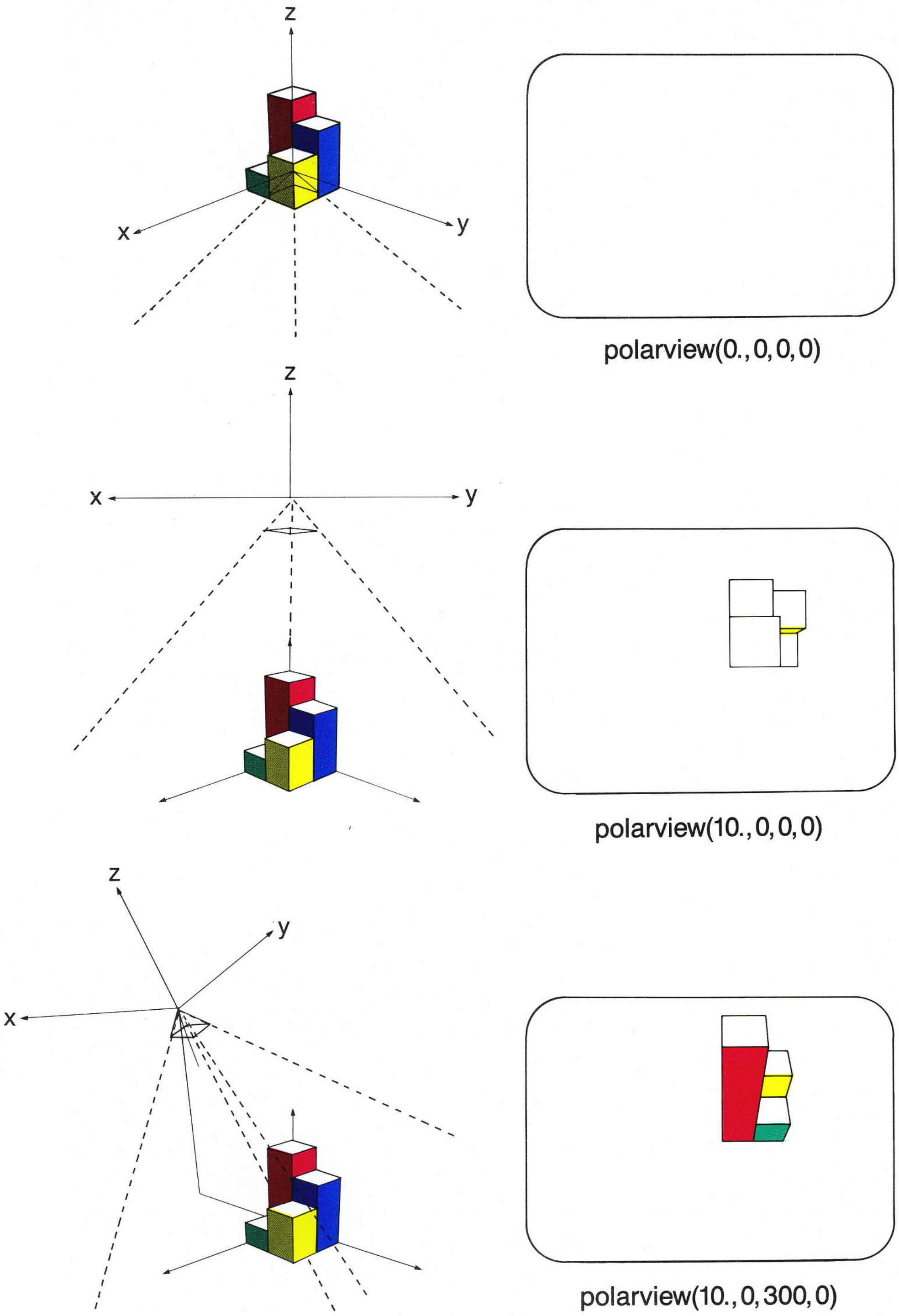

z
x
y
polarview(0.,0,0,0)
z
x
y
polarview(10.,0,0,0)
z
y
x
polarview(10.,0,300,0)

Figure 4.3

```
scale(x, y, z)
float x, y, z;

subroutine scale(x, y, z)
real x, y, z

procedure scale(x, y, z: real);
```

rotate, translate, and scale can be combined to produce more complicated transformations. The order in which these transformations are applied is important. Figure 4.2 shows two different orderings of translate and rotate, with different results.

4.2 Viewing Transformations

The viewing transformations place the viewer and the eye coordinate system in world space. In the process, they define the world coordinate system. The polarview and lookat commands define a right-handed world coordinate system with x to the right, y up, and z toward the viewer. All rotations are specified with integers in tenths of degrees. Rotations obey the right-hand rule. As the viewer looks down a positive axis to the origin, a positive rotation about an axis is counter-clockwise. Users may choose other orientations for the world space, and can form viewing transformations from the modeling commands described in the next section.

polarview and lookat specify points and directions of view. The eye is placed at the point of view and looks at the world coordinate system's origin. A viewing transformation command should always follow a projection command.

polarview defines the viewer's position in polar coordinates. The first three arguments, dist, azim, and inc, define a viewpoint. dist is the distance from the viewpoint to the world space origin. azim is the azimuthal angle in the x-y plane, measured from the y axis. inc is the incidence angle in the y-z plane, measured from the z axis. The line of sight is the line between the viewpoint and the world space origin. Twist rotates the viewpoint around the line of sight using the right-hand rule. All angles are specified in tenths of degrees and are integers. Figure 4.3 shows examples of polarview.

```
polarview(dist, azim, inc, twist)
Coord dist;
Angle azim, inc, twist;

subroutine polarv(dist, azim, inc, twist)
real dist
integer*4 azim, inc, twist

procedure polarview(dist: Coord; azim, inc, twist: Angle);
```

`lookat` specifies a viewpoint and a reference point on the line of sight in world coordinates. The viewpoint is at `(vx, vy, vz)` and the reference point at `(px, py, pz)`. These two points define the line of sight. `twist` measures right-handed rotation about the z axis in the eye coordinate system. Figure 4.4 illustrates `lookat`.

```
lookat(vx, vy, vz, px, py, pz, twist)
Coord vx, vy, vz, px, py, pz;
Angle twist;

subroutine lookat(vx, vy, vz, px, py, pz, twist)
real vx, vy, vz, px, py, pz
integer twist

procedure lookat(vx, vy, vz, px, py, pz: Coord; twist: Angle);
```

4.3 Projection Transformations

Projection transformations define the mapping from an eye-fixed coordinate system to the screen. The eye is placed in a right-handed system with the viewer at the origin looking down the negative z axis. Associated with each projection transformation is a viewport specifying a screen area to display the projected image.

The `perspective` and `window` commands specify perspective viewing pyramids into the world coordinate system and differ only in the method of defining the pyramid. The `ortho` command defines a 3D viewing rectangular parallelepiped and `ortho2` defines a 2D viewing rectangle for orthographic projections.

`perspective` defines the viewing pyramid by indicating the field-of-view angle `fovy` in the y direction of the eye coordinate system, the aspect ratio which determines the field of view in the x direction, and the location of the near and far

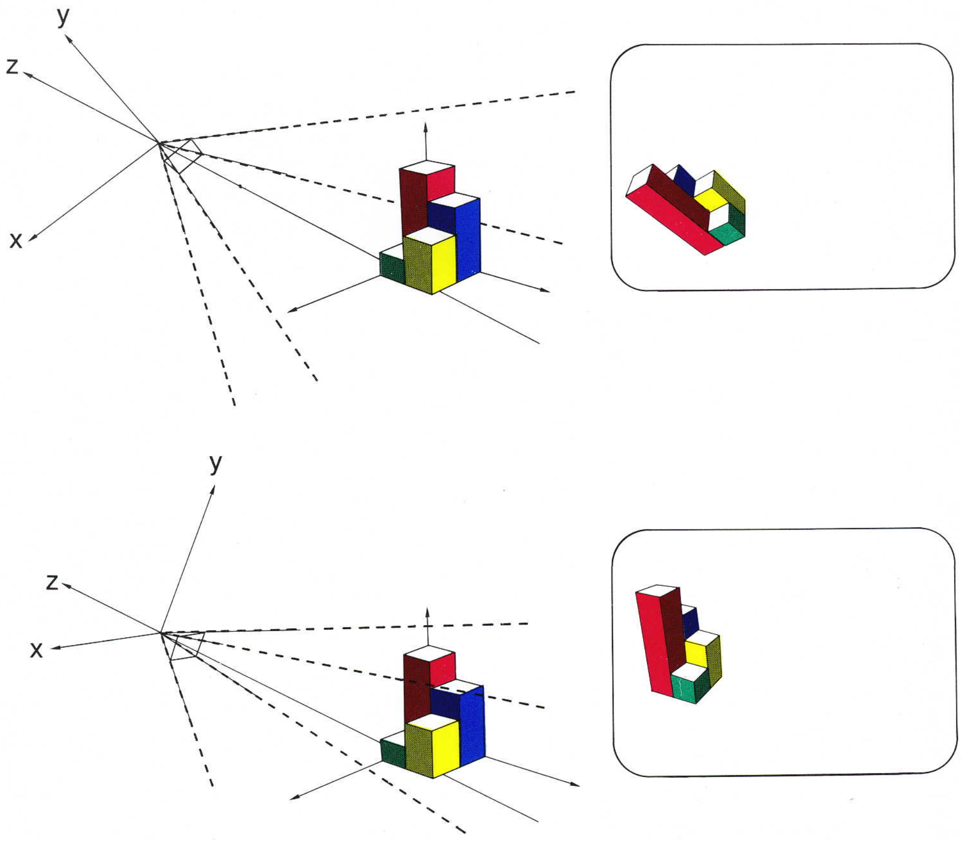


Figure 4.4
Lookat defines a viewpoint, a reference point along the line of sight, and a twist angle. The first pair of pictures shows the viewer and viewed image with no twist; twist is added to the second pair of frames.

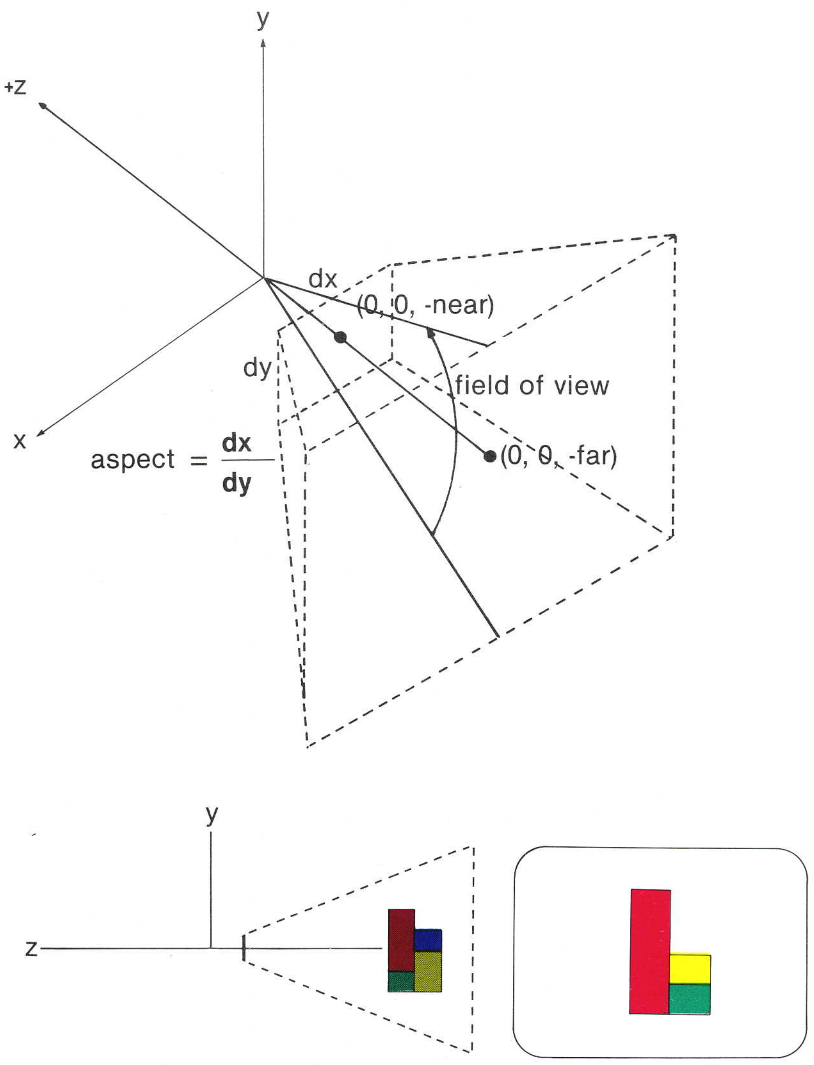


Figure 4.5
The *perspective* command defines a field of view, an aspect ratio, and near and far clipping planes.

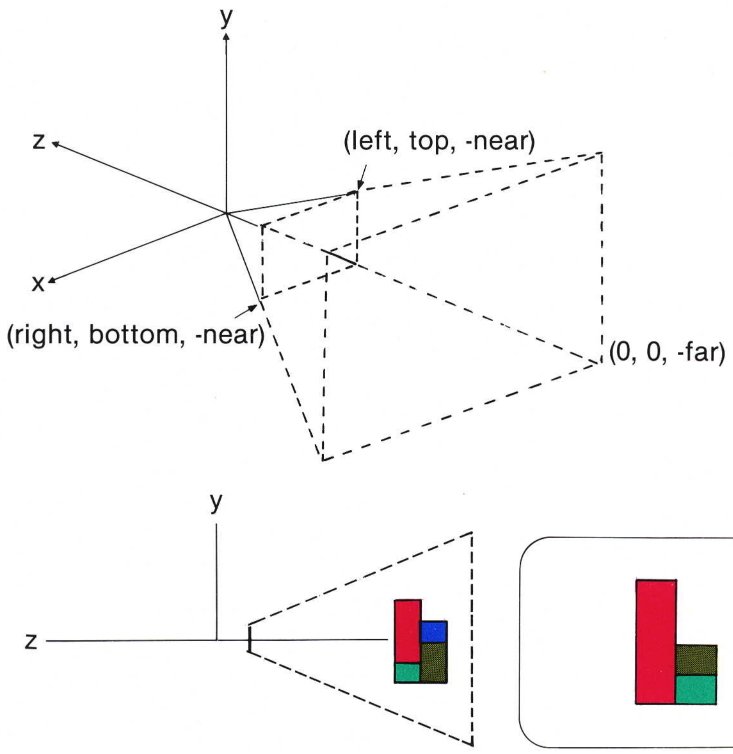


Figure 4.6

The *window* command defines a viewing window. A perspective view of the image is projected onto the window.

clipping planes in the z direction. The aspect ratio is given as a ratio of x to y. In general, the aspect ratio given in the `perspective` command should match the aspect ratio of the associated viewport. For example, `aspect` = 2 means the viewer sees twice as far in x as in y. If the viewport is also twice as wide as it is tall, the image is displayed without distortion. The arguments `near` and `far` are distances from the viewer to the near and far clipping planes, and are always positive. Figure 4.5 illustrates the `perspective` command.

```
perspective(fovy, aspect, near, far)
Angle fovy;
float aspect;
Coord near, far;

subroutine perspe(fovy, aspect, near, far)
integer*4 fovy
real aspect, near, far

procedure perspective(fovy: Angle; aspect: real; near, far: Coord);
```

`window` specifies the position and size of the rectangular viewing frustum closest to the eye (in the near clipping plane), and the location of the far clipping plane. The image is projected with perspective onto the screen. See Figure 4.6.

```
window(left, right, bottom, top, near, far)
Coord left, right, bottom, top, near, far;

subroutine window(left, right, bottom, top, near, far)
real left, right, bottom, top, near, far

procedure window(left, right, bottom, top, near, far: Coord);
```

`ortho` defines a box-shaped enclosure in the eye coordinate system. `left`, `right`, `bottom`, and `top` define the x and y clipping planes. `near` and `far` are distances along the line of sight and can be negative. In other words, the z clipping planes are located at z = -near and z = -far. Figure 4.7 shows an example of a 3D orthographic projection.

```
ortho(left, right, bottom, top, near, far)
Coord left, right, bottom, top, near, far;

subroutine ortho(left, right, bottom, top, near, far)
real left, right, bottom, top, near, far

procedure ortho(left, right, bottom, top, near, far: Coord);
```

`ortho2` defines a 2D clipping rectangle. When `ortho2` is used with 3D world coordinates, the z values are left unchanged.

```
ortho2(left, right, bottom, top)
Coord left, right, bottom, top;

subroutine ortho2(left, right, bottom, top)
real left, right, bottom, top

procedure ortho2(left, right, bottom, top: Coord);
```

4.4 Viewports

The area of the screen where an image is displayed is called a *viewport* and is specified in screen coordinates. The visible screen area is 1024 pixels wide and 768 pixels high. The arguments to the `viewport` command define a rectangular area on the screen by the left, right, bottom, and top coordinates.

```
viewport(left, right, bottom, top)
Screencoord left, right, bottom, top;

subroutine viewpo(left, right, bottom, top)
integer*4 left, right, bottom, top

procedure viewport(left, right, bottom, top: Screencoord);
```

The `getviewport` command returns the current viewport. The arguments to `getviewport` are the addresses of four memory locations. These will be assigned the left, right, bottom and top coordinates of the viewport.

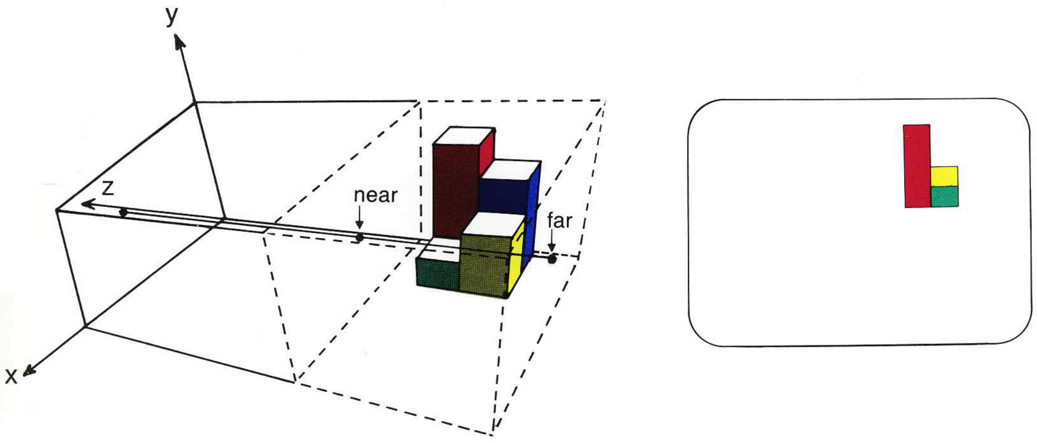


Figure 4.7

The *ortho* command defines a viewing window. An orthographic view of the image is projected onto the window.

```
getviewport(left, right, bottom, top)
Screencoord *left, *right, *bottom, *top;

subroutine getvie(left, right, bottom, top)
integer*2 left, right, bottom, top

procedure getviewport(var left, right, bottom, top: Screencoord);
```

A call to `viewport` sets both the viewport and the screenmask to the same area. A call to `scrmask` sets only the screenmask, which should be placed entirely within the viewport. Character strings that begin outside the viewport are clipped out; this is called *gross clipping*. Strings which begin inside the viewport but outside the screenmask are clipped to the screenmask. This is called *fine clipping*. For an illustration of character clipping, see Figure 3.3.

```
scrmask(left, right, bottom, top)
Screencoord left, right, bottom, top;

subroutine scrmas(left, right, bottom, top)
integer*4 left, right, bottom, top

procedure scrmask(left, right, bottom, top: Screencoord);
```

`getscrmask` returns the screen coordinates of the current screenmask in the arguments `left`, `right`, `bottom`, and `top`.

```
getscrmask(left, right, bottom, top)
Screencoord *left, *right, *bottom, *top;

subroutine getscr(left, right, bottom, top)
integer*2 left, right, bottom, top

procedure getscrmask(var left, right, bottom, top: Screencoord);
```

The IRIS maintains a stack of viewports and the top element in the stack is the current viewport. The `pushviewport` command duplicates the current viewport and pushes it on the stack.

```
pushviewport()

subroutine pushvi

procedure pushviewport;
```

The `popviewport` command pops the stack of viewports and sets the screenmask. The viewport on top of the stack is lost.

```
popviewport()

subroutine popvie

procedure popviewport;
```

4.5 User-Defined Transformations

A transformation is expressed as a 4x4 floating point matrix. Complex transformations can be built by concatenating a series of primitive ones. If *M*, *V*, and *P* are modeling, viewing, and projection transformations, then the transformation *S* that maps object space into screen space can be formulated as:

$$S = M\ V\ P$$

$$[\,x\ y\ z\ w\,]\ M\ V\ P = [x'\ y'\ z'\ w'\,]$$

The clipping boundaries are

$$x = \pm w\ ,\ y = \pm w\ ,\ \text{and}\ z = \pm w\ .$$

The resulting screen coordinates,

$$\frac{x}{w}\ ,\ \frac{y}{w}\ ,\ \text{and}\ \frac{z}{w}\ ,$$

are scaled to the current viewport.

The Geometry Pipeline maintains a hardware stack that can hold up to eight transformation matrices. (The stack can be extended in software to thirty-two matrices.) The matrix on top of the stack, the *current transformation matrix,* is applied to all coordinate data.

The Geometry Pipeline forms a complex transformation matrix by *pre-multiplying* the current matrix by each primitive transformation. The transformation S defined above is formed by executing coordinate transformation commands in reverse order: first projection commands, then viewing commands, and finally modeling commands. Note that P is loaded onto the matrix stack, while both V and M pre-multiply the current matrix.

The projection, viewing, and modeling commands above provide a high-level interface that manages the hardware matrix stack. Additional commands allow the user direct control over the stack. These commands load or multiply user-defined transformation matrices, push and pop the stack, and retrieve the matrix on the top of the stack.

`loadmatrix` loads a 4x4 floating point matrix onto the stack, replacing the current top of the stack.

```
loadmatrix(m)
Matrix m;

subroutine loadma(m)
real m(4,4)

procedure loadmatrix(m: Matrix);
```

`multmatrix` pre-multiplies the current top of the transformation stack by the given matrix; i.e., if T is the current matrix, `multmatrix(M)` replaces T with MT.

```
multmatrix(m)
Matrix m;

subroutine multma(m)
real m(4,4)

procedure multmatrix(m: Matrix);
```

`pushmatrix` pushes down the stack, duplicating the current matrix. If the stack contains one matrix, M, after a `pushmatrix` command it will contain two copies of M. Only the top copy can be modified.

```
pushmatrix()

subroutine pushma

procedure pushmatrix;
```

`popmatrix` pops the transformation stack.

```
popmatrix()

subroutine popmat

procedure popmatrix;
```

`getmatrix` copies the transformation matrix from the top of the stack to an array provided by the user; the stack is unchanged.

```
getmatrix(m)
Matrix m;

subroutine getmat(m)
real m(4,4)

procedure getmatrix(var m: Matrix);
```

---

5. Textures and Fonts

Chapter 3 presented commands for drawing images. This chapter presents commands that control the characteristics, or *attributes,* of images when they are displayed on the screen. Attributes such as linestyle, texture, and font determine precisely which pixels are to be drawn when a drawing command is executed. For example, the linestyle determines whether a line appears as a solid line, or as a series of dashes, or as some other pattern.

5.1 Linestyles

Lines are drawn on the IRIS monitor using a 16-bit pattern called a *linestyle.* This pattern is used cyclically to determine which pixels in a 16-pixel line segment are to be colored. For example, the linestyle 0xFFFF draws a solid line, while 0xFOFO draws a dashed line and 0x8888 draws a dotted one. The least significant bit of the pattern is the mask for the first pixel of the line and every sixteenth pixel thereafter. There is no performance penalty for drawing non-solid lines.

The `deflinestyle` command defines a linestyle. The arguments specify an index into a table where linestyles are stored and a sixteen-bit linestyle pattern. There are 2^{16} possible linestyle patterns and up to 128 of those patterns can be defined at one time. By default, index 0 contains the pattern 0xFFFF, which draws solid lines. The pattern at index 0 cannot be redefined.

```
deflinestyle(n, ls)
short n;
Linestyle ls;

subroutine deflin(n, ls)
integer*4 n, ls

procedure deflinestyle(n: Short; ls: Linestyle);
```

There is always a current linestyle; it is used for drawing lines and curves and for outlining rectangles, polygons, circles, and arcs. The default linestyle is linestyle 0. Another pattern can be chosen using the `setlinestyle` command. Its argument is an index into the linestyle table built by calls to `deflinestyle`.

```
setlinestyle(index)
short index;

subroutine setlin(index)
integer*4 index

procedure setlinestyle(index: Short);
```

Four commands modify the application of the linestyle pattern. The first command, `lsbackup`, guarantees that a line will have a clearly marked endpoint. Normally, the current linestyle is used as a rotating pattern:

```
for each pixel in the line {
    if low-order bit of pattern = 1 {
        write current color into pixel
    }
    rotate pattern right one bit;
    compute next pixel;
}
```

One implication of this algorithm is that the line may end without a clearly marked endpoint. If enabled, the `lsbackup` command guarantees the last two pixels in a line will be drawn. It takes one argument, a Boolean. If `b` = TRUE, backup mode is enabled. FALSE, the default setting, means the linestyle will be used as is, and lines may have invisible endpoints.

```
lsbackup(b)
Boolean b;

subroutine lsback(b)
logical b

procedure lsbackup(b: Boolean);
```

Normally, a fresh copy of the linestyle is used for each new line. To draw a series of line segments with a continuous pattern, the `resetls` command is used. It is used most often for drawing circles, arcs, or curves, since curved lines are approximated with many short straight lines. If the linestyle is not reset between segments, the pattern of the curve appears smooth and continuous.

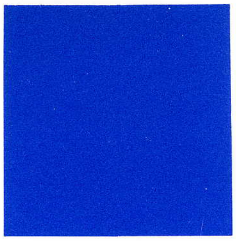
`resetls` has one Boolean argument. FALSE turns the mode off: the linestyle will *not* be reset between segments. TRUE, the default, means that each line will start with a fresh copy of the pattern. Calls to `resetls` have the side effect of initializing the linestyle, no matter what the argument. If `resetls` is FALSE when `setlinestyle` is called, the linestyle is not changed until `resetls` is called. `resetls` should be set to TRUE when linestyle backup mode is enabled.

```
resetls(b)
Boolean b;

subroutine resetl(b)
logical b

procedure resetls(b: Boolean);
```

The `lsrepeat` command is used to specify patterns longer than sixteen bits. The pattern in the current linestyle is multiplied by the integer argument to `lsrepeat`. Each 0 in the linestyle pattern becomes a series of `factor` 0's, and each 1 becomes a series of `factor` 1's.

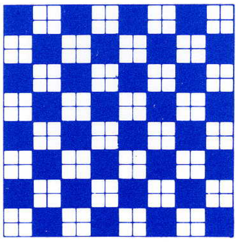
```
lsrepeat(factor)
long factor;

subroutine lsrepe(factor)
integer*4 factor

procedure lsrepeat(factor: longint);
```

The final command that modifies line drawing is `linewidth`, which specifies the width of a line. The width can be measured in pixels along the x axis, or along the y axis. The IRIS defines the width of a line to be the number of pixels along the axis which has the smallest change between the endpoints of the line. If `linewidth` is set to `n` > 1, `resetls` must be TRUE.



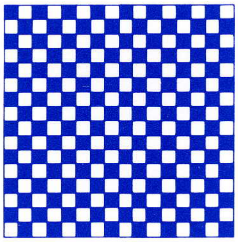
Pattern solid

= { 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF,
0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF, 0xFFFF }



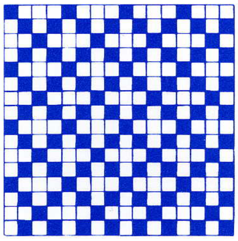
Pattern checked

= { 0x3333, 0x3333, 0xCCCC, 0xCCCC, 0x3333, 0x3333, 0xCCCC, 0xCCCC,
0x3333, 0x3333, 0xCCCC, 0xCCCC, 0x3333, 0x3333, 0xCCCC, 0xCCCC }



Pattern halftone

= { 0x5555, 0xAAAA, 0x5555, 0xAAAA, 0x5555, 0xAAAA, 0x5555, 0xAAAA,
0x5555, 0xAAAA, 0x5555, 0xAAAA, 0x5555, 0xAAAA, 0x5555, 0xAAAA }



Pattern crosshatch

= { 0x5555, 0x2222, 0x5555, 0x8888, 0x5555, 0x2222, 0x5555, 0x8888,
0x5555, 0x2222, 0x5555, 0x8888, 0x5555, 0x2222, 0x5555, 0x8888 }

Figure 5.1
A pattern is a 16 × 16, 32 × 32, or 64 × 64 array of bits with the origin in the lower left corner.

```
linewidth(n)
short n;

subroutine linewi(n)
integer*4 n

procedure linewidth(n: Short);
```

The current values of these line drawing attributes can be interrogated by the user.

`getlstyle` returns the index of the currently selected pattern.

```
long getlstyle()

integer*4 function getlst()

function getlstyle: longint;
```

`getlsbackup` returns the current value of the linestyle backup flag. Again, TRUE means that the last two pixels of a line will be colored regardless of the linestyle pattern. FALSE is the default.

```
long getlsbackup()

logical function getlsb()

function getlsbackup: longint;
```

`getresetls` returns the current value of the reset linestyle flag. TRUE means that the linestyle will be reinitialized for each line segment and is the default value. FALSE means that the pattern will rotate continuously across line segment boundaries.

```
Boolean getresetls()

logical function getres()

function getresetls: longint;
```

`getlsrepeat` returns the linestyle replication factor.

```
long getlsrepeat()

integer*4 function getlsr()

function getlsrepeat: longint;
```

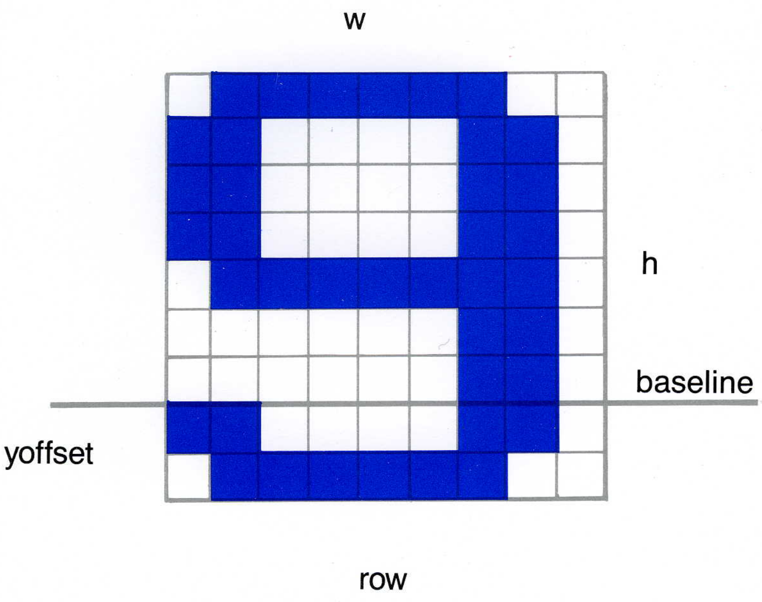
Finally, the `getlwidth` command returns the current linewidth in pixels.

```
long getlwidth()

integer*4 function getlwi()

function getlwidth: longint;
```

5.2 Patterns

Rectangles, polygons, and arcs can be filled with arbitrary textures. A texture pattern is an array of short integers that defines a rectangular pixel pattern. The texture pattern controls which pixels will be colored when filled objects are drawn. The pattern is aligned to the lower left corner of the screen rather than to the edge of the filled shape, so that it seems continuous over large areas.

Texture patterns are defined with the `defpattern` command. The arguments specify an index into a table of patterns, a size, and an array of shorts. A pattern can be 16X16, 32X32, or 64X64. The origin of the pattern is the lower left corner, so the bottom row is defined first. Each row of the pattern is specified as a short integer. Figure 5.1 shows some possible patterns and their definitions in C. By default, a solid pattern is defined as pattern 0 and this cannot be changed.



```
defrasterfont (n, ht, nc, chars, nr, rasters)

chars ['g']  = {      724,          8,     9,      0,        −2,     9  }
                raster offset      w      h    xoffset   yoffset   xinc

short raster [ ]       = { . . .
                           . . .
position 724 >              0x7E00,  0xC300,  0x0300,  0x0300,
                            0x7F00,  0xC300,  0xC300,  0xC300,
                            0x7E00,
                           . . .
                         }
```

Figure 5.2

Raster font characters are defined by a bitmap. The width and height of the character, the number of bits in one row of the bitmap, and the baseline position are also specified.

```
defpattern(n, size, mask)
short n, size;
Ushort mask[];

subroutine defpat(n, size, mask)
integer*4 n, size
integer*2 mask((size*size)/16)

procedure defpattern(n: longint; size: Short; mask: Ibuffer);
```

The `setpattern` command selects which of the defined patterns is to be used. The index provided in the `defpattern` command is the argument to `setpattern`. The default pattern is pattern 0.

```
setpattern(index)
short index;

subroutine setpat(index)
integer*4 index

procedure setpattern(index: Short);
```

The `getpattern` command returns the index of the currently selected pattern.

```
long getpattern()

integer*4 function getpat()

function getpattern: longint;
```

5.3 Fonts

`defrasterfont` defines a raster font and has six arguments. The first argument is an index into the font table and the second argument is an integer specifying the maximum height, in pixels, of characters in the font. `nc` gives the number of characters in the font and thus the number of elements in the `chars` array. `chars` contains a description of each character in the font. The description includes the height and width of the character in pixels, the offsets from the character origin to the lower left corner of the bounding box, an offset into the array of rasters, and the amount to add to the current character x position after drawing the character. Figure 5.2 gives a sample character definition. raster is an array of nr shorts of bitmap information. It is a one-dimensional array of mask bytes ordered left to right and then bottom to top. Mask bits are left-justified in the character's bounding box.

```
defrasterfont(n, ht, nc, chars, nr, raster)
short n, ht, nc, nr;
Fontchar chars[nc];
short raster[nr];

subroutine defras(n, ht, nc, chars, nr, raster)
integer*4 n, ht, nc, nr
integer*2 raster(nr), chars(4*nc)

procedure defrasterfont(n, ht, nr, nc: Short; var chars: Fntchrarray;
          var raster: Fontraster);
```

One raster font is defined by default. It is a Helvetica-like font with fixed-pitch characters. If the viewport is set to the whole screen, about 110 of these default characters will fit on a line (one character takes nine pixels). If baselines are sixteen pixels apart, 48 lines can be placed on the screen. The default font is font 0 and cannot be redefined.

The font command chooses the font that will be used whenever a charstr command draws a text string. The argument is an index into the font table built with the defrasterfont command. This font remains selected until another font command is executed. By default, font 0 is selected.

```
font(fntnum)
short fntnum;

subroutine font(fntnum)
integer*4 fntnum

procedure font(fntnum: Short);
```

The getfont command returns the index of the currently selected raster font.

```
long getfont()

integer*4 function getfon()

function getfont: longint;
```

The `getheight` command returns the maximum height of a character in the current raster font, including ascenders (present in characters like 't' and 'h') and descenders (as in 'y' and 'p'). The height is returned in pixels.

```
long getheight()

integer*4 function gethei()

function getheight: longint;
```

`strwidth` returns the width (in pixels) of a text string, using the character spacing parameters in the currently selected raster font. This routine is useful only when there is a simple mapping from screen to world space. The user must do the mapping.

```
long strwidth(str)
String str;

integer*4 function strwid(str, length)
character*(*) str
integer*4 length

function strwidth(str: pstring): longint;
```

6. Display Modes and Color

The preceding chapters discussed the drawing and attribute commands that determine which pixels are colored to create an image. This chapter discusses *how* those pixels are colored. When a pixel is drawn, a color value for the pixel is written into the *bitplanes*. The bitplanes store the screen image created by the drawing commands. There are three display modes which determine how the color values are stored into the bitplanes and how the values are used to display a screen image. A fourth mode, z-buffer mode, is used for hidden surface removal and is discussed in Chapter 12.

6.1 Display Modes

The screen image in an IRIS system is stored in a set of *bitplanes* (from four to twenty-four). See Figure 6.1. Each bitplane provides one bit of storage per pixel. The corresponding locations in all the bitplanes represent values (from four to twenty-four bits long) for each pixel. These values determine the color of the pixel when it is displayed on the screen. There are three *display modes* which determine how the values are stored in the bitplanes and how they are used: RGB mode, single buffer mode, and double buffer mode.

The display mode commands discussed in this chapter take effect only after the `gconfig` command is called. `gconfig` uses the display mode, the map mode (discussed in the next section), and the number of available bitplanes to define the mapping from colors to bitplanes.

```
gconfig()

subroutine gconfi

procedure gconfig;
```

The color of a pixel is determined by an RGB value. An RGB value consists of three eight-bit intensity values – one for red, one for green, and one for blue. These values are loaded into the three digital-to-analog converters which control the color and brightness of each pixel.

In the first display mode, *RGB mode*, the value written into the bitplanes when a pixel is drawn is an RGB value. RGB mode is only useful when the system has at least twenty-four bitplanes (room for three eight-bit values). RGB mode is

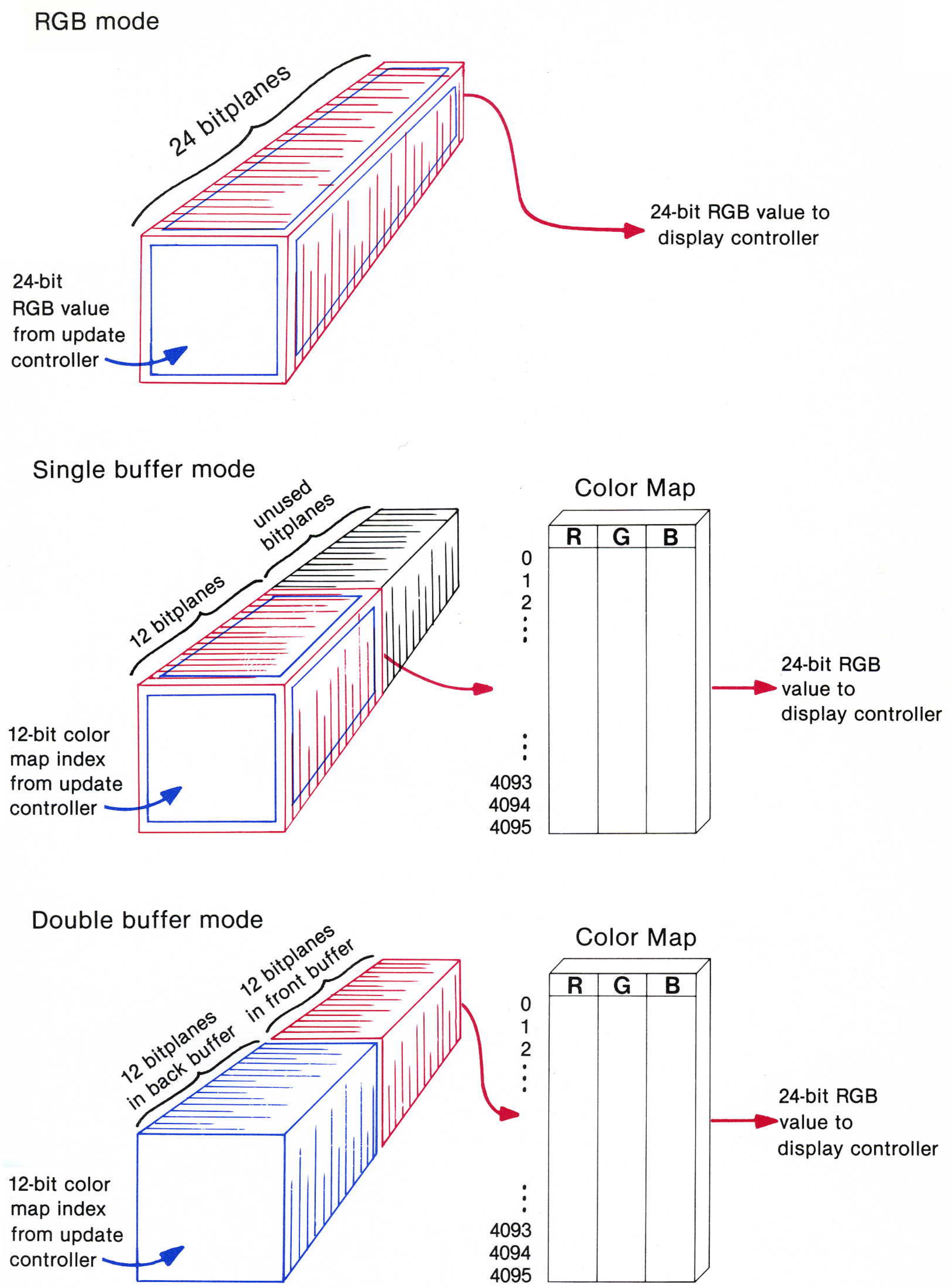

RGB mode
24 bitplanes
24-bit RGB value from update controller
24-bit RGB value to display controller
Single buffer mode
12 bitplanes
unused bitplanes
12-bit color map index from update controller
Color Map
R
G
B
0
1
2
4093
4094
4095
24-bit RGB value to display controller
Double buffer mode
12 bitplanes in back buffer
12 bitplanes in front buffer
12-bit color map index from update controller
Color Map
R
G
B
0
1
2
4093
4094
4095
24-bit RGB value to display controller

Figure 6.1

In RGB mode, 24-bit RGB values are stored in the bitplanes. In single and double buffer modes, 12-bit color map indices are stored in the bitplanes.

selected by issuing the `RGBmode` command.

```
RGBmode()

subroutine RGBmod

procedure RGBmode;
```

A more flexible way to use the bitplanes is provided by *single buffer* or *double buffer mode.* In these modes, the values contained in the bitplanes are indexes into a color map. The color map is a table of 24-bit RGB values. This means that a system with fewer than twenty-four bitplanes can still display the full range of colors specified by 24-bit RGB values. For example, although each pixel in a system with four bitplanes can store only sixteen different values, the colors specified in the color map can be any of the 2^{24}=16.8 million possible RGB colors. Even more flexibility can be obtained by dividing the color map into sixteen smaller maps. (See the following section for further discussion of color maps.)

In single buffer mode, up to twelve bitplanes (the color map is twelve-bit addressable) are used to store the color map indices. Any extra bitplanes remain unused or are used for z-buffering (see Chapter 12). Images are simultaneously updated and displayed in single buffer mode, so incomplete or changing pictures may appear on the screen. The `singlebuffer` command invokes this display mode.

```
singlebuffer()

subroutine single

procedure singlebuffer;
```

In double buffer mode, the bitplanes are partitioned into two groups, called *front* and *back buffers.* By default, the front buffer is displayed and the back buffer is updated by drawing commands. Thus, a completed image can be displayed while a new one is being drawn.

```
doublebuffer()

subroutine double

procedure doublebuffer;
```

The `swapbuffers` command swaps the front and back buffers during the next vertical retrace period. After an image is drawn in the back buffer, a `swapbuffers` command displays it.

```
swapbuffers()

subroutine swapbu

procedure swapbuffers;
```

`swapinterval` establishes a minimum time between buffer swaps. If the user specifies a swap interval of 5, the screen will be refreshed at least five times between execution of successive `swapinterval` commands. This command provides a way to change frames at a steady rate if a new image can be created within one swap interval. The default interval is 1. `swapinterval` is valid only in double buffer mode; it is ignored in single buffer and RGB modes.

```
swapinterval(i)
short i;

subroutine swapin(i)
integer*4 i

procedure swapinterval(i: Short);
```

It is sometimes convenient to update both the front and the back buffers, or to update the front instead of the back. `backbuffer` enables updating in the back buffer. If `b` = TRUE, the default, updating in the backbuffer is enabled; FALSE means it is not enabled.

```
backbuffer(b)
Boolean b;

subroutine backbu(b)
logical b

procedure backbuffer(b: Boolean);
```

`frontbuffer` enables updating in the front buffer. If `b` = FALSE, the default, the front buffer is not enabled; TRUE means it is enabled.

```
frontbuffer(b)
Boolean b;

subroutine frontb(b)
logical b

procedure frontbuffer(b: Boolean);
```

`getbuffer` indicates which buffers are enabled for writing. "1", the default, means that the back buffer is enabled, "2" means that the front buffer is enabled, and "3" means that both are enabled. `getbuffer` returns 0 if neither buffer is enabled or if the IRIS is not in double buffer mode.

```
long getbuffer()

integer*4 function getbuf()

function getbuffer: longint;
```

The `getdisplaymode` command returns the current display mode, indicated by an integer: 0 = RGB mode, 1 = single buffer mode, and 2 = double buffer mode.

```
long getdisplaymode()

integer*4 function getdis()

function getdisplaymode: longint;
```

The `getplanes` command returns the number of available bitplanes. For example, a 24-bitplane system returns 24 available planes in RGB mode and 12 available planes in single and double buffer modes. An 8-bitplane system returns 8 available planes in RGB mode, 8 available planes in single buffer mode, and 4 available planes in double buffer mode.

```
long getplanes()

integer*4 function getpla()

function getplanes: longint;
```

In single buffer and RGB modes, rapidly changing scenes should be synchronized with the refresh rate. The `gsync` command waits for the next vertical retrace period.

```
gsync()

subroutine gsync

procedure gsync;
```

6.2 Color Maps

In RGB mode, eight bits each of red, green, and blue intensities are written into the bitplanes. The programmer can choose from a palette of 2^{24}=16.8 million different colors. The disadvantage of RGB mode is that it is effective only in a system with at least 24 bitplanes. A more flexible technique is the use of a *color map*. Instead of RGB values, indices into the color map are stored in the bitplanes. The color map stores 2^{12}=4096 RGB values. A system with eight bitplanes, for example, can address only 2^8=256 of the 4096 entries in the color map. However, each of those entries has the full 24-bit precision of RGB mode.

The color map can be used in either one of two modes. onemap, the default, organizes the color map as discussed above — a single map with room for 4096 RGB entries.

```
onemap()

subroutine onemap

procedure onemap;
```

multimap organizes the color map as sixteen independent maps, each with a maximum of 256 RGB entries.

```
multimap()

subroutine multim

procedure multimap;
```

getcmmode returns the current color map mode: 0 for multimap mode and 1 for onemap mode.

```
long getcmmode()

integer*4 function getcmm()

function getcmmode: longint;
```

setmap chooses which of the small maps (0 through 15) is to be used. It is meaningful only in multimap mode.

```
setmap(mapnum)
short mapnum;

subroutine setmap(mapnum)
integer*4 mapnum

procedure setmap(mapnum: Short);
```

The getmap command returns the number (from 0 to 15) of the currently selected color map. If called in onemap mode, it returns 0.

```
long getmap()

integer*4 function getmap()

function getmap: longint;
```

There are two advantages to multimap mode. First, it increases (by up to a factor of sixteen) the number of colors available in a system with less than twelve bitplanes. Second, it provides an additional tool for altering screen images (e.g., an image can be color-inverted simply by switching to a different color map).

onemap and multimap take effect when gconfig is called (see Section 6.1). Note that color map indices are limited to twelve bits in onemap mode and eight bits in multimap mode.

cyclemap cycles through color maps at a selected rate. It specifies a duration (in vertical retraces), the current map, and what map to change to when the duration has timed out. For example, the following commands set up multimap mode and cycle between two maps, leaving map 1 on for ten vertical retraces and map 3 on for five retraces.

```
multimap();
gconfig();
cyclemap(10, 1, 3);
cyclemap(5, 3, 1);
```

Note that program termination does not stop these commands; you must explicitly set all durations to 0.

```
cyclemap(duration, map, nextmap)
short duration, map, nextmap;

subroutine cyclem(duration, map, nextmap)
integer*4 duration, map, nextmap

procedure cyclemap(duration, map, nextmap: Short);
```

mapcolor sets a color map entry to a specified RGB value. Its arguments are a color map index and eight bits each of red, green, and blue intensities. Pixels written with color color will be displayed with the specified RGB intensities. (See the following section for a discussion of the color command.) In multimap mode only the currently selected color map can be updated with mapcolor. Invalid indices are ignored.

```
mapcolor(color, red, green, blue)
Colorindex color;
RGBvalue red, green, blue;

subroutine mapcol(color, red, green, blue)
integer*4 color, red, green, blue

procedure mapcolor(color: Colorindex; red, green,
blue: RGBvalue);
```

getmcolor returns the red, green, and blue components of a color map entry.

```
getmcolor(color, r, g, b)
Colorindex color;
RGBvalue *r, *g, *b;

subroutine getmco(color, r, g, b)
integer*4 color, r, g, b

procedure getmcolor(color: Colorindex; var r, g, b: RGBvalue);
```

blink changes the color map entry at a selected rate. It specifies a blink rate, a color map index, and red, green, and blue values. Every rate vertical retraces, the color located at index color in the current color map is updated. Its value is either the original value or the new value supplied by the `red`, `green`, and `blue` arguments. Up to twenty colors can blink simultaneously, each at a different rate. The blink rate can be changed by calling `blink` again with the same `color` and a different `rate`. Calling `blink` with `rate=0` when `color` specifies a blinking color map entry terminates the blinking and restores the original color.

```
blink(rate, color, red, green, blue)
short rate;
Colorindex color;
RGBvalue red, green, blue;

subroutine blink(rate, color, red, green, blue)
integer*4 rate, color, red, green, blue

procedure blink(rate: Short; color: Colorindex; red, green,
blue: RGBvalue);
```

6.3 Colors and Writemasks

In the chapters on drawing primitives and user-defined shapes, the *current color* is often mentioned. This section describes the command for setting it.

When a pixel is drawn in single or double buffer mode, the current color map index is written into the bitplanes. The `color` command sets the current index. In onemap mode, the index can be in the range 0-4095. In multimap mode, the index is used in conjunction with a color map number and should be in the range 0-225. The color is also bounded by the number of available planes.

```
color(c)
Colorindex c;

subroutine color(c)
integer*4 c

procedure color(c: Colorindex);
```

The program below draws a BLUE rectangle around a RED circle. Here RED and BLUE are merely indices into the color map. They are defined in `gl.h` and correspond to the color map entries that `ginit` set to be the colors red and blue. They could, in fact, be set to any of 16.8 million colors.

```
#include "gl.h"

main()
{
     ginit();
     color(BLUE);
     recti(0, 0, 100, 100);
     color(RED);
     circi(50, 50, 50);
     gexit();
}
```

The `getcolor` command returns the current color. The system must be in single or double buffer mode when this command is executed.

```
long getcolor()

integer*4 function getcol()

function getcolor: Colorindex;
```

In RGB mode, the current color is set with the `RGBcolor` command. The lower-order eight bits of the three arguments are the intensity values for the colors red, green, and blue. These numbers are written into the bitplanes whenever a pixel is drawn; they directly control the intensity of red, green, and blue displayed on the screen.

```
RGBcolor(red, green, blue)
short red, green, blue;

subroutine RGBcol(red, green, blue)
integer*4 red, green, blue

procedure RGBcolor(red, green, blue: RGBvalue);
```

For example, the following program draws a blue rectangle around a red circle in RGB mode.

```
#include "gl.h"

main()
{
        ginit();
        RGBmode();
        gconfig();
        RGBcolor(0, 0, 225);
        recti(0, 0, 6, 6);
        RGBcolor(225, 0, 0);
        circi(3, 3, 2);
        gexit();
    }
```

The `gRGBcolor` command returns the current RGB value. The arguments are addresses of three locations that will be filled with the red, green, and blue values. The system must be in RGB mode when this command is executed; otherwise, it is ignored.

```
gRGBcolor(red, green, blue)
short *red, *green, *blue;

subroutine gRGBco(red, green, blue)
integer*2 red, green, blue

procedure gRGBcolor(var red, green, blue: RGBvalue);
```

As discussed so far, a color map index or an RGB value is written into the bitplanes when a pixel is drawn. However, an important tool available to the user is the ability to shield bitplanes from new values. This shielding mechanism allows a layering of images to be created. For example, color values for the cursor can be written into two of the bitplanes in the system. These two bitplanes can then be shielded from ordinary drawing commands (which will write values in the remaining bitplanes). As a result, the cursor will always appear on the screen. See Figures 6.2 and 6.3.

In single buffer or double buffer mode, the `writemask` command determines which bitplanes will be drawn into by the drawing commands. Its argument is a mask with one bit per available bitplane. The ones in the writemask enable a bitplane for writing. The corresponding bit in the current color index will be written into the bitplane wherever a pixel is drawn. Zeros in the writemask mark bitplanes as read-only. These planes are not changed, regardless of the bits in the color index.

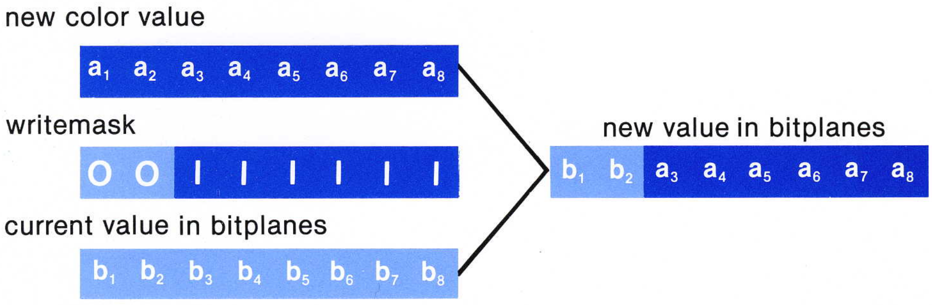


Figure 6.2

Writemasks determine whether or not a new value can be stored in each bitplane. A "1" in the writemask allows a new value (0 or 1) to be stored in the corresponding bitplane. A "0" prevents the new value from being stored and the corresponding bitplane retains its current value. Each **a** and each **b** can be either 0 or 1.

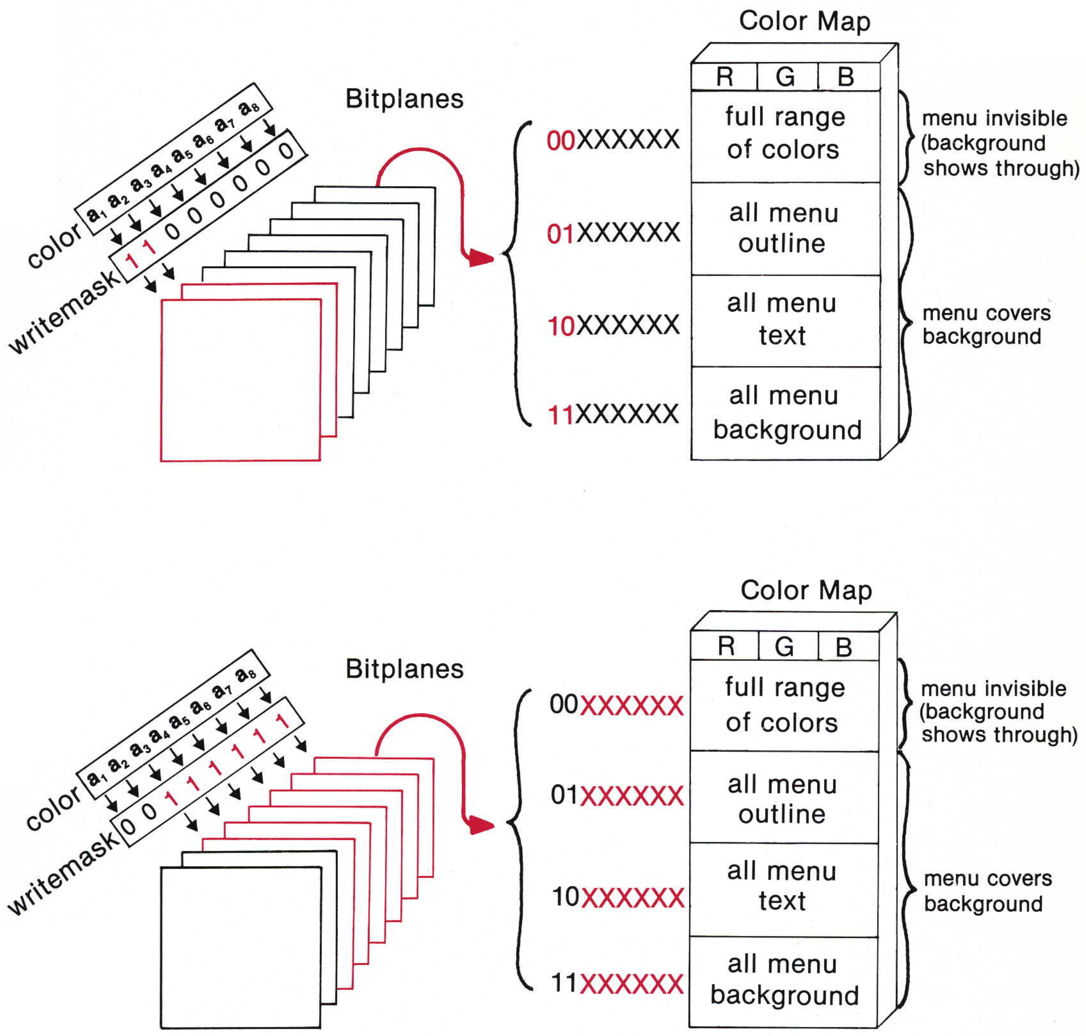


Figure 6.3

Writemasks can be used to create a layering of images. In this example, the first two bitplanes are reserved for a pop-up menu. Since two bitplanes provide four possible values, the menu can use four different parts of the color map. If the menu is invisible (or not positioned) at a particular location, the color value for that location is determined by the remaining bitplanes.

```
writemask(wtm)
Colorindex wtm;

subroutine writem(wtm)
integer*4 wtm

procedure writemask(wtm: Colorindex);
```

The getwritemask command returns the current writemask. It is an integer with up to twelve significant bits, one for each available bitplane.

```
long getwritemask()

integer*4 function getwri()

function getwritemask: Colorindex;
```

Similar commands mask bitplanes in RGB mode. The RGBwritemask command takes three arguments, masks for each of three sets of eight planes.

```
RGBwritemask(red, green, blue)
short red, green, blue;

subroutine RGBwri(red, green, blue)
integer*4 red, green, blue

procedure RGBwritemask(red, green, blue: RGBvalue);
```

The gRGBmask command returns the current RGB writemask as three eight-bit masks. The masks are placed in the locations addressed by redm, greenm, and bluem.

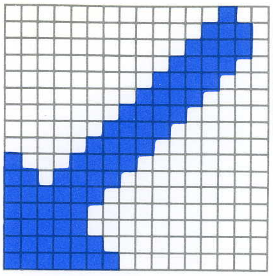
```
gRGBmask(redm, greenm, bluem)
short *redm, *greenm, *bluem;

subroutine gRGBma(redm, greenm, bluem)
integer*2 redm, greenm, bluem

procedure gRGBmask(var redm, greenm, bluem: RGBvalue);
```

6.4 Cursors

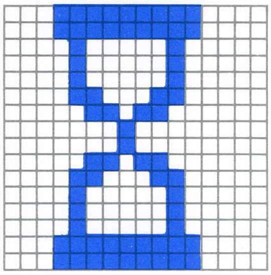
A cursor glyph is a 16x16 array of bits, and is used to show the current screen position of a graphics input device (see Chapter 7). The **defcursor** command defines an entry in a table of cursor glyphs. As with linestyles and textures, the arguments are a table index and the 16x16 bitmap. By default, one glyph (an arrow) is defined as cursor 0. Figure 6.4 shows some examples of cursor glyphs and their definitions in C.

```
defcursor(n, curs)
short n;
Cursor curs;

subroutine defcur(n, curs)
integer*4 n
integer*2 curs(16)

procedure defcursor(n: Short; curs: Cursor);
```

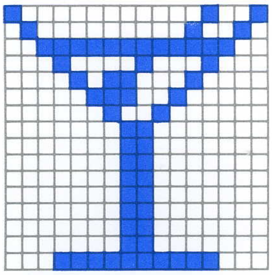
The **setcursor** command establishes the characteristics of the cursor. The first argument, **index**, picks a glyph from the definition table. **color** and **mask** set a color map index and writemask for the cursor.



```
Cursor arrow = { 0×FE00,  0×FC00,  0×F800,  0×F800,
                 0×FC00,  0×DE00,  0×8F00,  0×0780,
                 0×03C0,  0×01E0,  0×00F0,  0×0078,
                 0×003C,  0×001E,  0×000E,  0×0004}
```



```
Cursor hourglass = { 0×1FF0,  0×1FF0,  0×0820,  0×0820,
                     0×0820,  0×0C60,  0×06C0,  0×0100,
                     0×0100,  0×06C0,  0×0C60,  0×0820,
                     0×0820,  0×0820,  0×1FF0,  0×1FF0}
```



```
Cursor martini = { 0×1FF8,  0×0180,  0×0180,  0×0180,
                   0×0180,  0×0180,  0×0180,  0×0180,
                   0×0180,  0×0240,  0×0720,  0×0B10,
                   0×1088,  0×3FFC,  0×4022,  0×8011}
```

Figure 6.4

A cursor is a 16×16 array of bits with the origin in the lower left corner.

```
setcursor(index, color, wtm)
short index;
Colorindex color, wtm;

subroutine setcur(index, color, wtm)
integer*4 index, color, wtm

procedure setcursor(index: Short; color, wtm: Colorindex);
```

The `curorigin` sets the origin of a cursor (i.e., the position on the cursor that will be aligned with the valuators controlling the cursor position). `n` is the index of the cursor definition.

```
curorigin(n, xorigin, yorigin)
short n, xorigin, yorigin;

subroutine curori(n, xorigin, yorigin)
integer*4 n, xorigin, yorigin

procedure curorigin(n, xorigin, yorigin: Short);
```

The `getcursor` command returns the index of the glyph, the color, and the writemask associated with the cursor, and a Boolean indicating whether the cursor is automatically displayed and updated by the system. The arguments to the command are addresses of four locations where the four cursor attributes are to be returned. The default is the glyph at index 0 in the cursor table, displayed with the color 1, drawn in the first available bitplane, and automatically updated and displayed on each vertical retrace. This command is ignored in RGB mode.

```
getcursor(index, color, wtm, b)
short *index;
Colorindex *color, *wtm;
Boolean *b;

subroutine getcur(index, color, wtm, b)
integer*2 index, color, wtm
logical b

procedure getcursor(var index: Short; var color, wtm: Colorindex; var b: Boolean);
```

In RGB mode, the **RGBcursor** command allows selection of a cursor glyph from a table of 16x16 bit patterns already defined by the user. The first argument, **index**, picks a glyph from the definition table. **red**, **green**, and **blue** specify the cursor color in RGB mode, while **redm**, **greenm**, and **bluem** define an RGB writemask for the cursor.

```
RGBcursor(index, red, green, blue, redm, greenm, bluem)
short index;
RGBvalue red, green, blue, redm, greenm, bluem;

subroutine RGBcur(index, red, green, blue, redm, greenm, bluem)
integer*2 index, red, green, blue, redm, greenm, bluem

procedure RGBcursor(index: Short; red, green, blue, redm, greenm, bluem: RGBvalue);
```

The **gRGBcursor** command returns the six parameters of the **RGBcursor** command and a Boolean value indicating whether the cursor position is being automatically updated. The system must be in RGB mode when this command is executed.

```
gRGBcursor(index, red, green, blue, redm, greenm, bluem, b)
short *index, *red, *green, *blue, *redm, *greenm, *bluem;
Boolean *b;

subroutine gRGBcu(index, red, green, blue, redm, greenm, bluem, b)
integer*2 index, red, green, blue, redm, greenm, bluem
logical b

procedure gRGBcursor(var index: Short; var red, green, blue, redm,
                greenm, bluem: RGBvalue; var b: Boolean);
```

The cursor, by default, is always displayed. As it is drawn on the screen, the image that it covers is saved away. When the cursor moves, the saved image is restored. If the image changes while the cursor is displayed, the saved image might no longer be valid. This is a concern in single buffer and RGB modes, and in double buffer mode when the front buffer is enabled. Accordingly, there are commands to turn the cursor on and off.

`cursoff` prevents the cursor from being displayed. The command should precede any drawing commands that might write into the cursor planes.

```
cursoff()

subroutine cursof

procedure cursoff;
```

`curson` requests that the system automatically update and display a cursor. `curson` commands are usually paired with `cursoff` commands, though there is no harm in calling `curson` when the automatic cursor is already visible.

```
curson()

subroutine curson

procedure curson;
```

The code segment below shows a typical drawing sequence in single buffer mode.

```
{
greset();

color(BLUE);
cursoff();
move2i(1, 0);
draw2i(3, 6);
draw2i(5, 0);
move2i(4, 3);
draw2i(2, 3);
curson();
}
```

The cursor position, whether or not it is visible, is automatically updated to reflect the values of the valuator devices to which it is attached (see Section 7.1 for a discussion of the `attachcursor` command).

7. Input/Output Commands

The IRIS Graphics Library supports three classes of input devices:

- A *valuator* returns an integer value. A dial on a dial and button box is an example of a valuator. A mouse is a pair of valuators: one reports horizontal position, the other vertical position.
- A *button* returns a Boolean value with FALSE = not pushed. Keys on an unencoded keyboard, buttons on a mouse, and switches on a dial and button box are examples of buttons.
- A *keyboard* returns ASCII characters.

Within each class, individual devices are given unique device numbers. Appendix A contains a header file, "device.h", which defines symbolic names for many of the device numbers.

Input devices can be *polled* or *queued*. Polled devices are interrogated by the user and return the state of the device at the moment of polling. Queued devices make entries in an *event queue*, which is read at the user's convenience. (Queued devices can also be polled at any time.)

Polled devices tend to synchronize the user process and terminal process. The user program detects device events that either happen the instant before the device is polled, or last long enough to be valid the next time the device is polled. For example, a quick click of a button (press and release immediately) is lost if the user program does not poll the button between the press and release.

Queued devices act as asynchronous devices, independent of the user process. Whenever a queued device changes state, an entry is made in the *event queue*. The user program can process the queue in a timely fashion without loss of information. There is, however, some latency involved in reading the queue. All events are entered in the same queue; the search for a particular event may involve reading and servicing many events before the desired one is found.

The user can decide which devices, if any, are queued, and can establish some rules about what constitutes a state change, or *event*, for that device. By default, no devices are queued.

In addition to the input commands, there are commands for controlling the characteristics of the peripheral input/output devices of the IRIS. These commands turn on and off the keyboard click and the keyboard lights, ring the keyboard bell, and control the lights and text on the dial and button box.

Device	Description
MOUSE1	right mouse button
MOUSE2	middle mouse button
MOUSE3	left mouse button
MOUSERIGHT	right mouse button
MOUSEMIDDLE	middle mouse button
MOUSELEFT	left mouse button
SW0..SW31	32 buttons on dial and button box
AKEY..PADENTER	all the keys on the keyboard
LPENBUT	light pen button
BPAD0	pen stylus or button for digitizer tablet
BPAD1	button for digitizer tablet
BPAD2	button for digitizer tablet
BPAD3	button for digitizer tablet

Table 7.1: Input Buttons

Device	Description
MOUSEX	x valuator on mouse
MOUSEY	y valuator on mouse
DIAL0..DIAL8	dials on dial and button box
LPENX	x valuator on light pen
LPENY	y valuator on light pen
BPADX	x valuator on digitizer tablet
BPADY	y valuator on digitizer tablet
CURSORX	x valuator attached to cursor (usually MOUSEX)
CURSORY	y valuator attached to cursor (usually MOUSEY)

Table 7.2: Input Valuators

7.1 Initializing a Device

Valuators are single-valued input devices. The value is a 16-bit integer. Examples are the horizontal and vertical motion of a mouse, and a dial on a dial and button box. The `setvaluator` command assigns an initial value `init` to a valuator. `min` and `max` are lower and upper bounds for the values the device can assume.

```
setvaluator(v, init, min, max)
Device v;
short init, min, max;

subroutine setval(v, init, min, max)
integer*4 v, init, min, max

procedure setvaluator(v: Device; init, min, max: Short);
```

The cursor, described in Section 6.4, reflects the position of an input device controlled by the user. Since the cursor moves in two dimensions, its position can be determined by any two valuators. While it is customary to use the horizontal and vertical motion of the mouse to control the cursor, there is no restriction on which valuators may be used. If desired, the cursor can be controlled by two dials on the optional dial and button box.

The `attachcursor` command attaches the cursor glyph to the movement of two valuators. It takes two valuator device numbers as its arguments. The first valuator controls the horizontal motion of the cursor; the second argument determines vertical motion.

```
attachcursor(vx, vy)
Device vx, vy;

subroutine attach(vx, vy)
integer*4 vx, vy

procedure attachcursor(vx, vy: Device);
```

7.2 Polling a Device

Once a device has been initialized, it can be polled by the user to determine its current state. Valuators are interrogated with the `getvaluator` command. Any valuator can be polled, regardless of whether it is queued or not. The argument to `getvaluator` is a valuator device number. The returned value reflects the current state of the device.

```
long getvaluator(val)
Device val;

integer*4 function getval(val)
integer*4 val

function getvaluator(val: Device): longint;
```

The `getbutton` command polls a button and returns its current state. A device number is supplied as the argument. `getbutton` returns either TRUE or FALSE, with TRUE = pressed.

```
long getbutton(num)
Device num;

logical function getbut(num)
integer*4 num

function getbutton(num: Device): longint;
```

7.3 The Event Queue

The input devices can make entries in the event queue. Each entry has a type and some associated data. The `qdevice` command designates a device as a queued device. Its argument is a device number. An entry is made in the event queue each time the device changes state.

```
qdevice(v)
Device v;

subroutine qdevic(v)
integer*4 v

procedure qdevice(v: Device);
```

Devices are unqueued using the `unqdevice` command.

```
unqdevice(v)
Device v;

subroutine unqdev(v)
integer*4 v

procedure unqdevice(v: Device);
```

Some valuators are "noisy"; an unmoving device may report small fluctuations in value. The `noise` command allows the user to set a lower limit on what constitutes a move. The value of a noisy valuator `v` must change by at least `delta` before the motion is significant. `noise` determines how often queued valuators will make entries in the event queue. For example, `noise(v,5)` means that valuator `v` must move at least 5 units before a new queue entry is made.

```
noise(v, delta)
Device v;
short delta;

subroutine noise(v, delta)
integer*4 v, delta

procedure noise(v: Device; delta: Short);
```

A queued button and one or two valuators can be tied together such that whenever the button changes state, both the button change and the current valuator position are recorded in the event queue. The `tie` command takes three arguments: a button `b` and two valuators `v1` and `v2`. Whenever the button changes state, three entries are made in the queue, recording the current state of the button and the current positions of each valuator. One valuator can be tied to a button by making `v2` = 0. A button can be untied from valuators by making both `v1` and `v2` zero.

```
tie(b, v1, v2)
Device b, v1, v2;

subroutine tie(b, v1, v2)
integer*4 b, v1, v2

procedure tie(b, v1, v2: Device);
```

The user can place entries directly into the event queue using the `qenter` command. `qenter` takes two 16-bit integers, `qtype` and `value`, and enters them into the event queue.

```
qenter(qtype, val)
short qtype, val;

subroutine qenter(qtype, val)
integer*4 qtype, val

procedure qenter(qtype, val: Short);
```

Three commands read the event queue: `qtest`, `qread`, and `blkqread`. `qtest` returns the device number of the first entry in the event queue; if the queue is empty, it returns zero. `qtest` always returns immediately to the caller, and makes no changes to the queue.

```
long qtest()

integer*4 function qtest()

function qtest: long;
```

Like `qtest`, `qread` returns the device number of the first entry in the event queue. However, if the queue is empty, it waits until there is an entry in the queue. `qread` returns the device number, writes the data part of the entry into `data`, and removes the entry from the queue.

```
long qread(data)
short *data;

integer*4 function qread(data)
integer*2 data

function qread(var data: Short): longint;
```

The `blkqread` command returns multiple queue entries. The first argument `data` is an array of shorts, and the second argument `n` is the length of the array. Each entry consists of two shorts (one is the device number and the other is an associated value), thus the length of the array = 2*(# of entries). `blkqread` can provide more efficient network communication between an IRIS terminal and a host computer. It can also be used when only the last entry in the event queue is of interest (e.g., when a user-defined cursor is being dragged across the screen and only its final position is of interest).

```
long blkqread(data, n)
short data[];
short n;

integer*4 function blkqre(data, n)
integer*2 data(*)
integer*4 n

function blkqread(var data: Queuearray, n: Short): longint;
```

The `qreset` command removes all entries from the queue and discards them.

```
qreset()

subroutine qreset

procedure qreset;
```

7.4 Controlling Peripheral Input/Output Devices

In addition to commands for polling and queuing input devices, there are commands for controlling the characteristics and behavior of the IRIS's peripheral input/output devices.

