AssemblyScript Asteroids

WebGL bindings

I am currently working on WebGL bindings for the AssemblyScript language. These bindings are a work in progress, and the entire WebGL has not yet been implemented in AssemblyScript. If you would like to look at the status of the AssemblyScript WebGL bindings project, please take a look at the following GitHub URL:

https://github.com/battlelinegames/ASWebGLue

I do not currently have an npm package for this project. I want to wait until the bindings are closer to completion. If you would like to use the WebGL bindings for your project, you will need to include the ASWebGLue.js and webgl.asc files in your project and import them as modules into your JavaScript and AssemblyScript code.

ASWebGLue.js

ASWebGLue.js is the JavaScript glue code file. It adds functions to the import object passed to the WebAssembly module. It also adds array data to track JavaScript objects required by WebGL. When AssemblyScript code makes function calls, the WebAssembly passes integer indexes to the JavaScript functions. The code uses these as indexes into an array that tracks the JavaScript object so that the code can pass it to WebGL. For example, when AssemblyScript creates a WebGL program object, it receives a number, an index into the programArray. Any function call to WebGL that requires a program object will pass this integer to the JavaScript glue code.

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/ASWebGLue.js

webgl.asc

The webgl.asc file contains all of the function declarations for the imported JavaScript glue code. These functions correspond with WebGL functions in JavaScript and allow you to make WebGL calls from AssemblyScript.

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/webgl.asc

Asteroids Game Code

The AssemblyScript WebGL bindings are not complete, but they are ready for some simple game code. The first game I wrote to begin testing the AssemblyScript WebGL binding code is a simple clone of the early Atari game Asteroids. The game is not fully featured but intended to demonstrate one type of game written using the bindings as they exist in September of 2020. I plan to fully flesh out and test WebGL in

AssemblyScript over the next few months. This is a code walkthrough of the version of this game available on github: https://github.com/battlelinegames/AssemblyScriptAsteroids. It was originally intended as a tutorial, but became an in depth explanation of the code as of 10/1/2020. My goal is to create a series of AssemblyScript WebGL tutorials and make them available at https://embed.com/wasm/. You can play the game online at https://embed.com/wasm/asteroid/. If you have any questions or comments on the code or this document, please contact me on twitter: https://twitter.com/battagline (@battagline) or on the AssemblyScript discord channel: https://discord.gg/assemblyscript. Special thanks to @torch2424 (Aaron Turner) for his help and the awesome music and sound for the game!

AsteroidsGame.js

The WebAssembly module compiled by AssemblyScript must be loaded and initialized using the WebGL glue code in the *ASWebGLue.js* file. This JavaScript file imports the `initASWebGLue` and `ASWebGLReady` functions from *ASWebGLue.js*. It creates a `last_time` variable used for tracking the time between frame renders. The `exports` object will contain all of the functions exported by the WASM module. Here is the code at the beginning of the file:

```
import { initASWebGLue, ASWebGLReady } from './ASWebGLue.js';

// The last_time variable is used to track the time between frame renders.
var last_time = 0;

// The exports object contains the functions exported from the WASM module
var exports = {};
```

The next batch of variables are booleans set to the state of the keys pressed in the game. These are the left, right, up, and down arrow keys as well as the space bar:

```
var leftKeyPress = false;
var rightKeyPress = false;
var upKeyPress = false;
var downKeyPress = false;
var spaceKeyPress = false;
```

The next group of variables will be used as `Audio` objects later in the game.

```
// The Audio objects
var song;❶
var laser;❷
var explosion;❸
```

The three lines above are the global variables that will hold Audio objects. These are for the `song`❶ sound, `laser`❷ sound, and `explosion`❸ sound. The `song` will play in a loop, and the other sounds will play when the player fires a `laser` or destroys an asteroid❸.

After defining the audio variables, I define a function capturing the `keydown` event. This function sets the `keypress` flags we defined earlier. At the end of this function, it plays the song loop if it is not currently playing. That code starts up the sound loop when the player presses a key for the first time.

```
document.addEventListener('keydown', (event) => {❶
  if (event.code == 'ArrowLeft') {❷
    leftKeyPress = true;
  }
  if (event.code == 'ArrowUp') {❸
    upKeyPress = true;
  }
  if (event.code == 'ArrowRight') {❹
    rightKeyPress = true;
  }
  if (event.code == 'ArrowDown') {❺
    downKeyPress = true;
  }
  if (event.code == 'Space') {❻
    spaceKeyPress = true;
  }
  // The sound will not be started until the first key is pressed.
  if (song.ready == true) {❼
    song.start(0);❽
    song.ready = false;❾
  }
});
```

The code above captures the `keydown`❶ event. It looks for the `ArrowLeft`❷, `ArrowUp`❸, `ArrowRight`❹, `ArrowDown`❺, and `Space`❻ event code and sets the appropriate flag. After capturing the key status of the keys used by the game, the function checks the `song.ready`❼ flag, and if it is ready, the song is started❽ and the `song.ready`❾ flag is set to `false`. The code does this to begin playing the song as soon as the player hits a key.

After capturing the `keydown` event to set the key press flags to true, we need to set the key flags to `false` if the code released the key with a `keyup` event:

```
document.addEventListener('keyup', (event) => { ❶
  if (event.code == 'ArrowLeft') { ❷
    leftKeyPress = false;
  }
  if (event.code == 'ArrowUp') { ❸
    upKeyPress = false;
  }
  if (event.code == 'ArrowRight') { ❹
    rightKeyPress = false;
  }
  if (event.code == 'ArrowDown') { ❺
    downKeyPress = false;
  }
  if (event.code == 'Space') { ❻
    spaceKeyPress = false;
  }
});
```

The previous block of code captures the `keyup`❶ event. It looks at `event.code`, and if the code is `ArrowLeft`❷, `ArrowUp`❸, `ArrowRight`❹, `ArrowDown`❺ or `Space`❻, the appropriate key flag is set.

Now we need to write a function to call every time the browser renders a frame. The function will calculate the time difference between this render and the previous frame render. It will call the `LoopCallback` function exported by the WASM module. Then it will call the `requestAnimationFrame` on the render function so that the browser calls the render function on the next frame render.

```
function renderFrame() ❶ {
  // calculate the time difference between this render and the previous render
  let delta = 0;
  if (last_time !== 0) {
    delta = (new Date().getTime() - last_time); ❷
  }
  last_time = new Date().getTime(); ❸

  // call the LoopCallback function in the WASM module
  exports.LoopCallback(delta, ❹
    leftKeyPress, rightKeyPress,
    upKeyPress, downKeyPress,
    spaceKeyPress);

  // requestAnimationFrame calls renderFrame the next time a frame is rendered
  requestAnimationFrame(renderFrame); ❺
```

```
}
```

The above code defines the `renderFrame`❶ function. The function calculates the time `delta`❷ (time difference between this render and the previous). It also sets the `last_time`❸ variable so that the code can calculate the time delta in the next frame render. The `renderFrame` function calls `LoopCallback`❹ inside of the WASM module. Finally, the code calls `requestAnimationFrame`❺ passing the `renderFrame`. That calls `renderFrame` the next time JavaScript renders a frame.

Next, I will define the `getAudio` function, which will call the `getAudioSource` function several times to load all of the sound files I will be using for this game.

```
// load audio files
async function getAudio() { ❶
  song = new Audio('./audio/song-hq.mp3'); ❷
  song.loop = true; ❸
  song.addEventListener("canplaythrough", event => {
    song.ready = true; ❹
  });

  laser = new Audio('./audio/laser.mp3'); ❺
  laser.addEventListener("canplaythrough", event => {
    laser.ready = true;
  });

  explosion = new Audio('./audio/explosion.mp3'); ❻
  explosion.addEventListener("canplaythrough", event => {
    explosion.ready = true;
  });
}
```

The `getAudio`❶ function creates three `Audio`❷ objects for the `song`, `laser`, and `explosion` sounds. The `song` is played in a loop, because the `loop`❸ variable on the song object is true. Each sound has a flag that tells the game the sound is `ready`❹ to play, set on the `canplaythrough` event. After creating the `Audio` object for the song, I create an `Audio` object for the `laser`❺ and the `explosion`❻ in the same way.

