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Pixrect Reference Manual

Sun Microsystems, Inc. • 2550 Garcia Avenue • Mountain View, CA 94043 • 415-960-1300

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Preface

This document describes the **Pixrect** graphics library, a low-level RasterOp library for writing device-independent applications for Sun products.

Audience

The intended reader of this document is an applications programmer who is familiar with interactive computer graphics and the C programming language. This manual contains several example programs that can be used as templates for larger **Pixrect** applications

Documentation Conventions

Italic font is used to indicate file names, function arguments, variables and internal states of **Pixrect**. Italics are also used in the conventional manner (to emphasize important words and phrases). ALL CAPS is used to indicate values in enumerated types. **Bold font** is used for the names of Sun software packages. Function names are printed with `constant width font`.

1

Introduction

1

Introduction

This document describes the **Pixrect** graphics library, a set of RasterOp routines common among all Sun workstations. With these routines, application programs can be written that access the display on all Sun products.

In the Sun graphics software world, the **Pixrect** library is a low-level package, sitting on top of the device drivers. For most applications, the higher-level abstractions available in **SunView** and the Sun graphics libraries are more appropriate.

The **Pixrect** library is intended only for accessing and manipulating rectangular regions of a display device in a device-independent fashion. There are a few features that are available in higher-level graphics packages like **SunView**.

Windows
: The **Pixrect** library does not support overlapping window. These can be implemented with memory pixrects by the application, but it is recommended that the functions in **SunView** be used for this purpose.

Input Devices
: The **Pixrect** library does have any input functions. The application can use input functions in **SunView** or make calls on the raw input devices (see `mouse`(4) and `keyboard`(4).

This document is not a tutorial on writing application programs with the **Pixrect** library though some simple examples are given. The reader should be familiar with the C programming language and have access to some of the references listed below on bitmap graphics.

1.1. Overview

This manual is divided into chapters that describe the major features of the **Pixrect** library. Chapter 2 covers the operations for opening and manipulating pixrects. Chapter 3 describes the text facilities in the **pixrect** library. Chapter 4 discusses *memory pixrects* rectangular regions of virtual memory that have similar properties to pixrects. Chapter 5 explains the file I/O functions in the **Pixrect** library. These functions can be used to store and retrieve pixrects from disc files. Appendix A is a implementation guide for pixrect device drivers. Appendix B is a list of the functions and macros in the **Pixrect** library. Appendix C is a list of types and structures in the **Pixrect** library. Appendix D describes the curve facilities in **Pixrect**.

1.2. Important Concepts

This section describes some of the important concepts behind the **Pixrect** library. It is not intended to be complete but rather to explain some features of the **Pixrect** library that make it unique from other graphics packages.

Screen Coordinates

The *screen coordinate* system is two dimensional with the origin in the upper left corner, and x and y increasing to the right and down. The coordinates of a pixel in a pixrect are integers from 0 to the pixrect's width or height minus 1.

Pixels

A *pixel* is an individual picture element with an address in screen coordinates or relative to some rectangular sub-region of the screen.

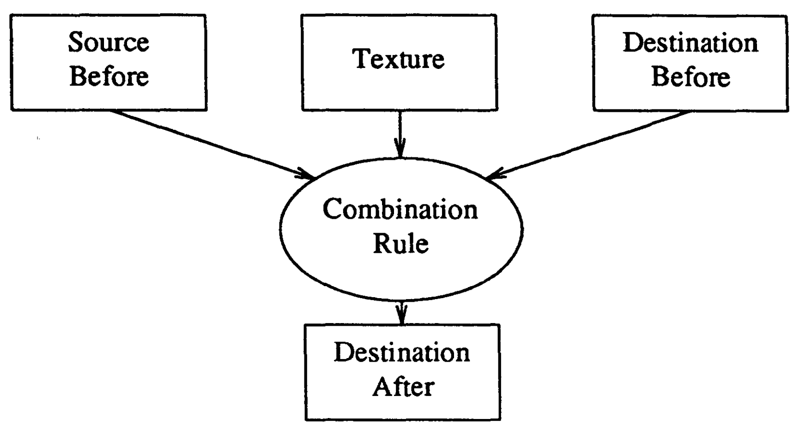
Bitmaps

A *bitmap* is a rectangular region of screen space. Examples of bitmaps include the screen, windows, the cursor or icons.

RasterOps

A *RasterOp* is an operation involving two or three bitmaps: a *source*, a *destination* and a *texture*. It computes the value of each pixel in the destination bitmap through a boolean operation of the previous value of that destination pixel, of a corresponding source pixel, and possibly a corresponding pixel in a mask. See Chapter 2 for an explanation of the RasterOp functions available in the **Pixrect** graphics library.

Figure 1-1 *RasterOp Function*



Pixrects

A *pixrect* combines the data of a bitmap with operations that can be performed on it. A pixrect can exist on a variety of devices including memory and printers. Since these operations are the same for each device, the programmer does not have to consider the peculiarities of each device when writing an application program.

1.3. Example

The following example draws a line on the display.

```
#include <pixrect/pixrect_hs.h>

main()
{
    struct pixrect *screen;

    screen = pr_open("/dev/fb");
    pr_vector(screen, 10, 20, 70, 80, PIX_SET, 1);
    pr_close(screen);
}
```

Figure 1-2 *Simple Example Program*

The header file `<pixrect/pixrect_hs.h>` will include all of the header files necessary for working with the functions, macros and data structures in **Pixrect**.

This program can be compiled as follows:

```
% cc line.c -o line -lpixrect
```

This command line compiles the program in `line.c`. The `-lpixrect` option causes the C compiler to link the **Pixrect** library to the application program and create an executable file named `line`.

The sample program can be executed by the UNIX shell:

```
% line
```

A line will appear in the upper left hand corner of the screen.

1.4. The Pixrect Lint Library

Pixrect provides a *lint* library which provides type checking beyond the capabilities of the C compiler. For example, you could use the **Pixrect** *lint* library to check a program called `glass.c` with command like this:

```
% lint glass.c -lpixrect
```

Note that most of the error messages generated by *lint* are warnings, and may not necessarily have any effect on the operation of the program. For a detailed explanation of *lint*, see the *lint* chapter in the *Programming Tools* manual.

1.5. References

[1] J.D. Foley and A. van Dam. *Fundamentals of Interactive Computer Graphics*. Addison-Wesley, 1982.

[2] *Smalltalk Graphics Kernel*. D. Ingalls. Byte, August 1981.

[3] B.W. Kernighan and D.M. Ritchie. *The C Programming Language*. Prentice-Hall, 1978.

[4] W.M. Newman and R.F. Sproull. *Principles of Interactive Computer Graphics*. McGraw-Hill, 1979.

[5] R. Pike, Leo Guibas, Dan Ingalls. *Bitmap Graphics*. ACM/SIGGRAPH 1984 Conference Course Notes.

[6] V.R. Pratt. *Standards and Performance Issues in the Workstation Market*. IEEE Computer Graphics and Applications, April 1984.

[7] *SunCore Reference Manual*.

[8] *SunCGI Reference Manual*.

[9] *SunView Programmer's Guide*.

[10] *SunView System Programmer's Guide*.

2

Pixrect Operations

2

Pixrect Operations

Pixrect provides procedures to perform the following operations:

- create and destroy a pixrect (`open`, `region` and `destroy`)
- read and write the values of single pixels `get(` and `put`)
- use RasterOp functions to affect multiple pixels in a single operation:

`pr_rop`	write from a source pixrect to a destination pixrect,
`pr_stencil`	write from a source pixrect to a destination pixrect under control of a mask,
`pr_replrop`	replicate a constant source pixrect pattern throughout a destination pixrect,
`pr_batchrop`	write a batch of source pixrects to different locations, in a single destination pixrect
`pr_vector`	draw a straight line in a pixrect.

- read and write a colormap (`getcolormap`, `putcolormap`)
- select particular bit-planes for manipulation on a color pixrect (`getattributes`, `putattributes`)

Some of these operations are the same for all pixrects, and are implemented by a single procedure. These device-independent procedures are called directly by **Pixrect** clients. Other operations must be implemented differently for each **Pixrect** device. Each pixrect includes a pointer (in its `pr_ops`) to a `pixrectops` structure, that holds the addresses of the particular device-dependent procedures appropriate to that pixrect. This allows clients to access those procedures in a device-independent fashion, by calling the procedure through a pointer, rather than naming the procedure directly. To simplify this indirection, the **Pixrect** library provides a set of macros which look like simple procedure calls to generic operations, and expand to invocations of the corresponding procedure in the `pixrectops` structure.

The description of each operation will specify whether it is a true procedure or a macro, since some of the arguments to macros are expanded multiple times, and could cause errors if the arguments contain expressions with side effects. (In fact, two sets of parallel macros are provided, which differ only in how their arguments use the geometry data structures.)

2.1. The `pixrectops` Structure

```
struct pixrectops {
    int (*pro_rop)();
    int (*pro_stencil)();
    int (*pro_batchrop)();
    int (*pro_nop)();
    int (*pro_destroy)();
    int (*pro_get)();
    int (*pro_put)();
    int (*pro_vector)();
    struct pixrect *(*pro_region)();
    int (*pro_putcolormap)();
    int (*pro_getcolormap)();
    int (*pro_putattributes)();
    int (*pro_getattributes)();
};
```

The `pixrectops` structure is a collection of pointers to the device-dependent procedures for a particular device. All other operations are implemented by device-independent procedures.

2.2. Conventions for Naming Arguments to Pixrect Operations

In general, the conventions listed in Table 2-1 are used in naming the arguments to pixrect operations.

Table 2-1 *Argument Name Conventions*

Argument	*Meaning*
`d`	destination
`s`	source
`x` and `y`	left and top origins
`w` and `h`	width and height

The `x` and `y` values for functions that operate on pixrects are constrained to be within the boundaries of a pixrect.

2.3. Pixrect Errors

Pixrect procedures which return a pointer to a structure will return NULL when they fail. Otherwise, a return value of PIX_ERR (-1) indicates failure and 0 indicates success. The section describing each library procedure makes note of any exceptions to this convention.

2.4. Creation and Destruction of Pixrects

Pixrects are created by the procedures `pr_open` and `mem_create`, by the procedures accessed by the macro `pr_region`, and at compile-time by the macro `mpr_static`. Pixrects are destroyed by the procedures accessed by the macro `pr_destroy`. `mem_create` and `mpr_static` are discussed in Chapter 4; the rest of these are described here.

Create a Primary Display Pixrect

```
struct pixrect *pr_open(devicename)
char *devicename;
```

The properties of a non-memory pixrect depend on an underlying UNIX device. Thus, when creating the first pixrect for a device you need to open it by a call to `pr_open`. The default device name for your display is `/dev/fb` (`fb` stands for *frame buffer*). Any other device name may be used provided that it is a display device, the kernel is configured for it, and it has pixrect support, for example, */dev/bwone0*, */dev/bwtwo0*, */dev/cgone0* or */dev/cgtwo0*.

`pr_open` does not work for creating a pixrect whose pixels are stored in memory; that function is served by the procedure `mem_create`, discussed in Chapter 4.

`pr_open` returns a pointer to a primary `pixrect` structure which covers the entire surface of the named device. If it cannot, it returns NULL, and prints a message on the standard error output.

Create Secondary Pixrect

```
#define struct pixrect *pr_region(pr, x, y, w, h)
struct pixrect *pr;
int x, y, w, h;

#define struct pixrect *prs_region(subreg)
struct pr_subregion subreg;
```

Given an existing pixrect, it is possible to create another pixrect which refers to some or all of the pixels in the parent pixrect. This *secondary pixrect* is created by a call to the procedures invoked by the macros `pr_region` and `prs_region`.

The existing pixrect is addressed by `pr`; it may be a pixrect created by `pr_open`, `mem_create` or `mpr_static` (a primary pixrect); or it may be another secondary pixrect created by a previous call to a region operation. The rectangle to be included in the new pixrect is described by `x`, `y`, `w` and `h` in the existing pixrect; (`x`, `y`) in the existing pixrect will map to (0, 0) in the new one. `prs_region` does the same thing, but has all its argument values collected into the single structure `subreg`. Each region procedure returns a pointer to the new pixrect. If it fails, it returns NULL, and prints a message on the standard error output.

If an existing secondary pixrect is provided in the call to the region operation, the result is another secondary pixrect referring to the underlying primary pixrect; there is no further connection between the two secondary pixrects. Generally, the distinction between primary and secondary pixrects is not important; however, no secondary pixrect should ever be used after its primary pixrect is destroyed.

Release Pixrect Resources

```
#define pr_close(pr)
struct pixrect *pr;

#define pr_destroy(pr)
struct pixrect *pr;

#define prs_destroy(pr)
struct pixrect *pr;
```

The macros `pr_close`, `pr_destroy` and `prs_destroy` invoke device-dependent procedures to destroy a pixrect, freeing resources that belong to it. The procedure returns 0 if successful, PIX_ERR if it fails. It may be applied to either primary or secondary pixrects. If a primary pixrect is destroyed before secondary pixrects which refer to its pixels, those secondary pixrects are invalidated; attempting any operation but `pr_destroy` on them is an error. The three macros are identical; they are all defined for reasons of history and stylistic consistency.

2.5. Single-Pixel Operations

The next two operations manipulate the value of a single pixel.

Get Pixel Value

```
#define pr_get(pr, x, y)
struct pixrect *pr;
int x, y;

#define prs_get(srcprpos)
struct pr_prpos srcprpos;
```

The macros `pr_get` and `prs_get` invoke device-dependent procedures to retrieve the value of a single pixel. `pr` indicates the pixrect in which the pixel is to be found; x and y are the coordinates of the pixel. For `prs_get`, the same arguments are provided in the single struct `srcprpos`. The value of the pixel is returned as a 32-bit integer; if the procedure fails, it returns PIX_ERR.

Set Pixel Value

```
#define pr_put(pr, x, y, value)
struct pixrect *pr;
int x, y, value;

#define prs_put(dstprpos, value)
struct pr_prpos dstprpos;
int value;
```

The macros `pr_put` and `prs_put` invoke device-dependent procedures to store a value in a single pixel. `pr` indicates the pixrect in which the pixel is to be found; x and y are the coordinates of the pixel. For `prs_put`, the same arguments are provided in the single struct `dstprpos`. `value` is truncated on the left if necessary, and stored in the indicated pixel. If the procedure fails, it returns PIX_ERR.

2.6. Constructing an Op Argument

The multi-pixel operations described in the next section all use a uniform mechanism for specifying the operation which is to produce destination pixel values. This operation is given in the op argument and includes several components.

We describe these three components of the op argument in order.

- A single constant source value may be specified as a color in bits 5 – 31 of the op argument.
- A RasterOp function is specified in bits 1 – 4 of the op argument.
- The clipping which is normally performed by every pixrect operation may be turned off by setting the PIX_DONTCLIP flag (bit 0) in the op.

Figure 2-1 *Structure of an* op *Argument*

color	*RasterOp function*	*clipping*	
31	5	1	0

Specifying a RasterOp Function

Four bits of the op are used to specify one of the 16 distinct logical functions which combine monochrome source and destination pixels to give a monochrome result. This encoding is generalized to pixels of arbitrary depth by specifying that the function is applied to corresponding bits of the pixels in parallel. Some functions are much more common than others; the most useful are identified in Table 2-2.

A convenient and intelligible form of encoding the function into four bits is supported by the following definitions:

```
#define PIX_SRC 0x18
#define PIX_DST 0x14
#define PIX_NOT(op) (0x1E & (~(op)))
```

PIX_SRC and PIX_DST are defined constants, and PIX_NOT is a macro. Together, they allow a desired function to be specified by performing the corresponding logical operations on the appropriate constants. Note that PIX_NOT must be used in all RasterOp operations, and not the ones complement (~) operator.

