COMP4002/G54GAM Lab Exercise 01 – Vertical shmup (shoot-em-up)

03/02/20

This lab exercise involves creating a simple top-down scrolling space shooter as an introduction to various Unity principles and features, and doing some scripting in C#. This exercise is a cut-down version of one of the official Unity tutorials, which gives step-by-step instructions and explanation, and you may find it useful to refer to it you get stuck:

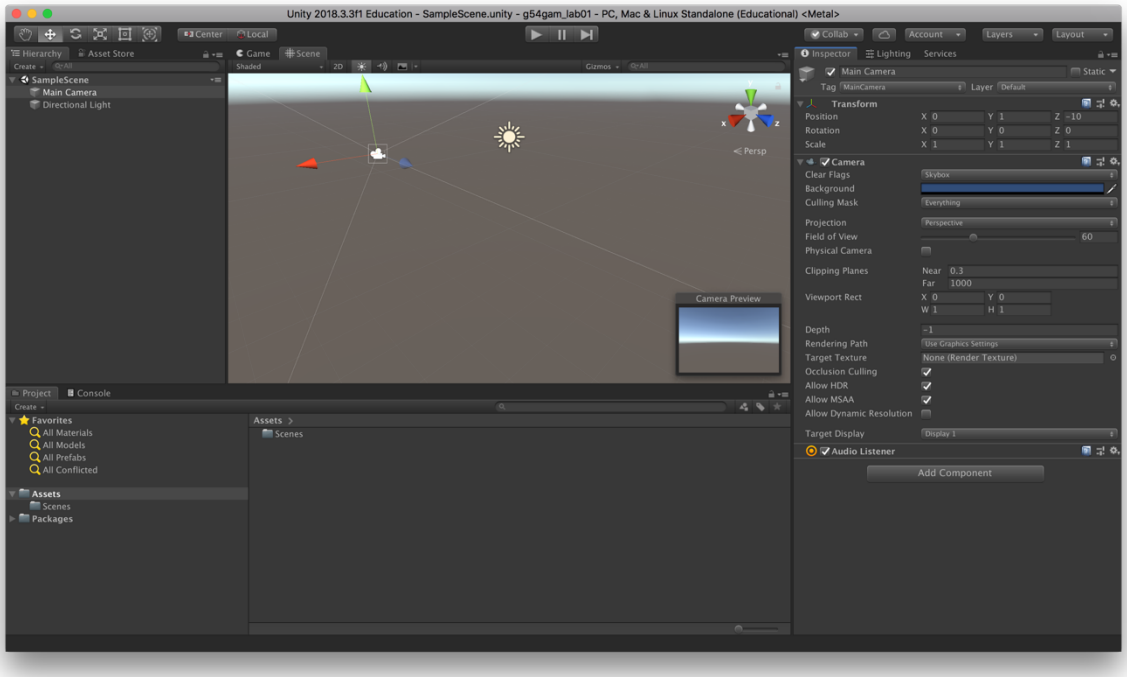
https://unity3d.com/learn/tutorials/s/space-shooter-tutorial

The assets (models, textures etc.) are available as an asset package file on Moodle.

All of the setup and code required for this exercise is given above, however it is incorrect to just copy and paste code, or to attempt to follow instructions in the tutorial by rote, as that is not the aim of the exercise. It is important that you experiment with various parameters and also try to put your own unique interpretation onto what you make. It is also important to note that there may be differences between versions of Unity.

This is the game: the player controls a spaceship that can move left and right, forwards and backwards, and fire a laser. The player's viewpoint is fixed and looks down on the spaceship for above. Asteroids appear at the top of the screen and fly towards the player's spaceship – they can be destroyed by the player's laser for points, but if one hits the spaceship it is game over and the game restarts.

Unity IDE



Start Unity – you can find it in the start menu.

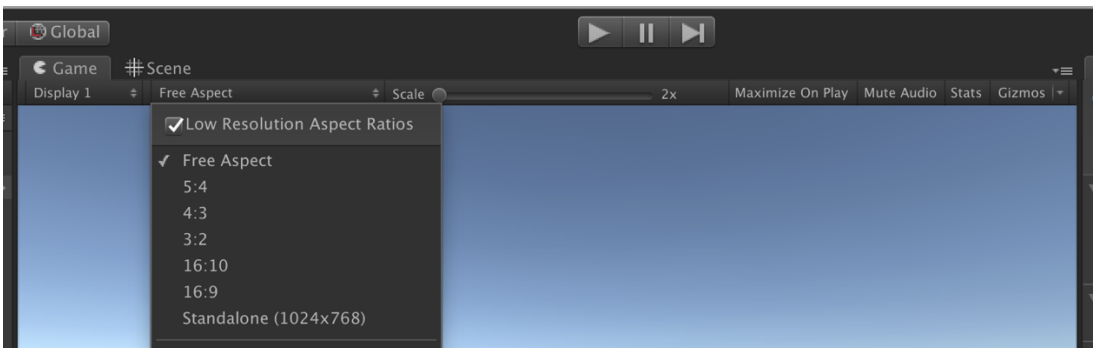
When you first start Unity you may be prompted to sign in. You can either create an account or choose to work offline – you'll need an account eventually to be able to download 3D assets from the asset store, but not for this exercise. Either way, click *New* to create a new project on disk in an appropriate location, leaving the default setting as 3D. This will open the main Unity window as above, with an empty scene to build the game in. The Unity IDE consists of multiple tabs:

- Bottom – Project assets and console. This shows assets associated with the project – the contents of the project's assets folder – textures, 3D models, C# scripts, and generic game objects – prefabs – that we want to reuse. Assets can be dragged from this tab into the scene or the hierarchy to instantiate them as game objects. The console tab prints debug logs and errors.

- Top-left – Hierarchy or scene graph. This is a hierarchical list of objects or entities that are currently in the scene. The scene is essentially the stage for the game, and contains the objects of the game. A game can have multiple scenes, with scenes mostly being used to create a level for the game. By default, the scene has a camera and a light in it, so we can see, but nothing else. Selecting an object here highlights it in the scene and opens its properties in the inspector.

- Right – Inspector. This displays the editable properties of the object selected in the hierarchy. Most objects in the scene will have a transform consisting of location, rotation and scale, as well as other properties depending on the functionality of the object. Functional *components* can be added to the object to extend its functionality, for example physics properties, collision detection, or custom C# scripts.

- Centre – Scene/Game. This presents a 3D view of the scene including the objects currently in it. Objects can be moved, rotated and scaled using their handles. The view onto this scene can be moved and rotated using the middle and right mouse buttons, and set to look along a given axis using the widget in the top right. Immediately above this view is the play button. Pressing this switches to the game tab, and starts the scene "running" – i.e. starts the game. Pressing it again stops the game and returns to the editable scene view. Here you can also set the game view to maximise on play, and also set a desired aspect ratio for the game window.



Most of the work of making a game in Unity consists of populating the scene with objects and configuring their properties, and writing scripts that determine how those objects behave and respond to user actions and events when the scene is playing.

Creating the Scene

When Unity creates a new project it will create a mostly empty scene in Assets/Scenes/SampleScene, and this is visible in the scene view. As we add to this scene, remember to regularly save it as otherwise changes will be lost – File->Save Scenes.

The first step is to import graphical assets for the ship that the player can control, asteroids that they must avoid, and a background image. Note that the process here may vary very slightly depending on which version of Unity you are using, and whether on PC or a Mac.

Download the asset package lab01.unitypackage from Moodle. This is essentially an archive that can be unpacked directly into the project to import various assets. Either drag the package onto the Project tab, or import it via Assets->Import Package->Custom Package.

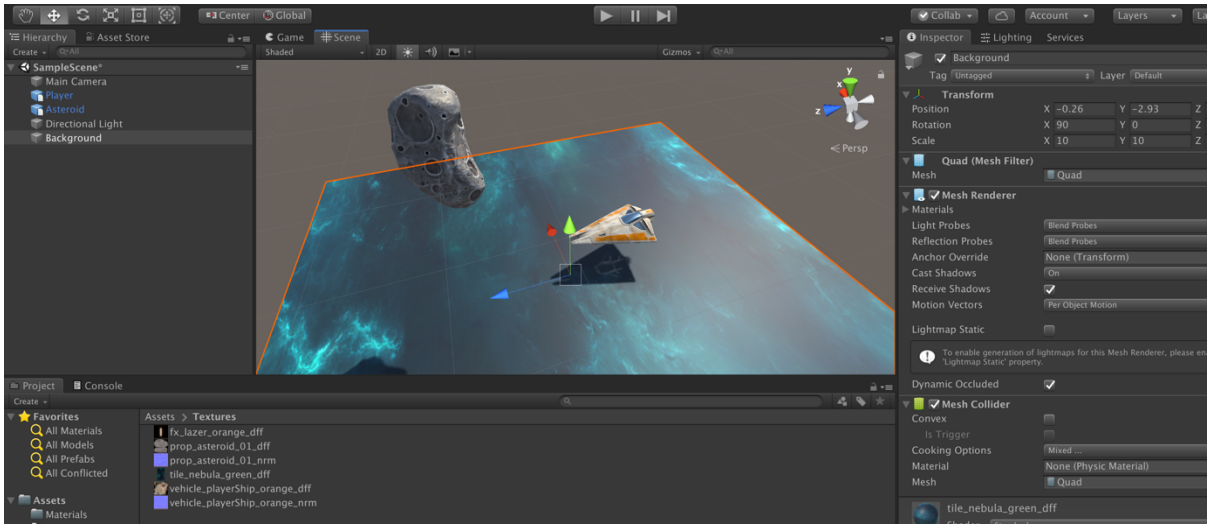
Click *Import* to copy the contents of the package into the relevant folders of your project. These are all graphical assets; **models** are 3D meshes that provide the *shape* of objects, **textures** are images that can be wrapped around the surface of a mesh to change its decorative appearance, and **materials** specify how the mesh surface should be drawn, including how it responds to light. If you click on the ship model in the assets tab, you should be able to see how in the inspector this references two of the materials, which in turn reference two of the textures.