Finally, the `startGame` function initializes the game.

```
// the startGame function calls initASWebGLue and instantiates the wasm module
```

```
export function startGame(wasm_file) {❶

  // load the audio when the game is started.
  getAudio();❷

  const memory = new WebAssembly.Memory({ initial: 100 });❸ // linear memory

  var importObject = {
    env: {
      memory: memory,
      seed: Date.now,
      ❹playLaser: function () {
        if (laser.ready === true) {
          laser.play();❺
        }
      },
      ❻playExplosion: function () {
        if (explosion.ready === true) {
          explosion.play();
        }
      },
    }
  };

 ❼initASWebGLue(importObject);

  (async () => {
    // use WebAssembly.instantiateStreaming in combination with
    // fetch instead of WebAssembly.instantiate and fs.readFileSync
    let obj = await WebAssembly.instantiateStreaming(❽
      fetch(wasm_file),
      importObject);
    exports = obj.instance.exports;
    ASWebGLReady(obj, importObject);❾
    requestAnimationFrame(renderFrame);❿
  })();
}
```

The `startGame`❶ function initializes everything the asteroid game needs to run. It takes in the `wasm_file` as a parameter, which we will initialize. This WASM module is the output of the AssemblyScript compiler, and after initializing it from this JavaScript file, we will run a function in the module that executes the game. WebAssembly can not play sounds directly. I need to load and execute the sound files from JavaScript. The `startGame` function calls the `getAudio`❷ function to load the audio files. I call `WebAssembly.memory`❸ with an initial memory allocation of 100 pages. That creates a memory object passed to WebAssembly through the `importObject`. The `playLaser`❹ function plays the laser sound when the player fires the space ship's laser. Defining it inside of the `importObject` allows us to access it from AssemblyScript. If the laser is ready to fire, the `playLaser` function calls `laser.play()`❺ to play the sound. The `playExplosion`❻ works the same way that the `playLaser` function. The code calls initASWebGLue❼passing the `importObject`, which adds the necessary WebGL glue functions into the `importObject` before the code instantiates the WebAssembly module. Then inside of an asynchronous IIFE, the `WebAssembly.instantiateStreaming`❽ function is called, passing in the `importObject`. After instantiating the module, I set the `exports` to the `obj.instance.exports` object returned by `instantateStreaming`. The code calls the `ASWebGLReady` ❾function passing the `importObject`. That allows the glue functions to access the real-time type information, to retrieve values from linear memory. Finally, the code calls `requestAnimationFrame`❿ passing the `renderFrame` function, which will execute `renderFrame` the next time the browser renders a frame to the canvas. The code is on GitHub at the following url:

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/AsteroidsGame.js

The AssemblyScript

The following files define the game as much as is possible from within WebAssembly. I am not going to go into details about the AssemblyScript bindings and glue code. You will need to import the WebGL functions you use, but it is my goal to create a complete set of bindings so that using WebGL from AssemblyScript is as similar to using WebGL from TypeScript as is possible. You will need to get files from the ASWebGLue project at https://github.com/battlelinegames/ASWebGLue on GitHub.

Vector.asc

The `Vector` class is in the Vector.asc file. I chose the .asc extension because I am using the AssemblyScript VS Code plugin that I created, which you can find here:

https://marketplace.visualstudio.com/items?itemName=battleLinegames.assemblyscript-lang

If you are using a different plugin, you can change the extension to whatever you need. The Vector class is a 2D vector with an x and y attribute and a set of methods to find the magnitude, the squared magnitude. There are other methods that copy, normalize, multiply, and add vectors. There is also a function to determine the angle of a 2D vector.

```
export class Vector {
❶public x: f32 = 0.0;
  public y: f32 = 0.0;
```

```
❷constructor( x: f32 = 0.0, y: f32 = 0.0) {
    this.x = x;
    this.y = y;
  }
  // get the magnitude (length) of a vector
❸public magnitude() : f32 {
     return Mathf.sqrt(this.x * this.x + this.y * this.y);
  }
  // get the squared magnitude of a vector
❹public magSq():f32 {
     return this.x * this.x + this.y * this.y;
  }
  // normalize a vector by giving it a specific length (default of 1)
❺public normalize(magnitude: f32 = 1.0): Vector {
    let len: f32 = this.magnitude();
    if( len == 0 ) {
      // don't want to divide by 0
      return this;
    }
    this.x /= len;
    this.y /= len;
    this.x *= magnitude;
    this.y *= magnitude;

    return this;
  }
  // copy the values in a second vector to this vector
❻public copy( second : Vector ): void {
    this.x = second.x;
    this.y = second.y;
  }
  // multiply the vector by a scalar value
❼public multiply(scalar: f32): void {
      this.x *= scalar;
      this.y *= scalar;
  }
  // add a second vector to this vector
❽public add(value: Vector): void {
      this.x += value.x;
      this.y += value.y;
  }
}
```

❶❷❸❹❺❻❼❽❾❿

This `Vector` class represents a 2D vector and provides us with several useful functions for vector math. It has two attributes which are the `x`❶ and `y` coordinates. The `constructor`❷ takes an `x` and `y` parameter and uses them to set the `x` and `y` attributes of `this` vector. The `magnitude` ❸ function uses the Pythagorean Theorem to find the length of a line from (0,0) to (x,y). That length is the `magnitude` of the current vector. The `magSq` ❹ function returns the squared magnitude of the vector. The `normalize` ❺ function sets the magnitude of the vector to a new value, or a value of `1.0` if no value is passed to the function. The `copy` ❻ function takes a second vector and copies the x and y values from the parameter vector to `this` vector. The `multiply` ❼ function multiplies the `x` and `y` attributes of `this` vector by the scalar value passed in as a parameter. Finally, the `add` ❽ function takes a parameter vector and adds the parameter's `x` value the `this x` and the parameter's `y` attribute to `this y`.

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/Vector.asc

Renderer.asc

The `Renderer` class will contain all of the calls to the WebGL bindings. It will need to import all of the functions it will call inside of the webgl.asc file, which contains the AssemblyScript WebGL bindings. We will define the shader code in this class and use it to compile and link our shader program. The renderer will be able to clear the canvas and render line loops to the canvas. The code in Renderer.asc will first need to import several functions from webgl.asc and the `Vector` class from Vector.asc.

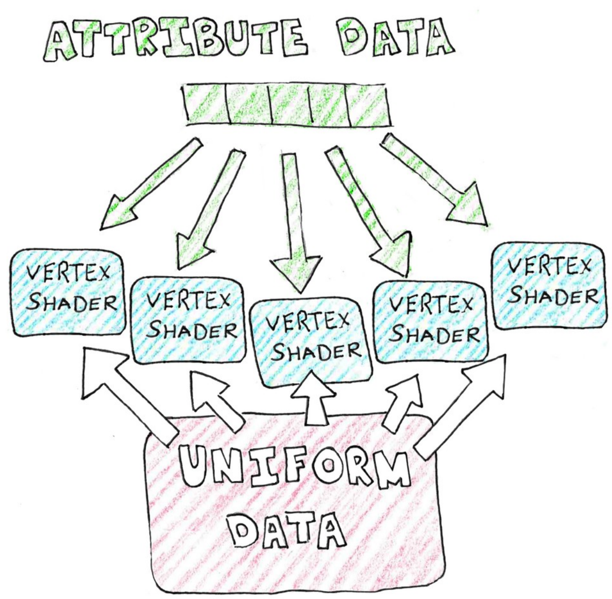
```
import {
  WebGLShader, shaderSource, createShader, compileShader,
  VERTEX_SHADER, FRAGMENT_SHADER, createProgram, WebGLProgram,
  attachShader, useProgram, WebGLUniformLocation, getUniformLocation,
  uniform4fv, uniform2fv, uniform1f, linkProgram, WebGLRenderingContext,
  createBuffer, WebGLBuffer, ARRAY_BUFFER, LINK_STATUS, COMPILE_STATUS,
  STATIC_DRAW, GLint, FLOAT, LINE_LOOP, COLOR_BUFFER_BIT,
  enableVertexAttribArray, bindBuffer, createContextFromCanvas,
  getProgramInfoLog, getShaderInfoLog, clearColor, clear,
  bufferData, getAttribLocation, drawArrays, getShaderParameter,
  vertexAttribPointer, GLuint,
} from './webgl';

import {Vector} from './Vector';
```

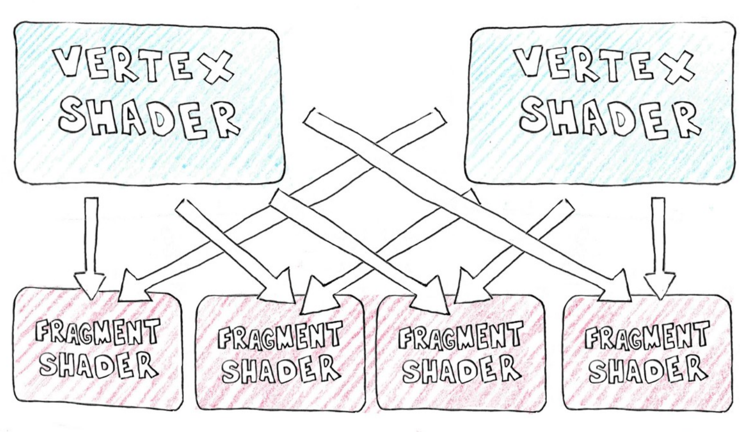
After importing the `Vector` class and the functions and types, I need to define the vertex and fragment shaders. Shaders are the heart of WebGL. Most calls to WebGL are to configure and load data into the shaders.