A particular application of these logical operations allows definition of PIX_SET and PIX_CLR operations. The definition of the PIX_SET operation that follows is always true, and hence sets the result:

```
#define PIX_SET (PIX_SRC | PIX_NOT(PIX_SRC))
```

The definition of the PIX_CLR operation is always false, and hence clears the result:

```
#define PIX_CLR (PIX_SRC & PIX_NOT(PIX_SRC))
```

Other common RasterOp functions are defined in the following table:

Table 2-2 *Useful Combinations of RasterOps*

Op with Value	*Result*
`PIX_SRC`	write (same as source argument)
`PIX_DST`	no-op (same as destination argument)
`PIX_SRC	PIX_DST`	paint (OR of source and destination)
`PIX_SRC & PIX_DST`	mask (AND of source and destination)
`PIX_NOT(PIX_SRC) & PIX_DST`	erase (AND destination with negation of source)
`PIX_NOT(PIX_DST)`	invert area (negate the existing values)
`PIX_SRC ^ PIX_DST`	inverting paint (XOR of source and destination)

Ops with a Constant Source Value

In certain cases, it is desirable to specify an infinite supply of pixels, all with the same value. This is done by using NULL for the source pixrect, and encoding a color in bits 5-31 of the `op` argument. The following macro supports this encoding:

```
#define PIX_COLOR(color) ((color)<<5)
```

This macro extracts the color from an `op`:

```
#define PIX_OPCOLOR(op) ((op)>>5)
```

If no color is specified in an `op`, 0 appears by default. The color specified in the `op` is used in the case of a null source pixrect or to specify the color of the 'ink' in a monochrome pixrect.

Note that the color is not part of the function component of the `op` argument; it should never be part of an argument to PIX_NOT.

The `color` component of `op` is also used when a monochrome pixrect is written to a color pixrect. In this case:

- if the value of the source pixels = 0, they are painted 0, or background.
- if the value of the source pixels = 1, they are painted `color`.

If the `color` component of `op` is 0 (e.g., because no color was specified), the color will default to (-1) (foreground).

Controlling Clipping in a RasterOp

Pixrect operations normally clip to the bounds of the operand pixrects. Sometimes this can be done more efficiently by the client at a higher level. If the client can guarantee that only pixels which ought to be visible will be written, it may instruct the pixrect operation to bypass clipping checks, thus speeding its operation. This is done by setting the following flag in the `op` argument:

```
#define PIX_DONTCLIP 0x1
```

The result of a pixrect operation is undefined and may cause a memory fault if

PIX_DONTCLIP is set and the operation goes out of bounds.

Note that the PIX_DONTCLIP flag is not part of the `function` component of an `op` argument; it should never be part of an argument to PIX_NOT.

Examples of Complete Op Argument Specification

A very simple `op` argument will specify that source pixels be written to a destination, clipping as they go:

```
op = PIX_SRC;
```

A more complicated example will be used to affect a rectangle (known to be valid) with a constant red color defined elsewhere. (The function is syntactically correct; it's not clear how useful it is to XOR a constant source with the negation of the OR of the source and destination):

```
op = (PIX_SRC ^ PIX_NOT(PIX_SRC | PIX_DST)) \
    | PIX_COLOR(red) | PIX_DONTCLIP
```

2.7. Multi-Pixel Operations

The following operations all apply to multiple pixels at one time: `pr_rop`, `pr_stencil`, `pr_replrop`, `pr_batchrop`, `pr_polygon_2`, and `pr_vector`. With the exceptions of `pr_vector` and `pr_polygon_2`, they refer to rectangular areas of pixels. They all use a common mechanism, the `op` argument described in the previous section, to specify how pixels are to be set in the destination. Appendix D describes the `pr_traprop` curve rendering function.

RasterOp Source to Destination

```
#define pr_rop(dpr, dx, dy, dw, dh, op, spr, sx, sy)
struct pixrect *dpr, *spr;
int dx, dy, dw, dh, op, sx, sy;

#define prs_rop(dstregion, op, srcprpos)
struct pr_subregion dstregion;
int op;
struct pr_prpos srcprpos;
```

The `pr_rop` and `prs_rop` macros invoke device-dependent procedures that perform the indicated raster operation from a source to a destination pixrect. `dpr` addresses the destination pixrect, whose pixels will be affected; (`dx, dy`) is the origin (the upper-left pixel) of the affected rectangle; `dw` and `dh` are the width and height of that rectangle. `spr` specifies the source pixrect, and (`sx, sy`) an origin within it. `spr` may be NULL, to indicate a constant source specified in the `op` argument, as described previously; in this case `sx` and `sy` are ignored. `op` specifies the operation which is performed; its construction is described in preceding sections.

For `prs_rop`, the `dpr`, `dx`, `dy`, `dw` and `dh` arguments are all collected in a `pr_subregion` structure.

Raster operations are clipped to the source dimensions, if those are smaller than the destination size given. `pr_rop` procedures return PIX_ERR if they fail, 0 if they succeed.

Source and destination pixrects generally must be the same depth. The only exception allows monochrome pixrects to be sources to a destination of any depth. In this case, source pixels = 0 are interpreted as 0 and source pixels = 1 are written as the color value from the op argument. If the color value in the op argument is 0, source pixels = 1 are written as the maximum value which can be stored in a destination pixel.

See the example program in Figure 4-1 for an illustration of pr_rop.

RasterOps through a Mask

```
#define pr_stencil(dpr, dx, dy, dw, dh, op,
stpr, stx, sty, spr, sx, sy)
struct pixrect *dpr, *stpr, *spr;
int dx, dy, dw, dh, op, stx, sty, sx, sy;

#define prs_stencil(dstregion, op, stenprpos, srcprpos)
struct pr_subregion dstregion;
int op;
struct pr_prpos stenprpos, srcprpos;
```

The pr_stencil and prs_stencil macros invoke device-dependent procedures that perform the indicated raster operation from a source to a destination pixrect only in areas specified by a third (stencil) pixrect. pr_stencil is identical to pr_rop except that the source pixrect is written through a stencil pixrect which functions as a spatial write-enable mask. The stencil pixrect must be a monochrome memory pixrect. The indicated raster operation is applied only to destination pixels where the stencil pixrect is non-zero. Other destination pixels remain unchanged. The rectangle from (sx, sy) in the source pixrect spr is aligned with the rectangle from (stx, sty) in the stencil pixrect stpr, and written to the rectangle at (dx, dy) with width dw and height dh in the destination pixrect dpr. The source pixrect spr may be NULL, in which case the color specified in op is painted through the stencil. Clipping restricts painting to the intersection of the destination, stencil and source rectangles. pr_stencil procedures return PIX_ERR if they fail, 0 if they succeed.

Replicating the Source Pixrect

```
pr_replrop(dpr, dx, dy, dw, dh, op, spr, sx, sy)
struct pixrect *dpr, *spr;
int dx, dy, dw, dh, op, sx, sy;

#define prs_replrop(dsubreg, op, sprpos)
struct pr_subregion dsubreg;
struct pr_prpos sprpos;
```

Often the source for a raster operation consists of a pattern that is used repeatedly, or replicated to cover an area. If a single value is to be written to all pixels in the destination, the best way is to specify that value in the color component of a pr_rop operation. But when the pattern is larger than a single pixel, a mechanism is needed for specifying the basic pattern, and how it is to be laid down repeatedly on the destination.

The pr_replrop procedure replicates a source pattern repeatedly to cover a destination area. dpr indicates the destination pixrect. The area affected is described by the rectangle defined by dx, dy, dw, dh. spr indicates the source pixrect, and the origin within it is given by sx, sy. The corresponding prs_replrop macro generates a call to pr_replrop, expanding its dsubreg into the five destination arguments, and sprpos into the three source arguments. op specifies the operation to be performed, as described above in Section 2.6.

The effect of pr_replrop is the same as though an infinite pixrect were constructed using copies of the source pixrect laid immediately adjacent to each other in both dimensions, and then a pr_rop was performed from that source to the destination. For instance, a standard gray pattern may be painted across a portion of the screen by constructing a pixrect that contains exactly one tile of the pattern, and by using it as the source pixrect.

The alignment of the pattern on the destination is controlled by the source origin given by sx, sy. If these values are 0, then the pattern will have its origin aligned with the position in the destination given by dx, dy. Another common method of alignment preserves a global alignment with the destination, for instance, in order to repair a portion of a gray. In this case, the source pixel which should be aligned with the destination position is the one which has the same coordinates as that destination pixel, modulo the size of the source pixrect. pr_replrop will perform this modulus operation for its clients, so it suffices in this case to simply copy the destination position (dx, dy) into the source position (sx, sy).

pr_replrop procedures return PIX_ERR if they fail, 0 if they succeed. Internally pr_replrop may use pr_rop procedures. In this case, pr_rop errors are detected and returned by pr_replrop.

Multiple Source to the Same Destination

```
#define pr_batchrop(dpr, dx, dy, op, items, n)
struct pixrect *dpr;
int dx, dy, op, n;
struct pr_prpos items[];

#define prs_batchrop(dstpos, op, items, n)
struct pr_prpos dstpos;
int op, n;
struct pr_prpos items[];
```

Applications such as displaying text perform the same operation from a number of source pixrects to a single destination pixrect in a fashion that is amenable to global optimization.

The pr_batchrop and prs_batchrop macros invoke device-dependent procedures that perform raster operations on a sequence of sources to successive locations in a common destination pixrect. items is an array of pr_prpos structures used by a pr_batchrop procedure as a sequence of source pixrects. Each item in the array specifies a source pixrect and an advance in x and y. The whole of each source pixrect is used, unless it needs to be clipped to fit the destination pixrect. advance is used to update the destination position, not as an origin in the source pixrect.

pr_batchrop procedures take a destination, specified by dpr, dx and dy, or by dstpos in the case of prs_batchrop; an operation specified in op, as described in Section 2.6, and an array of pr_prpos addressed by the argument items, and whose length is given in the argument n.

The destination position is initialized to the position given by dx and dy. Then, for each item, the offsets given in pos are added to the previous destination position, and the operation specified by op is performed on the source pixrect and the corresponding rectangle whose origin is at the current destination position. Note that the destination position is updated for each item in the batch, and these adjustments are cumulative.

The most common application of pr_batchrop procedures is in painting text; additional facilities to support this application are described in Chapter 3. Note that the definition of pr_batchrop procedures supports variable-pitch and rotated fonts, and non-roman writing systems, as well as simpler text.

pr_batchrop procedures return PIX_ERR if they fail, 0 if they succeed. Internally pr_batchrop may use pr_rop procedures. In this case, pr_rop errors are detected and returned by pr_batchrop.

Draw Vector

```
#define pr_vector(pr, x0, y0, x1, y1, op, value)
struct pixrect *pr;
int x0, y0, x1, y1, op, value;

#define prs_vector(pr, pos0, pos1, op, value)
struct pixrect *pr;
struct pr_pos pos0, pos1;
int op, value;
```

The pr_vector and prs_vector macros invoke device-dependent procedures that draw a vector one unit wide between two points in the indicated pixrect. pr_vector procedures draw a vector in the pixrect indicated by pr, with endpoints at (x0, y0) and (x1, y1), or at pos0 and pos1 in the case of prs_vector. Portions of the vector lying outside the pixrect are clipped as long as PIX_DONTCLIP is 0 in the op argument. The op argument is constructed as described in Section 2.6, and value specifies the resulting value of pixels in the vector. If the color in op is non-zero, it takes precedence over the value argument.

Any vector that is not vertical, horizontal or 45 degree will contain *jaggies*. This phenomenon, known as *aliasing*, is due to the digital nature of the bitmap screen. It can be visualized by imagining a vertical vector. Displace one endpoint horizontally by a single pixel. The resulting line will have to jog over a pixel at some point in the traversal to the other endpoint. Balancing the vector guarantees that the jog will occur in the middle of the vector. pr_vector draws *balanced* vectors. (The technique used is to balance the Bresenham error term). The vectors are balanced according to their endpoints as given and not as clipped, so that the same pixels will be drawn regardless of how the vector is clipped.

See the example program in Figure 1-2 for an illustration of pr_vector.

Draw Textured Polygon

```
pr_polygon_2(dpr, dx, dy, nbnds, npts, vlist, op, spr, sx, sy)
struct pixrect *dpr, *spr;
int dx, dy
int nbnds, npts[];
struct pr_pos *vlist;
int op, sx, sy;
```

`pr_polygon_2` draws a polygon in a pixrect. The polygon can have holes. In addition, you can fill it with an image or a texture. This routine is like `pr_rop` except that `nbnds`, `npts` and `vlist` specify the destination region instead of `(dw, dh)`.

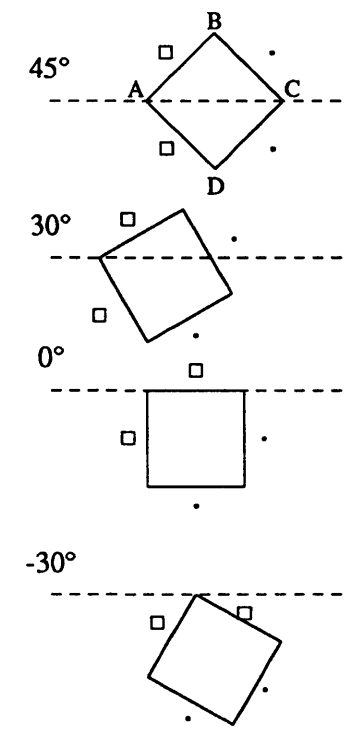
`nbnds` is the number of individual closed boundaries (vertex lists) in the polygon. For example, the polygon may have one boundary for its exterior shape and several boundaries delimiting interior holes. The boundaries may self intersect or intersect each other. Those pixels having an *odd wrapping number* are painted. That is, if any line connecting a pixel to infinity crosses an odd number of boundary edges, the pixel will be painted.

Polygons can be *wrapped* by vectors. To do this, draw the vectors using the same vertices of the polygon as endpoints. The edge of the polygon will match the vector pixel for pixel. Note that vectors are *balanced* (see `pr_vector`). Polygons are *semi-open* in the sense that on some of the edges, pixels are not drawn where the vector would go. The reason is to allow identical polygons (same size and orientation) to exactly tile the plane with no gaps and no overlaps. This greatly reduces the duplication of pixels drawn when the image contains many small adjacent polygons. In Figure 2-3, the edges AB and DA will be drawn, whereas edges BC and CD will not.

Figure 2-2 *Example Program with* `pr_polygon_2`

```
#include <pixrect/pixrect_hs.h>
#include <stdio.h>
#define CENTERX (1152/2)
#define NULLPR (struct pixrect *) NULL

struct pr_pos vlist0[4] = { {0,0} , {71,-71} , {141,0} , {71,71} }; /* 45 degrees */
struct pr_pos vlist1[4] = { {0,0} , {87,-50} , {137,37} , {50,87} }; /* 30 degrees */
struct pr_pos vlist2[4] = { {0,0} , {100,0} , {100,100} , {0,100} }; /* 0 degrees */
struct pr_pos vlist3[4] = { {0,0} , {87,50} , {37,137} , {-50,87} }; /* -30 degrees */

main()
{
    int i, nbnds = 1, npts[1];
    struct pixrect *screen;

    npts[0] = 4;

    screen = pr_open("/dev/fb");
    pr_polygon_2(screen, CENTERX, 100, nbnds, npts, vlist0, PIX_SET, NULLPR, 0, 0);
    for (i=0; i<4; i++)
        pr_vector(screen, (vlist0[i].x + CENTERX), (vlist0[i].y + 100),
            (vlist0[(i+1)%4].x + CENTERX), (vlist0[(i+1)%4].y + 100), PIX_SET, 1);
    pr_polygon_2(screen, CENTERX, 300, nbnds, npts, vlist1, PIX_SET, NULLPR, 0, 0);
    for (i=0; i<4; i++)
        pr_vector(screen, (vlist1[i].x + CENTERX), (vlist1[i].y + 300),
            (vlist1[(i+1)%4].x + CENTERX), (vlist1[(i+1)%4].y + 300), PIX_SET, 1);
    pr_polygon_2(screen, CENTERX, 500, nbnds, npts, vlist2, PIX_SET, NULLPR, 0, 0);
    for (i=0; i<4; i++)
        pr_vector(screen, (vlist2[i].x + CENTERX), (vlist2[i].y + 500),
            (vlist2[(i+1)%4].x + CENTERX), (vlist2[(i+1)%4].y + 500), PIX_SET, 1);
    pr_polygon_2(screen, CENTERX, 700, nbnds, npts, vlist3, PIX_SET, NULLPR, 0, 0);
    for (i=0; i<4; i++)
        pr_vector(screen, (vlist3[i].x + CENTERX), (vlist3[i].y + 700),
            (vlist3[(i+1)%4].x + CENTERX), (vlist3[(i+1)%4].y + 700), PIX_SET, 1);
    pr_close(screen);
}
```

Figure 2-3 *Four Polygons Drawn with* `pr_polygon_2`



For each of the `nbnds` boundaries `npts` specifies the number of points in the boundary. Hence the `npts` array is `nbnds` in length. The `vlist` contains all of the boundary points for all of the boundaries. The number of points in order are `npts[0]+...+npts[nbnds-1]`. `pr_polygon_2` joins the last point and first point to close each boundary. A boundary with less than 3 points is an error.

