Input, Interaction and Animation

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 WebGL

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
    - Position drift
    - Can get variable sensitivity
Logical Devices

- Consider the C and C++ code
  - C++: \( \text{cin} \gg x; \)
  - C: \( \text{scanf} \left( "\%d", \&x \right); \)
- 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

Animation

Callbacks

- Programming interface for event-driven input uses *callback functions* or event listeners
  - Define a callback for each event the graphics system recognizes
  - Browsers enter an event loop and respond to those events for which it has callbacks registered
  - The callback function is executed when the event occurs

Execution in a Browser

- Start with HTML file
  - Describes the page
  - May contain the shaders
  - Loads files
- Files are loaded asynchronously and JS code is executed
- Then what?
- Browser is in an event loop and waits for an event

onload Event

- What happens with our JS file containing the graphics part of our application?
  - All the "action" is within functions such as init() and render()
  - Consequently these functions are never executed and we see nothing
- Solution: use the onload window event to initiate execution of the init function
  - onload event occurs when all files read
  - window.onload = init;
Rotating Square

- Consider the four points

\[ (-\sin \theta, \cos \theta) \]
\[ (\cos \theta, \sin \theta) \]
\[ (-\cos \theta, -\sin \theta) \]
\[ (\sin \theta, -\cos \theta) \]

Animate display by rerendering with different values of \( \theta \)

Simple but Slow Method

```
for (var theta = 0.0; theta < thetaMax; theta += dtheta; {
    vertices[0] = vec2(Math.sin(theta), Math.cos(theta));
    vertices[1] = vec2(Math.sin(theta), -Math.cos(theta));
    vertices[3] = vec2(-Math.sin(theta), Math.cos(theta));
    gl.bufferSubData(…………………
    render();
})
```

Better Way

- Send original vertices to vertex shader
- Send \( \theta \) to shader as a uniform variable
- Compute vertices in vertex shader
- Render recursively/repeatedly

Render Function

```
var thetaLoc = gl.getUniformLocation(program, "theta");
function render() {
    gl.clear(gl.COLOR_BUFFER_BIT);
    gl.uniform1f(thetaLoc, theta);
    gl.drawArrays(gl.TRIANGLE_STRIP, 0, 4);
    render();
}
```

Vertex Shader

```
attribute vec4 vPosition;
uniform float theta;

void main() {
    gl_Position.x = cos(theta) * vPosition.x - sin(theta) * vPosition.y;
    gl_Position.y = sin(theta) * vPosition.x + cos(theta) * vPosition.y
    gl_Position.z = 0.0;
    gl_Position.w = 1.0;
}
```

Double Buffering

- Although we are rendering the square, it always goes into a buffer that is not displayed
- Browser uses double buffering
  - Always display front buffer
  - Rendering into back buffer
  - Need a buffer swap
- Prevents display of a partial rendering
Triggering a Buffer Swap

- Browsers refresh the display at ~60 Hz
  - redisplay of front buffer
  - not a buffer swap
- Trigger a buffer swap through an event
- Two options for rotating square
  - Interval timer
  - requestAnimFrame

Interval Timer

- Executes a function after a specified number of milliseconds
  - Also generates a buffer swap
- setInterval(render, interval);
- Note an interval of 0 generates buffer swaps as fast as possible
- Call setInterval() at end of render()

Interval Timer

- window.setInterval(function, interval);

- Calls a function or evaluates an expression at specified intervals (in milliseconds)
- Method will continue calling the function until clearInterval() is called, or the window is closed
- ID value returned by setInterval() is used as the parameter for the clearInterval() method

Add an Interval with setTimeout()

- Calls a function or evaluates an expression after a specified number of milliseconds

  function render()
  {
    gl.clear(gl.COLOR_BUFFER_BIT);
    theta += 0.1;
    gl.uniform1f(thetaLoc, theta);
    gl.drawArrays(gl.TRIANGLE_STRIP, 0, 4);
    setTimeout(function() { requestAnimFrame(render); }, 100);
  }

setTimeout()

- window.setTimeout(function, delay);

- Defers the invocation of a JavaScript function or the evaluation of a string of JavaScript code for delay milliseconds
- Executes code only once.
Working with Callbacks

Objectives

• Learn to build interactive programs using event listeners
  - Buttons
  - Menus
  - Mouse
  - Keyboard
  - Reshape

