Typical Graphics Problems

Which side of a plane is a point on?

Sign of $(\mathbf{X}-\mathbf{X}_0)\bullet\hat{\mathbf{n}}$

Is a 3D point in a convex 2D polygon?

Two issues.

First, is the point on the plane of the polygon?

If so, is it inside the polygon

Basic Matrix/Vector Operations (**must know**)

Multiply a matrix by a scalar

Add/subtract two matrices

Multiply a matrix by a vector

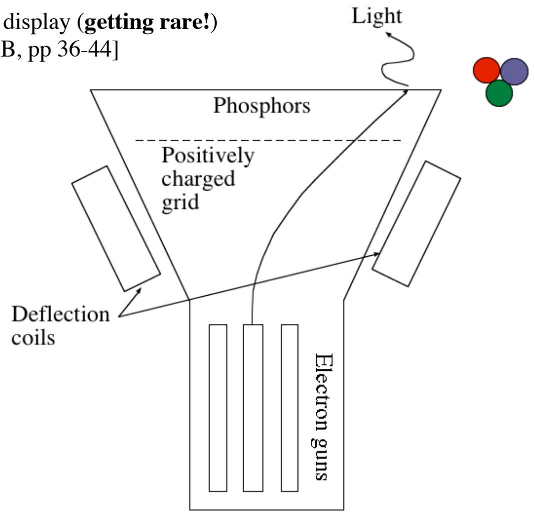
Multiply two matrices

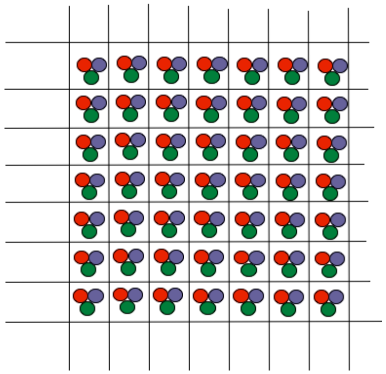
Transpose a matrix

Matrix inversion (concept)

Dots, Software, and Lines

CRT display (**getting rare!**)
[H&B, pp 36-44]



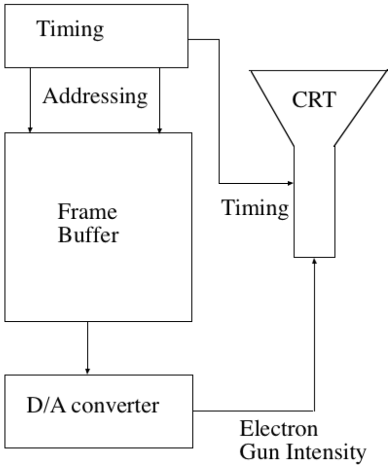


CRT Displays

- Phosphors glow when hit by electron beam.
- Color is adjusted via intensity of beam delivered to each of R,G, and B phosphor
- CRT display phosphors glow for limited time--need to be refreshed (typically about 75 times a second).
- Too much glow time would make animation hard.

CRT Displays

- Raster displays refresh by scanning from top to bottom in left right order.
- Timing is used to make screen elements correspond to memory elements.
- Memory elements called pixels
- Refresh method creates architectural and *programming* issues (e.g. double buffering), defines “real time” in animation.



Timing

Addressing

CRT

Frame Buffer

Timing

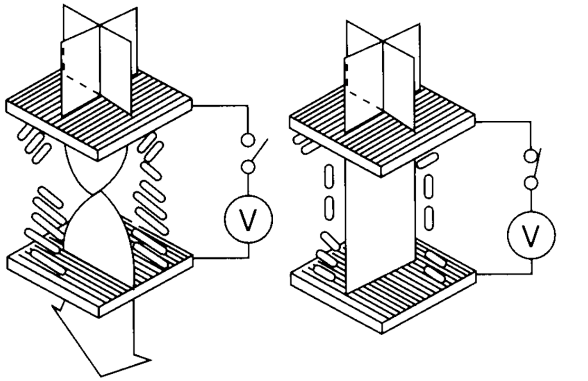
D/A converter

Electron Gun Intensity

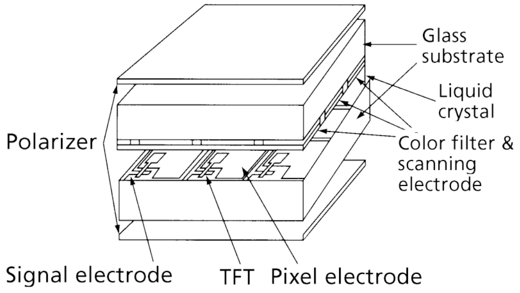
Flat Panel TFT* Displays

[H&B, pp 44-47]

*Thin film transistor



From http://www.atip.or.jp/fpd/src/tutorial



From http://www.atip.or.jp/fpd/src/tutorial

[H&B, pp 47-49]

3D displays

Enhances 3D effect by using some scheme to control what each eye sees. Examples:

Color	+ glasses with filters
Polarization	+ glasses
Temporal	+ shutter glasses
* Angles	+ assumptions about viewer's location (or head tracking)

*Google "3D display without glasses" OR "autostereo"

[H&B, pp 47-49]

3D displays

Questions:

Standard (properly constructed) 2D image of 3D looks three dimensional. Why?