Drag the ship model (Models/vehicle_playerShip) from the Assets tab into the Scene view. A couple of things will happen that it is important to understand:

- Unity has automatically created a **GameObject** in the scene hierarchy as a result of adding the model. By default it has been given the same name as the model, but it is very different. The model is simply mesh data – information about vertices and edges that define the shape of the spaceship so that it can be drawn. All GameObjects have a name, and a **Transform** – the position, rotation and scale of the object within the Scene.

- GameObjects can have one or more **Components** added to them. When the spaceship model was added to the scene, Unity automatically added a *Mesh Renderer* component to the newly created GameObject, and it is this that actually renders (draws) the spaceship model. We can have a GameObject without a Mesh Renderer – one that does not have a visible model but has some other functionality – but we cannot have a Mesh Renderer without a GameObject.

- GameObjects can be nested within the hierarchy, and inherit the Transform properties of their parent. In this case, the Transform property of the object is *relative* to its parent. Moving the parent also moves the object.



Rename the spaceship to something more informative, for example *Player* (Hierarchy->Right Click on the object->Rename). It is also good practice to position objects at 0,0,0 unless they need to start somewhere else in the scene. Select the ship in the hierarchy and then use the reset function to reset it to the origin (Inspector->Transform->"gear" menu->Reset).

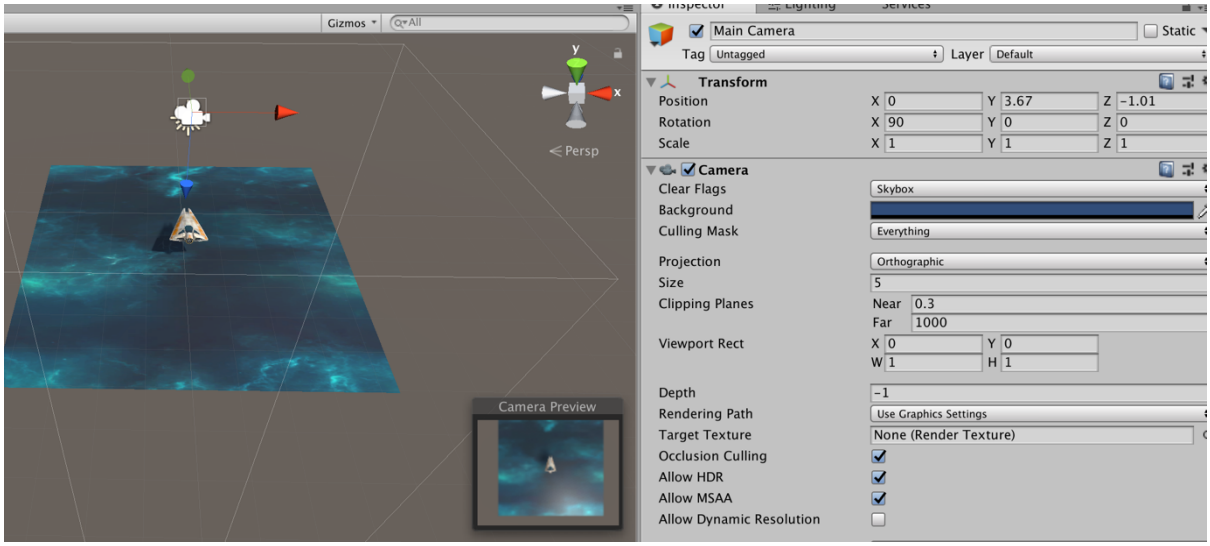
Try dragging another ship specifically onto the player object in the hierarchy. This will create a child object that inherits position, rotation etc from the parent object.