Shaders

WebGL uses the GLSL ES shader language, and our shaders will be using version 3.00 of GLSL ES. There are two types of shaders we will need to compile and link into a WebGLProgram object. These are a vertex shader and a fragment shader. The vertex shader processes the data associated with each vertex of the geometry you would like to render. The vertex shader then feeds data to a fragment shader, which determines the color of the pixel. WebGL sends data to the shaders in the form of attributes and uniforms. Attributes are data associated with each vertex such as x, y, z, color, etc. Uniforms are constants across all vertex and pixel data. It may be something like camera position, but uniform values do not change based on the vertex or fragment the shader is processing. The vertex shader can only access the attributes of the current vertex. However, it can access all of the uniform data. GPUs are highly parallel so that different attribute data is likely to run on different threads.



Each vertex shader then feeds multiple fragment shaders, interpolating values between the different vertices.



The vertex and fragment shader I wrote for this game are pretty simple. It supports basic 2D line drawing. The positional values for WebGL range from -1.0 to 1.0. An x value of -1.0 will be on the far left of the canvas, and 1.0 will be on the far right of the canvas no matter what size your canvas is. Similarly, a y value of 1.0 will be on the top of the canvas and -1.0 on the bottom. It works that way because I am always using a z value of 0.0 (this is a 2D game). Let's go ahead and take a look at the vertex shader code found in the Render.asc file.

Vertex Shader

The shaders are stored in strings inside of our AssemblyScript. The WebGL will take those strings and use them to compile and link a shader program. The first of these strings is the vertex shader, which I define using an AssemblyScript template string:

```
const V_COLOR_LINE_SHADER:string = `#version 300 es
  precision highp float;

  uniform uint u_color;❶
  uniform float u_scale;❷
  uniform float u_rotation;❸
  uniform float u_loop_x;❹
  uniform float u_loop_y;

  in vec2 position;❺
  out vec4 c;❻

  void main() {
    vec2 pos = (position * u_scale);❼

    float cosine = cos(u_rotation);❽
    float sine = sin(u_rotation);
    float x = (cosine * pos.x) + (sine * pos.y);
    float y = (cosine * pos.y) - (sine * pos.x);
```

```
    pos.x = x + u_loop_x;❾
    pos.y = y + u_loop_y;

    gl_Position = vec4( pos, 0.0, 1.0 );❿
    uint mask = uint(0xff);
    // convert 32-bit hexadecimal color to four float color
    uint red = u_color >> 24;
    uint green = (u_color >> 16) & mask;
    uint blue = (u_color >> 8) & mask;
    uint alpha = u_color & mask;

    c = vec4( float(red) / 255.0,
              float(green) / 255.0,
              float(blue) / 255.0,
              float(alpha) / 255.0 );
  }
`;
```

The first line of the string, `#version 300 es`, tells the shader that we are using GLSL ES version 3.00. The line `precision highp float` sets the precision of the float type to high. The `u_color`❶ uniform variable defines the color of the loop we are rendering. The uniforms `u_scale`❷ and `u_rotation`❸ scales and rotates the loop. The `u_loop_x`❹ and `u_loop_y` variables define the x and y position of the entire loop. I will use these to adjust the `position`❺ of each vector position attribute. The output of this vertex shader will include a color value in the `out vec4 c`❻ output variable.

Like in C, the `main` function is where the code begins to execute when the shader runs. The shader multiplies the `position` attribute by the `u_scale`❼ uniform. The shader scales the entire loop by the same amount. After scaling the point, the sine and cosine values for the `u_rotation`❽ angle are calculated and used to adjust the x and y values. The position x and y values are then adjusted by the `u_loop_x`❾ and `u_loop_y` values, representing the loop's x and y position. The shader sets the built-in variable `gl_Position`❿ to the output of the transformation. The color uniform value `u_color` is a 32-bit color value where the four bytes represent the red, green, blue, and alpha color channels. The color output from the fragment shader must be four floating-point values from 0.0 to 1.0. The last thing the vertex shader does is convert the 32-bit color value into four floating-point values to set the output color `c` variable to be passed to the fragment shader.

Fragment Shader

After the vertex shader, I define an extremely simple fragment shader. The fragment shader determines the rendered pixel color. This fragment shader passes the color value from the vertex shader back out as the pixel color. Here is that code:

```
const F_SHADER:string = `#version 300 es
  precision highp float;

  in vec4 c;❶
  out vec4 color;❷

  void main() {
    color = c;❸
  }
`;
```

The fragment shader takes a `vec4` input color named `c`❶ and outputs a `vec4` called `color`❷. The only thing the `main` function does is set the output `color`❸ variable to the input `c`.

Renderer Class

The beginning of the `Renderer` class has several attributes listed below:

```
export class Renderer {
  public static SN: Renderer;❶ // SINGLETON
  public static DELTA: f32;❷

  public color_line_program:WebGLProgram;❸
  public color_location:WebGLUniformLocation;❹
  public scale_location:WebGLUniformLocation;
  public rotation_location:WebGLUniformLocation;
  public offset_x_location:WebGLUniformLocation;
  public offset_y_location:WebGLUniformLocation;

  public buffer:WebGLBuffer;❺
  public position_al: GLint;❻

  public gl:WebGLRenderingContext;❼
```

The first two attributes are static. The `SN`❶ attribute is a singleton for the `Renderer` class. The code can then access this `Renderer` using `Renderer.SN`. The `DELTA`❷ attribute is a floating-point value representing the number of seconds between frames. After that, there is a variable called `color_line_program`❸, which is a `WebGLProgram`. There are five `WebGLUniformLocation`❹ variables that allow the `Renderer` to update the uniform values in the `WebGLProgram`. A `WebGLBuffer` named `buffer`❺ is defined after the uniform locations, along with the position attribute location `position_al`❻. Finally, there is a `WebGLRenderingContext` called `gl`❼.

Constructor

The constructor needs to create the WebGLContext object, compile and link the WebGLProgram object (the shader), and retrieve the uniform location from the WebGLProgram object. Here is the constructor code:

```
constructor() {
  if( Renderer.SN == null ) {
    Renderer.SN = this;❶
  }

  this.gl = createContextFromCanvas('cnvs', 'webgl2');❷
  let color_line_vertex_shader: WebGLShader = createShader(this.gl,❸
                                                 VERTEX_SHADER);
  shaderSource(this.gl, color_line_vertex_shader, V_COLOR_LINE_SHADER);
  compileShader(this.gl, color_line_vertex_shader);

  let fragment_shader: WebGLShader = createShader(this.gl, FRAGMENT_SHADER);
  shaderSource( this.gl, fragment_shader, F_SHADER);
  compileShader( this.gl, fragment_shader );

  this.color_line_program = createProgram(this.gl);❹

  attachShader(this.gl, this.color_line_program, color_line_vertex_shader);❺
  attachShader(this.gl, this.color_line_program, fragment_shader);

  linkProgram( this.gl, this.color_line_program );❻

  useProgram( this.gl, this.color_line_program );❼

  this.color_location = getUniformLocation(this.gl,❽
                                      this.color_line_program, "u_color");
  this.scale_location = getUniformLocation(this.gl,
                                      this.color_line_program, "u_scale");
  this.rotation_location = getUniformLocation(this.gl,
                                      this.color_line_program, "u_rotation");
  this.offset_x_location = getUniformLocation(this.gl,
```

```
                                              this.color_line_program, "u_loop_x");
    this.offset_y_location = getUniformLocation(this.gl,
                                              this.color_line_program, "u_loop_y");

      this.buffer = createBuffer(this.gl);❾
      bindBuffer(this.gl, ARRAY_BUFFER, this.buffer);

     ❿this.position_al = getAttribLocation(this.gl,
                                              this.color_line_program, 'position');
      enableVertexAttribArray(this.gl, this.position_al);
  }
```

