CS3241
Computer Graphics

Semester 1, 2019/2020

Lecture 3

Input & Interaction

School *of* Computing
National University *of* Singapore

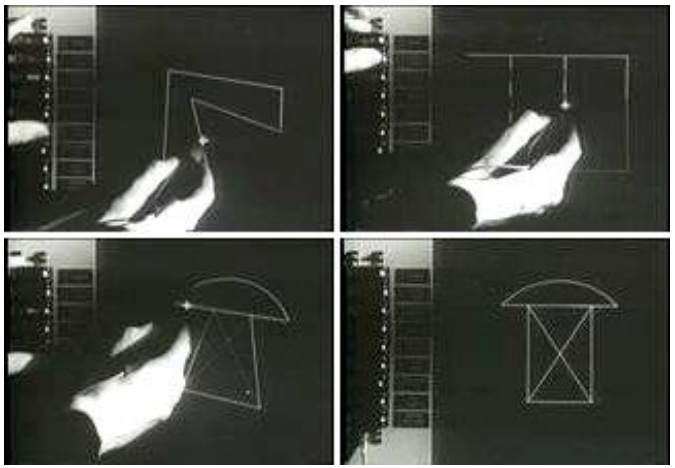
Input & Interaction

Outline

- Introduce the basic input devices
- **Event-driven** input
- Introduce **double buffering** for smooth animations
- Programming event input with GLUT

Project Sketchpad

- Ivan Sutherland (MIT 1963) established the basic interactive paradigm that characterizes **interactive computer graphics**:
  - User **sees** an object on the display
  - User points to (**picks**) the object with an input device (e.g. light pen, mouse, trackball)
  - Object **changes** (e.g. moves, rotates, morphs)
  - Repeat

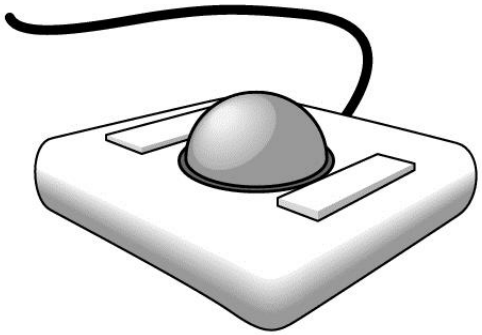


Graphical Input

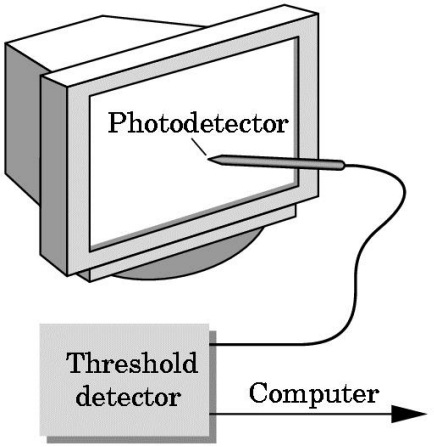
- Devices can be described either by
  - **Physical** properties
    - Mouse, Keyboard, Trackball, etc.
  - **Logical** properties
    - What is returned to program via API
      - A position
      - An object identifier

