Input and Interaction

CS 537 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

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:
  
  ```c
  glutMouseFunc(mymouse)
  ```

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
  ```c
  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
  ```c
  glutDisplayFunc(mydisplay)
  ```
  identifies the function to be executed
- Every GLUT program must have a display callback

Posting redisplay

- 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
    ```c
    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
  - Call glutPostRedisplay at the end of all callback functions that should change the display
Animating a Display

- When we redraw the display through the display callback, we usually start by clearing the window
  - `glClearColor()`
  - 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()
    {
        glClearColor();
        /* 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();
}
``` 

Using globals

- The form/interface 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 */
    glutSwapBuffers();
}
``` 

Objectives

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

```c
void mymouse(GLint button, GLint state, GLint x, GLint y)
```
- Is called with the following information
  - 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

```c
void mouse(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);
}
```

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

```c
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);
}
```

```c
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;
    glutPostRedisplay();
}
```

Drawing squares at cursor location

```c
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);
}
```
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

• The cursor generates an entry event whenever it enters or leaves the OpenGL window
• The callback for this event is registered with `glutEntryFunc()`
  ```c
  void glutEntryFunc(void (*f) (int state))
  ```
• Event specifies state of entry
  ```c
  (GLUT_ENTERED, GLUT_LEFT)
  ```

Using the keyboard

```c
void glutKeyboardFunc(mykey)
void mykey(unsigned char key, int x, int y)
- Is called with ASCII code of key depressed and mouse location
  ```c
  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`
  ```c
  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
  ```c
  GLUT_ACTIVE_SHIFT
  GLUT_ACTIVE_CTRL
  GLUT_ACTIVE_ALT
  ```
  is depressed with `glutGetModifiers()`
```c
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 possibilities

The Reshape callback

```c
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

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

Timers

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

```c
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 + reinitialize timer
    glutPostRedisplay();
    glutTimerFunc(1000, timerColor, 0);
}
```

Redefining Callbacks

```c
// Callback function that is triggered after a specified number of milliseconds
void timerShape(int value){
    // change the shape after five seconds
    glutPostRedisplay();
    // Make viewport and window the same size
    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

```c
#define RGB_MENU 3
#define RED 1
#define GREEN 2
#define BLUE 3
#define WHITE 4

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

Menu actions

- Menu callback
  ```c
  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)`

Submenu example

```c
void createGLUTMenus() {
    int menu, submenu;
    menu = glutCreateMenu(processMenuEvents);
    glutAddMenuEntry("Red", RED);
    glutAddMenuEntry("Blue", BLUE);
    glutAddMenuEntry("Green", GREEN);
    submenu = glutCreateMenu(processMenuEvents);
    glutAddMenuEntry("Red", RED);
    glutAddMenuEntry("Blue", BLUE);
    glutAddSubMenu("RGB Menu", submenu);
    glutAttachMenu(GLUT_RIGHT_BUTTON);
    glutPostRedisplay();
}
```

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

Submenu example

```c
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

```c
int glutCreateWindow(char *name)
void glutDestroyWindow(int id)
int glutGetWindow()  // returns id of current window
void glutSetWindow(int id)  
  – Set current window. This lets you change its properties, e.g. size
  – OpenGL renders to the current window!
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
```

Displaying in Multiple Windows

- Each window has its own graphics context
- For each window set up a separate VAO, buffers and compiled shader programs
- Creating a window / setting its ID makes it current
- Subsequent OpenGL structures will be associated with current window
- Be sure that the correct window is current before executing its display function

Subwindow Example

```c
int mainWindow, subWindow1;
int main(int argc, char **argv)
{
  glutInit(&argc, argv);
  glutInitDisplayMode(GLUT_DEPTH | GLUT_DOUBLE | GLUT_RGBA);
  glutInitWindowPosition(100,100);
  mainWindow = glutCreateWindow("SnowMen from 3D-Tech");
  glutKeyboardFunc(processNormalKeys);
  glutReshapeFunc(changeSize);
  glutDisplayFunc(renderScene);
  glutIdleFunc(renderScene);
  subWindow1 = glutCreateSubWindow(mainWindow, border,border,w-2*border, h/2 - border*3/2);
  glutDisplayFunc(renderScene1);
  glutMainLoop();
}
```

Suggestions for HW3

- Structure of `main()`
- Structure of `init()`
- Structure of display callback function

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- Structure of `main()`
- Structure of `init()`
- Structure of display callback function
Suggestion for HW3

• Structure of idle function

// Do calculations needed to animate objects
// e.g. increment angle or time

glutPostWindowRedisplay(mainWindow);
glutPostWindowRedisplay(subWindow);
glutPostWindowRedisplay(window2);