Introduction to Computer Graphics with WebGL

Ed Angel

Professor Emeritus of Computer Science

Founding Director, Arts, Research, Technology and Science Laboratory

University of New Mexico

Input and Interaction

Ed Angel
Professor Emeritus of Computer Science,
University of New Mexico

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

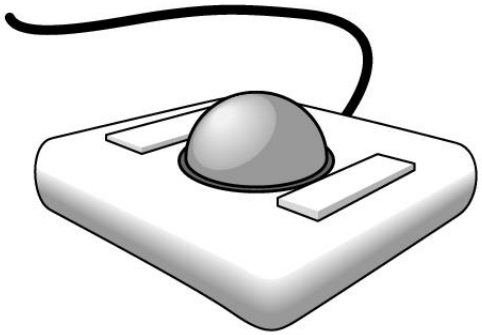
Graphical Input

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

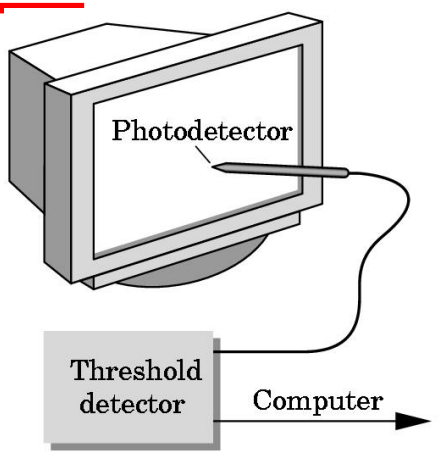
The University of New Mexico

Physical Devices

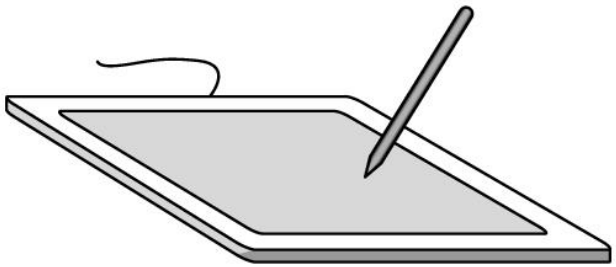
mouse



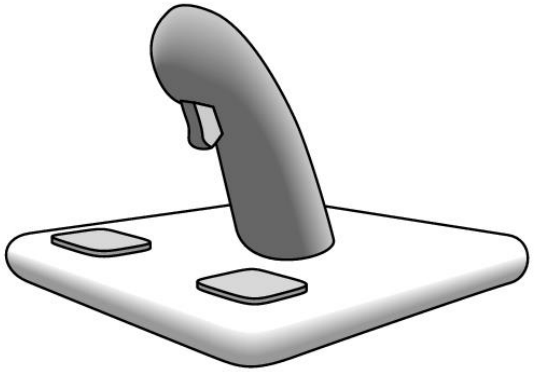
trackball



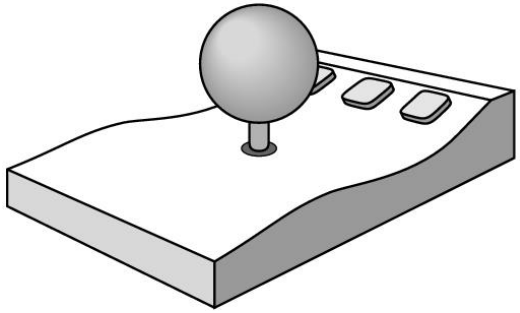