The **clkon** and **clkoff** commands turn on and off the keyboard click.

```
clkon()

subroutine clkon

procedure clkon;
```

```
clkoff()

subroutine clkoff

procedure clkoff;
```

The **lampon** and **lampoff** commands control the four lamps on the keyboard. Each "1" in the four lower-order bits of the **lamps** argument to **lampon** causes the corresponding keyboard lamp to be on. Each "1" in the four lower-order bits of the **lamps** argument to **lampoff** causes the corresponding keyboard lamp to be off.

```
lampon(lamps)
char lamps;

subroutine lampon(lamps)
integer*4 lamps

procedure lampon(lamps: Byte);
```

```
lampoff(lamps)
char lamps;

subroutine lampof(lamps)
integer*4 lamps

procedure lampoff(lamps: Byte);
```

The `ringbell` command rings the keyboard bell.

```
ringbell()

subroutine ringbe

procedure ringbell;
```

The `setbell` command sets the duration of the keyboard bell:

0 is off;
1 is a short beep;
2 is a long beep.

```
setbell(mode)
char mode;

subroutine setbel(mode)
integer*4 mode

procedure setbell(mode: Byte);
```

The `dbtext` command writes text to the LED display in a dial and button box. The string `str` must be eight or fewer characters.

```
dbtext(str)
char str[8];

subroutine dbtext(str)
character*(8) str

procedure dbtext(str: pstring);
```

The `setdblights` command controls the thirty-two lighted switches on a dial and switch box. To turn on switches 3 and 7, for example, `mask` would be `(1<<3)|(1<<7)`.

```
setdblights(mask)
long mask;

subroutine setdbl(mask)
integer*4 mask

procedure setdblights(mask: long);
```

8. Graphical Objects

In a conventional programming language, subroutines can be viewed as semantic extensions. Similarly, graphical objects extend the IRIS Graphics Library. An object is a sequence of graphics commands that is used more than once. By packaging these commands as an object, much of the overhead associated with translating the commands can be avoided. An object is "compiled" into a display list as it is defined. Calls to an object are interpreted directly without further compilation.

8.1 Defining An Object

Objects are created and named with the `makeobj` command. This command takes a single argument, a 31-bit integer that is the assigned name.

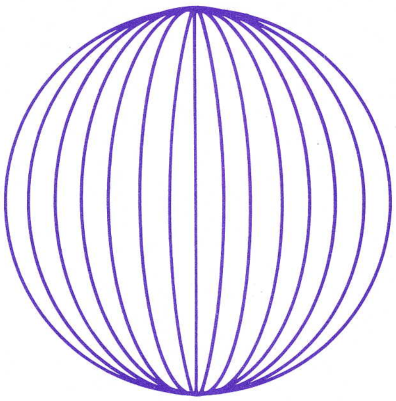
```
makeobj(obj)
Object obj;

subroutine makeob(obj)
integer*4 obj

procedure makeobj(obj: Object);
```

When a `makeobj` command is executed, the object name is entered into a symbol table and memory is allocated for a display list. Subsequent graphics commands are compiled into the display list instead of being executed.

`closeobj` terminates the object definition and closes the open object. All the display list commands between `makeobj` and `closeobj` become part of the object definition.

```
closeobj()

subroutine closeo

procedure closeobj;
```

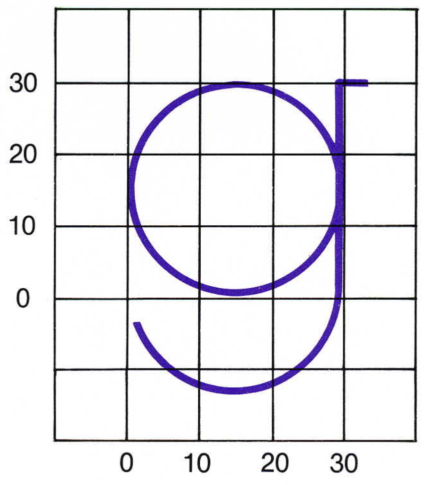
Figure 8.1 shows an object definition of a simple shape named sphere, and the figure it draws when called.



```
makeobj(sphere);
for (phi=0; phi≤PI; phi+=PI/9){
   for (theta=0; theta≤2*PI; theta+=PI/18){
      x=sin(theta) * cos(phi);
      y=sin(theta) * sin(phi);
      z=cos(theta);
      if (theta==0)move(x,y,z);
      else draw (x,y,z);
   }
}
closeobj ( );
```

Figure 8.1

The sphere above is defined as a *graphical object*. The *makeobj* command creates a new object containing all commands between *makeobj* and *closeobj*.



```
makeobj (g);
   circi (15,15,15);
   arci (15,3,15,2050,3600);
   move2i (38,30);
   draw2i (30,30);
   draw2i (30,3);
   translate (40.,0.,0.);
closeobj ( );
```

Figure 8.2

Stroked font characters can be graphical objects.

An object defined with a name currently in use replaces the prior contents with the new definition. `isobj` and `genobj` ensure that an object name is unique. `isobj` tests whether an object exists for a given name. If so, the `isobj` command returns TRUE. It returns FALSE if no object exists with that identification.

```
Boolean isobj(obj)
Object obj;

logical function isobj(obj)
integer*4 obj

function isobj(obj: Object): longint;
```

`genobj` generates unique object names. It will not generate an object name that is currently in use. `genobj` is useful in naming objects in library routines, where it is impossible to anticipate what object names will be in use when the routine is called.

```
Object genobj()

integer*4 function genobj()

function genobj: Object;
```

The `delobj` command deletes an object. All display list memory storage associated with the object is freed, and the object name is marked undefined until it is reused to create a new object. Calls to deleted or undefined objects are ignored.

```
delobj(obj)
Object obj;

subroutine delobj(obj)
integer*4 obj

procedure delobj(obj: Object);
```

8.2 Using Objects

An object is drawn by calling it. The `callobj` command takes the name of the object to be drawn as its argument.

```
callobj(obj)
Object obj;

subroutine callob(obj)
integer*4 obj

procedure callobj(obj: Object);
```

`callobj` can call one object from inside another object. More complex pictures can be drawn using a hierarchy of simple objects. An example is shown below. The single command `callobj (pearls)` will draw the object, a string of pearls, by calling the previously defined object `pearl` seven times.

```
Object PEARL = 1, PEARLS = 2;

makeobj(pearl);
   color(BLUE);
   for(angle=0; angle<=3600; angle=angle+300) {
      rotate(300, 'y');
      circ(0.0, 0.0, 1.0);
   }
closeobj();

makeobj(pearls);
   for(i=0; i<=7; i=i+1) {
      translate(2.0, 0.0, 0.0);
      color(i);
      callobj(pearl);
   }
closeobj();
```

Figure 8.3 shows another example using simple objects to build more complex ones. A solar system is defined as an hierarchical object. Calling the one object `solarsystem` causes all the other objects named in the definition of `solarsystem` (the sun, the planets, and their orbits) to be drawn.

Global attributes are not saved before a `callobj` command takes effect. Thus, if attributes like color are changed within an object, the change may affect the caller as well. Use `pushattributes` and `popattributes` to preserve global attributes across `callobj` commands.

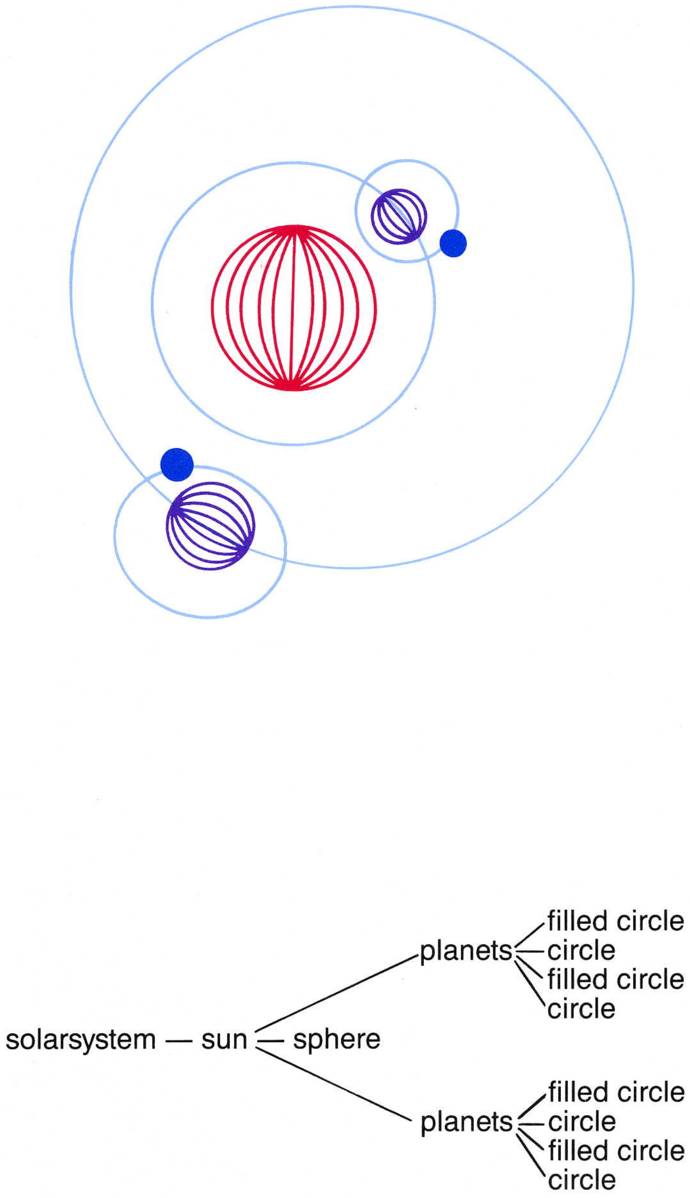


Figure 8.3

Solarsystem, a complex object, is defined hierarchically, as shown in the tree diagram. Branches in the tree represent *callobj* commands.

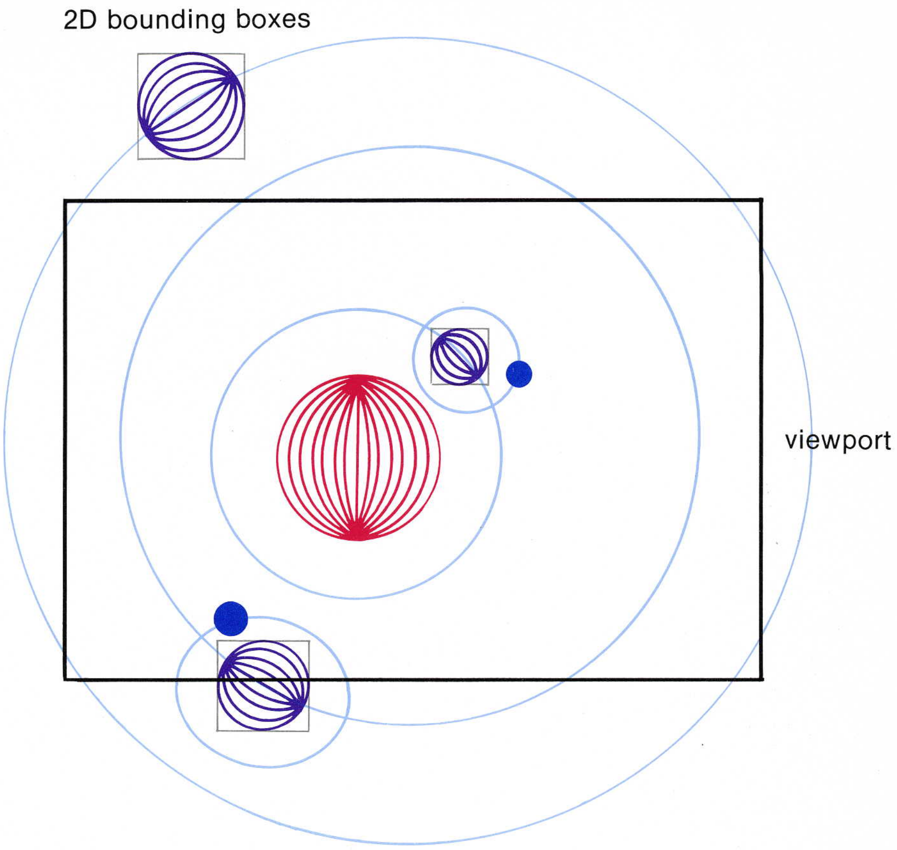
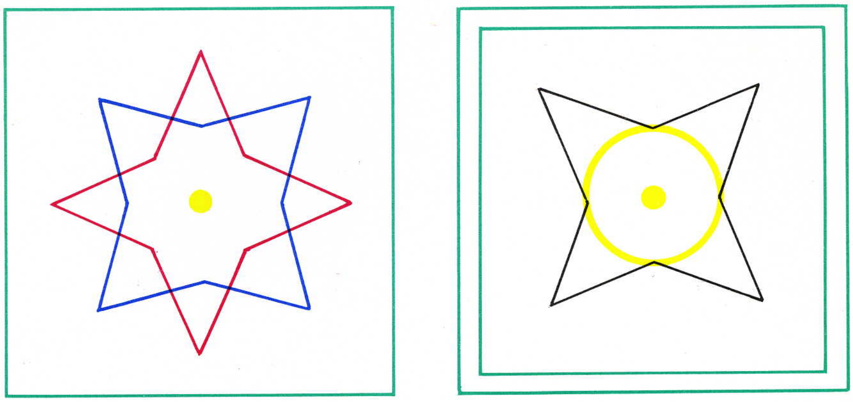


Figure 8.4

Bounding boxes can be computed to determine which objects are outside the screen viewport. If the bounding box is entirely outside the viewport the object will not be called. The sphere in the bounding box that lies partially within the viewport will be drawn.



```
makeobj (star);
  color (green);
  maketag (BOX);
  recti (0,0,10,10);
  maketag (INNER);
  color (blue);
  poly2i (8,Inner);
  maketag (OUTER);
  color (red);
  poly2i (8,Outer);
  maketag (CENTER);
  color (yellow);
  pnt2i (5,5);
closeobj ( );
```

```
editobj (star);
  circi (1,5,5);
  insert (BOX);
  recti (1,1,9,9);
  replace (INNER);
  color (black);
  objdelete (OUTER,
             CENTER);
closeobj ( );
```

```
makeobj (star);
  color (green);
  maketag (BOX);
  recti (1,1,9,9);
  recti (0,0,10,10);
  maketag (INNER);
  color (black);
  poly2i (8,Inner);
  maketag (OUTER);
  maketag (CENTER);
  color (yellow);
  pnt2i (5,5);
  circi (1,5,5);
closeobj ( );
```

Figure 8.5
The object definition on the left is being edited. Arrows indicate the movements of the editing cursor. The resulting object definition is on the right. The figures above show the object as it would be drawn before and after editing.

When a complex object is called, the whole hierarchy of objects in its definition is drawn. The object `solarsystem` in Figure 8.3 is an example. One negative aspect of this is that time may be spent on objects that are not visible in the screen viewport. The `bbox2` command determines whether or not an object is within the viewport or is large enough to be seen. `bbox2` performs the graphical functions known as *pruning*and *culling.*

The `bbox2` culling function determines which parts of a picture are less than the minimum feature size, and thus too small to draw on the screen. Its pruning function calculates whether an object is completely outside the viewport.

The `bbox2` command takes as its arguments an object space bounding box, and minimum horizontal and vertical feature sizes, in pixels. The bounding box is calculated, transformed to screen coordinates, and compared with the viewport. If the bounding box is completely outside the viewport, the commands between `bbox2` and the end of the object are ignored. Otherwise, it is compared with the minimum feature size. If the bounding box is too small in both the x and y dimensions, the rest of the commands in the object are ignored. Otherwise, interpretation of the object continues.

```
bbox2(xmin, ymin, x1, y1, x2, y2)
Screencoord xmin, ymin;
Coord x1, y1, x2, y2;

subroutine bbox2(xmin, ymin, x1, y1, x2, y2)
integer xmin, ymin
real x1, y1, x2, y2

procedure bbox2(xmin, ymin: Screencoord; x1, y1, x2, y2: Coord);
```

Figure 8.4 shows the `solarsystem` discussed previously. The bounding boxes shown in the figure might be used to perform pruning – determining what objects will be even partially in the viewport.

8.3 Object Editing

An object can be edited to change its contents. Object editing is useful for complex objects that are time-consuming to recompile. Commands can be added, removed, or replaced through object editing.

`editobj` opens an object for editing. A command pointer acts as a cursor for appending new commands. The command pointer is initially set to the end of the object.

```
editobj(obj)
Object obj;

subroutine editob(obj)
integer*4 obj

procedure editobj(obj: Object);
```

The editing commands following a `editobj` are interpreted, and the editing session is terminated with a `closeobj`. If `editobj` specifies an undefined object, an error message is printed.

Tags within an object make it easy to locate a given command for editing. Editing commands must be given tag names as arguments. It is useful to have tags throughout the object to move to when editing.

Each object has two predefined tags – `STARTTAG` and `ENDTAG`. `STARTTAG` is positioned just after `makeobj`, before any commands. `ENDTAG` is always positioned after all the commands in an object, before `closeobj`. These tags cannot be deleted, and no items can be added before `STARTTAG` or after `ENDTAG`. When an object is opened for editing, a pointer is just before `ENDTAG`, and just after the last command in the object. To perform edits on other lines, refer to them by their tags.

Commands can be explicitly flagged with the `maketag` command. The user supplies a 31-bit name that is assigned to the command immediately following the `maketag` command. The tag is local to that object. The same tag name can be used safely in different objects.

```
maketag(t)
Tag t;

subroutine maketa(t)
integer*4 t

procedure maketag(t: Tag);
```

`newtag` also adds tags to an object, but uses an existing tag to determine its relative position in the object. `newtag` creates a new tag offset the number of lines given as its argument beyond the other tag.

```
newtag(newtag, oldtag, offset)
Tag newtag, oldtag;
long offset;

subroutine newtag(newtag, oldtag, offset)
integer*4 newtag, oldtag, offset

procedure newtag(newtag, oldtag: Tag; offset: longint);
```

istag tells whether a given tag is in use within the currently open object. istag returns TRUE if the tag is in use, and FALSE if it is not. The result is undefined if there is currently no open object.

```
Boolean istag(t)
Tag t;

logical function istag(t)
integer*4 t

function istag(t: Tag): longint;
```

gentag generates a unique integer for use as a tag.

```
Tag gentag()

integer*4 function gentag()

function gentag: Tag;
```

deltag deletes tags from the object currently open for editing. The special tags STARTTAG and ENDTAG cannot be deleted.

```
deltag(t)
Tag t;

subroutine deltag(t)
integer*4 t

procedure deltag(t: Tag);
```

`objinsert` adds commands to an object at the given location. `objinsert` takes a tag as an argument, and positions an editing pointer on that tag. Graphics commands are added immediately after the tag. To terminate the insertion, use `closeobj` or another editing command `(objdelete, objinsert, objreplace)`.

```
objinsert(t)
Tag t;

subroutine objins(t)
integer*4 t

procedure objinsert(t: Tag);
```

`objdelete` removes commands from the currently open object. It removes everything between the two tagnames given as arguments – both commands and other tagnames are deleted. For example: `objdelete(STARTTAG, ENDTAG)` would delete every line (except `makeobj()` and `closeobj()`) in the object specified. The command is ignored if no object is open for editing. This command leaves the pointer at the end of the object after it takes effect.

```
objdelete(tag1, tag2)
Tag tag1, tag2;

subroutine objdel(tag1, tag2)
integer*4 tag1, tag2

procedure objdelete(tag1, tag2: Tag);
```

`objreplace` combines the functions of `objinsert` and `objdelete`. This command is a quick way to replace a command with a version of itself containing different arguments. It takes as its argument a single tag. Graphics commands that follow objreplace overwrite existing commands until a closeobj or editing command (objinsert, objreplace, objdelete) terminates the replacement. objreplace requires the new command to be exactly the same length in characters as the one replaced. This makes objreplace operations faster, but more general replacement should be done with objdelete and objinsert commands.

```
objreplace(t)
Tag t;

subroutine objrep(t)
integer*4 t

procedure objreplace(t: Tag);
```

Here is an example of object editing. An object star is defined:

```
makeobj(star);
      color(GREEN);
      maketag(BOX);
      recti(1, 1, 9, 9);
      maketag(INNER);
      color(BLUE);
      poly2i(8, Inner);
      maketag(OUTER);
      color(RED);
      poly2i(8, Outer);
      maketag(CENTER);
      color(YELLOW);
      pnt2i(5, 5);
closeobj();
```

Then this object is edited with the following commands to give a modified object:

```
editobj(star);
      circi(1, 5, 5);
      objinsert(BOX);
      recti(0, 0, 10, 10);
      objreplace(INNER);
      color(GREEN);
closeobj();
```

The resulting object after the editing session:

```
makeobj(star);
      color(GREEN);
      maketag(BOX);
      recti(0, 0, 10, 10);
      recti(1, 1, 9, 9);
      maketag(INNER);
      color(GREEN);
      poly2i(8, Inner);
      maketag(OUTER);
      color(RED);
      poly2i(8, Outer);
      maketag(CENTER);
      color(YELLOW);
      pnt2i(5, 5);
      circi(1, 5, 5);
closeobj();
```

`getopenobj` determines whether any objects are currently open for editing. If an object is open, it returns its number. If no objects are open, it returns -1.

```
Object getopenobj()

integer*4 function getope()

function getopenobj: Object;
```

Object memory management

Three commands perform necessary memory management tasks: `compactify`, `chunksize`, and `getmem`.

An open object may become fragmented and be stored inefficiently in memory as it is modified by the various editing commands. When the amount of wasted space becomes large, `compactify` is automatically called during the `closeobj` operation.

This command allows the user to perform the compaction explicitly. Unless new commands have been inserted, compaction is not necessary. Since `compactify` uses a significant amount of computing time, it should not be called unless storage space is critical.

```
compactify(obj)
Object obj;

subroutine compac(obj)
integer*4 obj

procedure compactify(obj: Object);
```

If there is a memory shortage, `chunksize` can allocate memory in standard amounts (chunks) to an object. `chunksize` specifies the minimum amount of memory allocated to an object, and as the object grows, it is allocated more memory in units of size `chunk`. `chunksize` may be called only once after `ginit` and before the first `makeobj`. The default `chunk` unit of size is 1020 bytes.

```
chunksize(chunk)
long chunk;

subroutine chunks(chunk)
integer*4 chunk

procedure chunksize(chunk: longint);
```

`getmem` determines the amount of available memory left on the system. On a terminal, it returns the amount of free physical memory. On a workstation with virtual memory up to 14 megabytes, it returns 14 megabytes less the amount in use.

```
long getmem()

integer*4 function getmem()

function getmem: longint;
```

`finish` is used only on an IRIS terminal running remote graphics. `finish` blocks the host process until all prior commands have been executed. It forces all unsent commands down the network/graphics pipeline to the bitplanes, sends a final token, and blocks until that token has gone through the network and graphics pipeline, and an acknowledgement has been sent. Network and pipeline delays make this command useful.

```
finish()

subroutine finish

procedure finish;
```

callfunc allows an arbitrary function call from within an object. When it is executed in the object, the function fctn(nargs, arg1, arg2, ..., argn) is called. callfunc is useful only for writing customized terminal programs. It cannot be called remotely.

```
callfunc(fctn, nargs, arg1, arg2, ..., argn)
int (*fctn)()
long nargs, arg1, arg2, ..., argn;

NOTE: works only in C

NOTE: works only in C
```

9. Picking and Selecting

Previous chapters have discussed how to define objects in world coordinates and then draw them to the screen. This chapter discusses how to specify an area of the screen (or of the "world") and then determine what objects are being drawn in that area.

The `mapw` command takes 2D screen coordinates and identifies the corresponding 3D world coordinates. The `pick` command puts the IRIS in picking mode – all the objects drawn to a small area around the cursor can be identified. The `select` command puts the IRIS in selecting mode – all the objects drawn to a 3D area (specified by the user) can be identified.

9.1 Mapping the Screen to World Space

The `mapw` command takes a 2D screen point and maps it onto a line in 3D world space. The viewing, projection, and viewport transformations that map the currently displayed objects to the screen are contained in the viewing object `vobj`. `mapw` reverses these transformations and maps the screen space point back to a world space line. It returns two points (`wx1, wy1, wz1`) and (`wx2, wy2, wz2`), which specify the endpoints of the line. `sx` and `sy` specify the screen point to be mapped.

```
mapw(vobj, sx, sy, wx1, wy1, wz1, wx2, wy2, wz2)
Object vobj;
Screencoord sx, sy;
Coord *wx1, *wy1, *wz1, *wx2, *wy2, *wz2;

subroutine mapw(vobj, sx, sy, wx1, wy1, wz1, wx2, wy2, wz2)
integer*4 vobj, sx, sy
real wx1, wy1, wz1, wx2, wy2, wz2

procedure mapw(vobj: Object; sx, sy: Screencoord; var wx1, wy1, wz1,
        wx2, wy2, wz2: Coord);
```

`mapw2` is the two-dimensional version of `mapw`. In the 2D case, a screen point is mapped to a world space point rather than a line. Again, `vobj` contains the projection and viewing transformations that map the displayed objects to world space, and `sx` and `sy` define a screen space point. The corresponding world space coordinates are returned in `wx` and `wy`. If the transformations in `vobj` are not 2D (i.e., not orthogonal projections), the result is undefined.

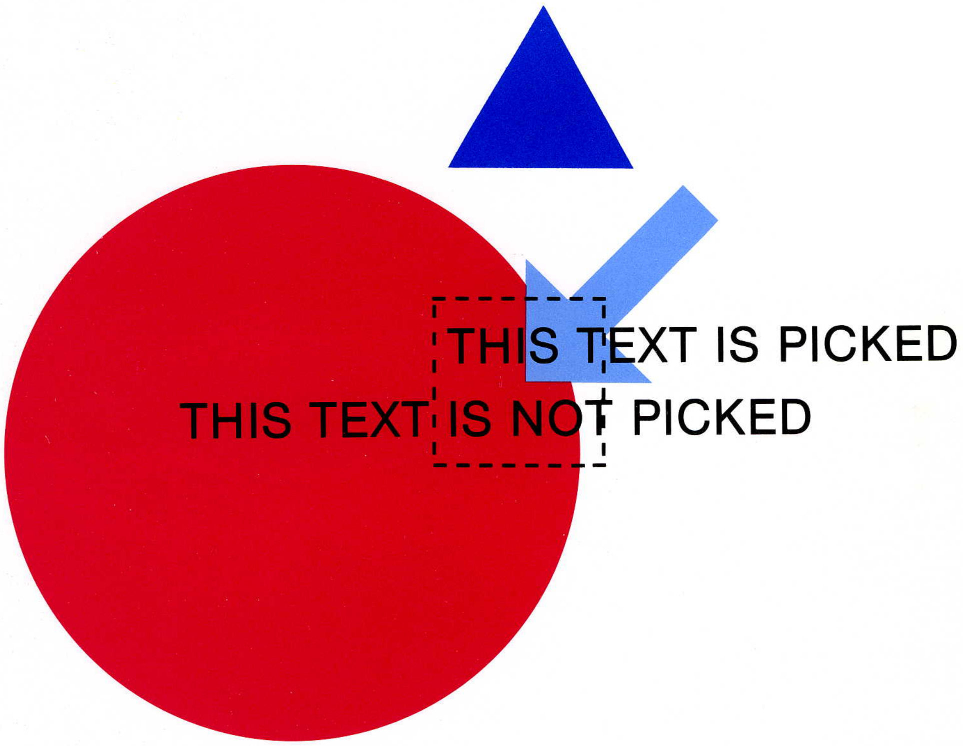


Figure 9.1

In picking mode, the user can identify the parts of an image that lie near the cursor. The cursor is shown as an arrow. The small box at the tip of the arrow is the *picking region*. The large shaded circle would be picked. The text string whose origin was in the picking region would also be picked. The shaded box and the other text string would not be picked.

```
mapw2(vobj, sx, sy, wx, wy)
Object vobj;
Screencoord sx, sy;
Coord *wx, *wy;

subroutine mapw2(vobj, sx, sy, wx, wy)
integer*4 vobj, sx, sy
real wx, wy

procedure mapw2(vobj: Object; sx, sy: Screencoord; var wx, wy: Coord);
```

9.2 Picking

Picking allows the user to identify objects by pointing at them with an input device. The `pick` command puts the IRIS in picking mode.

```
pick(buffer, numnames)
short buffer[];
long numnames;

subroutine pick(buffer, numnam)
integer*2 buffer(*)
integer*4 numnam

procedure pick(buffer: Ibuffer; numnames: longint);
```

When a command is called in picking mode, the screen does not change. Instead, the IRIS determines whether or not the command is drawing into a small rectangular area around the cursor called the *picking region*. Any command that does draw within the picking region is a "hit". (*charstr* causes a hit only when the origin of the string is located in the picking region.) Figure 9.1 shows four objects and a cursor glyph; only two of the objects would be picked if they were called during picking mode. Notice that `clear()` always causes a hit – it always draws in the picking region.

When a hit occurs, the contents of the *name stack* are copied into a buffer. It is the user's responsibility to maintain an informative list of names in the name stack. The commands that manipulate the name stack and examples of their use are presented below. At the end of a picking session, the picking buffer contains a series of name-lists, one list for each hit. The `numnames` argument to `pick` specifies the maximum number of values that can be stored in the buffer.

The user maintains the name stack with the `loadname`, `pushname`, `popname`, and `initnames` commands. These commands can be interspersed with drawing commands while in picking mode or they can be inserted into object definitions. See Chapter 8 for a discussion of objects.

`loadname` puts `name` at the top of the name stack and erases whatever was there before.

```
loadname(name)
short name;

subroutine loadna(name)
integer*4 name

procedure loadname(name: Short);
```

`pushname` puts `name` at the top of the stack and pushes all the other names in the stack one level lower.

```
pushname(name)
short name;

subroutine pushna(name)
integer*4 name

procedure pushname(name: Short);
```

`popname` discards the name at the top of the stack and moves all the other names up one level.

```
popname()

subroutine popnam

procedure popname;
```

`initnames` discards all the names in the stack and leaves the stack empty.

```
initnames()

subroutine initna

procedure initnames;
```

Each name in the name stack is sixteen bits long. The maximum number of names that can be stored in the name stack is 1000.

The `endpick` command takes the IRIS out of picking mode and returns the number of hits that occurred. If the returned number is positive, then there was space in the buffer for all of the name-lists. If the returned number is negative, then the buffer was too small to contain all the name-lists and the magnitude of the returned number is the number of name-lists that were stored.

```
long endpick(buffer)
short buffer[];

integer*4 function endpic(buffer)
integer*2 buffer(*)

function endpick(var buffer: Short): longint;
```

`buffer` contains all of the name-lists stored while in picking mode, one list for each valid hit. The first value in each name-list is the length of the name-list. If the name stack was empty when a hit occurred, the first and only name in the list for that hit is "0".

The default height and width of the picking region is ten pixels. The picking region can be changed with the `picksize` command. `deltax` and `deltay` specify a rectangle centered at the current cursor position (the origin of the cursor glyph). (See Section 6.4 for a discussion of cursors.)

```
picksize(deltax, deltay)
short deltax, deltay;

subroutine picksi(deltax, deltay)
integer*4 deltax, deltay

procedure picksize(deltax, deltay: Short);
```

Picking loads a projection matrix that makes the picking region fill the entire viewport. This picking matrix replaces the projection transformation matrix that would normally be used when the drawing commands are called. Therefore, the original projection transformation must be restated after the `pick` command (to ensure that the objects to be picked will be mapped to the proper coordinates). If no projection transformation was originally issued, the default `ortho2` must be specified. When the transformation command is restated, the product of the transformation matrix and the picking matrix is placed at the top of the matrix stack. If the projection transformation is not restated, picking does not work correctly. (Typically, every object will be picked, regardless of cursor position and picksize.)

The following program draws an object consisting of three shapes and then loops until the right mouse button is pressed. Each time the middle mouse button is pressed, the IRIS enters pick mode, calls the object, records hits for any commands that draw into the picking region, and prints out the contents of the picking buffer. Note that when the object is called in pick mode, the screen does not change. Since the picking matrix is recalculated only when `pick` is called, picking mode is exited and reentered to obtain new cursor positions.

```
#include "gl.h"
#include "device.h"

main()
{
    short namebuffer[50];
    long numpicked;
    short type, val, i, j, k;

    ginit();
    qdevice(MOUSE1);
    qdevice(MOUSE2);

    makeobj(1);
      color(RED);
      loadname(1); /* load the name "1" on the name stack */
```

```
        rectfi(20,20,100,100);
        loadname(2); /* load the name "2", replacing "1" */
        pushname(3); /* push name "3", so the stack has "3 2" */
        circi(50,500,50);
        loadname(4); /* replace "3" with "4", so the stack has "4 2" */
        circi(50,530,60);
    closeobj();

    color(BLACK);
    clear();
    callobj(1); /* draw the object on the screen */

    while (1) { /* loop until the right mouse button is pushed */
        type = qread(&val);
        if (val == 0)
            continue;
        switch (type) {
            case MOUSE1: /* if the right mouse button is pushed,
                            the program exits */
                gexit();
                exit(0);
            case MOUSE2: /* if the middle mouse button is pushed,
                            the IRIS enters pick mode */
                pick(namebuffer, 50);
                    /* restate the projection transformation for the object */
                ortho2(-0.5, XMAXSCREEN + 0.5, -0.5, YMAXSCREEN + 0.5);
                callobj(1); /* call the object (no actual drawing
                            takes place) */
                numpicked = endpick(namebuffer);
                        /* print out the number of hits and a name-list
                        for each hit */
                printf("hits: %d; ",numpicked);
                j = 0;
                for (i = 0; i < numpicked; i++) {
                    printf(" ");
                    k = namebuffer[j++];
                    printf("%d ", k);
                    for (;k; k--)
                        printf("%d ", namebuffer[j++]);
                    printf("|");
                }
                printf("\n");
        }
    }
}
```

Here is the FORTRAN version of the program:

```
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C    Installation note:
C   Various Fortran compilers may require different styles of INCLUDEs.
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      INCLUDE 'fgl.h'
      INCLUDE 'fdevice.h'
C
      INTEGER*2 NAMBUF(50)
      INTEGER*2 VAL, I, J, K, L
      INTEGER TYPE, NUMPIC
C
      CALL GINIT()
C
      CALL QDEVIC(MOUSE1)
      CALL QDEVIC(MOUSE2)
C
      CALL MAKEOB(1)
        CALL COLOR(RED)
C         load the name "1" on the name stack
        CALL LOADNA(1)
        CALL RECTFI(20,20,100,100)
C         load the name "2", replacing "1"
        CALL LOADNA(2)
C         push the name "3", so the stack has "3 2"
        CALL PUSHNA(3)
        CALL CIRCI(50,500,50)
C         replace "3" with "4", so the stack has "4 2"
        CALL LOADNA(4)
        CALL CIRCI(50,530,60)
      CALL CLOSEO()
C
      CALL COLOR(BLACK)
      CALL CLEAR()
C       draw the object on the screen
      CALL CALLOB(1)
C
C       loop until the left mouse button is pushed
100   CONTINUE
        TYPE = QREAD(VAL)
C         try again if the event was a button release
        IF (VAL .EQ. 0) GO TO 100
C         if the left mouse button is pushed, the program exits
        IF (TYPE .EQ. MOUSE1) THEN
          CALL GEXIT()
          GO TO 400
        END IF
C         if the middle mouse button is pushed, tghe IRIS enters pick mode
        IF (TYPE .EQ. MOUSE2) THEN
          CALL PICK(NAMBUF,50)
C           restate the projection transformation for the object
          CALL ORTHO2(-0.5, XMAXSC+0.5, -0.5, YMAXSC+0.5)
C           call the object (no actual drawing takes place)
          CALL CALLOB(1)
C           print out the number of hits and a name-list for each hit
          NUMPIC = ENDPIC(NAMBUF)
          PRINT *, 'Hits: ', NUMPIC
          J = 1
          DO 300 I=1,NUMPIC
            K = NAMBUF(J)
            J = J + 1
            PRINT *,K
            DO 200 L=1,K
              PRINT *,'   ',NAMBUF(J)
              J = J + 1
200           CONTINUE
300         CONTINUE
        END IF
C       loop until the left mouse button is pushed
      GO TO 100
400   CONTINUE
      STOP
      END
```

There are five possible outcomes for each picking session (the circles can be picked together because they overlap):

1) nothing is picked = "hits: 0;"
2) the rectangle is picked = "hits: 1; 1 1 |"
3) the first circle is picked = "hits: 1; 2 3 2 |"
4) the second circle is picked = "hits: 1; 2 4 2 |"
5) both the first and second circle are picked = "hits: 2; 2 3 2 | 2 4 2 |"

In addition to identifying the command that caused a hit, the IRIS provides a code that indicates which of the picking region's clipping planes were intersected by the last hit in a picking session. The *hitcode* is a six-bit number with one bit for each clipping plane, as shown in the following table.

5	4	3	2	1	0
far	near	top	bottom	right	left

After **endpick** has been called, the **gethitcode** command can be called to obtain the hitcode for picking session. "1" in the hitcode indicates that the corresponding plane was intersected during the picking session. "0" indicates the plane was not intersected. (Systems without near-far clipping always return "0"s for the near and far clipping planes.)

```
long gethitcode()

integer*4 function gethit()

function gethitcode: longint;
```

The **clearhitcode** command sets all the bits in the current hitcode to "0". It is used before the picking session begins to initialize the hitcode.

```
clearhitcode()

subroutine clearh

procedure clearhitcode;
```

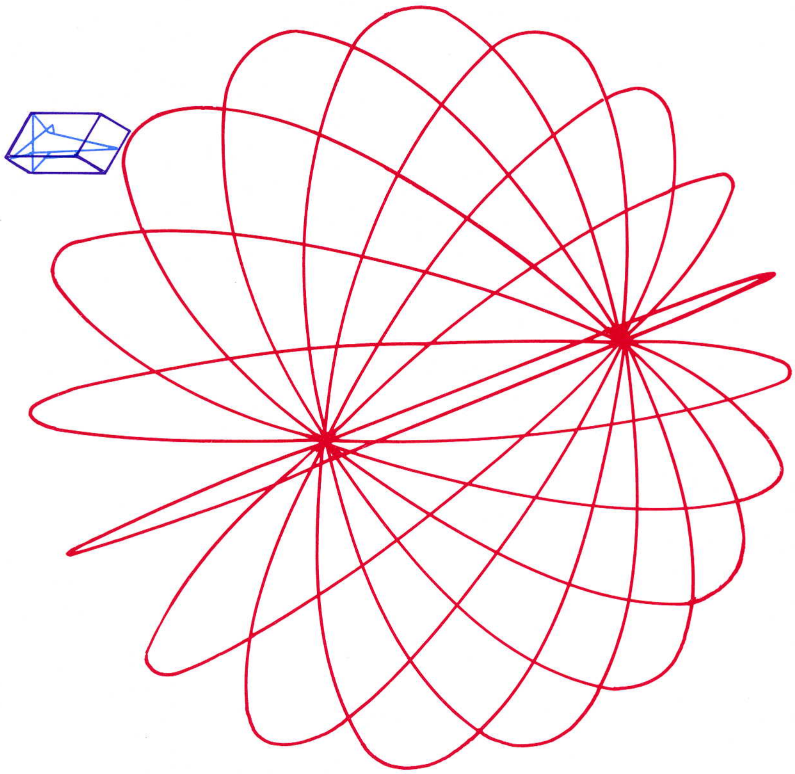


Figure 9.2

In selection mode, the user can identify all commands that draw things in an arbitrary region of world space. Here, we can detect that the rocket ship will crash into the planet by defining the selection region as a box around the ship.

9.3 Selecting

Selecting is a more general mechanism than picking for identifying the commands that draw to a particular region. A selecting region is a two- or three-dimensional area of world space. When the `select` command turns on selecting mode, the region represented by the current viewing matrix becomes the selecting region. The selecting region can be changed at any time by issuing a new viewing transformation command. To use selecting mode, issue a viewing transformation command that specifies the selecting region, call `select`, call the objects or commands of interest, exit selecting mode, and look to see what was selected.

```
select(buffer, numnames)
short buffer[0];
long numnames;

subroutine select(buffer, numnam)
integer*2 buffer(0)
integer*4 numnam

procedure select(buffer: Ibuffer; numnames: longint);
```

`numnames` specifies the maximum number of values that can be stored in the buffer. The name stack and the hitcode commands are used in the same way as picking. `endselect` turns off selecting mode. A series of name-lists is reported to the user in `buffer`. Each name-list represents the contents of the name stack when a command was called that drew into the selecting region. The number of name-lists in `buffer` is returned as the value of `endselect`. If the number is negative, more commands drew into the selecting region than were specified by `numnames`.

```
long endselect(buffer)
short buffer[];

integer*4 function endsel(buffer)
integer*2 buffer(*)

function endselect(var buffer: Ibuffer): integer;
```

Figure 9.2 shows a sample application of a rocket ship and a planet. The following program uses selecting to determine if the ship is colliding with the planet.

The program calls a simplified version of the planet and draws a box representing the ship each time the left mouse button is pressed. The program prints "CRASH" and exits when the ship collides with the planet.

```
#include "gl.h"
#include "device.h"

#define PLANET 1

main()
{
  short type, val;
  register short buffer[50], cnt, i;
  float shipx, shipy, shipz;

    /* initialize the buffer to zeros */
  for (i = 0; i < 50; i++)
    buffer[i] = 0;

  ginit();

  qdevice(MOUSE3);
  cursoff();
  color(BLACK);
  clear();
  color(RED);
    /* create the planet object */
  createplanet(PLANET);
    /* draw the planet on the screen */
  callobj(PLANET);

  while (1) {   /* loop until the left mouse button is pressed */
    type = qread(&val);
    if (val==0)
        continue;
    switch (type){
        case MOUSE3:
            /* set ship location to cursor location */
            shipz=0;
            shipx=getvaluator(MOUSEX);
            shipy=getvaluator(MOUSEY);
            /* draw the ship */
            color(BLUE);
            rect(shipx, shipy, shipx+20, shipy+10);

            /* specify the selecting region to be a box
```

```
                    surrounding the rocket ship */

                    pushmatrix(); /* save the current transformation matrix */
                    ortho(shipx,shipx+.05,shipy,shipy+.05,shipz-0.5,shipz+.05);

                    /* clear the name stack */
                    initnames();

                    select(buffer, 50); /* enter selecting mode */

                    /* put "1" on the name stack to be saved if PLANET
                    draws into the selecting region */
                    loadname(1);
                    pushname(2);

                    /* call the planet object (no actual drawing takes place) */
                    callobj(PLANET);

                    /* exit selecting mode */
                    cnt = endselect(buffer);
                    popmatrix(); /* restore the original transformation matrix */

                    /* check to see if PLANET was selected */
                    if (buffer[1]==1) {
                        printf("CRASH\n");
                        curson();
                        gexit();
                        }
        }
    }
    gexit();
}

createplanet(x)
{
    makeobj(x);
    circfi(200, 200, 20);
    closeobj();
}
```

10. Geometry Pipeline Feedback

The IRIS feedback facility provides access to the Geometry Pipeline for matrix multiplication and geometric computing. In feedback mode, the data output by the Geometry Pipeline are stored in a buffer, rather than being sent to the raster display subsystem. The buffer can then be examined to see how the data were transformed by the Geometry Engines. For example, if the `pnt` command is issued in feedback mode, the Geometry Pipeline performs its normal function of transforming, clipping, and scaling the world coordinates to screen coordinates. The command code for the `pnt` command, along with the new transformed coordinates, is then stored in the feedback buffer. (If the point is outside the clipping region, no command is output from the Geometry Pipeline and nothing is stored in the buffer.) The following sections discuss the functions of the Geometry Pipeline, how to start and stop feedback mode, how to pass markers through the Geometry Pipeline into the feedback buffer, and how to interpret what is saved in the buffer.

10.1 The Geometry Pipeline

To display images on the screen, the applications/graphics processor sends graphics commands through the Geometry Pipeline to the raster display subsystem. (See Figure 10.1.) All the commands issued by the processor can be divided into two classes – those that are interpreted by the Geometry Pipeline and those that are passed through unchanged. The commands that are interpreted by the Geometry Pipeline include the move, draw, point, polygon, curve, and matrix manipulation commands. Commands *not* interpreted by the Geometry Pipeline include (among others) the color, character string, texture, linestyle, and display mode commands.

The Geometry Pipeline consists of two geometry accelerators and ten or twelve Geometry Engines. (See Figure 10.2.) There are three Geometry Pipeline subsystems:

- The *matrix subsystem* consists of four matrix multipliers, one for each column in a 4x4 matrix.
- The *clipping subsystem* consists of four or six clippers, one for each clipping plane of the drawing space.
- The *scaling subsystem* consists of two scalers, which scale 2D and 3D coordinates to the coordinate system of a particular output device.

Each Geometry Engine can be configured to do any of the twelve possible jobs. (Systems with ten Geometry Engines have only four clippers and do not clip to the near and far planes.)

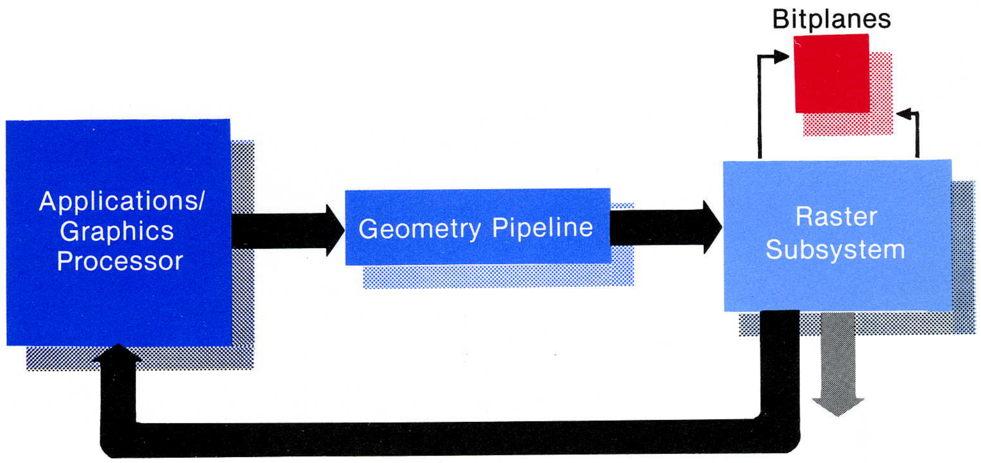


Figure 10.1

In feedback mode, the output of the **Geometry Pipeline** is returned to the **Applications/Graphics Processor**.

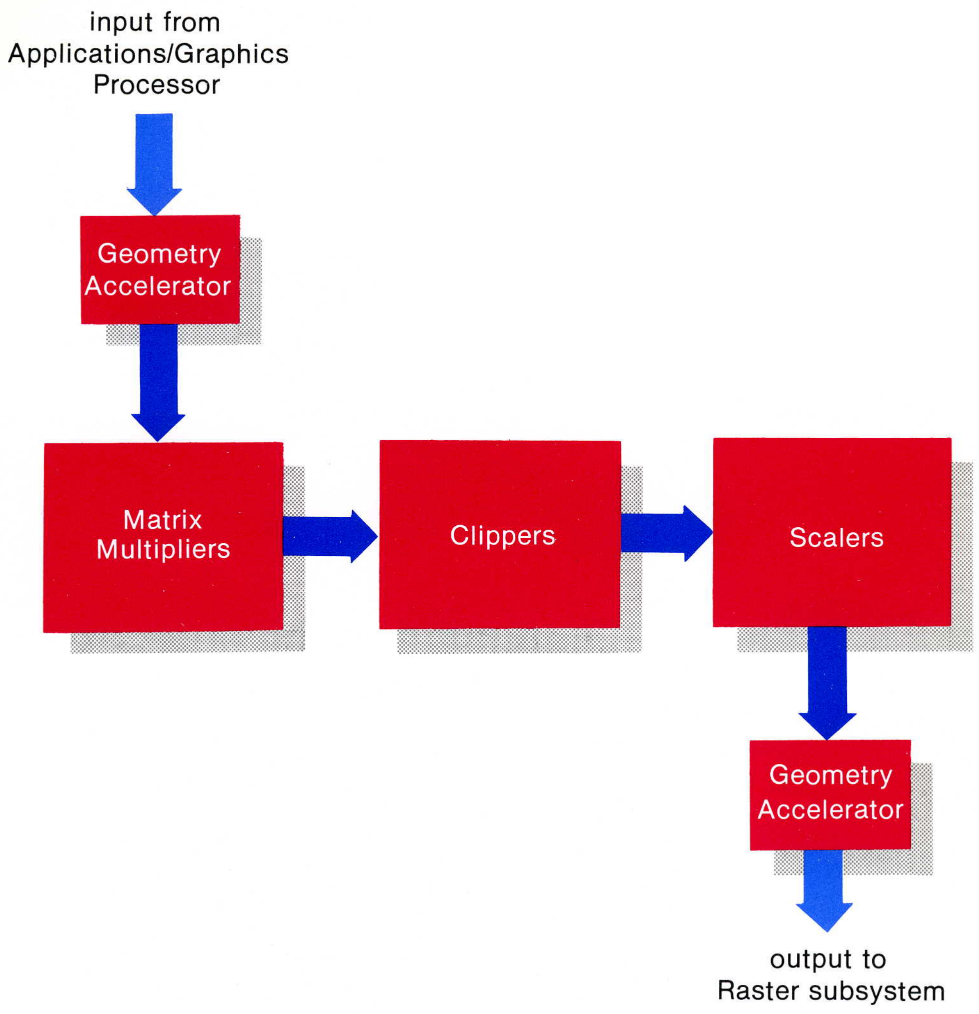


Figure 10.2

The **Geometry Pipeline** consists of two Geometry Accelerators and three Geometry Engine subsystems: the matrix multipliers, the clippers, and the scalers.

The applications/graphics processor issues graphics commands in user-defined coordinates. The first geometry accelerator converts the user-defined coordinates to floating-point numbers (if necessary) and adds zeros and ones to make 4-dimensional homogeneous coordinates. The first four Geometry Engines – the matrix multipliers – transform the coordinates to a normalized screen space. Each of these four engines performs the calculations for one column of the *current transformation matrix*. The current transformation matrix is computed from the modeling, viewing, and projection transformation commands issued by the user, and is automatically loaded into the Geometry Engines. The user can directly define the transformation matrix in the Geometry Engines with the matrix manipulation commands (e.g., **loadmatrix**) discussed in Chapter 4.

The next four Geometry Engines clip the normalized screen coordinates to the top, bottom, left, and right clipping planes. Two optional Geometry Engines clip to the near and far planes. The clipping process may cause commands to be clipped out entirely or it may cause new commands to be generated. Figure 10.3(a) shows how clipping can cause a new **move** command to be inserted in the command stream. Figure 10.3(b) shows how a three-point polygon turns into a seven-point polygon after being pass through the clippers.

The final two Geometry Engines – the scalers – map the normalized, clipped screen-space coordinates to a particular area of the screen. This area of the screen is defined by the **viewport** command. (See Chapter 4 for a discussion of viewports and Appendix B for further discussion of Geometry Engine computations.)

10.2 Feedback Mode

The IRIS feedback facility allows the user to perform matrix operations and geometric computing with the Geometry Pipeline. During feedback mode, the output of the Geometry Pipeline (a series of 16-bit integers) is saved in a buffer. Each command appears as a token, followed by data values. Table 10.1 shows the tokens for commands that are transformed by the Geometry Pipeline, along with the data associated with each command. Note that circles, arcs, polygons, curves, and patches all appear in the feedback buffer as **move**'s and **draw**'s. Most attribute and viewport commands appear in the feedback buffer but should be avoided in feedback mode since they are not transformed and complicate the interpretation of the buffer. The **passthrough** and **xfpt** commands at the bottom of the table are discussed later in this section.

command	normal mode	depth-cue mode z-buffer mode
move	16,x,y	16,x,y,x′,z
draw	17,x,y	17,x,y,x′,z
pnt	18,x,y	18,x,y,x′,z
pmov	48,x,y	48,x,y,x′,z
pdr	49,x,y	49,x,y,x′,z
pclos	51,x,y	51,x,y,x′,z
passthrough	8,value	8,value
xfpt	56,x,y,z,w	56,x,y,z,w

Table 10.1: Command tokens and associated data

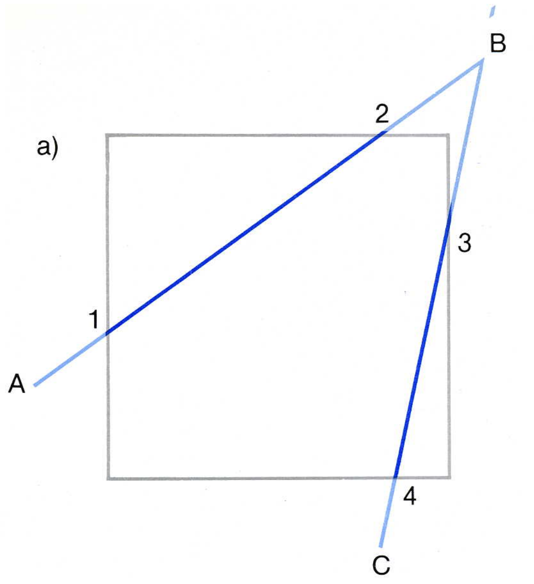
The **feedback** command puts the IRIS in feedback mode. The first argument to **feedback** is the name of the buffer where the Geometry Pipeline output is saved. The second argument specifies the numbers of items to be saved by the system. If more than **size** values appear, the extra values will be lost.

```
feedback(buffer,size)
short buffer[];
long size;

subroutine feedba(buffer,size)
integer*2 buffer(*)
integer*4 size

procedure feedback(buffer: Ibuffer; size: longint)
```

The **endfeedback** command returns the number of values stored in the buffer.

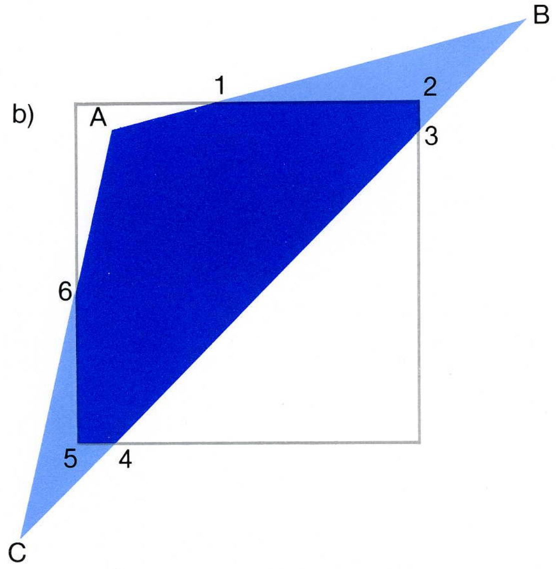
```
long endfeedback(buffer)
short buffer[];

integer*4 function endfee(buffer)
integer*2 buffer(*)

function endfeedback(buffer: Short): longint;
```

The **passthrough** command stores the command token 8 and an associated 16-bit integer in the feedback buffer. The passed-through value acts as a marker in the feedback buffer and can be used to match the input to the pipeline with the out-



The sequence: move(<A>)
move(<A>)
draw(<B>)
draw(<C>)

becomes: move(<1>)
draw(<2>)
move(<3>)
draw(<4>)



The sequence: pmov(<A>)
pdrw(<B>)
pdrw(<C>)
pclose

becomes: pmov(<A>)
pdrw(<1>)
pdrw(<2>)
pdrw(<3>)
pdrw(<4>)
pdrw(<5>)
pdrw(<6>)
pclose

Figure 10.3

Two examples of how the clipping subsystem of the **Geometry Pipeline** can generate new commands.

put from the pipeline. passthrough is especially useful for identifying commands that are clipped and do not appear in the feedback buffer.

```
passthrough(token)
short token;

subroutine passth(token)
integer*4 token

procedure passthrough(token: Short);
```

The following program issues three pnt commands in feedback mode and prints out the values stored in the feedback buffer. For the purposes of this example, the projection transformation is the default, ortho2, which maps the user-defined coordinates to screen coordinates without changing them.

```
#include "gl.h"

main()
{
    unsigned short buf[200];
    register i,j,num;
    float *bufptr;

    ginit();
    feedback(buf, 200); /* turns on feedback mode, buf is the name
                        of the feedback buffer and there is room
                        for 200 16-bit values */
    pnt(1.0,2.0,-0.2);
    passthrough(1);  /* store a marker in buf called "1" */
    pnt2(23.0,6.0);
    passthrough(2);  /* store a marker called "2" */
    pnt2i(0x123,0x234);  /* arguments are in hexidecimal */
    passthrough(3);  /* store a marker called "3" */
    num = endfeedback(buf);
        /* the following section of the program prints out
         the contents of the feedback buffer */
    for (i = 0; i < num; i++) {
        if (i % 8 == 0)
            printf("\n");
        printf(" %0.4x\t", buf[i]);
    }
    printf("\n");
    printf("\n");
```

```
          gexit();
     }
```

The output of the program is the contents of `buf` (in hexidecimal):

```
     0012  0001  0002  0008  0001  0012 0017 0006
     0008  0002  0012  0123  0234  0008 0003
```

or in decimal:

```
     18 1 2 8 1
     18 23 6 8 2
     18 291 564
```

In order to compute and save z coordinates in the feedback buffer, the IRIS can be put in z-buffer mode or depth-cue mode. (See Chapters 12 and 13.) In these modes, the output of the Geometry Pipeline is five values for each command: a command code, an x coordinate, a y coordinate, another x coordinate (used for stereo projection), and a z coordinate. (See Table 10.1.) The following program issues three `pnt` commands with both feedback mode and depth-cue mode turned on, and prints out the contents of the feedback buffer.

```
#include "gl.h"

main()
{
     unsigned short buf[200];
     register i,j,num;
     float *bufptr;

     ginit();
     setdepth(0,10); /* set the near clipping plane to 0 and the
                 far clipping plane to 10 */
     depthcue(1);  /* turn on depth-cue mode */
     feedback(buf,200);
     pnt(1.0,2.0,1.0);
     passthrough(1);
     pnt(1.0,2.0,-1.0);
     passthrough(2);
     pnt2i(0x123,0x234); /* arguments are in hexidecimal */
     passthrough(3);
     num = endfeedback(buf);
     depthcue(0);  /* turn off depth-cue mode */
          /* this section prints out the contents of buf */
     for (i = 0; i < num; i++) {
          if (i % 8 == 0)
               printf("\n");
          printf(" %0.4x\t", buf[i]);
```

```
        }
        printf("\n");
        printf("\n");

        gexit();
}
```

The output of the program is:

```
0012  0001  0002  0001  0000  0008 0001 0012
0001  0002  0001  000b  0008  0002 0012 0123
0234  0123  0005  0008  0003
```

This can be translated into:

```
18 1 2 1 0
8 1
18 1 2 1 10
8 2
18 291 564 291 5
```

The first number in each list is a command code. For the `pnt` commands, the following four values are x, y, x', and z.

In the first example, the coordinates for the points were transformed by the matrix multipliers, and then clipped and scaled. However, it is possible to transform coordinates with the matrix multipliers and then bypass the clippers and scalers. The `xfpt` command maps 4-dimensional points to new 4-dimensional points, using the current transformation matrix. The Geometry Pipeline outputs the `xfpt` command code 56 and four floating-point values, which are saved in the feedback buffer. `xfpt` always stores a four-dimensional transformed floating-point coordinate in the feedback buffer. The input for `xfpt` can be expressed in integer/floating-point/short and 2D/3D/4D versions. `xfpt` should only be called in feedback mode.

```
xfpt(x, y, z)
Coord x, y, z;

subroutine xfpt(x, y, z)
real x, y, z

procedure xfpt(x, y, z: Coord);
```

The following program issues three `xfpt` commands:

```
#include "gl.h"
        /* define the matrix that will transform the points
                (this particular matrix does not change the points) */
```

```
float idmat[4][4] = {
      1.0, 0.0, 0.0, 0.0,
      0.0, 1.0, 0.0, 0.0,
      0.0, 0.0, 1.0, 0.0,
      0.0, 0.0, 0.0, 1.0};

main()
{
      unsigned short buf[200];
      register i,j,num;
      float *bufptr;

      ginit();
      pushmatrix(); /* save the current transformation matrix */
      loadmatrix(idmat); /* load the transformation matrix */
      feedback(buf,50);
      xfpt(1.0,2.0,3.0);
      xfpt4(5.0,6.0,7.0,3.14159);
      xfpt2i(7,8);
      num = endfeedback(buf);
      popmatrix(); /* restore original transformation matrix */
            /* print out buf */
      for (i = 0; i < num; i++) {
            if i % 8 == 0)
                  printf("\n");
            printf(" %0.4x\t", buf[i]);
      }
      printf("\n");
      printf("\n");
            /* print out floating-point versions of the coordinates */
      for (i = 0; i < 3; i++) {
            bufptr = (float *)(&buf[1 + i*9]);
            for (j = 0; j < 4; j++)
                  printf(" %f\t", *bufptr++);
            printf("\n");
      }
      gexit();
}
```

The output of the program is:

```
0038  3f80  0000  4000  0000  4040 0000 3f80
0000  0038  40a0  0000  40c0  0000 40e0 0000
4049  0fd0  0038  40e0  0000  4100 0000 0000
0000  3f80  0000

1.000000   2.000000   3.000000 1.000000
```

```
        5.000000    6.000000    7.000000 3.141590
        7.000000    8.000000    0.000000 1.000000
```

Since the identity matrix was used, the coordinates in the feedback buffer are equal to the original coordinates.

11. Curves and Surfaces

The IRIS Graphics Library provides commands for representing curved lines and surfaces. The first section in this chapter describes the mathematical basis for the curve facility. The second and third sections describe how to draw curves and surfaces.

A curve segment is drawn by specifying:

- a set of four control points, and
- a *basis* which defines how the control points will be used to determine the shape of the segment.

Complex curved lines can be created by joining several curve segments end to end. The curve facility provides the means for making smooth joints between the segments.

Three-dimensional surfaces, or *patches,* are represented by a "wireframe" of curve segments. A patch is drawn by specifying:

- a set of sixteen control points,
- the number of curve segments to be drawn in each direction of the patch, and
- the two bases which define how the control points determine the shape of the patch.

Complex surfaces can be created by joining several patches into one large patch.

11.1 Curve Mathematics

The mathematical basis for the IRIS curve facility is the *parametric cubic curve.* The curves in most applications are too complex to be represented by a single curve segment and instead must be represented by a series of curve segments joined end to end. In order to create smooth joints, it is necessary to control the positions and curvatures at the endpoints of curve segments. Parametric cubic curves are the lowest-order representation of curve segments that can provide continuity of position, slope, and curvature at the point where two curve segments meet.

A parametric cubic curve has the property that x, y, and z can be defined as third-order polynomials for some variable t:

$$x(t) = a_x t^3 + b_x t^2 + c_x t + d_x$$

$$y(t) = a_y t^3 + b_y t^2 + c_y t + d_y$$

$$z(t) = a_z t^3 + b_z t^2 + c_z t + d_z$$

A cubic curve segment is defined over a range of values for t (usually $0 \leq t \leq 1$), and can be expressed as a vector product:

$$C(t) = at^3 + bt^2 + ct + d$$

$$= \begin{bmatrix} t^3 t^2 t\, 1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix}$$

$$= TM$$

The IRIS approximates the shape of a curve segment with a series of straight line segments. The endpoints for all the line segments can be computed by evaluating the vector product $C(t)$ for a series of t values between 0 and 1. The shape of the curve segment is determined by the coefficients of the vector product, which are stored in column vector M. These coefficients can be expressed as a function of a set of four control points. Thus, the vector product becomes

$$C(t) = TM = T(BG)$$

where G is a set of four control points, or the *geometry*, and B is a matrix called the *basis*. The basis matrix is determined from a set of constraints that express how the shape of the curve segment relates to the control points. For example, one constraint might be that one endpoint of the curve segment is located at the first control point. Another constraint could be that the tangent vector at that endpoint lies on the line segment formed by the first two control points. When the vector product C is solved for a particular set of constraints, the coefficients of the vector product are identified as a function of four variables (the control points). Then, given four control point values, the vector product can be used to generate the points on the curve segment.

Three classes of cubic curves are discussed here: Bezier, Cardinal spline, and B-spline. (Other classes of cubic curves are described in a paper by J.H. Clark.[1]) The set of constraints which define each class is given, along with the basis matrix derived from those constraints. The next section discusses how to use the basis matrices to draw curve segments.

A *Bezier* cubic curve segment passes through the first and fourth control points and uses the second and third points to determine the shape of the curve segment. Of the three kinds of curves, the Bezier form provides the most intuitive control over the shape of the curve. The Bezier basis matrix is derived from the following four constraints:

1) One endpoint of the segment is located at p_1:

$$Bezier(0) = p_1$$

2) The other endpoint is located at p_4:

$$Bezier(1) = p_4$$

3) The first derivative, or slope, of the segment at one endpoint is equal to this value:

$$Bezier(0)' = 3(p_2 - p_1)$$

4) The first derivative at the other endpoint is equal to this value:

$$Bezier(1)' = 3(p_4 - p_3)$$

Solving for these constraints yields the following equation:

$$Bezier(t) = \begin{bmatrix} t^3 t^2 t\, 1 \end{bmatrix} \begin{bmatrix} -1 & 3 & -3 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{bmatrix}$$

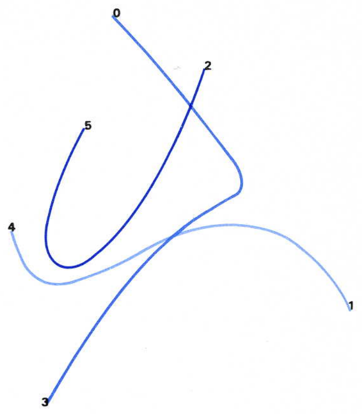
$$= TM_b G_b$$

All the points on the Bezier cubic curve segment from p_1 to p_4 can be generated by evaluating *Bezier(t)* for $0 \leq t \leq 1$. (It is more efficient, however, to construct

1. *Parametric Curves, Surfaces and Volumes in Computer Graphics and Computer-Aided Geometric Design,* James H. Clark, Technical Report No. 221, Computer Systems Laboratory, Stanford University.

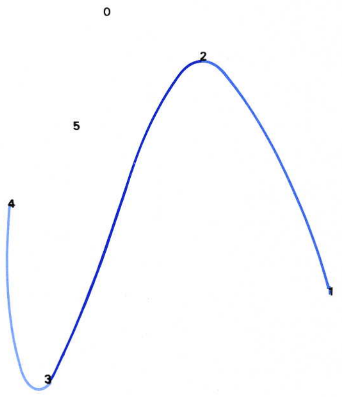
Bezier

(a) $$\begin{bmatrix} -1.0 & 3.0 & -3.0 & 1.0 \\ 3.0 & -6.0 & 3.0 & 0.0 \\ -3.0 & 3.0 & 0.0 & 0.0 \\ 1.0 & 0.0 & 0.0 & 0.0 \end{bmatrix}$$



Cardinal Spline

(b) $$\begin{bmatrix} -0.5 & 1.5 & -1.5 & 0.5 \\ 1.0 & -2.5 & 2.0 & -0.5 \\ -0.5 & 0.0 & 0.5 & 0.0 \\ 0.0 & 1.0 & 0.0 & 0.0 \end{bmatrix}$$



B-Spline

(c) $$\frac{1}{6}\begin{bmatrix} -1.0 & 3.0 & -3.0 & 1.0 \\ 3.0 & -6.0 & 3.0 & 0.0 \\ -3.0 & 0.0 & 3.0 & 0.0 \\ 1.0 & 4.0 & 1.0 & 0.0 \end{bmatrix}$$

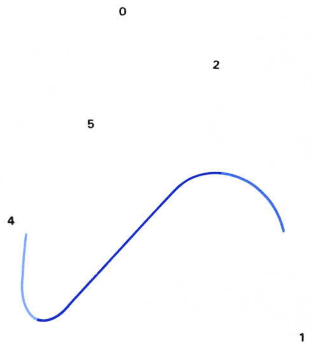


Figure 11.1

Three different curves are shown with appropriate basis matrices. With the Bezier basis matrix, three sets of overlapping control points result in three separate curve segments. With the Cardinal spline and B-spline matrices, the same overlapping sets of control points result in three joined curve segments.

a forward difference matrix which can generate the points in a curve segment incrementally. Forward difference matrices are discussed in the next section.)

Figure 11.1 shows three Bezier curve segments. The first segment uses points 0, 1, 2, and 3 as control points. The second uses 1, 2, 3, and 4. The third uses 2, 3, 4, and 5. The technique of overlapping sets of control points can be used more effectively with the following two classes of cubic curves to create a single large curve from a series of curve segments.

A *Cardinal spline* curve segment passes through the two interior control points and is continuous in the first derivative at the points where segments meet. The curve segment starts at p_2 and ends at p_3 , and uses p_1 and p_4 to define the shape of the curve. The mathematical derivation of the Cardinal spline basis matrix can be found in Clark's paper, referenced above.

The Cardinal spline basis matrix is derived from the following four constraints:

$$Cardinal(0) = p_2$$

$$Cardinal(1) = p_3$$

$$Cardinal(0)' = a(p_3 - p_1)$$

$$Cardinal(1)' = a(p_4 - p_2)$$

The scalar coefficient a must be positive, and determines the length of the tangent vector at point $p_2 : tangent_2 = a(p_3 - p_1)$ and $p_3 : tangent_3 = a(p_4 - p_2)$. Solving for these constraints yields the following equation:

$$Cardinal(t) = \begin{bmatrix} t^3 t^2 t\, 1 \end{bmatrix} \begin{bmatrix} -a & 2-a & -2+a & a \\ 2a & -3+a & 3-2a & -a \\ -a & 0 & a & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{bmatrix}$$

$$= TM_c G_c$$

The three joined Cardinal spline curve segments in Figure 11.1 use the same three sets of control points as the Bezier curve segments.

A *B-spline* curve segment does not in general pass through any control points, but is continuous in both the first and second derivatives at the points where segments meet. Thus, a series of joined B-spline curve segments is smoother than a series of Cardinal spline segments. (See Figure 11.1.)

