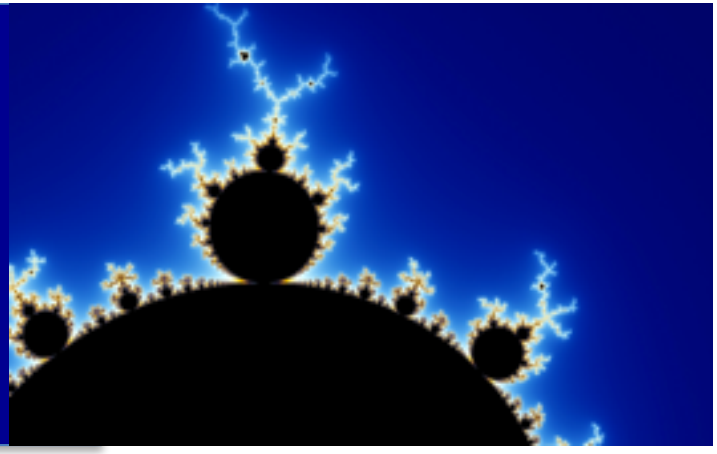
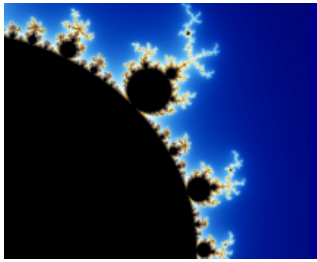
Computer Graphics

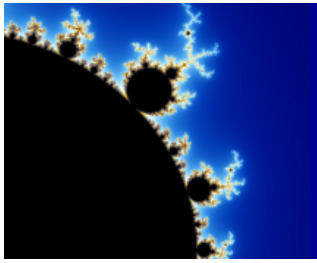


Interactivity



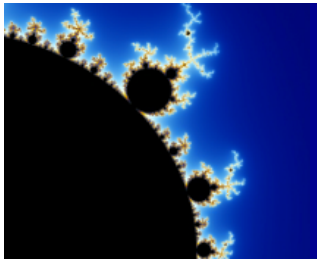
Callbacks

- 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

- 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

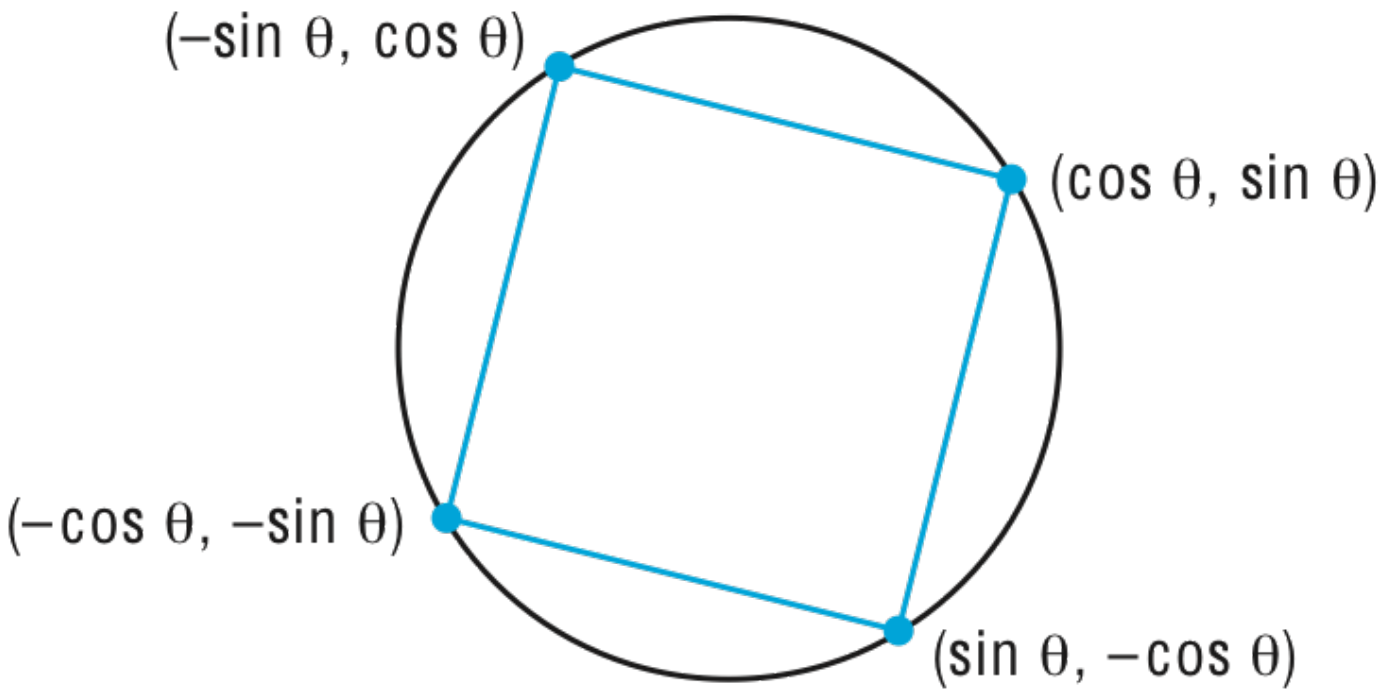


onload Event

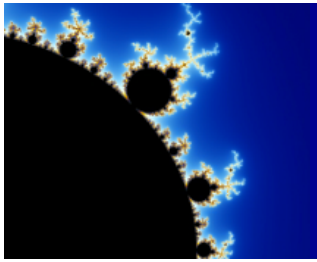
- What happens with our JS file containing the graphics part of our application?
  - All the “action” is within functions such as init() and render()
  - Consequently these functions are never executed and we see nothing
- Solution: use the onload window event to initiate execution of the init function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

Rotating Square

- Consider the four points

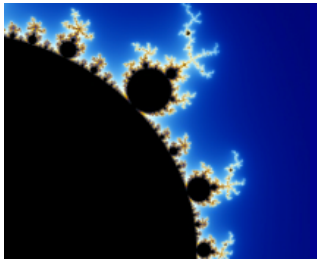


Animate display by rerendering with different values of θ



Simple but Slow Method

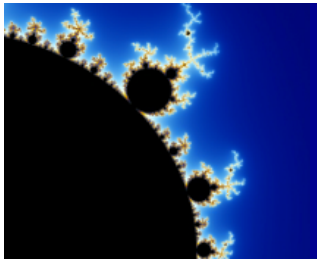
```
for(var theta = 0.0; theta <thetaMax; theta += dtheta; {

        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

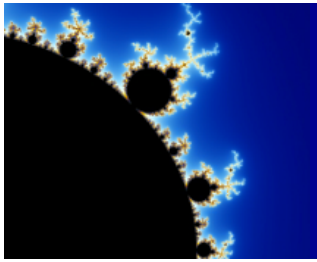
- Send original vertices to vertex shader

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



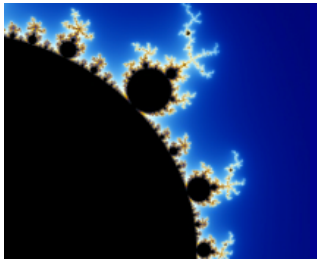
Render Function