Physical Devices

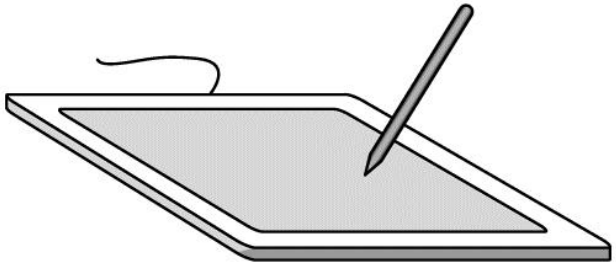
mouse



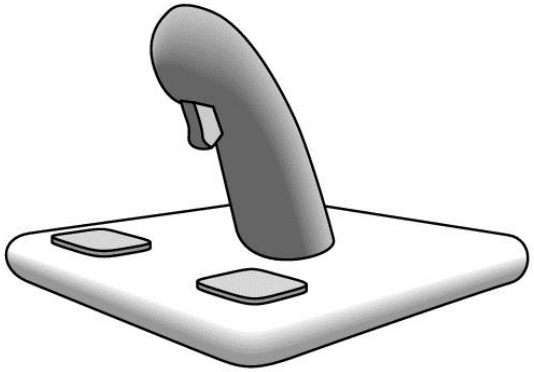
trackball



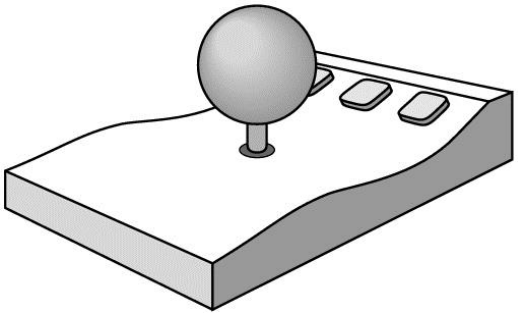
light pen



data tablet



joy stick



space ball

Incremental (Relative) Devices

- Devices such as the data tablet return a **position directly** to the operating system
- Devices such as the mouse, trackball, and joy stick return **incremental inputs** (or velocities) to the operating system
  - Must integrate these inputs to obtain an **absolute position**
    - Rotation of cylinders in mouse
    - Roll of trackball
    - Difficult to obtain absolute position
    - Can get variable sensitivity

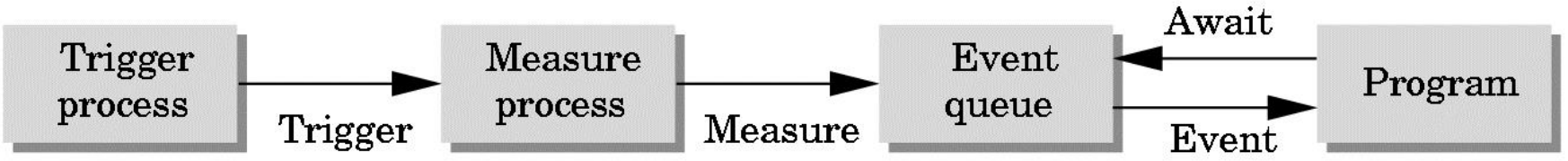
Trigger and Measure

- Input devices contain a **trigger** which can be used to send a signal to the operating system
  - Button on mouse
  - Pressing or releasing a key
- When triggered, input devices return information (their **measure**) to the system
  - Mouse returns position information
  - Keyboard returns ASCII code

Event Mode

- Most systems have more than one input device, each of which can be triggered at an arbitrary time by a user

- Each trigger generates an **event** whose measure is put in an **event queue** which can be examined by the user program



Event Types

- **Window:** resize, expose, minimize
- **Mouse:** click one or more buttons
- **Motion:** move mouse
- **Keyboard:** press or release a key
- **Idle:** non-event
  - Define what should be done if no other event is in queue

Callbacks

- Programming interface for **event-driven** input
- Define a **callback function** for each type of event the graphics system recognizes
- This user-supplied function is executed when the event occurs

- GLUT example:
  - `glutMouseFunc( mymouse );`

mouse callback function

GLUT Callbacks

- GLUT recognizes a subset of the events recognized by any particular window system (Windows, Mac, X)
  - `glutDisplayFunc`
  - `glutMouseFunc`
  - `glutReshapeFunc`
  - `glutKeyboardFunc`
  - `glutIdleFunc`
  - `glutMotionFunc, glutPassiveMotionFunc`

GLUT Event Loop

- Recall that the last statement in **`main()`** for a program using GLUT must be

```
glutMainLoop();
```

  which puts the program in an **infinite event loop**

- In each pass through the event loop, GLUT
  - looks at the events in the queue
  - for each event in the queue, GLUT executes the appropriate callback function if one is defined
  - if no callback is defined for the event, the event is ignored

The Display Callback

- The **display callback** is executed whenever GLUT determines that the window should be refreshed, for example
  - When the window is first **opened**
  - When the window is **reshaped**
  - When a window is **exposed**
  - When the user program decides it wants to **change** the display
- In `main()`
  - `glutDisplayFunc(mydisplay)` identifies the function to be executed
  - Every GLUT program must have a display callback

Posting Redisplays

- **Many events** may invoke the **display callback function**
  - Can lead to multiple executions of the display callback on a single pass through the event loop
- We can avoid this problem by instead using

```
glutPostRedisplay();
```

  which **sets a flag**
- GLUT checks to see if the flag is set at the end of the event loop
- If set, then the display callback function is executed

Animating a Display

- When we **redraw** the display through the display callback, we usually start by clearing the window
  - `glClear();`

  then draw the altered display

- **Problem:** the drawing of information in the frame buffer is decoupled from the display of its contents
  - Graphics systems use dual-ported memory