light pen



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

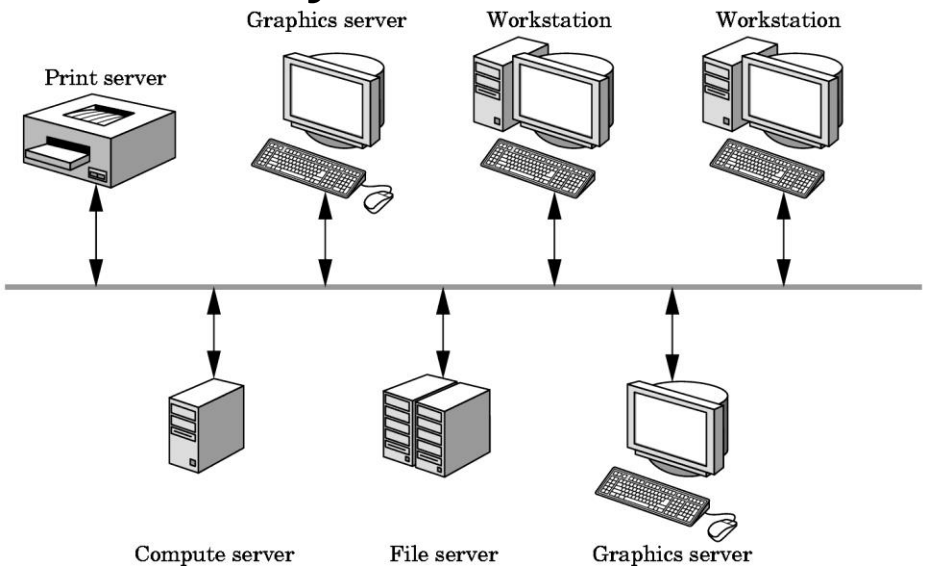
Graphical Logical Devices

- 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

The University of New Mexico

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



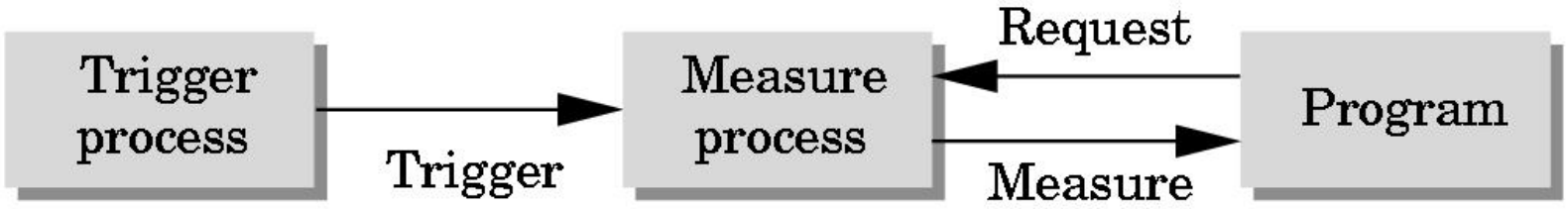
Input Modes

- 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

The University of New Mexico

Request Mode

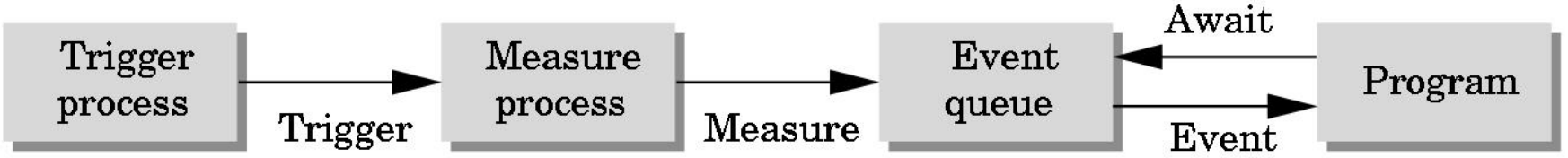
- Input provided to program only when user triggers the device
- Typical of keyboard input
  - Can erase (backspace), edit, correct until enter (return) key (the trigger) is depressed



