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
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

- mouse
- trackball
- data glove
- 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 joystick 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.
• 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
• 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
  - Browser enters an event loop and responds to those events for which it has callbacks registered
  - The callback function is executed when the event occurs
Execution in a Browser

Diagram:
- Browser
- Web Server
- URL
- Web Page
- HTML, JS files
- JS Engine
- CPU/GPU
- Framebuffer
- Canvas

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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 \( \theta \)

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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
var thetaLoc = gl.getUniformLocation(program, "theta");

function render()
{
    gl.clear(gl.COLOR_BUFFER_BIT);
    theta += 0.1;
    gl.uniform1f(thetaLoc, theta);
    gl.drawArrays(gl.TRIANGLE_STRIP, 0, 4);
    render();
}
in vec2 aPosition;
uniform float theta;

void main()
{
   gl_Position.x = cos(theta) * aPosition.x - sin(theta) * aPosition.y;
   gl_Position.y = sin(theta) * aPosition.x + cos(theta) * aPosition.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
  
  ```javascript
  setInterval(render, interval);
  ```

• Note an interval of 0 generates buffer swaps as fast as possible

• Call `setInterval()` at end of `render()` in case interval has changed
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
requestAnimFrame()

- Tells the browser that you wish to perform an animation
- Animation function is called before the browser performs the next repaint
- Calls generally match the display refresh rate

```javascript
function render {
    gl.clear(gl.COLOR_BUFFER_BIT);
    theta += 0.1;
    gl.uniform1f(thetaLoc, theta);
    gl.drawArrays(gl.TRIANGLE_STRIP, 0, 4);
    window.requestAnimFrame(render);
}
```
Add an Interval with setTimeout()

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

```javascript
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);
}
```

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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

```javascript
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

```javascript
var myButton = document.getElementById("DirectionButton");

myButton.addEventListener("click", function() {
  direction = !direction;
});

document.getElementById("DirectionButton").onclick =
  function() {
    direction = !direction;
  };
```
onclick Variants

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

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

```html
<button onclick="direction = !direction"></button>
```
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() {requestAnimFrame(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>
```
var m = document.getElementById("mymenu");
m.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

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;
    }
});
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 0 <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; };
Position Input
Objectives

• Learn to use the mouse to give locations
  - Must convert from position on canvas to position in application

• Respond to window events such as reshapes triggered by the mouse
Window Coordinates

(0, 0)

(\(x_w, y_w\))

\((w - 1, h - 1)\)
Window to Clip Coordinates

\[(0, h) \rightarrow (-1, -1)\]
\[(w, 0) \rightarrow (1, 1)\]

\[x = -1 + \frac{2 \times x_w}{w}\]
\[y = -1 + \frac{2 \times (h - y_w)}{h}\]

\[(-1, -1, -1) \rightarrow (1, 1, 1)\]
Canvas specified in HTML file with size canvas.width x canvas.height

Returned window coordinates are event.clientX and event.clientY

// add a vertex to GPU for each click
canvas.addEventListener("click", function() {
    gl.bindBuffer(gl.ARRAY_BUFFER, vBuffer);
    var t = vec2(-1 + 2*event.clientX/canvas.width,
                 -1 + 2*(canvas.height-event.clientY)/canvas.height);
    gl.bufferSubData(gl.ARRAY_BUFFER,
                     "sizeof(vec2)"*index, flatten(t));
    index++;
});
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
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);
  }
};