```
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();
}
```



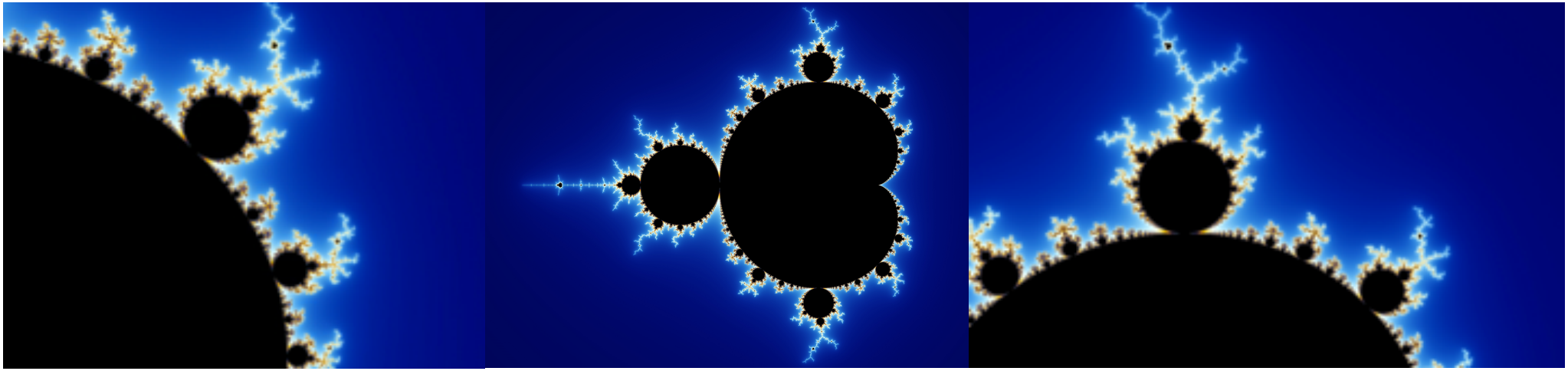
Vertex Shader

```
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;
}
```

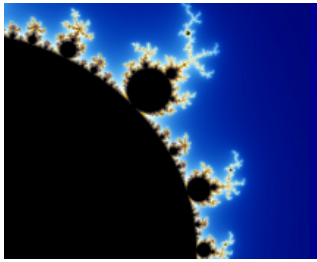


Double Buffering

- Although we are rendering the square, it always renders 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

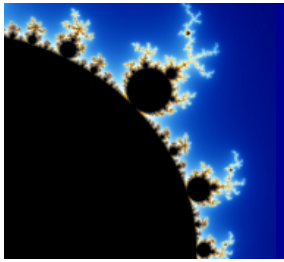


Animation



Triggering a Buffer Swap

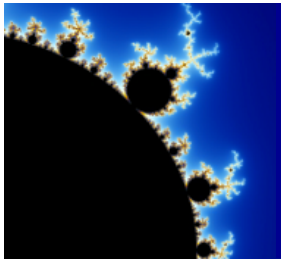
- Browsers refresh the display at ~60 Hz
  - redisplay of front buffer
  - not a buffer swap
- Trigger a buffer swap though an event
- Two options for rotating square
  - requestAnimFrame
  - Interval timer (setTimeout)



requestAnimFrame

- Requests the browser to display the rendering the next time it wants to refresh the display and then call the render function recursively.

```
function render {

    gl.clear(gl.COLOR_BUFFER_BIT);
    theta += 0.1;
    gl.uniform1f(thetaLoc, theta);
    gl.drawArrays(gl.TRIANGLE_STRIP, 0, 4);

