Buffers

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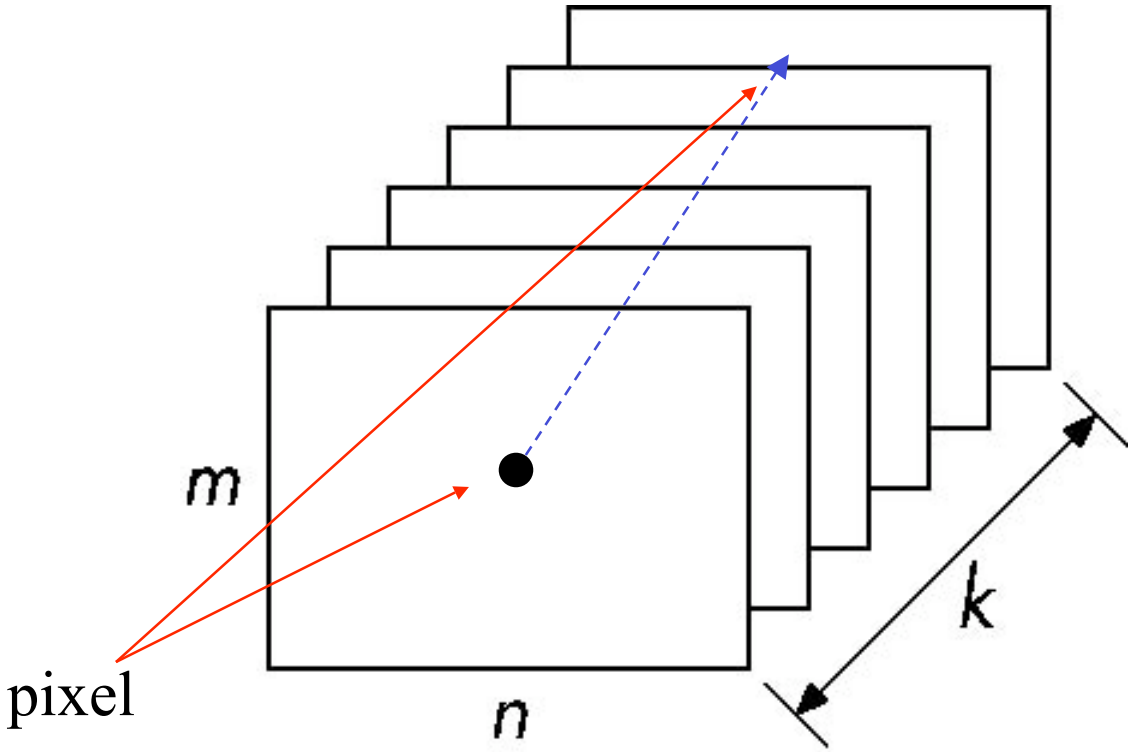
Objectives