- Hence we can see **partially drawn** display

Double Buffering

- Instead of one **color buffer**, we use two
  - **Front Buffer**: one that is **displayed** but not written to
  - **Back Buffer**: one that is **written to** but not displayed

- Program then requests a **double buffer** in **`main()`**
  - **`glutInitDisplayMode(GL_RGB | GL_DOUBLE)`**
  - At the end of the display callback buffers are **swapped**

```
void mydisplay()
{
    glClear(GL_COLOR_BUFFER_BIT|…)
    ...
    /* draw graphics here */
    ...
    glutSwapBuffers();
}
```

Using the Idle Callback

- The **idle callback** is executed whenever there are no events in the event queue
  - `glutIdleFunc(myidle);`
  - Useful for **animations**

```
void myidle() {
    /* change something */
    t += dt
    glutPostRedisplay();
}

void mydisplay() {
    glClear();
    /* draw something that depends on t */
    glutSwapBuffers();
}
```

Using Globals

- The form of all GLUT callbacks is fixed
  - `void mydisplay()`
  - `void mymouse(GLint button, GLint state, GLint x, GLint y)`

- Must use globals to pass information to callbacks

```
float t; /*global */

void mydisplay()
{
    /* draw something that depends on t
}
```

Working with Callbacks

Outline

- Building interactive programs using GLUT callbacks
  - Mouse
  - Keyboard
  - Reshape

- [Optional] Introduce menus in GLUT

Reference

The Mouse Callback

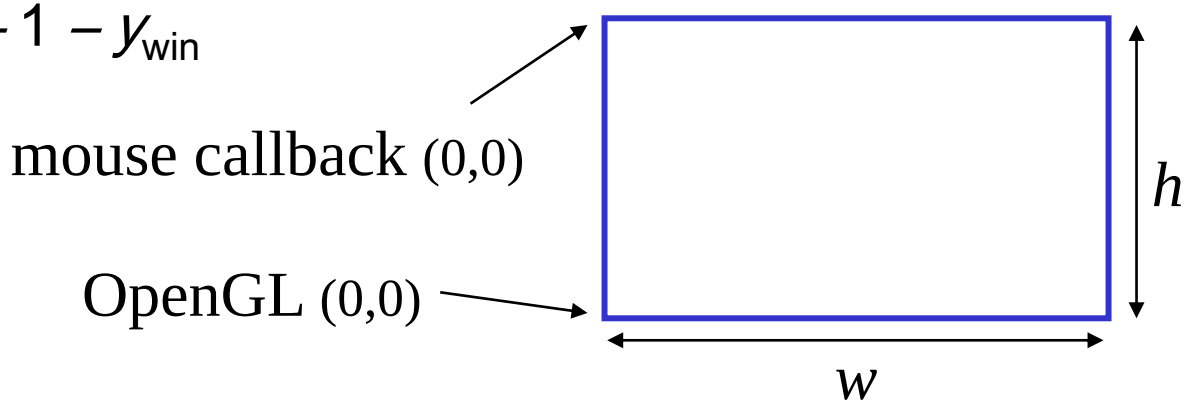
- `glutMouseFunc(mymouse)`
- `void mymouse(GLint button, GLint state, GLint x, GLint y)`

  Returns
  - which button caused the event
    - `GLUT_LEFT_BUTTON`, `GLUT_MIDDLE_BUTTON` or `GLUT_RIGHT_BUTTON`
  - state of that button
    - `GLUT_UP` or `GLUT_DOWN`
  - mouse cursor position in window
    - top-left corner is (0,0),
      top-right corner is (winWidth−1,0),
      bottom-left corner is (0, winHeight−1),
      bottom-right corner is (winWidth−1, winHeight−1)

Positioning

- To **window system** (and mouse & motion callback), position in window is measured in pixels with the **origin** at the top-left corner
  - Consequence of refresh done from top to bottom

- But to **OpenGL**, position in window is measured in pixels with the **origin** at the bottom-left corner
  - Must invert *y* coordinate returned by callback by height of window
  - $y_{opengl} = h - 1 - y_{win}$



Obtaining Window Size

- To invert the *y* position we need the window height
  - Height can change during program execution
    - Track with a global variable
    - New height returned to **reshape callback** (we will look at in detail soon)
    - Can also use query functions to obtain state values
      - `glGetIntv`
      - `glGetFloatv`

Terminating a Program

- In our original programs, there was no way to terminate them through OpenGL

- For example, in a simple mouse callback

```
void mouse( int btn, int state, int x, int y )
{
   if( btn == GLUT_RIGHT_BUTTON &&
       state == GLUT_DOWN )
     exit(0);
}
```