    requestAnimFrame(render);
}
```



requestAnimationFrame

`requestAnimationFrame` `(func)`

Requests the function specified by *func* to be called on redraw (see Figure 4.9). This request needs to be remade after each callback.

Parameters	func	Specifies the function to be called later. The function takes a "time" parameter, indicating the timestamp of the callback.
Return value	Request id	

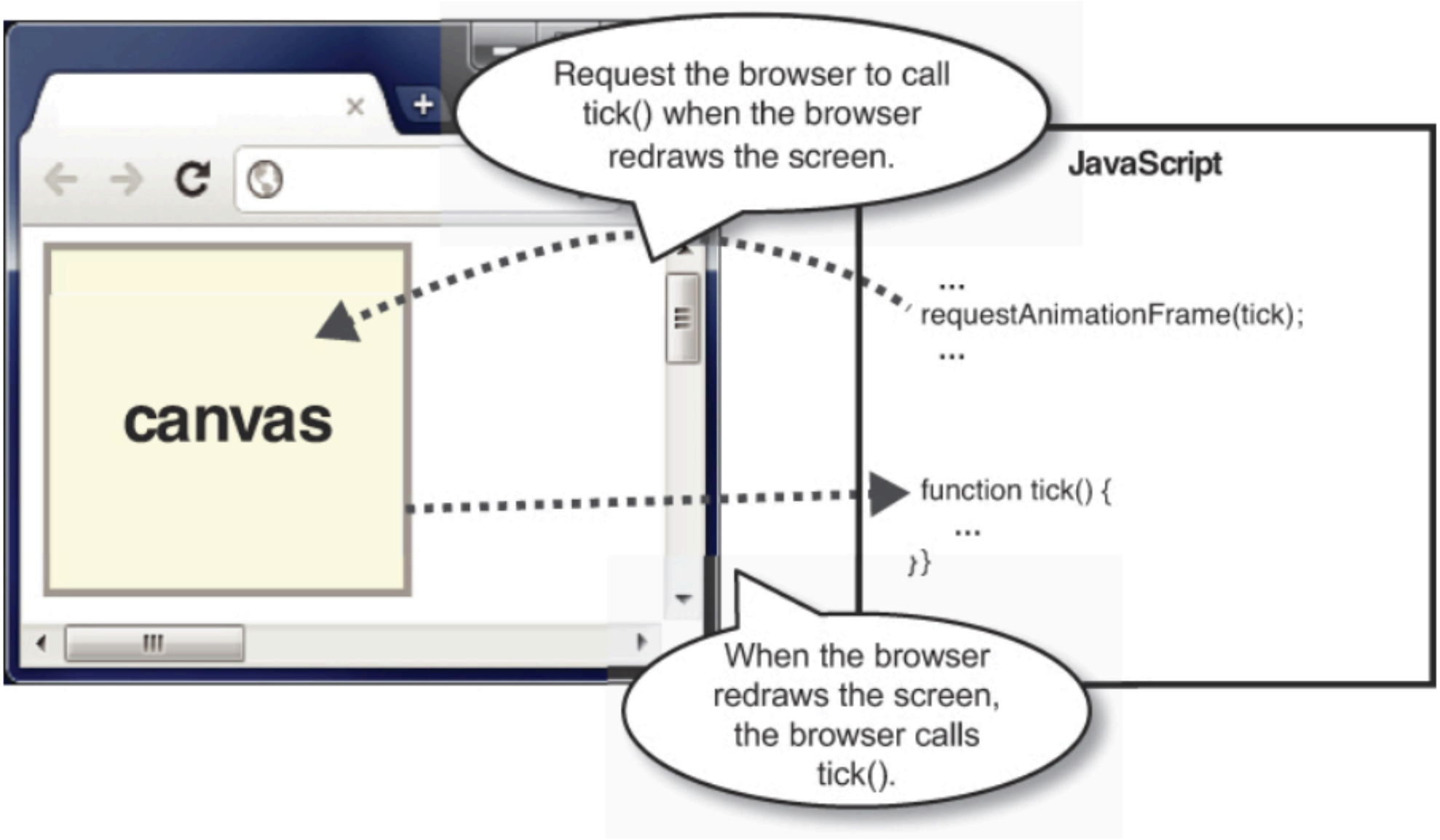
- func is only called when the tab to which it is defined is active
- By using this method, you avoid animation in inactive tabs and do not increase the load on the browser.

`cancelAnimationFrame` `(requestID)`

Cancel the function registered by `requestAnimationFrame()`.

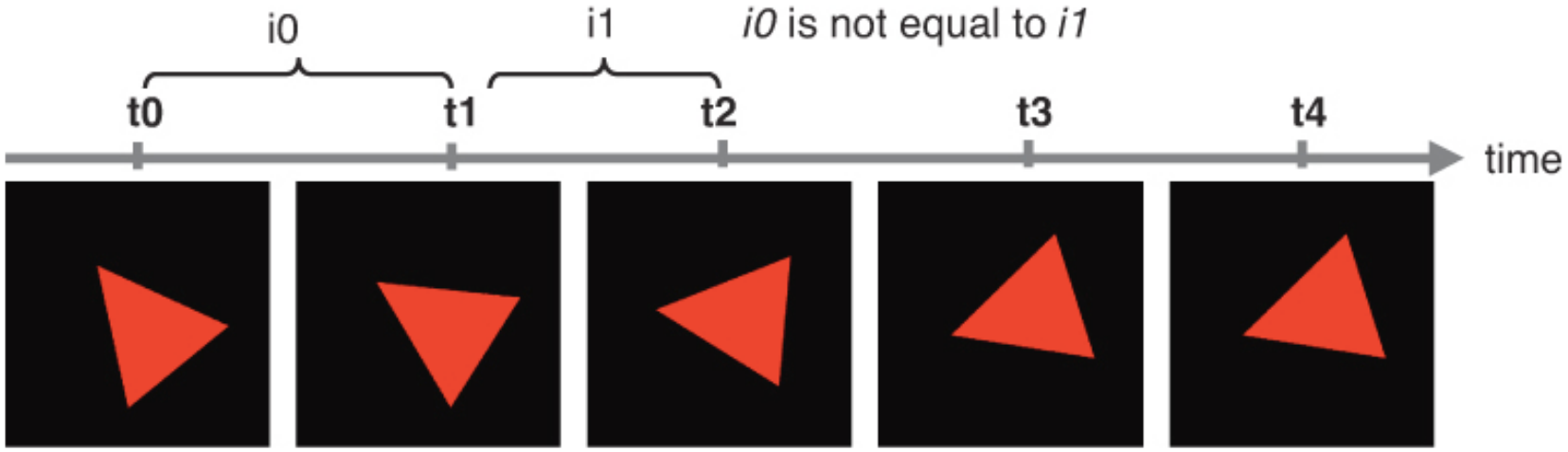
Parameter	requestID	Specifies the return value of `requestAnimationFrame()`.
Return value	None	

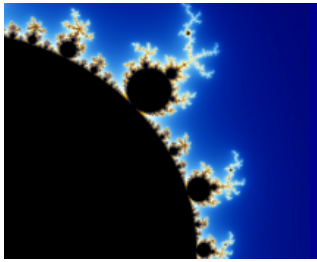
requestAnimationFrame(func)



Obtain a constant speed rotation

```
var g_last = Date.getTime();
function animate(angle) {
  // Calculate the elapsed time
  var now = Date.getTime();
  var elapsed = now - g_last;
  g_last = now;
  // Update the current rotation angle (adjusted by the elapsed time)
  var newAngle = angle + (ANGLE_STEP * elapsed) / 1000.0;
  return newAngle %= 360;
}
```



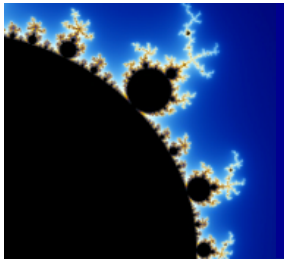


Interval Timer

- Executes a function after a specified number of milliseconds
  - Also generates a buffer swap

```
setTimeout(render, interval);
```

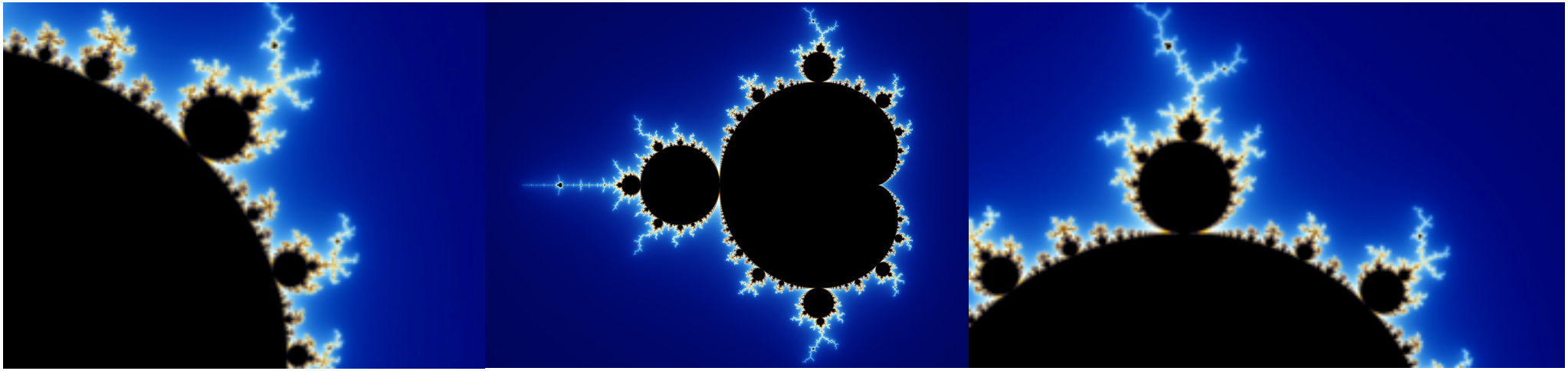
  - May not be smooth animation
- Note an interval of 0 generates buffer swaps as fast as possible



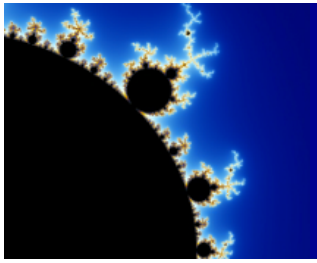
Add an Interval

- After the buffer in browser is ready for displaying the rendering, display it. Then, wait for 100 ms before calling the render function again.

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

                requestAnimFrame(render);
            },
            100
            );
}
```