The B-spline basis matrix is derived from the following four constraints:

$$B-spline(0)' = \frac{(p_3-p_1)}{2}$$

$$B-spline(1)' = \frac{(p_4-p_2)}{2}$$

$$B-spline(0)'' = p_1-2p_2+p_3$$

$$B-spline(1)'' = p_2-2p_3+p_4$$

Solving for these constraints yields the following equation:

$$B-spline(t) = \begin{bmatrix} t^3 t^2 t\, 1 \end{bmatrix} \frac{1}{6} \begin{bmatrix} -1 & 3 & -3 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 0 & 3 & 0 \\ 1 & 4 & 1 & 0 \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{bmatrix}$$

$$= TM_B G_B$$

11.2 Drawing Curves

Drawing a curve segment on the screen involves four steps:

1) The **defbasis** command defines and names a basis matrix.

```
defbasis(id, mat)
short id;
Matrix mat;

subroutine defbas(id, mat)
integer*4 id
real mat(4,4)

procedure defbasis(id: integer; mat: Matrix);
```

2) The **curvebasis** command selects a defined basis matrix as the *current basis matrix*.

```
curvebasis(basisid)
short basisid;

subroutine curveb(basisid)
integer*4 basisid

procedure curvebasis(basisid: integer);
```

3) The **curveprecision** command specifies the number of line segments to be used to approximate each curve segment.

```
curveprecision(nsegments)
short nsegments;

subroutine curvep(nsegments)
integer*4 nsegments

procedure curveprecision(nsegments: integer);
```

4) The **crv** command draws the curve segment using the current basis matrix, the current curve precision, and the four control points specified in the argument to **crv**.

```
crv(geom)
Coord geom[4][3];

subroutine crv(geom)
real geom(3,4)

procedure crv(geom: Curvearray);
```

When the **crv** command is issued, a matrix is built from the geometry, the current basis, and the current precision:

$$M = F_{precision} M_{basis} G_{geom}$$

$$= \begin{bmatrix} \frac{6}{n^3} & 0 & 0 & 0 \\ \frac{6}{n^3} & \frac{2}{n^2} & 0 & 0 \\ \frac{1}{n^3} & \frac{1}{n^2} & \frac{1}{n} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} M_{basis} G_{geom}$$

where n = the current precision. The bottom row of the resulting transformation matrix identifies the first of n points that will describe the curve. To generate the remaining points in the curve, the following algorithm is used to iterate the matrix as a forward difference matrix. The third row is added to the fourth row,

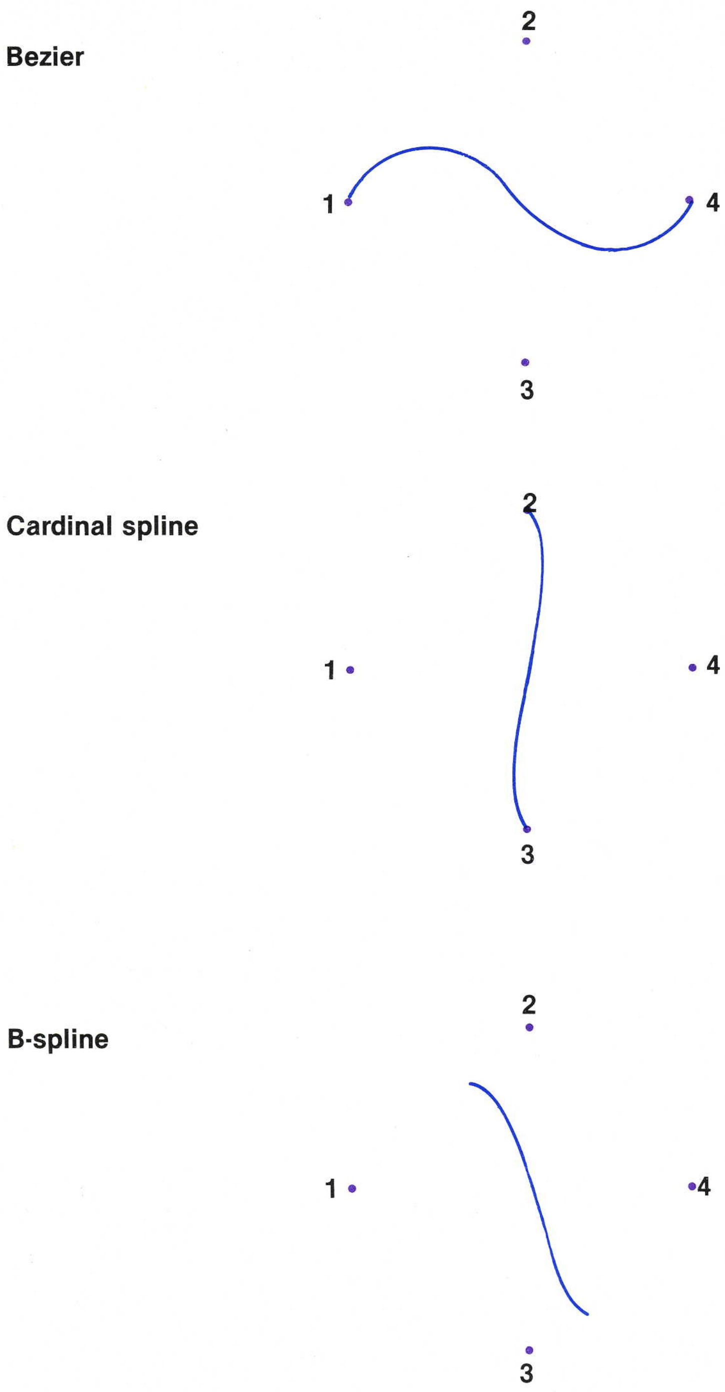


Figure 11.2

Each of the above curve segments uses the same set of four control points and the same precision, but a different basis matrix.

the second row is added to the third row, and the first row is added to the second row. The fourth row is then output as one of the points on the curve.

```
/* This is the forward difference algorithm */
/* M is the current transformation matrix */
move (M[3][0]/M[3][3], M[3][1]/M[3][3], M[3][2]/M[3][3]);
/* iteration loop */
for (cnt = 0; cnt < iterationcount; cnt++) {
     for (i=3; i>0; i--)
          for (j=0; j<4; j++)
               M[i][j] = M[i][j] + M[i-1][j];
     draw(M[3][0]/M[3][3], M[3][1]/M[3][3], M[3][2]/M[3][3]);
}
```

Each iteration draws one line segment of the curve segment. Note that if the precision matrix on the previous page is iterated as a forward difference matrix it generates the sequence of points: $(0, 0, 0, 1)$; $((\frac{1}{n})^3, (\frac{1}{n})^2, \frac{1}{n}, 1)$; $((\frac{2}{n})^3, (\frac{2}{n})^2, \frac{2}{n}, 1)$; $((\frac{3}{n})^3, (\frac{3}{n})^2, \frac{3}{n}, 1)$; . . . . This is the same sequence of points as is generated by $t = 0, \frac{1}{n}, \frac{2}{n}, \frac{3}{n}, \ldots$ for the vector $(t^3, t^2, t, 1)$.

The following program draws the three curve segments in Figure 11.2. All use the same set of four control points, which is contained in `geom1`. The three basis matrix arrays (`beziermatrix`, `cardinalmatrix`, and `bsplinematrix`) contain the values discussed in the previous section.

```
#include "gl.h"

Matrix beziermatrix = {
     { -1, 3, -3, 1 },
     { 3, -6, 3, 0 },
     { -3, 3, 0, 0 },
     { 1, 0, 0, 0 }
     };
Matrix cardinalmatrix = {
     { -0.5, 1.5, -1.5, 0.5 },
     { 1.0, -2.5, 2.0, -0.5 },
     { -0.5, 0, 0.5, 0 },
     { 0, 1, 0, 0 }
     };
Matrix bsplinematrix = {
     { -1.0/6.0, 3.0/6.0, -3.0/6.0, 1.0/6.0 },
     { 3.0/6.0, -6.0/6.0, 3.0/6.0, 0 },
     { -3.0/6.0, 0, 3.0/6.0, 0 },
     { 1.0/6.0, 4.0/6.0, 1.0/6.0, 0 }
     };
```

```
#define BEZIER 1
#define CARDINAL 2
#define BSPLINE 3
Coord geom1[4][3] = {
      { 100.0, 100.0, 0.0},
      { 200.0, 200.0, 0.0},
      { 200.0, 0.0, 0.0},
      { 300.0, 100.0, 0.0}
      };

main ()
{
ginit();
color(BLACK);
clear();
defbasis(BEZIER,beziermatrix); /* define a basis matrix
                  called BEZIER */
curvebasis(BEZIER); /* identify the BEZIER matrix
                  as the current basis matrix */
curveprecision(20); /* set the current precision to 20
            (the curve segment will be drawn using 20 line segments) */
color(RED);
crv(geom1); /* draw the curve based on the four control
                  points in geom1 */

defbasis(CARDINAL,cardinalmatrix); /* a new basis is defined */
curvebasis(CARDINAL); /* the current basis is reset */
            /* note that the curveprecision does not have to
            be restated unless it is to be changed */
color(BLUE);
crv(geom1); /* a new curve segment is drawn */

defbasis(BSPLINE,bsplinematrix); /* a new basis is defined */
curvebasis(BSPLINE); /* the current basis is reset */
color(GREEN);
crv(geom1); /* a new curve segment is drawn */

gexit();
}
```

Here is the FORTRAN version of the program:

```
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C     Installation note:
C   Various Fortran compilers may require different styles of INCLUDEs.
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      INCLUDE 'fgl.h'
```

```
C
      REAL BEZMAT(4,4), CARMAT(4,4), BSPMAT(4,4), GEOM1(3,4)
      INTEGER*2 BEZI, CARD, BSPL
      REAL ASIXTH, MSIXTH, TTHRDS
      INTEGER I, NOP
      PARAMETER ( BEZIER = 1 )
      PARAMETER ( CARDIN = 2 )
      PARAMETER ( BSPLIN = 3 )
      PARAMETER ( ASIXTH = 1.0/6.0 )
      PARAMETER ( MSIXTH = -1.0/6.0 )
      PARAMETER ( TTHRDS = 2.0/3.0 )
C
      DATA BEZMAT /-1.0,  3.0, -3.0,  1.0,
     2           3.0, -6.0,  3.0,  0.0,
     3          -3.0,  3.0,  0.0,  0.0,
     4           1.0,  0.0,  0.0,  0.0/
      DATA CARMAT /-0.5,  1.5, -1.5,  0.5,
     2           1.0, -2.5,  2.0, -0.5,
     3          -0.5,  0.0,  0.5,  0.0,
     4           0.0,  1.0,  0.0,  0.0/
      DATA BSPMAT /MSIXTH,   0.5,   -0.5, ASIXTH,
     2             0.5,  -1.0,    0.5,   0.0,
     3            -0.5,   0.0,    0.5,   0.0,
     4          ASIXTH, TTHRDS, ASIXTH,   0.0/
      DATA GEOM1 /100.0, 100.0, 0.0,
     2          200.0, 200.0, 0.0,
     3          200.0,   0.0, 0.0,
     4          300.0, 100.0, 0.0/
C
      CALL GINIT
      CALL COLOR(BLACK)
      CALL CLEAR()
C       define a basis matrix called BEZIER
      CALL DEFBAS(BEZIER,BEZMAT)
C       identify the BEZIER matrix as the current basis matrix
      CALL CURVEB(BEZIER)
C       set the current precision to 20
C       (the curve segment will be drawn using 20 line segments)
      CALL CURVEP(20)
      CALL COLOR(RED)
C       draw the curve based on the four control points in geom1
      CALL CRV(GEOM1)
C
C       define a new basis
      CALL DEFBAS(CARDIN,CARMAT)
```

```
C     reset the current basis
      CALL CURVEB(CARDIN)
C     note that the curveprecision does not have to
C     be restated unless it is to be changed
      CALL COLOR(BLUE)
C     draw a new curve segment
      CALL CRV(GEOM1)
C
C     define a new basis
      CALL DEFBAS(BSPLIN,BSPMAT)
C     reset the current basis
      CALL CURVEB(BSPLIN)
      CALL COLOR(GREEN)
C     draw a new curve segment
      CALL CRV(GEOM1)
C
cccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C    Installation note:
C     This is a delay loop, which may require adjustment.
cccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      CALL GFLUSH()
      DO 1000 I=1,1000000
      NOP = I * 2
1000  CONTINUE
      CALL GEXIT()
      STOP
      END
```

The crvn command takes a series of n control points and draws a curve segment using the current basis and precision. Calling crvn has the same effect as calling a sequence of crv commands with overlapping control points (see Figure 11.1).

```
crvn(n, geom)
long n;
Coord geom[] [3];

subroutine crvn(n,geom)
integer*4 n
real geom(3,n)

procedure crvn(n: longint; geom: Coord3array);
```

Note that a crvn command issued with a Cardinal spline or B-spline basis produces a single curve. A crvn command issued with a Bezier basis, however, pro-

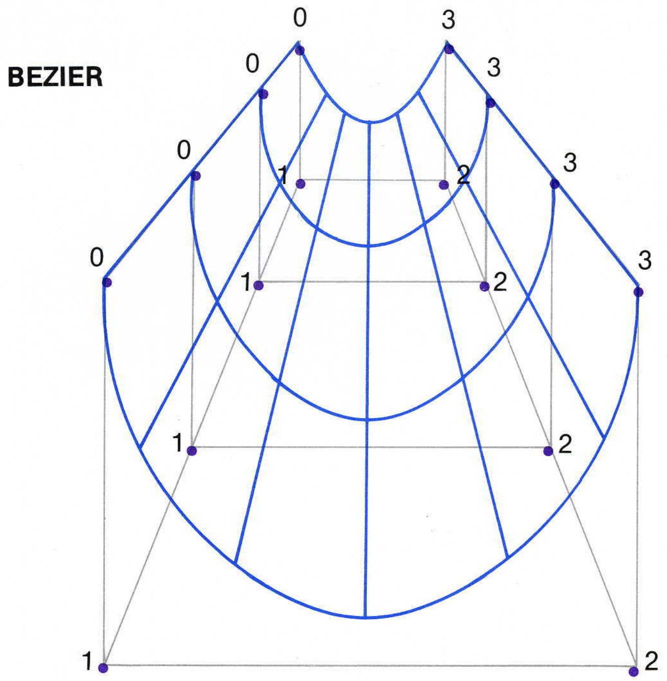
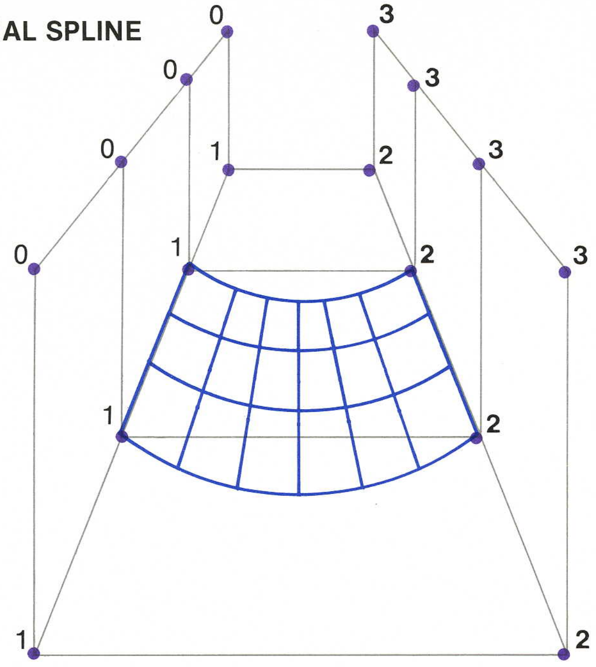


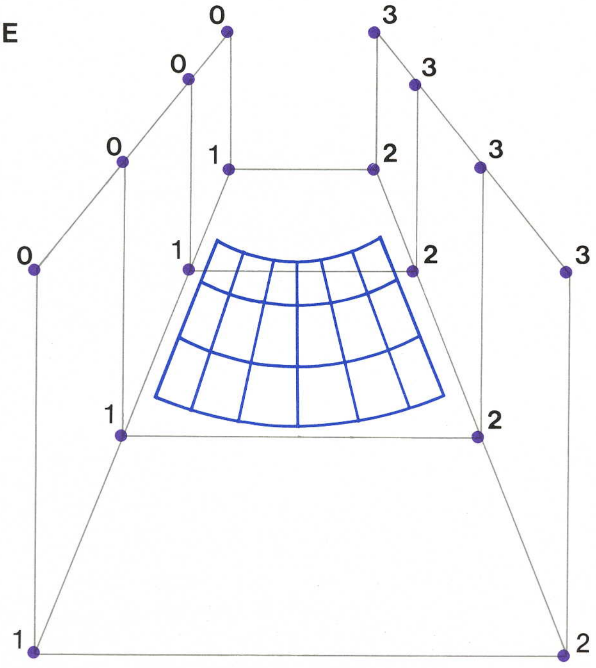
Figure 11.3

Each patch is drawn using the same set of sixteen control points, the same number of curve segments, the same precisions, but different basis matrices.

CARDINAL SPLINE



B-SPLINE



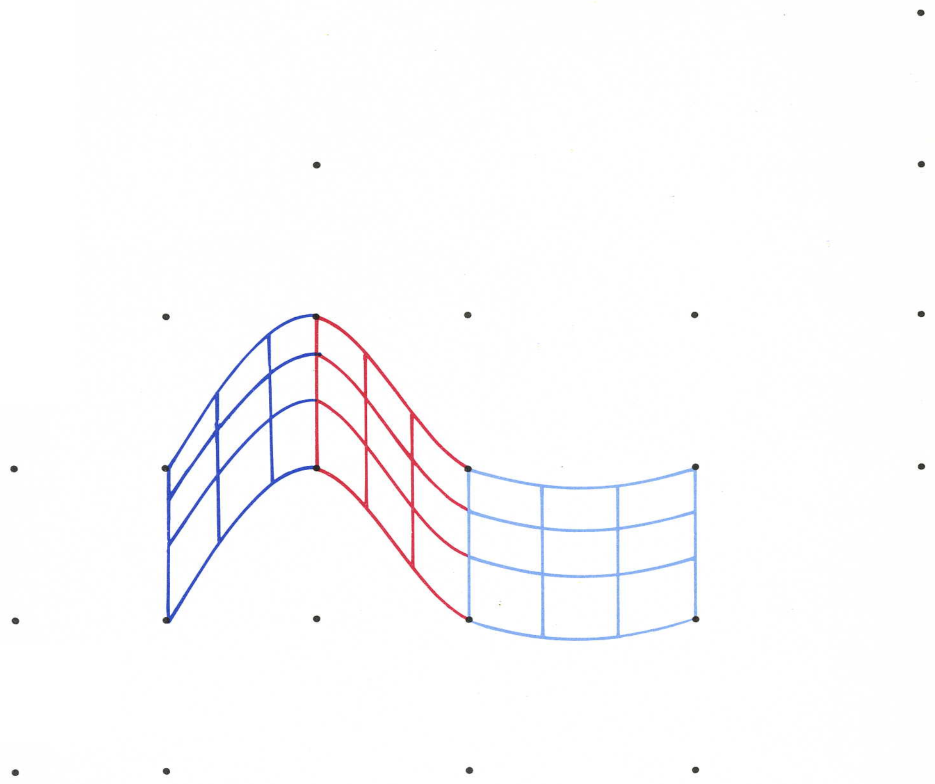


Figure 11.4

The above surface consists of three joined patches. The patches are drawn with overlapping sets of control points, using a Cardinal spline basis matrix.

duces several separate curve segments.

The following program draws the three joined curve segments in Figure 11.1 using the `crvn` command. `geom2` contains six control points.

```
#include "gl.h"

Matrix beziermatrix = {
        { -1, 3, -3, 1 },
        { 3, -6, 3, 0 },
        { -3, 3, 0, 0 },
        { 1, 0, 0, 0 }
        };
Matrix cardinalmatrix = {
        { -0.5, 1.5, -1.5, 0.5 },
        { 1.0, -2.5, 2.0, -0.5 },
        { -0.5, 0, 0.5, 0 },
        { 0, 1, 0, 0 }
        };
Matrix bsplinematrix = {
        { -1.0/6.0, 3.0/6.0, -3.0/6.0, 1.0/6.0 },
        { 3.0/6.0, -6.0/6.0, 3.0/6.0, 0 },
        { -3.0/6.0, 0, 3.0/6.0, 0 },
        { 1.0/6.0, 4.0/6.0, 1.0/6.0, 0 }
        };
#define BEZIER 1
#define CARDINAL 2
#define BSPLINE 3
Coord geom2[6][3] = {
        { 150.0, 400.0, 0.0},
        { 350.0, 100.0, 0.0},
        { 200.0, 350.0, 0.0},
        { 50.0, 0.0, 0.0},
        { 0.0, 200.0, 0.0},
        { 100.0, 300.0, 0.0},
        };
main ()
{
        ginit();
        color(BLACK);
        clear();

        defbasis(BEZIER,beziermatrix); /* define a basis matrix
                called BEZIER */
        defbasis(CARDINAL,cardinalmatrix); /* a new basis is defined */
        defbasis(BSPLINE,bsplinematrix); /* a new basis is defined */
        curvebasis(BEZIER); /* the Bezier matrix becomes the current basis */
        curveprecision(20); /* the precision is set to 20 */
        color(RED);
        crvn(6, geom2); /* the crvn command called with a Bezier basis
              causes three separate curve segments to be drawn */

        curvebasis(CARDINAL); /* the Cardinal basis becomes the current basis */
        color(GREEN);
        crvn(6, geom2); /* the crvn command called with a Cardinal spline basis
              causes a smooth curve to be drawn */

        curvebasis(BSPLINE); /* the B-spline basis becomes the current basis */
        color(BLUE);
        crvn(6, geom2);  /* the crvn command called with a B-spline basis
              causes the smoothest curve to be drawn */

        gexit();
    }
```

The iteration loop of the forward difference algorithm is implemented in the Geometry Pipeline. The `curveit` command provides direct access to this facility, making it possible to generate a curve directly from a forward difference matrix. `curveit` iterates the current matrix (the one on top of the matrix stack) `iterationcount` times. Each iteration draws one of the line segments that approximate the curve. The `curveit` command does not execute the initial `move` command in the forward difference algorithm. A `move(0.0,0.0,0.0)` command must precede the `curveit` command so that the correct first point will be generated from the forward difference matrix.

```
curveit(iterationcount)
short iterationcount;

subroutine curveit(count)
integer*4 count

procedure curveit(iterationcount: Short);
```

The following program draws the Bezier curve segment in Figure 11.2 using the `curveit` command. The Cardinal spline and B-spline curve segments could be drawn using a similar sequence of commands – only the basis matrix would be different.

```
#include "gl.h"

Matrix beziermatrix = {
      { -1, 3, -3, 1 },
      { 3, -6, 3, 0 },
      { -3, 3, 0, 0 },
      { 1, 0, 0, 0 }
      };
#define BEZIER 1
Matrix geom1[4][3] = {
      { 100.0, 100.0, 0.0, 1.0},
      { 200.0, 200.0, 0.0, 1.0},
      { 200.0, 0.0, 0.0, 1.0},
      { 300.0, 100.0, 0.0, 1.0}
      };
Matrix precisionmatrix = {
      { 6.0/8000.0, 0, 0, 0},
      { 6.0/8000.0, 2.0/400.0, 0, 0},
      { 1.0/8000.0, 1.0/400.0, 1/20.0, 0},
      { 0, 0, 0, 1}
      };
main()
{
      ginit();
      color(BLACK);
      clear();
      pushmatrix(); /* the current transformation matrix on the
            matrix stack is saved */
      multmatrix(geom1); /* the product of the current transformation
            matrix and the matrix containing the control points becomes
            the new current transformation matrix */
      multmatrix(beziermatrix); /* the product of the basis matrix and the
            current transformation matrix becomes the new current
            transformation matrix */
      multmatrix(precisionmatrix); /* the product of the precision matrix
            and the current transformation matrix becomes the new current
            transformation matrix */
      move(0.0,0.0,0.0); /* this command must be issued so that the correct
            first point is generated by the curveit command */
      color(RED);
      curveit(20); /* a curve consisting of 20 line segments is drawn */
      popmatrix(); /* the original transformation matrix is restored */
      gexit();
}
```

11.3 Drawing Surfaces

The method for drawing surfaces is similar to that of drawing curves. A *surface patch* appears on the screen as a "wireframe" of curve segments. The shape of the patch is determined by a set of user-defined control points. A complex surface consisting of several joined patches can be created by using overlapping sets of control points and the *B-spline* and *Cardinal spline* curve bases discussed in Section 11.1.

The mathematical basis for the IRIS surface facility is the *parametric bicubic surface*. Bicubic surfaces can provide continuity of position, slope, and curvature at the points where two patches meet. The points on a bicubic surface are defined by parametric equations for x, y, and z. The parametric equation for x is:

$$
\begin{aligned}
x(s,t) = {} & a_{11}s^3t^3 + a_{12}s^3t^2 + a_{13}s^3t + a_{14}s^3 \\
& + a_{21}s^2t^3 + a_{22}s^2t_2 + a_{23}s^2t + a_{24}s^2 \\
& + a_{31}st^3 + a_{32}st^2 + a_{33}st + a_{34}s \\
& + a_{41}t^3 + a_{42}t^2 + a_{43}t + a_{44}
\end{aligned}
$$

(The equations for y and z are similar.) The points on a bicubic patch are defined by varying the parameters s and t from 0 to 1. If one parameter is held constant and the other is varied from 0 and 1, the result is a cubic curve. Thus, a wireframe patch can be created by holding s constant at several values and using the IRIS curve facility to draw curve segments in one direction, and then doing the same for t in the other direction.

There are five steps involved in drawing a surface patch:

1) The appropriate curve bases are defined using the `defbasis` command. (See Section 11.1.) A Bezier basis provides "intuitive" control over the shape of the patch. The Cardinal spline and B-spline bases allow smooth joints to be created between patches.

2) A basis for each of the directions in the patch, u and v, must be specified with the `patchbasis` command. Note that the u basis and the v basis do not have to be the same.

```
patchbasis(uid, vid)
long uid, vid;

subroutine patchb(uid, vid)
integer*4 uid, vid

procedure patchbasis(uid, vid: longint);
```

3) The number of curve segments to be drawn in each direction is specified by the `patchcurves` command. A different number of curve segments can be drawn in each direction.

```
patchcurves(ucurves, vcurves)
long ucurves, vcurves;

subroutine patchc(ucurves, vcurves)
integer*4 ucurves, vcurves

procedure patchcurves(ucurves, vcurves: long);
```

4) The precisions for the curve segments in each direction must be specified with the `patchprecision` command. The precision is the minimum number of line segments approximating each curve segment and can be different for each direction. The actual number of line segments is a multiple of the number of curve segments being drawn in the opposing direction. This guarantees that the *u* and *v* curve segments which form the wireframe actually intersect.

```
patchprecision(usegments, vsegments)
long usegments, vsegments;

subroutine patchp(usegments, vsegments)
integer*4 usegments, vsegments

procedure patchprecision(usegments, vsegments: long);
```

5) The surface patch is actually drawn with the `patch` command. The arguments to `patch` contain the sixteen control points that govern the shape of the patch. `geomx` is a 4x4 matrix containing the x coordinates of the sixteen

control points; geomy contains the y coordinates; geomz contains the z coordinates. The curve segments in the patch are drawn using the current linestyle, linewidth, color, and writemask.

```
patch(geomx, geomy, geomz)
Matrix geomx, geomy, geomz;

subroutine patch(geomx, geomy, geomz)
real geomx(4,4), geomy(4,4), geomz(4,4)

procedure patch(geomx, geomy, geomz: Patcharray);
```

The following program draws three surface patches similar to those shown in Figure 11.3. All three use the same set of sixteen control points.

```
#include "gl.h"

Matrix beziermatrix = {
      { -1, 3, -3, 1 },
      { 3, -6, 3, 0 },
      { -3, 3, 0, 0 },
      { 1, 0, 0, 0 }
      };

Matrix cardinalmatrix = {
      { -0.5, 1.5, -1.5, 0.5 },
      { 1.0, -2.5, 2.0, -0.5 },
      { -0.5, 0.0, 0.5, 0.0 },
      { 0.0, 1.0, 0.0, 0.0 }
      };

Matrix bsplinematrix = {
      { -1.0/6.0, 3.0/6.0, -3.0/6.0, 1.0/6.0 },
      { 3.0/6.0, -6.0/6.0, 3.0/6.0, 0.0 },
      { -3.0/6.0, 0.0, 3.0/6.0, 0.0 },
      { 1.0/6.0, 4.0/6.0, 1.0/6.0, 0.0 }
      };

#define BEZIER 1
#define CARDINAL 2
#define BSPLINE 3

Coord geomx[4][4] = {
      { 0.0, 100.0, 200.0, 300.0},
        { 0.0, 100.0, 200.0, 300.0},
        { 700.0, 600.0, 500.0, 400.0},
        { 700.0, 600.0, 500.0, 400.0}
        };

Coord geomy[4][4] = {
        { 400.0, 500.0, 600.0, 700.0},
        { 0.0, 100.0, 200.0, 300.0},
        { 0.0, 100.0, 200.0, 300.0},
        { 400.0, 500.0, 600.0, 700.0}
        };

Coord geomz[4][4] = {
        { 100.0, 200.0, 300.0, 400.0 },
        { 100.0, 200.0, 300.0, 400.0 },
        { 100.0, 200.0, 300.0, 400.0 },
        { 100.0, 200.0, 300.0, 400.0 }
        };

main ()
{

ginit();
color(BLACK);
clear();

ortho(0.0, (float)XMAXSCREEN, 0.0, (float)YMAXSCREEN,
        (float)XMAXSCREEN, -(float)XMAXSCREEN);

defbasis(BEZIER,beziermatrix); /* define a basis matrix
                called BEZIER */
defbasis(CARDINAL,cardinalmatrix); /* define a basis matrix
                called CARDINAL */
defbasis(BSPLINE,bsplinematrix); /* define a basis matrix
                called BSPLINE */

patchbasis(BEZIER,BEZIER); /* a Bezier basis will be used for both
                directions in the first patch */
    patchcurves(4,7); /* seven curve segments will be drawn in the
                u direction and four in the v direction */
    patchprecision(20,20); /* the curve segments in u direction will consist
                of 20 line segments (the lowest multiple of
                vcurves greater than usegments) and the curve
                segments in the v direction will consist of 21
                line segments (the lowest multiple of ucurves
                         greater than vsegments) */
    color(RED);
        patch(geomx,geomy,geomz); /* the patch is drawn based on the sixteen
                         specified control points */

        patchbasis(CARDINAL,CARDINAL); /* the bases for both directions are reset */
        color(GREEN);
        patch(geomx,geomy,geomz);  /* another patch is drawn using the same
                         control points but a different basis */

        patchbasis(BSPLINE,BSPLINE);  /* the bases for both directions are
                         reset again */
        color(BLUE);
        patch(geomx,geomy,geomz);  /* a third patch is drawn */

    sleep(10);
    gexit();
    }
```

Here is the FORTRAN version of the program:

```
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C    Installation note:
C   Various Fortran compilers may require different styles of INCLUDEs.
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      INCLUDE 'fgl.h'
C
      REAL BEZMAT(4,4), CARMAT(4,4), BSPMAT(4,4)
      REAL GEOMX(4,4), GEOMY(4,4), GEOMZ(4,4)
      INTEGER*2 BEZI, CARD, BSPL
      REAL ASIXTH, MSIXTH, TTHRDS, XMAX, YMAX
      INTEGER I, NOP
      PARAMETER ( BEZIER = 1 )
      PARAMETER ( CARDIN = 2 )
      PARAMETER ( BSPLIN = 3 )
      PARAMETER ( ASIXTH = 1.0/6.0 )
      PARAMETER ( MSIXTH = -1.0/6.0 )
      PARAMETER ( TTHRDS = 2.0/3.0 )
C
      DATA BEZMAT /-1.0, 3.0, -3.0, 1.0,
     2         3.0, -6.0, 3.0, 0.0,
     3        -3.0, 3.0, 0.0, 0.0,
     4         1.0, 0.0, 0.0, 0.0/
      DATA CARMAT /-0.5, 1.5, -1.5, 0.5,
     2         1.0, -2.5, 2.0, -0.5,
     3        -0.5, 0.0, 0.5, 0.0,
     4         0.0, 1.0, 0.0, 0.0/
```

```
      DATA BSPMAT /MSIXTH,   0.5,   -0.5, ASIXTH,
     2            0.5,  -1.0,    0.5,    0.0,
     3           -0.5,   0.0,    0.5,    0.0,
     4         ASIXTH, TTHRDS, ASIXTH,   0.0/
      DATA GEOMX /  0.0, 100.0, 200.0, 300.0,
     2           0.0, 100.0, 200.0, 300.0,
     3         700.0, 600.0, 500.0, 400.0,
     4         700.0, 600.0, 500.0, 400.0/
      DATA GEOMY /400.0, 500.0, 600.0, 700.0,
     2           0.0, 100.0, 200.0, 300.0,
     3           0.0, 100.0, 200.0, 300.0,
     4         400.0, 500.0, 600.0, 700.0/
      DATA GEOMZ /100.0, 200.0, 300.0, 400.0,
     2         100.0, 200.0, 300.0, 400.0,
     3         100.0, 200.0, 300.0, 400.0,
     4         100.0, 200.0, 300.0, 400.0/
C
      CALL GINIT
      CALL COLOR(BLACK)
      CALL CLEAR()
      XMAX = XMAXSC
      YMAX = YMAXSC
      CALL ORTHO(0.0,XMAX,0.0,YMAX,XMAX,-XMAX)
C       define a basis matrix called BEZIER
      CALL DEFBAS(BEZIER,BEZMAT)
C       define a basis matrix called CARDIN
      CALL DEFBAS(CARDIN,CARMAT)
C       define a basis matrix called BSPLIN
      CALL DEFBAS(BSPLIN,BSPMAT)
C
C       a Bezier basis will be used for both directions in the first patch
      CALL PATCHB(BEZIER,BEZIER)
C       7 curve segments will be drawn in the u direction
C       and 4 in the v direction
      CALL PATCHC(4,7)
C       the curve segments in the u direction will consist of 20 line
C       segments (the lowest multiple of vcurves greater than usegments)
C       & the curve segments in the v direction will consist of 21 line
C       segments (the lowest multiple of ucurves greater than vsegments)
      CALL PATCHP(20,20)
      CALL COLOR(RED)
C       the patch is drawn based on the 16 specified control points
      CALL PATCH(GEOMX,GEOMY,GEOMZ)
C
C       reset the bases for both directions
```

```
      CALL PATCHB(CARDIN,CARDIN)
      CALL COLOR(GREEN)
C       draw another patch using the same control points
C       but a different basis
      CALL PATCH(GEOMX,GEOMY,GEOMZ)
C
C       reset the bases for both directions again
      CALL PATCHB(BSPLIN,BSPLIN)
      CALL COLOR(BLUE)
C       draw a third patch
      CALL PATCH(GEOMX,GEOMY,GEOMZ)
C
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C      Installation note:
C       This is a delay loop, which may require adjustment.
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      CALL GFLUSH()
      DO 1000 I=1,1000000
      NOP = I * 2
1000  CONTINUE
      CALL GEXIT()
      STOP
      END
```

Patches can be joined together to create a more complex surface by using the Cardinal spline or B-spline bases and overlapping sets of control points. The surface in Figure 11.4 consists of three joined patches and was drawn using a B-spline basis.

12. Hidden Surfaces

Chapter 4 (Coordinate Transformations) discussed how to create 3D models in world space and how to project images of those models onto the screen. This chapter discusses how to make those images more realistic by removing the hidden lines and surfaces from the images: z-buffering and backfacing polygon removal.

12.1 Z-Buffer Mode

When the IRIS is in z-buffer mode, the z coordinate for each pixel on the screen is stored in the bitplanes. (See Chapter 6 for a discussion of bitplanes and display modes.) When a pixel is to be drawn, its new z value is compared to the existing z value. If the new z value is less than or equal to the existing z value (i.e., closer to the viewer), the new color value for that pixel is written into the bitplanes, along with the new z value. Otherwise, the color and z values are unchanged. The result is that only the parts of the image visible to the viewer are displayed on the screen.

Z-buffering only works in single buffer display mode. The z-buffer bits occupy the sixteen high-order bitplanes of a 32-bitplane system and the twelve high-order bitplanes of a 28-bitplane system. See Figure 12.1. Z-buffering is not effective in a system with less than 28 bitplanes.

Three commands set up z-buffering:

1) The `setdepth` command sets the scaling of the near and far clipping planes. `setdepth` specifies the range of z values that will be stored in bitplanes. If there are sixteen bits of z-buffer, `near` should be set to 0x8000 (the smallest value that can be stored in the sixteen high-order bitplanes) and `far` should be set to 0x7FFF (the largest value that can be stored in the sixteen high-order bitplanes). If there are twelve bits of z-buffer, `near` should be set to 0 and `far` should be set to 0xFFF.

```
setdepth(near,far)
Screencoord near,far;

subroutine setdep(near,far)
integer*4 near,far

procedure setdepth(near,far: Screencoord);
```

`getdepth` returns the `near` and `far` values set by `setdepth`.

```
getdepth(near,far)
Screencoord *near, *far;

subroutine getdep(near,far)
integer*4 near,far

procedure getdepth(var near,far: Screencoord);
```

2) The `zclear` command initializes the z-buffer to the largest possible positive integer (0x7FFF). Any point with a z coordinate less than or equal to the initial z value will be drawn to the screen.

```
zclear()

subroutine zclear

procedure zclear;
```

3) `zbuffer(TRUE)` turns on z-buffer; `zbuffer(FALSE)` turns it off.

```
zbuffer(bool)
Boolean bool;

subroutine zbuffe(bool)
logical bool

procedure zbuffer(bool: Boolean);
```

`getzbuffer` indicates whether z-buffering is on or off. FALSE is the default value and means that z-buffering is off. TRUE means that z-buffering is on.

```
Boolean getzbuffer()

logical function getzbu()

function getzbuffer: longint;
```

The following program draws two intersecting polygons in z-buffer mode in a system with 28 bitplanes. Only the "visible" part of each polygon appears on the screen:

```
#include "gl.h"

main ()
{
ginit();
color(BLACK);
clear();
ortho(0.0, (float)XMAXSCREEN, 0.0, (float)YMAXSCREEN,
        0.0, -(float)XMAXSCREEN);
setdepth(0x000,0xFFF); /* the minimum and maximum z values are set */

zbuffer(TRUE); /* the IRIS enters z-buffering mode */
zclear(); /* the z-buffer is cleared to the maximum z value */

color(YELLOW);          /* draw the first polygon in yellow */
pmv(0.0, 0.0, 100.0);
pdr(100.0, 0.0, 100.0);
pdr(100.0, 100.0, 100.0);
pdr(0.0, 100.0, 100.0);
pclose();

color(RED);             /* draw the second polygon in red */
pmv(0.0, 0.0, 50.0);
pdr(100.0, 0.0, 50.0);
pdr(100.0, 100.0, 200.0);
pdr(0.0, 100.0, 200.0);
pclose();

zbuffer(FALSE); /* the IRIS exits z-buffering mode */
gexit();
}
```

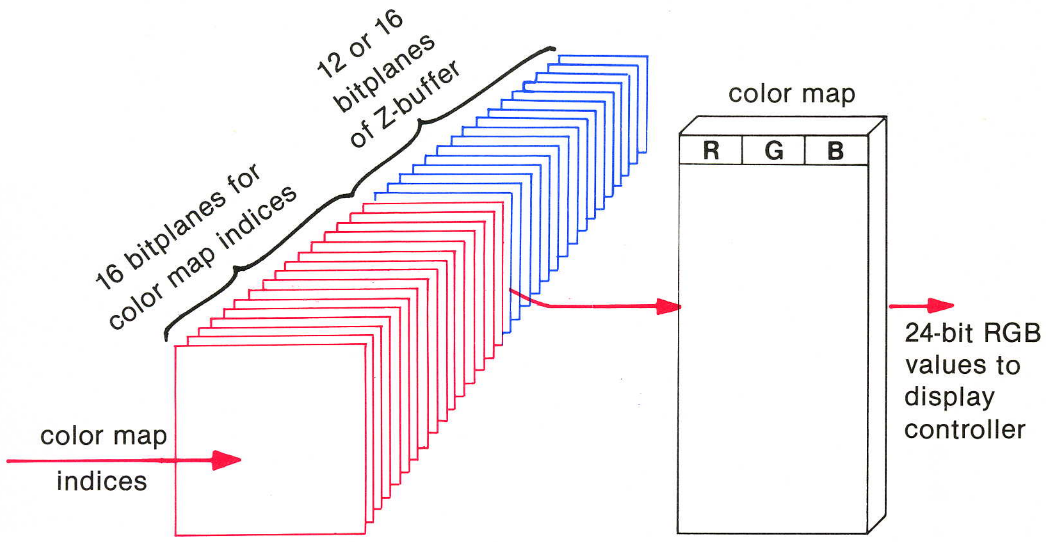


Figure 12.1
In Z-buffer mode, color map indices for each pixel are stored in the low-order sixteen bitplanes and the corresponding Z values for each pixel are stored in the high-order twelve or sixteen bitplanes.

12.2 Backfacing Polygon Removal

`backface` intiates or termiates backfacing polygon removal. A backfacing polygon is defined to be a polygon whose vertices appear in clockwise order in screen space. When backfacing polygon removal is turned on, only polygons whose vertices appear in conterclockwise order are displayed. Therefore, the vertices of all polygons should be specified in counterclockwise order.

The backface utility is used to improve the performance of programs which represent solid shapes as collections of polygons. The vertices of the polygons on the "far" side of the solid will be in clockwise order and will not be drawn.

Because the orientation of polygons is determined in screen space, backfacing polygon removal is not a rigorous technique for hidden surface removal. When a polygon shrinks to the point where its vertices are coincident, its orientation is indeterminant and it is displayed. Thus, backfacing polygon removal should be used in conjunction with some other hidden surface removal technique, such as z-buffering. (See previous section.)

```
backface(b)
Boolean b;

subroutine backfa(b)
logical b

procedure backface(b: Boolean);
```

The following example draws a cube in which only the visible surfaces are drawn. The cube can be rotated by moving the mouse.

```
#include "gl.h"
#include "device.h"

#define CUBE_SIZE 200

main()
{

  int foo;

  ginit();
  doublebuffer();
  gconfig();

  viewport(0, YMAXSCREEN, 0, YMAXSCREEN);
```

```
ortho(-YMAXSCREEN.0, YMAXSCREEN.0,
   -YMAXSCREEN.0, YMAXSCREEN.0,
   -YMAXSCREEN.0, YMAXSCREEN.0);

qdevice(KEYBD);
makeobj(1);
rectfi(-CUBE_SIZE,-CUBE_SIZE,CUBE_SIZE,CUBE_SIZE);
closeobj();

/* define a cube */
makeobj(2);
/* front face */
pushmatrix();
translate(0.0,0.0,CUBE_SIZE.0);
color(RED);
callobj(1);
popmatrix();

/* right face */
pushmatrix();
translate(CUBE_SIZE.0, 0.0, 0.0);
rotate(900, 'y');
color(GREEN);
callobj(1);
popmatrix();

/* backface */
pushmatrix();
translate(0.0, 0.0, -CUBE_SIZE.0);
rotate(1800, 'y');
color(BLUE);
callobj(1);
popmatrix();

/* left face */
pushmatrix();
translate(-CUBE_SIZE.0, 0.0, 0.0);
rotate(-900, 'y');
color(CYAN);
callobj(1);
popmatrix();

/* top face */
pushmatrix();
```

```
    translate(0.0, CUBE_SIZE.0, 0.0);
    rotate(-900, 'x');
    color(MAGENTA);
    callobj(1);
    popmatrix();

    /* bottom face */
    pushmatrix();
    translate(0.0, -CUBE_SIZE.0, 0.0);
    rotate(900, 'x');
    color(YELLOW);
    callobj(1);
    popmatrix();

    closeobj();

    /* turn on back facing polygon removal */
    backface(1);

    while ((foo=qtest()) !=KEYBD) {
      if(foo) qreset();
      pushmatrix();
      rotate(2*getvaluator(MOUSEX), 'x');
      rotate(2*getvaluator(MOUSEY), 'y');
      color(BLACK);
      clear();
      callobj(2);
      popmatrix();
      swapbuffers();
    }

    backface(0);

    gexit();
}
```

13. Shading and Depth-Cueing

The previous chapter discussed how to increase the realism of an image by removing the hidden lines and surfaces from the image. This chapter discusses two more techniques for increasing the realism of an image:

- the polygons in an image can be shaded, and
- the lines and points in an image can be depth-cued (i.e., their intensities can be varied based on their z values).

13.1 Shading

The IRIS shading facility provides *Gouraud* shading of polygons. This shading technique uses linear interpolation to determine the intensities of each of the pixels in a filled polygon. The user controls the shading of a polygon by specifying the intensities of each of the polygon's vertices. The intensity of a vertex is a color map index. The range of desired intensities must be reflected by the values contained in the color map. For example, if the vertex at one side of a polygon were assigned a color map index that contained a dark blue RGB value and the vertex at the other side were assigned an index with a light blue RGB value, then all of the indices between the two should be loaded with intermediate shades of blue.

The `splf` command draws a shaded polygon. The first two arguments to `splf` are the same as the ones in `polf`. (See Section 3.6.) `n` specifies the number of vertices in the polygon. `pnts` is the array of vertices. The third argument, `intens`, is an array of `n` color map indices, one for each vertex.

```
splf(n, parray, iarray)
long n;
Coord parray[][3];
Colorindex iarray[];

subroutine splf(n, parray, iarray)
integer*4 n
real parray(3,n)
integer*2 iarray(n)

procedure splf(n: longint; var parray: Coord3array; var iarray: Colorarray);
```

Figure 13.1 illustrates how Gouraud shading works. Each vertex of a polygon is assigned an intensity. The intensities for the points along the edges of the polygon are determined by interpolating linearly between the intensities at the vertices. The intensities for all of the interior points of the polygon are determined by interpolating linearly between the pairs of edge-points that lie along each scan line. The entries in the color map and the values assigned to the vertices of each polygon must be coordinated to create the desired shading effect.

Shaded polygons can also be drawn using the `pmv`, `pdr`, `rpmv`, and `rpdr` commands. (See Section 3.6.) The `setshade` command assigns an intensity to the vertex specified in the immediately following command. The `spclos` command closes and shades the polygon. If `pclos` is called instead, a filled, unshaded polygon is drawn in the current color and the `setshade` commands are ignored.

```
setshade(shade)
Colorindex shade;

subroutine setsha(shade)
integer*4 shade

procedure setshade(shade: Colorindex);
```

```
spclos()

subroutine spclos

procedure spclos;
```

The following program draws a shaded polygon using `pmv`, `pdr`, and `setshade`. Note that shading only works in single and double buffer display modes, and not in RGB mode.

```
#include "gl.h"

main ()
{

int i;

ginit();
color(BLACK);
clear();
```

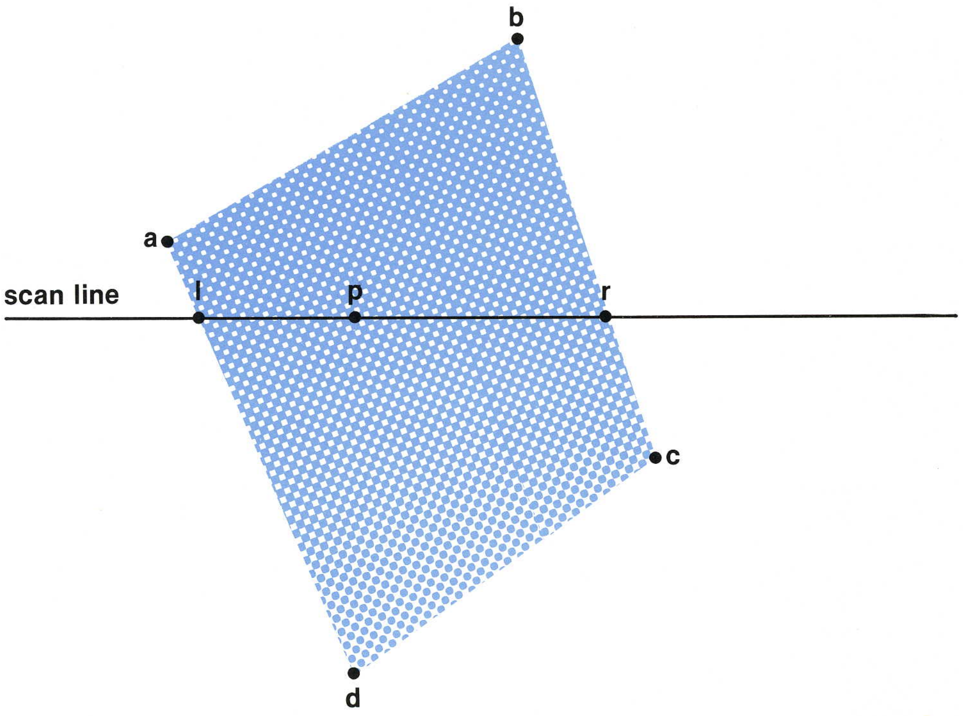
```
    /* create a magenta color ramp */
    for (i = 0; i < 128; i++)
       mapcolor(i, 2*i, 0, 2*i);

    setshade(0);            /* set the intensity for the first vertex */
    pmv(100.0,100.0,0.0);        /* specify the first vertex */
    setshade(127);  /* set the intensity for the second vertex */
    pdr(200.0,200.0,0.0);        /* specify the second vertex */
    setshade(64);           /* set the intensity for the third vertex */
    pdr(200.0,100.0,0.0);        /* specify the third vertex */
    spclose();              /* close the shaded polygon */

    sleep(5);
    greset();
    gexit();

}
```

13.2 Depth-Cueing

Depth-cueing increases the perception of three dimensions in an image. When the IRIS is in depth-cue mode, the intensities of all the lines and points drawn to the screen vary according to their z values — points closer to the viewer are of higher intensity and points farther from the viewer are of lower intensity. `depthcue(TRUE)` turns on depth-cue mode; `depthcue(FALSE)` turns it off.

```
depthcue(mode)
Boolean mode;

subroutine depthc(mode)
logical mode

procedure depthcue(mode: Boolean);
```

`getdcm` indicates whether depth-cue in on or off. `TRUE` means the IRIS is in depth-cue mode and `FALSE` means the IRIS is not in depth-cue mode.



$$c_l = c_d + \left[\frac{l_y - d_y}{a_y - d_y}\right]\left[c_a - c_d\right]$$

$$c_r = c_c + \left[\frac{r_y - c_y}{b_y - c_y}\right]\left[c_b - c_c\right]$$

$$c_p = c_l + \left[\frac{r_x - p_x}{r_x - l_x}\right]\left[c_r - c_l\right]$$

Figure 13.1

The intensities (color map indices) for points l and r are determined by linear interpolation between the intensities at the endpoints of their edges. The intensity at point p is determined by linear interpolation between the intensities at point l and point r.

```
Boolean getdcm()

logical function getdcm()

function getdcm: longint;
```

The shaderange command specifies the low-intensity color map index and the high-intensity color map index. These values are mapped to the low and high z values specified by z1 and z2. The high index must be greater than the low index and the difference between the high index and the low index must be greater than the difference between z1 and z2. The values of z1 and z2 should correspond to or lie within the range of z values specifies by setdepth.

```
shaderange(lowindex, highindex, z1, z2)
Colorindex lowindex, highindex;
Screencoord z1, z2;

subroutine shader(lowindex, highindex, z1, z2)
integer*4 lowindex, highindex, z1, z2

procedure shaderange(lowindex,highindex: Colorindex; z1, z2: Screencoord);
```

The entries for the color map between the low index and the high index should reflect the appropriate sequence of intensities for the color being drawn. When a depth-cued point is drawn, its z value is used to determine its intensity. When a depth-cued line is drawn, the intensities of its points are linearly interpolated from the intensities of its endpoints, which are determined from their z values. The following equation yields the color map index for a point with z coordinate z:

$$color_z = \left(\frac{lowindex - highindex}{z2 - z1}\right)(z - z1) + highindex$$

Note that this equation yields a non-linear mapping when z is less than z1 or greater than z2. Since depth-cued lines are linearly interpolated between endpoints, an endpoint outside the range of z1 and z2 may result in an undesirable image.

The following program draws a cube filled with points which rotates as the mouse is moved. Since the image is drawn in depth-cue mode, the edges of the cube and the points inside the cube that are closer to the viewer are brighter than the edges and points farther away from the viewer.

```
#include "gl.h"
#include "device.h"
#include "math.h"

float hrand();

main ()
{
   int val;
   int i;

   ginit();
   doublebuffer();
   gconfig();

   ortho(-350.0, 350.0,
        -350.0, 350.0,
        -350.0, 350.0);
   viewport(0, YMAXSCREEN, 0, YMAXSCREEN);
   qdevice(KEYBD);

   makeobj(1);

      /* a bunch of random points */
      for (i = 0; i < 100; i++)
         pnt(hrand(-200.0,200.0), hrand(-200.0,200.0), hrand(-200.0,200.0));

      /* and a cube */
      movei(-200, -200, -200);
      drawi(200, -200, -200);
      drawi(200, 200, -200);
      drawi(-200, 200, -200);
      drawi(-200, -200, -200);
      drawi(-200, -200, 200);
      drawi(-200, 200, 200);
      drawi(-200, 200, -200);
      movei(-200, 200, 200);
      drawi(200, 200, 200);
      drawi(200, -200, 200);
      drawi(-200, -200, 200);
      movei(200, 200, 200);
```

```
            drawi(200, 200, -200);
            movei(200, -200, -200);
            drawi(200, -200, 200);
        closeobj();

        /* load the color map with a cyan ramp */
        for (i = 0; i < 128; i++)
            mapcolor(128+i, 0, 2*i, 2*i);
        /* set the range of z values that will be stored
            in the bitplanes */
        setdepth(0, 0x7fff);
        /* set up the mapping of z values to color map indices:
            z value 0 is mapped to index 128 and z value 0x7fff is
            mapped to index 255 */
        shaderange(128,255,0,0x7fff);

        /* turn on depthcue mode: the color index of each pixel in points
            and lines is determined from the z value of the pixel */
        depthcue(1);
        /* until a key is pressed, rotate the cube according to the
            movement of the mouse */
        while ((val=qtest()) != KEYBD) {
            pushmatrix();
            rotate(3*getvaluator(MOUSEY), 'x');
            rotate(3*getvaluator(MOUSEX), 'y');
            color(BLACK);
            clear();
            callobj(1);
            popmatrix();
            swapbuffers();
        }

        gexit();
    }


    /* this routine returns random numbers in the specified range */
    float hrand(low,high)
        float low,high;
    {
        float val;
        val = ((float)( (short)rand(0) & 0xffff)) / ((float)0xffff);
        return( (2.0 * val * (high-low)) + low);
    }
```

14. Textports

The textport is a region of the display screen used to present textual output from programs, both graphical and non-graphical. A `printf()` command in a program causes characters to be printed to the textport. `charstr`, on the other hand, draws character strings to the viewport. A default textport (80 columns wide and 40 lines high) appears on the screen at (148, 875, 80, 687) when the IRIS is booted.

The textport can be turned off with the `tpoff` command. When the textport is off, characters are not written to the textport and the textport does not appear on the screen.

```
tpoff()

subroutine tpoff

procedure tpoff;
```

The textport will be automatically turned on when the program in which the `tpoff` command was called is exited. The textport can be turned on explicitly with the `tpon` command.

```
tpon()

subroutine tpon

procedure tpon;
```

`textport` changes the size and the location of the textport. It allocates an area of the screen for the textport by specifying the left, right, bottom, and top edges of the textport.

```
textport(left, right, bottom, top)
Screencoord left, right, bottom, top;

subroutine textpo(left, right, bottom, top)
integer*4 left, right, bottom, top

procedure textport(left, right, bottom, top: Screencoord);
```

`textport(0,0,0,0)` turns off the textport and it will not appear on the screen until the textport size is reset or `textinit` (see below) is called. The `gettp` command returns the current textport size and location (left, right, bottom, and top edges).

```
gettp(left, right, bottom, top)
Screencoord *left, *right, *bottom, *top;

subroutine gettp(left, right, bottom, top)
integer*2 left, right, bottom, top

procedure gettp(var left, right, bottom, top: Screencoord);
```

The color of the text in a textport is set with the `textcolor` command. Note that the color of text written in the viewport with `charstr` is determined by `color`.

```
textcolor(tcolor)
Colorindex tcolor;

subroutine textco(tcolor)
integer*4 tcolor

procedure textcolor(tcolor: Colorindex);
```

The `textwritemask` command grants write permission for text drawn in the textport. This command does not affect text drawn with `charstr`.

```
textwritemask(tmask)
Colorindex tmask;

subroutine textwr(tmask)
integer*4 tmask

procedure textwritemask(tmask: Colorindex);
```

The `pagecolor` command sets the color for the background of the textport.

```
pagecolor(c)
short c;

subroutine pageco(c)
integer*4 c

procedure pagecolor(c: Colorindex);
```

The `pagewritemask` command sets the writemask for the background of the textport.

```
pagewritemask(pmask)
short pmask;

subroutine pagewr(pmask)
integer*4 pmask

procedure pagewritemask(pmask: Colorindex);
```

The textport can be reset to its default values with the `textinit` command.

```
textinit()

subroutine textin

procedure textinit;
```

Appendix A
Type Definitions for C, FORTRAN, and Pascal

A.1 C Definitions

This is a listing of "gl.h", which should be included in each IRIS program. It contains the type definitions, useful constants, and external definitions for all commands.

```
/* graphics library header file */

/* maximum X and Y screen coordinates */

#define XMAXSCREEN                        1023
#define YMAXSCREEN                        767

/* various hardware/software limits       */

#define ATTRIBSTACKDEPTH                  10
#define VPSTACKDEPTH                      8
#define MATRIXSTACKDEPTH                  32
#define NAMESTACKDEPTH                    1025
#define STARTTAG                          -2
#define ENDTAG                            -3

/* names for colors in color map loaded by ginit() */

#define BLACK                             0
#define RED                               1
#define GREEN                             2
#define YELLOW                            3
#define BLUE                              4
#define MAGENTA                           5
#define CYAN                              6
#define WHITE                             7

#ifndef FALSE
#define                                   FALSE0
#endif
#ifndef TRUE
#define TRUE                              (!FALSE)
#endif
```

```
/* typedefs */

typedef unsigned char Byte;
typedef long Boolean;
typedef char *String;

typedef short Angle;
typedef short Screencoord;
typedef short Scoord;
typedef long Icoord;
typedef float Coord;
typedef float Matrix[4][4];

typedef unsigned short Colorindex;
typedef unsigned char RGBvalue;

typedef unsigned short Device;

#define PATTERN_16 16
#define PATTERN_32 32
#define PATTERN_64 64

#define PATTERN_16_SIZE                16
#define PATTERN_32_SIZE                64
#define PATTERN_64_SIZE                256

typedef unsigned short Pattern16[PATTERN_16_SIZE];
typedef unsigned short Pattern32[PATTERN_32_SIZE];
typedef unsigned short Pattern64[PATTERN_64_SIZE];

typedef unsigned short Linestyle;
typedef unsigned short Cursor[16];
typedef struct {
              unsigned short offset;
              Byte w,h;
              char xoff,yoff;
              short width;
} Fontchar;

typedef long Object;
typedef long Tag;
typedef long Offset;
extern void                 arc();
extern void                 arcf();
extern void                 arcfi();
extern void             arci();
extern void             arcfs();
extern void             arcs();
extern void             attachcursor();
extern void             backbuffer();
extern void             backface();
extern void             bbox2();
extern void             bbox2i();
extern void             bbox2s();
extern void             blankscreen();
extern void             blink();
extern long             blkqread();
extern void             callfunc();
extern void             callobj();
extern void             charstr();
extern void             circ();
extern void             circf();
extern void             circfi();
extern void             circi();
extern void             circfs();
extern void             circs();
extern void             clear();
extern void             clearhitcode();
extern void             clkoff();
extern void             clkon();
extern void             closeobj();
extern void             cmov();
extern void             cmov2();
extern void             cmov2i();
extern void             cmovi();
extern void             cmov2s();
extern void             cmovs();
extern void             color();
extern void             compactify();
extern void             crv();
extern void             crvn();
extern void             curorigin();
extern void             cursoff();
extern void             curson();
extern void             curvebasis();
extern void             curveit();
extern void             curveprecision();
extern void             cyclemap();
extern void             defbasis();
extern void             defcursor();
extern void             deflinestyle();
extern void             defpattern();
extern void             defrasterfont();
extern void             delobj();
extern void             deltag();
extern void             depthcue();
extern void             doublebuffer();
extern void             draw();
extern void             draw2();
extern void             draw2i();
extern void             drawi();
extern void             draw2s();
extern void             draws();
extern void             editobj();
extern long             endfeedback();
extern long             endpick();
extern long             endselect();
extern void             feedback();
extern void             finish();
extern void             font();
extern void             frontbuffer();
extern void             gconfig();
extern Object           genobj();
extern Tag              gentag();
extern long             getbuffer();
extern long             getbutton();
extern long             getcmmode();
extern long             getcolor();
extern void             getcpos();
extern void             getcursor();
extern long             getdcm();
extern void             getdepth();
extern long             getdisplaymode();
extern long             getfont();
extern void             getgpos();
extern long             getheight();
extern long             gethitcode();
extern long             getlsbackup();
extern long             getlsrepeat();
extern long             getlstyle();
extern long             getlwidth();
extern long             getmap();
extern void             getmatrix();
extern void             getmcolor();
extern long             getmem();
extern long             getmonitor();
extern Object           getopenobj();
extern long             getpattern();
extern long             getplanes();
extern long             getresetls();
extern void             getscrmask();
extern long             getvaluator();
extern void             getviewport();
extern long             getwritemask();
extern long             getzbuffer();
extern void             gewrite();
extern void             gexit();
extern void             ginit();
extern void             greset();
extern void             gsync();
extern void             gRGBcolor();
extern void             gRGBcursor();
extern void             gRGBmask();
extern void             initnames();
extern long             isobj();
extern long             istag();
extern void             lampoff();
extern void             lampon();
extern void             linewidth();
extern void             loadmatrix();
extern void             loadname();
extern void             lookat();
extern void             lsbackup();
extern void             lsrepeat();
extern void             makeobj();
extern void             maketag();
extern void             mapcolor();
extern void             mapw();
extern void             mapw2();
extern void             move();
extern void             move2();
extern void             move2i();
extern void             movei();
extern void             move2s();
extern void             moves();
extern void             multimap();
extern void             multmatrix();
extern void             newtag();
extern void             noise();
extern void             objdelete();
extern void                 objinsert();
extern void                 objreplace();
extern void                 onemap();
extern void                 ortho();
extern void                 ortho2();
extern void                 pagecolor();
extern void                 pagewritemask();
extern void                 passthrough();
extern void                 patch();
extern void                 patchbasis();
extern void                 patchprecision();
extern void                 pclos();
extern void                 spclos();
extern void                 pdr();
extern void                 pdr2();
extern void                 pdr2i();
extern void                 pdri();
extern void                 pdr2s();
extern void                 pdrs();
extern void                 perspective();
extern void                 pick();
extern void                 picksize();
extern void                 pmv();
extern void                 pmv2();
extern void                 pmv2i();
extern void                 pmvi();
extern void                 pmv2s();
extern void                 pmvs();
extern void                 pnt();
extern void                 pnt2();
extern void                 pnt2i();
extern void                 pnti();
extern void                 pnt2s();
extern void                 pnts();
extern void                 polarview();
extern void                 polf();
extern void                 polf2();
extern void                 polf2i();
extern void                 polfi();
extern void                 polf2s();
extern void                 polfs();
extern void                 poly();
extern void                 poly2();
extern void                 poly2i();
extern void                 polyi();
extern void                 poly2s();
extern void                 polys();
extern void                 popattributes();
extern void                 popmatrix();
extern void                 popname();
extern void                 popviewport();
extern void                 pushattributes();
extern void                 pushmatrix();
extern void                 pushname();
extern void                 pushviewport();
extern void                 qdevice();
extern void                 qenter();
extern long                 qread();
extern void                 qreset();
extern long                 qtest();
extern void                 rdr();
extern void                 rdr2();
extern void                 rdr2i();
extern void                 rdri();
extern void                 rdr2s();
extern void                 rdrs();
extern long                 readpixels();
extern long                 readRGB();
extern void                 rect();
extern void                 rectf();
extern void                 rectfi();
extern void                 recti();
extern void                 rectfs();
extern void                 rects();
extern void                 resetls();
extern void                 RGBcolor();
extern void                 RGBcursor();
extern void                 RGBmode();
extern void                 RGBwritemask();
extern void                 ringbell();
extern void                 rmv();
extern void                 rmv2();
extern void                 rmv2i();
extern void                 rmvi();
extern void                 rmv2s();
extern void                 rmvs();
extern void                 rotate();
extern void                 rpdr();
extern void                 rpdr2();
extern void                 rpdr2i();
extern void         rpdri();
extern void         rpdr2s();
extern void         rpdrs();
extern void         rpmv();
extern void         rpmv2();
extern void         rpmv2i();
extern void         rpmvi();
extern void         rpmv2s();
extern void         rpmvs();
extern void         scale();
extern void         scrmask();
extern void         select();
extern void         setbell();
extern void         setbutton();
extern void         setcursor();
extern void         setdepth();
extern void         setlinestyle();
extern void         setmap();
extern void         setmonitor();
extern void         setpattern();
extern void         setshade();
extern void         setvaluator();
extern void         shaderange();
extern void         singlebuffer();
extern void         splf();
extern void         splf2();
extern void         splf2i();
extern void         splfi();
extern void         splf2s();
extern void         splfs();
extern long         strwidth();
extern void         swapbuffers();
extern void         swapinterval();
extern void         textcolor();
extern void         textport();
extern void         textwritemask();
extern void         tie();
extern void         tpoff();
extern void         tpon();
extern void         translate();
extern void         viewport();
extern void         window();
extern void         writemask();
extern void         writepixels();
extern void         writeRGB();
extern void              xfpt();
extern void              xfpt2();
extern void              xfpt2i();
extern void              xfpti();
extern void              xfpts();
extern void              xfpt2s();
extern void              xfpt4();
extern void              xfpt4i();
extern void              xfpt4s();
extern void              zbuffer();
extern void              zclear();
```