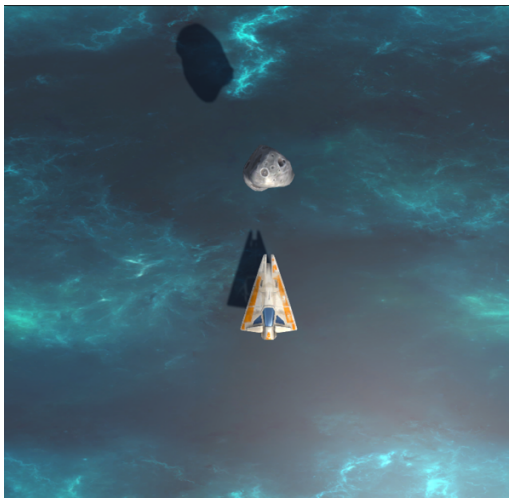
Add an asteroid (Models/prop_asteroid_01) to the scene in the same manner.

As well as using the mesh models that we have imported, we can make use of a variety of primitive shapes in the scene. Add a **Quad** object via the GameObject->3D Object->Quad menu. As before this creates a GameObject with a Mesh Renderer component, but the mesh is obviously much simpler.

Rotate this by 90 degrees around the X axis to make it flat rather than standing up, and scale it by a factor of 10. Drag the *tile_nebula_green_dff* material the assets folder onto this quad to make it look interesting. Finally move the quad down (-Y) in the scene so that it is below the ship.

Now select the Camera object in the hierachy, and move and rotate it (again by 90 degrees around the X axis) so that it is directly above the ship and pointing downwards. Change it to an *Orthographic* camera via the inspector, and change its settings until you feel like you have a good view of the ship in the scene. The orthographic camera, unlike a perspective camera, does not take into account depth – making it ideal for a top-down game.



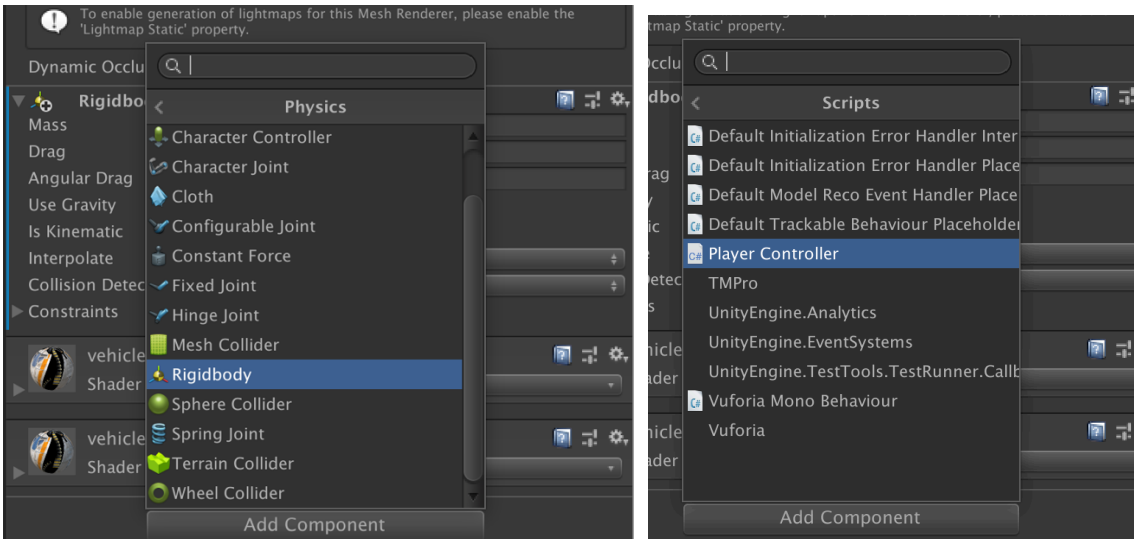


Playing the game should result in the view switching the camera view and displaying a top-down view onto the objects and background, although at this stage they will not do anything. For now the objects will only be drawn, and they do not have any components to provide them with any other functionality.

Movement and Control

To give the ship the ability to move and fly around it needs a physical as well as a visual presence. Select the Player object and in the inspector use the Add Component button to

add a Physics->Rigidbody component to the object. This prompts Unity to treat the object as if it had a physical body associated with it – i.e. one that can have forces applied to it, such as gravity, and will move accordingly.



If you play the game now the ship should disappear – gravity has pulled it down through the background quad and it can now longer be seen. In the Inspector you should see that the Rigidbody component also provides us with a variety of parameters as to how the Rigidbody should behave. Disable the *Use Gravity* flag in the properties for the Rigidbody component and it should remain still.

The next step is to create a *Script* that will apply forces to the Rigidbody in response to user input – essentially allowing the player to fly the ship around. Create a new *Script* asset by right clicking in the Asset view and then Create->C# Script. Name it something sensible such as PlayerController. Note, here we have created a new *Asset* rather than something tied to a specific GameObject, and as such we can add the new script to multiple GameObjects across multiple Scenes.

You should now be able to add the new script to the Player object as a component in the same way that a Rigidbody component was added to it.