Event Driven Interaction

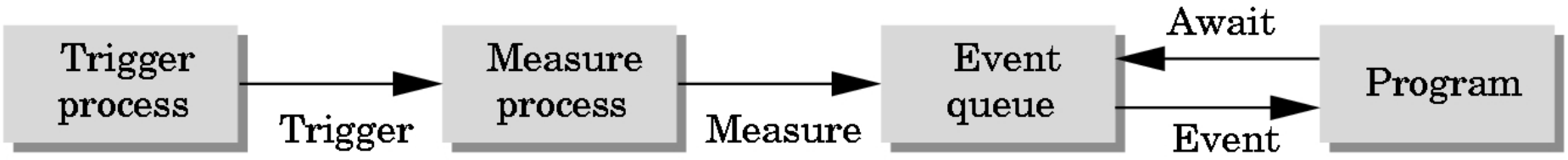


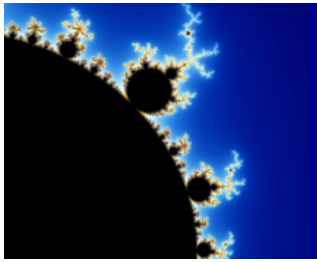
Input Modes

- 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

Event Mode

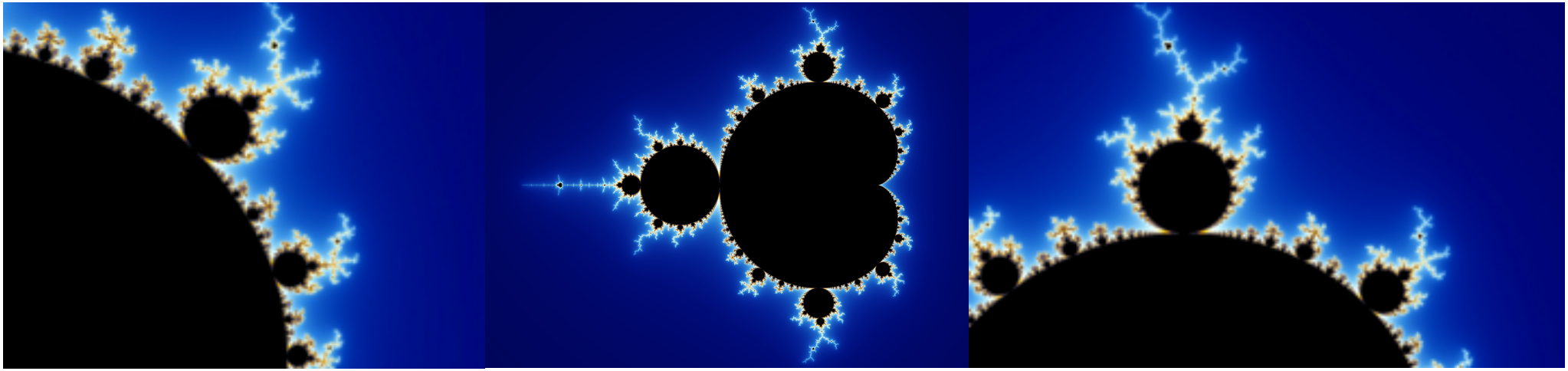
- Most systems have more than one input device, each of which can be triggered at an arbitrary time by a user
- Each trigger generates an *event* whose measure is put in an *event queue* which can be examined by the user program



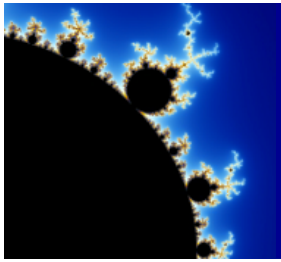


Event Types

- Window: resize, expose, iconify
- Mouse: click one or more buttons, slider, menu choice
- Motion: move mouse
- Keyboard: press or release a key
- Idle: nonevent
  - Define what should be done if no other event is in queue

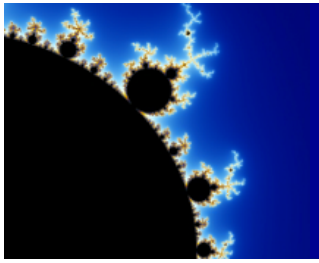


Working with Callbacks



Objectives

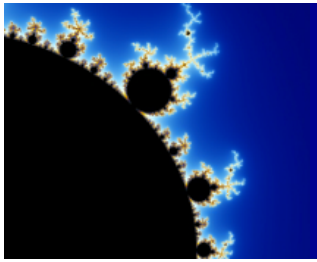
- Learn to build interactive programs using event listeners
  - Buttons
  - Menus
  - Mouse
  - Keyboard
  - Reshape



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;
```

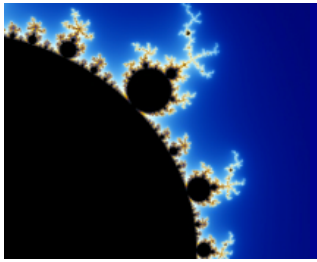


The Button

- 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

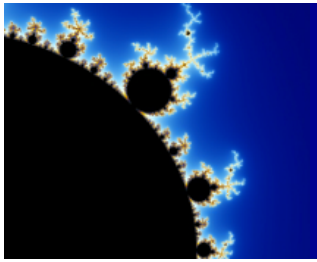


Button Event Listener

- 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;
                                    }
                           );
```

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

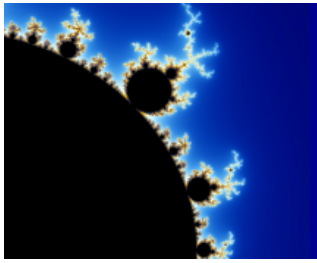


onclick Variants

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

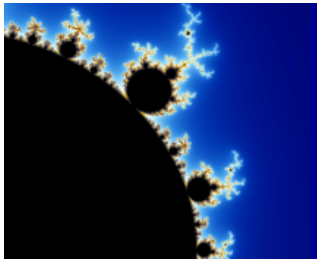
```
myButton.addEventListener("click", function() {
if (event.shiftKey == 0) { direction = !direction; }
});
```