The `spr` source pixrect fills the interior of the polygon as in `pr_rop`. The position `sx, sy` in `spr` coordinates coincides with position `dx, dy` in `dpr` coordinates. If `sx` = (-5) and `sy` = (-10), for example, the source pixrect is positioned at `(dx+5, dy+10)` in `dpr` coordinates. `pr_polygon_2` clips to both `spr` and `dpr` except in the case of NULL `spr`, where the polygon is filled with the color value in `op`. The source offset `sx, sy` is used to superimpose the source image over the polygon. The `spr` must have depth less than or equal to the depth of `dpr`. A point `(pts[n].x, pts[n].y)` in the boundary of a polygon is mapped to `(dx + pts[n].x, dy + pts[n].y)`.

2.8. Colormap Access

A *colormap* is a table which translates a pixel value into 8-bit intensities in red, green, and blue. For a pixrect of depth n, the corresponding colormap will have 2^n entries. The two most common cases are monochrome (two entries) and color (256 entries). Memory pixrects do not have colormaps.

Get Colormap Entries

```
#define pr_getcolormap(pr, index, count, red, green, blue)
struct pixrect *pr;
int index, count;
unsigned char red[], green[], blue[];

#define prs_getcolormap(pr, index, count, red, green, blue)
struct pixrect *pr;
int index, count;
unsigned char red[], green[], blue[];
```

The macros `pr_getcolormap` and `prs_getcolormap` invoke device-dependent procedures to read all or part of a colormap into arrays in memory.

These two macros have identical definitions; both are defined to allow consistent use of one set of names for all operations.

`pr` identifies the pixrect whose colormap is to be read; the `count` entries starting at `index` (zero origin) are read into the three arrays.

For monochrome pixrects the same value is read into corresponding elements of the `red`, `green` and `blue` arrays. These array elements will have their bits either all cleared, indicating `black`, or all set, indicating `white`. By default, the 0th (*background*) element is white, and the 1st (*foreground*) element is black. Colormap procedures return (-1) if the index or count are out of bounds, and 0 if they succeed.

Set Colormap Entries

```
#define pr_putcolormap(pr, index, count, red, green, blue)
struct pixrect *pr;
int index, count;
unsigned char red[], green[], blue[];

#define prs_putcolormap(pr, index, count, red, green, blue)
struct pixrect *pr;
int index, count;
unsigned char red[], green[], blue[];
```

The macros `pr_putcolormap` and `prs_putcolormap` invoke device-dependent procedures to store from memory into all or part of a colormap. These two macros have identical definitions; both are defined to allow consistent use of one set of names for all operations. The `count` elements starting at `index` (zero origin) in the colormap for the pixrect identified by `pr` are loaded from corresponding elements of the three arrays. For monochrome pixrects, the only value considered is `red[0]`. If this value is 0, then the pixrect will be set to a dark background and light foreground. If the value is non-zero, the foreground will be dark, e.g. black-on-white. Monochrome pixrects are dark-on-light by default.

Note: Full functionality of the colormap is not supported for monochrome pixrects. Colormap changes to monochrome pixrects apply only to subsequent operations whereas a colormap change to a color device instantly changes all affected pixels on the display surface.

Inverted Video Pixrects

```
pr_blackonwhite(pr, min, max)
struct pixrect *pr;
int min, max;

pr_whiteonblack(pr, min, max)
struct pixrect *pr;
int min, max;

pr_reversevideo(pr, min, max)
struct pixrect *pr;
int min, max;
```

Video inversion is accomplished by manipulation of the colormap of a pixrect. The colormap of a monochrome pixrect has two elements. The procedures `pr_blackonwhite`, `pr_whiteonblack` and `pr_reversevideo` provide video inversion control. These procedures are ignored for memory pixrects.

In each procedure, `pr` identifies the pixrect to be affected; `min` is the lowest index in the colormap, specifying the background color, and `max` is the highest index, specifying the foreground color. These will most often be 0 and 1 for monochrome pixrects; the more general definitions allow colormap-sharing schemes.

"Black-on-white" means that zero (background) pixels will be painted at full intensity, which is usually white. `pr_blackonwhite` sets all bits in the entry for colormap location `min` and clears all bits in colormap location `max`.

"White-on-black" means that zero (background) pixels will be painted at minimum intensity, which is usually black. `pr_whiteonblack` clears all bits in colormap location `min` and sets all bits in the entry for colormap location `max`.

`pr_reversevideo` exchanges the `min` and `max` color intensities.

Note: These procedures are intended for global foreground/background control, not for local highlighting. For monochrome frame buffers, `subsequent` operations will have inverted intensities. For color frame buffers, the colormap is modified immediately, which affects everything in the display.

2.9. Attributes for Bitplane Control

In a color pixrect, it is often useful to define bitplanes which may be manipulated independently; operations on one plane leave the other planes of an image unaffected. This is normally done by assigning a plane to a constant bit position in each pixel. Thus, the value of the i^{th} bit in all the pixels defines the i^{th} bitplane in the image. It is sometimes beneficial to restrict pixrect operations to affect a subset of a pixrect's bitplanes. This is done with a bitplane mask. A bitplane mask value is stored in the pixrect's private data and may be accessed by the attribute operations.

Get Attributes

```
#define pr_getattributes(pr, planes)
struct pixrect *pr;
int *planes;

#define prs_getattributes(pr, planes)
struct pixrect *pr;
int *planes;
```

The macros `pr_getattributes` and `prs_getattributes` invoke device-dependent procedures that retrieve the mask which controls which planes in a pixrect are affected by other pixrect operations. `pr` identifies the pixrect; its current bitplanes mask is stored into the word addressed by `planes`. If `planes` is NULL, no operation is performed.

The two macros are identically defined; both are provided to allow consistent use of the same style of names.

Put Attributes

```
#define pr_putattributes(pr, planes)
struct pixrect *pr;
int *planes;

#define prs_putattributes(pr, planes)
struct pixrect *pr;
int *planes;
```

The macros `pr_putattributes` and `prs_putattributes` invoke device-dependent procedures that manipulate a mask which controls which planes in a pixrect are affected by other pixrect operations. The two macros are identically defined; both are provided to allow consistent use of the same style of names.

`pr` identifies the pixrect to be affected. The `planes` argument is a pointer to a bitplane write-enable mask. Only those planes corresponding to mask bits having a value of 1 will be affected by subsequent pixrect operations. If `planes` is NULL, no operation is performed.

Note: If any `planes` are masked off by a call to `pr_putattributes`, no further write access to those planes is possible until a subsequent call to `pr_putattributes` unmasks them. However, these planes can still be read.

2.10. Efficiency Considerations

For maximum execution speed, remember the following points when you write pixrect programs:

- `pr_get` and `pr_put` are relatively slow. For fast random access of pixels it is usually faster to read an area into a memory pixrect and address the pixels directly.
- `pr_rop` is fast for large rectangles.
- `pr_vector` is fast.
- functions run faster when clipping is turned off. Do this only if you can guarantee that all accesses are within the pixrect bounds.

- pr_rop is three to five times faster than pr_stencil.
- pr_batch_rop cuts down the overhead of painting many small pixrects.
- For small standard shapes pr_rop should be used instead of pr_polygon_2.

3

Text Facilities for Pixrects

3

Text Facilities for Pixrects

Displaying text is an important task in many applications, so pixrect-level facilities are provided to address it directly. These facilities fall into two main categories: a standard format for describing fonts and character images, with routines for processing them; and a set of routines which take a string of text and a font, and handle various parts of painting that string in a pixrect.

3.1. Pixfonts and Pixchars

```
struct pixchar {
    struct pixrect *pc_pr;
    struct pr_pos pc_home;
    struct pr_pos pc_adv;
};
```

The `pixchar` structure defines the format of a single character in a font. The actual image of the character is a pixrect (a separate pixrect for each character) addressed by `pc_pr`. The entire pixrect gets painted. Characters that do not have a displayable image will have NULL in their entry in `pc_pr`. `pc_home` is the origin of pixrect `pc_pr` (its upper left corner) relative to the character origin. A character's origin is the leftmost end of its *baseline*, which is the lowest point on characters without descenders. Figure 3-1 illustrates the `pc_pr` origin and the character origin.

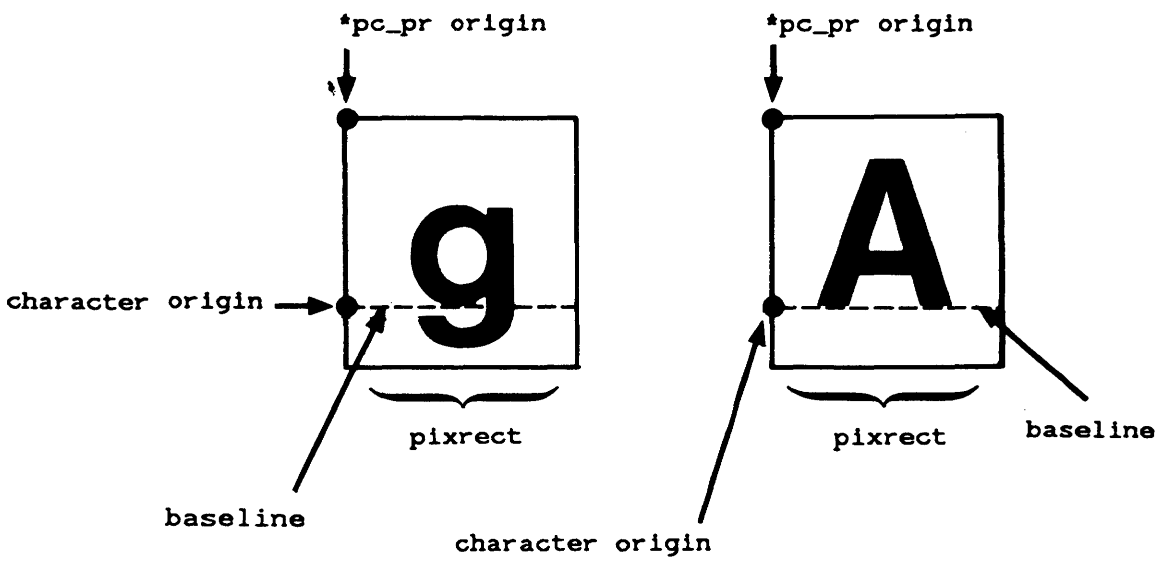
The leftmost point on a character is normally its origin, but *kerning* or mandatory letter spacing may move the origin right or left of that point. `pc_adv` is the amount the destination position is changed by this character; that is, the amounts in `pc_adv` added to the current character origin will give the origin for the next character. While normal text only advances horizontally, rotated fonts may have a vertical advance. Both are provided for in the font.

```
struct pixfont {
    struct pr_size pf_defaultsize;
    struct pixchar pf_char[256];
};
```

The `pixfont` structure contains an array of `pixchars`, indexed by the character code; it also contains the size (in pixels) of its characters when they are all the same. (If the size of a font's characters varies in one dimension, that value in `pf_defaultsize` will not have anything useful in it; however, the other may still be useful. Thus, for non-rotated variable-pitch fonts, `pf_defaultsize.y` will still indicate the unleaded interline spacing for that font.)

Note: The definition of a `pixfont` is expected to change.

Figure 3-1 *Character and* `pc_pr` *Origins*



Operations on Pixfonts

```
struct pixfont *pf_open(name)
char *name;
```

`pf_open` returns a pointer to a *shared* copy of a font in virtual memory. A NULL is returned if the font cannot be opened. The path name of the font file should be specified, for example:

```
myfont = pf_open("/usr/lib/fonts/fixedwidthfonts/screen.r.7")
```

`name` should be in the format described in *vfont*(5): the file is converted to pixfont format, allocating memory for its associated structures and reading in the data for it from disk. The utility `fontedit(1)` is a font editor for designing pixel fonts in *vfont*(5) format.

Load Private Copy of Font

```
struct pixfont *pf_open_private(name)
char *name;
```

`pf_open` returns a pointer to a *private* copy of a font in virtual memory. A NULL is returned if the font cannot be opened.

Default Fonts

```
struct pixfont *pf_default()
```

The procedure `pf_default` performs the same function for the system default font, normally a fixed-pitch, 16-point sans serif font with upper-case letters 12 pixels high. If the environment parameter DEFAULT_FONT is set, its value will be taken as the name of the font file to be opened by `pf_default`.

Close Font

```
pf_close(pf)
struct pixfont *pf;
```

When a client is finished with a font, it should call `pf_close` to free the memory associated with it. `pf` should be a font handle returned by a previous call to `pf_open` or `pf_default`.

Pixrect Text Display

```
pf_text(where, op, font, text)
struct pr_prpos where;
int op;
struct pixfont *font;
char *text;
```

Characters are written into a pixrect with the `pf_text` procedure. The `where` argument is the destination for the start of the text (nominal left edge, baseline; see Section 3.1; `op` is the raster operation to be used in writing the text, as described in Section 2.6; `font` is a pointer to the font in which the text is to be displayed; and `text` is the actual null-terminated string to be displayed. No error indicators are returned. *Note:* The color specified in the `op` specifies the color of the ink. The background of the text is painted 0 (background color).

Transparent Text

```
pf_ttext(where, op, font, text)
struct pr_prpos where;
int op;
struct pixfont *font;
char *text;
```

`pf_ttext` paints ''transparent'' text: it doesn't disturb destination pixels in blank areas of the character's image. The arguments to this procedure are the same as for `pf_text`. The characters' bitmaps are used as a stencil, and the color specified in `op` is painted through the stencil. No error indicators are returned.

(For monochrome pixrects, the same effect can be achieved by using `PIX_SRC | PIX_DST` as the function in the `op`; this procedure is for color pixrects.)

Auxiliary Pixfont Procedures

```
struct pr_size pf_textbatch(where, lengthp, font, text)
struct pr_pos where[];
int *lengthp;
struct pixfont *font;
char *text;

struct pr_size pf_textwidth(len, font, text)
int len;
struct pixfont *font;
char *text;
```

`pf_textbatch` is used internally by `pf_text`; it constructs an array of `pr_pos` structures and records its length, as required by `batchrop` (see Section 2.7). `where` should be the address of the array to be filled in, and `lengthp` should point to a maximum length for that array. `text` addresses the null-terminated string to be put in the batch, and `font` refers to the pixfont to be used to display it. When the function returns, `lengthp` will refer to a word containing the number of `pr_pos` structures actually used for `text`. The `pr_size` returned is the sum of the `pc_adv` fields in their `pixchar` structures.

`pf_textwidth` returns a `pr_size` which is computed by taking the product of `len`, is the number of characters, and `pc_adv`, the width of each character.

Text Bounding Box

```
pf_textbound(bound, len, font, text)
struct pr_subregion *bound;
int len;
struct pixfont *font;
char *text;
```

`pf_textbound` may be used to find the bounding box for a string of characters in a given font. `bound->pos` is the top-left corner of the bounding box, `bound->size.x` is the width, and `bound->size.y` is the height. `bound->pr` is not modified. `bound->pos` is computed relative to the location of the character origin (base point) of the first character in the text.

