Controling Rotation Speed

```
var delay = 100;

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

Introduction to Computer Graphics with WebGL

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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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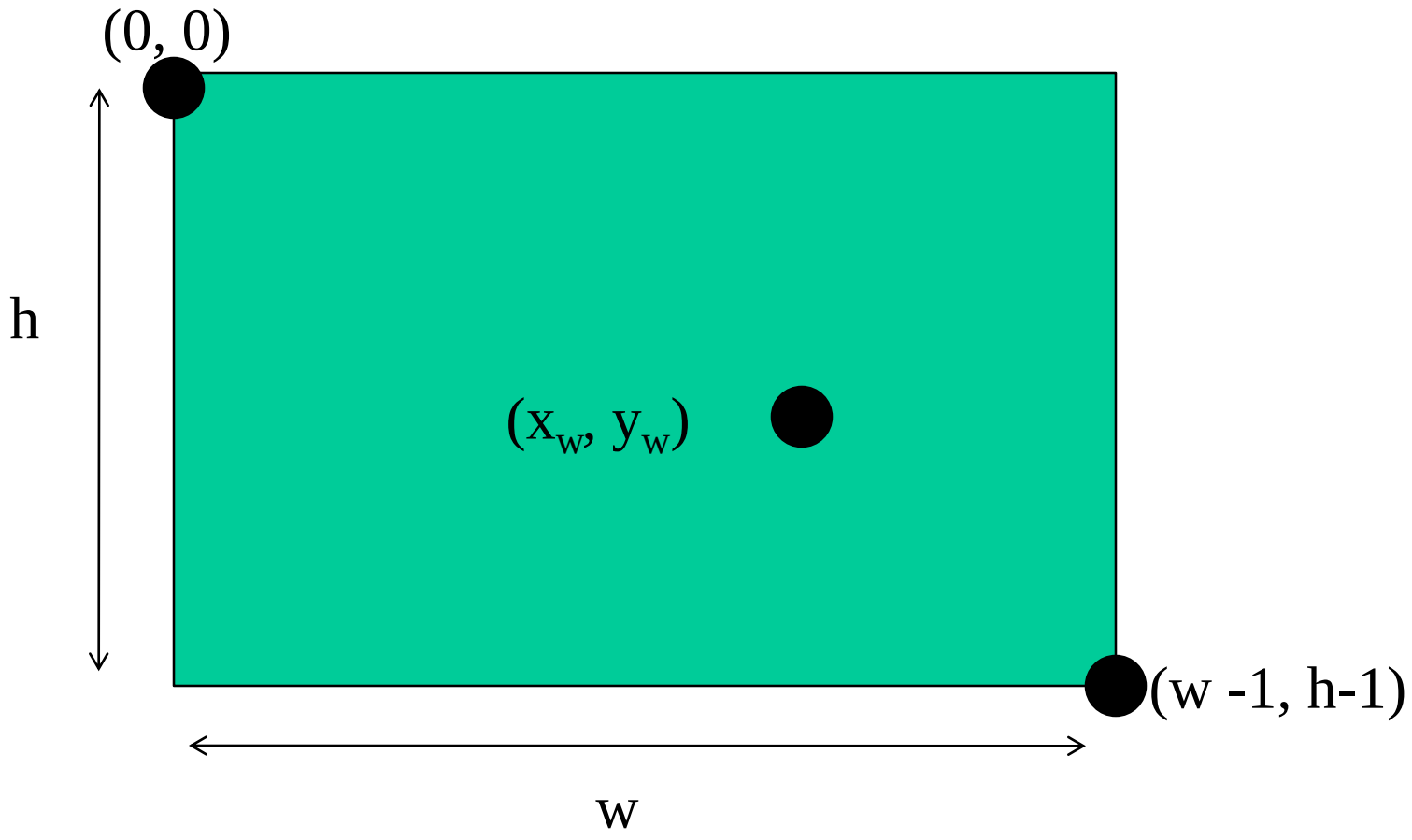
Window Coordinates



Window to Clip Coordinates

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

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

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

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

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
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++;
});
```

CAD-like Examples

www.cs.unm.edu/~angel/WebGL/7E/03

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

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 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

onresize Event

- Returns 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

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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Picking

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Objectives

- How do we identify objects on the display
- Overview three methods
  - selection
  - using an off-screen buffer and color
  - bounding boxes

Why is Picking Difficult?