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



Controlling Animation Speed

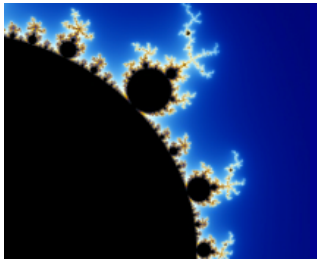
```
var delay = 100;
function render()
{
    setTimeout(
        function() {
            gl.clear(gl.COLOR_BUFFER_BIT);
            theta += (direction ? 0.1 : -0.1);
            gl.uniform1f(thetaLoc, theta);
            gl.drawArrays(gl.TRIANGLE_STRIP, 0, 4);
            requestAnimFrame(render);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

        delay
        );
}
```



Menus

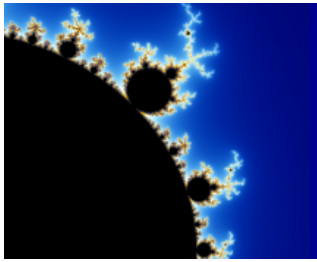
- Use the HTML select element
- Each entry in the menu is an option element with an integer value returned by click event

```
<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>
```



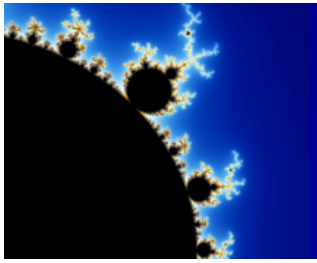
Menu Listener

```
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;
       }
});
```



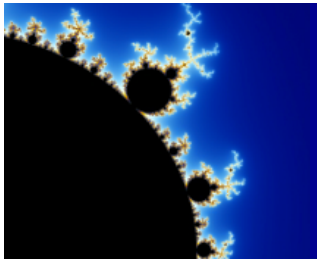
Using keydown Event

```
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;
   }
});
```



Don’t Know Unicode

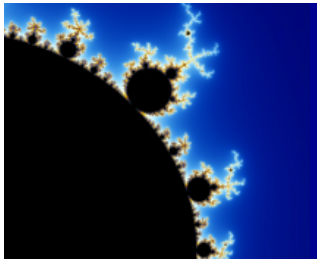
```
window.onkeydown = function(event) {

  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;
  }
};
```



Slider Element

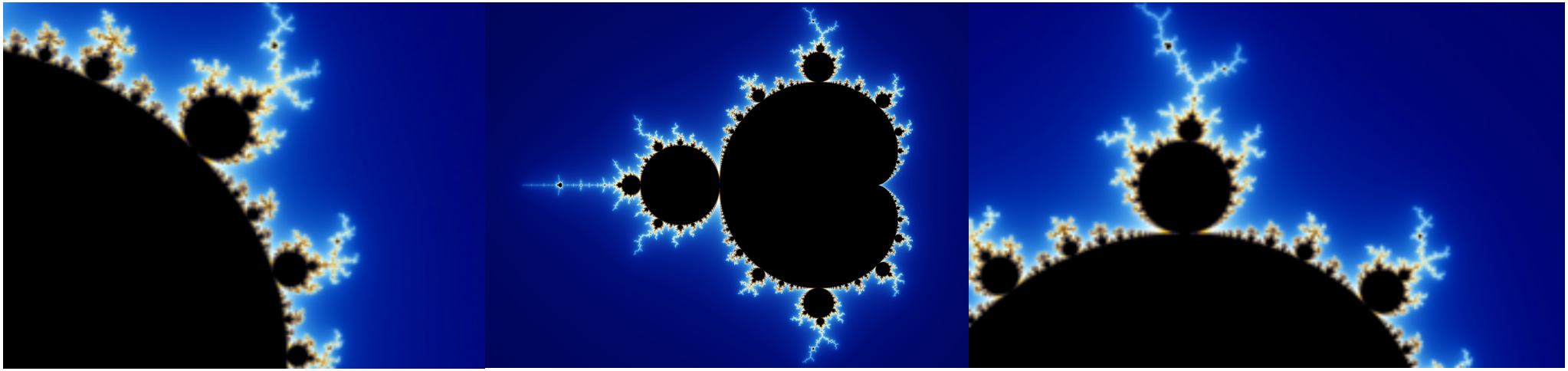
- Puts slider on page
  - Give it an identifier
  - Give it minimum and maximum values
  - Give it a step size needed to generate an event
  - Give it an initial value
- Use div tag to put below canvas

