NUSRI Summer Programme 2016

RI3004A
3D Graphics Rendering

Lecture 3
Input & Interaction

School *of* Computing
National University *of* Singapore

Input & Interaction

Objectives

- Introduce the basic input devices
    - Physical Devices
    - Logical Devices
    - Input Modes
- Event-driven input
- Introduce double buffering for smooth animations
- Programming event input with GLUT

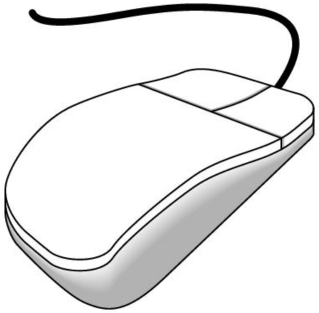
Project Sketchpad

- 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 (light pen, mouse, trackball)
  - Object changes (moves, rotates, morphs)
  - Repeat

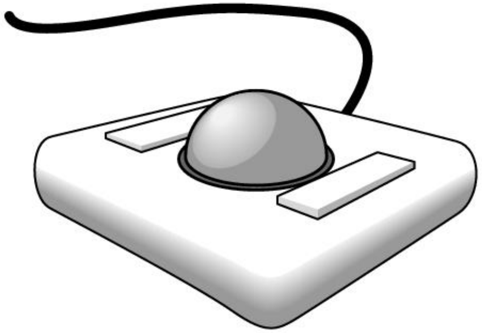
Graphical Input

- 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
- Modes
  - How and when input is obtained
    - Request or event

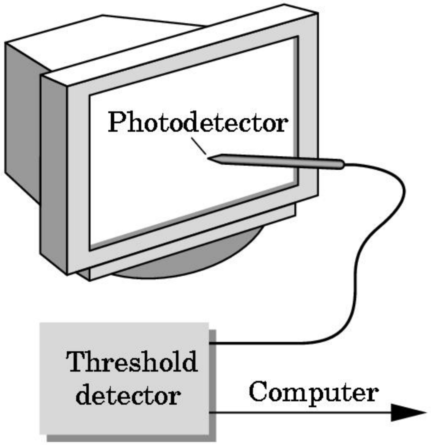
Physical Devices



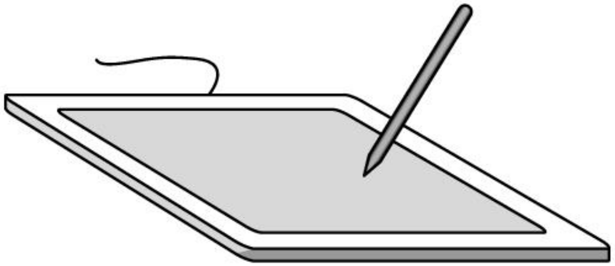
mouse



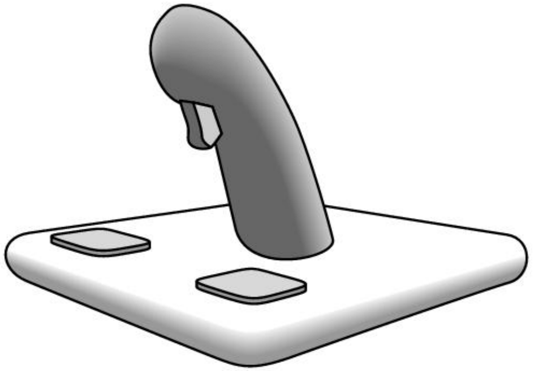
trackball



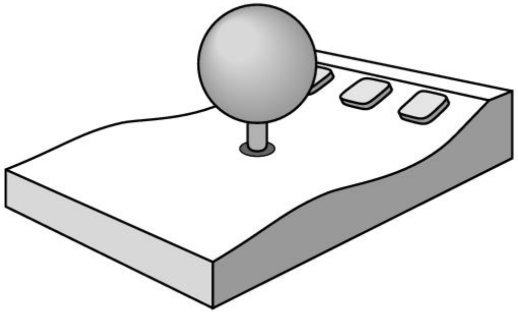
light pen



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

Logical Devices

- Consider the C and C++ code
  - C++: `cin >> x;`
  - C: `scanf("%d", &x);`
- What is the input device?
  - Can’t tell from the code
  - Could be keyboard, file, output from another program
- The code provides *logical input*
  - A number (an **`int`**) is returned to the program regardless of the physical device