- Given a point in the canvas how do map this point back to an object?
- Lack of uniqueness
- Forward nature of pipeline
- Take into account difficulty of getting an exact position with a pointing device

Selection

- Supported by fixed function OpenGL pipeline
- Each primitive is given an id by the application indicating to which object it belongs
- As the scene is rendered, the id's of primitives that render near the mouse are put in a hit list
- Examine the hit list after the rendering

Selection

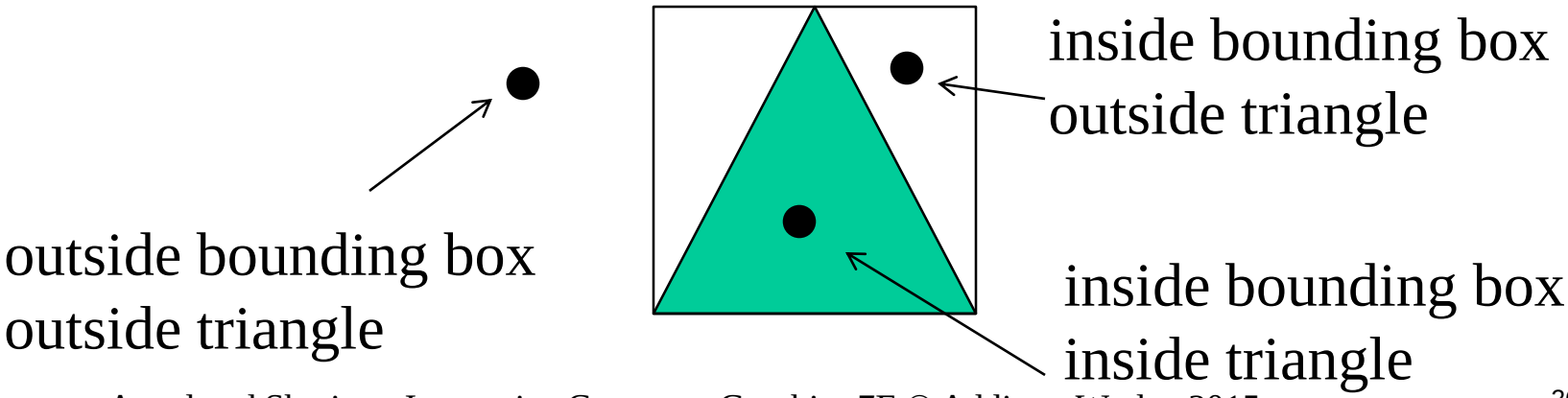
- Implement by creating a window that corresponds to small area around mouse
  - We can track whether or not a primitive renders to this window
  - Do not want to display this rendering
  - Render off-screen to an extra color buffer or user back buffer and don't do a swap
- Requires a rendering which puts depths into hit record
- Possible to implement with WebGL

Picking with Color

- We can use gl.readPixels to get the color at any location in window
- Idea is to use color to identify object but
  - Multiple objects can have the same color
  - A shaded object will display many colors
- Solution: assign a unique color to each object and render off-screen
  - Use gl.readPixels to get color at mouse location
  - Use a table to map this color to an object

Picking with Bounding Boxes

- Both previous methods require an extra rendering each time we do a pick
- Alternative is to use a table of (axis-aligned) bounding boxes
- Map mouse location to object through table



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Geometry

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Objectives

- Introduce the elements of geometry
  - Scalars
  - Vectors
  - Points
- Develop mathematical operations among them in a coordinate-free manner
- Define basic primitives
  - Line segments
  - Polygons

Basic Elements

- Geometry is the study of the relationships among objects in an n-dimensional space
  - In computer graphics, we are interested in objects that exist in three dimensions
- Want a minimum set of primitives from which we can build more sophisticated objects
- We will need three basic elements
  - Scalars
  - Vectors
  - Points

Coordinate-Free Geometry

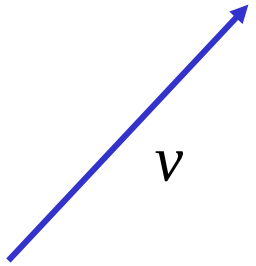
- When we learned simple geometry, most of us started with a Cartesian approach
  - Points were at locations in space **p**=(x,y,z)
  - We derived results by algebraic manipulations involving these coordinates
- This approach was nonphysical
  - Physically, points exist regardless of the location of an arbitrary coordinate system
  - Most geometric results are independent of the coordinate system
  - Example Euclidean geometry: two triangles are identical if two corresponding sides and the angle between them are identical

Scalars

- Need three basic elements in geometry
  - Scalars, Vectors, Points
- Scalars can be defined as members of sets which can be combined by two operations (addition and multiplication) obeying some fundamental axioms (associativity, commutivity, inverses)
- Examples include the real and complex number systems under the ordinary rules with which we are familiar
- Scalars alone have no geometric properties