Another header file, "device.h", defines symbolic names for many of the device numbers. IRIS programmers are not required to use it. In fact, they may wish to define their own names for the subset of devices actually used in a particular application program.

```
/* macros to test valuator and button numbers */

#define ISBUTTON( b )            ( ((b) >=BUTOFFSET) && ((b) < (BUTCOUNT+BUTOFFSET)) )
#define ISSCRBUTTON( b )   ( ((b) >=SBTOFFSET) && ((b) < (SBTCOUNT+SBTOFFSET)) )
#define ISVALUATOR( v )    ( ((v) >=VALOFFSET) && ((v) < (VALCOUNT+VALOFFSET)) )
#define ISTIMER( t )      ( ((t) >=TIMOFFSET) && ((t) < (TIMCOUNT+TIMOFFSET)) )
#define ISDIAL( t )       ( ((t) >=DIAL0   ) && ((t) <=DIAL8   ) )
#define ISLPEN( t )       ( ((t)==LPENX) || ((t)==LPENY) )
#define ISLPENBUT( t )     ( (t)==LPENBUT )
#define ISBPADBUT( t )     ( ((t) >=BPAD0) && ((t) <=BPAD0) )

/* include file with device definitions */
#define NULLDEV                  0
#define BUTOFFSET        1
#define SBTOFFSET        200
#define VALOFFSET        256
#define KEYOFFSET        512
#define TIMOFFSET        515

#define BUTCOUNT         144
#define SBTCOUNT         16
#define VALCOUNT         20
#define TIMCOUNT         8

/* buttons */

#define BUT0             1       /* 0+BUTOFFSET */
#define BUT1             2       /* 1+BUTOFFSET */
#define BUT2             3       /* 2+BUTOFFSET */
#define BUT3             4       /* 3+BUTOFFSET */
#define BUT4             5       /* 4+BUTOFFSET */
#define BUT5             6       /* 5+BUTOFFSET */
#define BUT6             7       /* 6+BUTOFFSET */
#define BUT7             8       /* 7+BUTOFFSET */
#define BUT8             9       /* 8+BUTOFFSET */
#define BUT9             10      /* 9+BUTOFFSET */
#define BUT10            11      /* 10+BUTOFFSET, A */
#define BUT11            12      /* 11+BUTOFFSET, B */
#define BUT12            13      /* 12+BUTOFFSET, C */
#define BUT13            14      /* 13+BUTOFFSET, D */
#define BUT14            15      /* 14+BUTOFFSET, E */
```

```
#define BUT15          16      /* 15+BUTOFFSET, F */
#define BUT16          17      /* 16+BUTOFFSET, 10 */
#define BUT17          18      /* 17+BUTOFFSET, 11 */
#define BUT18          19      /* 18+BUTOFFSET, 12 */
#define BUT19          20      /* 19+BUTOFFSET, 13 */
#define BUT20          21      /* 20+BUTOFFSET, 14 */
#define BUT21          22      /* 21+BUTOFFSET, 15 */
#define BUT22          23      /* 22+BUTOFFSET, 16 */
#define BUT23          24      /* 23+BUTOFFSET, 17 */
#define BUT24          25      /* 24+BUTOFFSET, 18 */
#define BUT25          26      /* 25+BUTOFFSET, 19 */
#define BUT26          27      /* 26+BUTOFFSET, 1A */
#define BUT27          28      /* 27+BUTOFFSET, 1B */
#define BUT28          29      /* 28+BUTOFFSET, 1C */
#define BUT29          30      /* 29+BUTOFFSET, 1D */
#define BUT30          31      /* 30+BUTOFFSET, 1E */
#define BUT31          32      /* 31+BUTOFFSET, 1F */
#define BUT32          33      /* 32+BUTOFFSET, 20 */
#define BUT33          34      /* 33+BUTOFFSET, 21 */
#define BUT34          35      /* 34+BUTOFFSET, 22 */
#define BUT35          36      /* 35+BUTOFFSET, 23 */
#define BUT36          37      /* 36+BUTOFFSET, 24 */
#define BUT37          38      /* 37+BUTOFFSET, 25 */
#define BUT38          39      /* 38+BUTOFFSET, 26 */
#define BUT39          40      /* 39+BUTOFFSET, 27 */
#define BUT40          41      /* 40+BUTOFFSET, 28 */
#define BUT41          42      /* 41+BUTOFFSET, 29 */
#define BUT42          43      /* 42+BUTOFFSET, 2A */
#define BUT43          44      /* 43+BUTOFFSET, 2B */
#define BUT44          45      /* 44+BUTOFFSET, 2C */
#define BUT45          46      /* 45+BUTOFFSET, 2D */
#define BUT46          47      /* 46+BUTOFFSET, 2E */
#define BUT47          48      /* 47+BUTOFFSET, 2F */
#define BUT48          49      /* 48+BUTOFFSET, 30 */
#define BUT49          50      /* 49+BUTOFFSET, 31 */
#define BUT50          51      /* 50+BUTOFFSET, 32 */
#define BUT51          52      /* 51+BUTOFFSET, 33 */
#define BUT52          53      /* 52+BUTOFFSET, 34 */
#define BUT53          54      /* 53+BUTOFFSET, 35 */
#define BUT54          5       /* 54+BUTOFFSET, 36 */
#define BUT55          56      /* 55+BUTOFFSET, 37 */
#define BUT56          57      /* 56+BUTOFFSET, 38 */
#define BUT57          58      /* 57+BUTOFFSET, 39 */
#define BUT58          59      /* 58+BUTOFFSET, 3A */
#define BUT59          60      /* 59+BUTOFFSET, 3B */
```

```
#define BUT60          61    /* 60+BUTOFFSET, 3C */
#define BUT61          62    /* 61+BUTOFFSET, 3D */
#define BUT62          63    /* 62+BUTOFFSET, 3E */
#define BUT63          64    /* 63+BUTOFFSET, 3F */
#define BUT64          65    /* 64+BUTOFFSET, 40 */
#define BUT65          66    /* 65+BUTOFFSET, 41 */
#define BUT66          67    /* 66+BUTOFFSET, 42 */
#define BUT67          68    /* 67+BUTOFFSET, 43 */
#define BUT68          69    /* 68+BUTOFFSET, 44 */
#define BUT69          70    /* 69+BUTOFFSET, 45 */
#define BUT70          71    /* 70+BUTOFFSET, 46 */
#define BUT71          72    /* 71+BUTOFFSET, 47 */
#define BUT72          73    /* 72+BUTOFFSET, 48 */
#define BUT73          74    /* 73+BUTOFFSET, 49 */
#define BUT74          75    /* 74+BUTOFFSET, 4A */
#define BUT75          76    /* 75+BUTOFFSET, 4B */
#define BUT76          77    /* 76+BUTOFFSET, 4C */
#define BUT77          78    /* 77+BUTOFFSET, 4D */
#define BUT78          79    /* 78+BUTOFFSET, 4E */
#define BUT79          80    /* 79+BUTOFFSET, 4F */
#define BUT80          81    /* 80+BUTOFFSET, 50 */
#define BUT81          82    /* 81+BUTOFFSET, 51 */
#define BUT82          83    /* 82+BUTOFFSET, 52 */
#define MAXKBDBUT      83    /* BUT82 */
#define BUT100         101   /* 100+BUTOFFSET, Mouse button 1 */
#define BUT101         102   /* 101+BUTOFFSET, Mouse button 2 */
#define BUT102         103   /* 102+BUTOFFSET, Mouse button 3 */
#define BUT110         111   /* 110+BUTOFFSET */
#define BUT111         112   /* 111+BUTOFFSET */
#define BUT112         113   /* 112+BUTOFFSET */
#define BUT113         114   /* 113+BUTOFFSET */
#define BUT114         115   /* 114+BUTOFFSET */
#define BUT115         116   /* 115+BUTOFFSET */
#define BUT116         117   /* 116+BUTOFFSET */
#define BUT117         118   /* 117+BUTOFFSET */
#define BUT118         119   /* 118+BUTOFFSET */
#define BUT119         120   /* 119+BUTOFFSET */
#define BUT120         121   /* 120+BUTOFFSET */
#define BUT121         122   /* 121+BUTOFFSET */
#define BUT122         123   /* 122+BUTOFFSET */
#define BUT123         124   /* 123+BUTOFFSET */
#define BUT124         125   /* 124+BUTOFFSET */
#define BUT125         126   /* 125+BUTOFFSET */
#define BUT126         127   /* 126+BUTOFFSET */
#define BUT127         128   /* 127+BUTOFFSET */
```

```
#define BUT128          129     /* 128+BUTOFFSET */
#define BUT129          130     /* 129+BUTOFFSET */
#define BUT130          131     /* 130+BUTOFFSET */
#define BUT131          132     /* 131+BUTOFFSET */
#define BUT132          133     /* 132+BUTOFFSET */
#define BUT133          134     /* 133+BUTOFFSET */
#define BUT134          135     /* 134+BUTOFFSET */
#define BUT135          136     /* 135+BUTOFFSET */
#define BUT136          137     /* 136+BUTOFFSET */
#define BUT137          138     /* 137+BUTOFFSET */
#define BUT138          139     /* 138+BUTOFFSET */
#define BUT139          140     /* 139+BUTOFFSET */
#define BUT140          141     /* 140+BUTOFFSET */
#define BUT141          142     /* 141+BUTOFFSET */
#define MOUSE1          101     /* BUT100 */
#define MOUSE2          102     /* BUT101 */
#define MOUSE3          103     /* BUT102 */
#define LEFTMOUSE       103     /* BUT102 */
#define MIDDLEMOUSE     102     /* BUT101 */
#define RIGHTMOUSE      101     /* BUT100 */
#define LPENBUT         104     /* LIGHT PEN BUTTON */
#define BPAD0           105     /* BITPAD BUTTON 0 */
#define BPAD1           106     /* BITPAD BUTTON 1 */
#define BPAD2           107     /* BITPAD BUTTON 2 */
#define BPAD3           108     /* BITPAD BUTTON 3 */

#define SWBASE          111     /* BUT110 */
#define SW0             111     /* SWBASE */
#define SW1             112     /* SWBASE+1 */
#define SW2             113     /* SWBASE+2 */
#define SW3             114     /* SWBASE+3 */
#define SW4             115     /* SWBASE+4 */
#define SW5             116     /* SWBASE+5 */
#define SW6             117     /* SWBASE+6 */
#define SW7             118     /* SWBASE+7 */
#define SW8             119     /* SWBASE+8 */
#define SW9             120     /* SWBASE+9 */
#define SW10            121     /* SWBASE+10 */
#define SW11            122     /* SWBASE+11 */
#define SW12            123     /* SWBASE+12 */
#define SW13            124     /* SWBASE+13 */
#define SW14            125     /* SWBASE+14 */
#define SW15            126     /* SWBASE+15 */
#define SW16            127     /* SWBASE+16 */
#define SW17            128     /* SWBASE+17 */
```

```
#define SW18            129     /* SWBASE+18 */
#define SW19            130     /* SWBASE+19 */
#define SW20            131     /* SWBASE+20 */
#define SW21            132     /* SWBASE+21 */
#define SW22            133     /* SWBASE+22 */
#define SW23            134     /* SWBASE+23 */
#define SW24            135     /* SWBASE+24 */
#define SW25            136     /* SWBASE+25 */
#define SW26            137     /* SWBASE+26 */
#define SW27            138     /* SWBASE+27 */
#define SW28            139     /* SWBASE+28 */
#define SW29            140     /* SWBASE+29 */
#define SW30            141     /* SWBASE+30 */
#define SW31            142     /* SWBASE+31 */

#define AKEY            11      /* BUT10 */
#define BKEY            36      /* BUT35 */
#define CKEY            28      /* BUT27 */
#define DKEY            18      /* BUT17 */
#define EKEY            17      /* BUT16 */
#define FKEY            19      /* BUT18 */
#define GKEY            26      /* BUT25 */
#define HKEY            27      /* BUT26 */
#define IKEY            40      /* BUT39 */
#define JKEY            34      /* BUT33 */
#define KKEY            35      /* BUT34 */
#define LKEY            42      /* BUT41 */
#define MKEY            44      /* BUT43 */
#define NKEY            37      /* BUT36 */
#define OKEY            41      /* BUT40 */
#define PKEY            48      /* BUT47 */
#define QKEY            10      /* BUT9 */
#define RKEY            24      /* BUT23 */
#define SKEY            12      /* BUT11 */
#define TKEY            25      /* BUT24 */
#define UKEY            33      /* BUT32 */
#define VKEY            29      /* BUT28 */
#define WKEY            16      /* BUT15 */
#define XKEY            21      /* BUT20 */
#define YKEY            32      /* BUT31 */
#define ZKEY            20      /* BUT19 */
#define ZEROKEY         46      /* BUT45 */
#define ONEKEY          8       /* BUT7 */
#define TWOKEY          14      /* BUT13 */
#define THREEKEY        15      /* BUT14 */
```

```
#define FOURKEY           22      /* BUT21 */
#define FIVEKEY           23      /* BUT22 */
#define SIXKEY            30      /* BUT29 */
#define SEVENKEY          31      /* BUT30 */
#define EIGHTKEY          38      /* BUT37 */
#define NINEKEY           39      /* BUT38 */
#define BREAKKEY          1       /* BUT0 */
#define SETUPKEY          2       /* BUT1 */
#define CTRLKEY           3       /* BUT2 */
#define CAPSLOCKKEY       4       /* BUT3 */
#define RIGHTSHIFTKEY     5       /* BUT4 */
#define LEFTSHIFTKEY      6       /* BUT5 */
#define NOSCRLKEY         13      /* BUT12 */
#define ESCKEY            7       /* BUT6 */
#define TABKEY            9       /* BUT8 */
#define RETKEY            51      /* BUT50 */
#define SPACEKEY          83      /* BUT82 */
#define LINEFEEDKEY       60      /* BUT59 */
#define BACKSPACEKEY      61      /* BUT60 */
#define DELKEY            62      /* BUT61 */
#define SEMICOLONKEY      43      /* BUT42 */
#define PERIODKEY         52      /* BUT51 */
#define COMMAKEY          45      /* BUT44 */
#define QUOTEKEY          50      /* BUT49 */
#define ACCENTGRAVEKEY    55      /* BUT54 */
#define MINUSKEY          47      /* BUT46 */
#define VIRGULEKEY        53      /* BUT52 */
#define BACKSLASHKEY      57      /* BUT56 */
#define EQUALKEY          54      /* BUT53 */
#define LEFTBRACKETKEY    49      /* BUT48 */
#define RIGHTBRACKETKEY   56      /* BUT55 */
#define LEFTARROWKEY      73      /* BUT72 */
#define DOWNARROWKEY      74      /* BUT73 */
#define RIGHTARROWKEY     80      /* BUT79 */
#define UPARROWKEY        81      /* BUT80 */
#define PAD0              59      /* BUT58 */
#define PAD1              58      /* BUT57 */
#define PAD2              64      /* BUT63 */
#define PAD3              65      /* BUT64 */
#define PAD4              63      /* BUT62 */
#define PAD5              69      /* BUT68 */
#define PAD6              70      /* BUT69 */
#define PAD7              67      /* BUT66 */
#define PAD8              68      /* BUT67 */
#define PAD9              75      /* BUT74 */
```

```
#define PADPF1            72     /* BUT71 */
#define PADPF2            71     /* BUT70 */
#define PADPF3            79     /* BUT78 */
#define PADPF4            78     /* BUT77 */
#define PADPERIOD         66     /* BUT65 */
#define PADMINUS          76     /* BUT75 */
#define PADCOMMA          77     /* BUT76 */
#define PADENTER          82     /* BUT81 */

/* screen buttons */

#define SCRBUT0           200    /* 0+SBTOFFSET */
#define SCRBUT1           201    /* 1+SBTOFFSET */
#define SCRBUT2           202    /* 2+SBTOFFSET */
#define SCRBUT3           203    /* 3+SBTOFFSET */
#define SCRBUT4           204    /* 4+SBTOFFSET */
#define SCRBUT5           205    /* 5+SBTOFFSET */
#define SCRBUT6           206    /* 6+SBTOFFSET */
#define SCRBUT7           207    /* 7+SBTOFFSET */
#define SCRBUT8           208    /* 8+SBTOFFSET */
#define SCRBUT9           209    /* 9+SBTOFFSET */
#define SCRBUT10          210    /* 10+SBTOFFSET */
#define SCRBUT11          211    /* 11+SBTOFFSET */
#define SCRBUT12          212    /* 12+SBTOFFSET */
#define SCRBUT13          213    /* 13+SBTOFFSET */
#define SCRBUT14          214    /* 14+SBTOFFSET */
#define SCRBUT15          215    /* 15+SBTOFFSET */
#define SCRBUT16          216    /* 16+SBTOFFSET */

/* valuators */

#define SGIRESERVED       256    /* 0+VALOFFSET */
#define DIAL0             257    /* 1+VALOFFSET */
#define DIAL1             258    /* 2+VALOFFSET */
#define DIAL2             259    /* 3+VALOFFSET */
#define DIAL3             260    /* 4+VALOFFSET */
#define DIAL4             261    /* 5+VALOFFSET */
#define DIAL5             262    /* 6+VALOFFSET */
#define DIAL6             263    /* 7+VALOFFSET */
#define DIAL7             264    /* 8+VALOFFSET */
#define DIAL8             265    /* 9+VALOFFSET */
#define MOUSEX            266    /* 10+VALOFFSET */
#define MOUSEY            267    /* 11+VALOFFSET */
#define LPENX             268    /* 12+VALOFFSET */
#define LPENY             269    /* 13+VALOFFSET */
```

```
#define BPADX                270    /* 14+VALOFFSET */
#define BPADY                271    /* 15+VALOFFSET */
#define CURSORX              272    /* 16+VALOFFSET */
#define CURSORY              273    /* 17+VALOFFSET */
#define GHOSTX               274    /* 18+VALOFFSET */
#define GHOSTY               275    /* 19+VALOFFSET */

/* timers */

#define TIMER0               515    /* 0+TIMOFFSET */
#define TIMER1               516    /* 1+TIMOFFSET */
#define TIMER2               517    /* 2+TIMOFFSET */
#define TIMER3               518    /* 3+TIMOFFSET */
#define TIMER4               519    /* 4+TIMOFFSET */
#define TIMER5               520    /* 5+TIMOFFSET */
#define TIMER6               521    /* 6+TIMOFFSET */
#define TIMER7               522    /* 7+TIMOFFSET */

/* misc devices */

#define KEYBD                513    /* keyboard */
#define RAWKEYBD             514    /* raw keyboard for keyboard manager */
#define VALMARK              523    /* valuator mark */
#define GERROR               524    /* errors device */
#define REDRAW               528    /* used by port manager to signal redraws */
#define WMSEND               529    /* data in proc's shmem */
#define WMREPLY              530    /* reply from port manager */
#define WMGFCLOSE            531    /* gf # is no longer being used */
#define WMTXCLOSE            532    /* tx # is no longer being used */
#define MODECHANGE           533    /* the display mode has changed */
#define INPUTCHANGE          534    /* input connected or disconnected */
#define QFULL                535    /* queue was filled */
#define PIECECHANGE          536    /* change in the window pieces */
```

A third header file, "get.h", defines constants for the values of global attributes like display mode and update buffers. It too is optional.

```
/* include file containing definitions for returned values of get* routines */


/* values returned by getbuffer() */

#define NOBUFFER                        0
#define BCKBUFFER                       1
#define FRNTBUFFER                      2
#define BOTHBUFFERS                     3

/* values returned by getcmmode() */

#define CMAPMULTI                       0
#define CMAPONE                         1

/* values returned by getdisplaymode() */

#define DMRGB                           0
#define DMSINGLE                        1
#define DMDOUBLE                        2

/* values returned by getmonitor()      */

#define HZ30                            0
#define HZ60                            1
#define NTSC                            2
#define PAL                             2
#define HZ50                            3
#define MONA                            5
#define MONB                            6
#define MONC                            7
#define MOND                            8
#define MONSPECIAL                      0x20

/* individual hit bits returned by gethitcode() */

#define FARPLANE                        0x0001
#define NEARPLANE                       0x0002
#define TOPPLANE                        0x0004
#define BOTTOMPLANE                     0x0008
#define RIGHTPLANE                      0x0010
#define LEFTPLANE                       0x0020
```

A.2 FORTRAN Definitions

```
C     "fgl.h"

C     graphics library header file

C     maximum X and Y screen coordinates

         INTEGER*4 XMAXSC
         INTEGER*4 YMAXSC

C     various hardware/software limits

         INTEGER*4 ATTRIB
         INTEGER*4 VPSTAC
         INTEGER*4 MATRIX
         INTEGER*4 STARTT
         INTEGER*4 ENDTAG

C     names for colors in color map loaded by ginit()

         INTEGER*4 BLACK
         INTEGER*4 RED
         INTEGER*4 GREEN
         INTEGER*4 YELLOW
         INTEGER*4 BLUE
         INTEGER*4 MAGENT
         INTEGER*4 CYAN
         INTEGER*4 WHITE

C     function return values

         INTEGER*4                 BLKQRE
         INTEGER*4                 ENDFEE
         INTEGER*4                 ENDPIC
         INTEGER*4                 ENDSEL
         INTEGER*4                 GENOBJ
         INTEGER*4                 GENTAG
         INTEGER*4                 GETBUF
         LOGICAL                   GETBUT
         LOGICAL                   GETCMM
         INTEGER*4                 GETCOL
         LOGICAL                   GETDCM
         INTEGER*4                 GETDIS
         INTEGER*4                 GETFON
```

```
      INTEGER*4                 GETHEI
      INTEGER*4                 GETHIT
      LOGICAL                   GETLSB
      INTEGER*4                 GETLSR
      INTEGER*4                 GETLST
      INTEGER*4                 GETLWI
      INTEGER*4                 GETMAP
      INTEGER*4                 GETMEM
      INTEGER*4                 GETMON
      INTEGER*4                 GETOPE
      INTEGER*4                 GETPAT
      INTEGER*4                 GETPLA
      LOGICAL                   GETRES
      INTEGER*4                 GETVAL
      INTEGER*4                 GETWRI
      LOGICAL                   GETZBU
      INTEGER*4 GVERSI
      LOGICAL                   ISOBJ
      LOGICAL                   ISTAG
      INTEGER*4                 QREAD
      INTEGER*4                 QTEST
      INTEGER*4                 READPI
      INTEGER*4                 READRG
      INTEGER*4                 STRWID

C    maximum X and Y screen coordinates

      PARAMETER (XMAXSC =       1023)
      PARAMETER (YMAXSC =       767)

C    various hardware/software limits

      PARAMETER (ATTRIB =       10)
      PARAMETER (VPSTAC =       8)
      PARAMETER (MATRIX =       32)
      PARAMETER (STARTT =       -2)
      PARAMETER (ENDTAG         =-3)

C    names for colors in color map loaded by ginit()

      PARAMETER (BLACK =        0)
      PARAMETER (RED   =        1)
      PARAMETER (GREEN =        2)
      PARAMETER (YELLOW=        3)
      PARAMETER (BLUE  =        4)
```

```
        PARAMETER (MAGENT=          5)
        PARAMETER (CYAN  =          6)
        PARAMETER (WHITE =          7)



C    "fget.h"

        integer*4 NOBUFF
        integer*4 BCKBUF
        integer*4 FRNTBU
        integer*4 BOTHBU
        integer*4 CMAPMU
        integer*4 CMAPON
        integer*4 DMRGB
        integer*4 DMSING
        integer*4 DMDOUB
        integer*4 HZ30
        integer*4 HZ60
        integer*4 NTSC
        integer*4 PAL
        integer*4 HZ50
        integer*4 MONA
        integer*4 MONB
        integer*4 MONC
        integer*4 MOND
        integer*4 MONSPE
        integer*4 FARPLA
        integer*4 NEARPL
        integer*4 TOPPLA
        integer*4 BOTTOM
        integer*4 RIGHTP
        integer*4 LEFTPL

c include file containing definitions for returned values of get* routines


c values returned by getbuffer()

        PARAMETER ( NOBUFF =        0 )
        PARAMETER ( BCKBUF =        1 )
        PARAMETER ( FRNTBU =        2 )
        PARAMETER ( BOTHBU =        3 )
```

```
c values returned by getcmmode()

      PARAMETER ( CMAPMU =          0 )
      PARAMETER ( CMAPON =          1 )

c values returned by getdisplaymode()

      PARAMETER ( DMRGB =           0 )
      PARAMETER ( DMSING =          1 )
      PARAMETER ( DMDOUB =          2 )

c values returned by getmonitor()

      PARAMETER ( HZ30              =0 )
      PARAMETER ( HZ60              =1 )
      PARAMETER ( NTSC              =2 )
      PARAMETER ( PAL               =2 )
      PARAMETER ( HZ50              =3 )
      PARAMETER ( MONA              =5 )
      PARAMETER ( MONB              =6 )
      PARAMETER ( MONC              =7 )
      PARAMETER ( MOND              =8 )
      PARAMETER ( MONSPE =          32 )

c individual hit bits returned by gethitcode()

      PARAMETER ( FARPLA =          1 )
      PARAMETER ( NEARPL =          2 )
      PARAMETER ( TOPPLA =          4 )
      PARAMETER ( BOTTOM =          8 )
      PARAMETER ( RIGHTP =          16 )
      PARAMETER ( LEFTPL =          32 )



C    "fdevice.h"
C    include file with device definitions

       INTEGER*4 NULLDE
       INTEGER*4 BUTOFF
       INTEGER*4 SBTOFF
       INTEGER*4 VALOFF
       INTEGER*4 KEYOFF
       INTEGER*4 TIMOFF
      INTEGER*4 BUTCOU
      INTEGER*4 SBTCOU
      INTEGER*4 VALCOU
      INTEGER*4 TIMCOU

C    buttons

      INTEGER*4 BUT0
      INTEGER*4 BUT1
      INTEGER*4 BUT2
      INTEGER*4 BUT3
      INTEGER*4 BUT4
      INTEGER*4 BUT5
      INTEGER*4 BUT6
      INTEGER*4 BUT7
      INTEGER*4 BUT8
      INTEGER*4 BUT9
      INTEGER*4 BUT10
      INTEGER*4 BUT11
      INTEGER*4 BUT12
      INTEGER*4 BUT13
      INTEGER*4 BUT14
      INTEGER*4 BUT15
      INTEGER*4 BUT16
      INTEGER*4 BUT17
      INTEGER*4 BUT18
      INTEGER*4 BUT19
      INTEGER*4 BUT20
      INTEGER*4 BUT21
      INTEGER*4 BUT22
      INTEGER*4 BUT23
      INTEGER*4 BUT24
      INTEGER*4 BUT25
      INTEGER*4 BUT26
      INTEGER*4 BUT27
      INTEGER*4 BUT28
      INTEGER*4 BUT29
      INTEGER*4 BUT30
      INTEGER*4 BUT31
      INTEGER*4 BUT32
      INTEGER*4 BUT33
      INTEGER*4 BUT34
      INTEGER*4 BUT35
      INTEGER*4 BUT36
      INTEGER*4 BUT37
      INTEGER*4 BUT38
      INTEGER*4 BUT39
      INTEGER*4 BUT40
      INTEGER*4 BUT41
      INTEGER*4 BUT42
      INTEGER*4 BUT43
      INTEGER*4 BUT44
      INTEGER*4 BUT45
      INTEGER*4 BUT46
      INTEGER*4 BUT47
      INTEGER*4 BUT48
      INTEGER*4 BUT49
      INTEGER*4 BUT50
      INTEGER*4 BUT51
      INTEGER*4 BUT52
      INTEGER*4 BUT53
      INTEGER*4 BUT54
      INTEGER*4 BUT55
      INTEGER*4 BUT56
      INTEGER*4 BUT57
      INTEGER*4 BUT58
      INTEGER*4 BUT59
      INTEGER*4 BUT60
      INTEGER*4 BUT61
      INTEGER*4 BUT62
      INTEGER*4 BUT63
      INTEGER*4 BUT64
      INTEGER*4 BUT65
      INTEGER*4 BUT66
      INTEGER*4 BUT67
      INTEGER*4 BUT68
      INTEGER*4 BUT69
      INTEGER*4 BUT70
      INTEGER*4 BUT71
      INTEGER*4 BUT72
      INTEGER*4 BUT73
      INTEGER*4 BUT74
      INTEGER*4 BUT75
      INTEGER*4 BUT76
      INTEGER*4 BUT77
      INTEGER*4 BUT78
      INTEGER*4 BUT79
      INTEGER*4 BUT80
      INTEGER*4 BUT81
```

```
INTEGER*4 BUT82
INTEGER*4 MAXKBD
INTEGER*4 BUT100
INTEGER*4 BUT101
INTEGER*4 BUT102
INTEGER*4 BUT110
INTEGER*4 BUT111
INTEGER*4 BUT112
INTEGER*4 BUT113
INTEGER*4 BUT114
INTEGER*4 BUT115
INTEGER*4 BUT116
INTEGER*4 BUT117
INTEGER*4 BUT118
INTEGER*4 BUT119
INTEGER*4 BUT120
INTEGER*4 BUT121
INTEGER*4 BUT122
INTEGER*4 BUT123
INTEGER*4 BUT124
INTEGER*4 BUT125
INTEGER*4 BUT126
INTEGER*4 BUT127
INTEGER*4 BUT128
INTEGER*4 BUT129
INTEGER*4 BUT130
INTEGER*4 BUT131
INTEGER*4 BUT132
INTEGER*4 BUT133
INTEGER*4 BUT134
INTEGER*4 BUT135
INTEGER*4 BUT136
INTEGER*4 BUT137
INTEGER*4 BUT138
INTEGER*4 BUT139
INTEGER*4 BUT140
INTEGER*4 BUT141
INTEGER*4 MOUSE1
INTEGER*4 MOUSE2
INTEGER*4 MOUSE3
INTEGER*4 LEFTMO
INTEGER*4 MIDDLE
INTEGER*4 RIGHTM
INTEGER*4 LPENBU
INTEGER*4 BPAD0
```

```
INTEGER*4 BPAD1
INTEGER*4 BPAD2
INTEGER*4 BPAD3
INTEGER*4 SWBASE
INTEGER*4 SW0
INTEGER*4 SW1
INTEGER*4 SW2
INTEGER*4 SW3
INTEGER*4 SW4
INTEGER*4 SW5
INTEGER*4 SW6
INTEGER*4 SW7
INTEGER*4 SW8
INTEGER*4 SW9
INTEGER*4 SW10
INTEGER*4 SW11
INTEGER*4 SW12
INTEGER*4 SW13
INTEGER*4 SW14
INTEGER*4 SW15
INTEGER*4 SW16
INTEGER*4 SW17
INTEGER*4 SW18
INTEGER*4 SW19
INTEGER*4 SW20
INTEGER*4 SW21
INTEGER*4 SW22
INTEGER*4 SW23
INTEGER*4 SW24
INTEGER*4 SW25
INTEGER*4 SW26
INTEGER*4 SW27
INTEGER*4 SW28
INTEGER*4 SW29
INTEGER*4 SW30
INTEGER*4 SW31

INTEGER*4 AKEY
INTEGER*4 BKEY
INTEGER*4 CKEY
INTEGER*4 DKEY
INTEGER*4 EKEY
INTEGER*4 FKEY
INTEGER*4 GKEY
INTEGER*4 HKEY
```

```
      INTEGER*4 IKEY
      INTEGER*4 JKEY
      INTEGER*4 KKEY
      INTEGER*4 LKEY
      INTEGER*4 MKEY
      INTEGER*4 NKEY
      INTEGER*4 OKEY
      INTEGER*4 PKEY
      INTEGER*4 QKEY
      INTEGER*4 RKEY
      INTEGER*4 SKEY
      INTEGER*4 TKEY
      INTEGER*4 UKEY
      INTEGER*4 VKEY
      INTEGER*4 WKEY
      INTEGER*4 XKEY
      INTEGER*4 YKEY
      INTEGER*4 ZKEY
      INTEGER*4 ZEROKE
      INTEGER*4 ONEKEY
      INTEGER*4 TWOKEY
      INTEGER*4 THREEK
      INTEGER*4 FOURKE
      INTEGER*4 FIVEKE
      INTEGER*4 SIXKEY
      INTEGER*4 SEVENK
      INTEGER*4 EIGHTK
      INTEGER*4 NINEKE
      INTEGER*4 BREAKK
      INTEGER*4 SETUPK
      INTEGER*4 CTRLKE
      INTEGER*4 CAPSLO
      INTEGER*4 RIGHTS
      INTEGER*4 LEFTSH
      INTEGER*4 NOSCRL
      INTEGER*4 ESCKEY
      INTEGER*4 TABKEY
      INTEGER*4 RETKEY
      INTEGER*4 SPACEK
      INTEGER*4 LINEFE
      INTEGER*4 BACKSP
      INTEGER*4 DELKEY
      INTEGER*4 SEMICO
      INTEGER*4 PERIOD
      INTEGER*4 COMMAK
      INTEGER*4 QUOTEK
      INTEGER*4 ACCENT
      INTEGER*4 MINUSK
      INTEGER*4 VIRGUL
      INTEGER*4 BACKSL
      INTEGER*4 EQUALK
      INTEGER*4 LEFTBR
      INTEGER*4 RIGHTB
      INTEGER*4 LEFTAR
      INTEGER*4 DOWNAR
      INTEGER*4 RIGHTA
      INTEGER*4 UPARRO
      INTEGER*4 PAD0
      INTEGER*4 PAD1
      INTEGER*4 PAD2
      INTEGER*4 PAD3
      INTEGER*4 PAD4
      INTEGER*4 PAD5
      INTEGER*4 PAD6
      INTEGER*4 PAD7
      INTEGER*4 PAD8
      INTEGER*4 PAD9
      INTEGER*4 PADPF1
      INTEGER*4 PADPF2
      INTEGER*4 PADPF3
      INTEGER*4 PADPF4
      INTEGER*4 PADPER
      INTEGER*4 PADMIN
      INTEGER*4 PADCOM
      INTEGER*4 PADENT

C   screen buttons
C   Hashing algorithm: SBUTx = SCRBUTx

      INTEGER*4 SBUT0
      INTEGER*4 SBUT1
      INTEGER*4 SBUT2
      INTEGER*4 SBUT3
      INTEGER*4 SBUT4
      INTEGER*4 SBUT5
      INTEGER*4 SBUT6
      INTEGER*4 SBUT7
      INTEGER*4 SBUT8
      INTEGER*4 SBUT9
      INTEGER*4 SBUT10
      INTEGER*4 SBUT11
      INTEGER*4 SBUT12
      INTEGER*4 SBUT13
      INTEGER*4 SBUT14
      INTEGER*4 SBUT15
      INTEGER*4 SBUT16

C   valuators

      INTEGER*4 SGIRES
      INTEGER*4 DIAL0
      INTEGER*4 DIAL1
      INTEGER*4 DIAL2
      INTEGER*4 DIAL3
      INTEGER*4 DIAL4
      INTEGER*4 DIAL5
      INTEGER*4 DIAL6
      INTEGER*4 DIAL7
      INTEGER*4 DIAL8
      INTEGER*4 MOUSEX
      INTEGER*4 MOUSEY
      INTEGER*4 LPENX
      INTEGER*4 LPENY
      INTEGER*4 BPADX
      INTEGER*4 BPADY
      INTEGER*4 NULLX
      INTEGER*4 NULLY

C   timers

      INTEGER*4 TIMER0
      INTEGER*4 TIMER1
      INTEGER*4 TIMER2
      INTEGER*4 TIMER3
      INTEGER*4 TIMER4
      INTEGER*4 TIMER5
      INTEGER*4 TIMER6
      INTEGER*4 TIMER7

C   misc devices
C   Hash algorithm: CURSRX = CURSORX

      INTEGER*4 KEYBD
      INTEGER*4 CURSRX
      INTEGER*4 CURSRY
      INTEGER*4 VALMAR
      INTEGER*4 GERROR
      INTEGER*4 REDRAW
      INTEGER*4                     WMSEND
      INTEGER*4                     WMREPL
      INTEGER*4                     WMGFCL
      INTEGER*4 WMTXCL

C    include file with device definitions

      PARAMETER ( NULLDE = 0 )
      PARAMETER ( BUTOFF = 1 )
      PARAMETER ( SBTOFF = 200 )
      PARAMETER ( VALOFF = 256 )
      PARAMETER ( KEYOFF = 512 )
      PARAMETER ( TIMOFF = 515 )

      PARAMETER ( BUTCOU = 144 )
      PARAMETER ( SBTCOU = 16  )
      PARAMETER ( VALCOU = 14  )
      PARAMETER ( TIMCOU = 8   )

C    buttons

      PARAMETER ( BUT0 = 1 )
      PARAMETER ( BUT1 = 2 )
      PARAMETER ( BUT2 = 3 )
      PARAMETER ( BUT3 = 4 )
      PARAMETER ( BUT4 = 5 )
      PARAMETER ( BUT5 = 6 )
      PARAMETER ( BUT6 = 7 )
      PARAMETER ( BUT7 = 8 )
      PARAMETER ( BUT8 = 9 )
      PARAMETER ( BUT9 = 10 )
      PARAMETER ( BUT10 = 11 )
      PARAMETER ( BUT11 = 12 )
      PARAMETER ( BUT12 = 13 )
      PARAMETER ( BUT13 = 14 )
      PARAMETER ( BUT14 = 15 )
      PARAMETER ( BUT15 = 16 )
      PARAMETER ( BUT16 = 17 )
      PARAMETER ( BUT17 = 18 )
      PARAMETER ( BUT18 = 19 )
      PARAMETER ( BUT19 = 20 )
      PARAMETER ( BUT20 = 21 )
PARAMETER ( BUT21 = 22 )
PARAMETER ( BUT22 = 23 )
PARAMETER ( BUT23 = 24 )
PARAMETER ( BUT24 = 25 )
PARAMETER ( BUT25 = 26 )
PARAMETER ( BUT26 = 27 )
PARAMETER ( BUT27 = 28 )
PARAMETER ( BUT28 = 29 )
PARAMETER ( BUT29 = 30 )
PARAMETER ( BUT30 = 31 )
PARAMETER ( BUT31 = 32 )
PARAMETER ( BUT32 = 33 )
PARAMETER ( BUT33 = 34 )
PARAMETER ( BUT34 = 35 )
PARAMETER ( BUT35 = 36 )
PARAMETER ( BUT36 = 37 )
PARAMETER ( BUT37 = 38 )
PARAMETER ( BUT38 = 39 )
PARAMETER ( BUT39 = 40 )
PARAMETER ( BUT40 = 41 )
PARAMETER ( BUT41 = 42 )
PARAMETER ( BUT42 = 43 )
PARAMETER ( BUT43 = 44 )
PARAMETER ( BUT44 = 45 )
PARAMETER ( BUT45 = 46 )
PARAMETER ( BUT46 = 47 )
PARAMETER ( BUT47 = 48 )
PARAMETER ( BUT48 = 49 )
PARAMETER ( BUT49 = 50 )
PARAMETER ( BUT50 = 51 )
PARAMETER ( BUT51 = 52 )
PARAMETER ( BUT52 = 53 )
PARAMETER ( BUT53 = 54 )
PARAMETER ( BUT54 = 55 )
PARAMETER ( BUT55 = 56 )
PARAMETER ( BUT56 = 57 )
PARAMETER ( BUT57 = 58 )
PARAMETER ( BUT58 = 59 )
PARAMETER ( BUT59 = 60 )
PARAMETER ( BUT60 = 61 )
PARAMETER ( BUT61 = 62 )
PARAMETER ( BUT62 = 63 )
PARAMETER ( BUT63 = 64 )
PARAMETER ( BUT64 = 65 )
PARAMETER ( BUT65 = 66 )
```

```
      PARAMETER ( BUT66 = 67 )
      PARAMETER ( BUT67 = 68 )
      PARAMETER ( BUT68 = 69 )
      PARAMETER ( BUT69 = 70 )
      PARAMETER ( BUT70 = 71 )
      PARAMETER ( BUT71 = 72 )
      PARAMETER ( BUT72 = 73 )
      PARAMETER ( BUT73 = 74 )
      PARAMETER ( BUT74 = 75 )
      PARAMETER ( BUT75 = 76 )
      PARAMETER ( BUT76 = 77 )
      PARAMETER ( BUT77 = 78 )
      PARAMETER ( BUT78 = 79 )
      PARAMETER ( BUT79 = 80 )
      PARAMETER ( BUT80 = 81 )
      PARAMETER ( BUT81 = 82 )
      PARAMETER ( BUT82 = 83 )
      PARAMETER ( MAXKBD = 83 )
      PARAMETER ( BUT100 = 101 )
      PARAMETER ( BUT101 = 102 )
      PARAMETER ( BUT102 = 103 )
      PARAMETER ( BUT110 = 111 )
      PARAMETER ( BUT111 = 112 )
      PARAMETER ( BUT112 = 113 )
      PARAMETER ( BUT113 = 114 )
      PARAMETER ( BUT114 = 115 )
      PARAMETER ( BUT115 = 116 )
      PARAMETER ( BUT116 = 117 )
      PARAMETER ( BUT117 = 118 )
      PARAMETER ( BUT118 = 119 )
      PARAMETER ( BUT119 = 120 )
      PARAMETER ( BUT120 = 121 )
      PARAMETER ( BUT121 = 122 )
      PARAMETER ( BUT122 = 123 )
      PARAMETER ( BUT123 = 124 )
      PARAMETER ( BUT124 = 125 )
      PARAMETER ( BUT125 = 126 )
      PARAMETER ( BUT126 = 127 )
      PARAMETER ( BUT127 = 128 )
      PARAMETER ( BUT128 = 129 )
      PARAMETER ( BUT129 = 130 )
      PARAMETER ( BUT130 = 131 )
      PARAMETER ( BUT131 = 132 )
      PARAMETER ( BUT132 = 133 )
      PARAMETER ( BUT133 = 134 )
```

```
PARAMETER ( BUT134 = 135 )
PARAMETER ( BUT135 = 136 )
PARAMETER ( BUT136 = 137 )
PARAMETER ( BUT137 = 138 )
PARAMETER ( BUT138 = 139 )
PARAMETER ( BUT139 = 140 )
PARAMETER ( BUT140 = 141 )
PARAMETER ( BUT141 = 142 )
PARAMETER ( MOUSE1 = 101 )
PARAMETER ( MOUSE2 = 102 )
PARAMETER ( MOUSE3 = 103 )
PARAMETER ( LEFTMO = 103 )
PARAMETER ( MIDDLE = 102 )
PARAMETER ( RIGHTM = 101 )
PARAMETER ( LPENBU = 104 )
PARAMETER ( BPAD0  = 105 )
PARAMETER ( BPAD1  = 106 )
PARAMETER ( BPAD2  = 107 )
PARAMETER ( BPAD3  = 108 )
PARAMETER ( SWBASE = 111 )
PARAMETER ( SW0 = 111 )
PARAMETER ( SW1 = 112 )
PARAMETER ( SW2 = 113 )
PARAMETER ( SW3 = 114 )
PARAMETER ( SW4 = 115 )
PARAMETER ( SW5 = 116 )
PARAMETER ( SW6 = 117 )
PARAMETER ( SW7 = 118 )
PARAMETER ( SW8 = 119 )
PARAMETER ( SW9 = 120 )
PARAMETER ( SW10 = 121 )
PARAMETER ( SW11 = 122 )
PARAMETER ( SW12 = 123 )
PARAMETER ( SW13 = 124 )
PARAMETER ( SW14 = 125 )
PARAMETER ( SW15 = 126 )
PARAMETER ( SW16 = 127 )
PARAMETER ( SW17 = 128 )
PARAMETER ( SW18 = 129 )
PARAMETER ( SW19 = 130 )
PARAMETER ( SW20 = 131 )
PARAMETER ( SW21 = 132 )
PARAMETER ( SW22 = 133 )
PARAMETER ( SW23 = 134 )
PARAMETER ( SW24 = 135 )
```

```
      PARAMETER ( SW25 = 136 )
      PARAMETER ( SW26 = 137 )
      PARAMETER ( SW27 = 138 )
      PARAMETER ( SW28 = 139 )
      PARAMETER ( SW29 = 140 )
      PARAMETER ( SW30 = 141 )
      PARAMETER ( SW31 = 142 )
      PARAMETER ( AKEY = 11 )
      PARAMETER ( BKEY = 36 )
      PARAMETER ( CKEY = 28 )
      PARAMETER ( DKEY = 18 )
      PARAMETER ( EKEY = 17 )
      PARAMETER ( FKEY = 19 )
      PARAMETER ( GKEY = 26 )
      PARAMETER ( HKEY = 27 )
      PARAMETER ( IKEY = 40 )
      PARAMETER ( JKEY = 34 )
      PARAMETER ( KKEY = 35 )
      PARAMETER ( LKEY = 42 )
      PARAMETER ( MKEY = 44 )
      PARAMETER ( NKEY = 37 )
      PARAMETER ( OKEY = 41 )
      PARAMETER ( PKEY = 48 )
      PARAMETER ( QKEY = 10 )
      PARAMETER ( RKEY = 24 )
      PARAMETER ( SKEY = 12 )
      PARAMETER ( TKEY = 25 )
      PARAMETER ( UKEY = 33 )
      PARAMETER ( VKEY = 29 )
      PARAMETER ( WKEY = 16 )
      PARAMETER ( XKEY = 21 )
      PARAMETER ( YKEY = 32 )
      PARAMETER ( ZKEY = 20 )
      PARAMETER ( ZEROKE = 46 )
      PARAMETER ( ONEKEY = 8 )
      PARAMETER ( TWOKEY = 14 )
      PARAMETER ( THREEK = 15 )
      PARAMETER ( FOURKE = 22 )
      PARAMETER ( FIVEKE = 23 )
      PARAMETER ( SIXKEY = 30 )
      PARAMETER ( SEVENK = 31 )
      PARAMETER ( EIGHTK = 38 )
      PARAMETER ( NINEKE = 39 )
      PARAMETER ( BREAKK = 1 )
      PARAMETER ( SETUPK = 2 )
      PARAMETER ( CTRLKE = 3 )
      PARAMETER ( CAPSLO = 4 )
      PARAMETER ( RIGHTS = 5 )
      PARAMETER ( LEFTSH = 6 )
      PARAMETER ( NOSCRL = 13 )
      PARAMETER ( ESCKEY = 7 )
      PARAMETER ( TABKEY = 9 )
      PARAMETER ( RETKEY = 51 )
      PARAMETER ( SPACEK = 83 )
      PARAMETER ( LINEFE = 60 )
      PARAMETER ( BACKSP = 61 )
      PARAMETER ( DELKEY = 62 )
      PARAMETER ( SEMICO = 43 )
      PARAMETER ( PERIOD = 52 )
      PARAMETER ( COMMAK = 45 )
      PARAMETER ( QUOTEK = 50 )
      PARAMETER ( ACCENT = 55 )
      PARAMETER ( MINUSK = 47 )
      PARAMETER ( VIRGUL = 53 )
      PARAMETER ( BACKSL = 57 )
      PARAMETER ( EQUALK = 54 )
      PARAMETER ( LEFTBR = 49 )
      PARAMETER ( RIGHTB = 56 )
      PARAMETER ( LEFTAR = 73 )
      PARAMETER ( DOWNAR = 74 )
      PARAMETER ( RIGHTA = 80 )
      PARAMETER ( UPARRO = 81 )
      PARAMETER ( PAD0 = 59 )
      PARAMETER ( PAD1 = 58 )
      PARAMETER ( PAD2 = 64 )
      PARAMETER ( PAD3 = 65 )
      PARAMETER ( PAD4 = 63 )
      PARAMETER ( PAD5 = 69 )
      PARAMETER ( PAD6 = 70 )
      PARAMETER ( PAD7 = 67 )
      PARAMETER ( PAD8 = 68 )
      PARAMETER ( PAD9 = 75 )
      PARAMETER ( PADPF1 = 72 )
      PARAMETER ( PADPF2 = 71 )
      PARAMETER ( PADPF3 = 79 )
      PARAMETER ( PADPF4 = 78 )
      PARAMETER ( PADPER = 66 )
      PARAMETER ( PADMIN = 76 )
      PARAMETER ( PADCOM = 77 )
      PARAMETER ( PADENT = 82 )
```

```
C   screen buttons

      PARAMETER ( SBUT0 = 200 )
      PARAMETER ( SBUT1 = 201 )
      PARAMETER ( SBUT2 = 202 )
      PARAMETER ( SBUT3 = 203 )
      PARAMETER ( SBUT4 = 204 )
      PARAMETER ( SBUT5 = 205 )
      PARAMETER ( SBUT6 = 206 )
      PARAMETER ( SBUT7 = 207 )
      PARAMETER ( SBUT8 = 208 )
      PARAMETER ( SBUT9 = 209 )
      PARAMETER ( SBUT10 = 210 )
      PARAMETER ( SBUT11 = 211 )
      PARAMETER ( SBUT12 = 212 )
      PARAMETER ( SBUT13 = 213 )
      PARAMETER ( SBUT14 = 214 )
      PARAMETER ( SBUT15 = 215 )
      PARAMETER ( SBUT16 = 216 )

C   valuators

      PARAMETER ( SGIRES = 256 )
      PARAMETER ( DIAL0 = 257 )
      PARAMETER ( DIAL1 = 258 )
      PARAMETER ( DIAL2 = 259 )
      PARAMETER ( DIAL3 = 260 )
      PARAMETER ( DIAL4 = 261 )
      PARAMETER ( DIAL5 = 262 )
      PARAMETER ( DIAL6 = 263 )
      PARAMETER ( DIAL7 = 264 )
      PARAMETER ( DIAL8 =  265 )
      PARAMETER ( MOUSEX = 266 )
      PARAMETER ( MOUSEY = 267 )
      PARAMETER ( LPENX =  268 )
      PARAMETER ( LPENY =  269 )
      PARAMETER ( BPADX =  270 )
      PARAMETER ( BPADY =  271 )
      PARAMETER ( NULLX =  270 )
      PARAMETER ( NULLY =  271 )

C timers

      PARAMETER ( TIMER0 = 515 )
```

```
        PARAMETER ( TIMER1 = 516 )
        PARAMETER ( TIMER2 = 517 )
        PARAMETER ( TIMER3 = 518 )
        PARAMETER ( TIMER4 = 519 )
        PARAMETER ( TIMER5 = 520 )
        PARAMETER ( TIMER6 = 521 )
        PARAMETER ( TIMER7 = 522 )

C  misc devices

        PARAMETER ( KEYBD = 513 )
        PARAMETER ( CURSRX = 526 )
        PARAMETER ( CURSRY = 527 )
        PARAMETER ( VALMAR =  523 )
        PARAMETER ( GERROR =  524 )
        PARAMETER ( REDRAW =  528 )
        PARAMETER ( WMSEND =  529 )
        PARAMETER ( WMREPL =  530 )
        PARAMETER ( WMGFCL =  531 )
        PARAMETER ( WMTXCL =  532 )
```

A. s Definitions

```
Pascal
const        MAXARRAY = 1023;
             MAXRASTER = 4095;
             MAXOBJECTS = 4095;
             PATTERN_16 = 16;
             PATTERN_32 = 32;
             PATTERN_64 = 64;
             PATTERN_16_SIZE = 16;
             PATTERN_32_SIZE = 64;
             PATTERN_64_SIZE = 256;

type         Byte = 0..255;
             Short = integer;
             UnsignedShort = 0..65535;
             Angle = integer;
             Screencoord = short;
             Icoord = longint;
             Coord = real;
             Scoord = UnsignedShort;
             Strng = paced array [1..128] of char;
             Matrix = array [0..3, 0..3] of real;

             Device = UnsignedShort;
```

```
string128 = string [128];
pstring = ^Strng;

Colorindex = UnsignedShort;
RGBvalue = Byte;

Linestyle = UnsignedShort;
Pattern = array [0..15] of Byte;
Pattern16 = [0..PATTERN_16-SIZE] of UnsignedShort;
Pattern32 = [0..PATTERN_32_SIZE] of UnsignedShort;
Pattern64 = [0..PATTERN_64-SIZE] of UnsignedShort;
Cursor = array [0..15] of UnsignedShort;
Fontchar = record
             offst: Short;
             w, h: Byte;
             xoff, yoff: -128..127;
             width: Short;
       end;

Object = longint;
Tag = longint;

Coord4array = array [0..MAXARRAY, 0..3] of Coord;
Coord3array = array [0..MAXARRAY, 0..2] of Coord;
Coord2array = array [0..MAXARRAY, 0..1] of Coord;
Icoord3array = array [0..MAXARRAY, 0..2] of Icoord;
Icoord2array = array [0..MAXARRAY, 0..1] of Icoord;
Scoord3array = array [0..MAXARRAY, 0..2] of Scoord;
Scoord2array = array [0..MAXARRAY, 0..1] of Scoord;
Screenarray = array [0..MAXARRAY, 0..2] of Screencoord;

Boolarray = array [0..MAXARRAY] of Boolean;
Colorarray = array [0..MAXARRAY] of Colorindex;
RGBarray = array [0..MAXARRAY] of RGBvalue;

Objarray = array [0..127] of Object;
Fntchrarray = array [0..127] of Fontchar;
Fontraster = array [0..MAXRASTER] of Short;
lbuffer = array [0..MAXOBJECTS] of Object;
Queuearray = array [0..MAXARRAY] of Short;
Curvearray = array [0..3] [0..2] of Coord;
Ibuffer = array [0..MAXARRAY] of Short;
Patcharray = array [0..3] [0..3] of Coord;
```

Appendix B
Geometry Engine Computations

The Geometry Engine system has three parts:

- **Matrix Subsystem** - A stack of 4x4 floating point matrices transform coordinate data.
- **Clipping Subsystem** - Transformed coordinate data is clipped to a 2D or 3D window.
- **Scaling Subsystem** - Clipped 2D or 3D coordinate data is scaled to the dimensions of the output device. In 3D, the system provides orthographic or perspective projection as well.

The Matrix Subsystem does the following computation:

$$\begin{bmatrix} x & y & z & w \end{bmatrix} = \begin{bmatrix} x' & y' & z' & w' \end{bmatrix} M$$

where M is the current transformation matrix and $\begin{bmatrix} x' & y' & z' & w' \end{bmatrix}$ is the vector to be transformed. The coordinates $\begin{bmatrix} x & y & z & w \end{bmatrix}$ are given to the Clipping Subsystem. The clipped results satisfy the following equations:

$$-w < x < w$$

$$-w < y < w$$

$$-w < z < w$$

After clipping, the Scaling Subsystem does the final mapping to screen coordinates with the following computations:

$$X_{screen} = \frac{x}{w} \times V_{sx} + V_{cx}$$

$$Y_{screen} = \frac{y}{w} \times V_{sy} + V_{cy}$$

$$Z_{screen} = \frac{z}{w} \times V_{sz} + V_{cz}$$

V_{cx} is the center of the viewport in the coordinate system of the output device, and V_{sx} is the horizontal distance from the center to the edge of the viewport. V_{cy}, V_{sy}, V_{cz}, and V_{sz} are similarly defined.

The IRIS user declares the viewport boundaries with the **viewport** and **setdepth** commands. The viewport centers and half-widths are computed as follows:

$$V_{cx} = \frac{left+right}{2} \qquad V_{sx} = \frac{right-left}{2}$$

$$V_{cy} = \frac{bottom+top}{2} \qquad V_{sy} = \frac{top-bottom}{2}$$

$$V_{cz} = \frac{near+far}{2} \qquad V_{sz} = \frac{far-near}{2}$$

Appendix C
Transformation Matrices

Here are the matrices that are created by the transformation commands.

C.1 Translation

$$Translate(T_x, T_y, T_z) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ T_x & T_y & T_z & 1 \end{bmatrix}$$

C.2 Scaling and Mirroring

$$Scale(S_x, S_y, S_z) = \begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

C.3 Rotation

$$Rot_x(\theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & \sin\theta & 0 \\ 0 & -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$Rot_y(\theta) = \begin{bmatrix} \cos\theta & 0 & -\sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ \sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$Rot_z(\theta) = \begin{bmatrix} \cos\theta & \sin\theta & 0 & 0 \\ -\sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

C.4 Viewing Transformations

$$\mathit{Polarview}(\mathit{dist}, \mathit{azim}, \mathit{inc}, \mathit{twist}) = \mathit{Rot}_y(-\mathit{azim}) \times \mathit{Rot}_x(-\mathit{inc}) \times \mathit{Rot}_z(-\mathit{twist}) \times \mathit{Trans}(0.0,\ 0.0,\ -\mathit{dist})$$

$$\mathit{Lookat}(v_x, v_y, v_z, p_x, p_y, p_z,\ \mathit{twist}) = \mathit{Trans}(-v_x,\ -v_y,\ -v_z) \times \mathit{Rot}_y(\theta) \times \mathit{Rot}_x(\phi) \times \mathit{Rot}_z(-\mathit{twist})$$

where $\sin(\theta) = \dfrac{p_x - v_x}{\sqrt{(p_x - v_x)^2 + (p_z - v_z)^2}}$

$$\cos(\theta) = \frac{v_x - p_x}{\sqrt{(p_x - v_x)^2 + (p_z - v_z)^2}}$$

$$\sin(\phi) = \frac{v_y - p_y}{\sqrt{(p_x - v_x)^2 + (p_y - v_y)^2 + (p_z - v_z)^2}}$$

$$\cos(\phi) = \frac{\sqrt{(p_x - v_x)^2 + (p_z - v_z)^2}}{\sqrt{(p_x - v_x)^2 + (p_y - v_y)^2 + (p_z - v_z)^2}}$$

C.5 Perspective Transformations

$$\mathit{Perspective}(\mathit{fov}, \mathit{aspect}, \mathit{near}, \mathit{far}) = \begin{bmatrix} \dfrac{\cot\left[\dfrac{\mathit{fov}}{2}\right]}{\mathit{aspect}} & 0 & 0 & 0 \\ 0 & \cot\left[\dfrac{\mathit{fov}}{2}\right] & 0 & 0 \\ 0 & 0 & -\dfrac{\mathit{far} + \mathit{near}}{\mathit{far} - \mathit{near}} & -1 \\ 0 & 0 & -\dfrac{2 \times \mathit{far} \times \mathit{near}}{\mathit{far} - \mathit{near}} & 0 \end{bmatrix}$$

$$Window(left,right,bottom,top,near,far) = \begin{bmatrix} \frac{2\times near}{right-left} & 0 & 0 & 0 \\ 0 & \frac{2\times near}{top-bottom} & 0 & 0 \\ \frac{right+left}{right-left} & \frac{top+bottom}{top-bottom} & -\frac{far+near}{far-near} & -1 \\ 0 & 0 & -\frac{2\times far\times near}{far-near} & 0 \end{bmatrix}$$

C.6 Orthographic Transformations

$$Ortho_{3d}(left,right,bottom,top,near,far) = \begin{bmatrix} \frac{2}{right-left} & 0 & 0 & 0 \\ 0 & \frac{2}{top-bottom} & 0 & 0 \\ 0 & 0 & -\frac{2}{far-near} & 0 \\ -\frac{right+left}{right-left} & -\frac{top+bottom}{top-bottom} & -\frac{far+near}{far-near} & 1 \end{bmatrix}$$

$$Ortho_{2d}(left,right,bottom,top) = \begin{bmatrix} \frac{2}{right-left} & 0 & 0 & 0 \\ 0 & \frac{2}{top-bottom} & 0 & 0 \\ 0 & 0 & -1 & 0 \\ -\frac{right+left}{right-left} & -\frac{top+bottom}{top-bottom} & 0 & 1 \end{bmatrix}$$

Appendix D
Feedback Parser

This feedback parser simplifies the use of the Geometry Engines in feedback mode. (See Chapter 10 for a discussion of the IRIS feedback utility.) The purpose of the parser is to pass to an application program the commands and data it is interested in while discarding unwanted commands.

The parser accepts a buffer of feedback data and parses it in normal or debugging mode. In normal mode the parser passes the indicated commands and data to the application. In debugging mode the parser produces a printed trace of all commands and data not passed to the application. If no commands are requested by the application then the entire feedback buffer is parsed and printed.

The interface to the parser consists of four routines. `parsefb` parses a feedback buffer. Its arguments are the name of the buffer, the size of the buffer, a flag indicating whether z-buffering is on, and a flag indicating whether depth-cueing is on. `parsefb` returns TRUE or FALSE to indicate whether the buffer was successfully parsed.

```
parsefb(buffer, count, zflag, depthflag)
short buffer[], count;
Boolean zflag, depthflag;

(not implemented in FORTRAN)

(not implemented in Pascal)
```

`setfbdebugging` turns on and off the debugging trace.

```
setfbdebugging(flag)
Boolean flag;

(not implemented in FORTRAN)

(not implemented in Pascal)
```

`bindfbfunc` associates an application-defined handling routine with a particular command.

```
bindfbfunc(command, handlingfunc)
short command;
int (*handlingfunc)();

(not implemented in FORTRAN)

(not implemented in Pascal)
```

getfbword is used by application-handling routines to get feedback words.

```
short getfbword()

(not implemented in FORTRAN)

(not implemented in Pascal)
```

The following program illustrates the use of the feedback parser. First, a feedback buffer is created and then the buffer is parsed.

```
#include "gl.h"

#define BUFFSIZE 400

main()
{
   char    zflag, depthflag;
   short   buffer[BUFFSIZE];
   short   count;

   zflag = getzbuffer();      /* set zflag to TRUE if z-buffering is on */
   depthflag = getdcm();      /* set depthflag to TRUE if depth-cueing is on */
   feedback(buffer, BUFFSIZE);/* enter feedback mode */

   color(BLACK);
   clear();

   color(RED);
   circi(200, 200, 200);

   color(GREEN);
   pnt2i(200, 200);
```

```
        color(BLUE);
        recti(0, 0, 400, 400);

        count = endfeedback(buffer); /* exit feedback mode */

        setfbdebugging(TRUE);  /* turn on debugging mode for parser */

        if (parsefb(buffer, count, zflag, depthflag)) /* parse the feedback buffer */
           printf("no errors in parse\n");
        else
           printf("error while parsing\n");

        gexit();
    }
```

This parsing utility can generate data for devices such as off-line plotters. A program can use `bindfbfunc` and `getfbword` to extract primitives such as line and point drawing commands and output them to a plotter. The functions passed in the `bindfbfunc` are of the form

```
    handlineroutine(count, command, string)
       int count;
       int command;
       char *string;
```

where `count` is the number of data words associated with the command, `command` is the command encountered, and `string` is a string corresponding to the command.

The following program produces a UNIX plot file from a feedback buffer:

```
    #include "gl.h"
    #include "gl2cmds.h"
    #include "stdio.h"

    #define BUFFSIZE 100

    int plotpoint();
    int plotmove();
    int plotdraw();

    main()
    {
       char     zflag, depthflag;
       short    buffer[BUFFSIZE];
       short    count;

       zflag = getzbuffer();
    depthflag = getdcm();
    feedback(buffer, BUFFSIZE);

    color(BLACK);
    clear();

    color(RED);
    circi(200, 200, 200);

    color(GREEN);
    pnt2i(200, 200);

    color(BLUE);
    recti(0, 0, 400, 400);

    count = endfeedback(buffer);

    bindfbfunc(FBCpoint, plotpoint);
    bindfbfunc(FBCmove, plotmove);
    bindfbfunc(FBCdraw, plotdraw);

    openpl();
    if (parsefb(buffer, count, zflag, depthflag))
        fprintf(stderr,"no errors in parse\n");
    else
        fprintf(stderr,"error while parsing\n");
    closepl();

    gexit();
}

static      int   lastx, lasty;

plotpoint(count, command, string)
    int     count;
    int     command;
    char    *string;
{
    int i, x, y;

    x = getfbword();
    y = getfbword();
    point(x, y);
    for (i = 2; i < count; i++)
        getfbword();
```

```
}

plotmove(count, command, string)
   int      count;
   int      command;
   char     *string;
{
   int i, x, y;

   lastx = getfbword();
   lasty = getfbword();
   for (i = 2; i < count; i++)
      getfbword();
}

plotdraw(count, command, string)
   int      count;
   int      command;
   char     *string;
{
   int i, x, y;

   x = getfbword();
   y = getfbword();
   line(x, y, lastx, lasty);
   lastx = x;
   lasty = y;
   for (i = 2; i < count; i++)
      getfbword();
}
```

Here is the code listing for the feedback parser:

```
/* "parse.c" */
#include "gl.h"
#include "uc4.h"

typedef struct {
   char     *fbcstring;
   int            two_d_count;
   int            three_d_count;
   int            (*handler)();
} Feedbacktable;
```

```
#include "parsetab.h"

static     short *buff_ptr;
static     short debugging;
static short    buff_count;
static short  word_no;
static char     parse_not_done;


parsefb(buffer, count, zbuff, depthcue)
  short         *buffer;
  short         count;
  short         zbuff, depthcue;
{

  int           (*handling_routine)();
  char     *FBCstring;
  short    in_3d;
  char     no_error = TRUE;
  short    opcode;
  short    highbyte;
  short    passthroughcount;
  int           paramcount;

  word_no = 0;
  parse_not_done = TRUE;
  buff_count = count;
  buff_ptr = buffer;
  in_3d = zbuff || (depthcue<<1);

  while (parse_not_done && no_error) {
     opcode = 0x3f & (highbyte = getfbword());
     highbyte = highbyte >> 8;
     if ((opcode < TABLE_END) && parse_not_done) {
        switch (opcode) {
           case FBCdrawmode :
              if (buff_ptr[1])
                 in_3d |= 1;
              else
                 in_3d &= (~1);
              break;
           case FBCconfig :
              if (*buff_ptr & UC_DEPTHCUE)
                 in_3d |= 2;
              else
```

```
                        in_3d &= (~2);
                    break;
                case FBCforcecompletion :
                    passthroughcount = highbyte;
                    break;
            }

            handling_routine = feedbacktable[opcode].handler;
            FBCstring = feedbacktable[opcode].fbcstring;
            if (in_3d)
                paramcount = feedbacktable[opcode].three_d_count;
            else
                paramcount = feedbacktable[opcode].two_d_count;
            if (paramcount == -1)
                paramcount = passthroughcount;
            (*handling_routine)(paramcount, opcode, FBCstring);
        } else
            no_error = FALSE;
    }
    if (parse_not_done)
        return FALSE;
    else
        return TRUE;
}

static char *UNDEFINED = {"ignored"};
static parsefdback(count, opcode, fbcstring)
    int             count;
    int             opcode;
    char        *fbcstring;
{
    int i;
    int inputword;

    if (debugging)
        printf("#%d: %s\n", word_no, (fbcstring?fbcstring:UNDEFINED));

    for (i = 0; i < count; i++) {
        inputword = getfbword();
        if (debugging)
            printf("\t\t#%d: %d:0x%x\n", word_no, inputword, inputword);
    }
}

getfbword()
```

```
{
   if (!(--buff_count))
      parse_not_done = FALSE;
   word_no++;
   return(*buff_ptr++);
}

setfbdebugging(flag)
{
   debugging = flag;
}

bindfbfunc(entryno, function)
   int entryno;
   int (*function)();
{
   if ((entryno >= 0) && (entryno < TABLE_END)) {
      feedbacktable[entryno].handler = function;
      return TRUE;
   } else
      return FALSE;
}




/*  "parsetab.h"  */
#include "gl2cmds.h"

static parsefdback();

/* fbcname 2d shorts, 3d shorts, function */
static Feedbacktable feedbacktable[] = {
/*0*/ {"FBCinitfbc",          0, 0,     parsefdback},
/*1*/ {0,                     0, 0,     parsefdback},
/*2*/ {"FBCmasklist",         -1,-1,    parsefdback},
/*3*/ {"GEstoremm",           32,32,    parsefdback},
/*4*/ {"FBCrgbcolor",         3, 3,     parsefdback},
/*5*/ {"FBCrgbwrten",         3, 3,     parsefdback},
/*6*/ {"FBCsethitmode",       0, 0,     parsefdback},
/*7*/ {"FBCclearhitmode",     0, 0,     parsefdback},
/*8*/ {"FBCforcecompletion",   0, 0,    parsefdback},
/*9*/ {"FBCbaseaddress",      1, 1,     parsefdback},
/*10*/{"FBCcdcolorwe",        2, 2,     parsefdback},
/*11*/{"GEstoreviewport",     12,12,    parsefdback},
/*12*/{"GEreconfigure",       0, 0,     parsefdback},
/*13*/{"FBCdrawpixels",        -1,-1,     parsefdback},
/*14*/{"FBCreadpixels",         1, 1,     parsefdback},
/*15*/{"GEnoop",                0, 0,     parsefdback},
/*16*/{"FBCmove",               2, 4,     parsefdback},
/*17*/{"FBCdraw",               2, 4,     parsefdback},
/*18*/{"FBCpoint",              2, 4,     parsefdback},
/*19*/{"GEcurve",               0, 0,     parsefdback},
/*20*/{"FBCcolor",              1, 1,     parsefdback},
/*21*/{"FBCwrten",              1, 1,     parsefdback},
/*22*/{"FBCconfig",             2, 2,     parsefdback},
/*23*/{"FBCloadmasks",         -1,-1,     parsefdback},
/*24*/{"FBCselectrgbcursor",    9, 9,     parsefdback},
/*25*/{"FBClinewidth",          1, 1,     parsefdback},
/*26*/{"FBCcharposnabs",        3, 5,     parsefdback},
/*27*/{"FBCcharposnrel",        3, 5,     parsefdback},
/*28*/{"FBCdrawchars",         -1,-1,     parsefdback},
/*29*/{"FBCselectcursor",       7, 7,     parsefdback},
/*30*/{"FBCdrawcursor",         2, 2,     parsefdback},
/*31*/{"FBCundrawcursor",       0, 0,     parsefdback},
/*32*/{"FBClinestipple",        2, 2,     parsefdback},
/*33*/{"FBCpolystipple",        1, 1,     parsefdback},
/*34*/{"FBCsaveregs",          -1,-1,     parsefdback},
/*35*/{"FBCunsaveregs",        -1,-1,     parsefdback},
/*36*/{"FBCdepthsetup",         6, 6,     parsefdback},
/*37*/{"FBCfeedback",           0, 0,     parsefdback},
/*38*/{"FBCeof",                1, 1,     parsefdback},
/*39*/{"FBCreadcharposn",       0, 0,     parsefdback},
/*40*/{"FBCcopyfont",           3, 3,     parsefdback},
/*41*/{"FBCpushname",           1, 1,     parsefdback},
/*42*/{"FBCloadname",           1, 1,     parsefdback},
/*43*/{"FBCpopname",            0, 0,     parsefdback},
/*44*/{"FBCfixharload",         3, 3,     parsefdback},
/*45*/{"FBCfixchardraw",        1, 1,     parsefdback},
/*46*/{"FBCinitnamestack",      0, 0,     parsefdback},
/*47*/{"FBCpixelsetup",         2, 2,     parsefdback},
/*48*/{"FBCmovepoly",           2, 4,     parsefdback},
/*49*/{"FBCdrawpoly",           2, 4,     parsefdback},
/*50*/{"FBCloadram",           -1,-1,     parsefdback},
/*51*/{"FBCclosepoly",          0, 0,     parsefdback},
/*52*/{"FBCdrawmode",           2, 2,     parsefdback},
/*53*/{"FBCsetintensity",       1, 1,     parsefdback},
/*54*/{"FBCsetbackfacing",      1, 1,     parsefdback},
/*55*/{"BPCreadbus",           -1,-1,     parsefdback},
/*56*/{"FBCxformpt",            8, 8,     parsefdback},
/*57*/{"FBCblockfill",          4, 4,     parsefdback},
/*58*/{"FBCdumpram",         -1,-1,      parsefdback},
/*59*/{"FBCzshadescanline",   10,10,      parsefdback},
/*60*/{"BPCcommand",         -1,-1,      parsefdback},
/*61*/{"FBCcopyscreen",       5, 5,      parsefdback},
/*62*/{"FBCinitscanline",     1, 1,      parsefdback}
};
#define TABLE_END 63
```

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Multiple Exposure: The IRIS Window Manager

1. Introduction

Multiple Exposure is the window manager for the IRIS workstation. It provides the user with multiple concurrent windows, or ports, for text and graphics output. These windows can be of various sizes and locations, and can overlap each other. The availability of multiple windows, in effect, creates multiple graphics systems on a single IRIS workstation.

Normally, an IRIS workstation provides a single rectangular area of the screen, called the *textport,* for interacting with system utilities and creating graphics programs. With the IRIS window manager, however, you can create multiple textports, each running its own UNIX shell. You use the mouse to specify the size and location of each new textport and to attach input from the keyboard to a textport. Whenever a graphics program is called from a textport, it draws to an area of the screen called a *graphics port.* The size and location of a graphics port either is specified in the program or is specified by the user with the mouse when the program is executed. Graphics programs in several textports can be run simultaneously, each drawing to a separate graphics port. Textports and graphics ports may be moved and reshaped after they have been created, and they may overlap each other.

2. The Default User Interface to the Window Manager

This section describes the default user interface to the window manager: how to start and stop the window manager, and how to communicate with the window manager to move, reshape, create, and delete windows. Section 6 (Customizing the User Interface) describes how to configure more complex interfaces.

Starting the window manager

When an IRIS is booted, a single textport appears on the screen. The size and location of this textport can be changed by a graphics program, using the textport commands discussed in Chapter 14 of the IRIS Programming Guide. The window manager program is called *mex* (for Multiple EXposure) and is located in **/usr/bin.** You start the window manager by typing "mex<return>". The existing textport is put into a window called the *console,* which is the same size and shape as the original textport. The console can be used to create, compile, and execute graphics programs, and to interact with any other system utilities. You can change the size and location of the console, but you cannot delete it. After mex has been called, you can create additional textports and run graphics programs which create graphics ports.

Communicating with the window manager

The right mouse button is the primary means of communication between the user and the window manager. The other buttons are ignored by the window manager in the default state. Pushing down on the right mouse button suggests an action. The window manager presents a menu or uses the shape of the cursor glyph to indicate the action. Letting up on the mouse button confirms the action.

When the right button initially is pressed, one of two menus will appear. If the cursor is within a window, this menu appears:

kill
push
pop
reshape
move
attach

If the cursor is located outside all windows (that is, in the background), this menu appears:

exit
new shell
attach

A third menu appears to confirm the selection of "kill" or "exit":

Nah...forget it
Do it. I'm sure

Creating new textports and selecting textports for input

You can create additional textports by pressing the right mouse button while the cursor is over the screen background (not in a window). The background menu described above will then appear on the screen. If "new shell" is selected, a red bracket will appear and will follow the movement of the cursor. Pressing the right button again sets the location of one corner of the new window. Releasing the button sets the opposite corner of the window. The new textport will run the UNIX shell located in **/bin/csh.** In the standard configuration, up to ten textports can be created.

Since the keyboard and other input devices are shared among all the windows on the screen, it is necessary to specify the window for which input is intended. To do this, move the cursor into the chosen window and press the right mouse button. When the window menu appears, select "attach". The chosen window is then activated for interaction with the user. Characters typed on the keyboard will be echoed in that textport and interpreted by that textport's shell.

You can also send input to the window manager by positioning the cursor over the background and selecting "attach". In this state, all the mouse button events (not just the right button) and any other non-textual input are put in the window manager's event queue. Input from the keyboard will be sent to the most recently selected textport.

Moving and resizing windows

To move windows, position the cursor in the window and press the right button. When the window menu appears, select "move" and release the button. The cursor will appear as four small red arrows. A copy of the window boundary will appear in red. The red outline will move along with the movement of the cursor. However, note that the outline always remains entirely within the boundaries of the screen. When the right mouse button is pressed and released again, the window is redrawn in the location identified by the red outline.

To change the shape of a textport, select "reshape". A second press of the right button indicates the location of one corner of the window, and a release indicates the location of the opposite corner.

Popping and pushing textports

The windows on the IRIS screen may overlap each other (like papers on a desktop). Two of the window menu items, "push" and "pop", allow you to arrange the order in which the windows are plastered on the screen. If you select "pop" while the cursor is located inside a particular window, that window is drawn on top of all the windows it may overlap. If you select "push", the window is placed beneath all of the windows it overlaps (i.e., the other windows are redrawn on top of the selected window).

Running graphics programs

You can run graphics programs by attaching input to a textport (as described above) and typing the name of the program into the textport. The output of a graphics program will appear on the screen in a graphics port. The size and location of the graphics port is determined by routines (described in Section 3) contained at the beginning of the program. However, not all of that information needs to be specified in the program. The window manager will prompt the user for whatever is missing. For example, if an application needs a square graphics port but the size and location does not matter, only the shape of the graphics port is specified in the program. When the program is called, the cursor prompts the user for the size and location of the graphics port. The square shape is maintained.

Graphics ports can be moved, reshaped, pushed, and popped (just like textports) using the right mouse button and the window menu. If a graphics program requires interaction with the user, you can attach input to the program's graphics port by selecting the "attach" menu item. All input from available devices (e.g., keyboard and mouse) will then be interpreted by the graphics program. In the standard configuration, the right mouse button is reserved for interaction with the window manager and is not available to graphics programs.

Removing textports and graphics ports from the screen

To remove a window from the screen, move the cursor into the chosen window and press the right mouse button. Then select "kill" and release the button. A confirmation menu will appear. If you are sure you want to remove the window, select "Do it. I'm sure". When a window is removed, any active processes associated with the window will be killed. Also, if you exit from a shell its textport will be removed and if you exit from a graphics program its graphics port will be removed. Note that the console textport cannot be removed.