3.2. Example

Here is an example program that writes text on the display surface with pixel fonts.

```
#include <pixrect/pixrect_hs.h>

main()
{
    struct pixrect *screen;

    struct pr_prpos where;
    int op = PIX_SET;
    struct pixfont *font;
    char *text = "This is a string.";

    screen = pr_open("/dev/fb");
    font = pf_open("/usr/lib/fonts/fixedwidthfonts/screen.r.12");

    where.pr = screen;
    where.pos.x = 400;
    where.pos.y = 400;

    pf_ttext(where, op, font, text);

    pf_close(font);
    pr_close(screen);
}
```

Figure 3-2 *Example Program with Text*

4

Memory Pixrects

4

Memory Pixrects

Memory pixrects store their pixels in memory, instead of displaying them on some display, are similar to other pixrects but have several special properties. Like all other pixrects, their dimensions are visible in the pr_size and pr_depth elements of their pixrect structure, and the device-dependent operations appropriate to manipulating them are available through their pr_ops. Beyond this, however, the format of the data which describes the particular pixrect is also public: pr_data will hold the address of an mpr_data struct described below. Thus, a client may construct and manipulate memory pixrects using non-pixrect operations. There is also a public procedure, mem_create, which dynamically allocates a new memory pixrect, and a macro, mpr_static, which can be used to generate an initialized memory pixrect in the code of a client program.

4.1. The mpr_data Structure

```
struct mpr_data {
    int md_linebytes;
    short *md_image;
    struct pr_pos md_offset;
    short md_primary;
    short md_flags;
};
#define MP_DISPLAY
#define MP_REVERSEVIDEO
```

The pr_data element of a memory pixrect points to an mpr_data struct, which contains the information needed to deal with a memory pixrect.

linebytes is the number of bytes stored in a row of the primary pixrect. This is the difference in the addresses between two pixels at the same x-coordinate, one row apart. Because a secondary pixrect may not include the full width of its primary pixrect, this quantity cannot be computed from the width of the pixrect — see Section 2.4. The actual pixels of a memory pixrect are stored someplace else in memory, usually an array, which md_image points to; the format of that area is described in the next section. The creator of the memory pixrect must ensure that md_image contains an even address. md_offset is the x,y position of the first pixel of this pixrect in the array of pixels addressed by md_image. md_primary is 1 if the pixrect is primary and had its image allocated dynamically (e.g. by mem_create). In this case, md_image will point to an area not referenced by any other primary pixrect. This flag is interrogated by the pr_destroy routine: if it is 1 when that routine is called, the pixrect's image memory will be freed.

`md_flags & (MP_DISPLAY)` is non-zero if this memory pixrect is in fact a display device. Otherwise, it is 0. (`md_flags & MP_REVERSEVIDEO`) is 1 if `reversevideo` is currently in effect for the display device. `md_flags` is present to support memory-mapped display devices like the Sun–2 monochrome video device.

Several macros are defined in `<pixrect/memvar.h>` to aid in addressing memory pixrects. The following macro obtains a pointer to the `mpr_data` of a memory pixrect.

```
#define mpr_d(pr)
    ((struct mpr_data *)(pr)->pr_data)
```

The following macro computes the bytes per line of a primary memory pixrect given its width in pixels and the bits per pixel. This includes the padding to word bounds. It is useful for incrementing pixel addresses in the *y* direction.

```
#define mpr_linebytes(width, depth)
    ( ((pr_product(width, depth)+15)>>3) &~1)
```

4.2. Creating Memory Pixrects

The `mem_create` and `mem_point` functions allow a client program to create memory pixrects.

Create Memory Pixrect

```
struct pixrect *mem_create(w, h, depth)
int w, h, depth;
```

A new primary pixrect is created by a call to the procedure `mem_create`. `w`, `h` and `depth` specify the width and height in pixels, and depth in bits per pixel of the new pixrect. Sufficient memory to hold those pixels is allocated and cleared to 0, new `mpr_data` and `pixrect` structures are allocated and initialized, and a pointer to the pixrect is returned. If this can not be done, the return value is NULL.

Create Memory Pixrect from an Image

```
struct pixrect *mem_point(width, height, depth, data)
int width, height, depth;
short *data;
```

The `mem_point` routine builds a pixrect structure that points to a dynamically created image in memory. Client programs may use this routine as an alternative to `mem_create` if the image data is already in memory. `width` and `height` are the width and height of the new pixrect, in pixels. `depth` is the depth of the new pixrect, in number of bits per pixel. `data` points to the image to be associated with the pixrect.

Example

Here is an example program program that uses memory pixrects to make an inverted copy of the frame buffer. It opens the default frame buffer and two memory pixrects, one the size of a scan line and the other the size of the frame buffer. It then copies in reverse order the frame buffer line by line into the larger memory pixrect. Finally it copies the memory pixrect back into the frame buffer.

```
#include <pixrect/pixrect_hs.h>

main()
{
    int i;
    struct pixrect *line, *screen, *screen_temp;

    screen = pr_open("/dev/fb");
    screen_temp = mem_create(screen->pr_size.x,
        screen->pr_size.y, 1);
    line = mem_create(screen->pr_size.x, 1, 1);

    for (i = 0; i < screen->pr_size.y; i++) {
        pr_rop(line, 0, 0, screen->pr_size.x,
            1, PIX_SET, screen, 0, i);
        pr_rop(screen_temp, 0, (screen->pr_size.y - i),
            screen->pr_size.x, 1, PIX_SET, line, 0, 0);
    }

    pr_rop(screen, 0, 0, screen->pr_size.x,
        screen->pr_size.y, PIX_SET, screen_temp, 0, 0);
}
```

Figure 4-1 *Example Program with Memory Pixrects*

4.3. Static Memory Pixrects

```
#define mpr_static(name, w, h, depth, image)
int w, h, depth;
short *image;
```

A memory pixrect may be created at compile time by using the `mpr_static` macro. `name` is a token to identify the generated data objects; `w`, `h`, and `depth` are the width and height in pixels, and depth in bits of the pixrect; and `image` is the address of an even-byte aligned data object that contains the pixel values in the format described above.

The macro generates two structures:

```
struct mpr_data name_data;
struct pixrect name;
```

The `mpr_data` is initialized to point to all of the image data passed in; the pixrect then refers to `mem_ops` and to `name_data`. *Note:* Contrary to its name, this macro generates structures of storage class `extern`.

4.4. Pixel Layout in Memory Pixrects

In memory, the upper-left corner pixel is stored at the lowest address. This address must be even. That first pixel is followed by the remaining pixels in the top row, left-to-right. Pixels are stored in successive bits without padding or alignment. For pixels more than 1 bit deep, it is possible for a pixel to cross a byte boundary. However, rows are rounded up to 16-bit boundaries. After any padding for the top row, pixels for the row below are stored, and so on through the whole rectangle. Currently, memory pixrects are only supported for pixels of

1, 8, 16, or 24 bits. If source and destination are both memory pixrects they must have an equal number of bits per pixel.

4.5. Using Memory Pixrects

Memory pixrects can be used to get data from and send data to the display device. Several routines exist for interfacing **Pixwins** with memory pixrects. These include `pw_read`, `pw_rop` and `pw_write`. Refer to the *SunView Programmer's Guide* for more details. For applications using the raw device without **SunView**, `pr_rop` can be used for operations on memory pixrects.

Another use of memory pixrects is for processing images that not intended for display. User programs can write directly into a pixrect using parameters found in the `mpr_data` structure, or they can use `mem_point` for a previously created image. Memory pixrects can also be written to raster files using the facilities described in Chapter 5.

5

File I/O Facilities for Pixrects

5

File I/O Facilities for Pixrects

Sun has specified a file format for files containing raster images. The format is defined in the header file <rasterfile.h>. The pixrect library contains routines to perform I/O operations between pixrects and files in this raster file format. This I/O is done using the routines of the C Library Standard I/O package, requiring the caller to include the header file <stdio.h>.

The raster file format allows for multiple types of raster images. This means that both unencoded and encoded images are supported. In addition, the pixrect library routines that read and write raster files support customer defined formats. This support is implemented by passing raster files with non-standard types through filters found in the directory /usr/lib/rasfilters. This directory also includes sample source code for a filter that corresponds to one of the standard raster file types to facilitate writing new filters.

5.1. Writing and Reading Raster Files

The sections that follow describe how to store and retrieve an image in a rasterfile.

Write Raster File

```
int pr_dump(input_pr, output, colormap, type, copy_flag)
struct pixrect *input_pr;
FILE *output;
colormap_t *colormap;
int type, copy_flag;
```

The pr_dump procedure stores the image described by a pixrect onto a file. It normally returns 0, but if any error occurs it returns PIX_ERR. The input_pr pixrect can be a secondary pixrect. This allows the caller to write a rectangular sub-region of a pixrect by first creating an appropriate input_pr via a call to pr_region. The output file is specified via output. The desired output type should either be one of the following standard types or correspond to a customer provided filter.

```
#define RT_OLD 0
#define RT_STANDARD 1
#define RT_BYTE_ENCODED 2
```

The RT_STANDARD type is the common raster file format in the same sense that memory pixrects are the common pixrect format: every raster file filter is required to read and write this format. The RT_OLD type is very close to the RT_STANDARD type; it was the former standard generated by old versions of Sun software. The RT_BYTE_ENCODED type implements a run-length encoding of bytes of the pixrect image; usually this results in shorter files. Specifying any other output type causes `pr_dump` to pipe a raster file of RT_STANDARD type to the filter named `/usr/lib/rasfilters/convert.`*type*, where `type` is the ASCII corresponding to the specified `type` in decimal. The output of the filter is then copied to `output`.

It is strongly recommended that customer-defined formats use a type of 100 or more, to avoid conflicts with additions to the set of standard types. To aid in development of filters for customer-defined formats, `pr_dump` recognizes the RT_EXPERIMENTAL type as special, and uses the filter named `./convert.65535` rather than `/usr/lib/rasfilters/convert.65535`.

```
#define RT_EXPERIMENTAL 65535
```

For pixrects displayed on devices with colormaps, the values of the pixels are not sufficient to recreate the displayed image. Thus, the image's colormap can also be specified in the call to `pr_dump`. If the `colormap` is specified as NULL but `input_pr` is not monochrome, `pr_dump` will attempt to write the colormap obtained from `input_pr` (via `pr_getcolormap` assuming a 256 element RGB colormap). The following structure is used to specify the colormap associated with `input_pr`:

```
typedef struct {
    int type;
    int length;
    unsigned char *map[3];
} colormap_t;
```

The colormap type should be one of the Sun supported types:

```
#define RMT_NONE 0
#define RMT_EQUAL_RGB 1
```

If the colormap type is RMT_NONE, then the colormap length must be 0. This case usually arises when dealing with monochrome displays and monochrome pixrects. If the colormap type is RMT_EQUAL_RGB, then the map array should specify the red (`map[0]`), green (`map[1]`) and blue (`map[2]`) colormap values, with each vector in the map array being of the same specified colormap length. For developers of customer-defined formats, the following colormap type is provided but not interpreted by the pixrect software:

```
#define RMT_RAW 2
```

Finally `copy_flag` specifies whether or not `input_pr` should be copied to a temporary pixrect before the image is output. There are two situations in which the `copy_flag` value should be non-zero:

- if the output type is RT_BYTE_ENCODED — This is because the encoding algorithm does the encoding in place and will destroy the image data of `input_pr` if it fails while working on `input_pr` directly.
- if `input_pr` is a pixrect in a frame buffer that is likely to be asynchronously modified — Note that use of `copy_flag` will still not guarantee that the correct image will be output unless the `pr_rop` to copy from the frame buffer

is atomic or otherwise made uninterruptable.

```
#include <pixrect/pixrect_hs.h>
#include <stdio.h>

#define FALSE   0
#define TRUE    !FALSE

main()
{
    struct pixrect *screen, *icon;
    FILE *output = stdout;
    colormap_t *colormap = NULL;
    int type = RT_STANDARD;
    int copy_flag = TRUE;

    screen = pr_open("/dev/fb");
    icon = pr_region(screen, 1050, 10, 64, 64);
    pr_dump(icon, output, colormap, type, copy_flag);
    pr_close(screen);
}
```

Figure 5-1 *Example Program with* `pr_dump`

Read Raster File

```
struct pixrect *pr_load(input, colormap)
FILE *input;
colormap_t *colormap;
```

The `pr_load` can be used to retrieve the image described by a file into a pixrect. The raster file's header is read from `input`, a pixrect of the appropriate size is dynamically allocated, the colormap is read and placed in the location addressed by `colormap`, and finally the image is read into the pixrect and the pixrect returned. If any problems occurs, `pr_load` returns NULL instead.

As with `pr_dump`, if the specified raster file is not of standard type, `pr_load` first runs the file through the appropriate filter to convert it to RT_STANDARD type and then loads the output of the filter.

Additionally, if colormap is NULL, `pr_load` will simply discard any and all colormap information contained in the specified input raster file.

```
#include <pixrect/pixrect_hs.h>
#include <stdio.h>

main()
{
    struct pixrect *screen, *icon, *pr_load();
    FILE *input = stdin;
    colormap_t *colormap = NULL;

    screen = pr_open("/dev/fb");
    icon = pr_load(input, colormap);
    pr_rop(screen, 1050, 110, 64, 64, PIX_SET, icon, 0, 0);
    pr_close(screen);
}
```

Figure 5-2 *Example Program with* `pr_load`

5.2. Details of the Raster File Format

A handful of additional routines are available in the pixrect library for manipulating pieces of raster files. In order to understand what they do, it is necessary to understand the exact layout of the raster file format.

The raster file is in three parts: first, a small header containing 8 `int`'s; second, a (possibly empty) set of colormap values; third, the pixel image, stored a line at a time, in increasing y order.

The image is essentially laid out in the file the exact way that it would appear in a memory pixrect. In particular, each line of the image is rounded out to a multiple of 16 bits, corresponding to the rounding convention used by the memory pixrects.

The header is defined by the following structure:

```
struct rasterfile {
    int ras_magic;
    int ras_width;
    int ras_height;
    int ras_depth;
    int ras_length;
    int ras_type;
    int ras_maptype;
    int ras_maplength;
};
```

The `ras_magic` field always contains the following constant:

```
#define RAS_MAGIC 0x59a66a95
```

The `ras_width`, `ras_height` and `ras_depth` fields contain the image's width and height in pixels, and its depth in bits per pixel, respectively. The depth is usually either 1 or 8, corresponding to the standard frame buffer depths.

The `ras_length` field contains the length in bytes of the image data. For an unencoded image, this number is computable from the `ras_width`, `ras_height`, and `ras_depth` fields, but for an encoded image it must be explicitly stored in order to be available without decoding the image itself. Note that the length of the header and of the possibly empty colormap values are not included in the value in the `ras_length` field; it is only the image data length. For historical reasons, files of type RT_OLD will usually have a 0 in the `ras_length` field, and software expecting to encounter such files should be prepared to compute the actual image data length if it is needed. The `ras_maptype` and `ras_maplength` fields contain the type and length in bytes of the colormap values, respectively.

If the `ras_maptype` is not RMT_NONE and the `ras_maplength` is not 0, then the colormap values are the `ras_maplength` bytes immediately after the header. These values are either uninterpreted bytes (usually with the `ras_maptype` set to RMT_RAW) or the equal length red, green and blue vectors, in that order (when the `ras_maptype` is RMT_EQUAL_RGB). In the latter case, the `ras_maplength` must be three times the size in bytes of any one of the vectors.

5.3. Writing Parts of a Raster File

The following routines are available for writing the various parts of a raster file. Many of these routines are used to implement `pr_dump`. First, the raster file header and the colormap can be written by calling `pr_dump_header`.

Write Header to Raster File

```
int pr_dump_header(output, rh, colormap)
FILE *output;
struct rasterfile *rh;
colormap_t *colormap;
```

`pr_dump_header` returns PIX_ERR if there is a problem writing the header or the colormap, otherwise it returns 0. If the colormap is NULL, no colormap values are written.

Initialize Raster File Header

```
struct pixrect *pr_dump_init(input_pr, rh, colormap,
    type, copy_flag)
struct pixrect *input_pr;
struct rasterfile *rh;
colormap_t *colormap;
int type, copy_flag;
```

For clients that do not want to explicitly initialize the rasterfile struct the following routine can be used to set up the arguments for `pr_dump_header`. The arguments to `pr_dump_init` correspond to the arguments to `pr_dump`. However, `pr_dump_init` returns the pixrect to write, rather than actually writing it, and initializes the structure pointed to by `rh` rather than writing it. If colormap is NULL, the `ras_maptype` and `ras_maplength` fields of `rh` will be set to RMT_NONE and 0, respectively.

