Input and Interaction

CS 432 Interactive Computer Graphics
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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

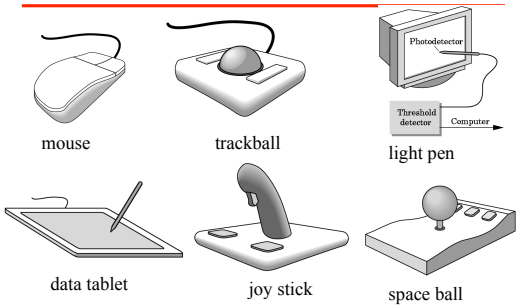
Project Sketchpad

- 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
  - Logical Properties
    - What is returned to program via API
      - A position
      - An object identifier
      - A scalar value
- Modes
  - How and when input is obtained
    - Request or event

Physical Devices



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

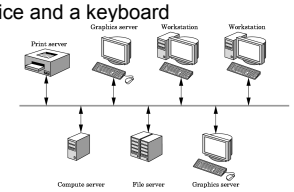
- Consider the C and C++ code
  - C++: `cin >> x;`
  - C: `scanf ("%d", &x);`
- What is the input device?
  - Can't tell from the code
  - Could be keyboard, file, output from another program
- The code provides *logical input*
  - A number (an `int`) is returned to the program regardless of the physical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

X Window Input

- The X Window System introduced a client-server model for a network of workstations
  - **Client**: OpenGL program
  - **Graphics Server**: bitmap display with a pointing device and a keyboard

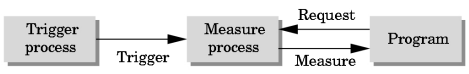


Input Modes

- 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

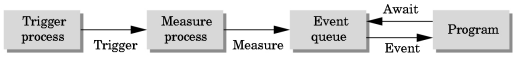
Request Mode

- 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: nonevent
  - 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 most/all window systems (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 displays
  - See the program `single_double.c` for an example with a rotating cube

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(GLUT_RGB | GLUT_DOUBLE)`
  - At the end of the display callback buffers are swapped

```
void mydisplay()
{
      glClear()
.
/* 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

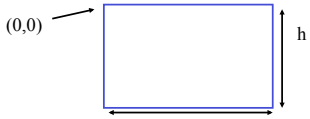
The mouse callback

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

- Returns
  - which button (**GLUT_LEFT_BUTTON**, **GLUT_MIDDLE_BUTTON**, **GLUT_RIGHT_BUTTON**) caused event
  - state of that button (**GLUT_UP**, **GLUT_DOWN**)
  - Position in window

Positioning

- The position in the screen window is usually measured in pixels with the origin at the top-left corner
  - Consequence of refresh done from top to bottom
- OpenGL uses a world coordinate system with origin at the bottom left
  - Must invert *y* coordinate returned by callback by height of window
  - *y = h – y;*



Obtaining the 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=h-y; /* invert y position */
    points[i] = point2(x+size, y+size);
    points[i+1] = point2(x-size, y+size);
    points[i+2] = point2(x-size, y-size);
    points[i+3] = point2(x+size, y-size);
    i+=4
}
```

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)`
- Calls **`drawSquare`** if mouse is moving in window and any button is depressed
- Function is called with mouse's `(x,y)` location at the time of the event

Using the motion callback

- We can draw squares without depressing a button using the passive motion callback
  - `glutPassiveMotionFunc(drawSquare)`
- The magnitude of motion that triggers this event is system dependent

The entry callback

- Mouse generates an entry event whenever it enters or leaves the OpenGL window
- The callback for this event is registered with `glutEntryFunc()`

```
void glutEntryFunc(void (*f) (int state))
```