Double clicking the script asset will open it for editing in Visual Studio so we can start to code behaviour for all GameObjects that have this script asset as one of their components.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class PlayerController : MonoBehaviour {

    // Use this for initialization
    void Start () {

    }

    // Update is called once per frame
    void Update () {
```

```
    }
}
```

Consider the above C# code.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
```

The using keyword brings in the libraries that the script will make use of.

```
public class PlayerController : MonoBehaviour
{
```

Our script defines a class, PlayerController, that inherits from MonoBehaviour. MonoBehaviour is the base class from which every Unity script derives. Like Java, and unlike Python, C# uses braces to delineate classes and functions. A statement must be ended with a semicolon. Indentation is not important.

```
    // Start is called before the first frame update
    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {

    }
}
```

There are two methods within the PlayerController object. Start() is called when the object is first instantiated. Update() is called once per frame – i.e. whenever the screen is updated, or 30 times per second (this is a simplification, but will suffice for now).

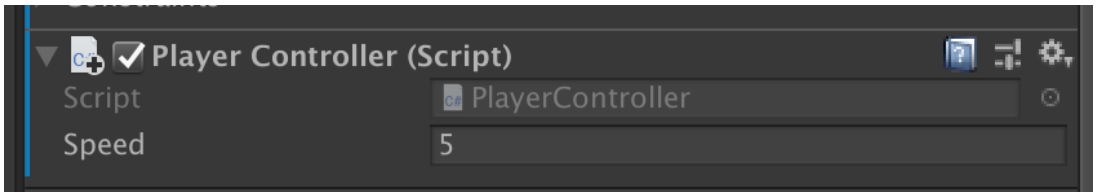
```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class PlayerController : MonoBehaviour
{
    public float speed = 5.0f;

    // Start is called before the first frame update
    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {
        float horizontalMovement = Input.GetAxis("Horizontal");
        float verticalMovement = Input.GetAxis("Vertical");

        Debug.Log("Input: " + horizontalMovement + " " + verticalMovement);

        Rigidbody r = GetComponent<Rigidbody>();
```

```
        r.velocity = new Vector3(
            horizontalMovement * speed,
            0.0f,
            verticalMovement * speed);
    }
}
```

The updated code now takes user keyboard input and applies a force to the game object. We could literally set the position of the object, but applying a force gives a slightly more naturalistic feel to the movement. Unity's physics simulation will then calculate how the object should move in response to the force applied.

```
    public float speed = 5.0f;
```

The component has a member variable, speed. Making the variable public causes it to appear as an editable property in the inspector view for the object that this script is attached to – meaning the it can be set, monitored and altered from within the Unity IDE, but importantly while the game is playing.




```
        float horizontalMovement = Input.GetAxis("Horizontal");
        float verticalMovement = Input.GetAxis("Vertical");

        Debug.Log("Input: " + horizontalMovement + " " + verticalMovement);
```

Each time Update() is called, the local variables horizontalMovement and verticalMovement are populated with the current user input. This is a number between -1.0 and 1.0 for each axis; forwards-backwards, left-right, and by default is controlled by the WASD keys and the cursor keys.

The Debug.Log call prints out the current input to the console tab.

```
        Rigidbody r = GetComponent<Rigidbody>();
```

Next, a reference to the Rigidbody component created earlier is obtained.

```
        r.velocity = new Vector3(
            horizontalMovement * speed,
            0.0f,
            verticalMovement * speed);
```

Finally, the velocity of the rigidbody is set based on the user input multiplied by the speed variable. As the scene is a 3D environment, the rigidbody's velocity is a Vector with a speed in the X, Y and Z axes.

Save the script then play the game and ensure that you can fly the ship around. As the movement of the rigidbody is unconstrained the ship can fly off the screen. Modify the

Update() function to limit the position within the view of the camera by updating the position of the rigidbody after setting its velocity. Create float variables named xMin, xMax, zMin and zMax, and make them public in the same manner as the speed variable, before deciding appropriate values for them.

```
r.position = new Vector3(
    Mathf.Clamp(r.position.x, xMin, xMax),
    r.position.y,
    Mathf.Clamp(r.position.z, zMin, zMax));
```

