CS 349
X Windows

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X Design Criteria 1

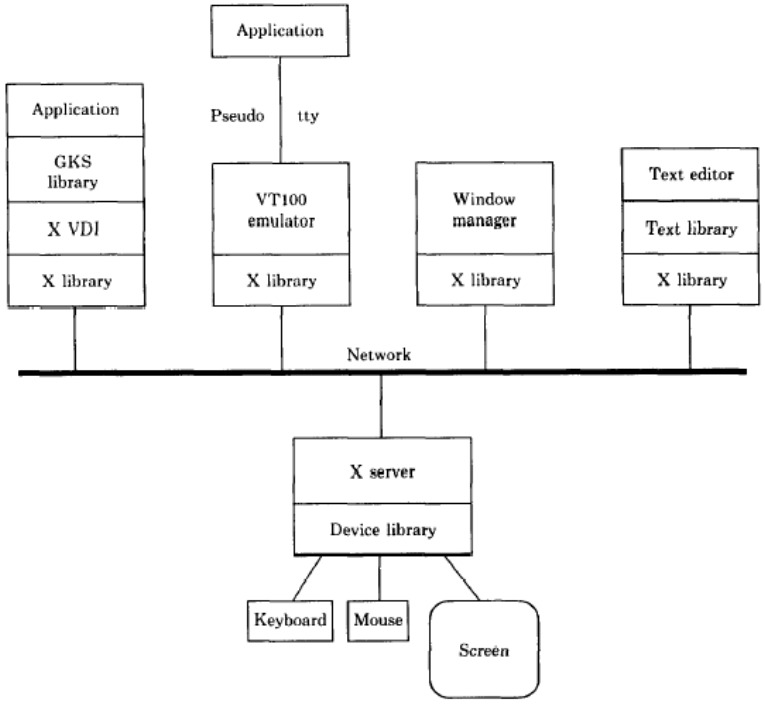
1. “implementable on a variety of displays”
2. “applications must be device independent”
3. “system must be network transparent”
4. “must support multiple applications displaying concurrently”
5. “support many different application and management interfaces”

X Design Criteria 2

6. “must support overlapping windows, including output to partially obscured windows”
7. “support a hierarchy of resizable windows, and an application should be able to use many windows at once.”
8. “provide high-performance, high-quality support for text, 2-D synthetic graphics, and imaging”
9. “system should be extensible”

X Windows: Quick Background

- Networked windowing system
- Server/client roles not what one would initially expect…
  - Server is tied to the graphics display
  - Client is the application that utilizes the display
- Enables *device independent* applications



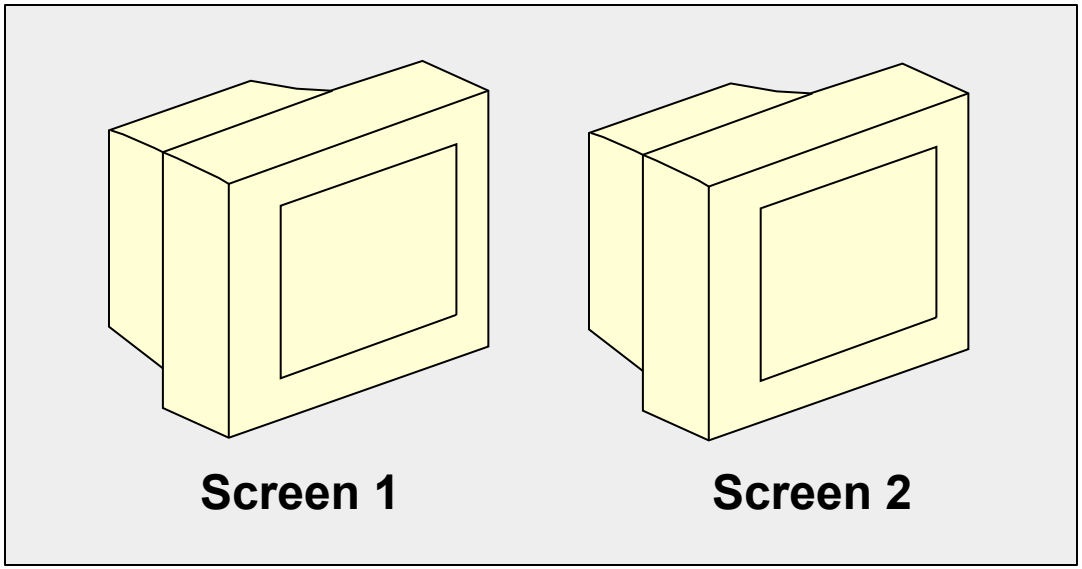
From "The X Window System," Scheifler & Gettys (1986)

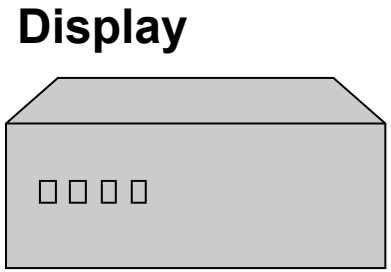
Invaluable X Refs

- The X Window System (PDF available online)
- The Xlib manual: http://tronche.com/gui/x/xlib
- Sample code in the Resources section of the web site.

