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

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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

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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

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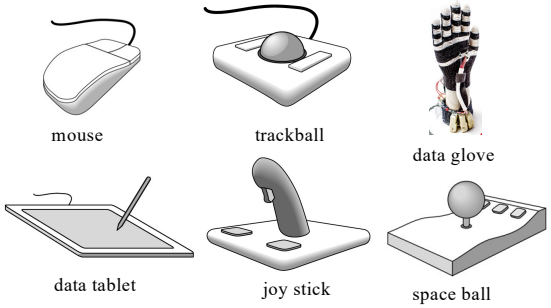
Physical Devices



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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

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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

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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

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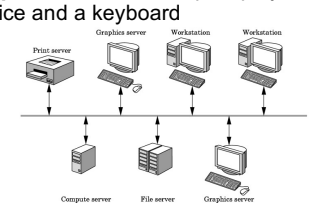
X Window Input

- 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



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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

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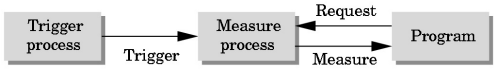
Request Mode

- 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



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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

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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

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Animation

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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

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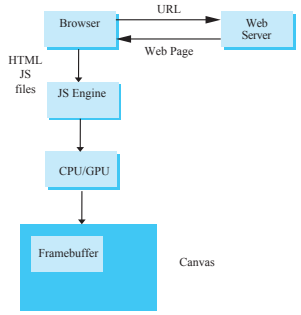
Execution in a Browser



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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

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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;

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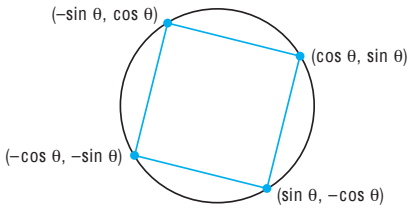
Rotating Square

- Consider the four points



Animate display by rerendering with different values of θ

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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();
}
```


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Better Way

- Send original vertices to vertex shader
- Send θ to shader as a uniform variable
- Compute vertices in vertex shader
- Render recursively/repeatedly

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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();
}
```


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Vertex Shader

```
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;
}
```


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Double Buffering

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

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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

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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() in case interval has changed

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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

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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

```
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);
}
```


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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);
}
```


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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.

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Working with Callbacks

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Objectives

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

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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;
```


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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

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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; };
```


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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>
```


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Controling Rotation Speed

```
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);
}
```


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Menus

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

```
<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>
```


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Menu Listener

```
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;}
});
```


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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;
  }
});
```


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Don't Know Unicode?

```
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;}
};
```


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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

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


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onchange Event Listener

```
document.getElementById("slide").onchange =
  function() { delay = event.srcElement.value; };
```


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Position Input

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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

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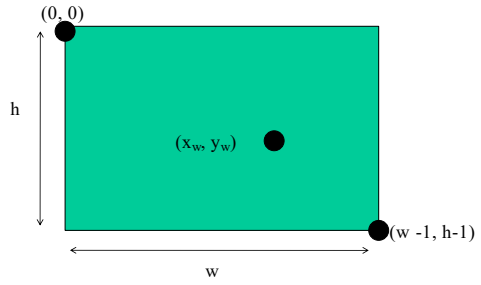
Window Coordinates



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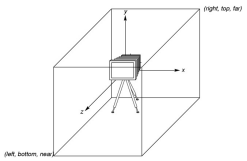
Window to Clip Coordinates

$$(0,h) \rightarrow (-1,-1)$$
$$(w,0) \rightarrow (1,1)$$
$$x = -1 + \frac{2 * x_w}{w}$$
$$y = -1 + \frac{2 * (h - y_w)}{h}$$



(-1,-1,-1) → (1,1,1)

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Returning Position from Click Event

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, 8*index, flatten(t));
  index++;
});                    //  8 == sizeof(vec2)
```


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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 'C'-style 32-bit numbers!

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Structure of HW3

- Initialize buffers for objects in onload function
  - Only create buffers once!
- Create a render function that draws all the objects in the scene
- The drawing uses global variables that define the properties of the objects
  - Orientation of red ellipse, Radius of circle
  - Square color, Ellipse color

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Structure of HW3 (cont.)

- Callback functions associated with the button, slider, menu and keystrokes
  - Change the associated object variables
  - Compute new vertices for the ellipse and circle
  - Generate new colors for the squares and ellipse
  - Update associated buffer data
  - Call the render function
- Render function
  - Bind needed buffers and enable vertex attributes
  - Calls appropriate drawArrays functions

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Structure of HW3 (cont.)

- For mouse click callback function
  - Base it on triangle.js
  - Get location of click
  - Append vertices and colors for new pentagon to appropriate buffers
  - Call the render function
- Render function
  - Call drawArrays in a loop for the number of pentagons
- Use HW2 shader programs

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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

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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

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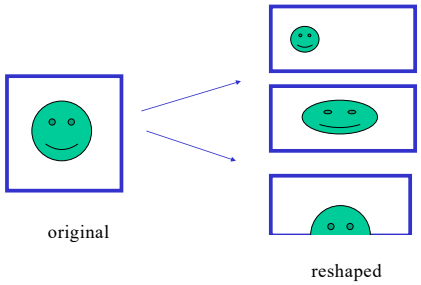
Reshape possiblities



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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

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Keeping Square Proportions

```
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);
  }
};
```


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