Adding a Button

• Let’s add a button to control the rotation direction for our rotating cube
• In the render function we can use a var direction which is true or false to add or subtract a constant to the angle

```
var direction = true; // global initialization
// in render()
if (direction) theta += 0.1;
else theta -= 0.1;
```

The Button

• In the HTML file
  `<button id="DirectionButton">Change Rotation Direction</button>`
  - Uses HTML button tag
  - id gives an identifier we can use in JS file
  - Text “Change Rotation Direction” displayed in button
• Clicking on button generates a click event
• Note we are using default style and could use CSS or jQuery to get a prettier button

Button Event Listener

• We still need to define the listener
  - no listener and the event occurs but is ignored
• Two forms for event listener in JS file

```
var myButton = document.getElementById("DirectionButton");
myButton.addEventListener("click", function() {
  direction = !direction;
});
```

onclick Variants

```
myButton.addEventListener("click", function() {
  if (event.button == 0) { direction = !direction; }
});
```

```
myButton.addEventListener("click", function() {
  if (event.shiftKey == true) { direction = !direction; }
});
```

```
<button onclick="direction = !direction"></button>
```
Controlling Rotation Speed

```javascript
var delay = 100;

function render()
{
  gl.clear(gl.COLOR_BUFFER_BIT);
  theta += 0.1;
  gl.uniform1f(thetaLoc, theta);
  gl.drawArrays(gl.TRIANGLE_STRIP, 0, 4);
  setTimeout(function() {requestAnimationFrame(render);}, delay);
}
```

Menus

- Use the HTML `select` element
- Each entry in the menu is an `option` element with an integer value returned by click event

```html
<select id="myMenu" size="3">
  <option value="0">Toggle Rotation Direction</option>
  <option value="1">Spin Faster</option>
  <option value="2">Spin Slower</option>
</select>
```

Menu Listener

```javascript
var m = document.getElementById("myMenu");
window.addEventListener("click", function() {
  switch (m.selectedIndex) {
    case 0:
      direction = !direction;
      break;
    case 1:
      delay /= 2.0;
      break;
    case 2:
      delay *= 2.0;
      break;
  }
});
```

Using keydown Event

```javascript
window.addEventListener("keydown", function() {
  switch (event.keyCode) {
    case 49: // '1' key
      direction = !direction;
      break;
    case 50: // '2' key
      delay /= 2.0;
      break;
    case 51: // '3' key
      delay *= 2.0;
      break;
  }
});
```

Don’t Know Unicode?

```javascript
window.onkeydown = function(event) {
  var key = String.fromCharCode(event.keyCode);
  switch (key) {
    case '1':
      direction = !direction;
      break;
    case '2':
      delay /= 2.0;
      break;
    case '3':
      delay *= 2.0;
      break;
  }
};
```

Slider Element

- Puts slider (type: range) on page
  - Give it an identifier
  - Give it minimum and maximum values
  - Give it a step size needed to generate an event
  - Give it an initial value
- Use `div` tag to put below canvas

```html
<div>
  speed <input id="slide" type="range" min="0" max="100" step="10" value="50" />
</div>
```
onchange Event Listener

document.getElementById("slide").onchange = function() { delay = event.srcElement.value; };
**CAD-like Example**

triangle_.html.js: first three mouse clicks define first triangle of triangle strip. Each succeeding mouse clicks adds a new triangle at end of strip. Colors are also defined for each vertex.

n.b. flatten() converts javascript 64-bit numbers into 32-bit numbers!

**Window Events**

- Events can be generated by actions that affect the canvas window
  - moving or exposing a window
  - resizing a window
  - opening a window
  - iconifying/deiconifying a window
- Note that events generated by other application that use the canvas can affect the WebGL canvas
  - There are default callbacks for some of these events

**Reshape Events**

- Suppose we use the mouse to change the size of our canvas
- Must redraw the contents
- Options
  - Display the same objects but change size
  - Display more or fewer objects at the same size
- Almost always want to keep proportions

**Reshape possibilities**

- Original
- Reshaped

**onresize Event**

- Size of new canvas is available through window.innerHeight and window.innerWidth
- Use innerHeight and innerWidth to change canvas.height and canvas.width
- Example (next slide): maintaining a square display

```javascript
window.onresize = function() {
    var min = innerWidth;
    if (innerHeight < min) {
        min = innerHeight;
    }
    if (min < canvas.width || min < canvas.height) {
        gl.viewport(0, canvas.height-min, min, min);
    }
};
```