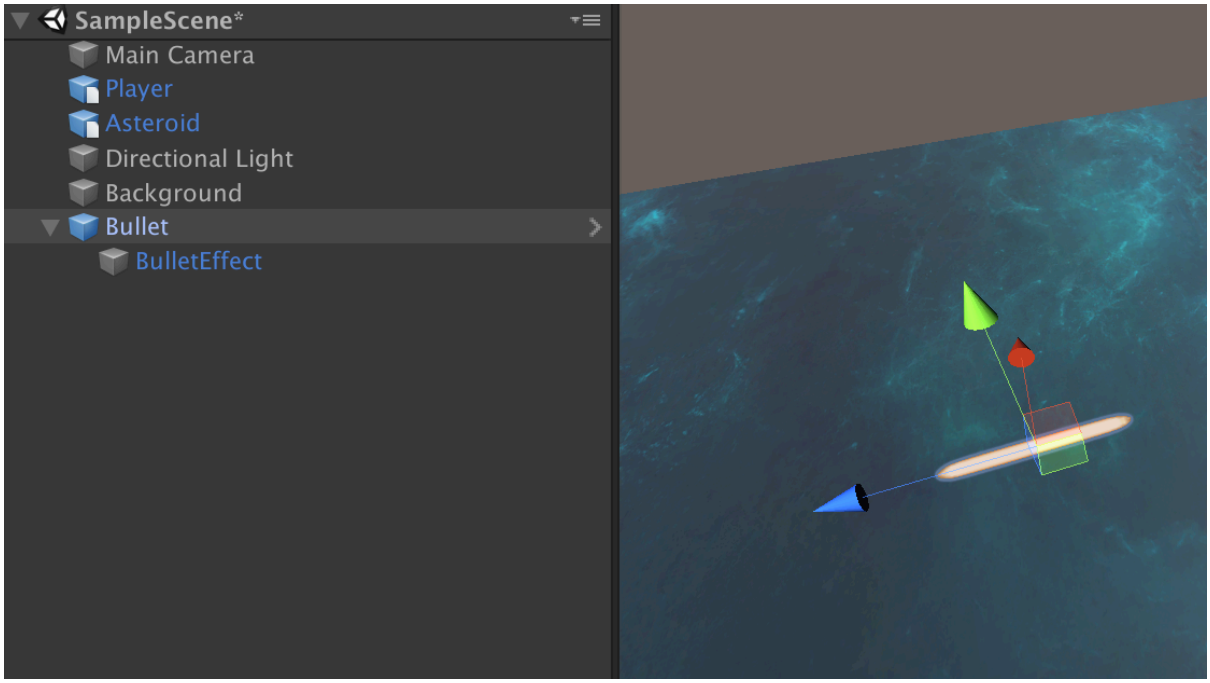
Firing

The next step is to give the ship a weapon to fire at asteroids. We're going to separate the logic of bullets from their visual display using children in the hierarchy, and then turn the object into a *Prefab* – a template that can be instantiated multiple times programmatically.

Create a new empty game object (Create Empty) in the hierarchy, give it a sensible name and reset its transform. Now create a Quad (called BulletEffect in the screenshot) in the hierarchy, and rotate it so that it is flat to the camera. Apply the *lazer* material to it. Drag the Quad over the Bullet object to make it a child. This means that when the parent Bullet object is created and moved, the BulletEffect Quad will also move, but will also be rotated relative to its parent ensuring it appears flat to the camera.

Why do we need to do this? Without rotation, the Quad stands upright – effectively invisible to the camera. By rotating the Quad and making it a child of the Bullet, when we instantiate a new Bullet the Quad will be facing the right way, without us needing to do any additional rotation.

You should also remove or disable the MeshCollider component from the BulletEffect child, or Unity will print warnings.



Go back to the *parent* bullet object, and as with the ship add a Physics->Rigidbody component to it.

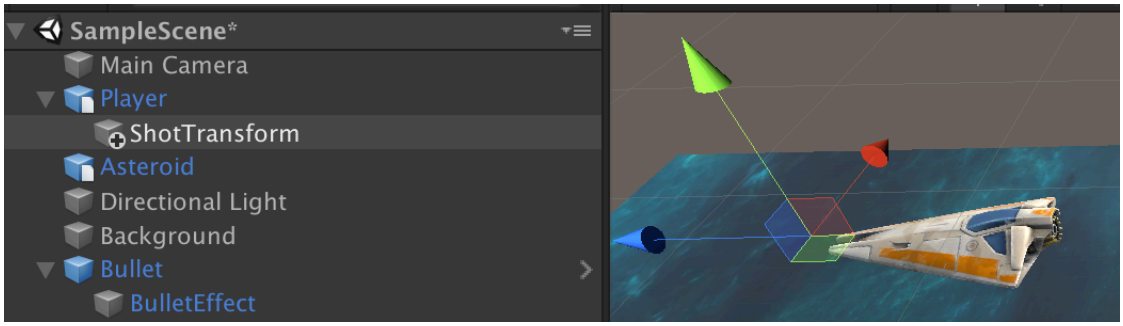
Next, we want to give the bullet movement. As before, add a new script component to the bullet, and call it Mover. This code will give the bullet forward velocity when it is instantiated.

```
public float speed = 5.0f;

// Start is called before the first frame update
void Start()
{
    Rigidbody r = GetComponent<Rigidbody>();
    r.velocity = transform.forward * speed;
}
```

Playing the game, you should see the single bullet object in the scene moving upwards, away from the ship.