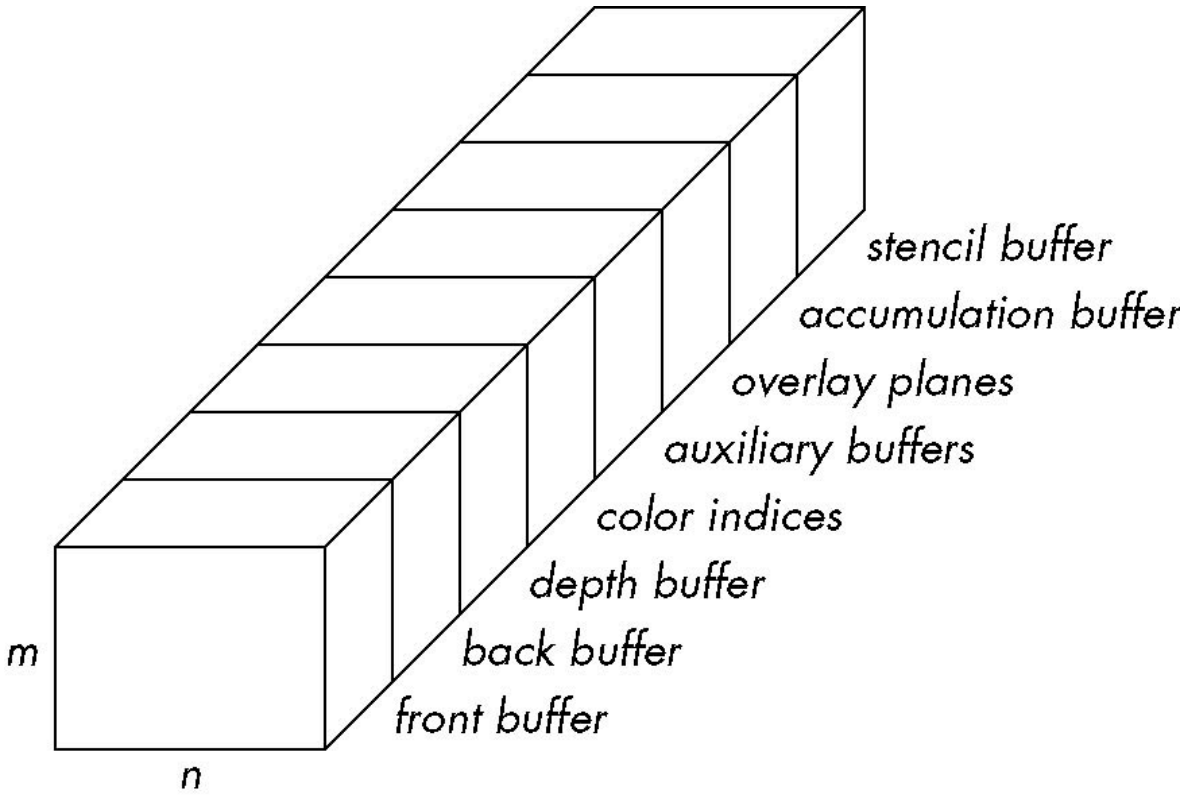
- Introduce additional OpenGL buffers
- Learn to read and write buffers
- Learn to use blending

Buffer

Define a buffer by its spatial resolution (n x m) and its depth (or precision) k, the number of bits/pixel



OpenGL Frame Buffer

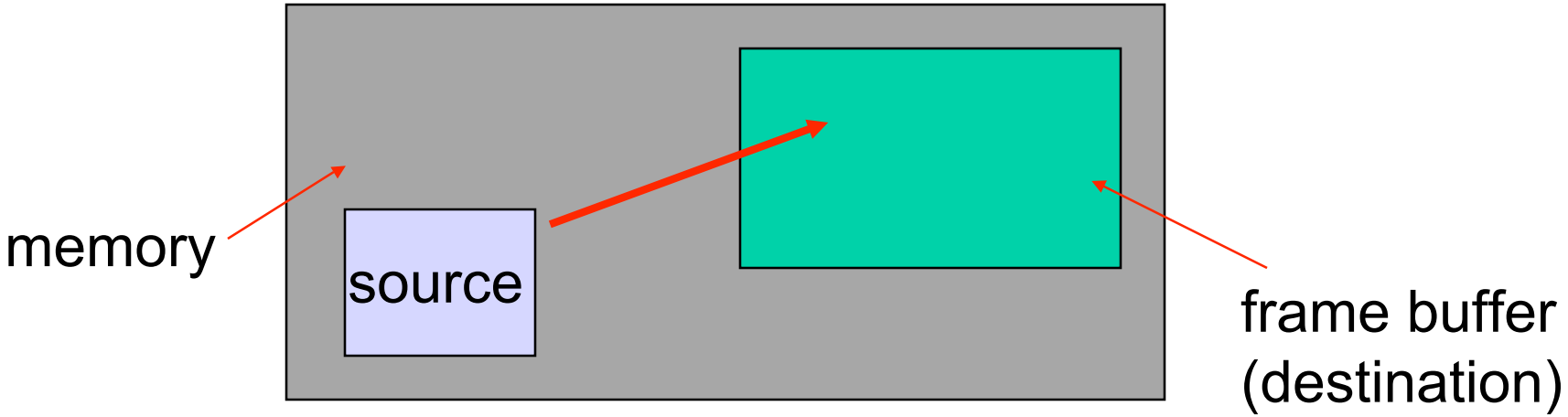


OpenGL Buffers

- Color buffers can be displayed
  - Front
  - Back
  - Auxiliary
  - Overlay
- Depth
- Accumulation
  - High resolution buffer
- Stencil
  - Holds masks