Basic X Programming Elements

- Display
- Screen
- Window
- Graphics Context
- Handles to other X objects





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Basic X Programming Elements

- Display: The structure used for interacting with the server
  - Manages all the screens available on the system (X allows 1+ screens)
  - Used to obtain screens, send messages back and forth between client/server
- Screen: Represents a physical device (display)
- Window: A window within the screen
- GC (Graphics Context): Used to set drawing options (e.g., drawing color)

Programming X

- Basic functions for creating/displaying a window:
  - XOpenDisplay()
  - DefaultScreen()
  - XCreateSimpleWindow()
  - XSetStandardProperties()
  - XMapRaised()
  - XFlush()

Getting User Input & Drawing

- Contrast batch/conversational interfaces with GUI's
  - How do we need to structure our code for batch/conversational interfaces?
  - How do we need to change this structure for a GUI?

Events + Event Loops

- Since user can initiate action at anytime (keyboard, mouse input, button press) need to be flexible and check whether any action has taken place
- *Events* encapsulate actions and changes to system
- Look for new events using *event loops*
- Basic event loop algorithm in pseudocode:

```
while (true)
    if (event_available())
        e = get_event(…);
        handle_event(e);
```

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Events in X

- Need to tell X what types of events we want to receive
  - Mouse, keyboard, exposure (repaint needed), etc.
- Use XSelectInput(…):

```
XSelectInput(display, window,
             ButtonPressMask
             | KeyPressMask
             | ExposureMask );
```

- Will notify us when mouse button is pressed, key is pressed, or the window has been “exposed” (needs updating)

Events in X

- XEvent is event type (a union in C)
- Getting an event
  - XNextEvent()
    - *Blocks* until a new event is received
  - XPending()
    - Returns number of events in event queue (non-blocking)
- Based on event type, process accordingly
  - Repaint window
  - Interpret mouse, keyboard input
  - …

Painting in X

- Will be notified whenever window has been “damaged” via Expose event
  - Need to repaint our window according to current state of application
  - Then flush the display

Painting in X

- To fill a rectangle: XFillRectangle(…)
- To draw a rectangle: XDrawRectangle(…)
- Other shapes:
  - XDrawPoint()
  - XDrawLine()
  - XDrawArc()
  - XDrawLines()

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Painting in X

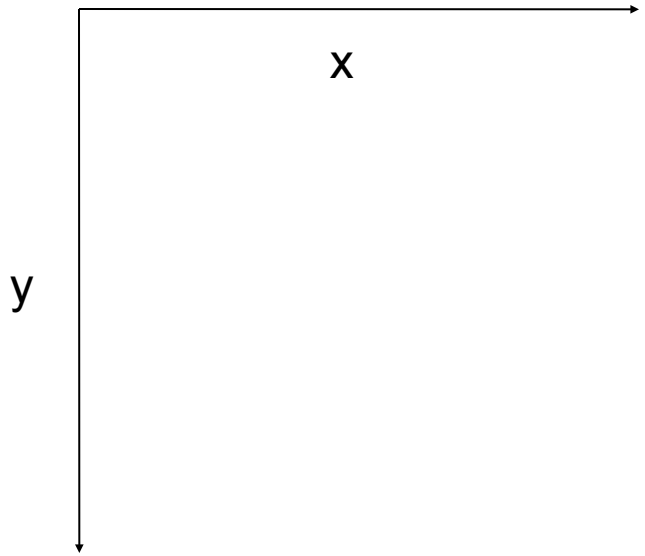
- Text:
  - XDrawImageString()
- Remember to flush display to see changes!
  - XFlush ()

Painting in X

- How can we specify the color or other attributes of what we paint?
- Can specify this information via a Graphics Context (GC)
  - XCreateGC()
  - XFreeGC()

Painting

- Coordinate system in X:
  - y increasing in value down
  - x increasing in value right



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More Sophisticated Drawing

- How could we draw a “brick” with holes in it?

Painter's Algorithm

- To draw "holes" or shapes with portions "cut out" of them, can draw background of object, then draw other shapes on top of it
- To draw a brick
  - Create graphics context with foreground color
  - Create graphics context with background color
  - Fill rectangle using foreground color GC
  - Fill set of arcs using background color GC (the holes in the brick)

Putting it all together...