Graphical Logical Devices

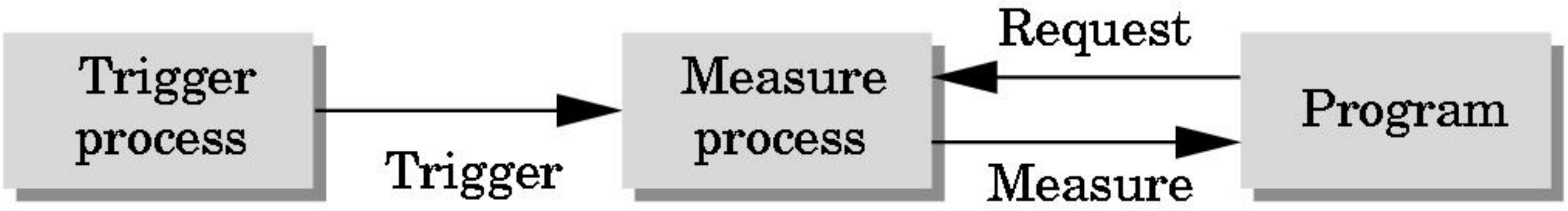
- Graphical input is more varied than input to standard programs which is usually numbers, characters, or bits
- Two older APIs (GKS, PHIGS) defined six types of logical input
    - **Locator**: return a position
    - **Pick**: return ID of an object
    - **Keyboard**: return strings of characters
    - **Stroke**: return array of positions
    - **Valuator**: return floating point number
    - **Choice**: return one of n items

Input Modes

- 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

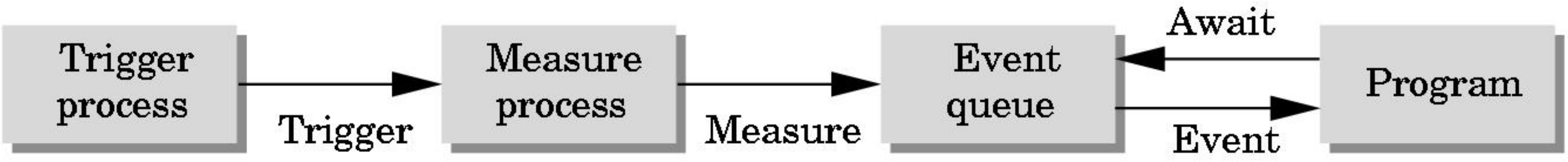
Request Mode

- Input provided to program only when user triggers the device
- Typical of keyboard input
  - Can erase (backspace), edit, correct until enter (return) key (the trigger) is depressed



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, iconify
- **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, X, Macintosh)
  - **`glutDisplayFunc`**
  - **`glutMouseFunc`**
  - **`glutReshapeFunc`**
  - **`glutKeyboardFunc`**
  - **`glutIdleFunc`**
  - **`glutMotionFunc, glutPassiveMotionFunc`**

GLUT Event Loop

- Recall that the last line in **`main.c`** 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.c`**
  - **`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.c`
  - `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

Objectives

- Learn to build interactive programs using GLUT callbacks
  - Mouse
  - Keyboard
  - Reshape
- Introduce menus in GLUT

The Mouse Callback

- `glutMouseFunc(mymouse)`

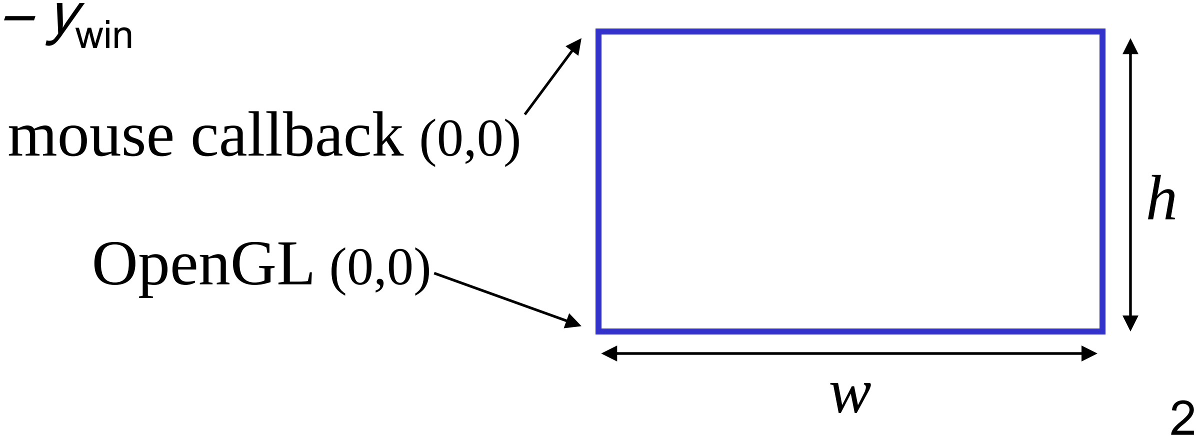
-
  ```
  void mymouse(GLint button, GLint state,
               GLint x, GLint y)
  ```