Leaving the window manager

To leave the window manager, position the cursor over the screen background and press the right mouse button. When the background menu appears, select "exit". When the confirmation menu appears, select "Do it. I'm sure".

3. Programming the Window Manager

Since the contents of a graphics port can only be created by a graphics program, the graphics port itself is created at the beginning of a program. Graphics programs have varying screen requirements. Some may need space with a specific aspect ratio (shape); some may have a minimum or maximum size; some may have their size or location fixed; and some don't need any screen space at all (for example, if the program only sets the color map).

The following commands are contained in the Graphics Library. They are divided into three categories: 1) commands for specifying graphics port characteristics; 2) commands for creating graphics ports; and 3) various graphics port utility commands.

Specifying graphics port characteristics

These commands are given before the graphics port is created. None of them are required; any or all of them can be given, in any order. If a characteristic is not specified, the window manager will interact with the user for the necessary information when the graphics port is created. This interaction follows the same conventions as the user interface described in the previous section. For example, if no characteristics are specified, the cursor appears as a red bracket when the graphics port is created and the user presses the right mouse button to locate one corner of the graphics port and releases the button to locate the opposite corner.

```
minsize(x, y)
long x, y;

subroutine minsiz(x, y)
integer*4 x, y

procedure minsize(x, y: long);
```

`minsize` specifies a minimum size for the graphics port. The graphics port cannot be reshaped to be smaller than this minimum size. The default minimum size is 40 pixels wide and 30 pixels high.

```
maxsize(x, y)
long x, y;

subroutine maxsiz(x, y)
integer*4 x, y

procedure maxsize(x, y: long);
```

`maxsize` specifies a maximum size for the graphics port. The default maximum size is 1024 pixels wide and 768 pixels high.

```
keepaspect(x, y)
long x, y;

subroutine keepas(x, y)
integer*4 x, y

procedure keepaspect(x, y: long);
```

`keepaspect` specifies the aspect ratio (height-to-width ratio) of the graphics port. If the graphics port is resized, its size will change but its shape will remain the same. `keepaspect(1,1)` will ensure that the graphics port is always square.

```
prefsize(x, y)
long x, y;

subroutine prefsi(x, y)
integer*4 x, y

procedure prefsize(x, y: long);
```

`prefsize` specifies that the size of the graphics port should be `x` pixels by `y` pixels. The window manager will not allow the graphics port to be resized.

```
prefposition(x1, x2, y1, y2)
long x1, x2, y1, y2;

subroutine prefpo(x1, x2, y1, y2)
integer*4 x1, x2, y1, y2

procedure prefposition(x1, x2, y1, y2: long);
```

`prefposition` specifies the preferred location and size of the graphics port. The window manager will not allow the graphics port to be relocated.

```
stepunit(xunit, yunit)
long xunit, yunit;

subroutine stepun(xunit, yunit)
integer*4 xunit, yunit

procedure stepunit(xunit, yunit: long);
```

`stepunit` makes the graphics port change size in steps of `xunit` and `yunit`. For example, an `xunit` of five would make it convenient to draw five equally sized columns in the graphics port, since the width of the graphics port would always be a multiple of five.

```
fudge(xfudge, yfudge)
long xfudge, yfudge;

subroutine fudge(xfudge, yfudge)
integer*4 xfudge, yfudge

procedure fudge(xfudge, yfudge: long);
```

fudge specifies that these fudge values should be added to the port dimensions as it is resized. This is useful for adjusting the size of a graphics port so that it is convenient for the program to draw a border or add a heading. **fudge** is often used in conjunction with **stepunit**. For example, specifying an **xunit** of five and an **xfudge** of two would make it convenient to create five equal columns with a small border around them.

```
noport()

subroutine noport

procedure noport;
```

noport specifies that the application does not need any screen space at all. This is useful for programs which only read or write the color map. A call to **getport** is still needed to do a graphics initialization (see the following section).

```
foreground()

subroutine foregr

procedure foreground;
```

foreground specifies that the graphics program will not be run in background when **getport** is called.

Creating a graphics port

```
getport(name)
char name[];

subroutine getpor(name)
character*(*) name

procedure getport(name: pstring);
```

`getport` is called after all the graphics port characteristics have been specified. `getport` does a graphics initialization and then has the window manager select a region on the screen. It also puts the program in background, unless the `foreground` command (see previous section) has been called. The default viewport is set to the size of the graphics port.

```
imakebackground()

subroutine imakeb

procedure imakebackground;
```

`imakebackground` is called instead of the characteristics given above and `getport` to set up a process which draws the background of the window manager's screen. The process should draw the background and then read the input queue. Every time there is a `REDRAW` event in the input queue, the process redraws the background.

Graphics port utilities

```
getsize(x, y)
long *x, *y;

subroutine getsiz(x, y)
integer*4 x, y

procedure getsize(x, y: long);
```

`getsize` returns the size of the graphics port. It should only be called after `getport`.

```
getorigin(x, y)
long *x, *y;

subroutine getori(x, y)
integer*4 x, y

procedure getorigin(x, y: long);
```

`getorigin` returns the position of the lower left corner of the graphics port. It should only be called after `getport`.

```
screenspace()

subroutine screen

procedure screenspace;
```

`screenspace` puts the program in screen space: graphics positions are expressed in absolute screen coordinates. (0, 0) is the lower left corner of the screen while (1023, 767) is the upper right corner of the screen. This allows you to read pixels and locations outside of the graphics port.

```
reshapeviewport()

subroutine reshap

procedure reshapeviewport;
```

`reshapeviewport` sets the viewport to current dimensions of the graphics port.

4. Programming Examples

The first example uses single buffer display mode and the second example uses double buffer display mode.

```
/*
 *    zoing - make a spiral out of circles
 */
#include "device.h"
#include "gl.h"

main()
{
   short val;

   keepaspect(1,1); /* the graphics port can be any location and
                            size, as long as it's square */
   getport("zoing");
   drawit();          /* image drawn the first time */
         /* the image is redrawn whenever a REDRAW
               appears in the event queue */
   while(1) {
      if(qread(&val) == REDRAW)
         drawit();
   }
}

drawit()
{
   register int i;

   reshapeviewport();
   color(7);
   clear();
   ortho2(-1.0,1.0,-1.0,1.0);
   color(0);
   translate(-0.1,0.0,0.0);
   pushmatrix();
      for(i=0; i<200; i++) {
         rotate(170,'z');
         scale(0.96,0.96,0.0);
         pushmatrix();
            translate(0.10,0.0,0.0);
            circ(0.0,0.0,1.0);
         popmatrix();
```

```
            }
        popmatrix();
    }


    /*
     *    A double buffered window manager program
     *    Draws a cube which is rotated by movements of the mouse.
     *
     */
    #include "gl.h"
    #include "device.h"

    main()
    {
        int x, y;       /* current rotation of object*/
        int active;          /* TRUE if window is attached*/
        short dev, val;

        keepaspect(3,2);
        getport("cube");
        doublebuffer();
        gconfig();
        qdevice(INPUTCHANGE);
        qdevice(REDRAW);
        qdevice(ESCKEY);
        qdevice(MOUSEX);
        qdevice(MOUSEY);
        perspective(400, 3.0/2.0, 0.001, 100000.0);
        translate(0.0, 0.0, -3.0);

        x = 0;  y = 0;
        active = 0;
        while(TRUE) {
            if(active) {
                frontbuffer(FALSE); /* draw scene in back buffer */
                drawcube(x, y);
                swapbuffers();
            } else {
                frontbuffer(TRUE); /* draw scene in both buffers */
                drawcube(x, y);
                while (!qtest())
                    swapbuffers(); /* swap buffers if not active */
            }
            while (qtest()) {      /* process queued tokens */
            dev = qread(&val);
            switch(dev) {
               case ESCKEY:      /* exit program with ESC */
                  exit(0);
                  break;
               case INPUTCHANGE:
                  active = val;
                  break;
               case REDRAW:
                  reshapeviewport();
                  break;
               case MOUSEX:
                  x = val;
                  break;
               case MOUSEY:
                  y = val;
                  break;
               default:
                  break;
            }
         }
      }
   }

   drawcube(rotx,roty)
   int rotx, roty;
   {
      color(0);
      clear();
      color(7);
      pushmatrix();
      rotate(rotx,'x');
      rotate(roty,'y');
      cube();
      scale(0.3,0.3,0.3);
      cube();
      popmatrix();
   }

   cube() /* make a cube out of 4 squares */
   {
         pushmatrix();
               side();
               rotate(900,'x');
               side();
```

```
                rotate(900,'x');
                side();
                rotate(900,'x');
                side();
            popmatrix();
        }

        side() /* make a square translated 0.5 in the z direction */
        {
            pushmatrix();
                translate(0.0,0.0,0.5);
                rect(-0.5,-0.5,0.5,0.5);
            popmatrix();
        }
```

5. Programming Considerations

1) All the windows on the screen share the same color map, texture patterns, raster fonts, and cursor glyphs. Groups of graphics programs that will be run at the same time should be designed to cooperate in their use the facilities.

2) Raster fonts are not scaled. Even though the size of a graphics port (and most of the graphics drawn inside of it) can vary, the raster font text will remain the same size.

3) Each graphics program has an event queue. A REDRAW token will appear in the owner's queue when a window is moved or reshaped, when part of a window that was obscured is revealed, or when the display mode is changed. Programs can also queue the pseudo device INPUTCHANGE. When an INPUTCHANGE event is read from the queue, a value of 1 means that the input focus has been moved to the window. A value of 0 means that input has been removed from the window. Another pseudo device, MODECHANGE, indicates that the display mode has changed from single buffer mode to double buffer mode or vice versa. When this happens, programs should do a **getplanes** to see how many bitplanes are available in the new display mode and perhaps change the color map to a different set of colors.

4) The window manager works only in single or double buffer mode (not in RGB mode). The window manager uses two bitplanes in single buffer mode and four bitplanes in double buffer mode. Each double buffered program is blocked until all other double buffered programs are ready to swap. Then all programs running in double buffer mode swap at the same time.

5) The **getport** command can replace **ginit**. **ginit** or **gbegin** request graphics ports with the default parameters.

6) The textport commands (**tpon**, **tpoff**, **textport**, **gettp**, **textcolor**, **textwritemask**, **pagecolor**, **pagewritemask**, **textinit**) do not work with the window manager.

6. Customizing the User Interface

The default window manager user interface reserves the right mouse button for its own use. Thus user applications can use only two of the mouse buttons. The default user interface was chosen primarily because of its simplicity – all window manager commands are accessed via one button, and that button always invokes a window manager command.

Many users prefer a more versatile interface. The window manager can be customized in many ways. This section describes the customization mechanism.

The .mexrc configuration file

When the window manager starts up, it looks for a file named .mexrc in your home directory. If none is found, you get the default user interface. The default user interface is defined by the default configuration file at the end of this section. There are five types of entries in a configuration file: `reservebut`, `bindfunc`, `bindindex`, `bindcolor`, and `mapcolor`.

Reserving buttons

`reservebut` reserves a button for the use of the window manager. The default user interface file contains the command:

```
        reservebut 101;
```

to reserve the right mouse button for the window manager. When a button is reserved for the window manager, input events from that button are sent to the window manager process. If a textport is the active window, all non-keyboard events go to the window manager. If a graphics port is active, only the reserved buttons go to the window manager. If the window manager is active, all button events go to it.

Binding functions to buttons

`bindfunc` binds a window manager function to a button. Available functions include: `menu`, `hogmode`, `hogwhiledown`, `kill`, `move`, `push`, `pop`, `attach`, `popattach`, and `movegrow`. Their actions are described below:

`menu`: The window manager popup menu is displayed when its button is pressed. If the cursor is over a window, the large menu with `kill`, `push`, `pop`, `reshape`, `move`, `attach` is displayed; otherwise, the small menu with `exit`, `new shell`, and `attach` is shown.

`hogmode`: When the bound button is pressed (assuming it is reserved by `reservebut`) the window manager becomes the active process. All button clicks go to it, and continue to do so until another window is attached.

`hogwhiledown`: While the button bound to this command is down, all button events go to the window manager. When it is released, the window that was previously attached again gets all the keystrokes unless an attach command occurred while the button was down.

`kill, move, push, pop, attach`: The window under the cursor is killed, moved, pushed, popped, or attached as if the corresponding commands in the main menu were used.

`popattach`: This does the equivalent of a pop and an attach to the window under the cursor.

`movegrow`: The window under the cursor is moved or resized, depending on whether the cursor is near the center or a corner of the window. If it is near the center, the window outline is moved rigidly, tracking the cursor, as long as the button is down. When the button is released, the window is moved to the new position. When the button is pressed near a corner, only that corner is moved. All movement and reshaping are constrained by the size and aspect ratio specifications for the window.

Binding color indices to window features

`bindindex` assigns color indices to various parts of the window. The border is two pixels wide: the inner pixels form an inner border, and the outer pixels an outer border. The border can be highlighted or not. In addition, some windows have a title, drawn in the inner border color. The text in the title has an interior and exterior as well, which can be highlighted or not. All these regions of a window can be assigned color indices. The names of the regions are: inborder, outborder, hiinborder, hioutborder, titletextin, titletextout, hititletextin, and hititletextout. The command

```
bindindex hititletextin 7
```

in the configuration file binds the colorindex 7 to the highlighted interior of the title text.

Binding colors to window manager features

`bindcolor` binds RGB colors to the reserved bitplanes of the window manager – the popup menu text, popup menu background, and cursor. The commands

```
bindcolor menu 255 0 0
bindcolor menuback 0 255 0
bindcolor cursor 0 0 255
```

will cause the menu text, menu background, and cursor to be pure red, green, and blue, respectively.

Setting color map entries

`mapcolor` changes a color map entry to a specified RGB value. The commands

```
mapcolor 1 255 0 0
mapcolor 2 0 255 0
mapcolor 3 0 0 255
```

set the color map indices 1, 2, and 3 to be pure red, green, and blue, respectively.

An example of a different interface

The following configuration file:

```
reservebut 78
bindfunc hogmode 78
reservebut 13
bindfunc hogwhiledown 13
bindfunc popattach 103
bindfunc movegrow 102
bindfunc menu 101
```

has a more interesting user interface than the default. Two buttons are reserved to it – the no-scroll key (button 13) at the lower left corner of the keyboard, and the PF4 key (button 78) at the upper right. When the PF4 key is pressed, all button events go to the window manager, including all the mouse buttons. The right mouse button brings up the menu, the center button invokes the **movegrow** command, and the left button the **popattach** command. All keystrokes go to the window manager until an **attach** command is issued (via the main popup menu).

While the no-scroll key is held down, the mouse events go to the window manager. When it is released, keystrokes revert to the window to which they were previously directed. Thus, to issue a single window manager command, the no-scroll button is easiest to use, and to issue a sequence of commands, the PF4 key is used.

All the default colors and color indices are used with this configuration file.

The default configuration file

```
reservebut 101
bindfunc menu 101
bindindex inborder 0
bindindex outborder 7
bindindex hiinborder 7
bindindex hioutborder 1
bindindex titletextin 4
bindindex titletextout 3
bindindex hititletextin 3
bindindex hititletextout 4
bindcolor menu 255 255 0
bindcolor menuback 0 0 255
bindcolor cursor 255 0 0
```

PROGRAMMING EXAMPLES

Example 1: Getting Started

Getting your first graphics program to run on an IRIS is much like getting your first program to run on any other computer — the problems will be more involved with learning to edit a file, to compile and load a program with the proper libraries, and finally, to get it to run. Thus, the first program in this tutorial is not interesting at all from a graphics point of view, but it will probably be harder to get running than any of the other programs in the tutorial.

The first example draws a small red box in the lower left corner of the screen:

```
/* "first.c" */
#include "gl.h"

main()
{
   ginit();
   cursoff();
   color(BLACK);
   clear();
   color(RED);
   move2i(20, 20);
   draw2i(50, 20);
   draw2i(50, 50);
   draw2i(20, 50);
   draw2i(20, 20);
   gexit();
}
```

The very first line:

```
#include "gl.h"
```

should be included in all graphics programs, as it defines type definitions, useful constants, and external definitions for all commands.

The graphical part of every program should begin with a call to `ginit()` (or `gbegin()`) and should end with `gexit()`. If you were to write a program to drive the raw hardware on the IRIS, you would find that there are literally hundreds of things you would have to initialize before you could draw the simplest thing on the screen. `ginit()` initializes the hardware and the software to a reasonable state so that a program as simple as the one above can run. (Note that `gbegin()` does everything `ginit()` does except it does not initialize the color map.)

This "reasonable" state includes definitions of the eight colors BLACK, WHITE, RED, GREEN, BLUE, YELLOW, CYAN, and MAGENTA. `ginit()` also sets up the screen as a 2-dimensional space with coordinates running from 0 to 1023 in the x-direction and 0 to 767 in the y-direction. Every pixel has size 1 in both the x- and y- directions. The origin is at the lower left corner of the screen.

The `cursoff()` command turns the cursor off (the default state has the cursor on). If you omit this command and try to draw across the cursor, you may get cursor glitches. After you get the program running, try deleting this command, and modifying the program so it draws a single line from (0, 0) to (1023, 767). The default cursor is in the center of the screen, so this line will draw across it.

All drawing is done in the current color, which is set by the `color()` command. "Drawing" means any command that draws something on the screen, including polygons, lines, text, points, pixels, and even the `clear` command. Thus the pair

```
color(BLACK);
clear();
```

clears the entire screen to black. `color(RED)` changes the current color to red. If this command were not in "first.c", the small box would be drawn in black and would not be visible.

The main part of "first.c" is made up of `move2i()` and `draw2i()` commands. The "2" stands for 2-dimensional, and the "i" means that the data are 32-bit integers (not floating-point numbers or 16-bit short integers). `move2i(x,y)` changes the current graphics position to the point (x, y); `draw2i(x,y)` draws a line from the current graphics position to the point (x, y), and changes the current graphics position to the new point. If you think of an imaginary pen doing the drawing, both `move2i(x,y)` and `draw2i(x,y)` put the pen at (x, y), but the `move` command causes it to be lifted before it is moved.

Note that many commands cause the current graphics position to become undefined. `clear()`, for example, does so. The sequence:

```
move2i(0, 500);
color(BLACK);
clear();
color(RED);
draw2i(500, 500);
```

will probably not draw a horizontal line — the `clear()` changes the current graphics position.

Example 2: Common Drawing Commands

The program "drawing.c" uses many of the more common drawing commands, including those to draw filled and unfilled polygons, circles, arcs, points, rectangles, and text. Note that after `ginit` is called, the textport is set to a small area in the lower left corner of the screen. This prevents the textport from covering up most of the screen when the program exits. To return the textport to its original size and location, the following program can be executed:

```
/* "tpbig.c" */
#include "gl.h"

main()
/* initialize the textport to be 40 lines and 80 columns */
{
  ginit();
  textinit();
  gexit();
}
```

This is the FORTRAN version of "tpbig":

```
C
C   initialize the textport to be 40 lines and 80 columns
C
C
     CALL GINIT()
     CALL TEXTIN()
     CALL GEXIT()
C
     STOP
     END
```

This is the code for "drawing.c":

```
/* "drawing.c" */
#include "gl.h"

long cone[] [2] = {100, 300,
                 150, 100,
                 200, 300};

char *singlechar = "X";

main()
```

```
{
  register long i, j;

  ginit();
  textport(50,300,50,200);
     /* the textport is set to a small area in the lower
     * left corner of the screen so that when the program is
     * finished, the textport will not cover up the image */
  cursoff();

  /* draw an ice-cream cone */

  color(WHITE);
  clear();
  color(YELLOW);
  polf2i(3, cone);     /* draw the ice-cream cone */
  color(GREEN);              /* first scoop is mint */
  arcfi(150, 300, 50, 0, 1800);/* only half of it shows */
  color(RED);                /* second scoop is cherry */
  circf(150.0, 400.0, 50.0);
  color(BLACK);
  poly2i(3, cone);     /* outline the cone in black */

  /* Next, draw a few filled and unfilled arcs in the upper
   * left corner of the screen.
   */

  arcf(100.0, 650.0, 40.0, 450, 2700);
  arci(100, 500, 40, 450, 2700);

  arcfi(250, 650, 80, 2700, 450);
  arc(250.0, 500.0, 80.0, 2700, 450);

  /* Now, put up a series of filled and unfilled rectangles with
   * the names of their colors printed inside of them across the
   * rest of the top of the screen.
   */

  color(GREEN);
  recti(400, 600, 550, 700);
  cmov2i(420, 640);
  charstr("Green");

  color(RED);
  rectfi(600, 600, 800, 650);
```

```
color(BLACK);
cmov2(690.0, 620.0);
charstr("Red");

color(BLUE);
rect(810.0, 700.0, 1000.0, 20.0);
cmov2i(900, 300);
charstr("Blue");

/* Now draw some text with a ruler on top to measure it by. */

/* First the ruler: */

color(BLACK);

move2i(300, 400);
draw2i(650, 400);
for (i = 300; i <= 650; i += 10) {
   move2i(i, 400);
   draw2i(i, 410);
}

/* Then some text: */

cmov2i(300, 380);
charstr("The first line is drawn ");
charstr("in two parts.");

cmov2i(300, 368);
charstr("This line is only 12 pixels lower.");

cmov2i(300, 354);
charstr("Now move down 14 pixels ...");

cmov2i(300, 338);
charstr("And now down 16 ...");

cmov2i(300, 320);
charstr("Now 18 ...");

cmov2i(300, 300);
charstr("And finally, 20 pixels.");

/* Finally, show off the entire font.  The cmov2i() before each
 * character is necessary in case that character is not defined.
```

```
     */

    for (i = 0; i < 4; i++)
       for (j = 0; j < 32; j++) {
          cmov2i(300 + 9*j, 200 - 18*i);
          *singlechar = (char)(32*i + j);
          charstr(singlechar);
       }

    for (i = 0; i < 4; i++) {
       cmov2i(300, 100 - 18*i);
       for (j = 0; j < 32; j++) {
          *singlechar = (char)(32*i + j);
          charstr(singlechar);
       }
    }

    gexit();
}
```

This is the FORTRAN version of "drawing":

```
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C     Installation note:
C    Various Fortran compilers may require different styles of INCLUDEs.
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      INCLUDE 'fgl.h'
C
      INTEGER CONE(2,3), I, J, STRLEN
      CHARACTER*1 ONECH, STRING*50
      DATA CONE /100,300,  150,100,  200,300/
C
      CALL GINIT()
C       set the textport to a small area in the lower right corner of
C       the screen so that when the program is finished, the textport
C       will not cover up the image
      CALL TEXTPO(650,900,50,200)
      CALL CURSOF()
C
C       draw an ice cream cone
      CALL COLOR(WHITE)
      CALL CLEAR()
C       draw the cone
      CALL COLOR(YELLOW)
      CALL POLF2I(3,CONE)
C       the first scoop is mint
      CALL COLOR(GREEN)
```

```
C     only half of it shows
      CALL ARCFI(150,300,50,0,1800)
C     the second scoop is cherry
      CALL COLOR(RED)
      CALL CIRCF(150.0,400.0,50.0)
      CALL COLOR(BLACK)
C     outline the cone in black
      CALL POLY2I(3,CONE)
C
C     next draw a few filled and unfilled arcs in the upper
C     left corner of the screen
      CALL ARCF(100.0,650.0,40.0,450,2700)
      CALL ARCI(100,500,40,450,2700)
      CALL ARCFI(250,650,80,2700,450)
      CALL ARC(250.0,500.0,80.0,2700,450)
C
C     Now, put up a series of filled and unfilled rectangles with
C     the names of their colors printed inside of them across the
C     rest of the top of the screen.
      CALL COLOR(GREEN)
      CALL RECTI(400,600,550,700)
      CALL CMOV2I(420,640)
      CALL CHARST('Green',5)
C
      CALL COLOR(RED)
      CALL RECTFI(600,600,800,650)
      CALL COLOR(BLACK)
      CALL CMOV2(690.0,620.0)
      CALL CHARST('Red',3)
C
      CALL COLOR(BLUE)
      CALL RECT(810.0,700.0,1000.0,20.0)
      CALL CMOV2I(900,300)
      CALL CHARST('Blue',4)
C
C     Now draw some text with a ruler on top to measure it by.
C
C     First the ruler:
      CALL COLOR(BLACK)
      CALL MOVE2I(300,400)
      CALL DRAW2I(650,400)
      DO 100 I=300,650,10
        CALL MOVE2I(I,400)
        CALL DRAW2I(I,410)
100   CONTINUE
```

```
C
C      Then some text:
       CALL CMOV2I(300,380)
       STRING = 'The first line is drawn incorrectly '
       CALL CHARST(STRING,LEN(STRING))
       CALL CHARST('in two parts.',13)
C      NOTE: Fortran pads STRING with spaces to its defined length,
C      and LEN(STRING) returns the defined length (50) instead of the
C      length of the character substring inserted into it.
C
       CALL CMOV2I(300,364)
       STRING = 'This line is drawn correctly '
       STRLEN = LEN('This line is drawn correctly ')
       CALL CHARST(STRING,STRLEN)
C      This is the only way (other than counting by hand, as was
C      done for the second part of this line, below) of getting
C      the length of the actual set of characters to be printed.
       CALL CHARST('in two parts.',13)
C
       CALL CMOV2I(300,352)
       STRLEN = LEN('This line is only 12 pixels lower.')
       CALL CHARST('This line is only 12 pixels lower.',STRLEN)
C
       CALL CMOV2I(300,338)
       STRLEN = LEN('Now move down 14 pixels ...')
       CALL CHARST('Now move down 14 pixels ...',STRLEN)
C
       CALL CMOV2I(300,322)
       STRLEN = LEN('And now down 16 ...')
       CALL CHARST('And now down 16 ...',STRLEN)
C
       CALL CMOV2I(300,304)
       STRLEN = LEN('Now 18 ...')
       CALL CHARST('Now 18 ...',STRLEN)
C
       CALL CMOV2I(300,284)
       STRLEN = LEN('And finally, 20 pixels.')
       CALL CHARST('And finally, 20 pixels.',STRLEN)
C
C      Finally, show off the entire font. The cmov2i() before each
C      character is necessary in case that character is not defined.
       DO 300 I=0,3
        DO 200 J=0,31
         CALL CMOV2I(300 + 9*J, 200 - 18*I)
         ONECH(1:1) = CHAR(32*I + J)
```

```
          CALL CHARST(ONECH,1)
200       CONTINUE
300     CONTINUE
C
        DO 500 I=0,3
          CALL CMOV2I(300, 100 - 18*I)
          DO 400 J=0,31
            ONECH(1:1) = CHAR(32*I + J)
            CALL CHARST(ONECH,1)
400       CONTINUE
500     CONTINUE
C
        CALL GEXIT()
        STOP
        END
```

The first thing the program draws is an ice-cream cone in the left part of the screen. The cone is drawn with the polygon command `polf2i()`. All of the polygon commands begin with the prefix "pol". In this case, we want the polygon to be filled in with the current color, and the "f" stands for filled. The characters "2i" mean the same thing that they do for the move and draw commands: "2" means 2-dimensional, and "i" means 32-bit integer. An unfilled (wire-frame) polygon has a "y" instead of an "f".

The first argument to all the polygon commands is the number of vertices, and the second is an array of points. A polygon can have many vertices (the exact number varies, but if you use fewer than 500 you will be safe). Filled polygons must be convex, or you will get unpredictable results.

The first scoop on the ice cream cone is a half-circle. A half circle is a special case of an arc so we use the `arcfi()` command. As was the case with polygons, the "f" stands for filled and the "i" for 32-bit integer. The first two arguments to the arc commands are the x and y coordinates of the center of the arc; the third is the radius. The last two arguments are the starting and ending angles. In the IRIS graphics library, all angles are integers measured in *tenths* of degrees, so an angle of 1800 is 180 degrees. Angles in the arc commands are measured counter-clockwise from the positive x-axis. More examples of arcs appear later in this sample program.

Circles come in the same variations as arcs — filled or unfilled, and floating-point, 32-bit integer, or 16-bit short integer. The three arguments to the circle commands are the same as the first three for the arc commands — x-center, y-center, and radius. In the sample program, we have used the floating-point version of the filled circle command for the sake of variety only — the integer versions would work fine.

Although it makes no difference yet, note that circles and arcs are 2-dimensional. They lie in the x-y plane with a z coordinate of zero. When we get to 3-

dimensional examples, we will see that circles rotated out of the x-y plane appear to be ellipses.

The second part of the program draws two filled arcs and two unfilled arcs. Notice that filled arcs are filled from the center — like pieces of pie — and that unfilled arcs are simply a portion of a circle. The order in which the angles are specified is important; the arc is filled in counterclockwise from the starting angle to the ending angle.

Like circles and arcs, rectangles are 2-dimensional, with their z-coordinates equal to zero. The edges are parallel to the edges of the screen, so you need specify only the two opposite corners. Any pair of opposite corners will do, as the example illustrates. Rectangles come filled or unfilled, and in floating-point, integer, or short versions.

Character strings are drawn beginning at the current character position (which is different from the current graphics position). The commands `cmov()`, `cmovi()`, `cmovs()`, `cmov2()`, `cmov2i()`, and `cmov2s()` set the current character position. In the example program, we only use the 2-dimensional versions of these commands. Notice that the second rectangle is filled with red. We have to change the color to something other than red so that the character string will show up on the red background.

The final examples in this program show how the current character position changes as characters are drawn. After each character string is printed, the current character position is automatically moved to follow the last character printed. The default font is 9 pixels wide and 16 high. The ruler above the text has a short cross mark every 10 pixels.

The next four lines of text show the default font. Note that the input to `charstr()` is a string, which in C is a null-terminated array of characters. The example uses a string with a single character in it, and replaces that character by the next character in the font. There is an explicit `cmov2i()` before each character is drawn because if the character is not defined in the font, nothing is drawn, and the current character position is not changed.

The whole font is drawn again below the first copy without the `cmov2i()`. Only characters 1 and 7 in the range 0-31 of the ASCII character set are defined in the default font. ASCII 1 (control-A) prints a solid rectangle, and ASCII 7 (control-G, or BELL) prints a little picture of a bell.

Example 3: Object Coordinate Systems

For many applications (in fact, probably most), screen coordinates are not the most convenient to use. It is usually more convenient to describe graphical objects in terms of their own coordinate systems, and then map those coordinate systems to the screen. The example program "doily.c" illustrates how the `ortho2()` command is used to perform such a mapping. In addition, it shows how the `viewport` command specifies the area of the screen where drawing takes place. Note that the textport is set to a small area in the lower left corner of the screen as it was in the previous example. It can be reset to its original size and location by calling the "tpbig.c" program.

```
/* "doily.c" */
#include "gl.h"
#include <math.h>

#define PI 3.1415926535

main(argc, argv)
int argc;
char *argv[];
{
   long numpts, i, j;
   float points[100][2];

   /* First figure out how many points there are. */

   if (argc != 2) {
      printf("Usage: %s <point count>\n", argv[0]);
      exit(0);
   }

   numpts = atoi(argv[1]);   /* convert argument to internal format */

   if (numpts > 100) {
      printf("Too many points\n");
      exit(0);
   }

   if (numpts < 3) {
      printf("Too few points\n");
      exit(0);
   }
```

```
        /* Now get the x and y coordinates of numpts equally-
         * spaced points around the unit circle.
         */

        for (i = 0; i < numpts; i++) {
           points[i][0] = cos((i*2.0*PI)/numpts);
           points[i][1] = sin((i*2.0*PI)/numpts);
        }

        ginit();
        textport(30,200,30,200);
        cursoff();

        color(WHITE);
        clear();       /* clear the whole screen */

        viewport(200, 800, 100, 700);  /* restrict to a square viewport */
        color(BLACK);
        clear();
        color(RED);

        ortho2(-1.2, 1.2, -1.2, 1.2);

        for (i = 0; i < numpts; i++)
           for (j = i+1; j < numpts; j++) {
              move2(points[i][0], points[i][1]);
              draw2(points[j][0], points[j][1]);
           }

        gexit();
    }
```

Typing "doily 21" will print a 21-point doily. A doily connects all pairs of evenly spaced points around a circle with straight lines. The first part of the program is standard UNIX to figure out how many vertices to use. We have arbitrarily restricted the number of vertices to be between 3 and 100. The next part of the program calculates the x and y coordinates of a set of `numpnts` equally spaced points on the unit circle. (The unit circle has radius 1.0 and is centered at the origin: x = 0.0, y = 0.0.)

The entire screen is cleared to white, and a `viewport()` command constrains drawing to a square region in the center of the screen ($200 <= x <= 800$, and $100 <= y <= 700$). Notice that the next clear will satisfy that constraint, and a square black region will be filled.

The `ortho2()` command sets things up so that the region ($-1.2 <= x, y <= 1.2$) completely fills the viewport. The unit circle will therefore fit into the viewport.

Finally, red lines are drawn in red between all possible pairs of points.

The `viewport()` command specifies the portion of the physical screen to be used for output, and the `ortho2()` command describes the world (or object) coordinate range that will fill that part of the screen. One command tells the part of the world to view, and the second tells where on the screen to draw it. There is a "2" in `ortho2()` because it is a 2-dimensional version. There is an `ortho()` command that will be described later.

Usually, the aspect ratios (the ratio of the x length to the y length) of the `viewport()` and the `ortho2()` commands will be the same (here, they are both square), but this is not required. If they are different, the drawing will be squashed in the x or the y direction. To see clipping in action, try changing the `ortho2()` command to `ortho2(-0.9,0.9,-0.9,0.9)`.

Example 4: Double Buffer Display Mode

The "bounce.c" program is the first dynamic example in this tutorial. A ball (a circle) bounces around on a rectangular piece of the screen. The program is simple, and introduces one new feature — double buffering.

In double buffer mode, the available bitplanes on your system are divided into two equal sets, and only one of the sets is viewed. In an eight-bitplane system in double buffer mode, for example, four bitplanes are assigned to the front buffer and four to the back buffer. Only the contents of the front buffer are displayed, and all writing is normally done into the back buffer.

To get the IRIS into double buffer mode, two commands are required: `doublebuffer()` and `gconfig()`. `doublebuffer()` tells the IRIS something about the display mode to use, and `gconfig()` changes to the new mode. The reason that two commands are required is that the display mode can be changed in other ways, and `gconfig()` is only called after all of the changes have been specified. Some sets of modes are inconsistent, and you must be able to specify the new setup completely before changing to it. For now, just remember to follow the `doublebuffer()` command by a `gconfig()` command, or you will remain in single buffer mode.

Before starting, we would like to clear the screen to white. Since there are two buffers, the obvious way to do this is to clear one buffer, swap buffers, and then clear the other buffer. Clearing large portions of the screen is one of the slowest things the IRIS does, so in general, this should be avoided. In this case, the two clears would occur only once at the beginning of the program, so it would not hurt too much.

As was stated earlier, there is a front buffer and a back buffer, and normally the contents of the front buffer are displayed while the contents of the back buffer are being updated. `frontbuffer(TRUE)` tells the IRIS to write into the front buffer as well as the back buffer. `frontbuffer(FALSE)` turns off writing into the front buffer. The sequence:

```
frontbuffer(TRUE);
clear();
frontbuffer(FALSE);
```

has the net effect of clearing both the front and back buffers.

There is a `backbuffer()` command with similar effects, but it is not used as much. `ginit()` effectively does a `frontbuffer(FALSE)` and a `backbuffer(TRUE)` command.

The next two lines in the sample program illustrate the cure for another common problem. You would like to set a viewport that is not the entire screen, but you would also like to have the screen coordinates correspond to the world coordinates. The problem is solved by adding 0.5 to the x and y maximums in the ortho2 command, and subtracting 0.5 from the x and y minimums. To see why this is necessary, consider just the x coordinates. A viewport(100,200,100,200) command says to use the screen coordinates from 100 to 200, inclusive. This is 101 pixels! If you use the command ortho2(100.0,200.0,100.0,200.0), the world x range is 100.0, so changing the world coordinates by 100 will change the screen range by 101. This may cause round-off problems, especially if you are trying to deal with individual pixels. If, instead, you use ortho2(99.5,200.5,99.5,200.5), things will match up perfectly. ginit() originally issues the command ortho2(-0.5,1023.5,-0.5,767.5). You might think that you could just add 1 to the maximum values and have things work out, but this will make every integer fall exactly on the boundary between two screen pixels. Rounding would occur for every pixel with unpredictable results.

Once the "bounce.c" program is initialized, it goes into an infinite loop and repeatedly recalculates the position of the ball, redraws it in the back buffer, and swaps the back and front buffers. The calculation in this simple program is straight-forward — increment the position by the velocity, and if the ball has rammed into a wall, flip the velocity to the other direction.

In most dynamic graphics, one first clears the screen, and then draws in the next view. If the view is complicated, the drawing process can block because the clear() command takes so long. If we do the clear() before the calculations, the hardware can start the clearing and get some of it done while the next frame is being calculated. After the next frame is drawn, a swapbuffers() command exchanges the front and back buffers.

The sample program runs forever, and must be terminated by interrupting the system. In the next example, we will provide a cleaner exit mechanism.

"Bounce.c" follows:

```
#include "gl.h"

#define XMIN 100/* XMIN, ... define the region of the */
#define YMIN 100/* screen where the ball bounces. */
#define XMAX 900
#define YMAX 700

main(argc, argv)
int argc;
char *argv[];
{
   long xpos = 500, ypos = 500;
   long xvelocity, yvelocity, radius;

   if (argc != 4) {
      printf("Usage: %s <xvelocity> <yvelocity> <radius>\n", argv[0]);
      exit(0);
```

```
        }

        xvelocity = atoi(argv[1]);/* convert the ascii values of the */
        yvelocity = atoi(argv[2]);/* parameters to internal integer */
        radius = atoi(argv[3]);   /* format */
        if (radius <= 0)     /* sanity check */
           radius = 10;

        ginit();
        doublebuffer();
        gconfig();
        color(WHITE);
        frontbuffer(TRUE);
        clear();
        frontbuffer(FALSE);
        viewport(XMIN, XMAX, YMIN, YMAX);
        ortho2(XMIN - 0.5, XMAX + 0.5, YMIN - 0.5, YMAX + 0.5);
        while(1) {
           color(BLACK);
           clear();
           xpos += xvelocity;
           ypos += yvelocity;
           if (xpos > XMAX - radius ||
              xpos < XMIN + radius) {
              xpos -= xvelocity;
              xvelocity = -xvelocity;
           }
           if (ypos > YMAX - radius ||
              ypos < YMIN + radius) {
              ypos -= yvelocity;
              yvelocity = -yvelocity;
           }
           color(YELLOW);
           circfi(xpos, ypos, radius);
           swapbuffers();
        }
     }
```

Example 5: Input/Output Devices

This example shows how to make use of the mouse to control a dynamic graphics program. We will modify the previous example, "bounce.c", as follows:

- The program will start with the ball at rest.
- When the left mouse button is pressed, the x velocity will increase by 1.
- The middle mouse button increases the y velocity by 1.
- The right mouse button stops the ball.
- Pressing the left and right mouse buttons simultaneously will exit the program.

An easy way to make this user interface work is to say an event occurs every time that all of the mouse buttons are up. Between times when they are all up, some subset of the mouse buttons will have gone down. The set of all mouse buttons that have been down between events will be the result of the event.

The routine `checkmouse()` is called every time the picture is drawn. `checkmouse()` looks to see if the state of any mouse button has changed, and records the results. If an event occurs as a result of such a change, velocities are adjusted accordingly.

In `checkmouse()`, the variable `buttons` records the current set of buttons that are down, and `pressed` records the total number of buttons pressed since the last event. We queue the mouse buttons so that no button events are missed. In both `buttons` and `pressed`, we use the 1, 2, and 4 bits to record the state of the `LEFT`, `MIDDLE`, and `RIGHT` mouse buttons, respectively. If we logically OR `LEFT` with `pressed` the `LEFT` bit is turned on in that variable. Similarly, logically XORing `LEFT` with `buttons` changes the state of the `LEFT` bit in the buttons variable. When buttons finally gets to zero (all buttons up), the set of all buttons pressed between events is recorded in `pressed`.

With a user interface like this, it is often a good idea to make the combination of all three buttons be an abort command. This way, if you accidentally press down the wrong button combination and notice it before you release them, you can just push down the rest of the buttons, and abort the entire command.

In the main routine, the three calls to `qbutton()` instruct the IRIS to record all changes of state of the mouse buttons (either down or up) in the event queue.

Another interesting thing to note is the use of the `qtest()` command. If we were to call `qread()` immediately, then everything would stop until a mouse button is pressed or released — the motion would stop. `qtest()` will return zero if nothing has happened, so the routine `checkmouse()` will just return.

The program as written can still be improved. It assumes that when things start up, all of the mouse buttons are up. It will behave in a very strange manner if you hold down a mouse button or two, and start the program. The sense of those buttons will be reversed. To fix this, you can add this line just before the three `qdevice()` commands:

```
while(getbutton(LEFTMOUSE)|getbutton(MIDDLEMOUSE)|getbutton(RIGHTMOUSE));
```

This will cause the program to spin its wheels until all mouse buttons are released.

Here is a listing of the "iobounce.c" program:

```
/* "iobounce.c" */
#include "gl.h"
#include "device.h"

#define XMIN 100
#define YMIN 100
#define XMAX 900
#define YMAX 700

long xvelocity, yvelocity;

main(argc, argv)
int argc;
char *argv[];
{
   long xpos = 500, ypos = 500;
   long radius;

   xvelocity = yvelocity = 0;
   radius = 10;

   ginit();
   doublebuffer();
   gconfig();
   color(WHITE);
   frontbuffer(TRUE);
   clear();
   frontbuffer(FALSE);
   viewport(XMIN, XMAX, YMIN, YMAX);
   ortho2(XMIN - 0.5, XMAX + 0.5, YMIN - 0.5, YMAX + 0.5);

   qdevice(LEFTMOUSE);
   qdevice(MIDDLEMOUSE);
   qdevice(RIGHTMOUSE);
```

```
        while(1) {
            color(BLACK);
            clear();
            checkmouse();
            xpos += xvelocity;
            ypos += yvelocity;
            if (xpos > XMAX - radius ||
               xpos < XMIN + radius) {
               xpos -= xvelocity;
               xvelocity = -xvelocity;
            }
            if (ypos > YMAX - radius ||
               ypos < YMIN + radius) {
               ypos -= yvelocity;
               yvelocity = -yvelocity;
            }
            color(YELLOW);
            circfi(xpos, ypos, radius);
            swapbuffers();
        }
    }

    #define LEFT 1
    #define MIDDLE 2
    #define RIGHT 4

    checkmouse()
    {
       static buttons = 0, pressed = 0;
       Device val;

       while (qtest()) {
          switch (qread(&val)) {
             case LEFTMOUSE:
                buttons ^= LEFT;
                pressed |= LEFT;
                break;
             case MIDDLEMOUSE:
                buttons ^= MIDDLE;
                pressed |= MIDDLE;
                break;
             case RIGHTMOUSE:
                buttons ^= RIGHT;
                pressed |= RIGHT;
                break;
            }
            if (buttons == 0) {
              switch (pressed) {
                case LEFT:          /* increase xvelocity */
                  if (xvelocity >= 0)
                    xvelocity++;
                  else
                    xvelocity--;
                  break;
                case MIDDLE:        /* increase yvelocity */
                  if (yvelocity >= 0)
                    yvelocity++;
                  else
                    yvelocity--;
                  break;
                case RIGHT:         /* stop ball */
                  xvelocity = yvelocity = 0;
                  break;
                case LEFT+RIGHT: /* exit */
                  gexit();
                  exit(0);
              }
            pressed = 0;
            }
          }
        }
```

Example 6: Interactive Drawing

This example is a simple interactive drawing program. Beginning with the screen cleared to black, you can move the cursor around with a mouse, and mark endpoints of lines to be drawn. The middle button sets the current graphics position to the cursor position; the left button draws from the current graphics position to the cursor position and then sets the current graphics position to the cursor position. A connected set of segments can be drawn by repeatedly moving the mouse and pressing the left button. The program exits when the right button is pressed.

Here is the source code:

```
/* "draw.c" */
#include "gl.h"
#include "device.h"

main()
{
  Device val, xpos, ypos;

  ginit();
  color(BLACK);
  cursoff();
  clear();
  curson();
  color(RED);
  qdevice(LEFTMOUSE);
  qdevice(MIDDLEMOUSE);
  qdevice(RIGHTMOUSE);
  tie(LEFTMOUSE, MOUSEX, MOUSEY);
  tie(MIDDLEMOUSE, MOUSEX, MOUSEY);

  while(1) {
     switch(qread(&val)) { /* wait for mouse down */
        case RIGHTMOUSE:   /* quit */
           gexit();
           exit(0);
        case MIDDLEMOUSE:  /* move */
           qread(&xpos);
           qread(&ypos);
           move2i(xpos, ypos);
           qread(&val);     /* these three reads clear out */
           qread(&val);     /* the button up report */
```

```
                qread(&val);
                break;
            case LEFTMOUSE:      /* draw */
                qread(&xpos);
                qread(&ypos);
                cursoff();
                draw2i(xpos, ypos);
                curson();
                qread(&val);
                qread(&val);
                qread(&val);
                break;
        }
    }
}
```

The program is controlled by the mouse. The right button exits, the middle button does a move to the current cursor position, and the left button draws to the current cursor. All input/output is done using the event queue.

All of the mouse buttons are queued, and the left and middle buttons are tied to the x- and y- coordinates of the mouse. The tie() command guarantees that when the left or middle mouse buttons change (go up or down), the values of MOUSEX and MOUSEY will be recorded in the event queue. The two entries in the queue after the button event will be the MOUSEX and MOUSEY values in that order. Thus the code in the case statement does not have to check to see that the following events are of type MOUSEX and MOUSEY.

The main part of the program is a loop that reads the event queue with qread(), and quits, moves, or draws, depending on the event recorded there. In the case of the MIDDLEMOUSE event, the xposition and yposition are read, and a move to those coordinates is issued. The next three qread() commands throw away the event where the mouse button comes up. Remember that when the button comes up, there will be a button event and then the MOUSEX and MOUSEY events.

The draw code is similar, except that the cursor must be turned off and on before each draw. This is because of the way the cursor works. The hardware draws the cursor directly onto the bitplanes, clobbering whatever was underneath it. To restore the image after drawing the cursor, the screen area where the cursor is to be drawn is first copied away. When the cursor moves to a new spot, the copy is written back onto the screen (thus erasing the cursor), the space under the new cursor position is copied away, and the cursor is drawn again. The problem is that if the cursor has been drawn, and something is drawn over it, when the cursor is erased by copying back the old data, the new drawing is also lost. In this program, the problem would be severe, since all of the drawing will be in the vicinity of the cursor.

Turning the cursor off erases the cursor by replacing the area it covered by the good copy. Drawing is done with no cursor, and when the cursor is turned back on, an updated version of the screen area is saved. Try commenting out the `cursoff()` and `curson()` commands if you like to see what happens.

As it stands, the program could be improved. It assumes that once a mouse button is pressed, it will be released before another button is pressed. To work correctly in all cases, the three `qread()` commands that throw away the upstroke should be replaced by code that makes sure that it was the same button that went down.

Example 7: Popup Menus

The program "popup.c" demonstrates how a simple popup menu can be implemented. The heart of the program is the routine `popup()` that returns the number of the user's selection. The main program itself is extremely simple — after some initialization, it goes into a loop where it waits for a popup menu event, and dispatches to the appropriate routine. Depending on which popup entry the user selects, it draws a line, some points, a circle, a filled or unfilled rectangle, or exits.

The popup menu is drawn when the left mouse button is pressed down. While the button is held down, the menu remains on the screen, and as the cursor moves across a menu entry, that entry is highlighted. When the button is released, the entry under the cursor at that time is selected. If the cursor is outside the menu when the button is released, `popup()` returns the value 0. There are many other ways a popup menu could be implemented, and the routine `popup()` can easily be modified to change its behavior.

The first thing to notice about the program is the way that the popup menus make use of the color map. Here, we make use of two bitplanes for the popup menu. In this simple example, the main program itself uses only one bitplane — it only draws in black and white, and assuming that no popup menus were used, it could get away with two `mapcolor()` commands:

```
mapcolor(0, 0, 0, 0);
mapcolor(1, 255, 255, 255);
```

The color map is set up for the popup menus as follows: Pixels on the screen that are not under the popup menu have the bits in bitplanes 1 and 2 equal to zero (Bitplane 0 is used for the drawing). When either of the bits in bitplanes 1 or 2 is one, bit zero has no effect. This is done by mapping both combinations to the same thing. There are three combinations with at least one bitplane nonzero: 10, 01, and 11. We use these three combinations to represent menu background, menu text, and highlighted menu. The map is set up as follows:

```
BP2 BP1 BP0
--- --- ---
 0   0   0  No menu, no drawing -- black (r = 0, g = 0, b = 0)
 0   0   1  No menu, drawing -- green (r = 0, g = 255, b = 0)
 0   1   0  Menu background, no drawing -- black (r = 0, g = 0, b = 0)
 0   1   1  Menu background, drawing -- black (r = 0, g = 0, b = 0)
 1   0   0  Menu text, no drawing -- white (r = 255, g = 255, b = 255)
 1   0   1  Menu text, drawing -- white (r = 255, g = 255, b = 255)
 1   1   0  Menu highlight, no drawing -- grey (r = 100, g = 100, b = 100)
 1   1   1  Menu highlight, drawing -- grey (r = 100, g = 100, b = 100)
```

The first eight `mapcolor()` commands in the main routine set up this color map. If the main drawing uses more than two colors (say eight), then there will be eight mapcolors for each of the three menu combinations to make the menu show up, regardless of the contents of the other planes.

The cursor draws in all three planes (writemask = 7) with color 4 (which is mapped to white) so the white cursor will always show up, no matter what combination of drawing and menu appears under it. Since the cursor is drawn in the same planes as everything else, it must be turned on and off every time a drawing operation is performed.

The sample program uses only the left mouse button, and will need to know where the mouse was when the button was pressed, so the button itself is queued, and tied to the x- and y- mouse coordinates.

Next, the main program clears the screen to black, and resets the viewport to a square near the middle of the screen, and uses an `ortho` command that maps world coordinates between -1.0 and 1.0 to that viewport.

Finally, the program goes into a loop, waiting for a menu event, and drawing the appropriate thing. All of the other interesting code is in the `popup()` routine.

`popup()` takes a menu structure as a parameter that includes the text of the menu, draws the menu under the cursor, waits for the selection to take place, and then returns the value of the selection. The menu structure is an array of pairs of entries, the first of which is an identifying number, and the second a text string. When a menu entry is picked, the identifying number is returned. It would have been easy to return the position of the entry in the menu, but attaching identifying numbers often makes things much easier to program.

The `popup()` routine needs to do a lot of things. When it is invoked, it has no idea what the current writemask, color, viewport, and matrix are, and it has to change all of these. Therefore, it saves away all that information, and restores it upon exit.

Next, it has to count the entries in the menu and calculate the size of the menu, and where on the screen to place the menu. It will try to center the menu under the cursor, but if the cursor is pressed near an edge or corner of the screen, entire menu will appear on the screen.

The menu is then drawn, restricted to the two menu bitplanes. `popup()` then goes into a loop waiting for the mouse button to come up. Before checking the event queue each time, it reads the current x- and y- locations of the cursor and checks to see if a highlighting change is necessary. The variable `lasthighlight` contains the number of the menu entry last highlighted — (0 <= `lasthighlight` < `menucount` — and is -1 if none of the entries are highlighted. If the cursor has moved to cover a new menu entry, the last highlighted entry (if there was one) is changed back to the normal color, and the new entry is highlighted. Note that the rectangle clears for erasing and redrawing are carefully chosen not to obliterate the boundary lines.

Finally, if the mouse button was released, the routine reads the current position, determines what menu entry it is above, if any, and returns the corresponding identifying number or zero.

For a general-purpose menu package, there really should be checks to see if the queue event is the correct mouse button, because a general menu package will have no idea what other events the user has queued.

The C version of "popup" follows:

```
/* "popup.c" */
#include "gl.h"
#include "device.h"
#define LINE 1
#define POINTS 2
#define CIRCLE 3
#define RECT 4
#define RECTF 5
#define QUIT 6
typedef struct {
   short type;
   char *text;
} popupentry;

popupentry mainmenu[] = {
   {LINE, "Line"},
   {POINTS, "100 points"},
   {CIRCLE, "Filled circle"},
   {RECT, "Outlined rectangle"},
   {RECTF, "Filled rectangle"},
   {QUIT, "Quit"},
   {0, 0}   /* mark end of menu */
};
main()
{
   register i, j;
   short command;

   ginit();
   mapcolor(0, 0, 0, 0);       /* background only */
   mapcolor(1, 0, 255, 0);     /* drawing only */
   mapcolor(2, 0, 0, 0);       /* popup background */
   mapcolor(3, 0, 0, 0);       /* popup background over drawing */
   mapcolor(4, 255, 255, 255);/* popup text only */
   mapcolor(5, 255, 255, 255);/* popup text over drawing */
   mapcolor(6, 100, 100, 100);/* popup highlight only */
   mapcolor(7, 100, 100, 100);/* popup highlight over drawing */
```

```
    setcursor(0, 4, 7);
    qdevice(LEFTMOUSE);
    tie(LEFTMOUSE, MOUSEX, MOUSEY);

    cursoff();
    color(0);
    clear();
    curson();
    viewport(150, 850, 50, 750);
    ortho2(-1.0, 1.0, -1.0, 1.0);
    while (1) {
       command = popup(mainmenu);
       cursoff();
       color(0);
       clear();
       color(1);
       switch(command) {
          case LINE:
             move2(-1.0, -1.0);
             draw2(1.0, 1.0);
             break;
          case POINTS:
             for (i = 0; i < 10; i++)
                for (j = 0; j < 10; j++)
                   pnt2(i/20.0, j/20.0);
             break;
          case CIRCLE:
             circf(0.0, 0.0, 0.5);
             break;
          case RECT:
             rect(-0.5, -0.5, 0.5, 0.5);
             break;
          case RECTF:
             rectf(-0.5, -0.5, 0.5, 0.5);
             break;
          case QUIT:
             greset();
             gexit();
             exit(0);
       }
       curson();
    }
}
```

popup(names)

```
popupentry names[];
{
    register short i, menucount;
    short menutop, menubottom, menuleft, menuright;
    short lasthighlight = -1, highlight;
    Device dummy, x, y;
    short savecolor, savemask;
    short llx, lly, urx, ury;

    menucount = 0;
    qread(&dummy);
    qread(&x);
    qread(&y);
    savecolor = getcolor();   /* save the state of everything */
    savemask = getwritemask();
    getviewport(&llx, &urx, &lly, &ury);
    pushmatrix();
    viewport(0, 1023, 0, 767);/* now setup to draw the menu */
    ortho2(-0.5, 1023.5, -0.5, 767.5);
    while (names[menucount].type)
        menucount++;
    menutop = y + menucount*8;
    menubottom = y - menucount*8;
    if (menutop > 767) {
        menutop = 767;
        menubottom = menutop - menucount*16;
    }
    if (menubottom < 0) {
        menubottom = 0;
        menutop = menubottom + menucount*16;
    }
    menuleft = x - 100;
    menuright = x + 100;
    if (menuleft < 0) {
        menuleft = 0;
        menuright = menuleft + 200;
    }
    if (menuright > 1023) {
        menuright = 1023;
        menuleft = 823;
    }
    writemask(6); /* restrict to menu planes */
    color(2);            /* menu background */
    cursoff();
    rectfi(menuleft, menubottom, menuright, menutop);
```

```
color(4);           /* menu text */
move2i(menuleft, menubottom);
draw2i(menuleft, menutop);
draw2i(menuright, menutop);
draw2i(menuright, menubottom);
for (i = 0; i < menucount; i++) {
   move2i(menuleft, menutop - (i+1)*16);
   draw2i(menuright, menutop - (i+1)*16);
   cmov2i(menuleft + 10, menutop - 14 - i*16);
   charstr(names[i].text);
}
curson();
while (1) {
   x = getvaluator(MOUSEX);
   y = getvaluator(MOUSEY);
   if (menuleft < x && x < menuright && menubottom < y && y < menutop) {
      highlight = (menutop - y)/16;
      cursoff();
      if (lasthighlight != -1 && lasthighlight != highlight) {
         color(2);
         rectfi(menuleft+1, menutop - lasthighlight*16 - 15,
              menuright-1, menutop - lasthighlight*16 - 1);
         color(4);
         cmov2i(menuleft + 10, menutop - 14 - lasthighlight*16);
         charstr(names[lasthighlight].text);
      }
      if (lasthighlight != highlight) {
         color(6);
         rectfi(menuleft+1, menutop - highlight*16 - 15,
              menuright-1, menutop - highlight*16 - 1);
         color(4);
         cmov2i(menuleft + 10, menutop - 14 - highlight*16);
         charstr(names[highlight].text);
      }
      lasthighlight = highlight;
      curson();
   } else /* the cursor is outside the menu */ {
      if (lasthighlight != -1) {
         cursoff();
         color(2);
         rectfi(menuleft+1, menutop - lasthighlight*16 - 15,
              menuright-1, menutop - lasthighlight*16 - 1);
         color(4);
         cmov2i(menuleft + 10, menutop - 14 - lasthighlight*16);
         charstr(names[lasthighlight].text);
```

```
                curson();
                lasthighlight = -1;
            }
        }
        if (qtest()) {
            qread(&dummy);
            qread(&x);
            qread(&y);
            color(0);
            cursoff();
            rectfi(menuleft, menubottom, menuright, menutop);
            curson();
            if (menuleft<x && x<menuright && menubottom<y && y<menutop)
                x = (menutop - y)/16;
            else
                x = 0;
            break;
        }
    }
    popmatrix();  /* now restore the state to what the user had */
    color(savecolor);
    writemask(savemask);
    viewport(llx, urx, lly, ury);
    return names[x].type;
}
```

Here is the FORTRAN version of "popup":

```
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C     Installation note:
C   Various Fortran compilers may require different styles of INCLUDEs.
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      INCLUDE 'fgl.h'
      INCLUDE 'fdevice.h'
C
      INTEGER I, J, MNAMES(7), COMAND, POPUP
      INTEGER LINE, POINTS, CIRCLE, RCTGL, RCTGLF, QUIT
      CHARACTER*20 MSTRGS(7)
      LINE = 1
      POINTS = 2
      CIRCLE = 3
      RCTGL = 4
      RCTGLF = 5
      QUIT = 6
C
C     Initialize main menu names and strings (names 1-6 are as per
C     the parameters above, but are easier to init. via the DO loop)
```

```
      DO 100 I=1,6
       MNAMES(I) = I
100    CONTINUE
      MNAMES(7) = 0
C
      MSTRGS(1) = 'Line'
      MSTRGS(2) = '100 points'
      MSTRGS(3) = 'Filled circle'
      MSTRGS(4) = 'Outlined rectangle'
      MSTRGS(5) = 'Filled rectangle'
      MSTRGS(6) = 'Quit'
      MSTRGS(7) = ' '
C
      CALL GINIT()
C       background only
      CALL MAPCOL(0,0,0,0)
C       drawing only
      CALL MAPCOL(1,0,255,0)
C       popup background
      CALL MAPCOL(2,0,0,0)
C       popup background over drawing
      CALL MAPCOL(3,0,0,0)
C       popup text only
      CALL MAPCOL(4,255,255,255)
C       popup text over drawing
      CALL MAPCOL(5,255,255,255)
C       popup highlight only
      CALL MAPCOL(6,100,100,100)
C       popup highlight over drawing
      CALL MAPCOL(7,100,100,100)
      CALL SETCUR(0,4,7)
      CALL QDEVIC(LEFTMO)
      CALL TIE(LEFTMO,MOUSEX,MOUSEY)
C
      CALL CURSOF()
      CALL COLOR(0)
      CALL CLEAR()
      CALL CURSON()
      CALL VIEWPO(150,850,50,750)
      CALL ORTHO2(-1.0,1.0,-1.0,1.0)
C
C       loop until quit selected
200   CONTINUE
        COMAND = POPUP(MNAMES,MSTRGS)
        CALL CURSOF()
      CALL COLOR(0)
      CALL CLEAR()
      CALL COLOR(1)
C
      IF (COMAND .EQ. LINE) THEN
       CALL MOVE2(-1.0,-1.0)
       CALL DRAW2(1.0,1.0)
      ELSE IF (COMAND .EQ. POINTS) THEN
       DO 400 I=1,10
        DO 300 J=1,10
         CALL PNT2(REAL(I)/20.0,REAL(J)/20.0)
300      CONTINUE
400     CONTINUE
      ELSE IF (COMAND .EQ. CIRCLE) THEN
       CALL CIRCF(0.0,0.0,0.5)
      ELSE IF (COMAND .EQ. RCTGL) THEN
       CALL RECT(-0.5,-0.5,0.5,0.5)
      ELSE IF (COMAND .EQ. RCTGLF) THEN
       CALL RECTF(-0.5,-0.5,0.5,0.5)
      ELSE IF (COMAND .EQ. QUIT) THEN
       CALL GRESET()
       CALL GEXIT()
       GO TO 500
      END IF
C
      CALL CURSON()
C      loop back until quit selected
      GO TO 200
C
500   STOP
      END
C
C
      INTEGER FUNCTION POPUP(NAMES,STRNGS)
      INTEGER NAMES(*)
      CHARACTER*20 STRNGS(*)
      INTEGER GETCOL, GETWRI, GETVAL, QTEST
      INTEGER I, MCOUNT, MTOP, MBOTOM, MLEFT, MRIGHT
      INTEGER LASTHL, HIGHLT
      INTEGER*2 DUMMY, X, Y
      INTEGER SVCOLR, SVMASK
      INTEGER*2 LLX, LLY, URX, URY
      INTEGER ILLX, ILLY, IURX, IURY
      LASTHL = -1
C
```

```
      CALL QREAD(DUMMY)
      CALL QREAD(X)
      CALL QREAD(Y)
C       save the state of everything
      SVCOLR = GETCOL()
      SVMASK = GETWRI()
      CALL GETVIE(LLX,URX,LLY,URY)
      ILLX = LLX
      IURX = URX
      ILLY = LLY
      IURY = URY
      CALL PUSHMA()
C       now set up to draw the menu
      CALL VIEWPO(0,1023,0,767)
      CALL ORTHO2(-0.5,1023.5,-0.5,767.5)
C       set MCOUNT equal to number of names in menu
      MCOUNT = 0
1000  CONTINUE
        IF (NAMES(MCOUNT+1) .NE. 0) THEN
          MCOUNT = MCOUNT + 1
          GO TO 1000
      END IF
C
      MTOP = Y + MCOUNT * 8
      IF (MTOP .GT. 767) MTOP = 767
      MBOTOM = MTOP - MCOUNT * 16
C
      IF (MBOTOM .LT. 0) THEN
        MBOTOM = 0
        MTOP = MBOTOM + MCOUNT * 16
      END IF
C
      MLEFT = X - 100
      IF (MLEFT .LT. 0) MLEFT = 0
      MRIGHT = MLEFT + 200
C
      IF (MRIGHT .GT. 1023) THEN
        MRIGHT = 1023
        MLEFT = 823
      END IF
C
C       restrict to menu planes
      CALL WRITEM(6)
C       menu background
      CALL COLOR(2)
      CALL CURSOF()
      CALL RECTFI(MLEFT,MBOTOM,MRIGHT,MTOP)
C       menu text
      CALL COLOR(4)
      CALL RECTI(MLEFT,MBOTOM,MRIGHT,MTOP)
      DO 2000 I=1,MCOUNT
        CALL MOVE2I(MLEFT, MTOP - I*16)
        CALL DRAW2I(MRIGHT, MTOP - I*16)
        CALL CMOV2I(MLEFT + 10, MTOP - I*16 + 2)
        CALL CHARST(STRNGS(I),LEN(STRNGS(I)))
2000  CONTINUE
C
      CALL CURSON()
C     loop to highlight potential selection & accept selection
3000  CONTINUE
        X = GETVAL(266)
        Y = GETVAL(267)
C
C       if the cursor is inside the menu
        IF ((MLEFT.LT.X).AND.(X.LT.MRIGHT) .AND. (MBOTOM.LT.Y).AND.(Y.LT
     2.MTOP)) THEN
          HIGHLT = (MTOP - Y)/16
          CALL CURSOF()
C
          IF ((LASTHL.NE.-1) .AND. (LASTHL.NE.HIGHLT)) THEN
            CALL COLOR(2)
            CALL RECTFI(MLEFT+1, MTOP - LASTHL*16 - 15, MRIGHT-1, MTOP -
     2 LASTHL*16 -1)
            CALL COLOR(4)
            CALL CMOV2I(MLEFT + 10, MTOP - 14 - LASTHL*16)
            CALL CHARST(STRNGS(LASTHL+1),LEN(STRNGS(LASTHL+1)))
          END IF
C
          IF (LASTHL.NE.HIGHLT) THEN
            CALL COLOR(6)
            CALL RECTFI(MLEFT+1, MTOP - HIGHLT*16 - 15, MRIGHT-1, MTOP -
     2 HIGHLT*16 -1)
            CALL COLOR(4)
            CALL CMOV2I(MLEFT + 10, MTOP - 14 - HIGHLT*16)
            CALL CHARST(STRNGS(HIGHLT+1),LEN(STRNGS(HIGHLT+1)))
          END IF
C
          LASTHL = HIGHLT
          CALL CURSON()
C
```

```
C       if the cursor is outside the menu
      ELSE
        IF (LASTHL.NE.-1) THEN
          CALL CURSOF()
          CALL COLOR(2)
          CALL RECTFI(MLEFT+1, MTOP - LASTHL*16 - 15, MRIGHT-1, MTOP -
     2 LASTHL*16 -1)
          CALL COLOR(4)
          CALL CMOV2I(MLEFT + 10, MTOP - 14 - LASTHL*16)
          CALL CHARST(STRNGS(LASTHL+1),LEN(STRNGS(LASTHL+1)))
          CALL CURSON()
          LASTHL = -1
        END IF
      END IF
C
       IF (QTEST().NE.0) THEN
         CALL QREAD(DUMMY)
         CALL QREAD(X)
         CALL QREAD(Y)
         CALL COLOR(0)
         CALL CURSOF()
         CALL RECTFI(MLEFT,MBOTOM,MRIGHT,MTOP)
         CALL CURSON()
         IF ((MLEFT.LT.X).AND.(X.LT.MRIGHT) .AND. (MBOTOM.LT.Y).AND.(Y.
     2LT.MTOP)) THEN
           X = (MTOP - Y)/16 + 1
         ELSE
           X = 1
         END IF
C            now restore the state to what the user had
         CALL POPMAT()
         CALL COLOR(SVCOLR)
         CALL WRITEM(SVMASK)
         CALL VIEWPO(ILLX,IURX,ILLY,IURY)
         POPUP = NAMES(X)
         GO TO 4000
       END IF
C
C       loop back to highlight potential selection & accept selection
      GO TO 3000
C
C
4000  RETURN
      END
```

Example 8: Modeling Transformations

The "trans.c" program shows how the `translate()`, `rotate()`, and `scale()` commands affect a drawing. The object being drawn is a cube of side 2 centered at the origin (x = 0, y = 0, and z = 0). For reference, the letters 'X', 'Y', and 'Z' are drawn on the faces x = 1, y = 1, and z = 1, respectively. It is always viewed from a fixed point in space (x = 10.0, y = 10.0, and z = 10.0), with a fixed perspective view. Exactly one transformation at a time is applied.

The cube is drawn in a viewport that is 800 by 600 pixels — an aspect ratio of 800/600 = 1.3333333. This value must be specified to the perspective command or the picture will be squashed sideways. In almost all cases, the aspect ratio used by the perspective command will be the ratio of the length to the height of the viewport that is used.

For reference, a fixed set of axes is also drawn untransformed. The code to draw the axes is in the `drawaxes()` routine. The most important feature of this example is the way that transformations are set up and restored. The heart of the program is this:

```
<set up initial viewing transformation>
<draw everything with the current view>
<do forever> {
    <get new transformation from user (but don't apply it)>
    <draw the axes (with the original transformation)>
    pushmatrix(); /* saves and copies the current transformation */
    <apply new transformation> /* this multiplies a new transformation */
                        /* by the current one */
    <draw the cube>
    popmatrix(); /* restores original transformation */
}
```

The user interface is simple — it uses only the left mouse button. When that button is pressed down, a popup menu appears. When it is released, the menu item under the cursor is selected. You can choose to translate, rotate, or scale along (or around) any of the three axes. If the button is released when the cursor is not over the menu, nothing happens, and the next press brings up the menu again. One of the menu entries is "Quit", and neither of the other buttons does anything.

Once a transformation selection is made with the menu, a control bar is drawn in the lower part of the screen. The bar is labeled with numbers that range from -10 to 10 for the translation and scaling routines, and from 0 to 3600 for the rotation commands. When the cursor is placed inside this bar, the labeled cube is drawn with the transformation selected by the menu, and with the value specified by the control bar. As long as the cursor is within the control bar, the figure will be redrawn continuously. To try a new transformation, press and release the left mouse button.

This program uses the routines in the "popuputil.c" file. The popup code is similar to that in the sample program "popup.c", so see the documentation for that program to learn how the popup menu itself works. The main difference between the code in "popup.c" and "popuputil.c" is that in "popuputil.c", four colors are reserved for drawing rather than two. The file "popup.h" defines constants for the four drawing colors. Note that the popup menu is used here in double buffer mode — it will work fine in single buffer mode too.

In many cases, popup menus in double buffer mode can be done using fewer bitplanes — especially if they are used in a dynamic scene. A menu in this mode does not need its own bitplanes since the scene is regenerated for each frame. The menu is simply drawn on top of the scene each time.

The code for the main routine is fairly simple. It gets a command and sets up the appropriate control bar. Then it goes into a loop that tests for a button press and if there is none, reads the control bar, performs the appropriate transformation, and goes back to test the event queue. Note that `pushmatrix()` and `popmatrix()` surround the transformation so that the transformation is done relative to the original viewing setup. If this were omitted, the transformations would be compounded (with astonishing results).

Note also that the transformation parameter has to be cast to an integer when it is used in a rotation command. As usual, all angles are in tenths of degrees, which is why the control bar runs from 0 to 3600.