If it already looks 3D, why bother with a 3D display?

Why do 3D displays enhance the three dimensional effect?

OpenGL and GLUT

[H&B, §2,9, pp 73-80]

Demo and discussion of example program

http://www.cs.arizona.edu/classes/cs433/fall07/triangle.c

OpenGL and GLUT

- Layer between your program and lower levels (hardware, low level display issues)
- Provides primitives
  - points
  - lines
  - polygons
  - bitmaps, fonts
- Provides standard graphics facilities
  - We will learn how some of these work. Some assignments will therefore have some routines "out of bounds"
  - GLUT simplifies interactive program development with intuitive callbacks and additional facilities (menus, window management).

Callbacks

- We are happy that OpenGL deals with the complexities of user actions (e.g. a click and drag action).
- If the user action is waited on, and interpreted by OpenGL, that means that the control is in OpenGL
- But **your** code needs to handle the action
- Standard solution --- "callback"
  - You give OpenGL a routine for each action you are interested in that it will call when the user does something ("register the callback").

OpenGL and GLUT

- Initialization code from the example

```
/* initialize GLUT system */
glutInit(&argc, argv);

glutInitDisplayMode(GLUT_RGB | GLUT_DOUBLE);
glutInitWindowSize(400,500);          /* width=400pixels height=500pixels */
win = glutCreateWindow("Triangle");   /* create window */

/* From this point on the current window is win */

/* set background to black */
glClearColor((GLclampf)0.0,(GLclampf)0.0,(GLclampf)0.0,(GLclampf)0.0);
gluOrtho2D(0.0,400.0,0.0,500.0); /* how object is mapped to window */
```

OpenGL and GLUT

- Window display callback. You will likely also call this function. Window repainting on expose and resizing is done for you

```
/* set window's display callback */
glutDisplayFunc(display_CB);
```

```
static void display_CB(void)
{
    glClear(GL_COLOR_BUFFER_BIT);         /* clear the display */

    /* set current color */
    glColor3d(triangle_red, triangle_green, triangle_blue);

    /* draw filled triangle */
    glBegin(GL_POLYGON);

    /* specify each vertex of triangle */
    glVertex2i(200 + displacement_x, 125 - displacement_y);
    glVertex2i(100 + displacement_x, 375 - displacement_y);
    glVertex2i(300 + displacement_x, 375 - displacement_y);

    glEnd();           /* OpenGL draws the filled triangle */
    glFlush();         /* Complete any pending operations */

    glutSwapBuffers(); /* Make the drawing buffer the frame buffer
                          and vice versa */
}
```

OpenGL and GLUT

- User input is through callbacks, e.g.,

```
/* set window's key callback */
glutKeyboardFunc(key_CB);

/* set window's mouse callback */
glutMouseFunc(mouse_CB);

/* set window's mouse move with button pressed callback */
glutMotionFunc(mouse_move_CB);
```

```
static void key_CB(unsigned char key, int x, int y)
{
    if( key == 'q' ) exit(0);
}

/*  /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\   */

/* Function called on mouse click */
static void mouse_CB(int button, int state, int x, int y)
{
    /*
     *  Code which responses to the button, the state (press, release), and where
     *  the pointer was when the mouse event occured (x, y).
     *
     *  See example on-line for sample code.
    */
}

/*  /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\ /\   */

/* Function called on mouse move while depressed. */
static void mouse_move_CB(int x, int y)
{
    /* See example on-line for sample code. */
}
```

OpenGL and GLUT

- GLUT makes pop-up menus easy. We will save development time by using (perhaps abusing) this facility.

```
/* Create a menu which is accessed by the right button. */
submenu = glutCreateMenu(select_triangle_color);
glutAddMenuEntry("Red", KJB_RED);
glutAddMenuEntry("Green", KJB_GREEN);
glutAddMenuEntry("Blue", KJB_BLUE);
glutAddMenuEntry("White", KJB_WHITE);
glutCreateMenu(add_object_CB);
glutAddMenuEntry("Triangle", KJB_TRIANGLE);
glutAddMenuEntry("Square", KJB_SQUARE);
glutAddSubMenu("Color", submenu);
glutAttachMenu(GLUT_RIGHT_BUTTON);
```

OpenGL and GLUT

- Ready for the user!

```
/* start processing events... */
glutMainLoop();
```

- For the rest of the code see
  http://www.cs.arizona.edu/classes/cs433/fall07/triangle.c

Assignment One

- Due in 19 days.

- Infrastructure, grid, lines, polygons, anti-aliasing (grads)

- For U-grads
  - Recommend that by mid next week, infrastructure and grid is done.
  - Recommend that early the following week, lines are done.
  - One week left for polygons