Writing in Buffers

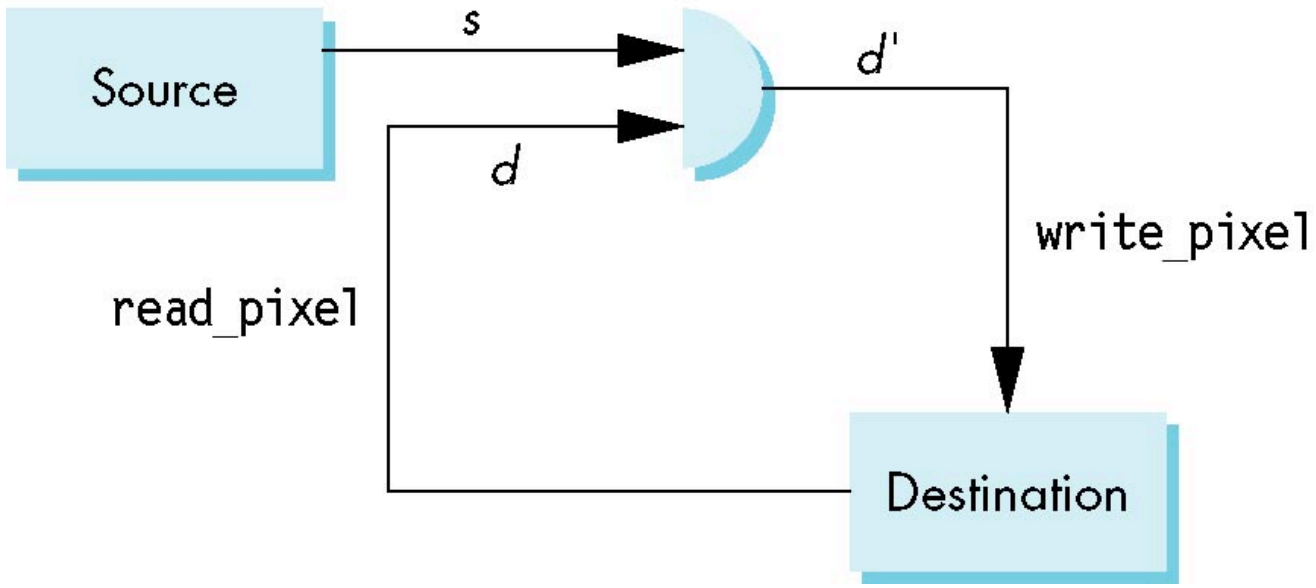
- Conceptually, we can consider all of memory as a large two-dimensional array of pixels
- We read and write rectangular block of pixels
  - *Bit block transfer* (*bitblt*) *operations*
- The frame buffer is part of this memory