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

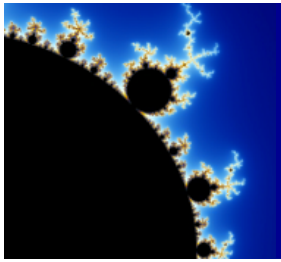


onchange Event Listener

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

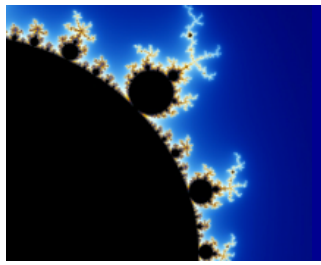


Position Input

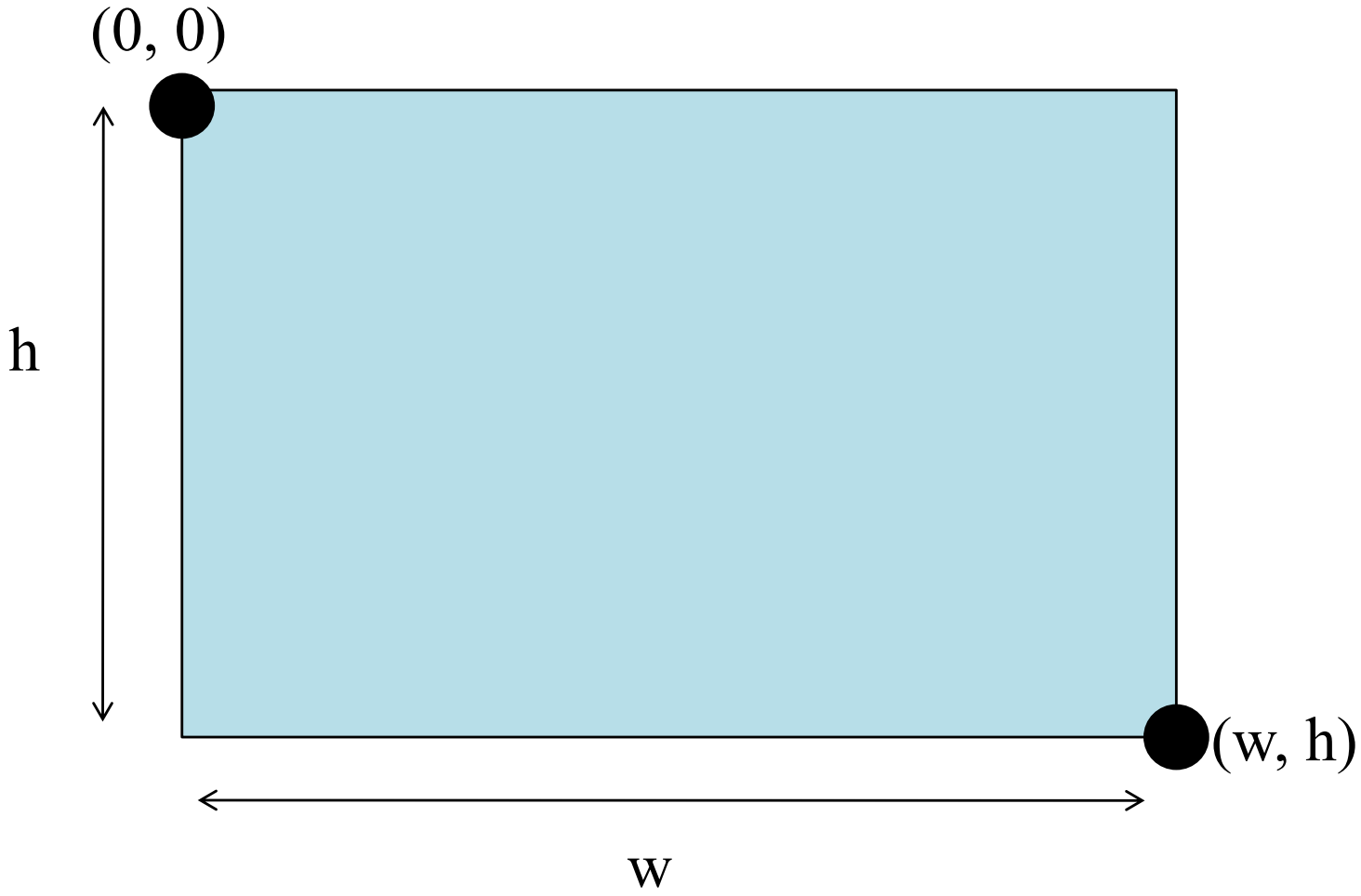


Objectives

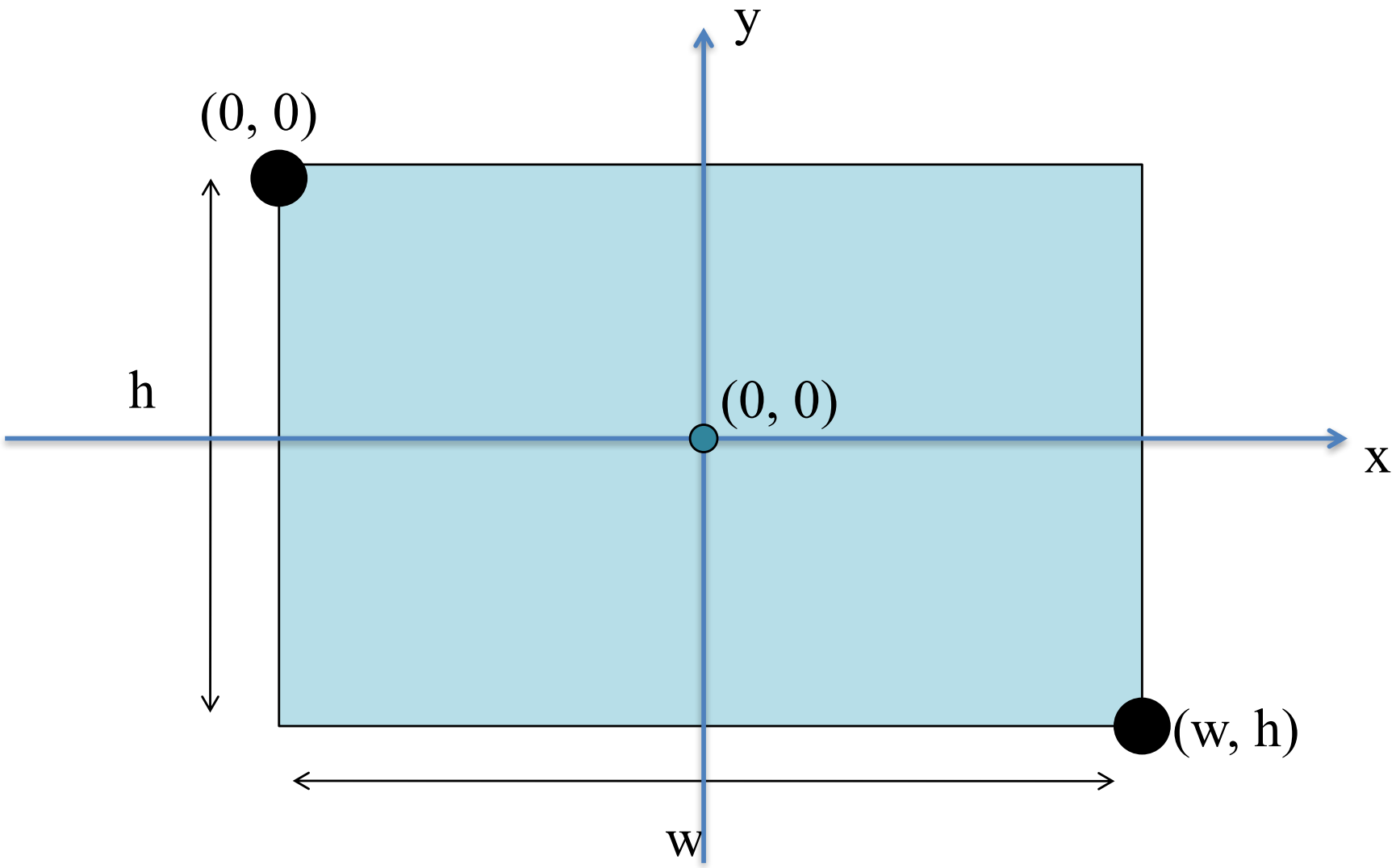
- Learn to use the mouse to give locations
  - Must convert from position on canvas to position in application
- Respond to window events such as reshapes triggered by the mouse