  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
  - $y_{\text{opengl}} = h - 1 - y_{\text{win}}$



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 that we will look at in detail soon
  - Can also use query functions
    - `glGetIntv`
    - `glGetFloatv`

  to obtain any value that is part of the state

Terminating a Program

- In our original programs, there was no way to terminate them through OpenGL
- We can use the 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);
}
```

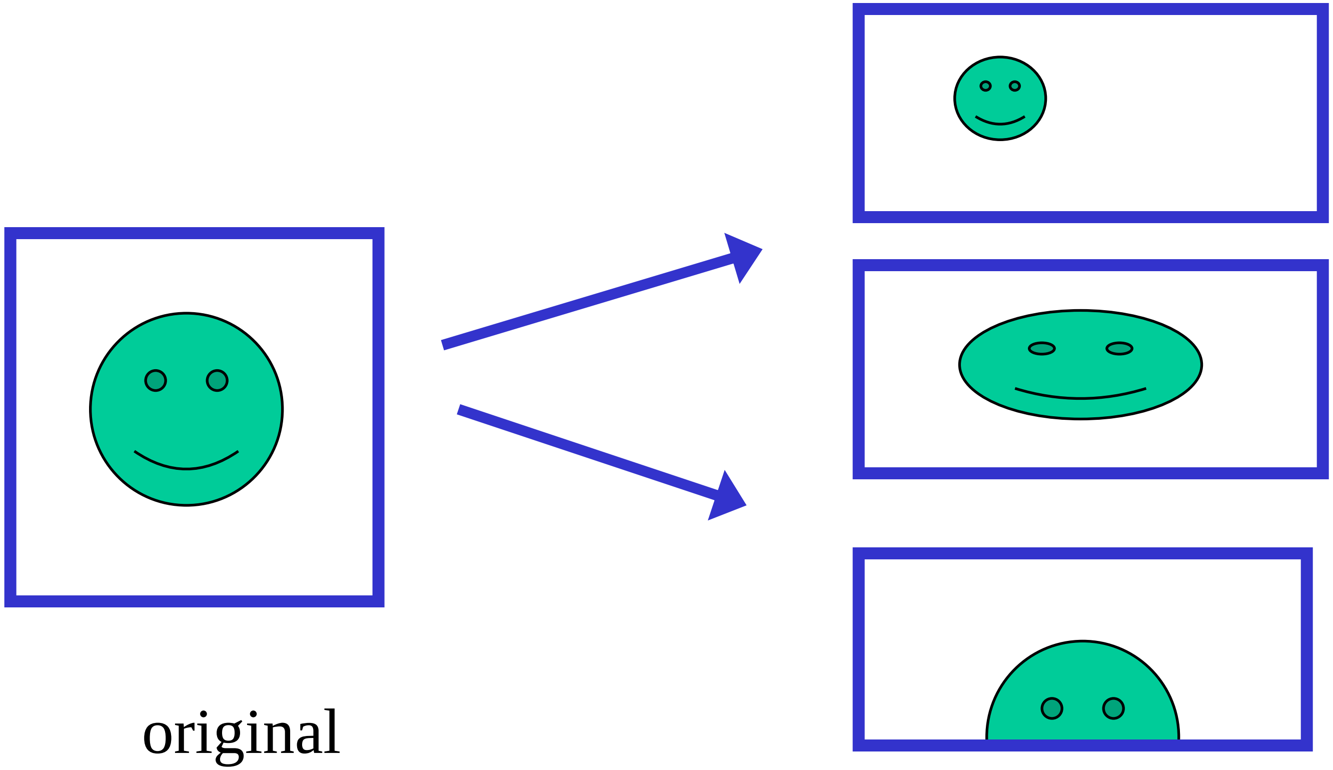
Special and Modifier Keys

- 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?
  - Must redraw from application
  - Two possibilities
    - Display part of world
    - Display whole world but force to fit in new window
      - Can alter aspect ratio

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 */
}
```

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

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

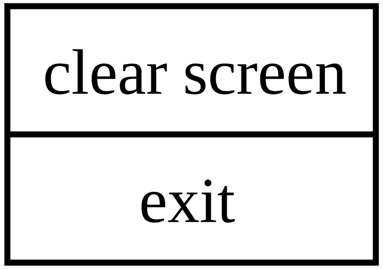
Defining a Simple Menu

- In `main.c`

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

gluAddMenuEntry("exit", 2);

glutAttachMenu(GLUT_RIGHT_BUTTON);
```



entries that appear when
right button depressed

identifiers

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
  - Useful for controlling speed of animation
- Portable fonts
  - **`glutBitmapCharacter`**
  - **`glutStrokeCharacter`**

End of Lecture 3