If any error is detected by `pr_dump_init`, the returned pixrect is NULL. If there is no error and the `copy_flag` is zero, the returned pixrect is simply `input_pr`. However, if `copy_flag` is non-zero, the returned pixrect is dynamically allocated and the caller is responsible for deallocating the returned pixrect after it is no longer needed.

Write Image Data to Raster File

```
int pr_dump_image(pr, output, rh)
struct pixrect *pr;
FILE *output;
struct rasterfile *rh;
```

The actual image data can be output via a call to `pr_dump_image`. This routine returns 0 unless there is an error, in which case it returns PIX_ERR.

Since these routines sequentially advance the output file's write pointer, `pr_dump_image` must be called after `pr_dump_header`.

5.4. Reading Parts of a Raster File

The following routines are available for reading the various parts of a raster file. Many of these routines are used to implement `pr_load`. Since these routines sequentially advance the input file's read pointer, rather than doing random seeks in the input file, they should be called in the order presented below.

Read Header from Raster File

```
int pr_load_header(input, rh)
FILE *input;
struct rasterfile *rh;
```

The raster file header can be read by calling `pr_load_header`. This routine reads the header from the specified input, checks it for validity and initializes the specified `rasterfile` structure from the header. The return value is 0 unless there is an error, in which case it returns PIX_ERR.

Read Colormap from Raster File

```
int pr_load_colormap(input, rh, colormap)
FILE *input;
struct rasterfile *rh;
colormap_t *colormap;
```

If the header indicates that there is a non-empty set of colormap values, they can be read by calling: `pr_load_colormap`. If the specified colormap is NULL, this routine will skip over the colormap values by reading and discarding them. Note that the caller is responsible for looking at the raster file header and setting up an appropriate colormap struct before calling this routine.

The return value is 0 unless there is an error, in which case it returns PIX_ERR.

Read Image from Raster File

```
struct pixrect *pr_load_image(input, rh, colormap)
FILE *input;
struct rasterfile *rh;
colormap_t *colormap;
```

An image can be read by calling: `pr_load_image`. If the input is a standard raster file type, this routine reads in the image directly. Otherwise, it writes the header, colormap, and image into the appropriate filter and then reads the output of the filter. In this case, both the rasterfile and the colormap structures will be modified as a side-effect of calling this routine. In either case, a pixrect is dynamically allocated to contain the image, the image is read into the pixrect, and the pixrect is returned as the result of calling the routine. If there is an error, the return value is NULL instead of a pixrect containing the image.

Read Standard Raster File

```
struct pixrect *pr_load_std_image(input, rh, colormap)
FILE *input;
struct rasterfile *rh;
colormap_t colormap;
```

If it is known that the image is from a standard raster file type, then it can be read in by calling: `pr_load_std_image`. This routine is identical to `pr_load_image`, except that it will not invoke a filter on non-standard raster file types.

A

Writing a Pixrect Driver

A

Writing a Pixrect Driver

Sun has defined a common programming interface to pixel addressable devices that enables, in particular, device independent access to all Sun frame buffers. This interface is called the `pixrect` interface. Existing Sun supported software systems access a frame buffer through the pixrect interface. Sun encourages customers with other types of frame buffers (or other types of pixel addressable devices) to provide a pixrect interface to these devices.

This chapter describes how to write a pixrect driver. It is assumed that you have already read Chapter 2; it describes the programming interface to the basic operations that must be provided in order to generate a complete pixrect implementation. It is also assumed that you have a copy of *Writing Device Drivers for the Sun Workstation*. The section in that manual on writing the kernel device driver portion of the pixrect implementation is important.

This chapter contains auxiliary material of interest only to pixrect driver implementors, not programmers accessing the pixrect interface. This document explains how to plug a new pixrect driver into the software architecture so that it may be used in a device independent manner. Also, utilities and conventions that may be of use to the pixrect driver implementor are discussed.

This chapter walks through some of the C language source code for the pixrect driver for the Sun-1 color frame buffer. There is no significance to the fact that we are using the Sun-1 color frame buffer as an example. Another pixrect driver would have been just as good.

The actual source code that is presented here is boiler-plate, i.e., almost every pixrect driver will be the same. You should be able to make your own driver just from the documentation alone. However, a complete source example for an existing pixrect driver would probably expedite the development of your own driver. The complete device specific source files for the Sun-1 color frame buffer pixrect driver is available as a source code purchase option (available without a UNIX source license).

A.1. What You'll Need

These are the tools and pieces that you'll need before assembling your pixrect driver:

- You need the correct documentation:

  [1] *SunView System Programmer's Guide*. Sun Microsystems, Inc.

[2] *SunView Programmer's Guide*. Sun Microsystems, Inc.

[3] *Writing Device Drivers for the Sun Workstation*. Sun Microsystems, Inc.

- You need to know how to drive the hardware of your pixel addressable device. At a minimum, a pixel addressable device must have the ability to read and write single pixel values. (One could imagine a device that doesn't even meet the minimum requirements being used as a pixel addressable device. We will not discuss any of the ways that such a device might fake the minimum requirements).
- You must have a UNIX kernel building environment. No extra source is required.
- You must have the current pixrect library file and its accompanying header files. No extra source is required.

A.2. Implementation Strategy

This is one possible step-by-step approach to implementing a pixrect driver:

- Write and debug pixrect creation and destruction. This involves the pixrect kernel device driver that lets you `open(2)` and `mmap(2)` he physical device from a user process. The private `cg1_make` routine must be written. The `cg1_region` and `cg1_destroy` pixrect operation must be written.
- Write and debug the basic pixel rectangular region function. The `cg1_putattributes` and `cg1_putcolormap` pixrect operations must be written in addition to the `cg1_rop` routine.
- Write and debug batchrop routines. The `cg1_batchrop` pixrect operation must be written.
- Write and debug vector drawer. The `cg1_vector` pixrect operation must be written.
- Write and debug remaining pixrect operations: `cg1_stencil`, `cg1_get`, `cg1_put`, `cg1_getattributes` and `cg1_getcolormap`.
- If the device is to run with **SunView**, build a kernel with minimal basic pixel rectangle function for use by the cursor tracking mechanism in the **SunView** kernel device driver. Also include the colormap access routines for use by the colormap segmentation mechanism in the **SunView** kernel device driver.
- Load and test **SunView** programs with new pixrect driver. Experience has shown that when you are able to run released **SunView** programs that your pixrect driver is in pretty good shape.

A.3. Files Generated

Here is the list of source files generated that implement the example pixrect driver:

- `cg1reg.h` - A header file describing the structure of the raster device. It contains macros used to address the raw device.
- `cg1var.h` - A header file describing the private data of the pixrect. It contains external references to pixrect operation of this driver.

- /sys/sundev/cgone.c - The pixrect kernel device driver code.
- cg1.c - The pixrect creation and destruction routines.
- cg1_region.c - The region creation routine.
- pr_makefun.c - Replaces an existing module and contains the vector of pixrect make operations.
- cg1_batch.c - The batchrop routine.
- cg1_colormap.c - The colormap access and attribute setting routines .
- cg1_getput.c - The single pixel access routines.
- cg1_rop.c - The basic pixel rectangle manipulation routine.
- cg1_stencil.c - The stencil routine.
- cg1_vec.c - The vector drawer.
- cg1_curve.c The curved shape routine.
- cg1_polyline.c The polyline routine.

Memory Mapped Devices

Some devices are memory mapped, e.g., the Sun-2 monochrome video frame buffer. With such devices, their pixels are manipulated directly as main memory; there are no device specific registers through which the pixels are accessed. Memory mapped devices are able to rely on the memory pixrect driver for many of its operations. The only files that the Sun 2 monochrome video frame buffer supplies are:

- bw2var.h - A header file describing the private data of the pixrect. It contains external references to pixrect operation of this driver.
- /sys/sundev/bwtwo.c - The pixrect kernel device driver code.
- bw2.c - The pixrect creation and destruction routines.

The operations vector for the Sun 2 monochrome pixrect driver is:

```
struct  pixrectops bw2_ops = {
    mem_rop, mem_stencil, mem_batchrop,
    0, bw2_destroy, mem_get, mem_put, mem_vector,
    mem_region, mem_putcolormap, mem_getcolormap,
    mem_putattributes, mem_getattributes
};
```

A.4. Pixrect Private Data

Each pixrect device must have a private data object that contains instance specific data about the state of the driver. It is not acceptible to have global data shared among all the pixrects objects. The device specific portion of the pixrect data must contain certain information:

- An offset from the upper left-hand corner of the pixel device. This offset, plus the width and height of the pixrect from the public portion, is used to determine the clipping rectangle used during pixrect operations.

- A flag for distinguishing between primary and secondary pixrects. Primary pixrects are the owners of dynamically allocated resources shared between primary and secondary pixrects.
- A file descriptor to the pixrect kernel device. Usually, the file descriptor is used while mapping pages into the user process address space so that the device may be addressed. One could imagine a pixrect driver that had some of its pixrect operations implemented inside the kernel. The file descriptor would then be the key to communicating with that portion of the package via `read`(2), `write`(2) and `ioctl`(2) system calls.

Here is other possible data maintained in the pixrect's private data:

- For many devices, a virtual address pointer is part of the private data so that the device can be accessed from user code.
- For color devices, there is a mask to enable access to specific bit planes.
- For monochrome devices, there is a video invert flag. This replaces the colormap of color devices.

A.5. Creation and Destruction

This section covers the code for pixrect object creation and destruction. Code for the Sun-1 color frame buffer pixrect driver is presented as an example.

There are three public pathways to creating a pixrect:

- `pr_open` creates a primary pixrect.
- `pr_region` creates a secondary pixrect which specifies a subregion in an existing pixrect.

There are two public pathways to destroying a pixrect:

- `pr_destroy` destroys a primary or secondary pixrect. Clients of the pixrect interface are responsible for destroying all extant secondary pixrects before destroying the primary pixrect from which they were derived.
- `pr_close` simply calls `pr_destroy`.

Creating a Primary Pixrect

In this section, the private `cg1_make` pixrect operation is described. This is the flow of control for `pr_open`:

- Higher levels of software call `pr_open`, which takes a device file name (e.g., `/dev/cgone0`).
- `pr_open` opens the device and finds out its type and size via an FBIOGTYPE `ioctl`(2) call (see `<sun/fbio.h>`).
- `pr_open` uses the type of pixel addressable device to index into the `pr_makefun` array of procedures (more on this later) and calls the referenced pixrect make function, `cg1_make`.
- `cg1_make` returns the primary pixrect (it workings are discussed below).
- `pr_open` closes its handle on the device and the pixrect is returned.

Here is a partial listing of `cg1.c` that contains code that is important to the `cg1_make` procedure. As it is for other code presented in this document, it is here so you can refer back to it as you read the subsequent explanation. Some lines are numbered for reference and normal C comments have been removed in favor of the accompanying text.

```
#include <sys/types.h>
#include <stdio.h>
#include <pixrect/pixrect.h>
#include <pixrect/pr_util.h>
#include <pixrect/cg1reg.h>
#include <pixrect/cg1var.h>

static  struct pr_devdata *cg1devdata;  /* cg1.1*/

struct  pixrectops cg1_ops = {  /* cg1.2*/
    cg1_rop, cg1_stencil, cg1_batchrop, 0, cg1_destroy, cg1_get,
    cg1_put, cg1_vector, cg1_region, cg1_putcolormap, cg1_getcolormap,
    cg1_putattributes, cg1_getattributes,
};

struct pixrect *
cg1_make(fd, size, depth)   /* cg1.3*/
    int fd;     /* cg1.4*/
    struct  pr_size size;
    int depth;
{
    struct pixrect *pr;
    register struct cg1pr *cgpr;    /* cg1.5*/
    struct  pr_devdata *dd; /* cg1.6*/

    if (depth != CG1_DEPTH || size.x != CG1_WIDTH
            || size.y != CG1_HEIGHT) {  /* cg1.7*/
        fprintf(stderr, "cg1_make sizes wrong %D %D %D\n",
            depth, size.x, size.y);
        return (0);
    }
    if (!(pr = pr_makefromfd(fd, size, depth, &cg1devdata, &dd,/* cg1.8*/
        sizeof(struct cg1fb), sizeof(struct cg1pr), 0)))
        return (0);
    pr->pr_ops = &cg1_ops;          /* cg1.9*/
    cgpr = (struct cg1pr *)pr->pr_data; /* cg1.10*/
    cgpr->cgpr_fd = dd->fd;         /* cg1.11*/
    cgpr->cgpr_va = (struct cg1fb *)dd->va;/* cg1.12*/
    cgpr->cgpr_planes = 255;        /* cg1.13*/
    cgpr->cgpr_offset.x = cgpr->cgpr_offset.y = 0;/* cg1.14*/
    cg1_setreg(cgpr->cgpr_va, CG_STATUS, CG_VIDEOENABLE);/* cg1.15*/
    return (pr);        /* cg1.16*/
}
```

Line *cg1.7* does some consistency checking to make sure that the dimensions of the pixel addressable device and the client's idea about the dimensions of the device match.

```
struct *pixrect pr_makefromfd(fd, size, depth, devdata, curd
    mmapbytes, privdatabytes, mmapoffsetbytes)
    struct  pr_size size;
    struct  pr_devdata **devdata, **curdd;
    int     fd, depth, mmapbytes, privdatabytes, mmapoffsetb
    int mmapbytes, privdatabytes, mmapoffsetbytes);
```

Line *cg1.8* calls the pixrect library routine `pr_makefromfd` to do most of the work:

- Allocates a `pixrect` structure object using the `calloc` library call. The pixrect is filled in with *size* and *depth* parameters.
- Allocates an object of the size *privdatabytes* using the `calloc` library call and placing a pointer to it in the *pr_data* field of the allocated pixrect.
- `dup`(2)s the passed in file descriptor *fd* so that when the caller closes the file descriptor the device wouldn't close.
- `valloc`(2)s the amount of space *mmapbytes*.
- `mmap`(2)s the space returned from `vallob` to the device.
- If an error is detected during any of the above calls, an error is written to the standard error output. A NULL pixrect handle is returned in this case.
- Returns the allocated pixrect.

This brings us to the issue of minimizing resources used by the pixrect driver. and`pr_open`, `cg1_make`, can be (and are) called many times thus creating a situation in which there are many primary pixrects open at a time. A pixrect should maintain an open file descriptor and (usually) a non-trivial amount of virtual address space mapped into the user process's address space. Both the number of open file descriptors, the virtual address space (max 16 megabytes) and the disk swap space needed to support the virtual memory (configurable) are finite resources. However, multiple open pixrects can share all these resources.

The pixrect library supports a resource sharing mechanism, part of which is implemented in `pr_makefromfd`. The `devdata` parameter passed to `pr_makefromfd` is the head of a linked list of `pr_devdata` structures of which there is one per pixrect driver. It is sufficient to say that through the data maintained on this list, sharing of the scarce resources described above can be accomplished.

The `curdd` parameter passed to `pr_makefromfd` is set to be the `pr_devdata` structure that applies to the device identified by `fd`.

Lines *cg1.9* through *cg1.14* are concerned with initializing the pixrect's private data with dynamic information described in `dd` (`curdd` in the previous paragraph) and static information about the pixel addressable device.

Line *cg1.15* is where the video signal for the device is enabled. By convention, every raster device should make sure that it is enabled.