If the singleton `Renderer.SN`❶ is not set, I set it to `this`. The WebGL bindings deviate a little from the WebGL API when creating a `WebGLContext` object. A function called `createContextFromCanvas`❷ is passed the canvas DOM id and the context type and returns a `WebGLContext` for that canvas. The code then calls `createShader`❸ to create a vertex shader. It sets the shader source calling `shaderSource` passing in the vertex shader code I defined in `V_COLOR_LINE_SHADER`. The vertex shader is compiled by calling the `compileShader` function. After creating, loading, and compiling the vertex shader, you will need to add all of those steps for the fragment shader. After that, I create a `WebGLProgram` called `color_line_program` using the `createProgram`❹ function. After making the program, I need to attach the vertex and fragment shader I created earlier. I do this by calling `attachShader`❺ once for each of the shaders. The `WebGLProgram` is then linked by calling `linkProgram`❼ and selected as the shader by calling the `useProgram`❽ function. Now that our application is using the program, I must retrieve the location of the uniform variables. I do this by calling the `getUniformLocation`❽ for `u_color`, `u_scale`, `u_rotation`, `u_loop_x`, and `u_loop_y`. Next, `this.buffer`❾ is set to a newly created buffer, and `bindBuffer` is used to bind `this.buffer` to the `WebGLContext` as an `ARRAY_BUFFER`. Finally, the position attribute location (`position_al`❿) is set by calling the `getAttribLocation` and then enabled by calling `enableVertexAttribArray`.

clear and renderLineLoop functions

The `clear` and `renderLineLoop` functions are the online functions in this game that draw to the canvas. The clear function clears the canvas with a solid black color. This game engine is simple and can only render line loops. The `renderLineLoop` function is the function that draws those line loops. It takes in an array of vertices, the position to render the loop, a `rotation`, `scale`, and `color_data` values. Here are those two functions:

```
   ❶public clear(): void {
      clearColor(this.gl, 0.0, 0.0, 0.0, 1.0);
```

```
    clear(this.gl, COLOR_BUFFER_BIT);
  }

 ❷public renderLineLoop(line_data: StaticArray<f32>, offset: Vector,
                rotation: f32, scale: f32,
                color_data: u32 = 0xff_ff_ff_ff): void {
  ❸bufferData<f32>(this.gl, ARRAY_BUFFER, line_data, STATIC_DRAW);

  ❹uniform1ui(this.gl, this.color_location, color_data);
    uniform1f(this.gl, this.scale_location, scale);
    uniform1f(this.gl, this.rotation_location, rotation);
    uniform1f(this.gl, this.offset_x_location, offset.x);
    uniform1f(this.gl, this.offset_y_location, offset.y);

  ❺const dimensions:i32 = 2;
    const data_type: i32 = FLOAT;
    const normalize: i32 = false;
    const stride:i32 = 0;
    const offset:i32 = 0;

  ❻vertexAttribPointer(this.gl, position_al, dimensions,
                      data_type, normalize, stride, offset);

  ❼drawArrays(this.gl, LINE_LOOP, 0, line_data.length/2);
  }

}
```

The `clear`❶ function clears the canvas with the color black. It calls two functions to do this. First, it sets the clear color with the `clearColor` function to black. Next, it calls the WebGL clear function passing in `COLOR_BUFFER_BIT`. The `renderLineLoop` function is the only rendering function in our `Renderer` class. Everything we will be rendering in this game is a line loop. The function calls `bufferData`❸ passing in the `line_data` as the vertices for the loop to be rendered. After buffering the data, a series of uniform variables are set in the `WebGLProgram` by calling `uniform1ui`❹ to set the color data and `uniform1f` to set the scale, rotation, x offset, and y offset.

I call `vertexAttribPointer` to tell the shaders how to read the data passed through the data buffer. I create some variables to indicate what each of the parameters are. The `dimensions`❺ are the number of variables we are packing into the data buffer. In our case, we are passing in an x and y value, so there are two dimensions. The data type is floating-point, so I set `data_type` to `FLOAT`. The code sets the `normalize` value to `false`. If `normalize` were `true`, the values you pass in are fixed to a certain range depending on the `data_type`. Stride is the distance between your group of attributes. The stride parameter

passed into `vertexAttribPointer`❻ is frequently set to `0`. That value tells WebGL not to add any number of buffer bytes between the attributes for each vertex. If you want to pad your vertex attributes, you need to set this value to the number of attribute bytes and buffer bytes. If the stride is not 0, you can add buffer bytes to the beginning or end.
The `offset` tells WebGL how many bytes into the `stride` the first attribute is located. This should always be 0 if the `stride` is 0. These values are then used in the call to `vertexAttribPointer`, which tells WebGL how the shader should read the buffer data. Finally, the `drawArrays`❼ function is called, passing in `LINE_LOOP`, because we are drawing the vertices as a line loop. The other two parameters passed into `drawArrays` are the starting index of the vectors you want to use. That should be 0 unless there is a vertex you don't want to draw at the start of the vertex array. The final parameter is the vertex count you want to render. Since each vertex has an x and y coordinate in `line_data`, I pass in the `line_data.length / 2`.

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/Renderer.asc

AsteroidShooter.asc

The `AsteroidShooter` class is a class driving the AssemblyScript portion of the game. My goal was to write as much of the game as possible in AssemblyScript. Still, some functionality is currently beyond the capabilities of AssemblyScript due to a lack of bindings. Playing audio, for example, is something that AssemblyScript is not able to do directly. At the time of this writing, the game is in a demo status. The player can destroy all of the asteroids, and new asteroids will respawn to replace them. The player can not be killed, and no score is kept. The player can maneuver his space ship with the arrow keys and shoot at the asteroids by pressing the space bar.

Imported Classes

The code in *AsteroidShooter.asc* begins with a series of class imports from other AssemblyScript files. The code imports the `Vector` class, which is used to perform much of the 2D vector math this game uses. The `Renderer` class, which renders game loops to the canvas. It also imports four game object classes, which are `Asteroid`, `Bullet`, `Explosion` and `PlayerShip`. Here is what that code looks like:

```
import {Vector} from "./Vector";

import {Renderer} from "./Renderer"

import {Asteroid} from "./Asteroid";
import {Bullet} from "./Bullet";
import {Explosion} from "./Explosion";
import {PlayerShip} from "./PlayerShip";
```

Importing Audio Functions

At the time of this writing, AssemblyScript is not able to directly play audio files. To play the laser sound when the player shoots or the explosion sound when an asteroid is destroyed, I must import functions from JavaScript that can play those sounds. The code is below:

```
@external("env", "playLaser")
export declare function playLaser(): void;

@external("env", "playExplosion")
export declare function playExplosion(): void;
```

The JavaScript for these functions are in the `importObject` inside the *AsteroidGame.js* file. The `playLaser` function plays the laser sound effect, and the `playExplosion` function will play the explosion sound. Next, we will define the `AsteroidShooter` class.

AsteroidShooter Attributes

The attributes in the `AsteroidShooter` class are in four groups. The static class variables, which include the `AsteroidShooter` singleton and the time delta in milliseconds. The game objects, which include asteroids, explosions, bullets, and the player. There are array indexes into the asteroid, explosion, and bullet arrays. Finally, there are two variables used for a shot cool-down time. Here are those attributes:

```
export class AsteroidShooter {
  // singleton
❶public static SN: AsteroidShooter;  // AsteroidShooter singleton

  // game objects
❷public asteroidArray: Array<Asteroid> = new Array<Asteroid>();
  public explosionArray: Array<Explosion> = new Array<Explosion>();
  public bulletArray: Array<Bullet> = new Array<Bullet>();
  public playerShip: PlayerShip = new PlayerShip();

  // array indexes
❸public asteroidIndex: i32 = 0;
  public explosionIndex: i32 = 0;
  public bulletIndex: i32 = 0;

  // shot cooldown variables
❹static readonly LAUNCH_WAIT: i32 = 250;
❺public bulletCoolDown: i32 = 50;
```

The first static variable is a singleton `SN`❶. There are four game object attributes. Three of them, `asteroidArray`❷, `explosionArray`, and `bulletArray`, are arrays which I will use as object pools for each of those game object types. In games, when you see the same object repeatedly, such as a bullet, those objects are usually created ahead of time, turned inactive when they are not being used, and then activated again later. Creating a new bullet object every time you pressed the space bar would quickly fill up memory. Using object pooling allows you to make all of the objects you need ahead of time and reuse them as necessary. After the game objects, there are index❸ variables used for spawning new game objects from the object pools. The code increments these indexes until they are the same size as the object pools array, at which point they will be set back to a value of 0. Finally, there are two variables used to manage the shot cool down for the player's ship. The `LAUNCH_WAIT`❹ is the number of milliseconds the game waits between launching bullets. The `bulletCoolDown`❺ is the amount of time remaining before the next shot launches.