Using the Mouse Position

- In the next example, we draw a **small square** at the **location** of the mouse each time the **left mouse button** is **clicked**

- This example does not use the display callback but one is required by GLUT; We can use the empty display callback function

```
mydisplay(){}
```

Drawing Squares at Cursor Location

```
void mymouse(int btn, int state, int x, int y)
{
   if (btn==GLUT_RIGHT_BUTTON && state==GLUT_DOWN) exit(0);
   if (btn==GLUT_LEFT_BUTTON && state==GLUT_DOWN) drawSquare(x, y);
}

void drawSquare(int x, int y)
{
   y = w - 1 - y; /* invert y position */
   /* a random color */
   glColor3ub((char)rand()%256,(char)rand()%256,(char)rand()%256 );
   glBegin(GL_POLYGON);
      glVertex2f(x+size, y+size);
      glVertex2f(x-size, y+size);
      glVertex2f(x-size, y-size);
      glVertex2f(x+size, y-size);
   glEnd();
}
```

Using the Motion Callback

- We can draw squares (or anything else) **continuously** as long as a mouse button is **depressed** by using the **motion callback**
  - `glutMotionFunc(drawSquare);`

- We can draw squares **without depressing** a button using the **passive motion callback**
  - `glutPassiveMotionFunc(drawSquare);`

Using the Keyboard

- `glutKeyboardFunc(mykey)`
- `void mykey(unsigned char key, int x, int y)`

Returns

- ASCII code of key depressed and
- mouse location

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

Special and Modifier Keys

- GLUT defines the special keys in **`glut.h`**
  - Function key 1: **`GLUT_KEY_F1`**
  - Up arrow key: **`GLUT_KEY_UP`**
    - `if (key == GLUT_KEY_F1) ……`

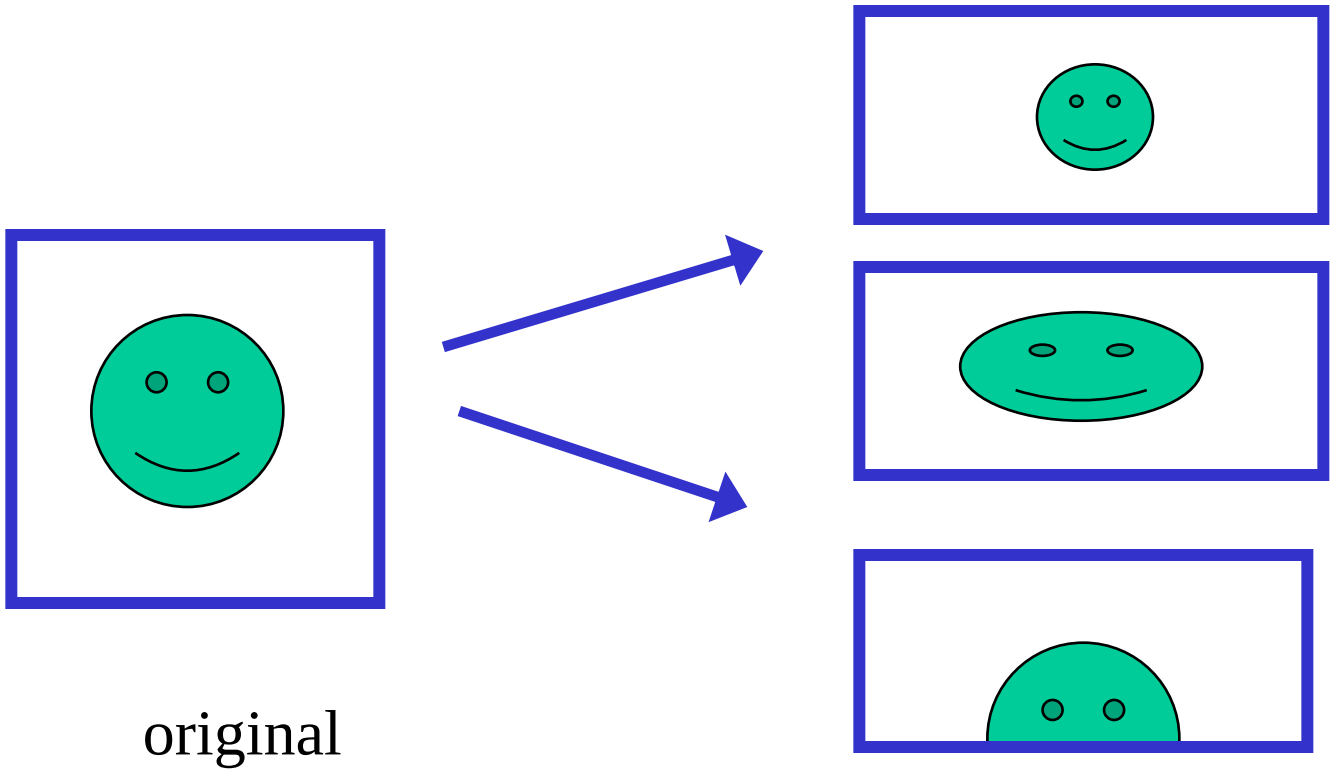
- Can also check whether any one of the modifiers
  - **`GLUT_ACTIVE_SHIFT`**, **`GLUT_ACTIVE_CTRL`**, **`GLUT_ACTIVE_ALT`** is depressed using **`glutGetModifiers()`**
    - `if (glutGetModifiers() == GLUT_ACTIVE_CTRL)……`
  - Allows emulation of three-button mouse with one- or two-button mice