- Event returns state of entry
  - `(GLUT_ENTERED, GLUT_LEFT)`

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()
{
     if(key == 'Q' || key == 'q')
          exit(0);
}
```


Special 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'` .....
- **`glutSpecialFunc(myspecial)`** specifies the callback function that is called when a special key (i.e. a function or arrow key) is depressed

Modifier Keys

- Can also check if one of the modifiers
  - `GLUT_ACTIVE_SHIFT`
  - `GLUT_ACTIVE_CTRL`
  - `GLUT_ACTIVE_ALT`

  is depressed with `glutGetModifiers()`

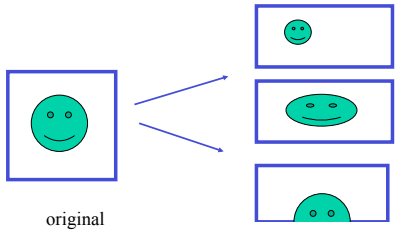
```
if((glutGetModifiers() == GLUT_ACTIVE_CTRL) &&
                  (key == 'c') || (key == 'C')))
   exit(0);
```

- 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 possiblities



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

- We will revisit this once we have learned about viewing

```
void myReshape(int w, int h)
{
    glViewport(0, 0, w, h);  /* Make viewport and window
                                the same size */

  // More to come

}
```


Timers

- Callback function that is triggered after a specified number of milliseconds

```
// change color each second
glutTimerFunc(1000,timerColor,0);
// change the shape after five seconds
glutTimerFunc(5000,timerShape,0);

void timerColor(int value){
  // get new color or a value in [0,1]
  r = (1.0*(random()%256))/256.0;
  g = (1.0*(random()%256))/256.0;
  b = (1.0*(random()%256))/256.0;

  // draw it + reinitialise timer
  glutPostRedisplay();
  glutTimerFunc(1000,timerColor,0);
}
```


Redefining Callbacks

- Callback functions can be redefined
- Change binding during program execution
- Callbacks can be undefined
  - `glutReshapeFunc(NULL);`

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);
```

clear screen
exit

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

Submenu example

```
void createGLUTMenus() {

      int menu,submenu;

      submenu = glutCreateMenu(processMenuEvents);
      glutAddMenuEntry("Red",RED);
      glutAddMenuEntry("Blue",BLUE);
      glutAddMenuEntry("Green",GREEN);

      menu = glutCreateMenu(processMenuEvents);
      glutAddMenuEntry("White",WHITE);
      glutAddSubMenu("RGB Menu",submenu);
      glutAttachMenu(GLUT_RIGHT_BUTTON);
}
```

http://www.lighthouse3d.com/opengl/glut

Submenu example

```
void processMenuEvents(int option)
{
  switch (option)
   {
     case RED : red = 1.0; green = 0.0; blue = 0.0; break;
     case GREEN : red = 0.0; green = 1.0; blue = 0.0; break;
     case BLUE : red = 0.0; green = 0.0; blue = 1.0; break;
     case WHITE : red = 1.0; green = 1.0; blue = 1.0; break;
    }

  glutPostRedisplay();
}
```

http://glprogramming.com

Dynamic, Multiple Windows and Subwindows

```
int glutCreateWindow(char *name)

void glutDestroyWindow(int id)

void glutSetWindow(int id)
```

– Set current window. This lets you change its properties, e.g. size

```
void glutCreateSubWindow(int parent, int x, int y,
                         int width, int height)

void glutPostWindowRedisplay(int winid)
```

– Posts a redisplay for a particular window

– Menus are defined for specific windows

Subwindow Example

```
int mainWindow, subWindow1;
int main(int argc, char **argv)
{
        glutInit(&argc, argv);
        glutInitDisplayMode(GLUT_DEPTH | GLUT_DOUBLE | GLUT_RGBA);
        glutInitWindowPosition(100,100);
        glutInitWindowSize(w,h);
        mainWindow = glutCreateWindow("SnowMen from 3D-Tech");
                //keyboard stuff
                glutKeyboardFunc(processNormalKeys);
                // reshape function
                glutReshapeFunc(changeSize);
                // display and idle function
                glutDisplayFunc(renderScene);
                glutIdleFunc(renderSceneAll);
        subWindow1 = glutCreateSubWindow(mainWindow,
                        border,border,w-2*border, h/2 - border*3/2);
                // Must register a display func for each window
                glutDisplayFunc(renderScene1);
```