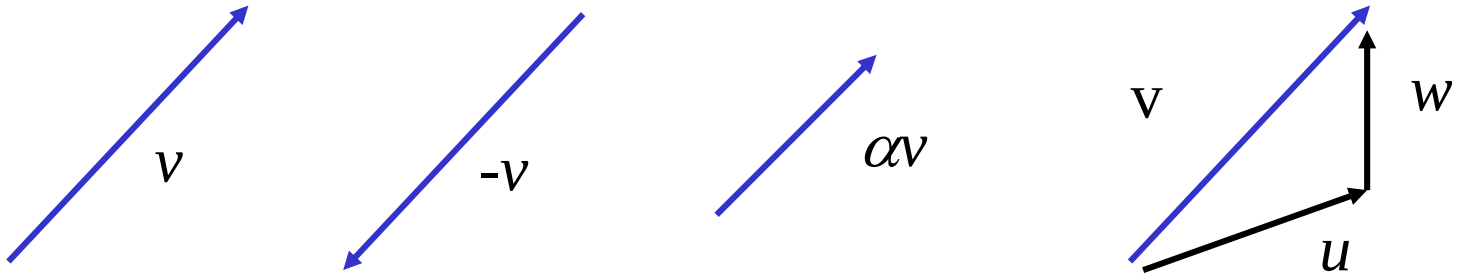
Vectors

- Physical definition: a vector is a quantity with two attributes
  - Direction
  - Magnitude
- Examples include
  - Force
  - Velocity
  - Directed line segments
    - Most important example for graphics
    - Can map to other types



Vector Operations

- Every vector has an inverse
  - Same magnitude but points in opposite direction
- Every vector can be multiplied by a scalar
- There is a zero vector
  - Zero magnitude, undefined orientation
- The sum of any two vectors is a vector
  - Use head-to-tail axiom



Linear Vector Spaces

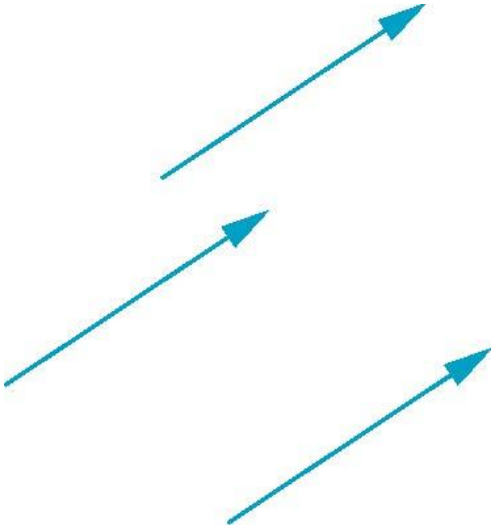
- Mathematical system for manipulating vectors
- Operations
  - Scalar-vector multiplication $u=\alpha v$
  - Vector-vector addition: $w=u+v$
- Expressions such as

  $v=u+2w-3r$

Make sense in a vector space

Vectors Lack Position

- These vectors are identical
  - Same length and magnitude



- Vectors spaces insufficient for geometry
  - Need points

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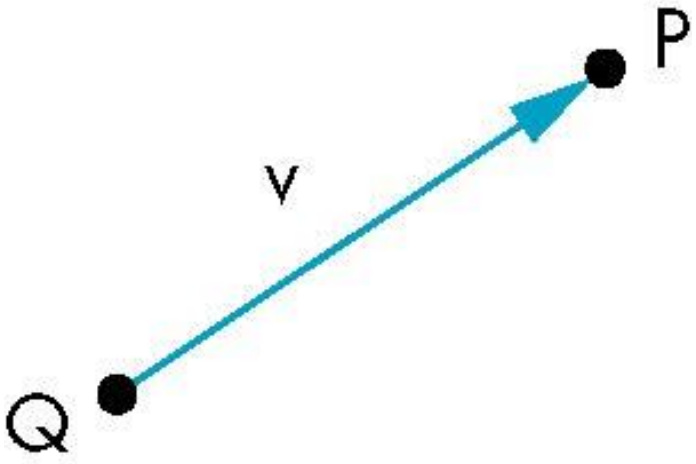
Points

- Location in space
- Operations allowed between points and vectors
  - Point-point subtraction yields a vector
  - Equivalent to point-vector addition



$v = P - Q$

$P = v + Q$

Affine Spaces

- Point + a vector space
- Operations
  - Vector-vector addition
  - Scalar-vector multiplication
  - Point-vector addition
  - Scalar-scalar operations
- For any point define
  - $1 \bullet P = P$
  - $0 \bullet P = \mathbf{0}$ (zero vector)

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Lines

- Consider all points of the form
  - $P(\alpha)=P_0 + \alpha \mathbf{d}$
  - Set of all points that pass through P_0 in the direction of the vector $\mathbf{d}$