writing into frame buffer

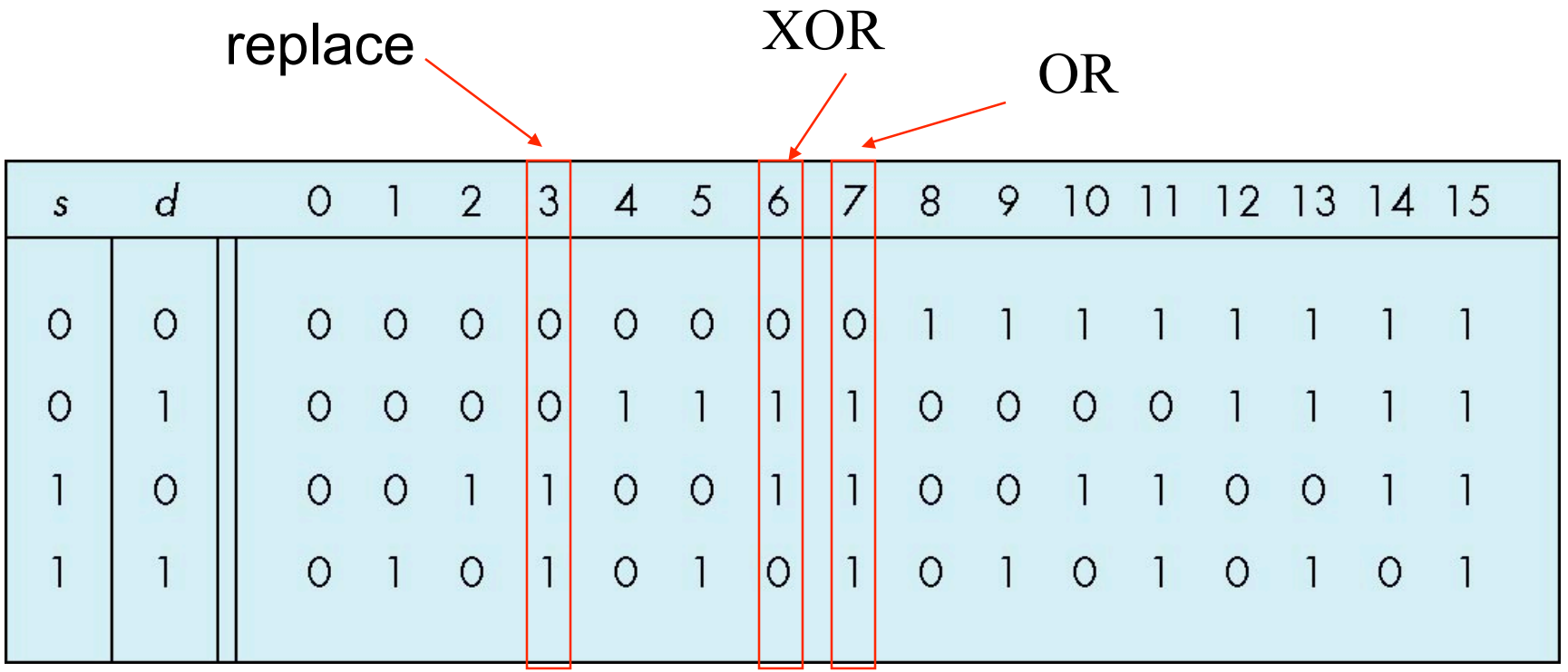
Writing Model

Read destination pixel before writing source



Bit Writing Modes

- Source and destination bits are combined bitwise
- 16 possible functions (one per column in table)



s	d	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
0	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
1	0	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

XOR mode

- Recall from Chapter 3 that we can use XOR by enabling logic operations and selecting the XOR write mode
- XOR is especially useful for swapping blocks of memory such as menus that are stored off screen

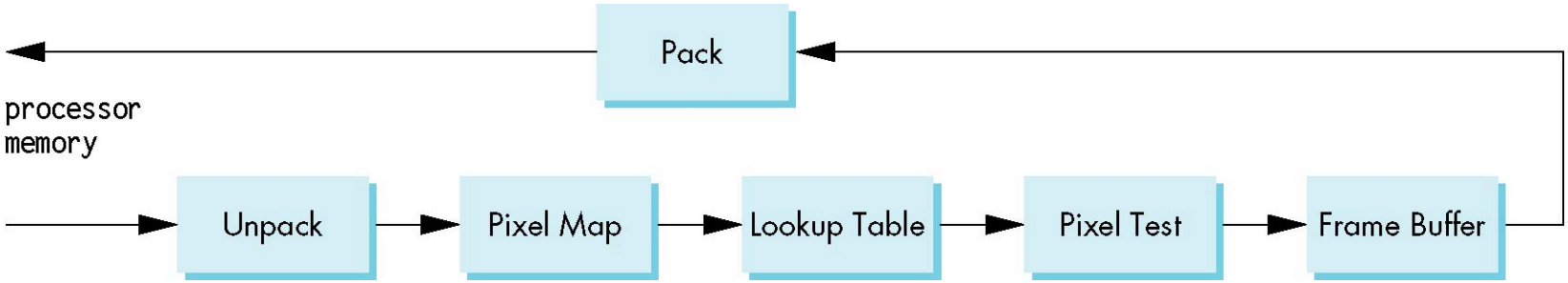
  If S represents screen and M represents a menu the sequence

  $$S \leftarrow S \oplus M$$
  $$M \leftarrow S \oplus M$$
  $$S \leftarrow S \oplus M$$

  swaps the S and M

The Pixel Pipeline

- OpenGL has a separate pipeline for pixels
  - Writing pixels involves
    - Moving pixels from processor memory to the frame buffer
    - Format conversions
    - Mapping, Lookups, Tests
  - Reading pixels
    - Format conversion