Reshaping the Window

- We can **reshape** and **resize** the OpenGL display window by pulling the corner of the window

- What happens to the display?
  - Application must **redraw**
  - Two possibilities
    - Display part of world
    - Display whole world but force to fit in new window
      - Can alter aspect ratio and cause distortion

Example Reshape Possibilities



original

reshaped

The Reshape Callback

- `glutReshapeFunc(myreshape)`
- `void myreshape(int w, int h)`

  Returns **width** and **height** of new window (in pixels)

  - A **redisplay is posted automatically** at end of execution of the callback
  - GLUT has a default reshape callback but you probably want to define your own

- The reshape callback is good place to put **viewing functions** because it is **invoked when the window is first opened**

Example Reshape

- This reshape **preserves shapes** by making the viewport and world window have the same **aspect ratio**

```
void myReshape(int w, int h)
{
  glViewport(0, 0, w, h);
  glMatrixMode(GL_PROJECTION); /* switch matrix mode */
  glLoadIdentity();

  if (w <= h)
    gluOrtho2D( -2.0, 2.0, -2.0 * (GLfloat) h / w,
                           2.0 * (GLfloat) h / w );
  else
    gluOrtho2D( -2.0 * (GLfloat) w / h,
                2.0 * (GLfloat) w / h, -2.0, 2.0 );

  glMatrixMode(GL_MODELVIEW); /* return to modelview mode */
}
```

Optional

Toolkits and Widgets

- Most window systems provide a toolkit or library of functions for building user interfaces that use special types of windows called **widgets**
- Widget sets include tools such as
  - Menus
  - Slidebars
  - Dials
  - Input boxes
- But toolkits tend to be platform dependent
- GLUT provides a few widgets including menus

Optional

Menus

- GLUT supports pop-up menus
  - A menu can have submenus
- Three steps
  - Define entries for the menu
  - Define action for each menu item
    - Action carried out if entry selected
  - Attach menu to a mouse button

Optional

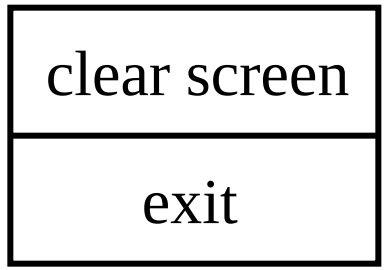
Defining a Simple Menu

- In `main()`

```
menu_id = glutCreateMenu(mymenu);
glutAddmenuEntry("clear screen", 1);

gluAddMenuEntry("exit", 2);

glutAttachMenu(GLUT_RIGHT_BUTTON);
```



entries that appear when right button depressed

identifiers

Optional

Menu Actions

- Menu callback

```
void mymenu(int id)
{
    if(id == 1) glClear();
    if(id == 2) exit(0);
}
```

- Note each menu has an id that is returned when it is created
- Add submenus by
  - `glutAddSubMenu(char *submenu_name, submenu id)`

entry in parent menu

Other Functions in GLUT

- Dynamic Windows
  - Create and destroy during execution
- Subwindows
- Multiple Windows
- Changing callbacks during execution
- **Timers** (look up **`glutTimerFunc`**)
  - Useful for controlling speed of animation
- Portable fonts
  - **`glutBitmapCharacter`**
  - **`glutStrokeCharacter`**

End of Lecture 3