The source for "trans.c" follows:

```
/* "trans.c" */
#include "gl.h"
#include "device.h"
#include "popup.h"

#define CUBEOBJ 1
#define AXISOBJ 2

#define TRANSX 1
#define TRANSY 2
#define TRANSZ 3
#define ROTX 4
#define ROTY 5
#define ROTZ 6
#define SCALEX 7
#define SCALEY 8
#define SCALEZ 9
#define EXITTRANS 10
```

```
popupentry mainmenu[] = {
   TRANSX, "Translate X",
   TRANSY, "Translate Y",
   TRANSZ, "Translate Z",
   ROTX, "Rotate X",
   ROTY, "Rotate Y",
   ROTZ, "Rotate Z",
   SCALEX, "Scale X",
   SCALEY, "Scale Y",
   SCALEZ, "Scale Z",
   EXITTRANS, "Quit",
   0, 0
};

main()
{
   Device val;
   int command, i;
   float transparam;

   ginit();
   doublebuffer();
   gconfig();
   initpopup();
   frontbuffer(TRUE);
   writemask(0xfff);
   color(BLACKDRAW);
   cursoff();
   clear();
   curson();
   frontbuffer(FALSE);
   viewport(100, 900, 100, 700);
   perspective(400, 1.3333333, 0.1, 1000.0);
   lookat(10.0, 10.0, 10.0, 0.0, 0.0, 0.0, 0);

   while (1) {
      frontbuffer(TRUE); /* make the menu visible */
      switch (command = popup(mainmenu)) {
         case 0:
            continue;
         case TRANSX:
         case TRANSY:
         case TRANSZ:
         case SCALEX:
            case SCALEY:
            case SCALEZ:
                drawbar(-10.0, 10.0);
                break;
            case ROTX:
            case ROTY:
            case ROTZ:
                drawbar(0.0, 3600.0);
                break;
            case EXITTRANS:
                greset();
                gexit();
                exit(0);
        }
        frontbuffer(FALSE);
        color(BLACKDRAW);
        clear();
        color(YELLOWDRAW);
        drawaxes();
        color(REDDRAW);
        drawcube();
        swapbuffers();
        gflush();
        while (qtest() == 0)    /* while no buttons pressed */ {
            if (readbar(&transparam)) {
                color(BLACKDRAW);
                clear();
                color(YELLOWDRAW);
                drawaxes();
                pushmatrix();
                switch (command) {
                    case TRANSX:
                        translate(transparam, 0.0, 0.0);
                        break;
                    case TRANSY:
                        translate(0.0, transparam, 0.0);
                        break;
                    case TRANSZ:
                        translate(0.0, 0.0, transparam);
                        break;
                    case SCALEX:
                        scale(transparam, 1.0, 1.0);
                        break;
                    case SCALEY:
                        scale(1.0, transparam, 1.0);
                        break;
                    case SCALEZ:
                        scale(1.0, 1.0, transparam);
                        break;
                    case ROTX:
                        rotate((int)transparam, 'x');
                        break;
                    case ROTY:
                        rotate((int)transparam, 'y');
                        break;
                    case ROTZ:
                        rotate((int)transparam, 'z');
                        break;
                }
                color(REDDRAW);
                drawcube();
                popmatrix();
                swapbuffers();
                gflush();
            }
        }
        for (i = 0; i < 6; i++)
            qread(&val);  /* throw away down and up strokes */
                          /* of the exit button press */
    }
}

float barmin, barmax, bardelta;

drawbar(minval, maxval)
float minval, maxval;
{
    register i;
    char str[20];

    barmin = minval;
    barmax = maxval;
    bardelta = (barmax - barmin)/800.0;
    pushmatrix();
    pushviewport();
    ortho2(-0.5, 1023.5, -0.5, 767.5);
    viewport(0, 1023, 0, 767);
    frontbuffer(TRUE);
    cursoff();
    color(BLACKDRAW);
    rectfi(99, 19, 1000, 70);
    color(REDDRAW);
    recti(100, 20, 900, 40);
    for (i = 0; i < 5; i++) {
        move2i(100 + i*200, 40);
        draw2i(100 + i*200, 50);
        cmov2i(103 + i*200, 44);
        sprintf(str, "%6.2f", minval + i*(maxval - minval)/4.0);
        charstr(str);
    }
    curson();
    frontbuffer(FALSE);
    popviewport();
    popmatrix();
}

/* The readbar routine returns 1 if the value stored in retval is valid,
 * and zero otherwise.
 */

readbar(retval)
float *retval;
{
    int xmouse, ymouse;

    ymouse = getvaluator(MOUSEY);
    if (20 <= ymouse && ymouse <= 40) {
        xmouse = getvaluator(MOUSEX);
        if (100 <= xmouse && xmouse <= 900) {
            *retval = barmin + bardelta*(xmouse - 100);
            return 1;
        }
    }
    return 0;
}

drawcube()
{
    static short initialized = 0;

    if (!initialized) {
        makeobj(CUBEOBJ);

        /* First draw the outline of the cube */
```

```
            move(-1.0, -1.0, -1.0);
            draw(1.0, -1.0, -1.0);
            draw(1.0, 1.0, -1.0);
            draw(-1.0, 1.0, -1.0);
            draw(-1.0, -1.0, -1.0);
            draw(-1.0, -1.0, 1.0);
            draw(1.0, -1.0, 1.0);
            draw(1.0, 1.0, 1.0);
            draw(-1.0, 1.0, 1.0);
            draw(-1.0, -1.0, 1.0);
            move(-1.0, 1.0, -1.0);
            draw(-1.0, 1.0, 1.0);
            move(1.0, 1.0, -1.0);
            draw(1.0, 1.0, 1.0);
            move(1.0, -1.0, 1.0);
            draw(1.0, -1.0, -1.0);

            /* now draw the letters 'X', 'Y', and 'Z' on the faces: */

            move(1.0, -0.6666666, -0.5);
            draw(1.0, 0.6666666, 0.5);
            move(1.0, 0.6666666, -0.5);
            draw(1.0, -0.6666666, 0.5);

            move(0.0, 1.0, 0.6666666);
            draw(0.0, 1.0, 0.0);
            draw(0.5, 1.0, -0.6666666);
            move(0.0, 1.0, 0.0);
            draw(-0.5, 1.0, -0.6666666);

            move(-0.5, 0.6666666, 1.0);
            draw(0.5, 0.6666666, 1.0);
            draw(-0.5, -0.6666666, 1.0);
            draw(0.5, -0.6666666, 1.0);
            closeobj();
            initialized = 1;
        }
        callobj(CUBEOBJ);
        gflush();
    }

    drawaxes()
    {
        static initialized = 0;
    if (!initialized) {
        makeobj(AXISOBJ);
        movei(0, 0, 0);
        drawi(0, 0, 2);
        movei(0, 2, 0);
        drawi(0, 0, 0);
        drawi(2, 0, 0);
        cmovi(0, 0, 2);
        charstr("z");
        cmovi(0, 2, 0);
        charstr("y");
        cmovi(2, 0, 0);
        charstr("x");
        closeobj();
        initialized = 1;
    }
    callobj(AXISOBJ);
    gflush();
}
```

The source for "popup.h" follows:

```
/* "popup.h" */
#ifndef POPUPHEADER
#define POPUPHEADER

#define BLACKDRAW     0
#define GREENDRAW     1
#define REDDRAW 2
#define YELLOWDRAW    3

typedef struct {
    short type;
    char *text;
} popupentry;

#endif
```

The source for "popuputil.c" follows:

```
/* "popuputil.c" */
#include "gl.h"
#include "device.h"
#include "popup.h"

initpopup()
{
    register i;

    mapcolor(BLACKDRAW, 0, 0, 0);/* background only */
    mapcolor(GREENDRAW, 0, 255, 0);/* green drawing */
    mapcolor(REDDRAW, 255, 0, 0);/* red drawing */
    mapcolor(YELLOWDRAW, 255, 255, 0);/* yellow drawing */
    for (i = 4; i < 8; i++)
        mapcolor(i, 0, 0, 0);  /* popup background */
    for (i = 8; i < 12; i++)
        mapcolor(i, 255, 255, 255);/* popup text */
    for (i = 12; i < 16; i++)
        mapcolor(i, 150, 150, 150);/* popup highlight */
    setcursor(0, 8, 15);
    qdevice(LEFTMOUSE);
    tie(LEFTMOUSE, MOUSEX, MOUSEY);
}

popup(names)
popupentry names[];
{
    register short i, menucount;
    short menutop, menubottom, menuleft, menuright;
    short lasthighlight = -1, highlight;
    Device dummy, x, y;
    short savecolor, savemask;

    menucount = 0;
    qread(&dummy);
    qread(&x);
    qread(&y);
    pushattributes();
    pushviewport();
    pushmatrix();
    viewport(0, 1023, 0, 767);
    ortho2(-0.5, 1023.5, -0.5, 767.5);
    while (names[menucount].type)
        menucount++;
    menutop = y + menucount*8;
    menubottom = y - menucount*8;
    if (menutop > 767) {
        menutop = 767;
        menubottom = menutop - menucount*16;
    }
    if (menubottom < 0) {
        menubottom = 0;
        menutop = menubottom + menucount*16;
    }
    menuleft = x - 100;
    menuright = x + 100;
    if (menuleft < 0) {
        menuleft = 0;
        menuright = menuleft + 200;
    }
    if (menuright > 1023) {
        menuright = 1023;
        menuleft = 823;
    }
    writemask(12);      /* restrict to menu planes */
    color(4);           /* menu background */
    cursoff();
    rectfi(menuleft, menubottom, menuright, menutop);
    color(8);           /* menu text */
    move2i(menuleft, menubottom);
    draw2i(menuleft, menutop);
    draw2i(menuright, menutop);
    draw2i(menuright, menubottom);
    for (i = 0; i < menucount; i++) {
        move2i(menuleft, menutop - (i+1)*16);
        draw2i(menuright, menutop - (i+1)*16);
        cmov2i(menuleft + 10, menutop - 14 - i*16);
        charstr(names[i].text);
    }
    curson();
    while (1) {
        x = getvaluator(MOUSEX);
        y = getvaluator(MOUSEY);
        if (menuleft < x && x < menuright && menubottom < y && y < menutop) {
            highlight = (menutop - y)/16;
            cursoff();
            if (lasthighlight != -1 && lasthighlight != highlight) {
                color(4);
                rectfi(menuleft+1, menutop - lasthighlight*16 - 15,
                    menuright-1, menutop - lasthighlight*16 - 1);
                color(8);
                cmov2i(menuleft + 10, menutop - 14 - lasthighlight*16);
                charstr(names[lasthighlight].text);
            }
            if (lasthighlight != highlight) {
                color(12);
                rectfi(menuleft+1, menutop - highlight*16 - 15,
                    menuright-1, menutop - highlight*16 - 1);
                color(8);
                cmov2i(menuleft + 10, menutop - 14 - highlight*16);
                charstr(names[highlight].text);
            }
            lasthighlight = highlight;
            curson();
        } else /* the cursor is outside the menu */ {
            if (lasthighlight != -1) {
                cursoff();
                color(4);
                rectfi(menuleft+1, menutop - lasthighlight*16 - 15,
                    menuright-1, menutop - lasthighlight*16 - 1);
                color(8);
                cmov2i(menuleft + 10, menutop - 14 - lasthighlight*16);
                charstr(names[lasthighlight].text);
                curson();
                lasthighlight = -1;
            }
        }
        if (qtest()) {
            qread(&dummy);
            qread(&x);
            qread(&y);
            color(0);
            cursoff();
            rectfi(menuleft, menubottom, menuright, menutop);
            curson();
            if (menuleft<x && x<menuright && menubottom<y && y<menutop)
                x = (menutop - y)/16;
            else
                x = 0;
            break;
        }
    }
    popmatrix();
    popviewport();
    popattributes();
    return names[x].type;
}
```

Example 9: Writemasks and Color Maps

The sample program "vlsi.c" illustrates the use of the writemask in conjunction with the color map. It happens to be a simple-minded VLSI circuit editor, although the principles illustrated would be useful in many applications. Even if you have no interest in VLSI, it is worthwhile to study this example until you understand it thoroughly — the tricks used here can be used in many applications.

The problem the program solves is this: an integrated circuit chip has many layers on it — metal (blue), polysilicon (red), diffusion (green), contact cuts (black), and others. The meanings of these layers do not matter here — the point is that the circuit designer would like to see what layers are present at any point on the screen. When red crosses green, for example, a transistor is formed, and where both green and red appear, it would be nice to show it as a brillant yellow. In most cases, it would also be nice to be able to look at the color and know exactly what layers are there.

The contact cut (black) is different — after the other layers have been put down, a contact cut removes everything that was there, so it might as well be shown as black, no matter what layers are present.

The way this sample editor will work is to draw each of the layers on a separate bitplane, so each pixel on the screen may be covered by any combination of the four layers mentioned above. Colors are then assigned to the layer patterns. In this example, the following color assignments are made:

BP3	BP2	BP1	BP0	RED	GREEN	BLUE	
(cut)	(poly)	(diff)	(metal)				
0	0	0	0	255	255	255	(white - nothing there)
0	0	0	X	0	0	255	(metal only - show blue
0	0	X	0	0	255	0	(diffusion only - gree
0	0	X	X	0	150	255	(metal + diff - purple)
0	X	0	0	255	0	0	(polysilicon only - re
0	X	0	X	150	0	255	(light blue)
0	X	X	0	255	255	0	(transistor - yellow)
0	X	X	X	150	100	0	(brown)
X	0	0	0	0	0	0	(contact cut present)
X	0	0	X	0	0	0	(")
X	0	X	0	0	0	0	(")
X	0	X	X	0	0	0	(")
X	X	0	0	0	0	0	(")
X	X	0	X	0	0	0	(")
X	X	X	0	0	0	0	(")
X	X	X	X	0	0	0	(")

The colors chosen to represent the combinations are arbitrary. In the bitplane columns (BP0, ...) above, X means that the substance is present; 0 means it is absent.

If we replace all of the X's in the bitplane columns above, we can read off each 4-bit pattern as a binary number. Think of BP0 as the 1's place, BP1 as the 2's place, BP2 as the 4's place, and BP3, BP4, BP5, ... as the 8's, 16's, 32's, ... place. Add up the numbers to find out the representation. For example, "X 0 X 0" (BP3 and BP1) above corresponds to the number 8+2 = 10. We would map this color with `mapcolor(10,0,0,0)`.

Notice that in the program a fifth plane (BP4) is also used. The cursor will be drawn in that plane, and the color maps are rigged so that the cursor will appear to be white if it is over a black area, and black otherwise. This way, the cursor will always show up.

The source for "vlsi.c" appears below:

```
/* "vlsi.c" */
#include "gl.h"
#include "device.h"

main()
{
   register i;
   Device dummy, xend, yend, xstart, ystart, type;
   short wm;

   ginit();
   mapcolor(0, 255, 255, 255);/* WHITE */
   mapcolor(1, 0, 0, 255);    /* BLUE */
   mapcolor(2, 0, 255, 0);    /* RED */
   mapcolor(3, 0, 150, 255); /* PURPLE */
   mapcolor(4, 255, 0, 0);    /* GREEN */
   mapcolor(5, 150, 0, 255); /* LIGHT BLUE */
   mapcolor(6, 255, 255, 0); /* YELLOW */
   mapcolor(7, 150, 100, 0); /* BROWN */
   for (i = 8; i < 24; i++)
      mapcolor(i, 0, 0, 0);  /* BLACK */
   for (i = 24; i < 32; i++)
      mapcolor(i, 255, 255, 255);/* WHITE */
   qdevice(LEFTMOUSE);
   tie(LEFTMOUSE, MOUSEX, MOUSEY);
   qdevice(MIDDLEMOUSE);
   tie(MIDDLEMOUSE, MOUSEX, MOUSEY);
   qdevice(RIGHTMOUSE);
   qdevice(KEYBD);
   setcursor(0, 16, 16);
```

```
restart();
while (1)
   switch (type = qread(&dummy)) {
     case KEYBD:
        gexit();
        exit(0);
     case RIGHTMOUSE:
        qread(&dummy);
        restart();
        break;
     case MIDDLEMOUSE:
     case LEFTMOUSE:
        qread(&xstart);
        qread(&ystart);
        if (xstart < 60) {
           if (10 <= xstart && xstart <= 50) {
              if (10 <= ystart && ystart <= 50)
                 wm = 1;
              else if (60 <= ystart && ystart <= 100)
                 wm = 2;
              else if (110 <= ystart && ystart <= 150)
                 wm = 4;
              else if (160 <= ystart && ystart <= 200)
                 wm = 8;
              writemask(wm);
              qread(&dummy);
              qread(&dummy);
              qread(&dummy);
           }
        } else {
           qread(&dummy);
           qread(&xend);
           qread(&yend);
           if (xend > 60) {
              cursoff();
              if (type == LEFTMOUSE)
                 color(31);/* draw */
              else
                 color(0);/* erase */
              rectfi(xstart, ystart, xend, yend);
              curson();
              gflush();
           }
        }
  }
```

```
}

restart()
{
    writemask(0xfff);
    cursoff();
    color(0);
    clear();
    color(1);
    rectfi(10, 10, 50, 50);
    color(2);
    rectfi(10, 60, 50, 100);
    color(4);
    rectfi(10, 110, 50, 150);
    color(8);
    rectfi(10, 160, 50, 200);
    move2i(60, 0);
    draw2i(60, 767);
    color(31);
    writemask(0);
    curson();
}
```

The user interface is quite simple — typing any keyboard character will cause the program to halt, and the right mouse button will clear the screen for a fresh start. The left and middle mouse buttons are draw and erase, respectively. The rectangle swept out between the time a button goes down and when it comes up is either drawn or erased. To draw a rectangle, press down the left mouse button at one corner, hold it down, and move the mouse to the opposite corner. When the button is released, the rectangle is drawn on the current layer.

The draw and erase buttons only work in the right part of the screen. If either of those buttons is pressed in the menu area (the leftmost 60 pixels on the screen) within one of the four menu regions, that color becomes the current layer.

The writemask is used to control which bit planes will be written into. In this example, except during the initialization and reinitialization, at most one bitplane is enabled for writing at a time — the writemask is set to 1, 2, 4, or 8. Once the writemask is set, the drawing code does not need to know its setting — it simply needs to know whether it is drawing or erasing. If it is drawing, a 1 must be written into the enabled plane; if it is erasing, a 0 must be written. Thus, to draw, set the color to 31 (= 16 + 8 + 4 + 2 + 1 — all planes). The writemask will only let one plane get written. To erase, set the color to 0.

Basically, the writemask tells which planes are to be changed, and for all those planes with writemask 1, the color tells what to write in as the new value.

Example 10: A Color Editor

The sample program "colored.c" is a very simple color editor. All the colors that the IRIS can display are combinations of various amounts of red, green, and blue components. Each of the three components can vary between 0 and 255. If red = green = blue = 0, the color is black; red = green = blue = 255 gives white. If red = 255 and green = blue = 0, we get the color red. Altogether, there are 256*256*256 = 16,777,216 such colors.

An IRIS in RGB mode with 24 bitplanes can display any combination of these colors; if there are fewer than 24 bitplanes, or if the IRIS is in single or double buffer mode, there are at most 4095 different colors available, and they are defined by a color map. Every entry in the map specifies an amount of red, green, and blue to use. The command `mapcolor(17,255,150,0)` defines color 17 to have a red component of 255, a green component of 150, and a blue component of zero — a light orange color. `color(17)` would then set the current color to that shade of orange. If anything on the screen was painted in color 17, it would also change to orange.

`ginit()` initializes all of the color map entries to black except for seven of them. Effectively, `ginit()` makes the following calls on `mapcolor()`:

```
for (i = 0; i < 4095; i++)
   mapcolor(i, 0, 0, 0);   /* BLACK */
mapcolor (1,255,0,0);       /* RED */
mapcolor (2,0,255,0);       /* GREEN */
mapcolor (3,255,255,0);     /* YELLOW */
mapcolor (4,0,0,255);       /* BLUE */
mapcolor (5,255,0,255);     /* MAGENTA */
mapcolor (6,0,255,255);     /* CYAN */
mapcolor (7,255,255,255);   /* WHITE */
```

The file "device.h" defines RED to be 1, GREEN to be 2, and so on. The definitions of any of these colors can be reset, as well as any of the other entries in the color map.

The "colored.c" program makes it possible to play with the red, green, and blue components to see how colors are affected by them. It always has a current color that is displayed in a large rectangle at the bottom of the screen. Above this rectangle, the numeric values of the red, green, and blue components are displayed. There are also three color bars (one for red, one for green, and one for blue). Along the red color bar are series of colors where the blue and green components are fixed (to those of the current color), but the red component varies through the range 0 to 255. The blue bar is the same, but with the blue component varying, and so on.

If the cursor is moved into one of the color bars (or slightly above it) and pressed, that color becomes the current color, and the shades on the other three color bars are recomputed. This makes it easy to zero in on a new color. This program is designed to work on an IRIS with eight bitplanes (the minimum configuration) which can only use 256 different colors, so only 64 shades are shown on each color bar. With minor modifications, the program could be made to show all 256 colors if the IRIS has twelve or more bitplanes.

The code for "colored.c" follows:

```
/* "colored.c" */
#include "gl.h"
#include "device.h"

#define MYBLACK 255
#define MYWHITE 254
#define CURRENTCOLOR 253

#define indextovalue(index) (4*index + 3)

short redindex = 0, greenindex = 0, blueindex = 0;

main()
{
   register i, j;
   Device dummy, xpos, ypos;

   ginit();
   color(0);
   writemask(0xfff);         /* get zeroes in all planes */
   clear();
   mapcolor(MYBLACK, 0, 0, 0);/* black */
   mapcolor(MYWHITE, 255, 255, 255);/* white */
   mapcolor(CURRENTCOLOR, 0, 0, 0);
   qdevice(LEFTMOUSE);
   tie(LEFTMOUSE, MOUSEX, MOUSEY);
   qdevice(RIGHTMOUSE);
   setcursor(0, MYWHITE, 0xfff);
   buildmap();
   displaymap();
   while (1) {
      j = -1;
      switch (qread(&dummy)) {
         case RIGHTMOUSE:
            greset();
            gexit();
```

```
                exit(0);
            case LEFTMOUSE:
                qread(&xpos);
                qread(&ypos);
                qread(&dummy);
                qread(&dummy);
                qread(&dummy);
                if (650 <= ypos && ypos <= 720)
                    i = 0;    /* red color bar */
                else if (550 <= ypos && ypos <= 620)
                    i = 1;    /* green color bar */
                else if (450 <= ypos && ypos <= 520)
                    i = 2;    /* blue color bar */
                else i = -1;
                if (i != -1) {
                    if (200 <= xpos && xpos < 840)
                        j = (xpos - 200)/10;
                }
                if (j != -1) {     /* valid input event */
                    switch (i) {
                        case 0:
                            redindex = j;
                            break;
                        case 1:
                            greenindex = j;
                            break;
                        case 2:
                            blueindex = j;
                            break;
                    }
                    buildmap();
                    displaymap();
                }
        }
    }
}

buildmap()
{
    register i, j;

    blankscreen(TRUE);
    for (i = 0; i < 3; i++)
        for (j = 0; j < 64; j++)
            switch (i) {
```

```
            case 0:          /* red */
               mapcolor(i*64+j, indextovalue(j),
                            indextovalue(greenindex),
                            indextovalue(blueindex));
               break;
            case 1:          /* green */
               mapcolor(i*64+j, indextovalue(redindex),
                            indextovalue(j),
                            indextovalue(blueindex));
               break;
            case 2:          /* blue */
               mapcolor(i*64+j, indextovalue(redindex),
                            indextovalue(greenindex),
                            indextovalue(j));
               break;
         }
   mapcolor(CURRENTCOLOR, indextovalue(redindex),
                  indextovalue(greenindex),
                  indextovalue(blueindex));
   blankscreen(FALSE);
}

displaymap()
{
   register i, j;
   static initialized = 0;
   char redstr[10], greenstr[10], bluestr[10];

   if (!initialized)
      {
         makeobj(1);
         color(MYBLACK);
         clear();
         for (i = 0; i < 3; i++)
            for (j = 0; j < 64; j++) {
               color(i*64 + j);
               rectfi(200 + 10*j, 700 - i*100, 210 + 10*j, 650 - i*100);
               color(MYWHITE);
               recti(200 + 10*j, 700 - i*100, 210 + 10*j, 650 - i*100);
            }
         color(CURRENTCOLOR);
         rectfi(400, 200, 600, 300);
         color(MYWHITE);
         recti(400, 200, 600, 300);
         cmov2i(150, 670);
```

```
                charstr("RED");
                cmov2i(150, 570);
                charstr("GREEN");
                cmov2i(150, 470);
                charstr("BLUE");
                cmov2i(275, 245);
                charstr("CURRENT COLOR");
                cmov2i(380, 100);
                charstr("Left mouse button: choose a color");
                cmov2i(380, 84);
                charstr("Right mouse button: exit");
                closeobj();
                initialized = 1;
            }
            cursoff();
            callobj(1);
            move2i(205 + 10*redindex, 700);
            draw2i(205 + 10*redindex, 720);
            cmov2i(210 + 10*redindex, 705);
            sprintf(redstr, "%d", indextovalue(redindex));
            charstr(redstr);
            move2i(205 + 10*greenindex, 600);
            draw2i(205 + 10*greenindex, 620);
            cmov2i(210 + 10*greenindex, 605);
            sprintf(greenstr, "%d", indextovalue(greenindex));
            charstr(greenstr);
            move2i(205 + 10*blueindex, 500);
            draw2i(205 + 10*blueindex, 520);
            cmov2i(210 + 10*blueindex, 505);
            sprintf(bluestr, "%d", indextovalue(blueindex));
            charstr(bluestr);
            cmov2i(450, 310);
            charstr("(");
            charstr(redstr);
            charstr(", ");
            charstr(greenstr);
            charstr(", ");
            charstr(bluestr);
            charstr(")");
            curson();
            gflush();
        }
```

The program uses colors 0 through 63 for the 64 shades on the red color bar; colors 64 through 127 for the green bar, and 128 through 191 for the blue bar. When the current color is changed, 192 new calls on `mapcolor()` are made to change the definitions of colors 1 through 191. To guarantee that the text and background are white and black, respectively, one of the first things done in the main program is to define color 255 to be black and color 254 to be white. These definitions never change. For convenience, color 253 is set to the current color (initially black).

The left mouse button selects new current colors, and the right mouse quits. Both of these buttons are queued, and the left mouse button is tied to the mouse coordinates. The cursor is set to use the color 254 (guaranteed white), and the values of the color bars are computed by `buildmap()`, and everything is displayed by the `displaymap()` command. From then on, the program sits in a loop waiting for an input event. If the left mouse button is pressed, the code in `main()` checks to see if it is within any of the color bars. If it is, the current red, green, or blue component is reset, the color map is rebuilt, and everything is redrawn.

The `buildmap()` procedure just issues a series of `mapcolor()` commands. Its only interesting feature is the `blankscreen(TRUE)` and `blankscreen(FALSE)` commands surrounding the `mapcolor()` commands. When many color map entries are changed, there may be glitches on the screen, and the `blankscreen()` command turns off the display while the changes are being made.

`displaymap()` redraws the screen, including all of the rectangles in the color bars, the current color rectangle, the text, and the little markers above each bar that show the current setting. Almost everything is the same in each redrawing. Color 0 is always drawn in the first rectangle of the red bar, color 1 in the second rectangle, and so on. (The definition of colors 0 and 1 will have changed, but the commands to display them are unchanged.) In fact, only a few things change — the positions and labels on the color bar current position markers, and the red, green, and blue components of the current color. To make redrawing faster, all the drawing commands that are constant are compiled into a display list object (object 1), and are redrawn with the single command `callobj(1)`. The very first time `displaymap()` is called, this object will not have been created, so the static variable `initialized` is checked before each drawing.

The easiest way to understand what the code in `displaymap()` is doing is to run the program and compare the picture on the screen with a listing of the `displaymap()` code.

INTRODUCTION

The *IRIS Reference Manual* contains descriptions of the commands in the Graphics Library.

Each description defines the number, order, and types of the arguments to each command. C, FORTRAN, and Pascal descriptions are provided under the heading **SPECIFICATION**. A description of the command, including function, side effects, and potential errors is given in the section called **DESCRIPTION**; related commands are listed under **SEE ALSO**.

Some of the commands come in several versions, depending on the number and type of the arguments. Coordinate data can be 2D or 3D, and can be floating-point numbers, integers, or short (16-bit) integers. The default is 3D floating-point data. Integer data and 2D points are specified with suffixes: "i" for integer, "s" for short, and "2" for 2D.

An icon appears on each page to indicate whether the command can be compiled into a display list:

These commands can be used in immediate mode or compiled into a display list.

These commands can be used only in immediate mode.

TEXT STRINGS

C and Pascal text strings are terminated with a null character (ASCII 0); FORTRAN has a **character** data type that includes the length of the string.

POINTERS

Many of the Graphics Library commands return several values to the caller. The arguments to these commands are *pointers*, or addresses of memory locations. In C, they are declared as pointer variables by prefixing the variable name with an asterisk in the declaration. FORTRAN passes all parameters by reference, so no special declaration is necessary. Pascal uses the *var* keyword to distinguish between value parameters and pointer arguments.

PASCAL ARRAYS

Pascal normally copies all arguments to a subroutine, including arrays. In the interest of efficiency, we have declared all array arguments to be reference parameters: an address to the data will be passed to the subroutine, rather than the data itself.

Furthermore, the Pascal language forces the size of the array to be part of the type of the array. Many Graphics Library commands accept variable-length arrays. Therefore, we have defined oversized arrays with *MAXARRAY* entries. The user can use some part of the array, or redefine *MAXARRAY* to a more realistic value.

BOOLEANS

Many of the commands have boolean arguments or return boolean values. These are declared as type *Boolean* in C and Pascal, and as *logical* or *integer* in FORTRAN. We assume that *FALSE* is zero, and that *TRUE* is anything except *FALSE*.

TYPE DECLARATIONS

We have constructed type declarations for C and Pascal wherever they add to the readability of the code. Here are the type definitions:

C

```
#define FALSE 0
#define TRUE !FALSE
#define PATTERN_16 16
#define PATTERN_32 32
#define PATTERN_64 64
#define PATTERN_16_SIZE 16
#define PATTERN_32_SIZE 64
#define PATTERN_64_SIZE 256

typedef unsigned char Byte;
typedef long Boolean;
typedef short Angle;
typedef short Scoord;
typedef short Screencoord;
typedef long Icoord;
typedef float Coord;
typedef char *String;
typedef float Matrix[4][4];

typedef unsigned short Device;

typedef unsigned short Colorindex;
typedef unsigned char RGBvalue;

typedef unsigned short Linestyle;
typedef unsigned short Cursor[16];
typedef struct {
        unsigned short offset;/* 2 bytes */
        Byte w,h;           /* 2 bytes */
        char xoff,yoff;     /* 2 bytes */
        short width;        /* 2 bytes */
} Fontchar;

typedef long Object;
typedef long Tag;

typedef unsigned short Pattern16[PATTERN_16_SIZE];
typedef unsigned short Pattern32[PATTERN_32_SIZE];
typedef unsigned short Pattern64[PATTERN_64_SIZE];
```

Pascal

```
const MAXARRAY = 1023;
      MAXRASTER = 4095;
      MAXOBJECTS = 4095;
      PATTERN_16 = 16;
      PATTERN_32 = 32;
      PATTERN_64 = 64;
      PATTERN_16_SIZE = 16;
      PATTERN_32_SIZE = 64;
      PATTERN_64_SIZE = 256;

type  Byte = 0..255;
      Short = integer;
      UnsignedShort = 0..65535;
      Angle = integer;
      Screencoord = short;
      Icoord = longint;
      Coord = real;
      Scoord = UnsignedShort;
      Strng = packed array [1..128] of char;
      Matrix = array [0..3, 0..3] of real;

      Device = UnsignedShort;
      string128 = string [128];
      pstring = ^Strng;
      pshort = ^Short;
      ppshort = ^pshort;

      Colorindex = UnsignedShort;
      RGBvalue = Byte;

      Linestyle = UnsignedShort;
      Pattern = array [0..15] of Byte;
      Pattern16 = [0..PATTERN_16-SIZE] of UnsignedShort;
      Pattern32 = [0..PATTERN_32_SIZE] of UnsignedShort;
      Pattern64 = [0..PATTERN_64-SIZE] of UnsignedShort;
      Cursor = array [0..15] of UnsignedShort;
      Fontchar = record
                    offst: Short;
                    w, h: Byte;
```

```
                xoff, yoff: -128..127;
                width: Short;
        end;

Object = longint;
Tag = longint;

Coord4array = array [0..MAXARRAY, 0..3] of Coord;
Coord3array = array [0..MAXARRAY, 0..2] of Coord;
Coord2array = array [0..MAXARRAY, 0..1] of Coord;
Icoord3array = array [0..MAXARRAY, 0..2] of Icoord;
Icoord2array = array [0..MAXARRAY, 0..1] of Icoord;
Scoord3array = array [0..MAXARRAY, 0..2] of Scoord;
Scoord2array = array [0..MAXARRAY, 0..1] of Scoord;
Screenarray = array [0..MAXARRAY, 0..2] of Screencoord;

Boolarray = array [0..MAXARRAY] of Boolean;
Colorarray = array [0..MAXARRAY] of Colorindex;
RGBarray = array [0..MAXARRAY] of RGBvalue;

Objarray = array [0..127] of Object;
Fntchrarray = array [0..127] of Fontchar;
Fontraster = array [0..MAXRASTER] of Short;
lbuffer = array [0..MAXOBJECTS] of Object;
Queuearray = array [0..MAXARRAY] of Short;
Curvearray = array [0..3] [0..2] of Coord;
Ibuffer = array [0..MAXARRAY] of Short;
Patcharray = array [0..3] [0..3] of Coord;
```

LIST OF GRAPHICS LIBRARY COMMANDS

arc - draws a circular arc

arcf - draws a filled circular arc

attachcursor - attaches the cursor to two valuators

backbuffer - enables updating in the back buffer

backface - turns on and off backfacing polygon removal

bbox2 - specifies bounding box and minimum pixel radius for drawing commands

blankscreen - turns off screen refresh

blink - changes the color map entry at a selectable rate

blkqread - reads multiple entries from the queue

callfunc - calls a function from within an object

callobj - draws an instance of an object

capture, rcapture - dumps screen images to file or hard copy device

charstr - draws a string of raster characters on the screen

chunksize - specifies minimum object size in memory

circ - outlines a circular region

circf - draws a filled circle

clear - clears the viewport

clearhitcode - sets the system hitcode to zero

clkoff - turns off the keyboard click

clkon - turns on the keyboard click

closeobj - closes an object

cmov - changes the current character position

color - sets the color attribute

compactify - compacts the memory storage of an object

crv - draws a curve

crvn - draws a series of curves segments

curorigin - sets the origin of a cursor

cursoff - turns the cursor off

curson - turns the cursor on

curvebasis - sets the basis matrix used in drawing curves

curveit - draws a curve segment

curveprecision - sets the number of line segments comprising a curve segment

cyclemap - cycles through color maps at a selected rate

dbtext - sets the dial and switch box text

defbasis - defines a basis matrix

defcursor - defines a cursor glyph

deflinestyle - defines a linestyle

defpattern - defines a texture pattern

defrasterfont - defines a raster font

delobj - deletes an object

deltag - deletes tags from objects

depthcue - turns on and off depth-cue mode

doublebuffer - sets the display mode to double buffer mode

draw - draws a line

editobj - opens an object for editing

endfeedback - turns off feedback mode

endpick - turns off picking mode

endselect - turns off selecting mode

feedback - turns on feedback mode

finish - waits until the terminal command queue and Geometry Pipeline are empty

font - selects a raster font for drawing text strings

foreground - requests that a process not be put in the background by getport while using the window manager

frontbuffer - enables updating in the front buffer

fudge - specifies fudge values to be added to a graphics port when it is resized

gbegin - initializes the IRIS without altering the color map

gconfig - reconfigures the IRIS

genobj - returns a unique integer for use as an object name

gentag - returns a unique integer for use as a tag

getbuffer - indicates which buffers are enabled for writing

getbutton - gets the state (up/down) of a button

getcmmode - returns the current color map mode

getcolor - returns the current color

getcpos - returns the current character position

getcursor - returns the cursor characteristics

getdcm - indicates whether depth-cue mode is on or off

getdepth - returns the parameters of setdepth

getdisplaymode - returns the current display mode

getfont - returns the current raster font number

getgpos - returns the current graphics position

getheight - returns the maximum height of the characters in the current raster font

gethitcode - returns the current system hitcode

getlsbackup - returns the status of the linestyle backup mode

getlsrepeat - returns the linestyle repeat count

getlstyle - returns the current linestyle

getlwidth - returns the current linewidth

getmap - returns the number of the currently selected color map

getmatrix - returns the current transformation matrix

getmcolor - returns a color map entry

getmem - returns amount of available memory

getmonitor - returns the display monitor mode

getopenobj - indicates if an object is currently open for editing

getorigin - returns the position of a graphics port in the window manager

getpattern - returns the index of the currently selected pattern

getplanes - returns the number of available bitplanes

getport - creates a graphics port in the window manager

getresetls - returns the status of resetls

gRGBcolor - returns the current RGB value

gRGBcursor - returns the characteristics of the cursor in RGB mode

gRGBmask - returns the current RGB writemask

getscrmask - returns the current screenmask

getsize - returns the size of a graphics port in the window manager

gettp - returns the location of the current textport

getvaluator - returns the current state of a valuator

getviewport - returns the current viewport

getwritemask - returns the current writemask

getzbuffer - indicates whether z-buffering is on or off

gexit - terminates an IRIS program

gflush - forces all unsent commands down the network to the Geometry Pipeline

ginit - initializes the IRIS

greset - resets all global attributes to their initial values

gsync - waits for a vertical retrace period

imakebackground - makes a process in charge of drawing the background of the window manager screen

initnames - initializes the name stack

isobj - indicates whether a given object name identifies an object

istag - indicates whether a given tag is in use within the currently open object

keepaspect - specifies the aspect ratio of a graphics port

lampoff - turns off display lights on the keyboard

lampon - turns on display lights on the keyboard

linewidth - specifies the linewidth

loadmatrix - loads a transformation matrix

loadname - replaces the name on the top of the name stack

lookat - defines a viewing transformation

lsbackup - controls whether the last two pixels of a line are colored

lsrepeat - sets repeat factor for linestyle

makeobj - creates an object

maketag - names the command in the display list

mapcolor - changes a color map entry

mapw - maps a point on the screen into a line in 3D world coordinates

mapw2 - maps a point on the screen into 2D world coordinates

maxsize - specifies a maximum size for a graphics port in the window manager

minsize - specifies a minimum size for a graphics port in the window manager

move - moves to a specified point

multimap - utilizes the color map as sixteen small maps
multmatrix - pre-multiplies the current transformation matrix
newtag - creates a new tag in an object
noise - filters valuator motion
noport - specifies that a program does not require a graphics port
objdelete - deletes commands from an object
objinsert - inserts commands in an object at the chosen location
objreplace - overwrites existing display list commands with new ones
onemap - organizes the color map as one large map
ortho - defines an orthographic projection transformation
pagecolor - sets the color of the textport background
pagewritemask - sets the writemask for the textport background
passthrough - passes a single token through the Geometry Pipeline
patch - draws a surface patch
patchbasis - sets current basis matrices
patchcurves - sets number of curves used to represent a patch
patchprecision - sets precision at which curves are drawn
pclos - polygon close
pdr - polygon draw
perspective - defines a perspective projection transformation
pick - puts the system in picking mode
picksize - sets the dimensions of the picking window
pmv - polygon move
pnt - draws a point
polarview - defines the viewer's position in polar coordinates
polf - draws a filled polygon
poly - outlines a polygon
popattributes - pops the attribute stack
popmatrix - pops the transformation matrix stack
popname - pops a name off the name stack
popviewport - restores the viewport, screenmask, and setdepth parameters
prefposition - specifies the preferred location and size of a graphics port
prefsize - specifies the preferred size of a graphics port in the window manager

pushattributes - pushes attributes on a stack

pushmatrix - pushes down the transformation matrix stack

pushname - pushes a new name on the name stack

pushviewport - save the current viewport, screenmask, and setdepth parameters

qdevice - queues a device (keyboard, button, or valuator)

qenter - creates an event queue entry

qread - reads the first entry in the event queue

qreset - empties the event queue

qtest - checks the contents of the event queue

rdr - relative draw

readRGB - returns values of specific pixels

readpixels - returns values of specific pixels

rect - outlines a rectangular region

rectcopy - copies a rectangle of pixels on the IRIS screen

rectf - fills a rectangular area

resetls - controls the continuity of linestyles

reshapeviewport - sets the viewport to the current dimensions of the graphics port in the window manager

RGBcolor - sets the current color in RGB mode

RGBcursor - sets the characteristics of the cursor in RGB mode

RGBmode - sets a display mode that bypasses the color map

RGBwritemask - grants write access to a subset of the available bitplanes

ringbell - rings the keyboard bell

rmv - relative move

rotate - rotates graphical primitives

rpdr - relative polygon draw

rpmv - relative polygon move

scale - scales and mirrors objects

screenspace - puts a program in screen space under the window manager

scrmask - defines a clipping mask for the screen

select - puts the IRIS in selecting mode

setbell - sets the duration of the keyboard bell

setcursor - sets the cursor characteristics

setdblights - sets the lights on the dial and button box

setdepth - sets up a 3D viewport

setlinestyle - selects a linestyle

setmap - chooses one of the sixteen small color maps

setmonitor - sets the monitor type

setpattern - selects a texture pattern for filling polygons, rectangles, and curves

setshade - sets the current polygon shade

setvaluator - assigns an initial value to a valuator

shaderange - sets range of color indices

singlebuffer - writes and displays all the bitplanes

spclos - draws currently open polygon

splf - draws a shaded filled polygon

stepunit - specifies that a graphics port should change size in discrete steps

strwidth - returns the width of the specified text string

swapbuffers - swaps the front and back buffers in double buffer mode

swapinterval - defines a minimum time between buffer swaps

textcolor - sets the color of text drawn in the textport

textinit - initializes the textport

textport - allocates an area of the screen for the textport

textwritemask - grants write permission for the textport

tie - ties two valuators to a button

tpoff - turns off the textport

tpon - turns on textport

translate - translates graphical primitives

unqdevice - unqueues a device from the event queue

viewport - allocates an area of the screen for an image

window - defines a perspective projection transformation

writeRGB - paints a row of pixels on the screen

writemask - grants write permission to available bitplanes

writepixels - paints a row of pixels on the screen

xfpt - transforms points

zbuffer - starts or ends z-buffer operation

zclear - initializes the z-buffer to largest possible integer

NAME

arc - draws a circular arc

SPECIFICATION

C

```
arc(x, y, radius, startang, endang)
Coord x, y, radius;
Angle startang, endang;

arci(x, y, radius, startang, endang)
Icoord x, y, radius;
Angle startang, endang;

arcs(x, y, radius, startang, endang)
Scoord x, y, radius;
Angle startang, endang;
```

FORTRAN

```
subroutine arc(x, y, radius, stang, endang)
real x, y, radius
integer*4 stang, endang

subroutine arci(x, y, radius, stang, endang)
integer*4 x, y, radius, stang, endang

subroutine arcs(x, y, radius, stang, endang)
integer*2 x, y, radius
integer*4 stang, endang
```

Pascal

```
procedure arc(x, y, radius: Coord; startang, endang: Angle);
procedure arci(x, y, radius: Icoord; startang, endang: Angle);
procedure arcs(x, y, radius: Scoord; startang, endang: Angle);
```

DESCRIPTION

arc draws a circular arc. The arc is defined by a center point, a starting angle, an ending angle, and a radius. The angle is measured from the positive x-axis and specified in integral tenths of degrees. Positive angles describe counterclockwise rotations. Since an arc is a two-dimensional shape, these commands have only 2D forms. The arc is drawn in the x-y plane, with z=0, and uses the current color, linestyle, linewidth and writemask. It is drawn counterclockwise from startang to endang, so that an arc from 10 degrees to 5 degrees is a nearly complete circle. After the execution of the **arc** command, the graphics position is undefined.

SEE ALSO

arcf, circ, circf, crv

NAME

arcf - draws a filled circular arc

SPECIFICATION

```
C           arcf(x, y, radius, startang, endang)
            Coord x, y, radius;
            Angle startang, endang;

            arcfi(x, y, radius, startang, endang)
            Icoord x, y, radius;
            Angle startang, endang;

            arcfs(x, y, radius, startang, endang)
            Scoord x, y, radius;
            Angle startang, endang;


FORTRAN     subroutine arcf(x, y, radius, stang, endang)
            real x, y, radius
            integer*4 stang, endang

            subroutine arcfi(x, y, radius, stang, endang)
            integer*4 x, y, radius, stang, endang

            subroutine arcfs(x, y, radius, stang, endang)
            integer*2 x, y, radius
            integer*4 stang, endang


Pascal      procedure arcf(x, y, radius: Coord; startang, endang: Angle);

            procedure arcfi(x, y, radius: Icoord; startang, endang: Angle);

            procedure arcfs(x, y, radius: Scoord; startang, endang: Angle);
```

DESCRIPTION

arcf draws a filled circular arc (pie section). The arc is specified as a center point, a starting angle, an ending angle, and a radius. The angle is measured from the x-axis and specified in integral tenths of degrees. Positive angles describe counterclockwise rotations. The arc is drawn using the current color and writemask, and filled with the current texture. Since an arc is a two-dimensional shape, these commands have only 2D forms. The arc is in the x-y plane with z=0. Arcs are drawn counterclockwise from startang to endang, so the arc from 10 degrees to 5 degrees is a nearly complete circle.

SEE ALSO

arc, circ, circf, crv

NAME

attachcursor - attaches the cursor to two valuators

SPECIFICATION

C	**attachcursor(vx, vy)**
	Device vx, vy;

FORTRAN	**subroutine attach(vx, vy)** **integer*4 vx, vy**
Pascal	**procedure attachcursor(vx, vy: Device);**

DESCRIPTION

attachcursor attaches the cursor to the movement of two valuators. It takes two arguments, both valuator device numbers. The first valuator controls the horizontal motion of the cursor; the second argument determines vertical motion. The values of the valuators determine the cursor position in screen coordinates.

SEE ALSO

noise, tie

NOTE

This command can be used only in immediate mode.

NAME

backbuffer - enables updating in the back buffer

SPECIFICATION

C	**backbuffer(b)**
	Boolean b;

FORTRAN	**subroutine backbu(b)** **logical b**
Pascal	**procedure backbuffer(b: Boolean);**

DESCRIPTION

backbuffer enables updating in the back bitplane buffer. If *b* = *TRUE*, the default, the buffer is enabled; *FALSE* means it is not enabled. This command is useful only in double buffer mode, and is ignored in single buffer and RGB modes.

backbuffer is set to *TRUE* by **gconfig.**

SEE ALSO

doublebuffer, frontbuffer, getbuffer

NAME

backface - turns on and off backfacing polygon removal

SPECIFICATION

C	**backface(b)**
	Boolean b;

FORTRAN	**subroutine backfa(b)** **logical b**
Pascal	**procedure backface(b: Boolean);**

DESCRIPTION

backface initiates or terminates backfacing polygon removal. A backfacing polygon is defined to be a polygon whose vertices appear in clockwise order in screen space. When backfacing polygon removal is turned on, only polygons whose vertices appear in counterclockwise order are displayed. The backface utility improves the performance of programs which represent solid objects as collections of polygons. Because the orientation of polygons is determined in screen space, backfacing polygon removal is not a rigorous technique. When a polygon shrinks to the point where its vertices are coincident, its orientation is indeterminate and it is displayed. Thus, backfacing polygon removal should be used in conjunction with some other hidden surface removal technique, such as z-buffering.

SEE ALSO

zbuffer

NAME

bbox2 - specifies bounding box and minimum pixel radius for drawing commands

SPECIFICATION

C

```
bbox2(xmin, ymin, x1, y1, x2, y2)
Screencoord xmin, ymin;
Coord x1, y1, x2, y2;

bbox2i(xmin, ymin, x1, y1, x2, y2)
Screencoord xmin, ymin;
Icoord x1, y1, x2, y2;

bbox2s(xmin, ymin, x1, y1, x2, y2)
Screencoord xmin, ymin;
Scoord x1, y1, x2, y2;
```

FORTRAN

```
subroutine bbox2(xmin, ymin, x1, y1, x2, y2)
integer*4 xmin, ymin
real x1, y1, x2, y2

subroutine bbox2i(xmin, ymin, x1, y1, x2, y2)
integer*4 xmin, ymin, x1, y1, x2, y2

subroutine bbox2s(xmin, ymin, x1, y1, x2, y2)
integer*4 xmin, ymin
integer*2 x1, y1, x2, y2
```

Pascal

```
procedure bbox2(xmin, ymin: Screencoord; x1, y1,
x2, y2: Coord);

procedure bbox2i(xmin, ymin: Screencoord; x1, y1,
x2, y2: Icoord);

procedure bbox2s(xmin, ymin: Screencoord; x1, y1,
x2, y2: Scoord);
```

DESCRIPTION

The **bbox2** command controls whether the commands in an object are executed. Its arguments are an object space bounding box and minimum horizontal and vertical feature sizes, in pixels. The bounding box is transformed to screen coordinates and compared with the viewport. If the bounding box is completely outside the viewport, the commands between the **bbox2** command and the end of the object will be ignored. Otherwise, the bounding box of the transformed bounding box is compared with the minimum feature size. If the bounding box is too small in both the x and y dimensions, the rest of the commands in the object are ignored. Otherwise, interpretation of the object continues.

SEE ALSO

makeobj

NAME

blankscreen - turns off screen refresh

SPECIFICATION

C **blankscreen(bool)**
Boolean bool;

FORTRAN **subroutine blanks(bool)**
logical bool

Pascal **procedure blankscreen(bool: Boolean);**

DESCRIPTION

blankscreen turns on and off screen refresh. *bool* = *TRUE* stops display and *bool* = *FALSE* restarts display. When bitplanes are being simultaneously viewed and updated (as in single-buffer mode, RGB mode, and when the front buffer is being displayed in double buffer mode) there is memory contention, and hence reduced performance. This is especially true for non-interlaced monitors. To speed up drawing in these cases, turn the display off while drawing.

NOTE

This command can be used only in immediate mode.

NAME

blink - changes the color map entry at a selectable rate

SPECIFICATION

C	**blink(rate, color, red, green, blue)** **short rate, red, green, blue;** **Colorindex color;**
FORTRAN	**subroutine blink(rate, color, red, green, blue)** **integer*4 rate, color, red, green, blue**
Pascal	**procedure blink(rate: Short; color: Colorindex; red, green, blue: RGBvalue);**

DESCRIPTION

blink specifies a blink rate, a color map index, and red, green, and blue values. Every *rate* vertical retraces, the color located at index *color* in the current colormap is updated. Its value is either the original value or the new value supplied by the *red, green,* and *blue* arguments.

Up to twenty colors can blink simultaneously, each at a different rate. The blink rate can be changed by calling **blink** again with the same *color* and a different *rate.* Calling **blink** with *rate*=0 when *color* specifies a blinking colormap entry terminates the blinking and restores the original color.

SEE ALSO

mapcolor, color

NOTE

This command can be used only in immediate mode.

NAME

blkqread - reads multiple entries from the queue

SPECIFICATION

```
C           long blkqread(data, n)
            short data[];
            short n;

FORTRAN     integer*4 function blkqre(data, n)
            integer*2 data(*)
            integer*4 n

Pascal      function blkqread(var data: Queuearray, n: Short):longint;
```

DESCRIPTION

blkqread allows multiple entries to be read from the input queue. This may be useful to programs running remotely. It is called with an array of shorts and the length of this array in shorts. **blkqread** returns the number of shorts in the array *data* (i.e., twice the number of event queue entries).

SEE ALSO

qread

NOTE

This command can be used only in immediate mode.

NAME

callfunc - calls a function from within an object

SPECIFICATION

C	**callfunc (fctn, nargs, arg1, arg2, ..., argn)**
	int (*fctn)();
	long nargs, arg1, arg2, ..., argn;

FORTRAN	**NOTE: works only in C**
Pascal	**NOTE: works only in C**

DESCRIPTION

callfunc allows an arbitrary function call from within an object. When it is executed in the object, the function *fctn (nargs, arg1, arg2, ..., argn)* is called. **callfunc** is useful only for writing customized terminal programs. It cannot be called remotely.

NAME

callobj - draws an instance of an object

SPECIFICATION

C	**callobj(obj)**
	Object obj;

FORTRAN	**subroutine callob(obj)** **integer*4 obj**
Pascal	**procedure callobj(obj: Object);**

DESCRIPTION

callobj draws an instance of a previously defined object. Its argument is the object name. If **callobj** specifies an undefined object, the command is ignored.

Global attributes are not saved before a **callobj**. Thus, if attributes like color are changed within an object, the change may affect the caller as well. Use **pushattributes** and **popattributes** to preserve global attributes across **callobj** commands.

SEE ALSO

makeobj, pushattributes, popattributes

NAME

capture, rcapture - dumps screen images to file or hard copy device

SPECIFICATION

C

```
capture(dest,cmap)
char *dest;
RGBvalue cmap[][3];

rcapture(dest,cmap,left,right,bottom,top,
            dithsize,dithmat,res)
char *dest;
RGBvalue cmap[][3];
Screencoord left,right,bottom,top;
long dithsize,res;
short **dithmat;
```

FORTRAN

```
subroutine captur(dest,cmap)
character*(*) dest
integer*2 cmap(3,*)

subroutine rcaptu(dest,cmap,left,right,bottom,top,
            dithsize,dithmat,res)
character*(*) dest
integer*2 cmap(3,*),dithmat(dithsize,dithsize)
integer*4 left,right,bottom,top,dithsize,res
```

Pascal

```
procedure capture(dest:String; var cmap:RGBarray);

procedure rcapture(dest:String; var cmap:RGBarray;
            left, right, bottom, top:Scoord;
            dithsize:integer; var dithmat:ppshort; res:integer);
```

DESCRIPTION

capture dumps a representation of the screen into the file *dest* in a format compatible with a Tektronix 4692 color inkjet printer. If *dest* is 0, then it will create a file called *capture.img*. The function used to open *dest* for output allows for spooling to other machines, such as print servers (see the **coloropen** manual pages in Section 3 of the *UNIX Programmer's Manual, Volume 1).* If **cmap** is 0, then **capture** will read the colormap from the hardware. Otherwise, **cmap** should be a pointer to a array of RGBvalue triplets. The size of the array depends on how many bitplanes you have and whether you are dumping an RGB image or a colormapped image. For a colormapped image, the size of the array should be $2^{NUMBER\_OF\_PLANES}$. The array is used as a software colormap of indices that identify the red, green, and blue values for each pixel. For RGBmode, only the first 256 entries in the array are used. In RGBmode, each channel (red, green, and blue) is looked up individually.

rcapture is an extension of **capture** that allows you to specify a few more variables. The variables **left, right, bottom, top** determine a rectangular section of the screen to capture. **dithsize** and **dithmat** are used for software dithering. **dithmat** should be a square matrix of size **dithsize.** If either **dithsize** or **dithmat** (or both) are 0, then no dithering is done.

The Tektronix printer accepts data containing 1, 2, or 4 bits per RGB component per pixel. The last argument, **res,** selects which of these formats to generate. The printer only has four colors (cyan, magenta, yellow, and black) and uses internal dithering if more than one bit per component is specified. One bit per component is used if dithering is selected.

SEE ALSO

Manual pages for the following commands are located in the *UNIX Programmer's Manual:*

colord(1) coloropen(3) tek(7)

NOTE

This command can be used only in immediate mode.

This command only works on workstations.

NAME

charstr - draws a string of raster characters on the screen

SPECIFICATION

C	**charstr(str)**
	String str;

FORTRAN	**subroutine charst(str, length)** **character*(*) str** **integer*4 length**
Pascal	**procedure charstr(str: pstring);**

DESCRIPTION

charstr draws a string of text using a raster font. The origin of the first character in the string will be placed at the current character position. After each character is drawn, the current character position is updated by the character's spacing parameter. The text string is drawn in the currently selected raster font and color, using the current writemask. Characters that are not defined in the current raster font are ignored.

In FORTRAN, there are two arguments to **charst** : *str* is the name of the text string and *length* is the number of characters in that string.

SEE ALSO

cmov, defrasterfont, font

NAME

chunksize - specifies minimum object size in memory

SPECIFICATION

C	**chunksize(chunk)**
	long chunk;

FORTRAN	**subroutine chunks(chunk)** **integer*4 chunk**
Pascal	**procedure chunksize(chunk: longint);**

DESCRIPTION

chunksize specifies the minimum object size. It should called only once after **ginit** and before the first **makeobj**. As objects grow, they grow in units of size *chunk*. This command should be used only if there is a severe memory shortage. The default chunk size is 1020 bytes.

SEE ALSO

compactify, ginit

NOTE

This command can be used only in immediate mode.

NAME

circ - outlines a circular region

SPECIFICATION

```
C          circ(x, y, radius)
           Coord x, y, radius;

           circi(x, y, radius)
           Icoord x, y, radius;

           circs(x, y, radius)
           Scoord x, y, radius;


FORTRAN    subroutine circ(x, y, radius)
           real x, y, radius

           subroutine circi(x, y, radius)
           integer*4 x, y, radius

           subroutine circs(x, y, radius)
           integer*2 x, y, radius


Pascal     procedure circ(x, y, radius: Coord);

           procedure circi(x, y, radius: Icoord);

           procedure circs(x, y, radius: Scoord);
```

DESCRIPTION

circ outlines a circle. The circle has its center at point (*x*,*y*) and a radius *radius*, both specified in world coordinates. Since a circle is two-dimensional, these commands have only 2D forms. The circle is in the *x*-*y* plane, with $z=0$, and is drawn using the current color, linestyle, linewidth, and writemask.

SEE ALSO

arc, arcf, circf, crv

NAME

circf - draws a filled circle

SPECIFICATION

```
C          circf(x, y, radius)
           Coord x, y, radius;

           circfi(x, y, radius)
           Icoord x, y, radius;

           circfs(x, y, radius)
           Scoord x, y, radius;


FORTRAN    subroutine circf(x, y, radius)
           real x, y, radius

           subroutine circfi(x, y, radius)
           integer*4 x, y, radius

           subroutine circfs(x, y, radius)
           integer*2 x, y, radius


Pascal     procedure circf(x, y, radius: Coord);

           procedure circfi(x, y, radius: Icoord);

           procedure circfs(x, y, radius: Scoord);
```

DESCRIPTION

circf draws a filled circle, using the current color, writemask, and pattern. The circle has its center at *(x,y)* and a radius *radius*, both specified in world coordinates. Since a circle is a two-dimensional shape, these commands have only 2D forms. The circle is drawn in the *x-y* plane, with $z=0$.

SEE ALSO

arc, arcf, circ, crv

NAME

clear - clears the viewport

SPECIFICATION

C	**clear()**
FORTRAN	**subroutine clear**
Pascal	**procedure clear;**

DESCRIPTION

The **clear** command sets the screen area within the current viewport to the current color using the current writemask and pattern.

SEE ALSO

rect, rectf

NAME

clearhitcode - sets the system hitcode to zero

SPECIFICATION

C	**clearhitcode()**
FORTRAN	**subroutine clearh**
Pascal	**procedure clearhitcode;**

DESCRIPTION

clearhitcode clears the global variable *hitcode*, which records clipping plane hits in picking and selecting modes.

SEE ALSO

gethitcode, pick, select

NOTE

This command can be used only in immediate mode.

NAME

clkoff - turns off the keyboard click

SPECIFICATION

C	**clkoff()**
FORTRAN	**subroutine clkoff**
Pascal	**procedure clkoff;**

DESCRIPTION

clkoff turns off the keyboard click.

SEE ALSO

clkon, lampoff, lampon, ringbell, setbell

NOTE

This command can be used only in immediate mode.

NAME

clkon - turns on the keyboard click

SPECIFICATION

C	**clkon()**
FORTRAN	**subroutine clkon**
Pascal	**procedure clkon;**

DESCRIPTION

clkon turns on the keyboard click.

SEE ALSO

clkoff, lampoff, lampon, ringbell, setbell

NOTE

This command can be used only in immediate mode.

NAME

closeobj - closes an object

SPECIFICATION

C	**closeobj()**
FORTRAN	**subroutine closeo**
Pascal	**procedure closeobj;**

DESCRIPTION

closeobj closes an open object. A new object is created and opened with **makeobj.** All display list commands between **makeobj** and **closeobj** become part of the object definition. An existing object is opened for editing with **editobj;** the editing session is terminated when the object is closed with a **closeobj.**

If no object is open, **closeobj** is ignored.

SEE ALSO

editobj, makeobj

NOTE

This command can be used only in immediate mode.

NAME

cmov - changes the current character position

SPECIFICATION

C

```
cmov(x, y, z)
Coord x, y, z;

cmovi(x, y, z)
Icoord x, y, z;

cmovs(x, y, z)
Scoord x, y, z;

cmov2(x, y)
Coord x, y;

cmov2i(x, y)
Icoord x, y;

cmov2s(x, y)
Scoord x, y;
```

FORTRAN

```
subroutine cmov(x, y, z)
real x, y, z

subroutine cmovi(x, y, z)
integer*4 x, y, z

subroutine cmovs(x, y, z)
integer*2 x, y, z

subroutine cmov2(x, y)
real x, y

subroutine cmov2i(x, y)
integer*4 x, y

subroutine cmov2s(x, y)
integer*2 x, y
```

Pascal

```
procedure cmov(x, y, z: Coord);

procedure cmovi(x, y, z: Icoord);

procedure cmovs(x, y, z: Scoord);
procedure cmov2(x, y: Coord);
procedure cmov2i(x, y: Icoord);
procedure cmov2s(x, y: Scoord);
```

DESCRIPTION

cmov is analogous to **move** except that it updates the current character position. Its arguments specify a world space point, and can be integers, shorts, or real numbers in 2D or 3D space. This world space point is transformed; the resulting screen space point becomes the new character position. The character position is undefined if the transformed point is outside the viewport.

cmov leaves the current graphics position undefined.

SEE ALSO

charstr, move, readpixels, readRGB, writepixels, writeRGB

NAME

color - sets the color attribute

SPECIFICATION

C	**color(c)**
	Colorindex c;

FORTRAN	**subroutine color(c)** **integer*4 c**
Pascal	**procedure color(c: Colorindex);**

DESCRIPTION

color sets the current color which is used until another **color** command changes it. The current color is an index into a color map. In onemap mode, the color can be in the range from 0 to 4095. In multimap mode, it is used in conjunction with a color map number and should be between 0 and 255. The color is also bounded by the number of available planes.

SEE ALSO

getcolor, RGBcolor, RGBwritemask, writemask

NAME

compactify - compacts the memory storage of an object

SPECIFICATION

C	**compactify(obj)**
	Object obj;

FORTRAN	**subroutine compac(obj)** **integer*4 obj**
Pascal	**procedure compactify(obj: Object);**

DESCRIPTION

As an open object is modified by the various editing commands, it may be stored inefficiently in memory. When the amount of wasted space becomes too large, **compactify** is called automatically during the **closeobj** operation. **compactify** is available to the user to perform the compaction explicitly. Unless insertion of some sort is done, compaction is never necessary. Since it is somewhat expensive, it should not be called unless storage space is critical.

SEE ALSO

closeobj, chunksize

NOTE

This command can be used only in immediate mode.

NAME

crv - draws a curve

SPECIFICATION

C	**crv(geom)**
	Coord geom[4][3];

FORTRAN	**subroutine crv(geom)** **real geom(3,4)**
Pascal	**procedure crv(geom: Curvearray);**

DESCRIPTION

crv draws a curve segment using the current curve basis and precision. The shape of the curve segment is determined by the four control points specified in *geom*.

SEE ALSO

curvebasis, defbasis, curveprecision, crvn

NAME

crvn - draws a series of curves segments

SPECIFICATION

C

```
crvn(n, geom)
long n;
Coord geom[][3];
```

FORTRAN

```
subroutine crvn(n, geom)
integer*4 n
real geom(3,n)
```

Pascal

```
procedure crvn(n: longint; geom: Coord3array);
```

DESCRIPTION

crvn draws a series of curve segments using the current basis and precision. The shapes of the curve segments are determined by the control points specified in *geom.* If the current basis is a B-spline, Cardinal spline or basis of similar properties the curve segments will be joined end to end and will appear as a single curve.

SEE ALSO

curvebasis, curveprecision, crv, defbasis

NAME

curorigin - sets the origin of a cursor

SPECIFICATION

C	**curorigin(n, xorigin, yorigin)** **short n, xorigin, yorigin;**
FORTRAN	**subroutine curori(n, xorigin, yorigin)** **integer*4 n, xorigin, yorigin**
Pascal	**procedure curorigin(n, xorigin, yorigin: Short);**

DESCRIPTION

curorigin sets the origin of a cursor. The origin is the position on the cursor that will be aligned with the current cursor valuators. The lower left corner of the cursor has coordinates (0,0). The cursor must already be defined with **defcursor** when **curorigin** is called. *n* is an index into the cursor table created by calls to **defcursor** .

SEE ALSO

defcursor, attachcursor

NOTE

This command can be used only in immediate mode.

NAME

cursoff - turns the cursor off

SPECIFICATION

C	**cursoff()**
FORTRAN	**subroutine cursof**
Pascal	**procedure cursoff;**

DESCRIPTION

cursoff prevents the cursor from being displayed. This command should precede any drawing commands that write into the currently displayed cursor bitplanes.

By default, the cursor is always displayed. Before it is drawn on the screen, the image that it covers is saved away. When the cursor moves, the saved image is restored. If the image changes while the cursor is displayed, the saved image may no longer be valid. This is a concern in single buffer and RGB modes and in double buffer mode when the front buffer is enabled.

SEE ALSO

curson, getcursor, setcursor

NOTE

This command can be used only in immediate mode.

NAME

curson - turns the cursor on

SPECIFICATION

C	**curson()**
FORTRAN	**subroutine curson**
Pascal	**procedure curson;**

DESCRIPTION

curson causes the system to update and display a cursor automatically. **curson** commands are usually paired with **cursoff** commands, though there is no harm in calling **curson** when the automatic cursor is already visible.

SEE ALSO

attachcursor, cursoff, getcursor, setcursor

NOTE

This command can be used only in immediate mode.

NAME

curvebasis - sets the basis matrix used in drawing curves

SPECIFICATION

C
```
curvebasis(basisid)
short basisid;
```

FORTRAN
```
subroutine curveb(basisid)
integer*4 basisid
```

Pascal
```
procedure curvebasis(basisid: integer);
```

DESCRIPTION

curvebasis selects a basis matrix (defined by **defbasis**) to be the current basis matrix for drawing curve segments.

SEE ALSO

crv, crvn, curveprecision, defbasis

NAME

curveit - draws a curve segment

SPECIFICATION

C	**curveit(iterationcount)**
	short iterationcount;

FORTRAN	**subroutine curvei(count)** **integer*4 count**
Pascal	**procedure curveit(iterationcount: Short);**

DESCRIPTION

curveit iterates the forward differences of the matrix on top of the transformation matrix stack *iterationcount* times, issuing a draw command with each iteration. This command provides access to the low-level hardware capabilities for curve drawing.

SEE ALSO

crv, resetls

NAME

curveprecision - sets the number of line segments comprising a curve segment

SPECIFICATION

C

```
curveprecision(nsegments)
short nsegments;
```

FORTRAN

```
subroutine curvep(nsegments)
integer*4 nsegments
```

Pascal

```
procedure curveprecision(nsegments: integer);
```

DESCRIPTION

curveprecision sets the number of line segments used in drawing curves. Whenever **crv** or **crvn** is executed, each curve segment is approximated by *nsegments* straight line segments. The greater the value of *nsegments* the smoother the curve.

SEE ALSO

crv, curvebasis, crvn

NAME

cyclemap - cycles through color maps at a selected rate

SPECIFICATION

C	**cyclemap(duration, map, nextmap)** **short duration, map, nextmap;**
FORTRAN	**subroutine cyclem(duration, map, nextmap)** **integer*4 duration, map, nextmap**
Pascal	**procedure cyclemap(duration, map, nextmap: Short);**

DESCRIPTION

cyclemap specifies a duration (in vertical retraces), a related map, and what map to change to when that duration has timed out. For example, the following commands set up multimap mode and cycle between two maps, leaving map 1 on for ten vertical retraces and map 3 on for five retraces.

```
...
multimap();
gconfig();
cyclemap(10, 1, 3);
cyclemap(5, 3, 1);
...
```

Note that program termination does not stop these commands; you must explicitly set all durations to 0.

SEE ALSO

blink, multimap, gconfig

NOTE

This command can be used only in immediate mode.

NAME

dbtext - sets the dial and switch box text

SPECIFICATION

C	**dbtext(str)**
	char str[8];

FORTRAN	**subroutine dbtext(str)** **character*(8) str**
Pascal	**procedure dbtext(str: pstring);**

DESCRIPTION

dbtext places up to eight characters of text into the text window on the dial and switch box. Only digits, spaces, and upper-case letters are allowed.

NOTE

This command can be used only in immediate mode.

NAME

defbasis - defines a basis matrix

SPECIFICATION

C

```
defbasis(id, mat)
short id;
Matrix mat;
```

FORTRAN

```
subroutine defbas(id, mat)
integer*4 id
real mat(4,4)
```

Pascal

```
procedure defbasis(id: integer; mat: Matrix);
```

DESCRIPTION

defbasis allows the user to define basis matrices for use in the generation of curves and patches. *matrix* is saved and is associated with *id. id* may then be used in subsequent calls to **curvebasis** and **patchbasis.**

SEE ALSO

curvebasis, curveprecision, patchbasis, patchprecision, patchcurves, crv, crvn, patch

NOTE

This command can be used only in immediate mode.

NAME

defcursor - defines a cursor glyph

SPECIFICATION

```
C           defcursor(n, curs)
            short n;
            Cursor curs;

FORTRAN     subroutine defcur(n, curs)
            integer*4 n
            integer*2 curs(16)

Pascal      procedure defcursor(n: Short; curs: Cursor);
```

DESCRIPTION

defcursor defines a cursor glyph. The arguments are a table index and a 16×16 bitmap. By default, the origin of the cursor is at the lower left corner, but it can be reset with the **curorigin** command. The cursor origin is the position influenced by valuators attached to the cursor, and is also the position used by **pick** for the picking region. The index into the table is used as the cursor character's name in subsequent cursor commands. By default, an arrow is defined as cursor 0, and cannot be redefined. To replace a cursor, define the new one to have the same index as the old one.

SEE ALSO

deflinestyle, defrasterfont, defpattern, curorigin, getcursor, pick, setcursor

NOTE

This command can be used only in immediate mode.

NAME

deflinestyle - defines a linestyle

SPECIFICATION

C	**deflinestyle(n, ls)**
	short n;
	Linestyle ls;

FORTRAN	**subroutine deflin(n, ls)** **integer*4 n, ls**
Pascal	**procedure deflinestyle(n: Short; ls: Linestyle);**

DESCRIPTION

deflinestyle defines a linestyle, a write-enable pattern that is applied when lines are drawn. The arguments specify an index into a table where the linestyles are stored, and a sixteen-bit pattern. Up to 2^{16} linestyles can be defined. By default, index 0 contains the pattern FFFF_x which draws solid lines, and cannot be redefined. There is no performance penalty for drawing non-solid lines. To replace a linestyle, define the new one to have the same index as the old one.

SEE ALSO

defcursor, defrasterfont, defpattern, getlstyle, setlinestyle

NOTE

This command can be used only in immediate mode.

NAME

defpattern - defines a texture pattern

SPECIFICATION

C

```
defpattern(n, size, mask)
short n, size;
Ushort mask[];
```

FORTRAN

```
subroutine defpat(n, size, mask)
integer*4 n, size
integer*2 mask((size*size)/16)
```

Pascal

```
procedure defpattern(n: longint; size: Short; mask: Ibuffer);
```

DESCRIPTION

defpattern defines an arbitrary texture pattern. The first argument specifies an index into a table of patterns. The next, the size of the pattern: 16, 32, or 64 for a 16 x 16, 32 x 32, or 64 x 64 bit pattern, respectively. Finally, the last argument is an array of shorts that form the actual bit pattern. The pattern is described from left to right, bottom to top – in the same way as characters in a raster font. By default, pattern 0 is a 16 x 16 solid pattern and cannot be changed. There is no performance penalty for non-solid patterns.

SEE ALSO

defcursor, defrasterfont, deflinestyle, getpattern, setpattern

NOTE

This command can be used only in immediate mode.