Creating a Secondary Pixrect

In this section, the `cg1_region` pixrect operation is described. Here is all of `cg1_region.c`.

```
struct pixrect *cg1_region(src)
    struct pr_subregion src;
{
    register struct pixrect *pr;
    register struct cg1pr *scgpr = cg1_d(src.pr), *cgpr;
    int zero = 0;

    pr_clip(&src, &zero);   /* cg1_region.1*/
    if ((pr = (struct pixrect *)calloc(1, sizeof (struct pixrect))) == 0)/* cg1_region.2*
        return (0);
    if ((cgpr = (struct cg1pr *)calloc(1, sizeof (struct cg1pr))) == 0) {/* cg1_region.3*
        free(pr);
        return (0);
    }
    pr->pr_ops = &cg1_ops;  /* cg1_region.4*/
    pr->pr_size = src.size; /* cg1_region.5*/
    pr->pr_depth = CG1_DEPTH;    /* cg1_region.6*/
    pr->pr_data = (caddr_t)cgpr;    /* cg1_region.7*/
    cgpr->cgpr_fd = -1; /* cg1_region.8*/
    cgpr->cgpr_va = scgpr->cgpr_va; /* cg1_region.9*/
    cgpr->cgpr_planes = scgpr->cgpr_planes;/*cg1_region.10*/
    cgpr->cgpr_offset.x = scgpr->cgpr_offset.x + src.pos.x;/*cg1_region.11*/
    cgpr->cgpr_offset.y = scgpr->cgpr_offset.y + src.pos.y;/*cg1_region.12*/
    return (pr);
}
```

`cg1_region` is less complex then `cg1_make`. The first thing done is to clip the requested subregion to fall within the source pixrect (line *cg1_region.1*).

```
pr_clip(dstp, srcp)
    struct  pr_subregion *dstp;
    struct  pr_prpos *srcp;
```

`pr_clip` adjusts the position and size of `dstp`, the destination pixrect subregion, to fall within `dstp->pr`. If `*scrp`, the source pixrect position, is not zero then the position of the source is clipped to fall within `dstp`.

Next, objects are allocated for the pixrect and the pixel addressable device's private data (line *cg1_region.2* and *cg1_region.3*). Then, similarly to the later part of `cg1_make`, the two new data objects are initialized (lines *cg1_region.4* through *cg1_region.12*). One thing to note is that the cg1 driver uses a –1 in the file descriptor field of the pixrect's private data to indicate that this pixrect is secondary (line *cg1_region.8*).

Destroying a Pixrect

In this section, the `cg1_destroy` pixrect operation is described. It works on secondary and primary pixrects. Here is more of `cg1.c`.

```
cg1_destroy(pr)
    struct pixrect *pr;
{
    register struct cg1pr *cgpr;

    if (pr == 0)
        return (0);
    if (cgpr = cg1_d(pr)) { /*cg1.30*/
        if (cgpr->cgpr_fd != -1) {  /*cg1.31*/
            pr_unmakefromfd(cgpr->cgpr_fd, &cg1devdata);/*cg1.32*/
        }
        free(cgpr); /*cg1.33*/
    }
    free(pr);       /*cg1.34*/
    return (0);
}
```

Note that dynamic memory is freed (lines *cg1.33* and *cg1.34*). Also, note that only a primary pixrect (as indicated by a file descriptor that is not –1) invokes a call to `pr_unmakefromfd` (line *cg1.32*).

```
pr_unmakefromfd(fd, devdata)
    struct  pr_devdata **devdata;
    int     fd;
```

This pixrect library routine is the counterpart of `pr_makefromfd`. If the device identified by the file descriptor `fd` has no more pixrects associated with it (as determined from `devdata`) then the resources associated with it are released.

The `pr_makefun` Operations Vector

As mentioned above, `pr_open` calls `cg1_make` through the `pr_makefun` procedure vector. This is what `pr_makefun` looks like (it is the sole contents of `pr_makefun.c`):

```
#include <pixrect/pixrect_hs.h>
#include <sun/fbio.h>
#include <sys/ioctl.h>

struct  pixrect *(*(pr_makefun[FBTYPE_LASTPLUSONE]))() = {
    (struct pixrect *(*)())bw1_make,
    (struct pixrect *(*)())cg1_make,
    (struct pixrect *(*)())bw2_make,
    (struct pixrect *(*)())cg2_make,
    (struct pixrect *(*)())gp1_make,
};
```

`pr_makefun` is the routine that pulls in all the code from the different frame buffers. If a site is not going to use programs on more than one kind of display, the unused slots can be commented out to prevent the code for the unused display from being loaded. This has the advantage of reducing disk space usage. However, working set size will presumably not be affected due to virtual memory not touching unused code.

For both the case of adding and deleting drivers, loading a compiled version of this edited file will have the effect of ignoring the commented out device drivers.

When adding some new pixrect driver, you need to assign it some unused constant from `<sun/fbio.h>`, e.g., FBTYPE_NOTSUN1. This then becomes the device identifier for your new pixrect driver. You need to generate a new version of the source file `pr_makefun.c` with the above data structure except that the array entry `pr_makefun` [FBTYPE_NOTSUN1] would contain the pixrect make procedure for your FBTYPE_NOTSUN1 pixrect driver (line `pr_makefun.1`). The old `pr_makefun.o` in the pixrect library could be replaced with your new `pr_makefun.o` using `ar(1)`.

A.6. Pixrect Kernel Device Driver

A pixrect kernel device driver supports the pixel addressable device as a complete UNIX device. It also supports use of this device by the **SunView** driver so that the cursor can be tracked and the colormap loaded within the kernel. The document *Writing Device Drivers for the Sun Workstation* contains the details of device driver construction. It also contains an overview.

The code in this section comes from `cgone.c`. In the kernel, suffixes that end with a number (like `cg1`) confuse the conventions surrounding device driver names. A number suffix refers to the minor device number of a device. Therefore, in our example, `cg1` becomes `cgone` where the naming has something to do with the pixrect kernel device driver.

Configurable Device Support

Raster devices typically hang off a high speed bus (e.g., Multibus) or are plugged into a high speed communications port. At kernel building time the UNIX auto-configuration mechanism is told what devices to expect and where they should be found. At boot time the auto-configuration mechanism checks to see if each of the devices it expects are present.

This section deals with the auto-configuration aspects of the driver. This driver is written in the conventional style that supports multiple units of the same device type. It is recommended that you follow this style even if you aren't anticipating multiple pixel addressable devices of your type on a single UNIX system.

```
#include "cgone.h"
#include "win.h"
#if NCGONE > 0
#include "../h/param.h"
#include "../h/systm.h"
#include "../h/dir.h"
#include "../h/user.h"
#include "../h/proc.h"
#include "../h/buf.h"
#include "../h/conf.h"
#include "../h/file.h"
#include "../h/uio.h"
#include "../h/ioctl.h"
```

```
#include "../machine/mmu.h"
#include "../machine/pte.h"
#include "../sun/fbio.h"
#include "../sundev/mbvar.h"
#include "../pixrect/pixrect.h"
#include "../pixrect/pr_util.h"
#include "../pixrect/cg1reg.h"
#include "../pixrect/cg1var.h"

#if NWIN > 0
#define CG1_OPS &cg1_ops
struct  pixrectops cg1_ops = {
    cg1_rop,
    cg1_putcolormap,
    cg1_putattributes,
};
#else
#define CG1_OPS (struct pixrectops *)0
#endif

#define CG1SIZE (sizeof (struct cg1fb))
struct  cg1pr cgoneprdatadefault =
    { 0, 0, 255, 0, 0 };
struct  pixrect cgonepixrectdefault =
    { CG1_OPS, { CG1_WIDTH, CG1_HEIGHT }, CG1_DEPTH, /* filled in later */ 0 };


/*
 * Driver information for auto-configuration stuff.
 */
int cgoneprobe(), cgoneintr();
struct  pixrect cgonepixrect[NCGONE];
struct  cg1pr cgoneprdata[NCGONE];
struct  mb_device *cgoneinfo[NCGONE];
struct  mb_driver cgonedriver = {
    cgoneprobe, 0, 0, 0, 0, cgoneintr,
    CG1SIZE, "cgone", cgoneinfo, 0, 0, 0,
};

/*
 * Only allow opens for writing or reading and writing
 * because reading is nonsensical.
 */
cgoneopen(dev, flag)
    dev_t dev;
{
    return(fbopen(dev, flag, NCGONE, cgoneinfo));
}

/*
 * When close driver destroy pixrect.
 */
/*ARGSUSED*/
```

```
cgoneclose(dev, flag)
    dev_t dev;
{
    register int unit = minor(dev);

    if ((caddr_t)&cgoneprdata[unit] == cgonepixrect[unit].pr_data) {
        bzero((caddr_t)&cgoneprdata[unit], sizeof (struct cg1pr));
        bzero((caddr_t)&cgonepixrect[unit], sizeof (struct pixrect));
    }
}

/*ARGSUSED*/
cgoneioctl(dev, cmd, data, flag)
    dev_t dev;
    caddr_t data;
{
    register int unit = minor(dev);

    switch (cmd) {

    case FBIOGTYPE: {
        register struct fbtype *fb = (struct fbtype *)data;

        fb->fb_type = FBTYPE_SUN1COLOR;
        fb->fb_height = 480;
        fb->fb_width = 640;
        fb->fb_depth = 8;
        fb->fb_cmsize = 256;
        fb->fb_size = 512*640;
        break;
        }
    case FBIOGPIXRECT: {
        register struct fbpixrect *fbpr = (struct fbpixrect *)data;
        register struct cg1fb *cg1fb =
            (struct cg1fb *)cgoneinfo[(unit)]->md_addr;

        /*
         * "Allocate" and initialize pixrect data with default.
         */
        fbpr->fbpr_pixrect = &cgonepixrect[unit];
        cgonepixrect[unit] = cgonepixrectdefault;
        fbpr->fbpr_pixrect->pr_data = (caddr_t) &cgoneprdata[unit];
        cgoneprdata[unit] = cgoneprdatadefault;
        /*
         * Fixup pixrect data.
         */
        cgoneprdata[unit].cgpr_va = cg1fb;
        /*
         * Enable video
         */
        cg1_setreg(cg1fb, CG_FUNCREG, CG_VIDEOENABLE);
        /*
         * Clear interrupt
```

```
         */
        cg1_intclear(cg1fb);
        break;
        }

    default:
        return (ENOTTY);
    }
    return (0);
}

/*
 * We need to handle vertical retrace interrupts here.
 * The color map(s) can only be loaded during vertical
 * retrace; we should put in ioctls for this to synchronize
 * with the interrupts.
 * FOR NOW, see comments in the code.
 */
cgoneintclear(cg1fb)
    struct  cg1fb *cg1fb;
{
    /*
     * The Sun-1 color frame buffer doesn't indicate that an
     * interrupt is pending on itself so we don't know if the interrupt
     * is for our device.  So, just turn off interrupts on the cgone board.
     * This routine can be called from any level.
     */
    cg1_intclear(cg1fb);
    /*
     * We return 0 so that if the interrupt is for some other device
     * then that device will have a chance at it.
     */
    return(0);
}

int
cgoneintr()
{
    return(fbintr(NCGONE, cgoneinfo, cgoneintclear));
}

/*ARGSUSED*/
cgonemmap(dev, off, prot)
    dev_t dev;
    off_t off;
    int prot;
{
    return(fbmmap(dev, off, prot, NCGONE, cgoneinfo, CG1SIZE));
}

#include "../sundev/cgreg.h"
    /*
     * Note: using old cgreg.h to peek and poke for now.
```

```
     */
/*
 * We determine that the thing we're addressing is a color
 * board by setting it up to invert the bits we write and then writing
 * and reading back DATA1, making sure to deal with FIFOs going and coming.
 */
#define DATA1 0x5C
#define DATA2 0x33
/*ARGSUSED*/
cgoneprobe(reg, unit)
    caddr_t reg;
    int unit;
{
    register caddr_t CGXBase;
    register u_char *xaddr, *yaddr;

    CGXBase = reg;
    if (pokec((caddr_t)GR_freg, GR_copy_invert))
        return (0);
    if (pokec((caddr_t)GR_mask, 0))
        return (0);
    xaddr = (u_char *)(CGXBase + GR_x_select + GR_update + GR_set0);
    yaddr = (u_char *)(CGXBase + GR_y_select + GR_set0);
    if (pokec((caddr_t)yaddr, 0))
        return (0);
    if (pokec((caddr_t)xaddr, DATA1))
        return (0);
    (void) peekc((caddr_t)xaddr);
    (void) pokec((caddr_t)xaddr, DATA2);
    if (peekc((caddr_t)xaddr) == (~DATA1 & 0xFF)) {
        /*
         * The Sun-1 color frame buffer doesn't indicate that an
         * interrupt is pending on itself.
         * Also, the interrupt level is user program changable.
         * Thus, the kernel never knows what level to expect an
         * interrupt on this device and doesn't know is an interrupt
         * is pending.
         * So, we add the cgoneintr routine to a list of interrupt
         * handlers that are called if no one handles an interrupt.
         * Add_default_intr screens out multiple calls with the same
         * interrupt procedure.
         */
        add_default_intr(cgoneintr);
        return (CG1SIZE);
    }
    return (0);
}

#endif
```

This is how the driver is plugged into the auto-configuration mechanism. `/etc/config` reads a line in the configuration file for a Sun-1 color frame buffer:

```
device          cgone0 at mb0 csr 0xec000 priority 3
```

An external reference to `cgonedriver` (line *cgone.4*) is made in a table maintained by the auto-configuration mechanism. At boot time, if the auto-configuration mechanism can resolve the reference to `cgonedriver` then the contents of this structure are used to configure in the device:

- `cgoneprobe` - The name of the probe procedure (line *cgone.5*).
- `cgoneintr` - The name of the interrupt procedure (line *cgone.6*).
- CG1SIZE - The size in bytes of the address space of the device.
- `cgone` - The prefix of the device. Used in status and error messages.
- `cgoneinfo` - The array of devices pointers of the driver's type (line *cgone.2*).
- The other field's defaults suffice for most pixel addressable devices.

`cgoneprobe` is called to let the driver decide if the virtual address at `reg` is indeed a device that this driver recognizes as one of its own. The `unit` argument is the minor device number of this device. Writing a good probe routine can be difficult. The trick is to use some idiosyncrasy of the device that differentiates it from others. The real driver for the Sun-1 color frame buffer determines that it is addressing a Sun-1 color frame buffer by setting it up to invert the data written to it and reading back the result. The details of this code are not important to this discussion and is not included. Zero is returned if the probe fails and CG1SIZE is returned if the probe succeeds.

`cgoneintr` is called when an interrupt is generated at the beginning of the vertical retrace. There are a variety of things that one might want to syncronize with such an interrupt, e.g., load the colormap or move the cursor. Currently, the utility `fbintr` simply disables the interrupt from happening again (line *cgone.6*).

```
int fbintr(numdevs, mb_devs, intclear)
    int     numdevs;
    struct  mb_device **mb_devs;
    int     (*intclear)();
```

`numdevs` is the maximum number of devices of these type configured. `mb_devs` is the array of devices descriptions. `intclear` is called back to actually turn off the interrupt for a particular device. `intclear` must have the same calling sequence as `cgoneintclear` (line *cgone.7*), i.e., it take the virtual address of the device to disable interrupts. `cg1_intclear` (line *cgone.8*) is a macro that actually disables the interrupts of `cg1fb`.

Open

When an open system call is made at the user level cgoneopen is called.

```
cgoneopen(dev, flag)
    dev_t dev;
{
    return(fbopen(dev, flag, NCGONE, cgoneinfo));
}
```

cgoneopen uses the utility fbopen.

```
int fbopen(dev, flag, numdevs, mb_devs)
    dev_t   dev;
    int     flag, numdevs;
    struct  mb_device **mb_devs;
```

fbopen checks to see if dev is available for opening. If not the error ENXIO is returned. If flag doesn't ask for write position (FWRITE) then the error EINVAL is returned. Normally, zero is returned on a successful open.