Constructor

The constructor needs to set the Singleton, create a renderer, and initialize the game objects. In the beginning, the game activates five asteroids. The game needs to make bullets and the explosions in their object pools. Here is the constructor code:

```
constructor() {
  // set the singleton
  if( AsteroidShooter.SN == null ) {
   ❶AsteroidShooter.SN = this;
  }

  // creating a renderer will set the singleton for the Renderer class
  // this constant will exit scope at the end of the constructor, so
  // I will access the Renderer using Renderer.SN
❷new Renderer();

  // create the objects for the asteroid object pool
  for( var i: i32 = 0; i < 50; i++ ) {
   ❸this.asteroidArray.push( new Asteroid() );
  }

  // activate five asteroids for the beginning of the game
 ❹this.activateAsteroid(0.25, -0.5,  0.5 );
    this.activateAsteroid(0.25,  0.5,  0.5 );
    this.activateAsteroid(0.25, -0.5, -0.5 );
    this.activateAsteroid(0.25,  0.5, -0.5 );
    this.activateAsteroid(0.25,  0.7, -0.2 );

  // create the objects for the explosion object pool
  for( i = 0; i < 30; i++ ) {
   ❺this.explosionArray.push( new Explosion() );
  }
```

```
  // create the objects for the bullet object pool
  for( i = 0; i < 30; i++ ) {
   ❻this.bulletArray.push( new Bullet() );
  }
}
```

The constructor starts by creating the `AsteroidShooter`❶ singleton. Then I create the `Renderer`❷. The `Renderer` is a singleton class. Later, I will access the `Renderer` using `Render.SN`. I create 50 `Asteroid` objects and add them to the asteroid pool by pushing them into `asteroidArray`❸. I then activate the first five asteroids in the asteroid pool by calling `this.activateAsteroid`❹ five times. After activating the asteroids, I need to create 30 `Explosion` objects for the `explosionArray`❺ and 30 `Bullet` objects for the `bulletArray`❻ object pool.

Respawn Check

The `respawnCheck` function checks to see if any visible asteroids are remaining in the asteroid pool. If there is an asteroid left, return from the function. If no visible asteroids remain, activate five asteroids from the asteroid pool by calling `activateAsteroid`. Here is the code for the function:

```
// each frame check to see if any asteroids remain
public respawnCheck(): void {
  // check for any asteroids that remain
  for( var i: i32 = 0; i < this.asteroidArray.length; i++ ) {
    if( this.asteroidArray[i].visible == true ) {
      // if there is a visible asteroid, return
     ❶return;
    }
  }
  // if all of the asteroids have been destroyed, spawn five more
❷this.activateAsteroid(0.25, -0.5,  0.5);
  this.activateAsteroid(0.25,  0.5,  0.5);
  this.activateAsteroid(0.25, -0.5, -0.5);
  this.activateAsteroid(0.25,  0.5, -0.5);
  this.activateAsteroid(0.25,  0.7, -0.2);
}
```

The loop at the beginning checks every `Asteroid` object in the `asteroidArray` to see if any are `visible`. As soon as a visible asteroid is found, the function returns ❶. If no visible asteroids are found, the `activateAsteroid`❷ function is called five times to activate five `Asteroid` objects if none remain.

Activate Explosion

The `activateExposion` function runs an explosion animation at the x, y coordinates provided as parameters. It increments the `explosionIndex`, resetting it to 0 if necessary. It then looks for the next available `Explosion` object from the pool, and activates it when it finds one:

```
  // when an asteroid is destroyed, activate an explosion from explosionArray
  public activateExplosion(x: f32, y: f32 ): void {
   ❶let count: i32 = 0;
    // advance the explosion index to get the next explosion in the pool
   ❷this.explosionIndex++;

    // if the index is greater than the number of objects in the pool,
    // reset it to 0
    if( this.explosionIndex >= this.explosionArray.length ) {
     ❸this.explosionIndex = 0;
    }

   ❹while( this.explosionArray[this.explosionIndex].visible == true ) {
      this.explosionIndex++;
      if( this.explosionIndex >= this.explosionArray.length ) {
        this.explosionIndex = 0;
      }
     ❺if( count++ > this.explosionArray.length ) return;
    }
   ❻this.explosionArray[this.explosionIndex].activate(x, y);
  }
}
```

The variable `count`❶ is used to check if all the explosions are currently visible. I don't want there to be an infinite loop, so I need to return if I have gone all the way through the loop. The `explosionIndex`❷ is incremented, and if it exceeds the length of the `explosionArray`, the index is set back to 0❸. If the `Explosion` object is `visible`, I need to advance the `explosionIndex`. I do this in a `while`❹ loop to continue to advance until it finds an `Explosion` that is not visible. I increment the `count`❺ and check to see if it is greater than the number of objects in the pool. If all the explosions are `visible`, it will `return` from the function. Finally, I `activate`❻ the `Explosion` object from the pool.

Launch Bullet

The `launchBullet` function looks for a `Bullet` object in the bullet object pool to fire from the player's location. It shares a lot in common with the code from `activateExplosion`.

```
public launchBullet(): void {
❶let count: i32 = 0;
❷this.bulletIndex++;
  if( this.bulletIndex >= this.bulletArray.length ) {
   ❸this.bulletIndex = 0;
  }
❹while( this.bulletArray[this.bulletIndex].visible == true ) {
    this.bulletIndex++;
    if( this.bulletIndex >= this.bulletArray.length ) {
      this.bulletIndex = 0;
    }
    if( count++ > this.bulletArray.length ) return;
  }
❺this.bulletArray[this.bulletIndex].launch(
      AsteroidShooter.SN.playerShip.rotation,
      AsteroidShooter.SN.playerShip.position );
}
```

The code sets the `count`❶ variable to `0`. It counts the number of `visible` checks performed. The `bulletIndex`❷ is incremented, and reset to `0`❸ if its value exceeds the `bulletArray length`. There is a `while`❹ loop that advances the `bulletIndex` if the `Bullet` is `visible`. Once we find a `Bullet` object that is not visible, call the `launch`❺ function on the selected `Bullet`.

Activate Asteroid

The last function in the `Asteroid` class is `activateAsteroid`. When an asteroid is destroyed, I need to activate two more asteroids, unless the asteroids are of the smallest size. When the player has destroyed all of the asteroids, new ones are activated to replace them. The code in the `activateAsteroid` function is very similar to the `activateExplosion` code.

```
public activateAsteroid(size: f32, x: f32, y: f32 ): void {
  ❶let count: i32 = 0;
  ❷this.asteroidIndex++;
    if( this.asteroidIndex >= this.asteroidArray.length ) {
    ❸this.asteroidIndex = 0;
    }
  ❹while( this.asteroidArray[this.asteroidIndex].visible == true ) {
```

```
      this.asteroidIndex++;
       if( this.asteroidIndex >= this.asteroidArray.length ) {
         this.asteroidIndex = 0;
       }
       if( count++ > this.asteroidArray.length ) return;
     }
   ❺this.asteroidArray[this.asteroidIndex].activate(size, x, y);
   }
 }
```

Like the `activateExplosion` function, the `activateAsteroid` function begins with a local `count`❶ variable set to 0. I increment the `asteroidIndex`❷. If it is greater than or equal to the `length` of the `asteroidArray`, reset the value to `0`❸. Like in `activateExplosion`, there is a `while`❹ loop that advances the `asteroidIndex` until it finds an `Asteroid` object that is not `visible`. When it finds an asteroid to use, it calls the `activate`❺ function on that pool object.

Creating the AsteroidShooter object

The `AsteroidShooter` class has a singleton called `SN`. Instantiate an `AsteroidShooter` to set the `Asteroid.SN` singleton. Immediately after the end of the `AsteroidShooter` class, I create a new `AsteroidShooter` object.

```
new AsteroidShooter();
```

Next I will create the LoopCallback function.