Create a folder in the asset tab and name it *Prefabs*. Now drag the Bullet *from* the hierarchy into this new folder, selecting to create an Original Prefab if prompted. This creates a reusable **asset** from our Bullet, essentially a template or a class from which multiple instances can be instantiated. You can create multiple Bullets by dragging the asset back into the scene, but we will now perform this programmatically.

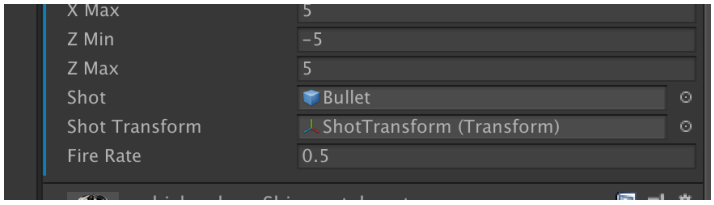
Return to the Player object. Create a new empty Game Object as a child of the Player object (named ShotTransform in the screenshot below), and place it just in front of the ship. We will use the location of this object as the position to create bullets, so that they appear from the front of the ship.




```
public GameObject shot;
public Transform shotTransform;

public float fireRate = 0.5F;
private float nextFire = 0.0F;

void Update()
{
    ...

    if (Input.GetButton("Fire1") && Time.time > nextFire)
    {
        nextFire = Time.time + fireRate;
        Instantiate(
            shot,
```

```
                shotTransform.position,
                shotTransform.rotation);
        }
    }
```

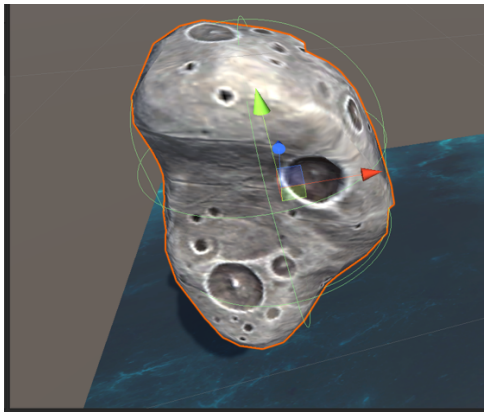
This code, added to the PlayerController script and further extending the Update function, allows the player to fire at a defined rate. It **instantiates** an instance of the object held in the *shot* variable, with a transform (position and rotation) as specified by the *shotTransform* variable. The final step is in the inspector to specify values for these variables – the bullet prefab and the child object at the front of the ship respectively.

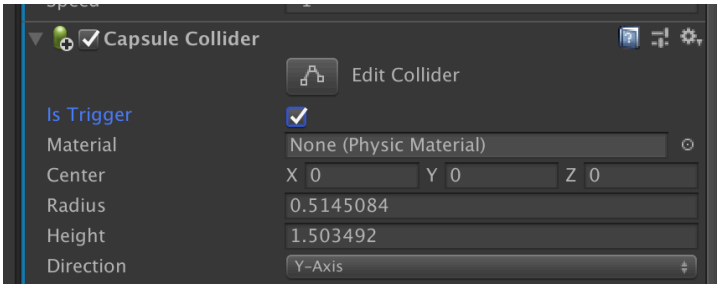


Ensure That you can fly the ship around and fire bullets (the CTRL key and left mouse click are the default fire inputs).

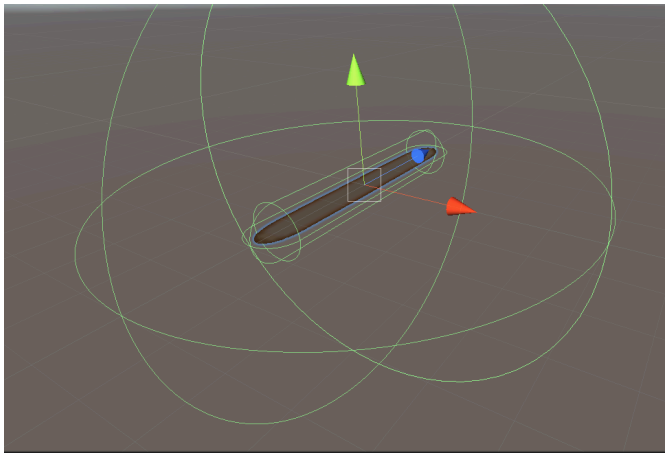
Asteroids and Detecting Collisions

The asteroid object currently does nothing – here we want to be able to shoot it, and have it destroy the ship if it collides with it. As before, give the asteroid in the scene a Rigidbody component. Attach your *Mover* script component to the asteroid, but this time set the speed to a negative value – this will give the asteroid a velocity down the screen towards the player.