Mmap

The memory map routine in a device driver is responsible for returning a single physical page number of a portion of a device.

```
/*ARGSUSED*/
cgonemmap(dev, off, prot)
    dev_t dev;
    off_t off;
    int prot;
{
    return(fbmmap(dev, off, prot, NCGONE, cgoneinfo, CG1SIZE));
}
```

cgonemmap used the utility fbmmap.

```
int fbmmap(dev, off, prot, numdevs, mb_devs, size)
    dev_t   dev;
    off_t   off;
    int     prot, numdevs, size;
    struct  mb_device **mb_devs;
```

The parameters to fbmmap are similar to fbopen. However, off is the offset in bytes from the beginning of the device. prot is passed through but currently not used.

ioctl

A pixrect kernel device driver *must* respond to two input/output control requests:

- FBIOGTYPE — Describe the characteristics of the pixel addressable device.
- FBIOGPIXRECT — Hand out a pixrect that may be used in the kernel. This ioctl call is made from within the kernel. This is only required of frame buffers.

```
#if NWIN > 0            /* cgone.9*/
#define  CG1_OPS  &cg1_ops
struct  pixrectops cg1_ops = {
    cg1_rop,        /*cgone.10*/
    cg1_putcolormap,
```

```
};
#else
#define  CG1_OPS  (struct pixrectops *)0
#endif

struct  cg1pr cgoneprdatadefault =
    { 0, 0, 255, 0, 0 };
struct  pixrect cgonepixrectdefault =
    { CG1_OPS, { CG1_WIDTH, CG1_HEIGHT }, CG1_DEPTH, /* filled in later */ 0 };

struct  pixrect cgonepixrect[NCGONE];    /*cgone.11*/
struct  cg1pr cgoneprdata[NCGONE];

cgoneioctl(dev, cmd, data, flag)
    dev_t dev;
    caddr_t data;
{
    register int unit = minor(dev);

    switch (cmd) {
    case FBIOGTYPE: {
        register struct fbtype *fb = (struct fbtype *)data;
        fb->fb_type = FBTYPE_SUN1COLOR;
        fb->fb_height = CG1_HEIGHT;
        fb->fb_width = CG1_WIDTH;
        fb->fb_depth = 8;
        fb->fb_cmsize = 256;
        fb->fb_size = CG1_HEIGHT*CG1_WIDTH;
        break;
        }
    case FBIOGPIXRECT: {
        register struct fbpixrect *fbpr = (struct fbpixrect *)data;
        register struct cg1fb *cg1fb =
            (struct cg1fb *)cgoneinfo[(unit)]->md_addr;
        fbpr->fbpr_pixrect = &cgonepixrect[unit];/*cgone.12*/
        cgonepixrect[unit] = cgonepixrectdefault;/*cgone.13*/
        fbpr->fbpr_pixrect->pr_data = (caddr_t) &cgoneprdata[unit];/*cgone.14*/
        cgoneprdata[unit] = cgoneprdatadefault;/*cgone.15*/
        cgoneprdata[unit].cgpr_va = cg1fb;/*cgone.16*/

        cg1_setreg(cg1fb, CG_FUNCREG, CG_VIDEOENABLE);/*cgone.17*/
        cg1_intclear(cg1fb);    /*cgone.18*/
        break;
        }

    default:
        return (ENOTTY);
    }
    return (0);
}
```

The **SunView** driver isn't configured into the system when NWIN = 0 (line *cgone.9*). When there is no **SunView** driver, don't reference the pixrect operations `cg1_rop` and `cg1_putcolormap`. The kernel version of `cg1_rop` (line *cgone.10*) only needs to be able to read and write memory pixrects for cursor management. Thus, you can

```
#ifndef KERNEL
/* code not associated with reading and writing memory pixrects
#endif KERNEL
```

to reduce the size of the code.

Memory for pixrect public (`pixrect` structure) and private (`cg1pr` structure) objects is provided by arrays of each (line *cgone.11*) NCGONE long. A device `n` in these correspond to device `n` in `cgoneinfo`.

Lines *cgone.12* through *cgone.16* initialize a pixrect for a particular device. This `ioctl` call should enable video for a frame buffer (line *cgone.17*) and disable interrupts as well (line *cgone.18*).

Close

When the device is no longer being referenced, `cgoneclose` is called. All that is done is that the pixrect data structures of the device are zeroed.

```
cgoneclose(dev, flag)
    dev_t dev;
{
    register int unit = minor(dev);

    if ((caddr_t)&cgoneprdata[unit] == cgonepixrect[unit].pr_data) {
        bzero((caddr_t)&cgoneprdata[unit], sizeof (struct cg1pr));
        bzero((caddr_t)&cgonepixrect[unit], sizeof (struct pixrect));
    }
}

#endif
```

Plugging Your Driver into UNIX

You need to add the device driver procedures to `cdevsw` in `/sys/sun/conf.c` after assigning a new major device number to your driver:

```
#include "cgone.h"
#if NCGONE > 0
int cgoneopen(), cgonemmap(), cgoneioctl();
int cgoneclose();
#else
#define cgoneopen  nodev
#define cgonemmap  nodev
#define cgoneioctl  nodev
#define cgoneclose  nodev
#endif

    {
    cgoneopen,  cgoneclose,  nodev,  nodev,  /*14*/
    cgoneioctl,  nodev,  nodev,  0,
    seltrue,  cgonemmap,
    },
```

Also, you need to add the new files associated with your driver to `/sys/conf/files.sun`:

```
pixrect/cg1_colormap.c optional cgone win device-driver
pixrect/cg1_rop.c optional cgone win device-driver
sundev/cgone.c optional cgone device-driver
```

A.7. Access Utilities

This section describes utilities used by pixrect drivers. The pixrect header files `memvar.h`, `pixrect.h` and `pr_util.h` contain useful macros that you should familiarize yourself with; they are not documented here.

`pr_clip` modifies `src->pos`, `dst->pos` and `dst->size` so that all references are to valid bits.

```
pr_clip(dstp, srcp)
    struct  pr_subregion *dst;
    struct  pr_prpos *src;
```

`src->pr` may be NULL.

Two operations on operations, `reversesrc` and `reversedst`, are provided for adjusting the operation code to take into account video reversing of monochrome pixrects of either the source or the destination.

```
char    pr_reversedst[16];
char    pr_reversesrc[16];
```

These are implemented by table lookup in which the index into the tables is `(op>>1)&0xF` where op is the operation passed into pixrect public procedures. This process can be iterated, e.g., `pr_reversedst[pr_reversesrc[op]]`.

A.8. Rop

These are the major cases to be considered with the `pwo_rop` operation:

- Case 1 -- we are the source for the pixel rectangle operation, but not the destination. This is a pixel rectangle operation from the frame buffer to another kind of pixrect. If the destination is not memory, then we will go indirect by allocating a memory temporary, and then asking the destination to operate from there into itself.
- Case 2 -- writing to your frame buffer. This consists of 4 different cases depending on where the data is coming from: from nothing, from memory, from some other pixrect, and from the frame buffer itself. When the source is some other pixrect, other than memory, ask the other pixrect to read itself into temporary memory to make the problem easier.

A.9. Batchrop

A simple batchrop implementation could iterate on the batch items and call rop for each. Even in a more sophisticated implementation, while iterating on the batch items, you might also choose to bail out by calling rop when the source is skewed, or if clipping causes you to chop off in left-x direction.

A.10. Vector

There are some notable special cases that you should consider when drawing vectors:

- Handle length 1 or 2 vectors by just drawing endpoints.
- If vector is horizontal, use fast algorithm.
- If vector is vertical, use fast algorithm.

Importance of Proper Clipping

The hard part in vector drawing is clipping, which is done against the rectangle of the destination quickly and with proper interpolation so that the jaggies in the vectors are independent of clipping.

A.11. Colormap

Each color raster device has its own way of setting and getting the colormap.

Monochrome

For monochrome raster devices, when `pr_putcolormap` is called, the convention is that if `red[0]` is zero then the display is light on dark, otherwise dark on light. For monochrome raster devices, when `pr_getcolormap` is called, the convention is that if the display is light on dark then zero is stored in `red[0]`, `green[0]` and `blue[0]` and -1 is stored in other positions in the color map. Otherwise, if the display is dark on light, then zero and -1 are reversed.

A.12. Attributes

`pr_getattributes` and `pr_putattributes` operations get/set a bitplane mask in color pixrects.

Monochrome

Monochrome devices ignore `pr_putattribute` calls that are setting the bitplane mask. Monochrome devices always return 1 when `pr_getattribute` asking for the bitplane mask.

A.13. Pixel

`pwo_get` and `pwo_put` operations get/set a single pixel.

A.14. Stencil

In its most efficient implementation, stencil code parallels rop code, all the while considering the 2 dimensional stencil. One way to implement stencil is to use rops. We pay a small efficiency penalty for this. You may not consider writing the special purpose code worthwhile for the bitmap stencils since they probably won't get used nearly as much as rop. Here's the basic idea (`Temp` is a temporary memory pixrect):

```
Temp = Dest
Temp = Dest op Source
Temp = Temp & Stencil
Dest = Dest & ~Stencil
Dest = Dest | Temp

i.e., Dest = (Dest & ~Stencil) | ((Dest op Source) & Stencil)
```

A.15. Curve

`pr_curve` allows for generalized shape drawing.

A.16. Polygon

`pr_polyline` is a natural extension to `pr_vector`. It is especially useful for devices that can optimize this operation.

B

Pixrect Functions and Macros

B

Pixrect Functions and Macros

Table B-1 *Pixrect Library Functions and Macros – Part I*

Name	*Function*

Compute Bounding Box of Text String	`pf_textbound(bound, len, font, text)`
	`struct pr_subregion *bound;`
	`int len;`
	`struct pixfont *font;`
	`char *text;`

Compute Location of Characters in Text String	`struct pr_size pf_textbatch(where, lengthp, font, text)`
	`struct pr_pos where[];`
	`int *lengthp;`
	`struct pixfont *font;`
	`char *text;`

Compute Width and Height of Text String	`struct pr_size pf_textwidth(len, font, text)`
	`int len;`
	`struct pixfont *font;`
	`char *text;`

Create Memory Pixrect from an Image	`struct pixrect *mem_point(width, height, depth, data)`
	`int width, height, depth;`
	`short *data;`

Create Memory Pixrect	`struct pixrect *mem_create(w, h, depth)` `int w, h, depth;`
Create Pixrect	`struct pixrect *pr_open(devicename)` `char *devicename;`

Create Secondary Pixrect	`#define struct pixrect *pr_region(pr, x, y, w, h)`
	`struct pixrect *pr;`
	`int x, y, w, h;`

Create Static Memory Pixrect	`#define mpr_static(name, w, h, depth, image)`
	`int w, h, depth;`
	`short *image;`

Table B-1 *Pixrect Library Functions and Macros – Part I— Continued*

Name	Function

Draw Textured Polygon	`pr_polygon_2(dpr, dx, dy, nbnds, npts, vlist, op,`
	`    spr, sx, sy)`
	`struct pixrect *dpr, *spr;`
	`int dx, dy`
	`int nbnds, npts[];`
	`struct pr_pos *vlist;`
	`int op, sx, sy;`

Draw Vector	`#define pr_vector(pr, x0, y0, x1, y1, op, value)`
	`struct pixrect *pr;`
	`int x0, y0, x1, y1, op, value;`

Exchange Foreground and Background Colors	`pr_reversevideo(pr, min, max)`
	`struct pixrect *pr;`
	`int min, max;`

Get Colormap Entries	`#define pr_getcolormap(pr, index, count, red, green,`
	`    blue)`
	`struct pixrect *pr;`
	`int index, count;`
	`unsigned char red[], green[], blue[];`

Get Memory Pixrect Data Bytes per Line	`#define mpr_linebytes(width, depth)` `( ((pr_product(width, depth)+15)>>3) &~1)`

Get Pixel Value	`#define pr_get(pr, x, y)`
	`struct pixrect *pr;`
	`int x, y;`

Get Plane Mask	`#define pr_getattributes(pr, planes)`
	`struct pixrect *pr;`
	`int *planes;`

Get Pointer to Memory Pixrect Data	`#define mpr_d(pr)` `((struct mpr_data *)(pr)->pr_data)`

Initialize Raster File Header	`struct pixrect *pr_dump_init(input_pr, rh, colormap,`
	`    type, copy_flag)`
	`struct pixrect *input_pr;`
	`struct rasterfile *rh;`
	`colormap_t *colormap;`
	`int type, copy_flag;`

Load Font	`struct pixfont *pf_open(name)` `char *name;`
Load Private Copy of Font	`struct pixfont *pf_open_private(name)` `char *name;`
Load System Default Font	`struct pixfont *pf_default()`

Table B-1 *Pixrect Library Functions and Macros – Part I— Continued*

Name	Function

Masked RasterOp	`#define pr_stencil(dpr, dx, dy, dw, dh, op, stpr, stx, sty, spr, sx, sy)`
	`struct pixrect *dpr, *stpr, *spr;`
	`int dx, dy, dw, dh, op, stx, sty, sx, sy;`

Multiple RasterOp	`#define pr_batchrop(dpr, dx, dy, op, items, n)`
	`struct pixrect *dpr;`
	`int dx, dy, op, n;`
	`struct pr_prpos items[];`

RasterOp	`#define pr_rop(dpr, dx, dy, dw, dh, op, spr, sx, sy)`
	`struct pixrect *dpr, *spr;`
	`int dx, dy, dw, dh, op, sx, sy;`

Read Colormap from Raster File	`int pr_load_colormap(input, rh, colormap)`
	`FILE *input;`
	`struct rasterfile *rh;`
	`colormap_t *colormap;`

Read Header from Raster File	`int pr_load_header(input, rh)`
	`FILE *input;`
	`struct rasterfile *rh;`

Read Image from Raster File	`struct pixrect *pr_load_image(input, rh, colormap)`
	`FILE *input;`
	`struct rasterfile *rh;`
	`colormap_t *colormap;`

Read Raster File	`struct pixrect *pr_load(input, colormap)`
	`FILE *input;`
	`colormap_t *colormap;`

Table B-2 *Pixrect Library Functions and Macros – Part II*

Name	Function

Read Standard Raster File	`struct pixrect *pr_load_std_image(input, rh, colormap)`
	`FILE *input;`
	`struct rasterfile *rh;`
	`colormap_t colormap;`

Release Pixfont Resources	`pf_close(pf)` `struct pixfont *pf;`
Release Pixrect Resources	`#define pr_close(pr)` `struct pixrect *pr;`
Release Pixrect Resources	`#define pr_destroy(pr)` `struct pixrect *pr;`

Table B-2 *Pixrect Library Functions and Macros – Part II— Continued*

Name	*Function*

Replicated Source RasterOp	`pr_replrop(dpr, dx, dy, dw, dh, op, spr, sx, sy)`
	`struct pixrect *dpr, *spr;`
	`int dx, dy, dw, dh, op, sx, sy;`

Set Background and Foreground Colors	`pr_blackonwhite(pr, min, max)`
	`struct pixrect *pr;`
	`int min, max;`

Set Colormap Entries	`#define pr_putcolormap(pr, index, count, red, green, blue)`
	`struct pixrect *pr;`
	`int index, count;`
	`unsigned char red[], green[], blue[];`

Set Foreground and Background Colors	`pr_whiteonblack(pr, min, max)`
	`struct pixrect *pr;`
	`int min, max;`

Set Pixel Value	`#define pr_put(pr, x, y, value)`
	`struct pixrect *pr;`
	`int x, y, value;`

Set Plane Mask	`#define pr_putattributes(pr, planes)`
	`struct pixrect *pr;`
	`int *planes;`

Subregion Create Secondary Pixrect	`#define struct pixrect *prs_region(subreg)` `struct pr_subregion subreg;`

Subregion Draw Vector	`#define prs_vector(pr, pos0, pos1, op, value)`
	`struct pixrect *pr;`
	`struct pr_pos pos0, pos1;`
	`int op, value;`

Subregion Get Colormap Entries	`#define prs_getcolormap(pr, index, count, red, green, blue)`
	`struct pixrect *pr;`
	`int index, count;`
	`unsigned char red[], green[], blue[];`

Subregion Get Pixel Value	`#define prs_get(srcprpos)` `struct pr_prpos srcprpos;`

Subregion Get Plane Mask	`#define prs_getattributes(pr, planes)`
	`struct pixrect *pr;`
	`int *planes;`

Subregion Masked RasterOp	`#define prs_stencil(dstregion, op, stenprpos, srcprpos)`
	`struct pr_subregion dstregion;`
	`int op;`
	`struct pr_prpos stenprpos, srcprpos;`

Table B-2 *Pixrect Library Functions and Macros – Part II— Continued*

Name	*Function*

Subregion Multiple RasterOp	`#define prs_batchrop(dstpos, op, items, n)`
	`struct pr_prpos dstpos;`
	`int op, n;`
	`struct pr_prpos items[];`