LoopCallback

The app calls the `LoopCallback` function every time the browser renders a frame. It acts as a game loop, driving the logic of the game. It calls functions to move and render the game objects and checks the status of the keyboard. The `playerShip` object moves based on the pressed keys.

```
export function LoopCallback( delta_ms: i32,
                        leftKeyPress: bool, rightKeyPress: bool,
                        upKeyPress: bool, downKeyPress: bool,
                        spaceKeyPress: bool ): void {
  // subtract the time delta from the bulletCoolDown
❶AsteroidShooter.SN.bulletCoolDown -= delta_ms;

  // clear the canvas
❷Renderer.SN.clear();
  // set DELTA to a fraction of a second
  Renderer.DELTA = <f32>delta_ms / 1000.0;
```

```
  // move and draw all the asteroids
❸ for( var i: i32 = 0; i < AsteroidShooter.SN.asteroidArray.length; i++ ) {
    AsteroidShooter.SN.asteroidArray[i].move();
    AsteroidShooter.SN.asteroidArray[i].draw();
  }

  // move the playerShip if a key is pressed
❹ if( leftKeyPress ) {
    AsteroidShooter.SN.playerShip.turnLeft();
  }
  if( rightKeyPress ) {
    AsteroidShooter.SN.playerShip.turnRight();
  }
  if( upKeyPress ) {
    AsteroidShooter.SN.playerShip.accelerate();
  }

❺ if( spaceKeyPress && AsteroidShooter.SN.bulletCoolDown <= 0 ) {
    AsteroidShooter.SN.bulletCoolDown = AsteroidShooter.LAUNCH_WAIT;
    AsteroidShooter.SN.launchBullet();
    playLaser();
  }

  // move and draw the bullets. Then run a hit test against the asteroids
❻ for( i = 0; i < AsteroidShooter.SN.bulletArray.length; i++ ) {

    if( AsteroidShooter.SN.bulletArray[i].visible == true ) {
      AsteroidShooter.SN.bulletArray[i].move();
      AsteroidShooter.SN.bulletArray[i].draw();

      // hit test visible bullets against visible asteroids
   ❼ for( var j: i32 = 0; j < AsteroidShooter.SN.asteroidArray.length; j++ ) {
        if( AsteroidShooter.SN.asteroidArray[j].visible == true &&
            AsteroidShooter.SN.bulletArray[i].hitTest(
                      AsteroidShooter.SN.asteroidArray[j]) ) {
          // if a bullet collides with an asteroid create an explosion
          AsteroidShooter.SN.activateExplosion(
            AsteroidShooter.SN.asteroidArray[j].position.x,
            AsteroidShooter.SN.asteroidArray[j].position.y );

          playExplosion();

          if( AsteroidShooter.SN.asteroidArray[j].scale >= 0.05 ) {
            const half_scale = AsteroidShooter.SN.asteroidArray[j].scale / 2;
            const asteroid_x = AsteroidShooter.SN.asteroidArray[j].position.x;
            const asteroid_y = AsteroidShooter.SN.asteroidArray[j].position.y;
            AsteroidShooter.SN.activateAsteroid(
```

```
                            half_scale,
                            asteroid_x + half_scale,
                            asteroid_y - half_scale );
              AsteroidShooter.SN.activateAsteroid(
                            half_scale,
                            asteroid_x - half_scale,
                            asteroid_y + half_scale );
            }

            AsteroidShooter.SN.bulletArray[i].visible = false;
            AsteroidShooter.SN.asteroidArray[j].visible = false;
            break;
          }
        }
      }
    }

    // move and draw the explosions
❽ for( i = 0; i < AsteroidShooter.SN.explosionArray.length; i++ ) {
      AsteroidShooter.SN.explosionArray[i].move();
      AsteroidShooter.SN.explosionArray[i].draw();
    }

    // move and draw the player ship
❾ AsteroidShooter.SN.playerShip.move();
    AsteroidShooter.SN.playerShip.draw();

❿ AsteroidShooter.SN.respawnCheck();
  }
```
The JavaScript calls the `LoopCallback` function every frame rendered. The `delta_ms` parameter contains the number of milliseconds since the previous render. There are also parameter flags for every game key pressed. The first thing the `LoopCallback` does is reduce the `bulletCooldown` ❶ by `delta_ms`. I then call `Renderer.SN.clear` ❷ to clear the canvas. I set `Renderer.DELTA` to the fraction of a second since the previous render by dividing `delta_ms` by 1000. I loop over each of the asteroids in the `asteroidArray` ❸ and call `move` and `draw` on every `Asteroid` object. I check to see if the `leftKeyPress` ❹ or `rightKeyPress` flag is set to `true` and turn the `playerShip` right or left if either is. I check the `upKeyPress` and accelerate the `playerShip` if that key is pressed. If the `spaceKeyPress` ❺ is `true`, and the `bulletCoolDown` is less than or equal to `0`, I reset the `bulletCoolDown` value and I call the `launchBullet` and `playLaser` functions. Those calls launch a new `Bullet` object from the object pool and play the laser sound. I then loop through every bullet in the `bulletArray` ❻, calling `move` and `draw` on each one. Inside the loop over the `bulletArray`, I loop through the `asteroidArray` ❼ checking for a collision between each bullet and each asteroid. If the

hitTest returns true, I call activateExplosion and playExplosion to create an explosion animation and play the explosion sound. If the asteroid's scale is greater than 0.05, I create two asteroids that are half the size. I set the bullet and asteroid's visible attribute set to false. This prevents them from being rendered, and makes them available in the object pool. There is a loop that calls move and draw on each of the explosions in the explosionArray❽. The playerShip❾ is moved and drawn, and the respawnCheck❿ is run.

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/AsteroidShooter.asc

PlayerShip.asc

The PlayerShip class has functions to move and render the player's space ship. Rendering the player ship requires code that draws four different loops for different parts of the ship. Some trigonometry is required to accelerate the player ship in the correct direction. The player ship caps its movement to a maximum velocity. The first few lines of the *PlayerShip.asc* file import the Vector and Renderer classes:

```
import {Vector} from './Vector';
import {Renderer} from './Renderer';
```

The Vector class does all of the 2D vector math for the player ship. The Renderer renders the four loops of the player ship. At the beginning of the PlayerShip class, I define the class attributes:

```
export class PlayerShip {
  // readonly static properties of PlayerShip
❶static readonly TWO_PI: f32 = 6.2831853;
  static readonly ACCELERATION: f32 = 0.3;
  static readonly ROTATE_VEL: f32 = 2.0;
  static readonly MAX_VEL_SQ: f32 = 0.25;
  static readonly MAX_VEL: f32 = 0.5;

  // movement, position, scale and rotation
❷public velocity: Vector = new Vector();
  public delta_velocity: Vector = new Vector();
  public position: Vector = new Vector();

  // scale and rotation
❸public scale: f32 = 0.1;
  public rotation: f32 = 3.14159;

  // position loop data
❹public shipBody:StaticArray<f32> = [-0.1,-0.7,
                                     0.1,-0.7,
                                     0.5,0.1,
                                     0.5,0.5,
```

```
                                    0,0.4,
                                    -0.5,0.5,
                                    -0.5,0.1,];
    public shipCockpit:StaticArray<f32> = [0,-0.6,
                                      -0.2,0,
                                      0,-0.1,
                                      0.2,0,];
    public leftGun:StaticArray<f32>  = [-0.4,-0.1,
                                    -0.4,-0.5,
                                    -0.3,-0.5,
                                    -0.3,-0.3,];
    public rightGun:StaticArray<f32> = [ 0.3,-0.3,
                                    0.3,-0.5,
                                    0.4,-0.5,
                                    0.4,-0.1,];
```
The attributes start with a group of `static readonly` variables that define constants used by `PlayerShip`. These variables include `TWO_PI`❶, which is two times the value π. `ACCELERATION`, is the scalar acceleration value. `ROTATE_VEL` which is the rotation velocity. `MAX_VEL`, is the maximum scalar velocity of the space ship. And finally, `MAX_VEL_SQ` which squares the maximum scalar velocity.

After the `readonly` values, there are four `Vector`❷ variables. These vectors are all used for moving and positioning the player ship on the canvas. The `velocity` vector is the player ship's x-axis and y-axis speed. The `delta_velocity` is the `velocity` adjusted by `DELTA` for changing frame rates. The player's coordinates are in the `position` vector.

The `scale`❸ and `rotation` values follow the `Vector` variables. The `scale` is the resize value multiplied against each vertex to display the loop to the screen. It is also used when moving the ship to wrap it from top to bottom and left to right when the player ship exits the canvas on one side and must reappear on the other. The `PlayerShip` class uses `rotation` for rotating the vertices and acceleration.