NAME

defrasterfont - defines a raster font

SPECIFICATION

C

```
defrasterfont(n, ht, nc, chars, nr, raster)
short n, ht, nc, nr;
Fontchar chars[nc];
Ushort raster[nr];
```

FORTRAN

```
subroutine defras(n, ht, nc, chars, nr, raster)
integer*4 n, ht, nc, nr
integer*2 raster(nr), chars(4*nc)
```

Pascal

```
procedure defrasterfont(n, ht, nc, nr: Short; var chars: Fntchrarray;
var raster: Fontraster);
```

DESCRIPTION

defrasterfont defines a raster font and has six arguments. The first two are *n,* an index into the font table, and *ht,* an integer specifying the maximum height, in pixels, of characters in the font. The index *n* becomes the font's internal name. *nc* gives the number of characters in the font and thus the number of elements in the *chars* array. *chars* contains a description of each character in the font. The description includes the height and width of the character in pixels, the offsets from the character origin to the lower left corner of this character's bounding box, an offset into the array of rasters, and the amount to add to the current character position *x* after drawing the character. *raster* is an array of *nr* shorts of bitmap information. It is a one-dimensional array of mask shorts, ordered left to right and then bottom to top. Mask bits are left-justified in the character's bounding box.

To replace a raster font, define the new one to have the same index as the old one. To delete a raster font, define a font with no characters. The default font, 0, is a fixed pitch font of height 16 and width 9. Font 0 cannot be redefined.

SEE ALSO

charstr, font

NOTE

This command can be used only in immediate mode.

NAME

delobj - deletes an object

SPECIFICATION

C	**delobj(obj)**
	Object obj;

FORTRAN	**subroutine delobj(obj)** **integer*4 obj**
Pascal	**procedure delobj(obj: Object);**

DESCRIPTION

delobj deletes an object. Most of the display list storage associated with the object is freed, and the object name is marked undefined until it is used to create a new object. Attempts to call an object with the deleted name will be ignored.

SEE ALSO

makeobj, compactify

NOTE

This command can be used only in immediate mode.

NAME

deltag - deletes tags from objects

SPECIFICATION

C	**deltag(t)**
	Tag t;

FORTRAN	**subroutine deltag(t)** **integer*4 t**
Pascal	**procedure deltag(t: Tag);**

DESCRIPTION

deltag removes the tag *t* from the object currently open for editing. The special tags STARTTAG and ENDTAG cannot be deleted.

SEE ALSO

editobj, maketag

NOTE

This command can be used only in immediate mode.

NAME

depthcue - turns on and off depth-cue mode

SPECIFICATION

C

```
depthcue(mode)
Boolean mode;
```

FORTRAN

```
subroutine depthc(mode)
logical mode
```

Pascal

```
procedure depthcue(mode: Boolean);
```

DESCRIPTION

depthcue sets the current depth cue mode. If *mode* is *TRUE* all line and points drawn will be drawn depth cued. This means that the color of the lines and points is determined from their z values and the range of color indices specified by **shaderange.** The z values, whose range is set by the **setdepth** command, are mapped linearly into the range of color indices. In this mode, lines with large delta z's will span the full range of colors, typically appearing bright at one end and dim at the other.

In order for depth cueing to work properly the color map locations in the range specified by **shaderange** must be loaded with a series of colors gradually increasing or decreasing in intensity.

SEE ALSO

setdepth, shaderange

NAME

doublebuffer - sets the display mode to double buffer mode

SPECIFICATION

C	**doublebuffer()**
FORTRAN	**subroutine double**
Pascal	**procedure doublebuffer;**

DESCRIPTION

The IRIS has three display modes: single buffer, double buffer, and RGB. **doublebuffer** sets the display mode to double buffer mode. It does not take effect until after a call to **gconfig.** In double buffer mode, the bitplanes are partitioned into two groups, called the front and back planes. Only the front planes are displayed. Drawing commands normally update only the back planes; **frontbuffer** and **backbuffer** can override the default.

gconfig sets **frontbuffer** = *TRUE* and **backbuffer** = *FALSE* in double buffer mode.

SEE ALSO

backbuffer, frontbuffer, gconfig, getbuffer, getdisplaymode, RGBmode, singlebuffer, swapbuffers

NOTE

This command can be used only in immediate mode.

NAME

draw - draws a line

SPECIFICATION

```
C          draw(x, y, z)
           Coord x, y, z;

           drawi(x, y, z)
           Icoord x, y, z;

           draws(x, y, z)
           Scoord x, y, z;

           draw2(x, y)
           Coord x, y;

           draw2i(x, y)
           Icoord x, y;

           draw2s(x, y)
           Scoord x, y;


FORTRAN    subroutine draw(x, y, z)
           real x, y, z

           subroutine drawi(x, y, z)
           integer*4 x, y, z

           subroutine draws(x, y, z)
           integer*2 x, y, z

           subroutine draw2(x, y)
           real x, y

           subroutine draw2i(x, y)
           integer*4 x, y

           subroutine draw2s(x, y)
           integer*2 x, y


Pascal     procedure draw(x, y, z: Coord);

           procedure drawi(x, y, z: Icoord);

           procedure draws(x, y, z: Scoord);
procedure draw2(x, y: Coord);
procedure draw2i(x, y: Icoord);
procedure draw2s(x, y: Scoord);
```

DESCRIPTION

draw connects the specified point and the current graphics position with a line segment using the current linestyle, linewidth, color (if in depth cue mode, then the depth cued color is used), and writemask. The current graphics position is updated to the specified point. Commands that invalidate the current graphics position should not be placed within sequences of moves and draws.

SEE ALSO

move, pnt, rdr, rmv

NAME

editobj - opens an object for editing

SPECIFICATION

C	**editobj(obj)**
	Object obj;

FORTRAN	**subroutine editob(obj)** **integer*4 obj**
Pascal	**procedure editobj(obj: Object);**

DESCRIPTION

editobj opens an object for editing. A command pointer acts as a cursor for appending new commands. The command pointer is initially set to the end of the object. Graphics commands are appended to the object until either a **closeobj** or a pointer positioning command (**objdelete, objinsert,** or **objreplace**) is executed. Usually, the user need not be concerned about storage allocation. Objects grow and shrink automatically as commands are added and deleted.

If **editobj** specifies an undefined object, an error message is printed.

SEE ALSO

compactify, objdelete, objinsert, objreplace

NOTE

This command can be used only in immediate mode.

NAME

endfeedback - turns off feedback mode

SPECIFICATION

C	**long endfeedback(buffer)** **short buffer[];**
FORTRAN	**integer*4 function endfee(buffer)** **integer*2 buffer(*)**
Pascal	**function endfeedback(buffer: Short): longint;**

DESCRIPTION

endfeedback turns off feedback mode. *buffer* contains the values output by the Geometry Pipeline during the feedback session. The value returned by **endfeedback** is the number of shorts in *buffer*.

SEE ALSO

feedback

NOTE

This command can be used only in immediate mode.

NAME

endpick - turns off picking mode

SPECIFICATION

C
```
long endpick(buffer)
short buffer[];
```

FORTRAN
```
integer*4 function endpic(buffer)
integer*2 buffer(*)
```

Pascal
```
function endpick(var buffer: Short): longint;
```

DESCRIPTION

endpick takes the IRIS out of picking mode. When a drawing command draws into the picking region, the contents of the name stack are stored in *buffer* along with the number of names in the stack. Thus, if the name stack contained 5, 9, 17 when a hit occurred, the numbers 3, 5, 9, 17 are added to the buffer. The magnitude of the value returned by **endpick** is the number of such name lists in the buffer. If the value returned is positive, then all hits are recorded in the name lists, if it is negative, the buffer was not large enough to hold them all.

SEE ALSO

pick, gethitcode, clearhitcode, loadname, initnames

NOTE

This command can be used only in immediate mode.

NAME

endselect - turns off selecting mode

SPECIFICATION

C	**long endselect(buffer)** **short buffer[];**
FORTRAN	**integer*4 function endsel(buffer)** **integer*2 buffer(*)**
Pascal	**function endselect(var buffer: Ibuffer): integer;**

DESCRIPTION

endselect takes the IRIS out of selecting mode. Any hits caused by drawing commands that occurred between the calls to **select** and **endselect** are stored in the buffer. Every hit that occurs causes the entire contents of the name stack to be recorded in the buffer, preceded by the number of names in the stack. Thus, if the name stack contained 5, 9, 17 when a hit occurred, the numbers 3, 5, 9, 17 are added to the buffer. The magnitude of the value returned by **endselect** is the number of such name lists in the buffer. If the value returned is positive, then all hits are recorded in the name lists, if it is negative, the buffer was not large enough to hold them all.

SEE ALSO

select, gethitcode, clearhitcode, loadname, initnames

NOTE

This command can be used only in immediate mode.

NAME

feedback - turns on feedback mode

SPECIFICATION

C	**feedback(buffer, size)**
	short buffer[];
	long size;

FORTRAN	**subroutine feedba(buffer, size)** **integer*2 buffer(*)** **integer*4 size**
Pascal	**procedure feedback(buffer: Ibuffer; size: longint);**

DESCRIPTION

The **feedback** command puts the IRIS in feedback mode. During feedback mode, the output of the Geometry Pipeline is stored in *buffer,* rather than being sent to the raster display system. *size* specifies the maximum number of values that can be stored in *buffer.* While in feedback mode, the IRIS does not draw anything on the screen.

SEE ALSO

endfeedback

NOTE

This command can be used only in immediate mode.

NAME

finish - waits until the terminal command queue and Geometry Pipeline are empty

SPECIFICATION

C	**finish()**
FORTRAN	**subroutine finish**
Pascal	**procedure finish;**

DESCRIPTION

finish blocks the host process until all previous commands have been executed. It forces all unsent commands down the Geometry Pipeline to the bitplanes, sends a final token, and blocks until that token has gone through the pipeline and an acknowledgment has been sent. It is useful in the presence of network and pipeline delays.

SEE ALSO

gflush

NOTE

This command can be used only in immediate mode on the IRIS Terminal.

NAME

font - selects a raster font for drawing text strings

SPECIFICATION

C **font(fntnum)**
short fntnum;

FORTRAN **subroutine font(fntnum)**
integer*4 fntnum

Pascal **procedure font(fntnum: Short);**

DESCRIPTION

font chooses a raster font that will be used whenever a **charstr** command draws a text string. The argument is an index into the font table built with the **defrasterfont** command. This font remains in effect until another **font** command is executed. By default, font 0 is selected.

If **font** specifies a font number that is not defined, font 0 is selected.

SEE ALSO

defrasterfont, getfont

NAME

foreground - requests that a process not be put in the background by **getport** while using the window manager

SYNOPSIS

C	**foreground()**
FORTRAN	**subroutine foregr**
Pascal	**procedure foreground;**

DESCRIPTION

Normally, when **getport** is called, the application is run in the background. If the user wants to interact with the program through the textport, then calling **foreground** will keep the process in the foreground after **getport.**

SEE ALSO

getport

NOTE

This command can be used only in immediate mode.

NAME

frontbuffer - enables updating in the front buffer

SPECIFICATION

C	**frontbuffer(b)**
	Boolean b;

FORTRAN	**subroutine frontb(b)** **logical b**
Pascal	**procedure frontbuffer(b: Boolean);**

DESCRIPTION

frontbuffer enables updating in the front buffer. If b = *FALSE*, the default, the front buffer is not enabled; *TRUE* means it is enabled. This command is useful only in double buffer mode and is ignored otherwise.

frontbuffer is set to *FALSE* by **gconfig.**

SEE ALSO

backbuffer, doublebuffer, getbuffer

NAME

fudge - specifies fudge values to be added to a graphics port when it is resized

SPECIFICATION

C

```
fudge(xfudge, yfudge)
long xfudge, yfudge;
```

FORTRAN

```
subroutine fudge(xfudge, yfudge)
integer*4 xfudge, yfudge
```

Pascal

```
procedure fudge(xfudge, yfudge: longint);
```

DESCRIPTION

fudge specifies fudge values to be added to the dimensions of a graphics port when it is resized. Typically, this command is used to provide for a window border. The extra area will appear as part of the port and will be reflected in the size of the drag box as the user sizes it. **fudge** is useful in conjunction with **stepunit** and **keepaspect.** With **stepunit** the port size is constrained to be:

width = xunit*n + xfudge
height = yunit*m + yfudge

for integers n and m. With **keepaspect** the port size is (w, h) where:

(w–xfudge)*yaspect = (h–yfudge)*xaspect

It is called at the beginning of a graphics program that will be run with the window manager. If **getport** is not called or if the system is not running the window manager, **fudge** is ignored.

SEE ALSO

getport, keepaspect, stepunit

NOTE

This command can be used only in immediate mode.

NAME

gbegin - initializes the IRIS without altering the color map

SPECIFICATION

C	**gbegin()**
FORTRAN	**subroutine gbegin**
Pascal	**procedure gbegin;**

DESCRIPTION

gbegin may be called instead of **ginit** as the first Graphics Library command in IRIS programs. **gbegin** does a **ginit** without changing the contents of any of the entries in the color map and without calling **setcursor.**

SEE ALSO

ginit, greset

NOTE

This command can be used only in immediate mode.

NAME

gconfig - reconfigures the IRIS

SPECIFICATION

C	**gconfig()**
FORTRAN	**subroutine gconfi**
Pascal	**procedure gconfig;**

DESCRIPTION

gconfig uses the map mode, display mode, and number of requested planes to compute and allocate available planes and define the mapping from colors to bitplanes. **doublebuffer, multimap, onemap, RGBmode, setplanes,** and **singlebuffer** do not take effect until **gconfig** is called. After the **gconfig** call, the writemask, color, cursor color, and writemask are all undefined. The contents of the color map are unchanged.

SEE ALSO

doublebuffer, multimap, onemap, RGBmode, setplanes, singlebuffer

NOTE

This command can be used only in immediate mode.

NAME

genobj - returns a unique integer for use as an object name

SPECIFICATION

C	**Object genobj()**
FORTRAN	**integer*4 function genobj()**
Pascal	**function genobj: Object;**

DESCRIPTION

Object names can be up to 31 bits long and must be unique within the program. **genobj** generates unique 31-bit integer names. Names might be pointers into data structures, hashed string names or randomly chosen numbers. **genobj** will not generate an object name that is currently in use. The user must take care in generating names when using a combination of user-defined and **genobj**-defined names.

Use of **genobj** is not required to name an object.

SEE ALSO

callobj, gentag, isobj, makeobj

NOTE

This command can be used only in immediate mode.

NAME

gentag - returns a unique integer for use as a tag

SPECIFICATION

C	**Tag gentag()**
FORTRAN	**integer*4 function gentag()**
Pascal	**function gentag: Tag;**

DESCRIPTION

gentag generates a unique integer to be used as a tag. Tags must be unique within the enclosing object. The **gentag** command provides a unique 31-bit integer for use when the tag has no significance beyond labeling a command. Note that the generated tag is unique when **gentag** is executed. If the user later defines a tag with the same value, the first command tag is lost.

Use of **gentag** is not required to name an object.

SEE ALSO

genobj, istag

NOTE

This command can be used only in immediate mode.

NAME

getbuffer - indicates which buffers are enabled for writing

SPECIFICATION

C	**long getbuffer()**
FORTRAN	**integer*4 function getbuf()**
Pascal	**function getbuffer: longint;**

DESCRIPTION

getbuffer indicates which buffers are enabled for writing. *1*, the default, means that the back buffer is enabled; *2* means that the front buffer is enabled; and *3* means that both are enabled. **getbuffer** returns *0* if neither buffer is enabled or the IRIS is not in double buffer mode.

Value	Buffer Enabled
0	neither
1	back buffer
2	front buffer
3	both buffers

SEE ALSO

backbuffer, doublebuffer, frontbuffer

NOTE

This command can be used only in immediate mode.

NAME

getbutton - gets the state (up/down) of a button

SPECIFICATION

C	**Boolean getbutton(num)** **Device num;**
FORTRAN	**logical function getbut(num)** **integer*4 num**
Pascal	**function getbutton(num: Device): longint;**

DESCRIPTION

getbutton returns the state of the button numbered *num*. A return value of *0* means that the button is up; *1* means that it is down.

NOTE

The command can be used only in immediate mode.

NAME

getcmmode - returns the current color map mode

SPECIFICATION

C	**Boolean getcmmode()**
FORTRAN	**logical function getcmm()**
Pascal	**function getcmmode: longint;**

DESCRIPTION

getcmmode returns the current color map mode. The returned value is either *0* for multimap mode or *1* for onemap mode.

SEE ALSO

multimap, onemap

NOTE

This command can be used only in immediate mode.

NAME

getcolor - returns the current color

SPECIFICATION

C	**long getcolor()**
FORTRAN	**integer*4 function getcol()**
Pascal	**function getcolor: Colorindex;**

DESCRIPTION

getcolor returns the current color. It is an index into the color map, and is meaningful in either single or double buffer mode. The command is ignored in RGB mode.

SEE ALSO

color, singlebuffer, doublebuffer

NOTE

This command can be used only in immediate mode.

NAME

getcpos - returns the current character position

SPECIFICATION

C	**getcpos(ix, iy)**
	Screencoord *ix, *iy;

FORTRAN	**subroutine getcpo(ix, iy)** **integer*2 ix, iy**
Pascal	**procedure getcpos(var ix, iy: Screencoord);**

DESCRIPTION

getcpos returns the current character position (in screen coordinates).

SEE ALSO

getgpos

NOTE

This command can be used only in immediate mode.

NAME

getcursor - returns the cursor characteristics

SPECIFICATION

C

```
getcursor(index, color, wtm, b)
short *index;
Colorindex *color, *wtm;
Boolean *b;
```

FORTRAN

```
subroutine getcur(index, color, wtm, b)
integer*2 index, color, wtm
logical b
```

Pascal

```
procedure getcursor (var index: Short;
var color, wtm: Colorindex; var b: Boolean);
```

DESCRIPTION

getcursor returns the index of the cursor glyph, the color and the writemask associated with the cursor, and a boolean indicating whether the cursor is automatically displayed and updated by the system. The arguments to the command are addresses of four locations where the four cursor attributes are to be returned. The default is the glyph at location 0 in the cursor table, displayed with the color 1, drawn in the first available plane, and automatically updated and displayed on each vertical retrace. This command is undefined in RGB mode.

SEE ALSO

defcursor, setcursor

NOTE

This command can be used only in immediate mode.

NAME

getdcm - indicates whether depth-cue mode is on or off

SPECIFICATION

C	**Boolean getdcm()**
FORTRAN	**logical function getdcm()**
Pascal	**function getdcm: longint;**

DESCRIPTION

getdcm returns *TRUE* (0) if the IRIS is in depth-cue mode, and *FALSE* (1) otherwise.

NOTE

This command can be used only in immediate mode.

NAME

getdepth - returns the parameters of **setdepth**

SPECIFICATION

C	**getdepth(near, far)**
	Screencoord *near, *far;

FORTRAN	**subroutine getdep(near, far)** **integer*2 near, far**
Pascal	**procedure getdepth(var near, far: Screencoord);**

DESCRIPTION

getdepth returns the *near* and *far* parameters of the **setdepth** command.

SEE ALSO

setdepth

NOTE

This command can be used only in immediate mode.

NAME

getdisplaymode - returns the current display mode

SPECIFICATION

C	**long getdisplaymode()**
FORTRAN	**integer*4 function getdis()**
Pascal	**function getdisplaymode: longint;**

DESCRIPTION

getdisplaymode returns the current display mode, where the values 0, 1, and 2 indicate the display modes as shown:

Value	Display Mode
0	RGB mode
1	single buffer mode
2	double buffer mode

SEE ALSO

doublebuffer, RGBmode, singlebuffer

NOTE

This command can be used only in immediate mode.

NAME

getfont - returns the current raster font number

SPECIFICATION

C	**long getfont()**
FORTRAN	**integer*4 function getfon()**
Pascal	**function getfont: longint;**

DESCRIPTION

getfont returns the index of the currently selected raster font.

SEE ALSO

defrasterfont, font

NOTE

This command can be used only in immediate mode.

NAME

getgpos - returns the current graphics position

SPECIFICATION

C	**getgpos(fx, fy, fz, fw)** **Coord *fx, *fy, *fz, *fw;**
FORTRAN	**subroutine getgpo(fx, fy, fz, fw)** **real fx, fy, fz, fw**
Pascal	**procedure getgpos(var fx, fy, fz, fw: Coord);**

DESCRIPTION

getgpos returns the current graphics position.

SEE ALSO

getcpos

NOTE

This command can be used only in immediate mode.

NAME

getheight - returns the maximum height of the characters in the current raster font

SPECIFICATION

C	**long getheight()**
FORTRAN	**integer*4 function gethei()**
Pascal	**function getheight: longint;**

DESCRIPTION

getheight returns the maximum height (as defined in the **defrasterfont** command that defined the font) of the characters in the current raster font, including ascenders (present in characters like 't' and 'h') and descenders (as in 'y' and 'p'). The height is usually the number of pixels between the top of the tallest ascender and the bottom of the lowest descender.

SEE ALSO

strwidth

NOTE

This command can be used only in immediate mode.

NAME

gethitcode - returns the current system hitcode

SPECIFICATION

C	**long gethitcode()**
FORTRAN	**integer*4 function gethit()**
Pascal	**function gethitcode: longint;**

DESCRIPTION

gethitcode returns the global variable *hitcode,* which keeps a cumulative record of clipping plane hits. It does not change the hitcode value.

The hitcode is a six-bit number, as shown below, with one bit for each clipping plane. (Systems configured without near-far clipping always return 0's for the near and far clipping planes.)

5	4	3	2	1	0
far	near	top	bottom	right	left

SEE ALSO

clearhitcode, pick, select

NOTE

This command can be used only in immediate mode.

NAME

getlsbackup - returns the status of the linestyle backup mode

SPECIFICATION

C	**Boolean getlsbackup()**
FORTRAN	**logical function getlsb()**
Pascal	**function getlsbackup: longint;**

DESCRIPTION

getlsbackup returns the current value of the linestyle backup flag. *TRUE* means that **lsbackup** is on and the last three pixels of a line will be colored regardless of the linestyle pattern; *FALSE* means that **lsbackup** is off and the pattern will determine the state of all the pixels in the line.

SEE ALSO

lsbackup

NOTE

This command can be used only in immediate mode.

NAME

getlsrepeat - returns the linestyle repeat count

SPECIFICATION

C	**long getlsrepeat()**
FORTRAN	**integer*4 function getlsr()**
Pascal	**function getlsrepeat: longint;**

DESCRIPTION

getlsrepeat returns the current linestyle repeat factor (set by **lsrepeat**).

SEE ALSO

lsrepeat

NOTE

This command can be used only in immediate mode.

NAME

getlstyle - returns the current linestyle

SPECIFICATION

C	**long getlstyle()**
FORTRAN	**integer*4 function getlst()**
Pascal	**function getlstyle: longint;**

DESCRIPTION

getlstyle returns the currently selected linestyle. The returned value is an index into the linestyle table.

SEE ALSO

deflinestyle, setlinestyle

NOTE

This command can be used only in immediate mode.

NAME

getlwidth - returns the current linewidth

SPECIFICATION

C	**long getlwidth()**
FORTRAN	**integer*4 function getlwi()**
Pascal	**function getlwidth: longint;**

DESCRIPTION

getlwidth returns the current linewidth in pixels.

SEE ALSO

linewidth

NOTE

This command can be used only in immediate mode.

NAME

getmap - returns the number of the currently selected color map

SPECIFICATION

C	**long getmap()**
FORTRAN	**integer*4 function getmap()**
Pascal	**function getmap: longint;**

DESCRIPTION

getmap returns the number, from 0 to 15, of the currently selected color map. If called in onemap mode, it returns zero.

SEE ALSO

multimap, onemap

NOTE

This command can be used only in immediate mode.

NAME

getmatrix - returns the current transformation matrix

SPECIFICATION

C	**getmatrix(m)**
	Matrix m;

FORTRAN	**subroutine getmat(m)** **real m(4,4)**
Pascal	**procedure getmatrix(var m: Matrix);**

DESCRIPTION

getmatrix copies the transformation matrix from the top of the stack to an array provided by the user. The matrix stack is unchanged.

SEE ALSO

loadmatrix, multmatrix

NOTE

This command can be used only in immediate mode.

NAME

getmcolor - returns a color map entry

SPECIFICATION

C

```
getmcolor(color, r, g, b)
Colorindex color;
short *r, *g, *b;
```

FORTRAN

```
subroutine getmco(color, r, g, b)
integer*4 color
integer*2 r, g, b
```

Pascal

```
procedure getmcolor(color: Colorindex; var r, g, b: RGBvalue);
```

DESCRIPTION

getmcolor returns the red, green, and blue components of a color map entry.

SEE ALSO

mapcolor

NOTE

This command can be used only in immediate mode.

NAME

getmem - returns amount of available memory

SPECIFICATION

C	**long getmem()**
FORTRAN	**integer*4 function getmem()**
Pascal	**function getmem: longint;**

DESCRIPTION

getmem returns the amount of available memory left on the system. On a workstation with virtual memory up to 14 megabytes, it will return 14 MB less the amount used. On a terminal, it will return the amount of free physical memory.

NOTE

This command can be used only in immediate mode.

NAME

getmonitor - returns the display monitor mode

SPECIFICATION

C	**long getmonitor()**
FORTRAN	**integer*4 function getmon()**
Pascal	**function getmonitor: longint;**

DESCRIPTION

getmonitor returns the current display monitor mode. Current possibilities include 60Hz non-interlaced, 30Hz interlaced, and NTSC. In the file *get.h* , values for HZ30, HZ60, and NTSC are defined.

NOTE

This command can be used only in immediate mode.

NAME

getopenobj - indicates if an object is currently open for editing

SPECIFICATION

C	**Object getopenobj()**
FORTRAN	**integer*4 function getope()**
Pascal	**function getopenobj: Object;**

DESCRIPTION

getopenobj returns the number of the object currently open for editing. If no object is open, it returns -1. It is useful for writing routines that create objects, but may be called while another object is open for editing.

NOTE

This command can be used only in immediate mode.

NAME

getorigin - returns the position of a graphics port in the window manager

SPECIFICATION

C

```
getorigin(x, y)
long *x, *y;
```

FORTRAN

```
subroutine getori(x, y)
integer*4 x, y
```

Pascal

```
procedure getorigin(x, y: longint);
```

DESCRIPTION

getorigin returns the position of the lower left corner of a graphics port. It should only be called after **getport.** When the window manager is not running, **getorigin** always returns (0, 0).

SEE ALSO

getport

NOTE

This command can be used only in immediate mode.

NAME

getpattern - returns the index of the currently selected pattern

SPECIFICATION

C	**long getpattern()**
FORTRAN	**integer*4 function getpat()**
Pascal	**function getpattern: longint;**

DESCRIPTION

getpattern returns the index of the pattern currently in use from the table of available patterns.

SEE ALSO

defpattern, setpattern

NOTE

This command can be used only in immediate mode.

NAME

getplanes - returns the number of available bitplanes

SPECIFICATION

C	**long getplanes()**
FORTRAN	**integer*4 function getpla()**
Pascal	**function getplanes: longint;**

DESCRIPTION

getplanes returns the number of available bitplanes in the system.

SEE ALSO

multimap, onemap

NOTE

This command can be used only in immediate mode.

NAME

getport - creates a graphics port in the window manager

SPECIFICATION

C	**getport(name)**
	char name[];

FORTRAN	**subroutine getpor(name)** **character*(*) name**
Pascal	**procedure getport(name: pstring);**

DESCRIPTION

getport does a graphics initialization and creates a graphics port based on the characteristics specified in the commands preceding the call to **getport.** If no characteristics are specified or the description is incomplete, the window manager prompts the user for the missing information. The user employs the cursor to show the size and location of the graphics port. **getport** puts the graphics program in the background, unless the **foreground** command is called (before **getport**).

When it is called outside the window manager, **getport** creates a standard-sized graphics port: (xmin 0, xmax 1023, ymin 0, ymax 767).

SEE ALSO

minsize, maxsize, keepaspect, prefsize, prefposition, stepunit, fudge, noport, foreground

NOTE

This command can be used only in immediate mode.

NAME

getresetls - returns the status of **resetls**

SPECIFICATION

C	**Boolean getresetls()**
FORTRAN	**logical function getres()**
Pascal	**function getresetls: longint;**

DESCRIPTION

getresetls returns the current value of the reset linestyle flag. *TRUE,* the default value, means that the linestyle will be reinitialized for each line segment. *FALSE* means that the pattern will rotate continuously across line segment boundaries.

SEE ALSO

resetls

NOTE

This command can be used only in immediate mode.

NAME

getscrmask - returns the current screenmask

SPECIFICATION

C	**getscrmask(left, right, bottom, top)** **Screencoord *left, *right, *bottom, *top;**
FORTRAN	**subroutine getscr(left, right, bottom, top)** **integer*2 left, right, bottom, top**
Pascal	**procedure getscrmask(var left, right, bottom, top: Screencoord);**

DESCRIPTION

getscrmask returns the screen coordinates of the current sceenmask.

SEE ALSO

scrmask, popviewport, pushviewport

NOTE

This command can be used only in immediate mode.

NAME

getsize - returns the size of a graphics port in the window manager

SPECIFICATION

C
```
getsize(x, y)
long *x, *y;
```

FORTRAN
```
subroutine getsiz(x, y)
integer*4 x, y
```

Pascal
```
procedure getsize(x, y: longint);
```

DESCRIPTION

getsize returns the dimensions (in pixels) of the graphics port being used by a graphics program. It should be called after **getport.**

If **getsize** is called outside the window manager, the size will always be (1024, 768).

SEE ALSO

getport

NOTE

This command can be used only in immediate mode.

NAME

gettp - returns the location of the current textport

SPECIFICATION

C

```
gettp(left, right, bottom, top)
Screencoord *left, *right, *bottom, *top;
```

FORTRAN

```
subroutine gettp(left, right, bottom, top)
integer*2 left, right, bottom, top
```

Pascal

```
procedure gettp(var left, right, bottom, top: Screencoord);
```

DESCRIPTION

gettp returns the location of the current textport.

SEE ALSO

textport

NOTE

This command can be used only in immediate mode

NAME

getvaluator - returns the current state of a valuator

SPECIFICATION

C

```
long   getvaluator(val)
Device  val;
```

FORTRAN

```
integer*4  function  getval(val)
integer*4  val
```

Pascal

```
function  getvaluator(val: Device): longint;
```

DESCRIPTION

This command returns the current value of the valuator numbered *val.*

SEE ALSO

getbutton, qvaluator

NOTE

This command can be used only in immediate mode

NAME

getviewport - returns the current viewport

SPECIFICATION

C
```
getviewport(left, right, bottom, top)
Screencoord *left, *right, *bottom, *top;
```

FORTRAN
```
subroutine getvie(left, right, bottom, top)
integer*2 left, right, bottom, top
```

Pascal
```
procedure getviewport(var left, right, bottom, top: Screencoord);
```

DESCRIPTION

getviewport returns the current viewport, non-destructively reading the top of the viewport stack. The arguments to **getviewport** are the addresses of four memory locations. These will be assigned the left, right, bottom, and top coordinates of the viewport.

SEE ALSO

popviewport, pushviewport, viewport

NOTE

This command can be used only in immediate mode.

NAME

getwritemask - returns the current writemask

SPECIFICATION

C	**long getwritemask()**
FORTRAN	**integer*4 function getwri()**
Pascal	**function getwritemask: Colorindex;**

DESCRIPTION

getwritemask returns the current writemask. It is an integer with up to twelve significant bits, one for each available bitplane. This command is undefined in RGB mode.

SEE ALSO

RGBwritemask, writemask

NOTE

This command can be used only in immediate mode.

NAME

getzbuffer - indicates whether z-buffering is on or off

SPECIFICATION

C	**Boolean getzbuffer()**
FORTRAN	**logical function getzbu()**
Pascal	**function getzbuffer: longint;**

DESCRIPTION

getzbuffer returns the current value of the z-buffer flag. *FALSE,* the default value, means that z-buffering is off. *TRUE* means that z-buffering is on.

SEE ALSO

zbuffer, zclear, setdepth

NOTE

This command can be used only in immediate mode.

NAME

gexit - terminates an IRIS program

SPECIFICATION

C	**gexit()**
FORTRAN	**subroutine gexit**
Pascal	**procedure gexit;**

DESCRIPTION

gexit is the final graphics command in an IRIS program. It flushes communication buffers and waits for the Geometry Pipeline to empty.

SEE ALSO

ginit, greset, finish

NOTE

This command can be used only in immediate mode.

NAME

gflush - forces all unsent commands down the network to the Geometry Pipeline

SPECIFICATION

C	**gflush()**
FORTRAN	**subroutine gflush**
Pascal	**procedure gflush;**

DESCRIPTION

Most graphics commands are buffered at the host by the communication software for efficient block transfer of data from the host to the IRIS. **gflush** delivers all buffered yet untransmitted graphics data to the IRIS. Certain graphics commands (notably those which return values) flush the host buffer when they are executed. **gflush** is only used on an IRIS Terminal.

SEE ALSO

finish

NOTE

This command can be used only in immediate mode.

NAME

ginit - initializes the IRIS

SPECIFICATION

C	**ginit()**
FORTRAN	**subroutine ginit**
Pascal	**procedure ginit;**

DESCRIPTION

ginit is the first command in every IRIS graphics program. It initializes the hardware, allocates memory for symbol tables and display lists, and sets up default values for global state variables in the same manner as **greset.** It has no arguments and should be called only once, before any other IRIS Graphics Library command.

SEE ALSO

gexit, greset, gbegin

NOTE

This command can be used only in immediate mode.

NAME

greset - resets all global attributes to their initial values

SPECIFICATION

C	**greset()**
FORTRAN	**subroutine greset**
Pascal	**procedure greset;**

DESCRIPTION

greset returns the following global state variables to their initial values, and can be called at any time.

State Variable	Initial Value
available bitplanes	all bitplanes[1]
backface mode	off
color	undefined
color map mode	one map
cursor	0 (arrow)[2]
depthcue mode	off
display mode	single buffer
font	0 [3]
linestyle	0 (solid)
linestyle backup	off
linewidth	1 pixel
lsrepeat	1
picking size	10×10 pixels
reset linestyle	on
RGB color	undefined
RGB writemask	undefined
shaderange	(0,7,0,1023)
texture	0 (solid)
viewport	entire screen
writemask	all planes enabled[1]
zbuffer mode	off

1. If there are more than three bitplane boards installed, the number of available planes is set to twelve.
2. The color and writemask of the cursor are set to 1.
3. Rasterfont 0 is a Helvetica-like font.

In addition, **greset** puts a two-dimensional orthographic projection transformation on the matrix stack with left, right, bottom, and top set to the boundaries of the screen. It also turns the cursor on, ties it to *MOUSEX* and *MOUSEY*, and unqueues all buttons, valuators, and the keyboard. Each button is set to *FALSE* and untied from valuators. Each valuator is set to *XMAXSCREEN/2*; the range is *0..XMAXSCREEN*. *MOUSEY* is an exception. It is set to *YMAXSCREEN/2* and has range *0..YMAXSCREEN*.

greset also defines every entry in the color map, as follows:

Index	**Name**	**RGB Value**		
		Red	*Green*	*Blue*
0	BLACK	0	0	0
1	RED	255	0	0
2	GREEN	0	255	0
3	YELLOW	255	255	0
4	BLUE	0	0	255
5	MAGENTA	255	0	255
6	CYAN	0	255	255
7	WHITE	255	255	255
all others	unnamed		undefined	

SEE ALSO

ginit, gbegin

NOTE

This command can be used only in immediate mode.

NAME

gRGBcolor - returns the current RGB value

SPECIFICATION

C

```
gRGBcolor(red, green, blue)
short *red, *green, *blue;
```

FORTRAN

```
subroutine gRGBco(red, green, blue)
integer*2 red, green, blue
```

Pascal

```
procedure gRGBcolor(var red, green, blue: RGBvalue);
```

DESCRIPTION

gRGBcolor returns the current RGB color values. The arguments are addresses of three locations that will be filled with the red, green, and blue values. The system must be in RGB mode when this command is executed.

SEE ALSO

RGBcolor, RGBmode

NOTE

This command can be used only in immediate mode.

NAME

gRGBcursor - returns the characteristics of the cursor in RGB mode

SPECIFICATION

C

```
gRGBcursor(index, red, green, blue, redm, greenm, bluem, b)
short *index, *red, *green, *blue, *redm, *greenm, *bluem;
Boolean *b;
```

FORTRAN

```
subroutine gRGBcu(index, red, green, blue, redm, greenm,
bluem, b)
integer*2 index, red, green, blue, redm, greenm, bluem
logical b
```

Pascal

```
procedure gRGBcursor(var index: Short;
var red, green, blue, redm, greenm, bluem: RGBvalue;
var b: Boolean);
```

DESCRIPTION

gRGBcursor returns the seven parameters of the last **RGBcursor** command executed. These are: *index, red, green, blue, redm, greenm* and *bluem*. **gRGBcursor** also returns a boolean *b* that is *TRUE* if the automatic cursor is on. The system must be in RGB mode when this command is executed.

SEE ALSO

RGBcursor

NOTE

This command can be used only in immediate mode.

NAME

gRGBmask - returns the current RGB writemask

SPECIFICATION

C	**gRGBmask(redm, greenm, bluem)**
	short *redm, *greenm, *bluem;

FORTRAN	**subroutine gRGBma(redm, greenm, bluem)** **integer*2 redm, greenm, bluem**
Pascal	**procedure gRGBmask(var redm, greenm, bluem: RGBvalue);**

DESCRIPTION

gRGBmask returns the current RGB writemask as three eight-bit masks. The masks are placed in the locations addressed by *redm, greenm* and *bluem.* The system must be in RGB mode when this command is executed.

SEE ALSO

getwritemask, RGBwritemask

NOTE

This command can be used only in immediate mode.

NAME

gsync - waits for a vertical retrace period

SPECIFICATION

C	**gsync()**
FORTRAN	**subroutine gsync**
Pascal	**procedure gsync;**

DESCRIPTION

In single buffer and RGB modes, rapidly changing scenes should be synchronized with the refresh rate. The **gsync** command waits for the next vertical retrace period.

SEE ALSO

RGBmode, singlebuffer

NOTE

This command can be used only in immediate mode.

NAME

imakebackground - makes a process in charge of drawing the background of the window manager screen

SPECIFICATION

C	**imakebackground()**
FORTRAN	**subroutine imakeb**
Pascal	**procedure imakebackground;**

DESCRIPTION

imakebackground is called to register a process as the maintainer of the screen background. It is called instead of the graphics port characteristic commands and **getport.** The process draws the background and reads the input queue. Every time the process gets a REDRAW token in the queue, it should redraw the background.

SEE ALSO

getport

NOTE

This command can be used only in immediate mode.

NAME

initnames - initializes the name stack

SPECIFICATION

C	**initnames()**
FORTRAN	**subroutine initna**
Pascal	**procedure initnames;**

DESCRIPTION

initnames clears the name stack for picking and selecting.

SEE ALSO

pick, select

NAME

isobj - indicates whether a given object name identifies an object

SPECIFICATION

C	**Boolean isobj(obj)** **Object obj;**
FORTRAN	**logical function isobj(obj)** **integer*4 obj**
Pascal	**function isobj(obj: Object): longint;**

DESCRIPTION

isobj returns *TRUE* if *obj* names an object and *FALSE* if it does not. It will return *TRUE* any time after the **makeobj** call for the object.

SEE ALSO

genobj, istag, makeobj

NOTE

This command can be used only in immediate mode.

NAME

istag - indicates whether a given tag is in use within the currently open object

SPECIFICATION

C	**Boolean istag(t)** **Tag t;**
FORTRAN	**logical function istag(t)** **integer*4 t**
Pascal	**function istag(t: Tag): longint;**

DESCRIPTION

istag returns *TRUE* if *t* is in use within the currently open object and *FALSE* if it is not in use. The result is undefined if there is no currently open object.

SEE ALSO

gentag, isobj

NOTE

This command can be used only in immediate mode.

NAME

keepaspect - specifies the aspect ratio of a graphics port

SPECIFICATION

C	**keepaspect(x, y)**
	long x, y;

FORTRAN	**subroutine keepas(x, y)** **integer x, y**
Pascal	**procedure keepaspect(x, y: longint);**

DESCRIPTION

keepaspect specifies the aspect ratio of a graphics port. It is called at the beginning of a graphics program that will be run with the window manager. It takes effect when **getport** is called. The resulting graphics port will maintain the aspect ratio specified in **keepaspect,** even if its size is changed. For example, **keepaspect(1, 1)** will always result in a square graphics port. If **getport** is not called or if the system is not running the window manager, **keepaspect** will be ignored.

SEE ALSO

getport, fudge

NOTE

This command can be used only in immediate mode.

NAME

lampoff - turns off display lights on the keyboard

SPECIFICATION

C	**lampoff(lamps)**
	char lamps;

FORTRAN	**subroutine lampof(lamps)** **integer*4 lamps**
Pascal	**procedure lampoff(lamps: Byte);**

DESCRIPTION

lampoff turns off any combination of the four user-controllable lamps on the IRIS keyboard. The four low-order bits of the argument *lamps* control lamps 1 through 4.

SEE ALSO

clkoff, clkon, lampon, ringbell, setbell

NOTE

This command can be used only in immediate mode.

NAME

lampon - turns on display lights on the keyboard

SPECIFICATION

C	**lampon(lamps)**
	char lamps;

FORTRAN	**subroutine lampon(lamps)** **integer*4 lamps**
Pascal	**procedure lampon(lamps: Byte);**

DESCRIPTION

lampon turns on any combination of the four user-controllable lamps on the keyboard. The four low-order bits of the argument *lamps* control lamps 1 through 4.

SEE ALSO

clkon, clkoff, lampoff, ringbell, setbell

NOTE

This command can be used only in immediate mode.

NAME

linewidth - specifies the linewidth

SPECIFICATION

C	**linewidth(n)**
	short n;

FORTRAN	**subroutine linewi(n)** **integer*4 n**
Pascal	**procedure linewidth(n: Short);**

DESCRIPTION

linewidth specifies the width of a line. The width is the number of pixels along the screen axis having the least change between the endpoints of the line. The wide line will be centered (as far as possible) about the true line. If **linewidth** is set to *n =1,* **resetls** must be *TRUE.*

SEE ALSO

lsbackup, resetls, setlinestyle

NAME

loadmatrix - loads a transformation matrix

SPECIFICATION

C	**loadmatrix(m)**
	Matrix m;

FORTRAN	**subroutine loadma(m)** **real m(4,4)**
Pascal	**procedure loadmatrix(m: Matrix);**

DESCRIPTION

loadmatrix loads a 4×4 floating point matrix onto the matrix stack, replacing the current top of the stack.

SEE ALSO

multmatrix, popmatrix, pushmatrix

NAME

loadname - replaces the name on the top of the name stack

SPECIFICATION

C

```
loadname(name)
short name;
```

FORTRAN

```
subroutine loadna(name)
integer*4 name
```

Pascal

```
procedure loadname(name: Short);
```

DESCRIPTION

loadname replaces the top name in the name stack with a new 16-bit integer name. The contents of the name stack are stored in a buffer each time a command causes a "hit" in picking or selecting mode.

SEE ALSO

pick, select

NAME

lookat - defines a viewing transformation

SPECIFICATION

C

```
lookat(vx, vy, vz, px, py, pz, twist)
Coord vx, vy, vz, px, py, pz;
Angle twist;
```

FORTRAN

```
subroutine lookat(vx, vy, vz, px, py, pz, twist)
real vx, vy, vz, px, py, pz
integer*4 twist
```

Pascal

```
procedure lookat(vx, vy, vz, px, py, pz: Coord; twist: Angle);
```

DESCRIPTION

lookat defines the viewpoint and a reference point on the line of sight in world coordinates. The viewpoint is at *(vx, vy, vz)*. The viewpoint and reference point *(px, py, pz)* define the line of sight. *twist* measures right-handed rotation about the *z*-axis in the eye coordinate system.

SEE ALSO

polarview

NAME

lsbackup - controls whether the last two pixels of a line are colored

SPECIFICATION

C	**lsbackup(b)**
	Boolean b;

FORTRAN	**subroutine lsback(b)** **logical b**
Pascal	**procedure lsbackup(b: Boolean);**

DESCRIPTION

lsbackup is one of two commands that modify the application of the linestyle pattern. If enabled, it overrides the current linestyle to guarantee that the final two pixels in a line will be colored. It takes one argument, a boolean. If *b* = *TRUE*, backup mode is enabled. **resetls** should also be set to *TRUE* when backup mode is enabled. *FALSE*, the default setting, means the linestyle will be used as is, and lines may have invisible endpoints.

SEE ALSO

deflinestyle, getlsbackup, setlinestyle, resetls

NAME

lsrepeat - sets repeat factor for linestyle

SPECIFICATION

C	**lsrepeat(factor)**
	long factor;

FORTRAN	**subroutine lsrepe(factor)** **integer*4 factor**
Pascal	**procedure lsrepeat(factor: longint);**

DESCRIPTION

lsrepeat sets a repeat factor for the current linestyle. When a line is being drawn, pixels are turned on if there is a 1 in the corresponding position of the linestyle mask. Thus the mask 0x5555 specifies alternate pixels be turned on (assuming the lsrepeat factor is 1). If the repeat factor is *n*, then the 0x5555 pattern above would draw a line with *n* bits on and *n* bits off, alternately.

SEE ALSO

getlsrepeat, setlinestyle

NAME

makeobj - creates an object

SPECIFICATION

```
C          makeobj(obj)
           Object obj;

FORTRAN    subroutine makeob(obj)
           integer*4 obj

Pascal     procedure makeobj(obj: Object);
```

DESCRIPTION

Objects are created with the **makeobj** command. **makeobj** takes an argument, a 31-bit integer name, that will be associated with the object. If an object with the given name previously existed, that object is deleted. When a **makeobj** command is executed, the object name is entered into a symbol table and memory is allocated for a display list. Subsequent graphics commands are compiled into the display list instead of being executed.

SEE ALSO

callobj, closeobj, genobj, isobj

NOTE

This command can be used only in immediate mode.

NAME

maketag - names the command in the display list

SPECIFICATION

C

```
maketag(t)
Tag t;
```

FORTRAN

```
subroutine maketa(t)
integer*4 t
```

Pascal

```
procedure maketag(t: Tag);
```

DESCRIPTION

Commands can be explicitly named with the **maketag** command. The user supplies a 31-bit name that is assigned to the command immediately following the **maketag** command. The tag is local to that object. The same 31-bit name can be used safely in different objects.

SEE ALSO

gentag, istag

NAME

mapcolor - changes a color map entry

SPECIFICATION

C	**mapcolor(color, red, green, blue)** **Colorindex color;** **short red, green, blue;**
FORTRAN	**subroutine mapcol(color, red, green, blue)** **integer*4 color, red, green, blue**
Pascal	**procedure mapcolor(color: Colorindex; red, green, blue: RGBvalue);**

DESCRIPTION

mapcolor changes a single color map entry to the specified RGB value. Its arguments are a color map index and eight bits each of red, green, and blue intensities. Pixels written with color *color* will be displayed with the specified RGB intensities.

In multimap mode only the currently selected color map can be updated with **mapcolor** . Invalid indices are ignored.

SEE ALSO

multimap, onemap, setmap

NOTE

This command can be used only in immediate mode.

NAME

mapw - maps a point on the screen into a line in 3D world coordinates

SPECIFICATION

C

```
mapw(vobj, sx, sy, wx1, wy1, wz1, wx2, wy2, wz2)
Object vobj;
Screencoord sx, sy;
Coord *wx1, *wy1, *wz1, *wx2, *wy2, *wz2;
```

FORTRAN

```
subroutine mapw(vobj, sx, sy, wx1, wy1, wz1, wx2, wy2, wz2)
integer*4 vobj, sx, sy
real wx1, wy1, wz1, wx2, wy2, wz2
```

Pascal

```
procedure mapw(vobj: Object; sx, sy: Screencoord;
var wx1, wy1, wz1, wx2, wy2, wz2: Coord);
```

DESCRIPTION

mapw takes a pair of 2D screen coordinates and maps them into 3D world space. Since the *z*-coordinate is missing from screen space, the point becomes a line in world space. **mapw** computes the inverse mapping from *vobj*, a viewing object. A *viewing object* is a graphical object that contains only viewport, projection, viewing transformation, and modelling commands. A correct mapping from screen to world space requires that the viewing object contain the projection and viewing transformations that mapped the displayed object from world to screen coordinates. The world space line that is computed from *(sx, sy)* and *vobj* is returned as two points and stored in the locations addressed by *wx1, wy1, wz1* and *wx2, wy2, wz2*.

SEE ALSO

mapw2

NOTE

This command can be used only in immediate mode.

NAME

mapw2 - maps a point on the screen into 2D world coordinates

SPECIFICATION

C

```
mapw2(vobj, sx, sy, wx, wy)
Object vobj;
Screencord sx, sy;
Coord *wx, *wy;
```

FORTRAN

```
subroutine mapw2(vobj, sx, sy, wx, wy)
integer*4 vobj, sx, sy
real wx, wy
```

Pascal

```
procedure mapw2(vobj: Object; sx, sy: Screencoord;
var wx, wy: Coord);
```

DESCRIPTION

mapw2 is the two-dimensional version of **mapw**. *vobj* is a viewing object containing the viewport, projection, viewing, and modelling transformations that define world space; *sx* and *sy* define a screen space point. The corresponding world space coordinates are returned in *wx* and *wy*. If the transformation is not 2D, the result is undefined.

SEE ALSO

mapw

NOTE

This command can be used only in immediate mode.

NAME

maxsize - specifies a maximum size for a graphics port in the window manager

SPECIFICATION

C	**maxsize(x, y)**
	long x, y;

FORTRAN	**subroutine maxsiz(x, y)** **integer*4 x, y**
Pascal	**procedure maxsize(x, y: long);**

DESCRIPTION

maxsize specifies a maximum size for a graphics port. It is called at the beginning of a graphics program that will be run with the window manager, and takes effect when **getport** is called. The default maximum size is 1024 pixels wide and 768 pixels high. As the graphics port is reshaped, the window manager will not allow it to become larger than this maximum size. If **maxsize** is called without **getport** or if the system is not running the window manager, the command will be ignored.

SEE ALSO

getport, minsize

NOTE

This command can be used only in immediate mode.

NAME

minsize - specifies a minimum size for a graphics port in the window manager

SPECIFICATION

C	**minsize(x, y)**
	long x, y;

FORTRAN	**subroutine minsiz(x, y)** **integer*4 x, y**
Pascal	**procedure minsize(x, y: long);**

DESCRIPTION

minsize specifies a minimum size for a graphics port. It is called at the beginning of a graphics program that will be run with the window manager, and takes effect when **getport** is called. The default minimum size is 40 pixels wide and 30 pixels high. The port can be reshaped by the user, but the window manager will not allow it to become smaller than this minimum size. **minsize** has no effect if **getport** is not called or if the program is not being run with the window manager.

SEE ALSO

getport, maxsize

NOTE

This command can be used only in immediate mode.

NAME

move - moves to a specified point

SPECIFICATION

C

```
move(x, y, z)
Coord x, y, z;

movei(x, y, z)
Icoord x, y, z;

moves(x, y, z)
Scoord x, y, z;

move2(x, y)
Coord x, y;

move2i(x, y)
Icoord x, y;

move2s(x, y)
Scoord x, y;
```

FORTRAN

```
subroutine move(x, y, z)
real x, y, z

subroutine movei(x, y, z)
integer*4 x, y, z

subroutine moves(x, y, z)
integer*2 x, y, z

subroutine move2(x, y)
real x, y

subroutine move2i(x, y)
integer*4 x, y

subroutine move2s(x, y)
integer*2 x, y
```

Pascal

```
procedure move(x, y, z: Coord);

procedure movei(x, y, z: Icoord);

procedure moves(x, y, z: Scoord);
procedure move2(x, y: Coord);
procedure move2i(x, y: Icoord);
procedure move2s(x, y: Scoord);
```

DESCRIPTION

The **move** command moves (without drawing) the current graphics position to the specified point. The command has six forms: 3D floating point, 3D integer, 2D floating point, 2D integer, 3D short integer, and 2D short integer; **move2(x,y)** is equivalent to **move(x,y,0.0)**.

SEE ALSO

draw, pnt, rdr, rmv

NAME

multimap - utilizes the color map as sixteen small maps

SPECIFICATION

C	**multimap()**
FORTRAN	**subroutine multim**
Pascal	**procedure multimap;**

DESCRIPTION

multimap organizes the color map as sixteen small maps, each with a maximum of 256 RGB entries. The number of entries in each map is 2^p, where *p* is the number of available planes. **multimap** does not take effect until **gconfig** is called.

SEE ALSO

gconfig, getcmmode, getmap, onemap, setmap, setplanes

NOTE

This command can be used only in immediate mode.

NAME

multmatrix - pre-multiplies the current transformation matrix

SPECIFICATION

C	**multmatrix(m)**
	Matrix m;

FORTRAN	**subroutine multma(m)** **real m(4,4)**
Pascal	**procedure multmatrix(m: Matrix);**

DESCRIPTION

multmatrix pre-multiplies the current top of the transformation stack by the given matrix. If *T* is the current matrix, **multmatrix(M)** replaces *T* with $M*T$.

SEE ALSO

loadmatrix, popmatrix, pushmatrix

NAME

newtag - creates a new tag in an object

SPECIFICATION

```
C          newtag(newtag, oldtag, offset)
           Tag newtag, oldtag;
           long offset;

FORTRAN    subroutine newtag(newtag, oldtag, offset)
           integer*4 newtag, oldtag, offset

Pascal     procedure newtag(newtag, oldtag: Tag; offset: longint);
```

DESCRIPTION

newtag creates a new tag *offset* positions beyond *oldtag*.

SEE ALSO

maketag

NOTE

This command can be used only in immediate mode.

NAME

noise - filters valuator motion

SPECIFICATION

C

```
noise(v, delta)
Device v;
short delta;
```

FORTRAN

```
subroutine noise(v, delta)
integer*4 v, delta
```

Pascal

```
procedure noise(v: Device; delta: Short);
```

DESCRIPTION

noise determines how often queued valuators will make entries in the event queue. Some valuators are "noisy": an unmoving device may report small fluctuations in value. The **noise** command allows the user to set a lower limit on what constitutes a move. That is, the value of a noisy valuator *v* must change by at least *delta* before the motion is considered significant. For example, **noise(v,5)** means that valuator *v* must move at least 5 units before a new queue entry is made.

SEE ALSO

setvaluator

NOTE

This command can be used only in immediate mode.

NAME

noport - specifies that a program does not require a graphics port

SPECIFICATION

C	**noport()**
FORTRAN	**subroutine noport**
Pascal	**procedure noport;**

DESCRIPTION

noport specifies that a graphics program does not need any screen space and therefore does not need a graphics port in the window manager. This is useful for programs which only read or write the color map. This command is called at the beginning of a graphics program; a call to **getport** is still needed to do a graphics initialization. If **getport** is not called or if the system is not running the window manager, **noport** is ignored.

SEE ALSO

getport

NOTE

This command can be used only in immediate mode.

NAME

objdelete - deletes commands from an object

SPECIFICATION

C	**objdelete(tag1, tag2)**
	Tag tag1, tag2;

FORTRAN	**subroutine objdel(tag1, tag2)** **integer*4 tag1, tag2**
Pascal	**procedure objdelete(tag1, tag2: Tag);**

DESCRIPTION

objdelete is an object editing command. It removes commands from an object between *tag1* and *tag2*. The tags remain. Any tags defined between *tag1* and *tag2* are also deleted.

If no object is open for editing when **objdelete** is called, the command is ignored. This command leaves the pointer at the end of the object after it takes effect.

SEE ALSO

editobj, objinsert, objreplace

NOTE

This command can be used only in immediate mode.

NAME

objinsert - inserts commands in an object at the chosen location

SPECIFICATION

C	**objinsert(t)**
	Tag t;

FORTRAN	**subroutine objins(t)** **integer*4 t**
Pascal	**procedure objinsert(t: Tag);**

DESCRIPTION

objinsert takes a tag *t* as an argument, and positions an editing pointer on the indicated command. Subsequent graphics commands are added following the tag. **closeobj** or another positioning command **(objdelete, objinsert,** or **objreplace)** terminates the insertion.

SEE ALSO

closeobj, objdelete, editobj, objreplace, maketag

NOTE

This command can be used only in immediate mode.

NAME

objreplace - overwrites existing display list commands with new ones

SPECIFICATION

C **objreplace(t)**
Tag t;

FORTRAN **subroutine objrep(t)**
integer*4 t

Pascal **procedure objreplace(t: Tag);**

DESCRIPTION

objreplace combines the functions of **objinsert** and **objdelete.** It takes a single argument, a tag *t*. Graphics commands that follow **objreplace** overwrite existing commands until a **closeobj, objinsert, objdelete,** or **objreplace** command terminates the replacement. **objreplace** requires the new command to be the same length as the one it replaces, which makes replacement operations fast. More general replacement can be done with **objdelete** and **objinsert** commands. **objreplace** is meant as a quick means of replacing a command with a version of itself containing different arguments.

SEE ALSO

closeobj, objdelete, editobj, objinsert

NOTE

This command can be used only in immediate mode.

NAME

onemap - organizes the color map as one large map

SPECIFICATION

C	**onemap()**
FORTRAN	**subroutine onemap**
Pascal	**procedure onemap;**

DESCRIPTION

onemap organizes the color map as a single map with a maximum of 4096 RGB entries. The number of entries is 2^p, where *p* is the number of available planes. **onemap** does not take effect until **gconfig** is called. The IRIS is initially in **onemap** mode.

SEE ALSO

gconfig, getcmmode, multimap, setmap, setplanes

NOTE

This command can be used only in immediate mode.

NAME

ortho - defines an orthographic projection transformation

SPECIFICATION

C

ortho(left, right, bottom, top, near, far)
Coord left, right, bottom, top, near, far;

ortho2(left, right, bottom, top)
Coord left, right, bottom, top;

FORTRAN

subroutine ortho(left, right, bottom, top, near, far)
real left, right, bottom, top, near, far

subroutine ortho2(left, right, bottom, top)
real left, right, bottom, top

Pascal

procedure ortho(left, right, bottom, top, near, far: Coord);

procedure ortho2(left, right, bottom, top: Coord);

DESCRIPTION

ortho specifies a box-shaped enclosure in the eye coordinate system that will be mapped to the viewport. *left, right, bottom,* and *top* are the *x* and *y* clipping planes. *near* and *far* are distances along the line of sight from the eye space origin, and can be negative. The *z* clipping planes are at *−near* and *−far*.

ortho2 defines a 2D clipping rectangle. When **ortho2** is used with 3D world coordinates, the *z* values are left unchanged.

Both **ortho** and **ortho2** load a matrix onto the transformation stack, overwriting whatever was there.

SEE ALSO

perspective, window

NAME

pagecolor - sets the color of the textport background

SPECIFICATION

C	**pagecolor(c)**
	short c;

FORTRAN	**subroutine pageco(c)** **integer*4 c**
Pascal	**procedure pagecolor(c: Colorindex);**

DESCRIPTION

pagecolor sets the textport background color.

SEE ALSO

color, pagewritemask, textcolor, textport, textwritemask, tpoff, tpon

NOTE

This command can be used only in immediate mode.

NAME

pagewritemask - sets the writemask for the textport background

SPECIFICATION

C	**pagewritemask(pmask)**
	short pmask;

FORTRAN	**subroutine pagewr(pmask)** **integer*4 pmask**
Pascal	**procedure pagewritemask(pmask: Colorindex);**

DESCRIPTION

pagewritemask sets the textport background writemask.

SEE ALSO

color, pagecolor, textcolor, textport, textwritemask, tpoff, tpon, writemask

NOTE

This command can be used only in immediate mode.

NAME

passthrough - passes a single token through the Geometry Pipeline

SPECIFICATION

C	**passthrough(token)**
	short token;

FORTRAN	**subroutine passth(token)** **integer*4 token**
Pascal	**procedure passthrough(token: Short);**

DESCRIPTION

passthrough passes a single 16-bit integer through the Geometry Pipeline. It is useful in feedback mode to parse the information returned. Suppose, for example, that points are being transformed and clipped by the geometry engines. If **passthrough** is used between every pair of points, then if a point is clipped out, two **passthrough** commands will appear in a row in the output buffer. This command is very dangerous to use when not in feedback mode – it has the effect of sending a random command to the raster subsystem.

NOTE

Should be used only in feedback mode.

NAME

patch - draws a surface patch

SPECIFICATION

C	**patch(geomx, geomy, geomz)** **Matrix geomx, geomy, geomz;**
FORTRAN	**subroutine patch(geomx, geomy, geomz)** **real geomx(4,4), geomy(4,4), geomz(4,4)**
Pascal	**procedure patch(geomx, geomy, geomz: Patcharray);**

DESCRIPTION

patch draws a surface patch using the current **patchbasis, patchprecision,** and **patchcurves.** The shape of the patch is determined by the control points specified in *geomx, geomy,* and *geomz.*

SEE ALSO

patchbasis, patchprecision, patchcurves, defbasis

NAME

patchbasis - sets current basis matrices

SPECIFICATION

C	**patchbasis(uid, vid)**
	long uid, vid;

FORTRAN	**subroutine patchb(uid, vid)** **integer*4 uid, vid**
Pascal	**procedure patchbasis(uid, vid: longint);**

DESCRIPTION

patchbasis sets the current basis matrices (defined by **defbasis)** for both the *u* and *v* parametric directions of a surface patch. The current *u* and *v* bases are used when the **patch** command is issued.

SEE ALSO

defbasis, patch, patchprecision, patchcurves

NAME

patchcurves - sets number of curves used to represent a patch

SPECIFICATION

C	**patchcurves(ucurves, vcurves)**
	long ucurves, vcurves;

FORTRAN	**subroutine patchc(ucurves, vcurves)** **integer*4 ucurves, vcurves**
Pascal	**procedure patchcurves(ucurves, vcurves: long);**

DESCRIPTION

patchcurves sets the current number of *u* and *v* curves used to represent a patch as a wire frame.

SEE ALSO

patch, patchbasis, patchprecision

NAME

patchprecision - sets precision at which curves are drawn

SPECIFICATION

C	**patchprecision(usegments, vsegments)**
	long usegments, vsegments;

FORTRAN	**subroutine patchp(usegments, vsegments)** **integer*4 usegments, vsegments**
Pascal	**procedure patchprecision(usegments, vsegments: long);**

DESCRIPTION

patchprecision sets the precision at which curves defining a wire frame patch are drawn. Precisions are specified independently in the *u* and *v* directions for a patch. Patch precisions are similar to curve precisions – they specify the minimum number of line segments used in drawing a patch. The actual number of line segments used in the display of a patch is an even multiple of the number of curves used in drawing the patch greater than the specified precision. This multiple is used in order to guarantee the intersection of patch curves.

SEE ALSO

curveprecision, patchcurves, patchbasis, patch

NAME

pclos - polygon close

SPECIFICATION

C	**pclos()**
FORTRAN	**subroutine pclos**
Pascal	**procedure pclos;**

DESCRIPTION

pclos closes a filled polygon. It is used to terminate a sequence of **pmv** and **pdr** or **rpmv** and **rpdr** commands. The polygon so defined is filled using the current texture, color, writemask. For example, the following sequence draws a square:

```
pmv(0.0, 0.0, 0.0);
pdr(1.0, 0.0, 0.0);
pdr(1.0, 1.0, 0.0);
pdr(0.0, 1.0, 0.0);
pclos();
```

The results are undefined if the polygon is not convex.

SEE ALSO

pdr, pmv, rpdr, rpmv

NAME

pdr - polygon draw

SPECIFICATION

C

```
pdr(x, y, z)
Coord x, y, z;

pdri(x, y, z)
Icoord x, y, z;

pdrs(x, y, z)
Scoord x, y, z;

pdr2(x, y)
Coord x, y;

pdr2i(x, y)
Icoord x, y;

pdr2s(x, y)
Scoord x, y;
```

FORTRAN

```
subroutine pdr(x, y, z)
real x, y, z

subroutine pdri(x, y, z)
integer*4 x, y, z

subroutine pdrs(x, y, z)
integer*2 x, y, z

subroutine pdr2(x, y)
real x, y

subroutine pdr2i(x, y)
integer*4 x, y

subroutine pdr2s(x, y)
integer*2 x, y
```

Pascal

```
procedure pdr(x, y, z: Coord);

procedure pdri(x, y, z: Icoord);

procedure pdrs(x, y, z: Scoord);
procedure pdr2(x, y: Coord);
procedure pdr2i(x, y: Icoord);
procedure pdr2s(x, y: Scoord);
```

DESCRIPTION

pdr is the draw command for filled polygons. A typical polygon is drawn with a **pmv,** a sequence of **pdr**'s, and is closed with a **pclos.** For example, the following sequence draws a square:

```
pmv(0.0, 0.0, 0.0);
pdr(1.0, 0.0, 0.0);
pdr(1.0, 1.0, 0.0);
pdr(0.0, 1.0, 0.0);
pclos();
```

The results are undefined if the polygon is not convex.

SEE ALSO

pclos, pmv, rpdr, rpmv

NAME

perspective - defines a perspective projection transformation

SPECIFICATION

C

```
perspective(fovy, aspect, near, far)
Angle fovy;
float aspect;
Coord near, far;
```

FORTRAN

```
subroutine perspe(fovy, aspect, near, far)
integer*4 fovy
real aspect, near, far
```

Pascal

```
procedure perspective(fovy: Angle; aspect: real; near, far: Coord);
```

DESCRIPTION

perspective defines a projection transformation by indicating the field-of-view angle, *fovy,* in the *y* direction of the eye coordinate system, the *aspect* ratio which determines the field of view in the *x* direction, and the distance to the *near* and *far* clipping planes in the *z* direction. The aspect ratio is given as a ratio of *x* to *y*. In general, the aspect ratio given in the **perspective** command should match the aspect ratio of the associated viewport. For example, *aspect=2.0* means the viewer sees twice as far in *x* as in *y*. If the viewport is twice as wide as it is tall, the image will be displayed without distortion. The arguments *near* and *far* are distances from the viewer to the near and far clipping planes, and these are always positive. **perspective** loads a matrix onto the transformation stack, overwriting whatever was there.

fovy is in 10^{th} of degrees, as are all angles. *fov* must be ≥ 2 or an error will result.

SEE ALSO

ortho, window

NAME

pick - puts the system in picking mode

SPECIFICATION

C

```
pick(buffer, numnames)
short buffer[];
long numnames;
```

FORTRAN

```
subroutine pick(buffer, numnam)
integer*2 buffer(*)
integer*4 numnam
```

Pascal

```
procedure pick(buffer: Ibuffer; numnames: longint);
```

DESCRIPTION

pick facilitates the use of the cursor as a pointing object. When an image is drawn in picking mode, the screen does not change. Instead, a special viewing matrix is placed on the stack, and everything in the image that does not intersect a small neighborhood around the lower left corner of the cursor is discarded. The commands that do intersect the picking region are "hits" and cause the contents of the name stack to be stored in *buffer*. *numnames* specifies the maximum number of names to be saved by the system.

SEE ALSO

clearhitcode, endpick, endselect, gethitcode, picksize, select, pushname, popname, loadname

NOTE

This command can be used only in immediate mode.

NAME

picksize - sets the dimensions of the picking window

SPECIFICATION

C

```
picksize(deltax, deltay)
short deltax, deltay;
```

FORTRAN

```
subroutine picksi(deltax, deltay)
integer*4 deltax, deltay
```

Pascal

```
procedure picksize(deltax, deltay: Short);
```

DESCRIPTION

picksize has two arguments, *deltax* and *deltay*, which define the dimensions of a rectangle, called the picking region, centered at the current cursor position, the origin of the cursor glyph. In picking mode, any objects that intersect the picking region are reported.

SEE ALSO

pick

NOTE

This command can be used only in immediate mode.

NAME

pmv - polygon move

SPECIFICATION

C

```
pmv(x, y, z)
Coord x, y, z;

pmvi(x, y, z)
Icoord x, y, z;

pmvs(x, y, z)
Scoord x, y, z;

pmv2(x, y)
Coord x, y;

pmv2i(x, y)
Icoord x, y;

pmv2s(x, y)
Scoord x, y;
```

FORTRAN

```
subroutine pmv(x, y, z)
real x, y, z

subroutine pmvi(x, y, z)
integer*4 x, y, z

subroutine pmvs(x, y, z)
integer*2 x, y, z

subroutine pmv2(x, y)
real x, y

subroutine pmv2i(x, y)
integer*4 x, y

subroutine pmv2s(x, y)
integer*2 x, y
```

Pascal

```
procedure pmv(x, y, z: Coord);

procedure pmvi(x, y, z: Icoord);

procedure pmvs(x, y, z: Scoord);
```

procedure pmv2(x, y: Coord);
procedure pmv2i(x, y: Icoord);
procedure pmv2s(x, y: Scoord);

DESCRIPTION

pmv is the move command for filled polygons. A typical polygon is drawn with a **pmv**, a sequence of **pdr**'s, and is closed with a **pclos**. For example, the following sequence draws a square:

```
pmv(0.0, 0.0, 0.0);
pdr(1.0, 0.0, 0.0);
pdr(1.0, 1.0, 0.0);
pdr(0.0, 1.0, 0.0);
pclos();
```

SEE ALSO

pclos, pdr, rpdr, rpmv

NOTE

The results are undefined if the polygon is not convex.

NAME

pnt - draws a point

SPECIFICATION

C

```
pnt(x, y, z)
Coord x, y, z;

pnti(x, y, z)
Icoord x, y, z;

pnts(x, y, z)
Scoord x, y, z;

pnt2(x, y)
Coord x, y;

pnt2i(x, y)
Icoord x, y;

pnt2s(x, y)
Scoord x, y;
```

FORTRAN

```
subroutine pnt(x, y, z)
real x, y, z

subroutine pnti(x, y, z)
integer*4 x, y, z

subroutine pnts(x, y, z)
integer*2 x, y, z

subroutine pnt2(x, y)
real x, y

subroutine pnt2i(x, y)
integer*4 x, y

subroutine pnt2s(x, y)
integer*2 x, y
```

Pascal

```
procedure pnt(x, y, z: Coord);

procedure pnti(x, y, z: Icoord);

procedure pnts(x, y, z: Scoord);
procedure pnt2(x, y: Coord);
procedure pnt2i(x, y: Icoord);
procedure pnt2s(x, y: Scoord);
```

DESCRIPTION

pnt colors a world space point. If the point is visible in the current viewport, it will be shown as one pixel. The pixel is drawn in the current color (if in depth-cue mode, the depth-cued color is used) using the current writemask. The current graphics position is updated after the **pnt** command is executed.

SEE ALSO

draw, move

NAME

polarview - defines the viewer's position in polar coordinates

SPECIFICATION

C

```
polarview(dist, azim, inc, twist)
Coord dist;
Angle azim, inc, twist;
```

FORTRAN

```
subroutine polarv(dist, azim, inc, twist)
real dist
integer*4 azim, inc, twist
```

Pascal

```
procedure polarview(dist: Coord; azim, inc, twist: Angle);
```

DESCRIPTION

polarview defines the viewer's position in polar coordinates. The first three parameters, *dist*, *azim*, and *inc*, define a viewpoint. *dist* is the distance from the viewpoint to the world space origin. *azim* is the angle in the x-y plane, measured from the y axis. *inc* is the angle in y-z plane, measured from the z axis. The line of sight extends from the viewpoint through the world space origin. *twist* rotates the viewpoint around the line of sight using the right-hand rule. All angles are specified in tenths of degrees and are integers.