Subregion RasterOp	`#define prs_rop(dstregion, op, srcprpos)`
	`struct pr_subregion dstregion;`
	`int op;`
	`struct pr_prpos srcprpos;`

Subregion Release Pixrect Resources	`#define prs_destroy(pr)` `struct pixrect *pr;`

Subregion Replicated Source RasterOp	`#define prs_replrop(dsubreg, op, sprpos)`
	`struct pr_subregion dsubreg;`
	`struct pr_prpos sprpos;`

Subregion Set Colormap Entries	`#define prs_putcolormap(pr, index, count, red, green, blue)`
	`struct pixrect *pr;`
	`int index, count;`
	`unsigned char red[], green[], blue[];`

Subregion Set Pixel Value	`#define prs_put(dstprpos, value)`
	`struct pr_prpos dstprpos;`
	`int value;`

Subregion Set Plane Mask	`#define prs_putattributes(pr, planes)`
	`struct pixrect *pr;`
	`int *planes;`

Trapezon RasterOp	`pr_traprop(dpr, dx, dy, t, op, spr, sx, sy)`
	`struct pixrect *dpr, *spr;`
	`struct pr_trap t;`
	`int dx, dy, sx, sy op;`

Write Header to Raster File	`int pr_dump_header(output, rh, colormap)`
	`FILE *output;`
	`struct rasterfile *rh;`
	`colormap_t *colormap;`

Write Image Data to Raster File	`int pr_dump_image(pr, output, rh)`
	`struct pixrect *pr;`
	`FILE *output;`
	`struct rasterfile *rh;`

Write Raster File	`int pr_dump(input_pr, output, colormap, type, copy_flag)`
	`struct pixrect *input_pr;`
	`FILE *output;`
	`colormap_t *colormap;`
	`int type, copy_flag;`

Table B-2 *Pixrect Library Functions and Macros – Part II— Continued*

Name	*Function*

Write Text and Background	`pf_text(where, op, font, text)`
	`struct pr_prpos where;`
	`int op;`
	`struct pixfont *font;`
	`char *text;`

Write Text	`pf_ttext(where, op, font, text)`
	`struct pr_prpos where;`
	`int op;`
	`struct pixfont *font;`
	`char *text;`

C

Pixrect Data Structures

C

Pixrect Data Structures

Table C-1 *Pixrect Data Structures*

Name	Function

Character Descriptor	`struct pixchar {`
	`    struct pixrect *pc_pr;`
	`    struct pr_pos pc_home;`
	`    struct pr_pos pc_adv;`
	`};`

Font Descriptor	`struct pixfont {`
	`    struct pr_size pf_defaultsize;`
	`    struct pixchar pf_char[256];`
	`};`

Pixrect	`struct pixrect {`
	`    struct pixrectops *pr_ops;`
	`    struct pr_size pr_size;`
	`    int pr_depth;`
	`    caddr_t pr_data;`
	`};`

Pixrect Operations	`struct pixrectops {`
	`    int (*pro_rop)();`
	`    int (*pro_stencil)();`
	`    int (*pro_batchrop)();`
	`    int (*pro_nop)();`
	`    int (*pro_destroy)();`
	`    int (*pro_get)();`
	`    int (*pro_put)();`
	`    int (*pro_vector)();`
	`    struct pixrect *(*pro_region)();`
	`    int (*pro_putcolormap)();`
	`    int (*pro_getcolormap)();`
	`    int (*pro_putattributes)();`
	`    int (*pro_getattributes)();`
	`};`

Table C-1 *Pixrect Data Structures— Continued*

<table>
<tr><th>Name</th><th>Function</th></tr>
<tr><td>Position</td><td><pre>struct pr_pos {
    int x, y;
};</pre></td></tr>
<tr><td>Position Within a Pixrect</td><td><pre>struct pr_prpos {
    struct pixrect *pr;
    struct pr_pos pos;
};</pre></td></tr>
<tr><td>Size</td><td><pre>struct pr_size {
    int x, y;
};</pre></td></tr>
<tr><td>Subregion</td><td><pre>struct pr_subregion {
    struct pixrect *pr;
    struct pr_pos pos;
    struct pr_size size;
};</pre></td></tr>
<tr><td>Trapezon</td><td><pre>struct pr_trap {
    struct pr_fall *left, *right;
    int y0, y1;
};</pre></td></tr>
<tr><td>Trapezon Chain</td><td><pre>struct pr_chain {
    struct pr_chain *next;
    struct pr_size size;
    int *bits;
};</pre></td></tr>
<tr><td>Trapezon Fall</td><td><pre>struct pr_fall {
    struct pr_pos pos;
    struct pr_chain *chain;
};</pre></td></tr>
</table>

D

Curved Shapes

D

Curved Shapes

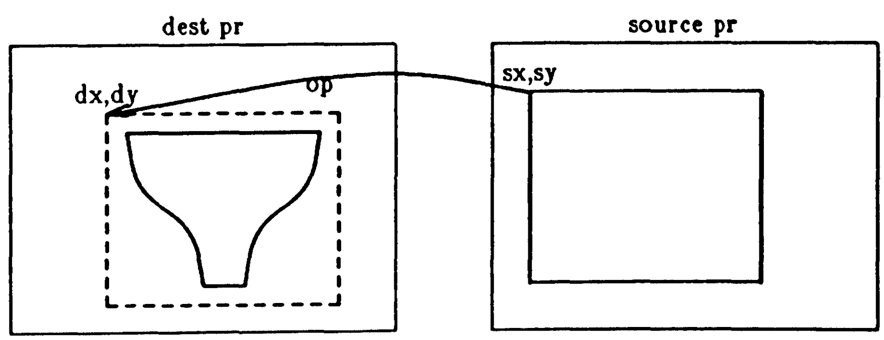
This appendix[1] describes `pr_traprop`, a function for rendering curved shapes with **Pixrect**. `pr_traprop` is an advanced pixrect operation analogous to `pr_rop`.

The curve to be rendered must first be stored in a data structure called `pr_trap` which is based on a region called a *trapezon*, rather than on a rectangle. A trapezon is a region with an irregular boundary. Like a rectangle, a trapezon has four sides: top, bottom, left, and right. The top and bottom sides of a trapezon are straight and horizontal. A trapezon differs from a rectangle in that its left and right sides are irregular curves, called *falls*, rather than straight lines.

A fall is a line of irregular shape. Vertically, a fall may only move downward. Horizontally, a fall may move to the left or to the right, and this horizontal motion may reverse itself. A fall may also sustain pure horizontal motion, that is, horizontal motion with no vertical motion.

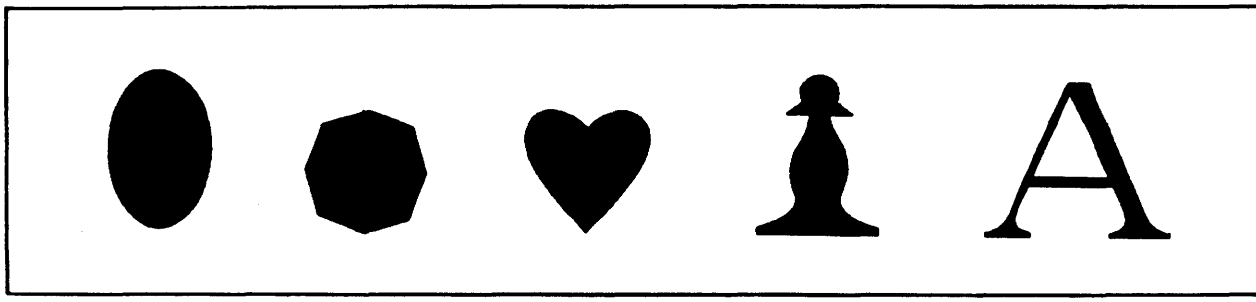
The figures below show a typical trapezon with source and destination pixrects, and some examples of filled regions that were drawn by `pr_traprop`.

Figure D-1 *Typical Trapezon*



[1] The functionality of curve support in **Pixrect** may change in the future.

Figure D-2 *Some Figures Drawn by* pr_traprop



```
pr_traprop(dpr, dx, dy, t, op, spr, sx, sy)
struct pixrect *dpr, *spr;
struct pr_trap t;
int dx, dy, sx, sy op;
```

dpr and spr are pointers to the destination and source pixrects, respectively. t is the trapezon to be used. dx and dy specify an offset into the destination pixrect. sx and sy specify an offset into the source pixrect. op is an op-code as specified previously (see Section 2.6).

```
struct pr_trap {
    struct pr_fall *left, *right;
    int y0, y1;
};

struct pr_fall {
    struct pr_pos pos;
    struct pr_chain *chain;
};

struct pr_chain {
    struct pr_chain *next;
    struct pr_size size;
    int *bits;
};
```

pr_traprop performs a rasterop from the source to the destination, clipped to the trapezon's boundaries. A program must call pr_traprop once per trapezon; therefore this procedure must be called at least twice to draw the letter 'A' in Figure D-2.

The source pixrect is aligned with the destination pixrect; the pixel at (sx, sy) in the source pixrect goes to the pixel at (dx, dy) in the destination pixrect (see Figure D-2).

Positions within the trapezon are relative to position (dx, dy) in the destination pixrect. Thus, a position defined as (0,0) in the trapezon would actually be at (dx, dy) in the destination pixrect.

The structure `pr_trap` defines the boundaries of a trapezon. A trapezon consists of pointers to two falls (`left` and `right`) and two *y* coordinates specifying the top and bottom of the trapezon (`y0` and `y1`). Note that the trapezon's top and bottom may be of zero width; `y0` and `y1` may simply serve as points of reference.

Each fall consists of a starting position (`pos`) and a pointer to the head of the list of chains describing the path the fall is to take (`chain`). A fall may start anywhere above the trapezon and end anywhere below it. `pr_traprop` ignores the portions of a fall that lie above and below the trapezon. If a fall is shorter than the trapezon, `pr_traprop` will clip the trapezon horizontally to the endpoint of the fall in question. Figure D-3 illustrates the way this works.

A `chain` is a member of a linked list of structures that describes the movement of the fall. Each chain describes a single segment of the fall. Each chain consists of a pointer to the next member of the chain (`next`), the size of the bounding box for the chain (`size`), and a pointer to a bit vector containing motion commands (`bits`). See Section 1.3 for a description of the `pr_size` structure.

Each chain may specify motion to the right and/or down, or motion to the left and/or down; however, a single chain may not specify both rightward and leftward motion. Remember that motion may not proceed upward, and that straight horizontal motion is permitted.

The *x* value of the chain's `size` determines the direction of the motion: a positive *x* value indicates rightward motion, while a negative *x* value indicates leftward motion. The *y* value of the chain's `size` must always be positive, since a fall may not move upward (in the direction of negative y).

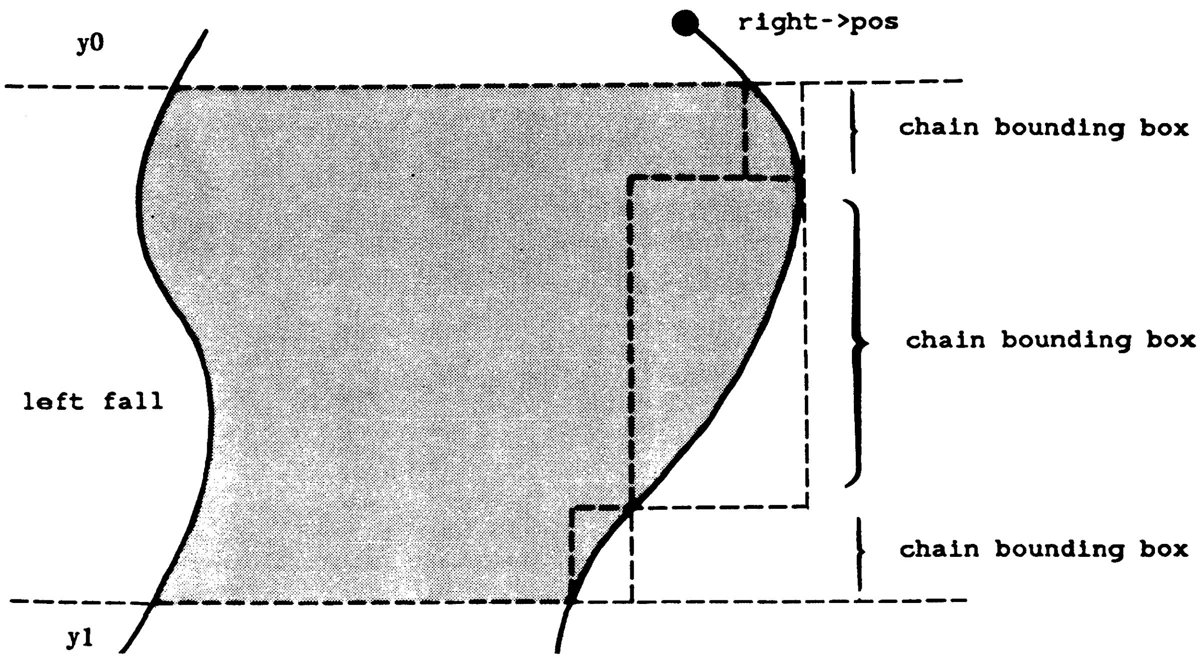
A chain's bit vector is a command string that tells `pr_traprop` how to draw each segment of the fall. Each set (1) bit in the vector is a command to move one pixel horizontally and each clear (0) bit is a command to move one pixel vertically. The bits within the bit vector are stored in byte order, from most significant bit to least significant bit. This ordering corresponds to the left-to-right ordering of pixels within a memory pixrect.

The fall begins at the starting position specified in `pr_fall`. The motion proceeds downward as specified in the first bit vector in the chain, from the high-order bit to the low-order bit. When the fall reaches the bottom of the bounding box, it continues at the top of the next chain's bounding box. Note that the fall will always begin and end at diagonally opposite corners of a given bounding box.

If a bit vector specifies a segment of the fall that would run outside of the bounding box, `pr_traprop` clips that segment of the fall to the bounding box. This would occur when the sum of the 1's in a chain's bit vector exceeds the chain's *x* size, or when the sum of the 0's in the chain's bit vector exceeds the chain's *y* size. When this happens, the segment in question runs along the edge of the bounding box until it reaches the corner of the bounding box diagonally opposite to the corner in which it started.

If the fall has a straight vertical segment, the *x* size of its chain must be 0. If the fall has a straight horizontal segment, the *y* size of its chain must be 0.

Figure D-3 *Trapezon with Clipped Falls*



The following program draws the octagon in the middle of the display surface.

Figure D-4 *Example Program with* `pr_traprop`

```
#include <pixrect/pixrect_hs.h>

int shallowsteep[] = {0xbbbbbbbb, 0xbbbbbbbb,
                      0x44444444, 0x44444444};
int steepshallow[] = {0x44444444, 0x44444444,
                      0xbbbbbbbb, 0xbbbbbbbb};

struct pr_chain left1 = {0, {64, 64}, steepshallow},
        left0 = {&left1, {-64, 64}, shallowsteep},
        right1 = {0, {-64, 64}, steepshallow},
        right0 = {&right1, {64, 64}, shallowsteep};

struct pr_fall left_oct = {{0, 0}, &left0},
        right_oct = {{0, 0}, &right0};

struct pr_trap octagon = {&left_oct, &right_oct, 0, 128};

main()
{
    struct pixrect *screen;

    screen = pr_open("/dev/fb");
    pr_traprop(screen, 576, 450, octagon, PIX_SET, 0, 0, 0);
    pr_close(screen);
}
```

`pr_chain` specifies the left lower, the left upper, the right lower, and the right upper sides of the octagon, in that order. `pr_fall` specifies first the left side, then the right side of the octagon.

Each of the eight sides of the octagon is half a chain. The two upper left sides correspond to chain `left0`. The bits start out with mostly 1's (0xb is binary 1011) for the shallow uppermost left edge. They turn to mostly 0's (0x4 is binary 0100) for the next edge down, which is steeper.

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Revision History

Revision	*Date*	*Comments*
A	2/17/86	3.0 Production Release.

Notes

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