Next is a series of `StaticArray`❹ variables that contain point data for each loop to render. The series of arrays include the `shipBody`, `shipCockpit`, `leftGun` and `rightGun`. The `draw` function will render each of these to the canvas. These arrays alternate x and y coordinates. In the code, I put an x, y coordinate pair on each line.

move

There are five functions in the code. They are `move`, `draw`, `accelerate`, `turnLeft`, and `turnRight`. The `move` function is defined as follows:

```
public move(): void {
  // cap the velocity to MAX_VEL
  if( this.velocity.magSq() > PlayerShip.MAX_VEL_SQ ) {
```

```
      ❶this.velocity.normalize(PlayerShip.MAX_VEL);
    }
    // move the position by the delta_velocity
  ❷this.delta_velocity.copy( this.velocity );
    this.delta_velocity.multiply( Renderer.DELTA );
    this.position.add( this.delta_velocity );

    // if position moves off the canvas to left or right move to opposite side
  ❸if( this.position.x < -1 - this.scale/2 ) {
      this.position.x = 1 + this.scale / 3;
    }
    else if( this.position.x > 1 + this.scale/2 ) {
      this.position.x = -1 - this.scale / 3;
    }

    // if position moves off the canvas top or bottom move to opposite side
  ❹if( this.position.y < -1 - this.scale/2 ) {
      this.position.y = 1 + this.scale / 3;
    }
    else if( this.position.y > 1 + this.scale/2 ) {
      this.position.y = -1 - this.scale / 3;
    }
  }
```

If the squared magnitude of the `velocity` is greater than `MAX_VEL_SQ`, normalize the `velocity` vector to `MAX_VEL`❶. I use the squared value of the magnitude to avoid making a square root call. The `velocity` vector is then adjusted by `DELTA` to set `delta_velocity`❷. The `position` vector adds `delta_velocity` to move the player ship. After that, an `if`❸/`else` block that checks if the position has moved off the canvas. If it has, it is moved to the opposite side.

draw

The `draw` function calls the `renderLineLoop` on the `Renderer` class four times to render the four loops defined as `StaticArray` variables earlier. Here is what that code looks like:

```
public draw(): void {
  Renderer.SN.renderLineLoop(this.shipBody, this.position,
                             this.rotation, this.scale, 0x00_ff_00_ff );
  Renderer.SN.renderLineLoop(this.shipCockpit, this.position,
                             this.rotation, this.scale, 0x00_ff_ff_ff );
  Renderer.SN.renderLineLoop(this.leftGun, this.position,
                             this.rotation, this.scale, 0xa1_00_00_ff );
  Renderer.SN.renderLineLoop(this.rightGun, this.position,
                             this.rotation, this.scale, 0xa1_00_00_ff );
```

```
}
```

The `draw` function renders four loops with different colors. The function renders `shipBody` green (`0x00_ff_00_ff`), `shipCockpit` teal (`0x00_ff_ff_ff`), `leftGun` and `rightGun` dark red (`0xa1_00_00_ff`). The color value passed as the last parameter has a hex color value for red, green, blue, and alpha channels.

accelerate

The `accelerate` function uses a little trigonometry to add the acceleration to the `velocity` vector. Here is the code that does this:

```
public accelerate(): void {
  this.velocity.y += Mathf.sin(this.rotation) *
                     (PlayerShip.ACCELERATION * Renderer.DELTA);
  this.velocity.x += Mathf.cos(this.rotation) *
                     (PlayerShip.ACCELERATION * Renderer.DELTA);
}
```

The `accelerate` function uses the angle's sine to accelerate the `velocity` along the y-axis and the angle's cosine for the `velocity` x-axis.

Turning the Player Ship

Two functions turn the `PlayerShip` object left and right.

```
  public turnRight(): void {
    this.rotation -= PlayerShip.ROTATE_VEL * Renderer.DELTA;
    if( this.rotation < 0.0 ) {
      this.rotation += PlayerShip.TWO_PI;
    }
  }

  public turnLeft(): void {
    this.rotation += PlayerShip.ROTATE_VEL * Renderer.DELTA;
    if( this.rotation >= PlayerShip.TWO_PI ) {
      this.rotation -= PlayerShip.TWO_PI;
    }
  }
}
```

The `turnRight` function turns the player ship to the right by subtracting the rotation velocity from the ship's `rotation`. The `turnLeft` function turns the player ship to the left by adding the rotation velocity to the ship's `rotation`.

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/PlayerShip.asc

Bullet.asc

The `Bullet` class draws the projectile when the player shoots at the asteroids in the game. It also moves the object and runs the collision detection between the bullet and an `Asteroid` object. The beginning of the *Bullet.asc* file imports four classes, defines the class, and the several attributes:

```
import {Vector} from './Vector';
import {Renderer} from './Renderer';
import {Asteroid} from './Asteroid';
import {PlayerShip} from './PlayerShip';

export class Bullet {
❶public lineLoop: StaticArray<f32> = [-0.01, 0.01,
                                        0.0,0.04,
                                        0.01,0.01,
                                        0.04,0.0,
                                        0.01,-0.01,
                                        0.0,-0.04,
                                        -0.01,-0.01,
                                        -0.04,0.0,];
  // scale and rotation values
❷public scale: f32 = 0.5;
  public scaledRadius: f32 = 0.1;
  public rotation: f32 = 0.0;

  // vector variables
❸public velocity: Vector = new Vector();
  public delta_velocity: Vector = new Vector();
  public position: Vector = new Vector();

❹public visible: bool = false;
```

The first four lines import the `Vector`, `Renderer`, `Asteroid`, and `PlayerShip` classes. Inside the `Bullet` class, there are several groups of attributes. The first is a `StaticArray lineLoop`❶. This `lineLoop` contains all the vertex data used to define the bullet object.

The next three values are `scale`❷, `scaleRadius`, and `rotation`. The `scale` variable is passed to the `Renderer`, scaling the `lineLoop` data. The `scaledRadius` is the size used for collision detection. The `rotation` attribute will be changed every frame to cause the bullet to spin when rendered. After the `rotation` and `scaling`, there are three `Vector` attributes. These attributes `move` and `position` the object. The `velocity`❸ `Vector` holds the distance and direction the bullet will move in a second. The `delta_velocity` is the `velocity` adjusted by the time delta. Finally, the position holds the x and y coordinates of the `Bullet` object. The `visible`❹ attribute tells the game where the bullet should be rendered and used for collision detection.

move

The move function moves the bullet based on the velocity, rotates the bullet, and checks to see if it has exited the canvas. Here is the code for that function:

```
public move(): void {
  // only move if this is visible
❶if( this.visible == true ) {
    // adjust the position based on the position and the time delta
  ❷this.delta_velocity.copy( this.velocity );
    this.delta_velocity.multiply( Renderer.DELTA );
  ❸this.position.add(this.delta_velocity);

    // rotate this bullet every frame
  ❹this.rotation += 0.75;
    if( this.rotation > 6.283 ) {
      this.rotation -= 6.283;
    }

    // check to see if the bullet has moved off screen
  ❺if( this.position.x < -1 - this.scale ||
         this.position.x > 1 + this.scale ||
        this.position.y < -1 - this.scale ||
        this.position.y > 1 + this.scale ) {
        ❻this.visible = false;
    }
  }
}
```

If the visible❶ attribute is true, I move the object. If it is false, this function exits. The delta_velocity❷ is then set from the velocity vector, multiplying it by the Render.DELTA. The delta_velocity is added to the position❸ vector to move the Bullet object. The rotation❹ is increased by 0.75, and if its value is greater than two π, the value is reduced by two π. After that, there is an if❺ block that checks to see if the bullet has moved off the canvas. If so, visible❻ is set to false, which will prevent it from being rendered or moved in the future.

draw

The draw function checks if the bullet is visible, and if so, calls renderLineLoop to render this bullet:

```
public draw(): void {
  if( this.visible == true ) {
    Renderer.SN.renderLineLoop(this.lineLoop, this.position,
```

```
                        this.rotation, this.scale, 0xff_ff_00_ff );
  }
}
```

launch

The launch function sets the bullet's position to the `ship_position` and sets the `visible` attribute to `true`. It also sets the `velocity` x and y values based on the angle of the player ship. Here is that code:

```
public launch( ship_angle: f32, ship_position: Vector ): void {
❶this.position.copy(ship_position);
❷this.visible = true;

  // use ship_angle to calculate velocity
❸this.velocity.y = Mathf.sin(ship_angle) * 2.5;
❹this.velocity.x = Mathf.cos(ship_angle) * 2.5;
}
```