Raster Position

- OpenGL maintains a *raster position* as part of the state
- Set by **`glRasterPos*()`**
  - **`glRasterPos3f(x, y, z);`**
- The raster position is a geometric entity
  - Passes through geometric pipeline
  - Eventually yields a 2D position in screen coordinates
  - This position in the frame buffer is where the next raster primitive is drawn

Buffer Selection

- OpenGL can draw into or read from any of the color buffers (front, back, auxiliary)
- Default to the back buffer
- Change with **`glDrawBuffer`** and **`glReadBuffer`**
- Note that format of the pixels in the frame buffer is different from that of processor memory and these two types of memory reside in different places
  - Need packing and unpacking
  - Drawing and reading can be slow

Bitmaps

- OpenGL treats 1-bit pixels (*bitmaps*) differently from multi-bit pixels (*pixelmaps*)
- Bitmaps are masks that determine if the corresponding pixel in the frame buffer is drawn with the *present raster color*
  - 0 ⇒ color unchanged
  - 1 ⇒ color changed based on writing mode
- Bitmaps are useful for raster text
  - GLUT font: **`GLUT_BIT_MAP_8_BY_13`**

Raster Color

- Same as drawing color set by `glColor*()`
- Fixed by last call to `glRasterPos*()`

```
glColor3f(1.0, 0.0, 0.0);
glRasterPos3f(x, y, z);
glColor3f(0.0, 0.0, 1.0);
glBitmap(…….
glBegin(GL_LINES);
  glVertex3f(…..)
```

- Geometry drawn in blue
- Ones in bitmap use a drawing color of red

Drawing Bitmaps

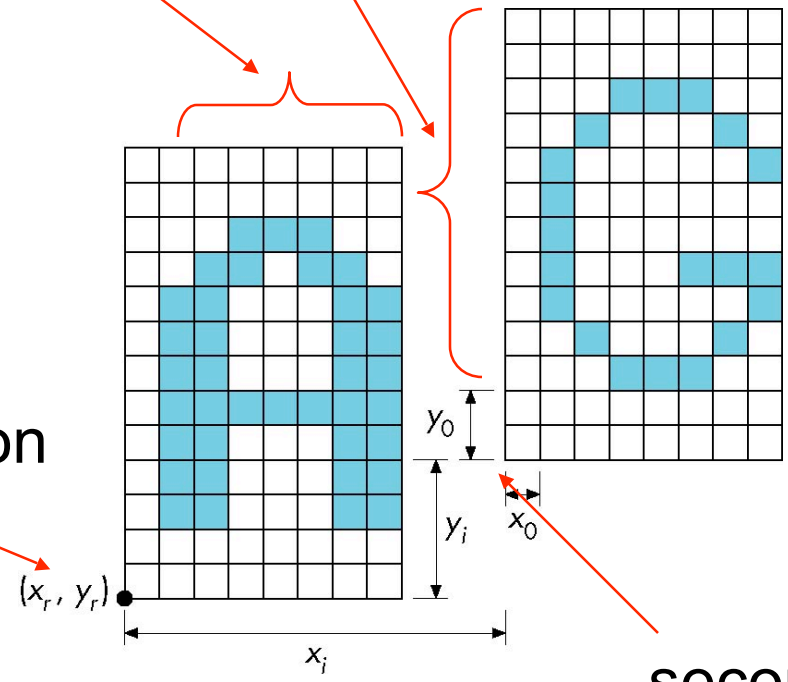
```
glBitmap(width, height, x0, y0, xi, yi, bitmap)
```