SEE ALSO

lookat

NAME

polf - draws a filled polygon

SPECIFICATION

```
C            polf(n, parray)
             long n;
             Coord parray[][3];

             polfi(n, parray)
             long n;
             Icoord parray[][3];

             polfs(n, parray)
             long n;
             Scoord parray[][3];

             polf2(n, parray)
             long n;
             Coord parray[][2];

             polf2i(n, parray)
             long n;
             Icoord parray[][2];

             polf2s(n, parray)
             long n;
             Scoord parray[][2];


FORTRAN      subroutine polf(n, parray)
             integer*4 n
             real parray(3,n)

             subroutine polfi(n, parray)
             integer*4 n
             integer*4 parray(3,n)

             subroutine polfs(n, parray)
             integer*4 n
             integer*2 parray(3,n)

             subroutine polf2(n, parray)
             integer*4 n
             real parray(2,n)

             subroutine polf2i(n, parray)
             integer*4 n
```

```
            integer*4 parray(2,n)

            subroutine polf2s(n, parray)
            integer*4 n
            integer*2 parray(2,n)

Pascal      procedure polf(n: longint; var parray: Coord3array);
            procedure polfi(n: longint; var parray: Icoord3array);
            procedure polfs(n: longint; var parray: Scoord3array);
            procedure polf2(n: longint; var parray: Coord2array);
            procedure polf2i(n: longint; var parray: Icoord2array);
            procedure polf2s(n: longint; var parray: Scoord2array);
```

DESCRIPTION

polf fills polygonal areas using the current texture pattern, color, and writemask. It takes two arguments: an array of points and the number of points in that array. Polygons are represented as arrays of points. The first and last points are automatically connected to close a polygon. The points can be expressed as integers, shorts, or real numbers, in 2D or 3D space. Two-dimensional polygons are drawn with z=0. After the polygon is filled, the current graphics position is set to the first point in the array.

The results are undefined if the polygon is not convex.

SEE ALSO

poly, rect, rectf, pdr, pmv, rpdr, rpmv

NAME

poly - outlines a polygon

SPECIFICATION

```
C          poly(n, parray)
           long n;
           Coord parray[][3];

           polyi(n, parray)
           long n;
           Icoord parray[][3];

           polys(n, parray)
           long n;
           Scoord parray[][3];

           poly2(n, parray)
           long n;
           Coord parray[][2];

           poly2i(n, parray)
           long n;
           Icoord parray[][2];

           poly2s(n, parray)
           long n;
           Scoord parray[][2];


FORTRAN    subroutine poly(n, parray)
           integer*4 n
           real parray(3,n)

           subroutine polyi(n, parray)
           integer*4 n
           integer*4 parray(3,n)

           subroutine polys(n, parray)
           integer*4 n
           integer*2 parray(3,n)

           subroutine poly2(n, parray)
           integer*4 n
           real parray(2,n)

           subroutine poly2i(n, parray)
           integer*4 n
```

```
        integer*4 parray(2,n)

        subroutine poly2s(n, parray)
        integer*4 n
        integer*2 parray(2,n)
```

Pascal

```
        procedure poly(n: longint; var parray: Coord3array);
        procedure polyi(n: longint; var parray: Icoord3array);
        procedure polys(n: longint; var parray: Scoord3array);
        procedure poly2(n: longint; var parray: Coord2array);
        procedure poly2i(n: longint; var parray: Icoord2array);
        procedure poly2s(n: longint; var parray: Scoord2array);
```

DESCRIPTION

poly takes two arguments: an array of points and the number of points in that array. A polygon is represented as an array of points. The first and last points are automatically connected to close the polygon. The points can be expressed as integers, shorts, or real numbers, in 2D or 3D space. Two-dimensional polygons are drawn with z=0. The polygon is outlined using the current linestyle, linewidth, color, and writemask. The maximum number of points in a polygon is 384.

SEE ALSO

polf, rect, rectf, pmv, pdr, pclos, rpmv, rpdr

NOTE

This command can be used only in immediate mode.

NAME

popattributes - pops the attribute stack

SPECIFICATION

C	**popattributes()**
FORTRAN	**subroutine popatt**
Pascal	**procedure popattributes;**

DESCRIPTION

popattributes restores the most recently saved values (those pushed by **pushattributes)** of the global state variables:

Attributes	
backbuffer	linewidth
color	lsrepeat
raster font	pattern
frontbuffer	reset linestyle
linestyle	RGB color
linestyle backup	RGB writemask
writemask pattern	

An error message is printed if you attempt to pop an empty attributes stack.

SEE ALSO

backbuffer, color, defcursor, frontbuffer, linewidth, lsbackup, lsrepeat, pushattributes, resetls, RGBcolor, RGBwritemask, setlinestyle, setpattern, writemask

NAME

popmatrix - pops the transformation matrix stack

SPECIFICATION

C	**popmatrix()**
FORTRAN	**subroutine popmat**
Pascal	**procedure popmatrix;**

DESCRIPTION

popmatrix pops the transformation matrix stack. The matrix on top of the stack before the execution of **popmatrix** is lost.

SEE ALSO

loadmatrix, multmatrix, pushmatrix

NAME

popname - pops a name off the name stack

SPECIFICATION

C	**popname()**
FORTRAN	**subroutine popnam**
Pascal	**procedure popname;**

DESCRIPTION

popname removes the top name from the name stack (used in picking and selecting modes).

SEE ALSO

loadname, pushname, pick, select

NAME

popviewport - restores the viewport, screenmask, and **setdepth** parameters

SPECIFICATION

C	**popviewport()**
FORTRAN	**subroutine popvie**
Pascal	**procedure popviewport;**

DESCRIPTION

The **popviewport** command pops the stack of viewports and screenmasks. The viewports on top of the stack are lost. In addition, **popviewport** restores the **setdepth** parameters.

SEE ALSO

getscrmask, pushviewport, setdepth, viewport

NAME

prefposition - specifies the preferred location and size of a graphics port

SPECIFICATION

C	**prefposition(x1, x2, y1, y2)**
	long x1, x2, y1, y2;

FORTRAN	**subroutine prefpo(x1, x2, y1, y2)** **integer*4 x1, x2, y1, y2**
Pascal	**procedure prefposition(x1, x2, y1, y2: long);**

DESCRIPTION

prefposition specifies the preferred location and size of a graphics port. The location is specified in screen coordinates. The window manager will not allow the graphics port to be relocated or resized.

prefposition is called at the beginning of a graphics program that will be run with the window manager. If **getport** is not called or if the system is not running the window manager, **prefposition** will be ignored.

SEE ALSO

getport

NOTE

This command can be used only in immediate mode.

NAME

prefsize - specifies the preferred size of a graphics port in the window manager

SPECIFICATION

C	**prefsize(x, y)**
	long x, y;

FORTRAN	**subroutine prefsi(x, y)** **integer*4 x, y**
Pascal	**procedure prefsize(x, y: long);**

DESCRIPTION

prefsize specifies that the size of a graphics port should be *x* pixels by *y* pixels. It is called at the beginning of a graphics program that will be run with the window manager. The window manager will not allow the graphics port to be resized. **prefsize** will be ignored if **getport** is not called or if the system is not running the window manager.

SEE ALSO

getport

NOTE

This command can be used only in immediate mode.

NAME

pushattributes - pushes attributes on a stack

SPECIFICATION

C	**pushattributes()**
FORTRAN	**subroutine pushat**
Pascal	**procedure pushattributes;**

DESCRIPTION

pushattributes saves the global state. A stack of attributes is maintained, and **pushattributes** puts copies of global state variables on the stack. The global state variables that will be saved are:

Attributes	
backbuffer	linewidth
color	lsrepeat
raster font	reset linestyle
frontbuffer	RGB color
linestyle	RGB writemask
linestyle backup	pattern
writemask	

The attribute stack is 12 levels deep. **pushattributes** is ignored if the stack is full.

SEE ALSO

backbuffer, color, frontbuffer, linewidth, lsbackup, lsrepeat, popattributes, resetls, RGBcolor, RGBwritemask, setlinestyle, settexture, writemask

NAME

pushmatrix - pushes down the transformation matrix stack

SPECIFICATION

C	**pushmatrix()**
FORTRAN	**subroutine pushma**
Pascal	**procedure pushmatrix;**

DESCRIPTION

pushmatrix pushes down the transformation matrix stack, duplicating the current matrix; i.e., if the stack contains one matrix, , after a **pushmatrix** command it will contain two copies of . The top copy can be modified. The stack is eight levels deep in hardware, and extends to 32 levels in software.

SEE ALSO

loadmatrix, multmatrix, popmatrix

NAME

pushname - pushes a new name on the name stack

SPECIFICATION

C	**pushname(name)**
	short name;

FORTRAN	**subroutine pushna(name)** **integer*4 name**
Pascal	**procedure pushname(name: Short);**

DESCRIPTION

pushname pushes the name stack down one level, and puts a new 16-bit name on top. The contents of the name stack are stored in a buffer for each "hit" in picking and selecting modes.

SEE ALSO

popname, loadname, pick, select

NAME

pushviewport - save the current viewport, screenmask, and **setdepth** parameters

SPECIFICATION

C	**pushviewport()**
FORTRAN	**subroutine pushvi**
Pascal	**procedure pushviewport;**

DESCRIPTION

The current viewport is the top element in a stack of viewports. The **pushviewport** command duplicates the current viewport and pushes it on the stack. After **pushviewport,** there are two copies of the current viewport in the stack; the top one can be changed without losing the old one. In addition, it saves the screenmask and the parameters specified by the **setdepth** command.

SEE ALSO

getscrmask, popviewport, setdepth, viewport

NAME

qdevice - queues a device (keyboard, button, or valuator)

SPECIFICATION

C	**qdevice(v)**
	Device v;

FORTRAN	**subroutine qdevic(v)** **integer*4 v**
Pascal	**procedure qdevice(v: Device);**

DESCRIPTION

qdevice causes changes in the state of the named device to be entered in the event queue. The device can be a keyboard key, a button, or a valuator.

SEE ALSO

unqdevice, noise, tie

NOTE

This command can be used only in immediate mode.

NAME

qenter - creates an event queue entry

SPECIFICATION

C	**qenter(qtype, val)**
	short qtype, val;

FORTRAN	**subroutine qenter(qtype, val)** **integer*4 qtype, val**
Pascal	**procedure qenter(qtype, val: Short);**

DESCRIPTION

qenter takes two 16-bit integers, *qtype* and *value*, and enters them into the event queue. There is no way to distinguish user-defined and system-defined entries unless disjoint sets of types are used. See Appendix A for a list of system-defined types.

SEE ALSO

qreset, qtest, qread

NOTE

This command can be used only in immediate mode.

NAME

qread - reads the first entry in the event queue

SPECIFICATION

C	**long qread(data)** **short *data;**
FORTRAN	**integer*4 function qread(data)** **integer*2 data**
Pascal	**function qread(var data: Short): longint;**

DESCRIPTION

qread waits until there is an entry in the queue. It returns the device number of a queue entry, writes the data part of the entry into *data*, and removes the entry from the queue.

SEE ALSO

qtest, qreset

NOTE

This command can be used only in immediate mode.

NAME

qreset - empties the event queue

SPECIFICATION

C	**qreset()**
FORTRAN	**subroutine qreset**
Pascal	**procedure qreset;**

DESCRIPTION

qreset removes all entries from the event queue and discards them.

SEE ALSO

qenter, qread, qtest

NOTE

This command can be used only in immediate mode.

NAME

qtest - checks the contents of the event queue

SPECIFICATION

C	**long qtest()**
FORTRAN	**integer*4 function qtest()**
Pascal	**function qtest: long;**

DESCRIPTION

qtest returns zero if the queue is empty. Otherwise, the device number of the first entry is returned, and the queue remains unchanged.

SEE ALSO

qenter, qread, qreset

NOTE

This command can be used only in immediate mode.

NAME

rdr - relative draw

SPECIFICATION

```
C          rdr(dx, dy, dz)
           Coord dx, dy, dz;

           rdri(dx, dy, dz)
           Icoord dx, dy, dz;

           rdrs(dx, dy, dz)
           Scoord dx, dy, dz;

           rdr2(dx, dy)
           Coord dx, dy;

           rdr2i(dx, dy)
           Icoord dx, dy;

           rdr2s(dx, dy)
           Scoord dx, dy;


FORTRAN    subroutine rdr(dx, dy, dz)
           real dx, dy, dz

           subroutine rdri(dx, dy, dz)
           integer*4 dx, dy, dz

           subroutine rdrs(dx, dy, dz)
           integer*2 dx, dy, dz

           subroutine rdr2(dx, dy)
           real dx, dy

           subroutine rdr2i(dx, dy)
           integer*4 dx, dy

           subroutine rdr2s(dx, dy)
           integer*2 dx, dy


Pascal     procedure rdr(dx, dy, dz: Coord);

           procedure rdri(dx, dy, dz: Icoord);

           procedure rdrs(dx, dy, dz: Scoord);
procedure rdr2(dx, dy: Coord);
procedure rdr2i(dx, dy: Icoord);
procedure rdr2s(dx, dy: Scoord);
```

DESCRIPTION

rdr is the relative version of the **draw** command. It connects the current graphics position and the point at the specified distance away with a line segment using the current linestyle, linewidth, color (if in depth cue mode, the depth cued color is used), and writemask. The current graphics position is updated to the new point. Commands that invalidate the current graphics position should not be placed within sequences of relative moves and draws.

SEE ALSO

draw, move, rmv

NAME

readpixels - returns values of specific pixels

SPECIFICATION

C

```
long readpixels(n, colors)
short n;
Colorindex colors[];
```

FORTRAN

```
integer*4 function readpi(n, colors)
integer*4 n
integer*2 colors(n)
```

Pascal

```
function readpixels(n: Short; var colors: Colorarray): longint;
```

DESCRIPTION

readpixels attempts to read up to *n* pixel values from the bitplanes. They are read into the array *colors* starting from the current character position along a single scan line (constant *y*) in the direction of increasing *x*. **readpixels** returns the number of pixels actually read, which is only guaranteed to be the number requested if the starting point is at least that many away from the edge of the current viewport. The values of pixels read outside the current viewport are undefined. The current character position is updated to be one pixel to the right of the last one read, or is undefined if the new position is outside the viewport.

In double buffer mode only the back buffer is read. Use **readRGB** to read pixels in RGB mode.

SEE ALSO

readRGB, writepixels

NOTE

This command can be used only in immediate mode.

NAME

readRGB - returns values of specific pixels

SPECIFICATION

C

```
long readRGB(n, red, green, blue)
short n;
RGBvalue red[], green[], blue[];
```

FORTRAN

```
integer*4 function readRG(n, red, green, blue)
integer*4 n
character*(*) red, green, blue
```

Pascal

```
function readRGB(n: Short; var red, green, blue:
RGBarray): longint;
```

DESCRIPTION

readRGB attempts to read up to *n* pixel values from the bitplanes. They are read into the *red, green,* and *blue* arrays starting from the current character position along a single scan line (constant *y*) in the direction of increasing *x*. **readRGB** returns the number of pixels actually read, which is only guaranteed to be the number requested if the starting point is at least that many away from the edge of the current viewport. The values of pixels read outside the current viewport are undefined. The current character position is updated to be one pixel to the right of the last one read, or is undefined if the new position is outside the viewport.

SEE ALSO

readpixels, writeRGB

NOTE

This command can be used only in immediate mode.

NAME

rect - outlines a rectangular region

SPECIFICATION

C

```
rect(x1, y1, x2, y2)
Coord x1, y1, x2, y2;

recti(x1, y1, x2, y2)
Icoord x1, y1, x2, y2;
```

FORTRAN

```
subroutine rect(x1, y1, x2, y2)
real x1, y1, x2, y2

subroutine recti(x1, y1, x2, y2)
integer*4 x1, y1, x2, y2
```

Pascal

```
procedure rect(x1, y1, x2, y2: Coord);

procedure recti(x1, y1, x2, y2: Icoord);
```

DESCRIPTION

rect draws a rectangle using the current linestyle, linewidth, color, and writemask. The sides of the rectangle are parallel to the *x* and *y* coordinate system. Since a rectangle is a two-dimensional shape, **rect** takes only 2D arguments, and sets the *z* coordinate to zero. The points *(x1, y1)* and *(x2, y2)* are the opposite corners of the rectangle.

SEE ALSO

poly, rectf, rpdr, rpmv

NAME

rectcopy - copies a rectangle of pixels on the IRIS screen

SPECIFICATION

C	**rectcopy(x1, y1, x2, y2, newx, newy)**
	Screencoord x1, y1, x2, y2, newx, newy;

FORTRAN	**subroutine rectco(x1, y1, x2, y2, newx, newy)** **integer*4 x1, y1, x2, y2, newx, newy**
Pascal	**procedure rectcopy(x1, y1, x2, y2, newx, newy:** **Screencoord);**

DESCRIPTION

rectcopy copies a rectangular array of pixels defined in screen coordinates to another position on the screen whose lower-left corner is defined by the point *(newx, newy)*. The drawing of the copied region is masked by the current viewport and screenmask.

NOTE

This command can be used only in immediate mode.

NAME

rectf - fills a rectangular area

SPECIFICATION

C

```
rectf(x1, y1, x2, y2)
Coord x1, y1, x2, y2;

rectfi(x1, y1, x2, y2)
Icoord x1, y1, x2, y2;
```

FORTRAN

```
subroutine rectf(x1, y1, x2, y2)
real x1, y1, x2, y2

subroutine rectfi(x1, y1, x2, y2)
integer*4 x1, y1, x2, y2
```

Pascal

```
procedure rectf(x1, y1, x2, y2: Coord);

procedure rectfi(x1, y1, x2, y2: Icoord);
```

DESCRIPTION

rectf produces a filled rectangular region, using the current texture pattern, color, and writemask. The sides of the rectangle are parallel to the *x* and *y* axes of the object coordinate system. Since a rectangle is a two-dimensional shape, **rectf** takes only 2D arguments, and sets the *z* coordinate to zero. The points *(x1, y1)* and *(x2, y2)* are the opposite corners of the rectangle. The current graphics position is set to *(x1, y1)* after the region is drawn.

SEE ALSO

polf, rect, rdr, rmv

NAME

resetls - controls the continuity of linestyles

SPECIFICATION

C	**resetls(b)**
	Boolean b;

FORTRAN	**subroutine resetl(b)** **logical b**
Pascal	**procedure resetls(b: Boolean);**

DESCRIPTION

resetls affects the re-initialization of the linestyle pattern between segments. It takes one boolean argument. *TRUE,* the default, means that stippling of each line will start from the beginning of the linestyle pattern. *FALSE* turns the mode off: the linestyle will *not* be reset between segments, and the stippling of one segment will continue from where it left off at the end of the previous segment. Calls to **resetls** have the side effect of initializing the linestyle, no matter what the argument, and of invalidating the current graphics position.

resetls is used most often when approximating circles, arcs, and curves with many short lines. If the linestyle is not reset between segments, the pattern of the curve appears smooth and continuous. The linewidth should not be set to 2 unless **resetls** is *TRUE.*

SEE ALSO

deflinestyle, getresetls, lsbackup, setlinestyle

NAME

reshapeviewport - sets the viewport to the current dimensions of the graphics port in the window manager

SPECIFICATION

C	**reshapeviewport()**
FORTRAN	**subroutine reshap**
Pascal	**procedure reshapeviewport;**

DESCRIPTION

reshapeviewport sets the viewport to the current dimensions of the graphics port.

reshapeviewport is equivalent to:

```
{
   int xmin, xmax, ymin, ymax;
      getorigin(&xmin, &ymin);
      getsize(&xmax, &ymax);
      xmax += xmin -1;
      ymax += ymin -1;
      viewport(xmin, xmax, ymin, ymax);
}
```

SEE ALSO

getorigin, getsize, viewport

NOTE

This command can be used only in immediate mode.

NAME

RGBcolor - sets the current color in RGB mode

SPECIFICATION

C	**RGBcolor(red, green, blue)** **short red, green, blue;**
FORTRAN	**subroutine RGBcol(red, green, blue)** **integer*4 red, green, blue**
Pascal	**procedure RGBcolor(red, green, blue: RGBvalue);**

DESCRIPTION

In RGB mode, the current color is set with the **RGBcolor** command. Its arguments are three eight-bit values, one each for red, green, and blue. These numbers are written directly into the bitplanes whenever a pixel is drawn; they control the intensity of red, green, and blue displayed on the screen. **RGBcolor** is ignored in single or double buffer mode.

SEE ALSO

color, gRGBcolor, RGBwritemask

NAME

RGBcursor - sets the characteristics of the cursor in RGB mode

SPECIFICATION

C

```
RGBcursor(index, red, green, blue, redm, greenm, bluem)
short index, red, green, blue, redm, greenm, bluem;
```

FORTRAN

```
subroutine RGBcur(index, red, green, blue, redm,
 greenm, bluem)
integer*4 index, red, green, blue, redm, greenm, bluem
```

Pascal

```
procedure RGBcursor(index: Short;
red, green, blue, redm, greenm, bluem: RGBvalue);
```

DESCRIPTION

RGBcursor allows selection of a cursor glyph from a table of 16×16 bit patterns already defined by the user. The first argument, *index*, picks a glyph from the definition table. *red*, *green*, and *blue* specify the cursor color in RGB mode, while *redm*, *greenm*, and *bluem* define an RGB writemask for the cursor. **RGBcursor** can be used only in RGB mode.

SEE ALSO

RGBmode, RGBwritemask, setcursor, defcursor

NOTE

This command can be used only in immediate mode.

NAME

RGBmode - sets a display mode that bypasses the color map

SPECIFICATION

C	**RGBmode()**
FORTRAN	**subroutine RGBmod**
Pascal	**procedure RGBmode;**

DESCRIPTION

There are three display modes: single buffer, double buffer, and RGB. In RGB mode, all the bitplanes are simultaneously written and displayed. Eight-bit values of red, green, and blue are written into the bitplanes, and directly control the monitor's intensity. RGB mode is useful only when the system has 24 bitplanes: the first sixteen are shared equally between red and green; the last eight define the blue component. A twelve-plane system provides one-quarter the maximum intensity in red and green, and no blue at all. **RGBmode** does not take effect until **gconfig** is called.

SEE ALSO

doublebuffer, gconfig, getdisplaymode, singlebuffer

NOTE

This command can be used only in immediate mode.

NAME

RGBwritemask - grants write access to a subset of the available bitplanes

SPECIFICATION

C	**RGBwritemask(red, green, blue)** **short red, green, blue;**
FORTRAN	**subroutine RGBwri(red, green, blue)** **integer*4 red, green, blue**
Pascal	**procedure RGBwritemask(red, green, blue: RGBvalue);**

DESCRIPTION

RGBwritemask shields bitplanes reserved for special uses from ordinary drawing commands in RGB mode. The three arguments are masks for each of the three sets of eight planes. Wherever there are ones in the writemask, the corresponding bits in the RGB color will be written into the bitplanes. Zeros in the writemask mark bitplanes as read-only. These planes will not be changed, regardless of the bits in the RGB color.

SEE ALSO

gRGBmask, RGBcolor, writemask

NAME

ringbell - rings the keyboard bell

SPECIFICATION

C	**ringbell()**
FORTRAN	**subroutine ringbe**
Pascal	**procedure ringbell;**

DESCRIPTION

ringbell rings the keyboard bell.

SEE ALSO

clkoff, clkon, lampoff, lampon, setbell

NOTE

This command can be used only in immediate mode.

NAME

rmv - relative move

SPECIFICATION

C

```
rmv(dx, dy, dz)
Coord dx, dy, dz;

rmvi(dx, dy, dz)
Icoord dx, dy, dz;

rmvs(dx, dy, dz)
Scoord dx, dy, dz;

rmv2(dx, dy)
Coord dx, dy;

rmv2i(dx, dy)
Icoord dx, dy;

rmv2s(dx, dy)
Scoord dx, dy;
```

FORTRAN

```
subroutine rmv(dx, dy, dz)
real dx, dy, dz

subroutine rmvi(dx, dy, dz)
integer*4 dx, dy, dz

subroutine rmvs(dx, dy, dz)
integer*2 dx, dy, dz

subroutine rmv2(dx, dy)
real dx, dy

subroutine rmv2i(dx, dy)
integer*4 dx, dy

subroutine rmv2s(dx, dy)
integer*2 dx, dy
```

Pascal

```
procedure rmv(dx, dy, dz: Coord);

procedure rmvi(dx, dy, dz: Icoord);

procedure rmvs(dx, dy, dz: Scoord);
```

procedure rmv2(dx, dy: Coord);

procedure rmv2i(dx, dy: Icoord);

procedure rmv2s(dx, dy: Scoord);

DESCRIPTION

rmv is the relative version of the **move** command. It moves (without drawing) the graphics position the specified amount relative to its current value. The command has six forms: 3D floating point, 3D integer, 2D floating point, 2D integer, 3D short integer, and 2D short integer. **rmv2(x, y)** is equivalent to **rmv(x, y, 0.0)**.

SEE ALSO

draw, move, rdr

NAME

rotate - rotates graphical primitives

SPECIFICATION

C

```
rotate(a, axis)
Angle a;
char axis;
```

FORTRAN

```
subroutine rotate(a, axis)
integer*4 a
character axis
```

Pascal

```
procedure rotate(a: Angle; axis: char);
```

DESCRIPTION

rotate specifies an angle and an axis of rotation. The angle is given in tenths of degrees according to the right-hand rule. The axis of rotation is defined by a character, either 'x', 'y', or 'z' (the character can be upper or lower case). **rotate** is a modeling command; thus, it changes the current transformation matrix. All objects drawn after the **rotate** command is executed will be rotated. Use **pushmatrix** and **popmatrix** to preserve and restore an unrotated world space.

SEE ALSO

popmatrix, pushmatrix, scale, translate

NAME

rpdr - relative polygon draw

SPECIFICATION

```
C          rpdr(dx, dy, dz)
           Coord dx, dy, dz;

           rpdri(dx, dy, dz)
           Icoord dx, dy, dz;

           rpdrs(dx, dy, dz)
           Scoord dx, dy, dz;

           rpdr2(dx, dy)
           Coord dx, dy;

           rpdr2i(dx, dy)
           Icoord dx, dy;

           rpdr2s(dx, dy)
           Scoord dx, dy;


FORTRAN    subroutine rpdr(dx, dy, dz)
           real dx, dy, dz

           subroutine rpdri(dx, dy, dz)
           integer*4 dx, dy, dz

           subroutine rpdrs(dx, dy, dz)
           integer*2 dx, dy, dz

           subroutine rpdr2(dx, dy)
           real dx, dy

           subroutine rpdr2i(dx, dy)
           integer*4 dx, dy

           subroutine rpdr2s(dx, dy)
           integer*2 dx, dy


Pascal     procedure rpdr(dx, dy, dz: Coord);

           procedure rpdri(dx, dy, dz: Icoord);

           procedure rpdrs(dx, dy, dz: Scoord);
procedure rpdr2(dx, dy: Coord);
procedure rpdr2i(dx, dy: Icoord);
procedure rpdr2s(dx, dy: Scoord);
```

DESCRIPTION

rpdr is the relative version of the **pdr** command. It creates an edge of a filled polygon between the current graphics position and the point at the specified distance away. The current graphics position is updated to the new point. The results are undefined if the polygon is not convex.

SEE ALSO

pclos, pdr, pmv, rpmv

NAME

rpmv - relative polygon move

SPECIFICATION

C

```
rpmv(dx, dy, dz)
Coord dx, dy, dz;

rpmvi(dx, dy, dz)
Icoord dx, dy, dz;

rpmvs(dx, dy, dz)
Scoord dx, dy, dz;

rpmv2(dx, dy)
Coord dx, dy;

rpmv2i(dx, dy)
Icoord dx, dy;

rpmv2s(dx, dy)
Scoord dx, dy;
```

FORTRAN

```
subroutine rpmv(dx, dy, dz)
real dx, dy, dz

subroutine rpmvi(dx, dy, dz)
integer*4 dx, dy, dz

subroutine rpmvs(dx, dy, dz)
integer*2 dx, dy, dz

subroutine rpmv2(dx, dy)
real dx, dy

subroutine rpmv2i(dx, dy)
integer*4 dx, dy

subroutine rpmv2s(dx, dy)
integer*2 dx, dy
```

Pascal

```
procedure rpmv(dx, dy, dz: Coord);

procedure rpmvi(dx, dy, dz: Icoord);

procedure rpmvs(dx, dy, dz: Scoord);
procedure rpmv2(dx, dy: Coord);
procedure rpmv2i(dx, dy: Icoord);
procedure rpmv2s(dx, dy: Scoord);
```

DESCRIPTION

rpmv is the relative version of the **pmv** command. It starts a filled polygon at the point at the specified distance from the current graphics position. The current graphics position is updated to the new point. The results are undefined if the polygon is not convex.

SEE ALSO

pclos, pdr, pmv, rpdr

NAME

scale - scales and mirrors objects

SPECIFICATION

C	**scale(x, y, z)** **float x, y, z;**
FORTRAN	**subroutine scale(x, y, z)** **real x, y, z**
Pascal	**procedure scale(x, y, z: real);**

DESCRIPTION

scale shrinks, expands, and mirrors objects. Its three arguments specify scaling in each of the three coordinate directions. Values with magnitude of more than 1 expand the object; values with magnitude less than 1 shrink it. Negative values cause mirroring. **scale** is a modeling command; it changes the current transformation matrix. All objects drawn after the **scale** command is executed will be affected. Use **pushmatrix** and **popmatrix** to limit the scope of the **scale** command.

SEE ALSO

popmatrix, pushmatrix, rotate, translate

NAME

screenspace - puts a program in screen space under the window manager

SPECIFICATION

C	**screenspace()**
FORTRAN	**subroutine screen**
Pascal	**procedure screenspace;**

DESCRIPTION

screenspace puts the specified program in screen space. Graphics positions are expressed in absolute screen coordinates. This allows pixels and locations outside a program's graphics port to be read.

screenspace is equivalent to:

```
{
  int xmin, ymin;
    getorigin(&xmin, &ymin);
    viewport(-xmin, 1023-xmin, -ymin, 767-ymin);
    ortho2(-0.5, 1023.5, -0.5, 767.5);
}
```

SEE ALSO

getorigin, viewport, ortho2

NOTE

This command can be used only in immediate mode.

NAME

scrmask - defines a clipping mask for the screen

SPECIFICATION

C	**scrmask(left, right, bottom, top)** **Screencoord left, right, bottom, top;**
FORTRAN	**subroutine scrmas(left, right, bottom, top)** **integer*4 left, right, bottom, top**
Pascal	**procedure scrmask(left, right, bottom, top: Screencoord);**

DESCRIPTION

scrmask makes it possible to do fine character clipping. A call to **viewport** sets both the viewport and the screenmask to the same area, which is defined by the *left, right, bottom,* and *top* boundaries. A call to **scrmask** sets only the screenmask, which should be placed entirely within the viewport. Strings that begin outside the viewport will be clipped out; this is "gross clipping". Strings which begin inside the viewport but outside the screenmask will be clipped to the pixel boundaries of the screenmask. This is called "fine clipping". All drawing commands are also clipped to this viewport, but it is only useful for characters; gross clipping is sufficient for all other primitives.

SEE ALSO

getscrmask, viewport

NAME

select - puts the IRIS in selecting mode

SPECIFICATION

C **select(buffer, numnames)**
short buffer[0];
long numnames;

FORTRAN **subroutine select(buffer, numnam)**
integer*2 buffer(0)
integer*4 numnam

Pascal **procedure select(buffer: Ibuffer; numnames: longint);**

DESCRIPTION

select turns on the selecting mode. The viewing matrix in use when **select** is executed defines the selecting region. Alternatively, however, a viewing matrix can be constructed after selecting mode has begun. **select** and **pick** are identical except for the ability to create a viewing matrix in selection mode. *numnames* specifies the maximum number of names to be saved by the system. Names are 16-bit numbers, and are loaded onto the name stack by the user. Each drawing command that intersects the selecting region causes the contents of the name stack to be stored in *buffer*.

SEE ALSO

endpick, endselect, pick, picksize, initnames pushname, popname, loadname

NOTE

This command can be used only in immediate mode.

NAME

setbell - sets the duration of the keyboard bell

SPECIFICATION

C

```
setbell(mode)
char mode;
```

FORTRAN

```
subroutine setbel(mode)
integer*4 mode
```

Pascal

```
procedure setbell(mode: Byte);
```

DESCRIPTION

setbell sets the duration of the keyboard bell.

Mode	Meaning
0	off
1	short beep
2	long beep

SEE ALSO

clkoff, clkon, lampoff, lampon, ringbell

NOTE

This command can be used only in immediate mode.

NAME

setcursor - sets the cursor characteristics

SPECIFICATION

C

```
setcursor(index, color, wtm)
short index;
Colorindex color, wtm;
```

FORTRAN

```
subroutine setcur(index, color, wtm)
integer*4 index, color, wtm
```

Pascal

```
procedure setcursor(index: Short; color, wtm: Colorindex);
```

DESCRIPTION

setcursor selects a cursor glyph from among those the user has defined with **defcursor.** The first argument, *index,* picks a glyph from the definition table. *color* and *wtm* select a color and writemask for the cursor. The default cursor is 0; it is displayed with the color 1 drawn in the first available bitplane, and is automatically updated and displayed on each vertical retrace.

SEE ALSO

attachcursor, defcursor, getcursor, RGBcursor, curorigin

NOTE

This command can be used only in immediate mode.

NAME

setdblights - sets the lights on the dial and button box

SPECIFICATION

C	**setdblights(mask)**
	long mask;
FORTRAN	**subroutine setdbl(mask)**
	integer*4 mask
Pascal	**procedure setdblights(mask: long);**

DESCRIPTION

setdblights turns on some combination of the lights on the dial and button box. Each bit in the mask corresponds to a light. To turn on lights 4, 7 and 22 and all the others off, the mask should be set to (1<<4)|(1<<7)|(1<<22) = 400090.

NOTE

This command can be used only in immediate mode.

NAME

setdepth - sets up a 3D viewport

SPECIFICATION

C	**setdepth(near, far)**
	Screencoord near, far;

FORTRAN	**subroutine setdep(near, far)** **integer*4 near, far**
Pascal	**procedure setdepth(near, far: Screencoord);**

DESCRIPTION

viewport specifies a mapping from the left, right, bottom, and top clipping planes in world coordinates to screen coordinate values. **setdepth** completes this mapping for homogeneous world coordinates. The two arguments map the near and far clipping planes to the desired screen coordinate values. The default is **setdepth(0, 1023)**.

SEE ALSO

pushviewport, popviewport, feedback, endfeedback

NAME

setlinestyle - selects a linestyle

SPECIFICATION

C	**setlinestyle(index)**
	short index;

FORTRAN	**subroutine setlin(index)** **integer*4 index**
Pascal	**procedure setlinestyle(index: Short);**

DESCRIPTION

setlinestyle chooses a linestyle pattern. Its argument is an index into the linestyle table built by calls to **deflinestyle.** There is always a current linestyle; it is used for drawing lines and curves and for outlining rectangles, polygons, circles, and arcs. The default linestyle, 0, is a solid line and cannot be redefined.

SEE ALSO

deflinestyle, getlstyle, linewidth, lsbackup, resetls

NAME

setmap - chooses one of the sixteen small color maps

SPECIFICATION

C	**setmap(mapnum)**
	short mapnum;

FORTRAN	**subroutine setmap(mapnum)** **integer*4 mapnum**
Pascal	**procedure setmap(mapnum: Short);**

DESCRIPTION

setmap chooses one of the sixteen small maps, numbered 0 through 15. **setmap** is ignored in singlemap mode.

SEE ALSO

getmap, multimap, onemap

NOTE

This command can be used only in immediate mode.

NAME

setmonitor - sets the monitor type

SPECIFICATION

C

```
setmonitor(type)
short type;
```

FORTRAN

```
subroutine setmon(type)
integer*4 type
```

Pascal

```
procedure setmonitor(type: Short)
```

DESCRIPTION

setmonitor sets the monitor to 30 Hz interlaced, 60 Hz non-interlaced, or NTSC, depending on whether *type* is HZ30, HZ60, or NTSC, respectively. Those constants are defined in the file **get.h**.

TYPE	Monitor Type
HZ30	30 Hz interlaced
HZ60	60 Hz non-interlaced
NTSC	NTSC

SEE ALSO

getmonitor

NOTE

This command can be used only in immediate mode.

NAME

setpattern - selects a texture pattern for filling polygons, rectangles, and curves

SPECIFICATION

C	**setpattern(index)**
	short index;

FORTRAN	**subroutine setpat(index)** **integer*4 index**
Pascal	**procedure setpattern(index: Short);**

DESCRIPTION

setpattern selects a texture pattern from among those the user has defined with **defpattern.** The default pattern is pattern 0, which is solid. If an undefined pattern is specified, the default pattern is selected.

SEE ALSO

color, defpattern, getpattern, writemask

NAME

setshade - sets the current polygon shade

SPECIFICATION

C	**setshade(shade)**
	Colorindex shade;

FORTRAN	**subroutine setsha(shade)** **integer*4 shade**
Pascal	**procedure setshade(shade: Colorindex);**

DESCRIPTION

setshade sets the current shade value. This value is a color index which is associated with the vertices specified immediately following the **setshade** command. The **setshade** values are used to shade polygons using **spclos.**

SEE ALSO

spclos, splf

NAME

setvaluator - assigns an initial value to a valuator

SPECIFICATION

C	**setvaluator(v, init, min, max)** **Device v;** **short init, min, max;**
FORTRAN	**subroutine setval(v, init, min, max)** **integer*4 v, init, min, max**
Pascal	**procedure setvaluator(v: Device; init, min, max: Short);**

DESCRIPTION

setvaluator assigns an initial value *init* to a valuator. Some devices, like tablets, report values fixed to a grid. In this case, the device defines an initial position and *init* will be ignored. *min* and *max* are lower and upper bounds for the values the device can assume.

SEE ALSO

getvaluator

NOTE

This command can be used only in immediate mode.

NAME

shaderange - sets range of color indices

SPECIFICATION

C
```
shaderange(lowindex, highindex, z1, z2)
Colorindex lowindex, highindex;
Screencoord z1, z2;
```

FORTRAN
```
subroutine shader(lowindex, highindex, z1, z2)
integer*4 lowindex, highindex, z1, z2
```

Pascal
```
procedure shaderange(lowindex, highindex: Colorindex;
        z1, z2: Screencoord);
```

DESCRIPTION

shaderange sets the range of color indices used in drawing depthcued lines and points. The range of values specified by **z1, z2** is mapped linearly into the range of color indices used to draw lines and points.

SEE ALSO

depthcue

NAME

singlebuffer - writes and displays all the bitplanes

SPECIFICATION

C	**singlebuffer()**
FORTRAN	**subroutine single**
Pascal	**procedure singlebuffer;**

DESCRIPTION

The IRIS has three display modes: single buffer, double buffer, and RGB. In single buffer mode, all the available bitplanes are simultaneously updated and displayed. Incomplete or changing pictures appear on the screen. **singlebuffer** invokes this buffer mode. It does not take effect until **gconfig** is called.

SEE ALSO

doublebuffer, gconfig, getdisplaymode, gsync, RGBmode

NOTE

This command can be used only in immediate mode.

NAME

spclos - draws currently open polygon

SPECIFICATION

C	**spclos()**
FORTRAN	**subroutine spclos**
Pascal	**procedure spclos();**

DESCRIPTION

spclos, like **pclos** causes the currently "open" polygon to be drawn. **spclos** draws a Gouraud-shaded polygon using intensities specified by the **setshade** command.

SEE ALSO

setshade, splf, pclos, pdr, pmv

NAME

splf - draws a shaded filled polygon

SPECIFICATION

C

```
splf(n, parray, iarray)
long n;
Coord parray[][3];
Colorindex iarray[];

splfi(n, parray, iarray)
long n;
Icoord parray[][3];
Colorindex iarray[];

splfs(n, parray, iarray)
long n;
Scoord parray[][3];
Colorindex iarray[];

splf2(n, parray, iarray)
long n;
Coord parray[][2];
Colorindex iarray[];

splf2i(n, parray, iarray)
long n;
Icoord parray[][2];
Colorindex iarray[];

splf2s(n, parray, iarray)
long n;
Scoord parray[][2];
Colorindex iarray[];
```

FORTRAN

```
subroutine splf(n, parray, iarray)
integer*4 n
real parray(3,n)
integer*2 iarray(n)

subroutine splfi(n, parray, iarray)
integer*4 n
integer*4 parray(3,n)
integer*2 iarray(n)
```

```
subroutine splfs(n, parray, iarray)
integer*4 n
integer*2 parray(3,n)
integer*2 iarray(n)

subroutine splf2(n, parray, iarray)
integer*4 n
real parray(2,n)
integer*2 iarray(n)

subroutine splf2i(n, parray, iarray)
integer*4 n
integer*4 parray(2,n)
integer*2 iarray(n)

subroutine splf2s(n, parray, iarray)
integer*4 n
integer*2 parray(2,n)
integer*2 iarray(n)
```

Pascal

```
procedure splf(n: longint; var parray: Coord3array;
var iarray: Colorarray);

procedure splfi(n: longint; var parray: Icoord3array;
var iarray: Colorarray);

procedure splfs(n: longint; var parray: Scoord3array;
var iarray: Colorarray);

procedure splf2(n: longint; var parray: Coord2array;
var iarray: Colorarray);

procedure splf2i(n: longint; var parray: Icoord2array;
var iarray: Colorarray);

procedure splf2s(n: longint; var parray: Scoord2array;
var iarray: Colorarray);
```

DESCRIPTION

splf draws Gouraud-shaded polygonal areas using the current texture pattern and writemask. It takes three arguments: an array of points, an array of the intensities at these points, and the number of points in each array. Polygons are represented as arrays of points. The first and last points are automatically connected to close a polygon. The points can be expressed as integers, shorts, or real numbers, in 2D or 3D space. Two-dimensional polygons are drawn with $z = 0$. After the polygon is drawn, the current graphics position is set to the first point in the array. The results are undefined if the polygon is not convex.

SEE ALSO

poly, rect, rectf, pdr, pmv, rpdr, rpmv

NAME

stepunit - specifies that a graphics port should change size in discrete steps

SPECIFICATION

C	**stepunit(xunit, yunit)**
	long xunit, yunit;

FORTRAN	**subroutine stepun(xunit, yunit)** **integer*4 xunit, yunit**
Pascal	**procedure stepunit(xunit, yunit: long);**

DESCRIPTION

stepunit specifies that the size of a graphics port will change in discrete steps of *xunit* in the x direction and *yunit* in the y direction. It is called at the beginning of a graphics program that will be run with the window manager and takes effect when **getport** is called. It is used to resize graphics ports in units of a standard size (in pixels). When **stepunit** is called, the dimensions of the graphics port will be:

width = xunit*n
height = yunit*m

If **getport** is not called, or if the system is not running the window manager, **stepunit** will be ignored.

SEE ALSO

getport, fudge

NOTE

This command can be used only in immediate mode.

NAME

strwidth - returns the width of the specified text string

SPECIFICATION

C	**long strwidth(str)** **String str;**
FORTRAN	**integer*4 function strwid(str, length)** **character*(*) str** **integer*4 length**
Pascal	**function strwidth(str: pstring): longint;**

DESCRIPTION

strwidth returns the width, in pixels, of a text string, using the character spacing parameters of the currently selected raster font. **strwidth** is useful only when there is a simple mapping from screen to world space. The user must do the mapping.

Undefined characters have zero width.

In FORTRAN, there are two arguments to **strwid** : *str* is the name of the string and *length* is the number of characters in that string.

SEE ALSO

getheight, getlwidth, mapw, mapw2

NOTE

This command can be used only in immediate mode.

NAME

swapbuffers - swaps the front and back buffers in double buffer mode

SPECIFICATION

C	**swapbuffers()**
FORTRAN	**subroutine swapbu**
Pascal	**procedure swapbuffers;**

DESCRIPTION

swapbuffers swaps the front and back buffers in double buffer mode during the next vertical retrace period. After an image is drawn in the back buffer, a **swapbuffers** command displays it. **swapbuffers** is ignored in single buffer or RGB mode.

SEE ALSO

backbuffer, doublebuffer, frontbuffer, swapinterval, gsync

NAME

swapinterval - defines a minimum time between buffer swaps

SPECIFICATION

C	**swapinterval(i)**
	short i;

FORTRAN	**subroutine swapin(i)** **integer*4 i**
Pascal	**procedure swapinterval(i: Short);**

DESCRIPTION

swapinterval establishes a minimum time between buffer swaps. If the user specifies a swap interval of 5, for example, the screen will be refreshed at least five times between execution of successive **swapbuffers** commands. This command provides a way to change frames at a steady rate if a new image can be created within one swap interval. The default interval is 1. **swapinterval** is valid only in double buffer mode. It is ignored in single buffer or RGB mode.

SEE ALSO

doublebuffer, swapbuffers, gsync

NOTE

This command can be used only in immediate mode.

NAME

textcolor - sets the color of text drawn in the textport

SPECIFICATION

C **textcolor(tcolor)**
Colorindex tcolor;

FORTRAN **subroutine textco(tcolor)**
integer*4 tcolor

Pascal **procedure textcolor(tcolor: Colorindex);**

DESCRIPTION

textcolor sets the color of the text drawn in the textport. The color of text drawn using **charstr** is determined by **color.**

SEE ALSO

color, pagecolor, pagewritemask, textport, textwritemask, tpoff, tpon

NOTE

This command can be used only in immediate mode.

NAME

textinit - initializes the textport

SPECIFICATION

C	**textinit()**
FORTRAN	**subroutine textin**
Pascal	**procedure textinit;**

DESCRIPTION

textinit initializes the textport to default size, location, textcolor, pagecolor, and textwritemask.

NOTE

This command can only be used in immediate mode.

SEE ALSO

textport, textcolor, pagecolor, textwritemask

NOTE

This command can be used only in immediate mode.

NAME

textport - allocates an area of the screen for the textport

SPECIFICATION

C	**textport(left, right, bottom, top)** **Screencoord left, right, bottom, top;**
FORTRAN	**subroutine textpo(left, right, bottom, top)** **integer*4 left, right, bottom, top**
Pascal	**procedure textport(left, right, bottom, top: Screencoord);**

DESCRIPTION

textport allocates an area on the screen for the textport.

SEE ALSO

pagecolor, pagewritemask, textcolor, textwritemask, tpoff, tpon, viewport

NOTE

This command can be used only in immediate mode.

NAME

textwritemask - grants write permission for the textport

SPECIFICATION

C	**textwritemask(tmask)**
	Colorindex tmask;

FORTRAN	**subroutine textwr(tmask)** **integer*4 tmask**
Pascal	**procedure textwritemask(tmask: Colorindex);**

DESCRIPTION

textwritemask grants write permission for text drawn in the textport. This command does not affect text drawn with **charstr.**

SEE ALSO

pagecolor, pagewritemask, textcolor, textport, tpoff, tpon, writemask

NOTE

This command can be used only in immediate mode.

NAME

tie - ties two valuators to a button

SPECIFICATION

C **tie(b, v1, v2)**
Device b, v1, v2;

FORTRAN **subroutine tie(b, v1, v2)**
integer*4 b, v1, v2

Pascal **procedure tie(b, v1, v2: Device);**

DESCRIPTION

tie takes three arguments, a button *b* and two valuators *v1* and *v2*. Whenever the button is queued, the valuators are also queued. If the button is queued, whenever the button changes state, three entries are made in the queue, recording the current state of the button and the current positions of each valuator. One valuator can be tied to a button by making $v2 = 0$. A button can be untied by making both *v1* and *v2* zero. *v1* will appear before *v2* in the event queue; both are preceded by *b*.

SEE ALSO

getbutton

NOTE

This command can be used only in immediate mode.

NAME

tpoff - turns off the textport

SPECIFICATION

C	**tpoff()**
FORTRAN	**subroutine tpoff**
Pascal	**procedure tpoff;**

DESCRIPTION

tpoff turns off the textport.

SEE ALSO

pagecolor, pagewritemask, textcolor, textport, textwritemask, tpon

NOTE

This command can be used only in immediate mode.

NAME

tpon - turns on textport

SPECIFICATION

C	**tpon()**
FORTRAN	**subroutine tpon**
Pascal	**procedure tpon;**

DESCRIPTION

tpon turns on the textport allocated by **textport.**

SEE ALSO

color, pagecolor, pagewritemask, textcolor, textport, textwritemask, tpoff

NOTE

This command can be used only in immediate mode.

NAME

translate - translates graphical primitives

SPECIFICATION

C	**translate(x, y, z)** **Coord x, y, z;**
FORTRAN	**subroutine transl(x, y, z)** **real x, y, z**
Pascal	**procedure translate(x, y, z: Coord);**

DESCRIPTION

translate places the object space origin at a given world coordinate point. **translate** is a modeling command, and changes the current transformation matrix. All objects drawn after **translate** is executed will be translated. Use **pushmatrix** and **popmatrix** to limit the scope of the translation.

SEE ALSO

popmatrix, pushmatrix, rotate, scale

NAME

unqdevice - unqueues a device from the event queue

SPECIFICATION

C	**unqdevice(v)**
	Device v;

FORTRAN	**subroutine unqdev(v)** **integer*4 v**
Pascal	**procedure unqdevice(v: Device);**

DESCRIPTION

unqdevice removes the specified device from the list of those whose changes are automatically recorded in the event queue. If the device already has recorded events in the queue that have not been read, they remain there. **qreset** can be used to flush the event queue.

SEE ALSO

qdevice, qreset

NOTE

This command can be used only in immediate mode.

NAME

viewport - allocates an area of the screen for an image

SPECIFICATION

C	**viewport(left, right, bottom, top)** **Screencoord left, right, bottom, top;**
FORTRAN	**subroutine viewpo(left, right, bottom, top)** **integer*4 left, right, bottom, top**
Pascal	**procedure viewport(left, right, bottom, top: Screencoord);**

DESCRIPTION

The first step in defining the mapping from world coordinates to screen coordinates is to choose an area of the screen to display an image. This area is called the *viewport* and is specified in screen coordinates. The portion of world space described by one of the commands window, ortho, or perspective is mapped into the viewport. The arguments to the **viewport** command define a rectangular area on the screen by the left, right, bottom, and top coordinates. This command also loads the screenmask.

SEE ALSO

scrmask, getviewport, popviewport, pushviewport

NAME

window - defines a perspective projection transformation

SPECIFICATION

C	**window(left, right, bottom, top, near, far)** **Coord left, right, bottom, top, near, far;**
FORTRAN	**subroutine window(left, right, bottom, top, near, far)** **real left, right, bottom, top, near, far**
Pascal	**procedure window(left, right, bottom, top, near, far: Coord);**

DESCRIPTION

window specifies the position and size of a rectangular viewing frustum in terms of the distance to the surface closest to the eye (in the near clipping plane), the boundaries of a rectangular region, and the distance to the far clipping plane. The image will be projected with perspective onto the screen area defined by viewport.

window loads a matrix onto the transformation stack, overwriting whatever was there.

SEE ALSO

ortho, perspective, viewport

NAME

writemask - grants write permission to available bitplanes

SPECIFICATION

C	**writemask(wtm)**
	Colorindex wtm;

FORTRAN	**subroutine writem(wtm)** **integer*4 wtm**
Pascal	**procedure writemask(wtm: Colorindex);**

DESCRIPTION

writemask shields selected bitplanes reserved for special uses from ordinary drawing commands. Its argument is a mask with one bit per available bitplane. Wherever there are ones in the writemask, the corresponding bits in the color will be written into the bitplanes. Zeros in the writemask mark bitplanes as read-only. These planes will not be changed, regardless of the bits in the color. **RGBwritemask** should be used in RGB mode.

SEE ALSO

RGBwritemask, color

NAME

writepixels - paints a row of pixels on the screen

SPECIFICATION

C

```
writepixels(n, colors)
short n;
Colorindex colors[n];
```

FORTRAN

```
subroutine writep(n, colors)
integer*4 n
integer*2 colors(n)
```

Pascal

```
procedure writepixels(n: Short; var colors: Colorarray);
```

DESCRIPTION

writepixels paints a row of pixels on the screen, specifying the number of pixels to paint and a color for each pixel. The current character position provides the starting location; it is updated to point to the pixel following the last one painted. The current character position becomes undefined if the updated pixel position is greater than XMAXSCREEN. Pixels are painted from left to right, and are clipped to the current screenmask. **writepixels** does not automatically wrap from one line to the next. It can be used in single and double buffer display modes. Use **writeRGB** in RGB mode.

SEE ALSO

scrmask, color, readpixels, writeRGB

NOTE

This command can be used only in immediate mode.

NAME

writeRGB - paints a row of pixels on the screen

SPECIFICATION

C	**writeRGB(n, red, green, blue)**
	short n;
	RGBvalue red[], green[], blue[];

FORTRAN	**subroutine writeR(n, red, green, blue)** **integer*4 n** **character*(*) red, green, blue**
Pascal	**procedure writeRGB(n: Short; var red, green, blue: RGBarray);**

DESCRIPTION

writeRGB paints a row of pixels on the screen in RGB mode. It specifies the number of pixels to paint and a color for each pixel. The current character position provides the starting location; it is updated to point to the pixel following the last one painted. The current character position becomes undefined if the updated pixel position is greater than XMAXSCREEN. Pixels are painted from left to right, and are clipped to the current screenmask. **writeRGB** does not automatically wrap from one line to the next. It supplies a 24-bit RGB value (eight bits for each color) for each pixel. This value is written directly into the bitplanes.

SEE ALSO

scrmask, readRGB, RGBcolor, RGBwritemask, writepixels

NOTE

This command can be used only in immediate mode and RGB mode.

NAME

xfpt - transforms points

SPECIFICATION

```
C          xfpt(x, y, z)
           Coord x, y, z;

           xfpti(x, y, z)
           Icoord x, y, z;

           xfpts(x, y, z)
           Scoord x, y, z;

           xfpt2(x, y)
           Coord x, y;

           xfpt2i(x, y)
           Icoord x, y;

           xfpt2s(x, y)
           Scoord x, y;

           xfpt4(x, y, z, w)
           Coord x, y, z, w;

           xfpt4i(x, y, z, w)
           Icoord x, y, z, w;

           xfpt4s(x, y, z, w)
           Scoord x, y, z, w;


FORTRAN    subroutine xfpt(x, y, z)
           real x, y, z

           subroutine xfpti(x, y, z)
           integer*4 x, y, z

           subroutine xfpts(x, y, z)
           integer*2 x, y, z

           subroutine xfpt2(x, y)
           real x, y

           subroutine xfpt2i(x, y)
           integer*4 x, y

           subroutine xfpt2s(x, y)
           integer*2 x, y
```

subroutine xfpt4(x, y, z, w)
real x, y, z, w

subroutine xfpt4i(x, y, z, w)
integer*4 x, y, z, w

subroutine xfpt4s(x, y, z, w)
integer*2 x, y, z, w

Pascal

procedure xfpt(x, y, z: Coord);

procedure xfpti(x, y, z: Icoord);

procedure xfpts(x, y, z: Scoord);

procedure xfpt2(x, y: Coord);

procedure xfpt2i(x, y: Icoord);

procedure xfpt2s(x, y: Scoord);

procedure xfpt4(x, y, z, w: Coord);

procedure xfpt4i(x, y, z, w: Icoord);

procedure xfpt4s(x, y, z, w: Scoord);

DESCRIPTION

xfpt multiplies the specified point by the top matrix on the matrix stack and turns off the clippers and scalers in the Geometry Pipeline. In feedback mode, the 4-dimensional result of the multiplication is saved in the feedback buffer. In non-feedback mode, the command is ignored.

NOTE

This command can be used only in immediate mode.

NAME

zbuffer - starts or ends z-buffer operation

SPECIFICATION

C **zbuffer(bool)**
Boolean bool;

FORTRAN **subroutine zbuffe(bool)**
logical bool

Pascal **procedure zbuffer(bool: Boolean);**

DESCRIPTION

zbuffer starts *(bool = TRUE)* or ends *(bool = FALSE)* z-buffer mode. In z-buffer mode, each pixel has an associated z value. When a pixel is to be drawn, a new z value is compared with the z value already associated with the pixel. If the new z value is less than or equal to the existing one (i.e., closer to the viewer), then a new color and z value for the pixel are stored in the bitplanes; otherwise the color and z value for the pixel are left unchanged. The result of drawing objects in this mode is an image in which all obscured surfaces are left undisplayed. z values range from 0x8000 to 0x7FFF on a 32-bitplane system, and 0x0 to 0xFFF on a 28-bitplane system. This range is set using the **setdepth** command. z-buffering is not effective on systems with less than 28 bitplanes. Because memory bandwidth is reduced on 60hz monitors, performance is improved by blanking the screen during z-buffer drawing with the **blankscreen** command.

SEE ALSO

getzbuffer, zclear, setdepth, blankscreen

NAME

zclear - initializes the z-buffer to largest possible integer

SPECIFICATION

C	**zclear()**
FORTRAN	**subroutine zclear**
Pascal	**procedure zclear;**

DESCRIPTION

zclear initializes the z-buffer to the largest possible integer. This is most frequently done when z-buffer mode is entered to clear the buffer so that primitives drawn in z-buffer mode are only affected by each other.

SEE ALSO

zbuffer

Glossary †

aspect ratio : The ratio of the height of an object to its width. A rectangle of width ten inches and height five inches has an aspect ratio of 10/5 or 2.

asynchronous : Not synchronized in time. For example, input events occur at the whim of the user – the program may read them later.

attribute : A model feature in the graphics. If the color is set to "RED", it will remain red until changed, and everything that is drawn will be drawn in red. Color is an attribute. Other attributes include linestyle, linewidth, texture, pattern, and font.

azimuthal angle : If an object is sitting on the ground, with its z coordinate straight up, the azimuthal viewing angle is the angle the observer makes with the y axis in the x-y plane. If the observer walks in a circle with the object at the center, the azimuthal angle is the only thing that varies.

B-spline : A cubic spline approximation to a set of four control points having the property that slope and curvature are continuous across sets of control points.

basis : In the Graphics Library, a curve or patch basis is a 4x4 matrix that controls the relationship between control points and the approximating spline. B-splines, Bezier curves, and Cardinal splines all differ in that they have different bases. If B is a basis, and P_1, P_2, P_3, and P_4 are 4D control points, then the spline determined by them is given by:

$$C(t) = [1,t,t^2,t^3]B\begin{bmatrix}P_1\\P_2\\P_3\\P_4\end{bmatrix}, \quad (0 \leq t \leq 1)$$

Bezier : A cubic spline approximation to a set of four control points that passes through the first and fourth control points, and has a continuous slope where two spline segments meet.

† We used two sources for definitions of standard graphics terminology: William M. Newman and Robert F. Sproull, *Principles of Interactive Graphics*, (1979) and James D. Foley and Andries Van Dam, *Fundamentals of Interactive Graphics*, (1982).

bitplanes : A bitplane supplies one bit of color information per pixel on the display. Thus, an eight bitplane system allows 2^8 different colors to be displayed at each pixel.

Boolean : A value of TRUE or FALSE. TRUE=1 and FALSE=0

bounding box : A rectangle (2D) that bounds an object. A bounding box is used to determine whether the object lies inside a clipping region. See **clipping.**

button : Buttons on the IRIS include those on the keyboard, mouse, lightpen, or buttons on the dial and button box.

Cardinal spline : A cubic spline whose endpoints are the second and third of four control points. A series of cardinal splines will have a continuous slope, and will pass through all but the first and last control points.

clipping : If an object overlaps the boundaries of a window, it is *clipped.* The part of an object that appears in the window is displayed and the rest is ignored. See **window**.

clipping planes : Before clipping occurs, object space is mapped to normalized viewing coordinates in homogeneous coordinates. Each of the clipping Geometry Engines clips to one of the clipping planes $x=\pm w$; $y=\pm w$; or $z=\pm w$. These clipping planes correspond to the left, right, top, bottom, near, and far planes bounding the viewing frustum.

clipping subsystem : Four or six Geometry Engines that clip to four or six of the clipping planes.

color map : A hardware map that associates eight bits each of red, green, and blue with bit combinations from the bitplanes. There are, therefore, $2^{24}\simeq16,700,000$ colors, but on an eight bitplane system, for example, only $2^8\simeq256$ of these colors would be visible at once. The color map determines which ones these will be.

concatenation : In the Graphics Library, concatenation refers to combining a series of geometric transformations – rotations, translations, scaling, etc. Concatenation of transformations corresponds to matrix multiplication.

control points : Three-dimensional points that control the shape of an approximating spline curve. The IRIS provides hardware support for rational cubic splines, the specifications of which requires four control points.

culling : If an object is smaller than the minimum size specified in the **bbox2** command, it is *culled*: no further commands in the object are interpreted. See **clipping, pruning.**

current character position : the two-dimensional screen coordinates where the next character string or pixel read/write will occur.

current color : The color in which geometry will be drawn.

current graphics position : The homogeneous three-dimensional point from which geometric drawing commands will draw. The current graphics position is not necessarily visible.

current transformation matrix : The transformation matrix on top of the matrix stack. All points passed through the Geometry Pipeline are multiplied by the current transformation matrix before being passed on to the clipping and scaling subsystem.

cursor : A graphical object such as an arrowhead which can be moved about the screen by means of an input device (typically a mouse).

cursor glyph : a 16x16 raster pattern that determines the shape of the cursor.

depth-cueing : Varying the intensity of a line with z-depth. Typically, the points on the line further from the eye are darker, so the line seems to fade into the distance.

device : A valuator, button, or the keyboard. Buttons have values of 0 or 1 (up or down); valuators return values in a range, and the keyboard returns ASCII values.

dial and switch box : An I/O device with eight dials (valuators) and thirty-two switches.

display list : A data structure that contains a sequence of compiled commands. This intermediate form can be quickly and efficiently converted into hardware commands.

double buffer mode : A mode in which two buffers are alternately displayed and updated. A new image can be created in the buffer while the previous image is being displayed. In double buffer mode, colors are taken from the **color map**. See **color map, RGB mode, single buffer mode**.

event queue : A queue that records changes in input devices – buttons, valuators, and the keyboard. The event queue provides a time-ordered list of input events.

eye coordinates, eye space : The coordinate system whose origin lies at the viewpoint. See **object space, screen space, world space**.

feedback : Geometrical data that is passed through some or all of the clipping, scaling, and matrix subsystems and is returned to the applications processor.

field of view : The extent of the area which is under view. The field of view is defined by the **viewing object** in use.

fine clipping : Fine clipping masks all drawing commands to a rectangular region on the screen. It would be unnecessary except for the case of character strings. The origin of a character string after transformation may be clipped out, and the string would not be drawn. By doing gross clipping with the viewport and fine clipping with the screen masks, strings can be moved smoothly off the screen to the left or bottom. See **gross clipping.**

font : A set of characters in a particular style. See **raster font, object font**.

forward difference matrix : A 4x4 matrix that is interacted by adding each row to the next and the bottom row is output as the next point. Points so generated generally fall on a rational cubic curve.

front and back buffers : In double buffer mode, the bitplanes are separated into two sets – the front and the back buffers. Bits in front buffer planes are visible and those in the back are not. Typically, an application draws into the back buffer and views the front buffer for dynamic graphics.

gamma correction : A logarithmic assignment of intensities to color map entries for shading applications. This is required since the human eye perceives intensities logarithmically rather than linearly.

Geometry Accelerator : A custom VLSI chip that provides floating-point conversion and buffering for the Geometry Pipeline.

Geometry Engine : A custom VLSI chip that performs matrix multiplication, clipping, or scaling in 3D homogeneous coordinates. There are 10 or 12 Geometry Engines in the Geometry Pipeline.

Geometry Pipeline : A combination of Geometry Accelerators and Geometry Engines that does geometric transformations, clipping, and scaling in the IRIS.

Gouraud shading : A method to shade polygons smoothly based on the intensities at their vertices. The color index is uniformly interpolated along each edge, and then the edge values are uniformly interpolated along each scan line. For realistic shading, the colors associated with the color indices should be gamma-corrected.

graphical object : A set of drawing commands and transformation commands compiled into a user-defined object. This object can then be drawn with a single `callobj` command.

gross clipping : Clipping done by the viewport. It is the same (typically) as fine clipping except in the case of character strings. See **fine clipping**.

hidden surface : A surface of a geometric object that is not visible because it is obscured by other surfaces. See **z-buffering**.

hitcode : In picking or selecting mode, an object can be clipped against any combination of the 6 (or 4) clipping planes. The hitcode is a 6-bit number that indicates the planes against which clipping occurred.

immediate mode : The IRIS is in immediate mode except while an object is being edited. In this mode, graphics commands are executed immediately rather than being compiled into a graphical object.

incidence angle : In the `polarview` command the incidence angle is the angle the viewport makes with the z axis in the z-y plane.

instantiate : To make an instance of. To replicate.

line of sight : A line which extends from the viewpoint through a point specified by the user. The line of sight defines the direction of view.

linear interpolation : Linear interpolation approximates an output value for an input between two other inputs whose exact output values are known. If a and b are input values whose outputs are A and B, respectively, and $a<c<b$, then the approximate output value of c given by linear interpolation is:

$$A+(B-A)\cdot\left(\frac{c-a}{b-a}\right)$$

linestyle : The pattern used to draw a line. A linestyle might be solid or broken into a pattern of dashes.

linewidth : The width of a line in pixels.

matrix stack : A stack of matrices on the IRIS with hardware and software support. The top matrix on the stack is the active matrix, and all points passed through the Geometry Pipeline are multiplied by that matrix.

matrix multiplier : The first four Geometry Engines in the Pipeline form a hardware matrix multiplier unit. An input matrix is multiplied by the matrix on top of the matrix stack.

mirroring : The creation of a mirror image of an object.

modeling : The representation of a real object as a graphical object in world space.

name stack : A stack of 16-bit names kept by the raster subsystem and used to locate hits in display lists during picking and selecting operations.

NTSC : A video display format supported by the IRIS that is used for broadcast style pictures.

null-terminated : Having a zero byte at the end. In the C language, character strings are stored this way internally.

object : A graphical representation in world space which is composed of a series of primitive graphical units such as line segments, points, characters, or text strings. The object is compiled into a display list and can be instantiated in different orientations and sizes through appropriate use of modeling.

object font : A font in which characters are defined as graphical objects. Like all other graphical objects, object font characters can be scaled and rotated. See **raster font.**

object coordinates, object space : The space in which a graphical object is defined. A convenient point is chosen as the origin and the object is defined relative to this point. See **eye space, screen space, world space.**

orthographic projection : A representation in which the lines of projection are parallel. Orthographic projections lack *perspective foreshortening* and its accompanying sense of depth and realism. Because they are simple to draw, orthographic projections are often used by draftsmen. See **perspective projection.**

parametric cubic curve : A curve defined by the equation:

$$C(t) = (x(t), y(t), z(t)),$$

where x, y, z, and w are cubic polynomials. t is the parameter and typically varies between 0 and 1.

patch : A local homeomorphism of the Euclidean plane.

pattern : A 16x16, 32x32, or 64x64 array of bits defining the texturing of polygons on the IRIS display.

perspective projection : Perspective projection is a technique used to achieve realism when drawing objects. In a perspective projection, the lines of projection meet at the viewpoint; thus the size of an object varies inversely with its distance from the source of projection. The farther an object or part of an object is from the viewer, the smaller it will be drawn. This effect, known as *perspective foreshortening,* is similar to the effect achieved by photography and by the human visual system. See **orthographic projection.**

picking : Determining the geometric objects that lie at or near the cursor on the display screen.

picking region : A region around the cursor origin in which objects will be picked if they appear there.

pixel : A rectangular picture element. A display screen is composed of an array of pixels. In a black-and-white system, pixels are turned on and off to form images. In a color system, each pixel has three components: red, green, and blue. The intensity of each component can be controlled.

polar coordinates : A coordinate system in the plane related to the standard Cartesian (x,y) coordinates by the following equations:

$$x = r \cos \Theta$$

$$y = r \sin \Theta$$

r and Θ are the polar coordinates of the point.

polled i/o devices : Devices whose current values are read by the user process.

pre-multiplication : Matrix multiplication on the left. If a matrix M is pre-multiplied by a matrix T, the result is TM.

precision : The number of straight line segments used to approximate one segment of a spline.

pruning : Eliminating the drawing of parts of the display list because a bounding box test shows that they are not visible.

queued i/o devices : Devices whose changes are recorded in the event queue.

raster font : A font in which the characters are defined directly by a raster bit map. See **font, object font**.

raster subsystem : That part of the IRIS concerned with geometry after it has been transformed and scaled to screen coordinates. It includes scan conversion and recording.

refresh rate : The rate at which a monitor is refreshed. A 60 Hz monitor is redrawn 60 times per second.

relative drawing commands : Commands that draw relative to the current graphics position as opposed to being drawn at absolute locations.

RGB mode : A mode in which colors are directly controlled by the user without using a **color map**. Images are simultaneously updated and displayed. See **color map, double buffer mode, single buffer mode**.

RGB value : The set of red, green, and blue intensities that compose a color is that color's **RGB value**.

right-hand rule : If the right hand is wrapped around the axis of rotation, the fingers curl in the same direction as positive rotation.

rotation : The transformation of an object by rotating it about an axis. See **transformation.**

scaling : Uniform stretching of an object along an axis.

scaling subsystem : The final two Geometry Engines in the Geometry Pipeline scale normalized world coordinates in the range $-1 \leq x,y,z \leq)$ to physical screen coordinates.

screen coordinates, screen space : The coordinate system that defines the display screen. The screen on the IRIS measures 1024 pixels wide by 768 pixels high, with the origin in the lower left corner. See **eye space, object space, world space.**

screenmask : A rectangular area of the screen that all drawing operations are clipped to. It is normally set equal to the viewport.

selecting : A mechanism for finding the objects lying in an arbitrary rectangle on the screen. See **picking.**

selecting region : A rectangle on the display screen. Objects drawn within this region will be reported as hits when the `select` command is used. See **picking.**

short : A 16-bit integer.

single buffer mode : A mode in which images are simultaneously displayed and updated in a single buffer. Colors are taken from a color map. See **double buffer mode, RGB mode.**

swap interval : The number of retrace intervals that go by between swapping the front and back buffers.

tags : Markers in the display list used as locations for object editing.

textport : A region on the display screen used to present textual output from graphical or non-graphical programs.

texture : A pattern used to fill rectangles, convex polygons, arcs, and circles.

transformations : Transformations change the size and orientation of an object under view by changing the object itself or the position of the viewpoint. Standard mathematical techniques like coordinate geometry, trigonometry, and matrix methods are used to compute the new position of the object after the transformation. Modeling transformations change the position or orientation of the *object.* Viewing transformations change the position, size, or orientation of the *viewpoint.* Projection transformations redefine the boundaries of the *clipping region.*

twist : A rotation around the line of sight.

valuator : An input/output device that returns a value in a range. For example, a mouse is logically two valuators – the x position and the y position.

vector product : Another term for the vector cross product. If $a = (a_1, a_2, a_3)$ and $b = (b_1, b_2, b_3)$ are two 3D vectors, the vector product $a \times b = (a_2b_3 - b_2a_2, a_3b_1 - b_3a_1, a_1b_2 - b_1a_2)$.

vertical retrace period : On a 30Hz interlaced display, it is 1/30 second.

viewing object : A graphical object which defines the region of **world space** which can be seen on the display screen. See **world space, field of view.**

viewpoint : The center of the **field of view**. The **viewpoint** is the origin of both the **line of sight** and the **eye coordinate system**. See **eye space, field of view, line of sight, viewing object**.

viewport : A rectangle on the screen in which the contents of the window are displayed. See **window**.

window : A truncated pyramid in **world space** which the user defines and which is mapped to the display screen. See **viewport**.

world coordinates, world space : The user-defined coordinate system in which an image is described. Modeling commands are used to position graphical objects in world space. Viewing and projection transformations define the mapping of world space to screen space. See **modeling, object space, screen space, transformations**.

writemask : A bit mask that controls write access to the bitplanes. During any drawing operation, only those planes enabled by a "1" in the bit mask can be altered.

z-buffering : A method for hidden surface removal that keeps track (for each pixel) of the distance from that point to the eye. Additional geometry is drawn over that pixel only if it is closer to the eye that what was previously there. The IRIS supports such a z-buffer in the raster subsystem.

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Reader's Comments

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