- Sample code on web site (see Resources):
  - hello.cpp (mouse events)
  - xdemo_str.c (key events, clipping)
  - xdemo_2.c   (expose events)
- Up next… hello.cpp

```
/* Header files for X functions  */
#include <X11/Xlib.h>
#include <X11/Xutil.h>

using namespace std;
const int Border = 5;
const int BufferSize = 10;

/* Information to draw on the window.  */
struct XInfo
{  Display  *display;
   Window   window;
   GC          gc;
};
...       /* skip lots of stuff */

/* Execution starts here... */
int main ( int argc, char *argv[ ] )
{  XInfo xinfo;

   initX(argc, argv, xinfo);
   eventloop(xinfo);
}
```

```
void initX(int argc, char *argv[ ], XInfo &xinfo)
{   XSizeHints hints;
    unsigned long background, foreground;
    int screen;

    xinfo.display = XOpenDisplay( "" );
    if ( !xinfo.display )
      error( "Can't open display." );

    screen = DefaultScreen( xinfo.display );
    background = WhitePixel( xinfo.display, screen );
    foreground = BlackPixel( xinfo.display, screen );

    hints.x = 100;
    hints.y = 100;
    hints.width = 400;
    hints.height = 300;
    hints.flags = PPosition | PSize;
    xinfo.window = XCreateSimpleWindow( xinfo.display,
                          DefaultRootWindow( xinfo.display ),
                          hints.x, hints.y, hints.width, hints.height,
                          Border, foreground, background );
    XSetStandardProperties( xinfo.display, xinfo.window, "Hello1", "Hello2", None,
                          argv, argc, &hints );
```

Initizialize X:
- Open the display
- Get the default screen
- Create a window
- Set window properties
- Set up the Graphics Context
- Say what kind of events we're interested in
- Show the window to the user

```
    xinfo.gc = XCreateGC (xinfo.display, xinfo.window, 0, 0 );
    XSetBackground( xinfo.display, xinfo.gc, background );
    XSetForeground( xinfo.display, xinfo.gc, foreground );

    XSelectInput( xinfo.display, xinfo.window,
            ButtonPressMask | KeyPressMask | ExposureMask );

   XMapRaised( xinfo.display, xinfo.window );
}
```

Initizialize X:

- Open the display
- Get the default screen
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```
void eventloop(XInfo &xinfo)
{   XEvent event;        KeySym key;            char text[BufferSize];
    list<Displayable *> dList;          // list of Displayables

    while( true )
    {   XNextEvent( xinfo.display, &event );
        switch( event.type ) {

        case Expose:
        if ( event.xexpose.count == 0 )
            repaint( dList, xinfo);
        break;

        case ButtonPress:
        dList.push_front(new Text(event.xbutton.x, event.xbutton.y, "Urrp!"));
        repaint( dList, xinfo );
        break;

        case KeyPress:
        int i = XLookupString( (XKeyEvent *)&event, text, BufferSize, &key, 0 );
        if ( i == 1 && text[0] == 'q' )
           error( "Terminated normally." );
        break;
        }
    }}
```

Get events from the user and decide how to handle them.

```
class Displayable
{ public:
      virtual void paint(XInfo &xinfo) = 0;
      virtual ~Displayable() {}
};

class Text : public Displayable
{  public:
      virtual void paint(XInfo &xinfo)
      {  XDrawImageString( xinfo.display, xinfo.window, xinfo.gc,
               this->x, this->y, this->s.c_str(), this->s.length() );
      }

      // constructor
      Text(int x, int y, string s):x(x), y(y), s(s)  {}
      virtual ~Text() {}

   private:
      int x;
      int y;
      string s;
};
```

Data structures to store information used to repaint the display.

```
void repaint( list<Displayable *> dList, XInfo &xinfo)
{
    list<Displayable *>::const_iterator begin = dList.begin();
    list<Displayable *>::const_iterator end = dList.end();

    XClearWindow( xinfo.display, xinfo.window );

    while( begin != end )
    {  Displayable *d = *begin;
        d->paint(xinfo);
        begin++;
    }

    /* flush our instructions to the display */
    XFlush( xinfo.display );
}
```

Repaint the entire display.

Compiling X…

To compile X, use gcc and link in Xlib library:

```
gcc –o xdemo xdemo.c –L/usr/X11R6/lib –lX11
```

Outputs a file named xdemo

1. Compiles xdemo.c
2. Adds /usr/X11R6/lib as a search path for linking libraries
   - This command should work in a typical X11 installation
3. Links in library X11
4. You may also need to use the `-I` switch to indicate where your header files are located
5. On a some machines, add `-lstdc++`

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The Makefile

```
.phony: all

all:

    gcc -o xdemo xdemo.c -L/usr/X11R6/lib \
   -lX11
```

Demo Files

- There are several demos in the Resources section of the course account. Three on the virtual machine.
  - hello.cpp
  - xdemo_str.c
  - xdemo_2.c

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