offset from raster position

increments in raster position after bitmap drawn

first raster position

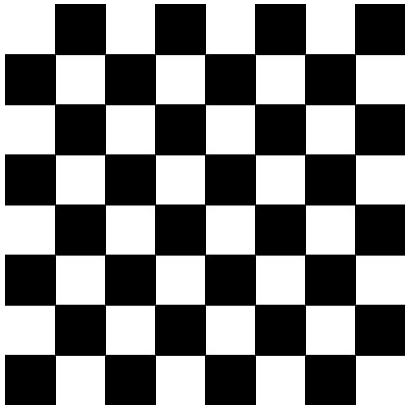
second raster position



Example: Checker Board

```
GLubyte wb[2] = {0 x 00, 0 x ff};
GLubyte check[512];
int i, j;
for(i=0; i<64; i++) for (j=0; j<64, j++)
   check[i*8+j] = wb[(i/8+j)%2];

glBitmap( 64, 64, 0.0, 0.0, 0.0, 0.0, check);
```



Pixel Maps

- OpenGL works with rectangular arrays of pixels called pixel maps or images
- Pixels are in one byte (8 bit) chunks
  - Luminance (gray scale) images 1 byte/pixel
  - RGB 3 bytes/pixel
- Three functions
  - Draw pixels: processor memory to frame buffer
  - Read pixels: frame buffer to processor memory
  - Copy pixels: frame buffer to frame buffer

OpenGL Pixel Functions

```
glReadPixels(x,y,width,height,format,type,myimage)
```

start pixel in frame buffer

size

type of pixels

type of image

pointer to processor memory

```
GLubyte myimage[512][512][3];
glReadPixels(0,0, 512, 512, GL_RGB,
      GL_UNSIGNED_BYTE, myimage);
```

```
glDrawPixels(width,height,format,type,myimage)
```

starts at raster position

Image Formats

- We often work with images in a standard format (JPEG, TIFF, GIF)
- How do we read/write such images with OpenGL?
- No support in OpenGL
  - OpenGL knows nothing of image formats
  - Some code available on Web
  - Can write readers/writers for some simple formats in OpenGL

Displaying a PPM Image

- PPM is a very simple format
- Each image file consists of a header followed by all the pixel data
- Header

```
P3
# comment 1
# comment 2
      .
#comment n
rows columns maxvalue
pixels
```

Reading the Header

```
FILE *fd;
int  k, nm;
char c;
int i;
char b[100];
float s;
int red, green, blue;
printf("enter file name\n");
scanf("%s", b);
fd = fopen(b, "r");
fscanf(fd,"%[^\n] ",b);
if(b[0]!='P'|| b[1] != '3'){
      printf("%s is not a PPM file!\n", b);
      exit(0);
}
printf("%s is a PPM file\n",b);
```

check for “P3” in first line

Reading the Header (cont)

```
fscanf(fd, "%c",&c);
while(c == '#')
{
        fscanf(fd, "%[^\n] ", b);
        printf("%s\n",b);
        fscanf(fd, "%c",&c);
}
        ungetc(c,fd);
```

skip over comments by
looking for # in first column

Reading the Data

```
fscanf(fd, "%d %d %d", &n, &m, &k);
printf("%d rows  %d columns  max value= %d\n",n,m,k);

nm = n*m;
image=malloc(3*sizeof(GLuint)*nm);
s=255./k;

for(i=0;i<nm;i++)
{
      fscanf(fd,"%d %d %d",&red, &green, &blue );
      image[3*nm-3*i-3]=red;
      image[3*nm-3*i-2]=green;
      image[3*nm-3*i-1]=blue;
}
```

scale factor

Scaling the Image Data

We can scale the image in the pipeline

```
glPixelTransferf(GL_RED_SCALE, s);
glPixelTransferf(GL_GREEN_SCALE, s);
glPixelTransferf(GL_BLUE_SCALE, s);
```

We may have to swap bytes when we go from processor memory to the frame buffer depending on the processor. If so, we can use

```
glPixelStorei(GL_UNPACK_SWAP_BYTES,GL_TRUE);
```

The display callback

```
void display()
{
 glClear(GL_COLOR_BUFFER_BIT);
 glRasterPos2i(0,0);
 glDrawPixels(n,m,GL_RGB,
    GL_UNSIGNED_INT, image);
 glFlush();
}
```