The `launch` function calls `copy` on the `position` attribute to copy the `x` and `y` values from the `ship_position` parameter to the `position` attribute. The `visible` attribute is set to `true` so that the bullet is rendered and used for collision detection. The `velocity.y` is set based on the sine of the `ship_angle` parameter and the `velocity.x` value is set based on the cosine of the `ship_angle`.

hitTest

The final function in the `Bullet` class is `hitTest`. The `hitTest` function uses the Pythagorean Theorem to determine if there is a collision between the bullet and an `asteroid`. If the distance between the two objects is less than the sum of the radii, the `hitTest` returns `true`; otherwise, it returns `false`:

```
  public hitTest( asteroid: Asteroid ): bool {
  ❶let rad_sum_sq: f32 = asteroid.scaledRadius + this.scaledRadius;
  ❷rad_sum_sq *= rad_sum_sq;
  ❸let x_dist: f32 = this.position.x - asteroid.position.x;
  ❹let y_dist: f32 = this.position.y - asteroid.position.y;
  ❺let dist_sq: f32 = x_dist * x_dist + y_dist * y_dist;

  ❻if( dist_sq < rad_sum_sq ) {
      return true;
    }
    return false;
  }
```

```
}
```

The rad_sum_sq❶ variable is the sum of the scaledRadius of the asteroid and this bullet. The rad_sum_sq❷ variable then needs to be squared and compared to the squared distance between the two objects. I use the Pythagorean Theorem ($A^2 + B^2 = C^2$). However, I don't take the square root because it is faster to square a number than take its square root. The x_dist❸ variable is the distance between the bullet and the asteroid on the x-axis, y_dist❹ the y-axis. The dist_sq❺ variable is the squared distance (C^2 in the Pythagorean Theorem). I don't need to find C because we squared the sum of the object sizes. I check to see if the dist_sq❻ is less than the rad_sum_sq. If it is, that indicates a collision, and I return true. Otherwise, return false.

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/Bullet.asc

Explosion.asc

The *Explosion.asc* file contains the Explosion class, a simple explosion animation that runs when a bullet destroys an asteroid. The function imports the Vector and Renderer class before defining the Explosion class:

```
import {Vector} from './Vector';
import {Renderer} from './Renderer';
```

The Explosion class begins with a series of attributes that set the animation time and frame number for the explosion and the loops to render. Here is the beginning of the Explosion class:

```
export class Explosion {
❶static readonly FRAME_TIME: f32 = 0.04;
❷public frameTimeRemaining: f32 = 0.04;

  // these four loops will be used in the animation
❸public exp1Loop: StaticArray<f32> = [0,0.2,
                                      -0.1,0,
                                      0,-0.2,
                                      0.1,0,];
  public exp2Loop: StaticArray<f32> = [0,0.3,
                                      -0.1,0.1,
                                      -0.3,0,
                                      -0.1,-0.1,
                                      0,-0.3,
                                      0.1,-0.1,
```

```
                                    0.3,0,
                                    0.1,0.1,];
    public exp3Loop: StaticArray<f32> = [0.3,0.3,
                                    0,0.2,
                                    -0.3,0.3,
                                    -0.2,0,
                                    -0.3,-0.3,
                                    0,-0.2,
                                    0.3,-0.3,
                                    0.2,0,];
    public exp4Loop: StaticArray<f32> = [0.6,0.6,
                                    0.1,0.3,
                                    0,0.8,
                                    -0.1,0.3,
                                    -0.6,0.6,
                                    -0.3,0.1,
                                    -0.8,0,
                                    -0.3,-0.1,
                                    -0.6,-0.6,
                                    -0.1,-0.3,
                                    0,-0.8,
                                    0.1,-0.3,
                                    0.6,-0.6,
                                    0.3,-0.1,
                                    0.8,0,
                                    0.3,0.1,];

❹public position: Vector = new Vector(0.0, 0.0);
    public rotation: f32 = 0.0;
    public scale: f32 = 0.2;
❺public visible: bool = false;
❻public currentFrame: i32 = 0;
```

The attributes begin with the `FRAME_TIME` and `frameTimeRemaining`. The `FRAME_TIME` is a `readonly` variable that is the time between changing the loops that it renders. The `frameTimeRemaining` is the time left until the class renders the next set of loops. After that, there are four loops rendered sequentially. There is a `position` vector, as well as a `rotation` and `scale` variable. The `visible` variable moves the object to and from the explosion object pool. Finally, the `currentFrame` tells the object which loops to render.

move

The move function checks to see if the explosion is visible and exits if it is not. The function advances the current frame, rotates, and scales the animation. If the animation is complete, it sets the visible flag back to false, making this explosion available in the explosion pool. Here is the move code:

```
public move(): void {
❶if( this.visible == true ) {
  ❷this.frameTimeRemaining -= Renderer.DELTA;
  ❸if( this.frameTimeRemaining < 0 ) {
    ❹this.frameTimeRemaining = Explosion.FRAME_TIME
    ❺this.currentFrame++;
    ❻if( this.currentFrame >= 4 ) {
      ❼this.visible = false;
      }
    }
  ❽this.rotation += 0.2;
  ❾this.scale += 0.02;
  }
}
```

The first line checks to see if the explosion if `visible`. If it is not visible, there is no need to move the explosion. The `frameTimeRemaining` is reduced by the `DELTA` time. If the `frameTimeRemaining` is less than `0`, I need to reset `frameTimeRemaining` to `FRAME_TIME` and increment the `currentFrame`. If `currentFrame` is `>= 4`, the `visible` flag is set to `false`, making this object available in the explosion object pool. The `rotation` and the `scale` is incremented for the animation.

draw

The draw function checks to see if this object is visible, and if it is visible, it will render one or more line loops based on the value of `currentFrame`. Here is the code:

```
public draw(): void {
❶if( this.visible == true ) {
  ❷if( this.currentFrame == 0 ) {
      Renderer.SN.renderLineLoop(this.exp1Loop, this.position,
                                 this.rotation, this.scale, 0xff_00_00_ff );
    }
    else if( this.currentFrame == 1 ) {
      Renderer.SN.renderLineLoop(this.exp2Loop, this.position,
                                 this.rotation, this.scale, 0xff_00_00_ff );
    }
    else if( this.currentFrame == 2 ) {
    ❸Renderer.SN.renderLineLoop(this.exp1Loop, this.position,
                                 this.rotation, this.scale, 0xff_ff_00_ff );
      Renderer.SN.renderLineLoop(this.exp3Loop, this.position,
                                 this.rotation, this.scale, 0xff_00_00_ff );
    }
    else if( this.currentFrame == 3 ) {
```

```
      ❹Renderer.SN.renderLineLoop(this.exp2Loop, this.position,
                                   this.rotation, this.scale, 0xff_ff_00_ff );
        Renderer.SN.renderLineLoop(this.exp4Loop, this.position,
                                   this.rotation, this.scale, 0xff_00_00_ff );
      }
    }
  }
```

The `draw` function first checks to see if the explosion is `visible` and only renders if it is. It branches on the `currentFrame` value and renders the appropriate line loop based on the frame number. If the `currentFrame` is `2` or `3`, the function renders more than one loop.

activate

The `activate` function is the final function in the `Explosion` class. It sets the `position`, `scale`, `currentFrame`, and `frameTime`. It also sets the `visible` flag to `true`, which takes the explosion out of the pool and causes the explosion to `move` and `draw` until the animation is complete. Here is the code:

```
    public activate( x:f32, y:f32 ): void {
    ❶this.position.x = x;
      this.position.y = y;
    ❷this.scale = 0.2;
    ❸this.visible = true;
    ❹this.currentFrame = 0;
    ❺this.frameTimeRemaining = Explosion.FRAME_TIME;
    }
  }
```

The `activate` function starts by setting the `position.x`❶ and `position.y` values to the `x` and `y` coordinates passed to the function. The `scale`❷ is reset to `0.2`, which will grow throughout the animation. The `visible`❸ flag will be set to `true`, which will make the explosion unavailable to activate in the future until the animation is complete. The `currentFrame`❹ is reset to `0`, which renders the first frame. Finally, the `frameTimeRemaining`❺ is set to the `FRAME_TIME`, which is the time to wait until the `currentFrame` increments.

https://github.com/battlelinegames/AssemblyScriptAsteroids/blob/master/src/Explosion.asc