The University of New Mexico

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

Introduction to Computer Graphics with WebGL

Ed Angel

Professor Emeritus of Computer Science

Founding Director, Arts, Research, Technology and Science Laboratory

University of New Mexico

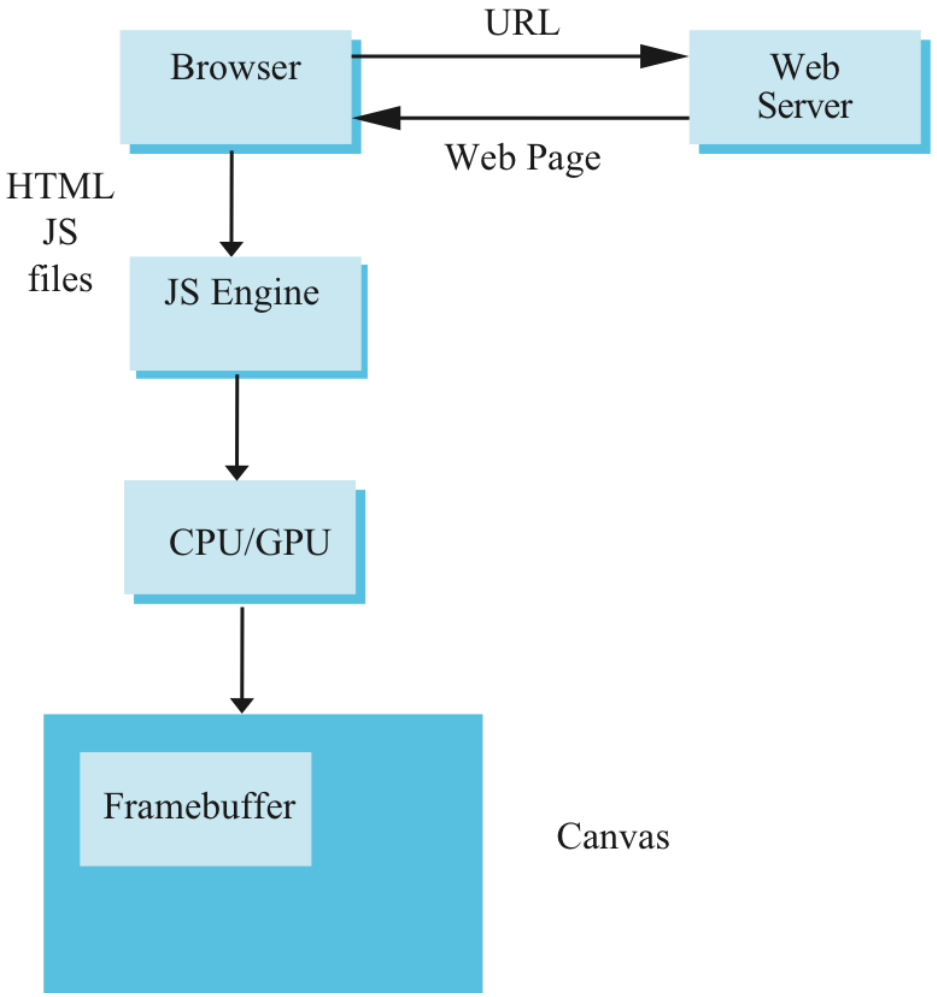
Animation

Ed Angel
Professor Emeritus of Computer Science,
University of New Mexico

Callbacks

- Programming interface for event-driven input uses *callback functions* or *event listeners*
  - Define a callback for each event the graphics system recognizes
  - Browsers 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



Execution in a Browser

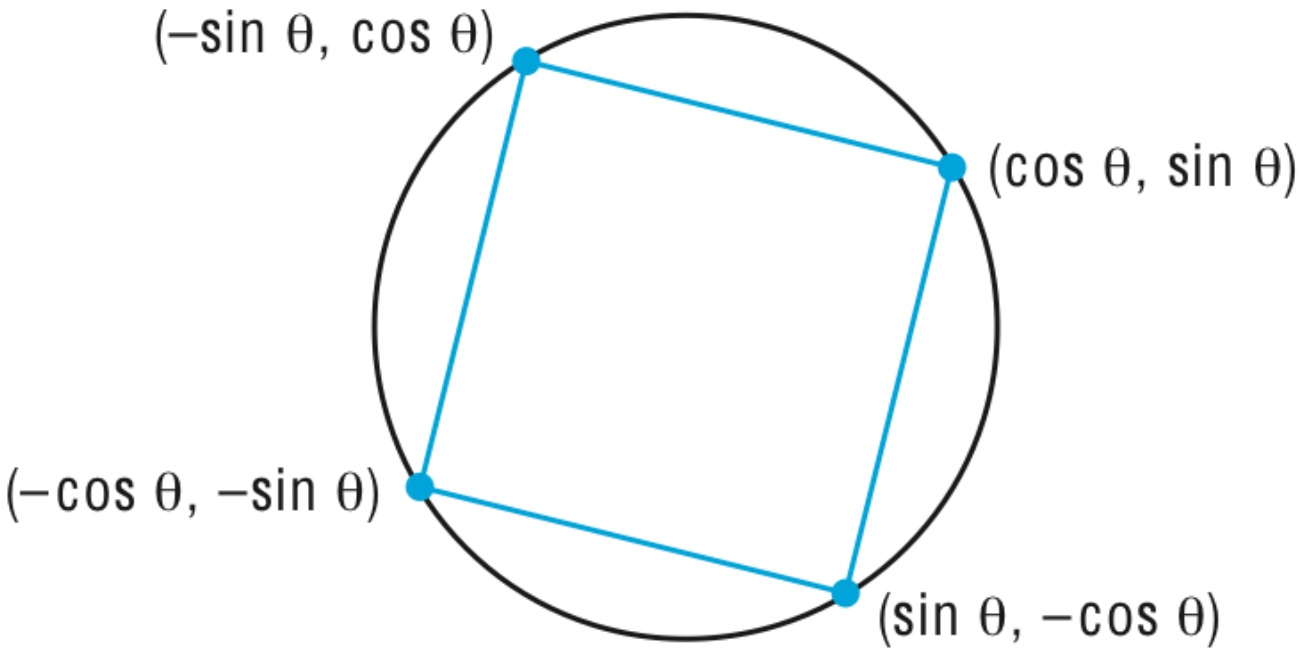
- Start with HTML file
  - Describes the page
  - May contain the shaders
  - Loads files
- Files are loaded asynchronously and JS code is executed
- Then what?
- Browser is in an event loop and waits for an event

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



Animate display by rerendering with different values of θ

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[2] = 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 θ to shader as a uniform variable
- Compute vertices in vertex shader
- Render recursively

Render Function

```
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();
}
```

Vertex Shader

```
attribute vec4 vPosition;
uniform float theta;

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

Double Buffering

- Although we are rendering the square, it always 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 though 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

requestAnimFrame

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

Add an Interval

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

Introduction to Computer Graphics with WebGL

Ed Angel

Professor Emeritus of Computer Science

Founding Director, Arts, Research, Technology and Science Laboratory

University of New Mexico

Working with Callbacks

Ed Angel
Professor Emeritus of Computer Science
University of New Mexico

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;
});
```

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

onclick Variants

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

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

```
<button onclick="direction = !direction"></button>
```