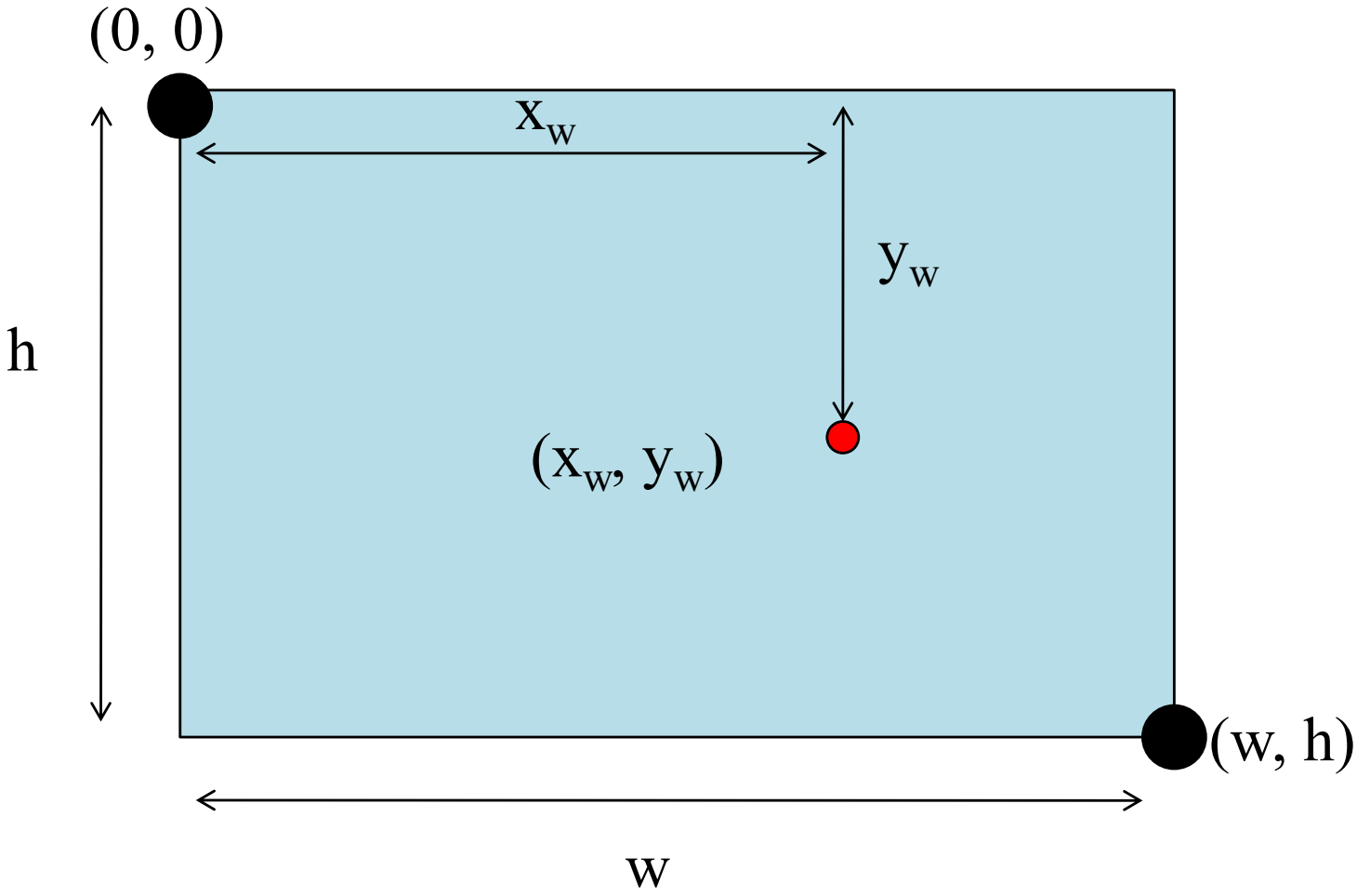
Window Coordinates



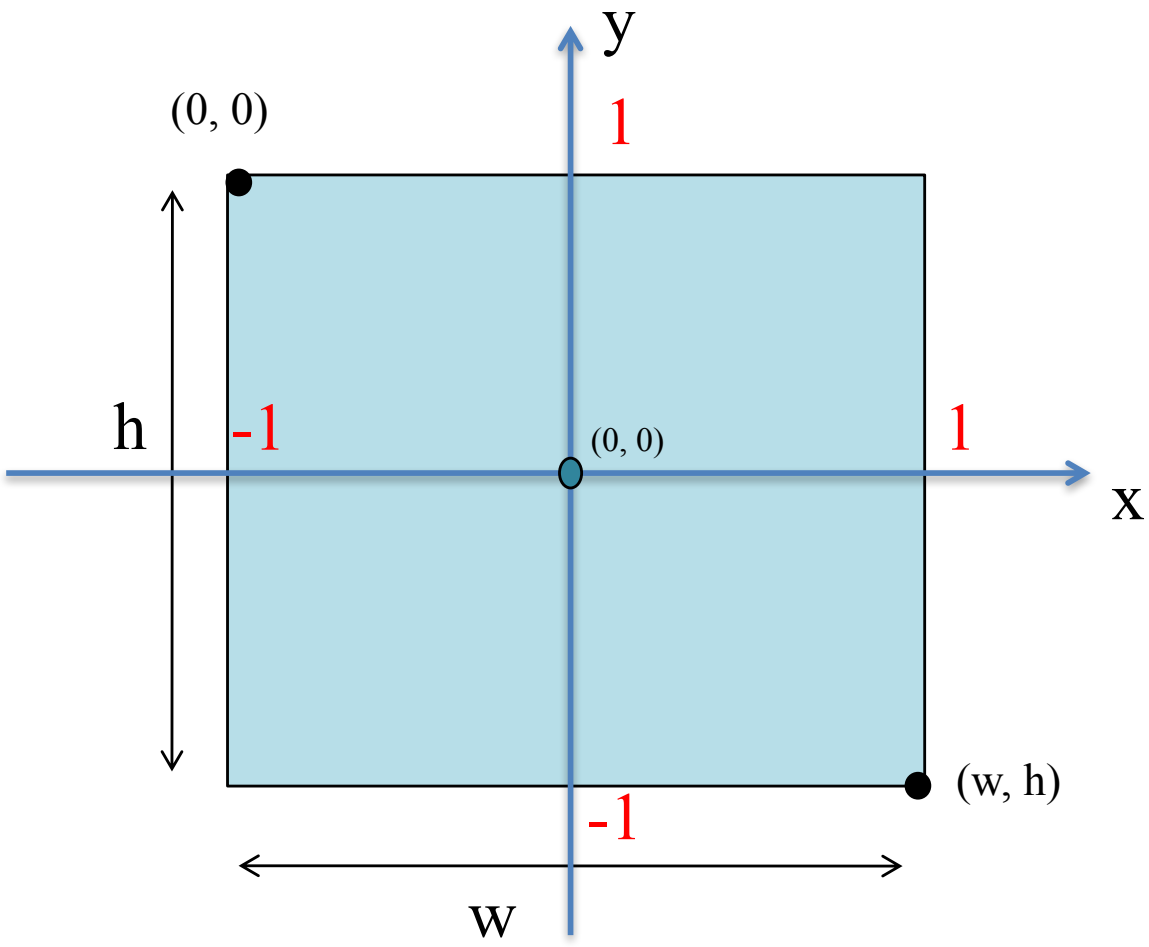
Clip Coordinates



Window Coordinates



Clip Coordinates

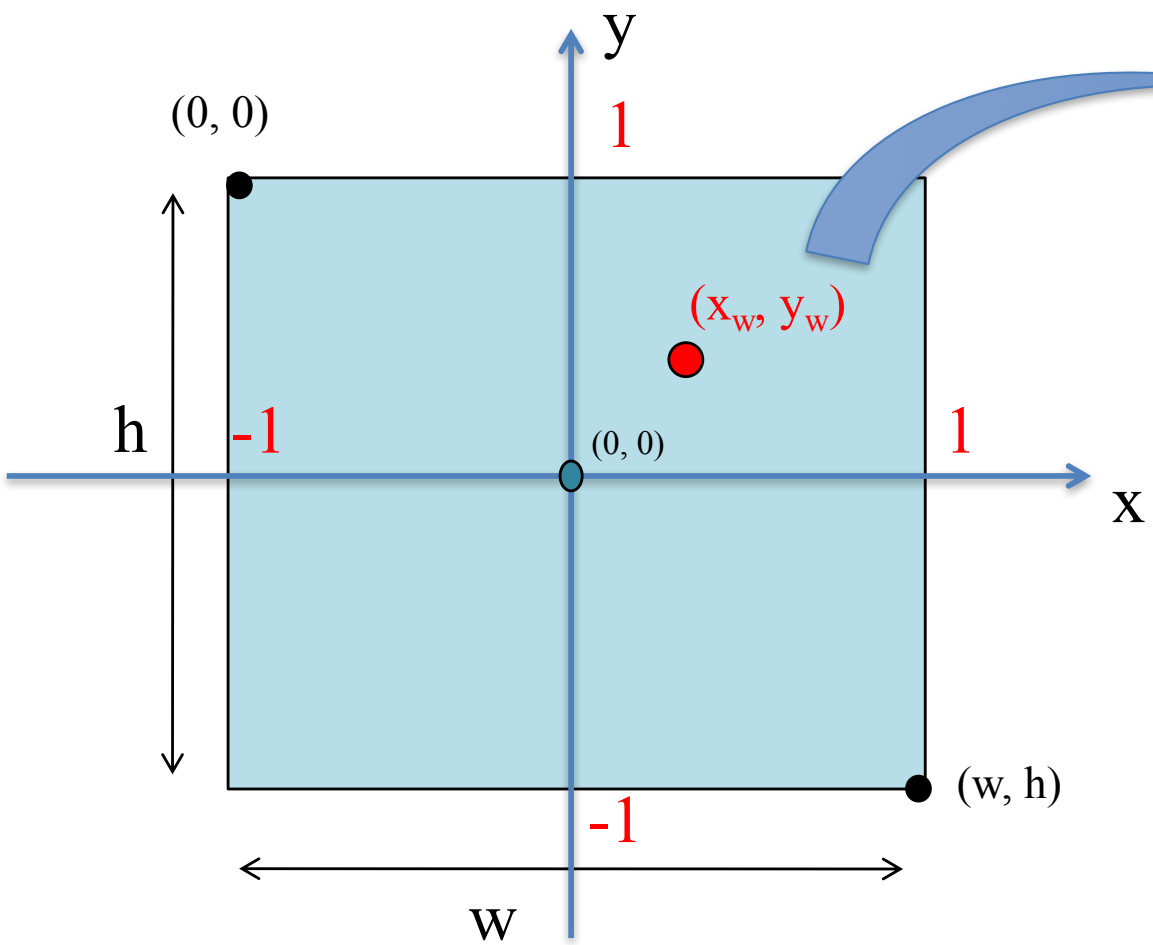


$$(0,0) \rightarrow (-1,1)$$
$$(0,h) \rightarrow (-1,-1)$$
$$(w,0) \rightarrow (1,1)$$
$$(w,h) \rightarrow (1,-1)$$

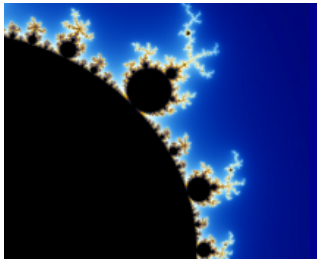
$$x = \frac{x_w * 2}{w} - 1$$

$$y = \frac{(h - y_w) * 2}{h} - 1$$

Clip Coordinates



$$\left(\frac{x_w * 2}{w} - 1, \quad \frac{(h - y_w) * 2}{h} - 1\right)$$

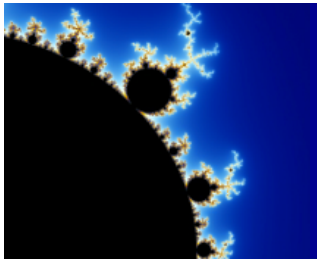


Returning Position from Click Event

Canvas specified in HTML file of size canvas.width x canvas.height

Returned window coordinates are event.clientX and event.clientY

```
// add a vertex to GPU for each click
// initialize index to the location where replacement is to occur
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, t);
        index++;
});
```



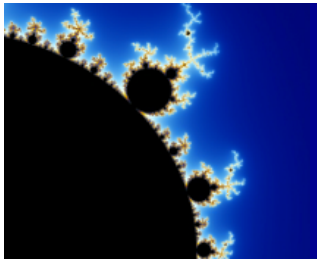
bufferSubData

- bufferSubData: update a subset of a buffer object's data store

```
void bufferSubData(GLenum target,
                   GLintptr offset,
                   const GLvoid * data);
```

- *target* - Specifies the target buffer object. The symbolic constant must be GL_ARRAY_BUFFER or GL_ELEMENT_ARRAY_BUFFER.
- *offset* - Specifies the offset into the buffer object's data store where data replacement will begin, measured in bytes.
- *data* - Specifies a pointer to the new data that will be copied into the data store.
- bufferSubData redefines some or all of the data store for the buffer object currently bound to *target*. Data starting at byte offset *offset*.

https://msdn.microsoft.com/en-us/library/Dn434079(v=VS.85).aspx



CAD-like Examples

square.html: puts a colored square at location of each mouse click

triangle.html: first three mouse clicks define first triangle of triangle strip. Each succeeding mouse clicks adds a new triangle at end of strip

cad1.html: draw a rectangle for each two successive mouse clicks

cad2.html: draws arbitrary polygons