Add a *Physics->Capsule Collider* component the asteroid. This will give the asteroid a measurable presence within the physics simulation and allow Unity to calculate when other objects touch or intersect with it. The capsule collider is a primitive capsule shape that should roughly coincide with the shape of the asteroid with some manipulation, but can be much more efficiently used for collision detection than the asteroid shape itself. Enable *Is Trigger* within the component – this will allow it to trigger collision events, and so we can tidy it up if it escapes from the boundaries of the game.



Repeat this process with the bullet parent Prefab, again making it a trigger. Similarly, add a capsule collider to the ship, however this time you do not need to enable it as a trigger.

Finally, we need to script what Unity should do when a physics event (i.e. a collision) occurs. Create a new script component for the asteroid object called something like DestroyByContact. This code will override the physics event when the asteroid encounters another collider (the ship or bullet colliders you have just created), and as is hopefully obvious will destroy both the object that it has collided with (the ship or the bullet), and itself.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class DestroyByContact : MonoBehaviour
{
    // Start is called before the first frame update
    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {

    }

    void OnTriggerEnter(Collider other)
    {
        Destroy(other.gameObject);
        Destroy(gameObject);
    }
}
```

Check that this works as desired with the single asteroid in the scene. If it does, drag the asteroid into the Prefabs folder, and try adding several asteroids to the scene to see how the game works. You might notice that asteroids also destroy each other if collide with one another.

Putting it all together

You should now have the basic core mechanic of a simple game – fly around, shoot asteroids, avoid being destroyed. The final step is to create waves of asteroids to provide a challenge for the player.

Create a new empty game object and name it GameController. This object will have no visual representation or physics behaviour in the scene, but will control the overall logic of the game. It will have an infinite loop that continually spawns asteroids for the player to shoot and/or dodge. Create a new script for this object (call it GameController). This code is more complicated, and somewhat daunting for those new to C#, so consider what it does a step at a time.

```
public GameObject hazard;
public Vector3 spawnValues;
public int hazardCount;
public float spawnWait;
public float waveWait;

// Start is called before the first frame update
void Start()
{
    StartCoroutine(SpawnWaves());
}

IEnumerator SpawnWaves()
{
    while (true)
    {
        for (int i = 0; i < hazardCount; i++)
        {
            Vector3 spawnPosition = new Vector3(
                Random.Range(-spawnValues.x, spawnValues.x),
                spawnValues.y,
                spawnValues.z);

            Quaternion spawnRotation = Quaternion.identity;

            GameObject asteroid =
                Instantiate(hazard, spawnPosition, spawnRotation);

            asteroid.GetComponent<Rigidbody>().angularVelocity =
                Random.insideUnitSphere * 10;

            yield return new WaitForSeconds(spawnWait);
        }
        yield return new WaitForSeconds(waveWait);
    }
}
```

The logic we want to implement is a simple wave system. Asteroids should be instantiated at a random position at the top of the screen. There should be a set number of asteroids per wave, and a gap between each asteroid being instantiated so they do not collide. There should be a gap between wave.

A complexity here is how Unity handles threads. By default there is a single thread of execution that is handling the Start and Update function calls. If a function fails to return (for example contains an infinite loop), or takes a long time (for example waits for something to happen) then the game will appear to hang.

To get around this, we use a Unity object called a Coroutine, which has the effect of allowing things to happen in parallel. When the GameController is instantiated – at the beginning of the game, as the object is in the hierarchy - the Start() method starts a Coroutine. Coroutines must return an *IEnumerator*, specifically a *WaitForSeconds* object, which we don't need to understand the details of, but which allows us to execute some code, but then yield control back to the rest of the engine until a certain amount of time has elapsed.

[WaitForSeconds is like using Thread.sleep(time) in Java, but we're returning control to the main thread until the time is up. This gives multiple objects within the scene the semblance of their own individual threads, but a single thread services all of the Coroutines in turn.]

In the code above we have a simple for loop, that generates *i* hazards (in this case the asteroid) waiting for a small amount of time (spawnWait) between each one, so that they're a little spaced out coming towards the player. It then waits for a longer time between these *waves* of asteroids (waveWait) before starting again.

```
Vector3 spawnPosition = new Vector3(
    Random.Range(-spawnValues.x, spawnValues.x),
    spawnValues.y,
    spawnValues.z);

Quaternion spawnRotation = Quaternion.identity;

GameObject asteroid =
    Instantiate(hazard, spawnPosition, spawnRotation);
```

The position of each new asteroid is randomised across the x axis (the width of the screen) just off the top of the screen out of view). These values, and the object to create (the asteroid prefab) are again exposed via the inspector so that we can assign them).

```
GameObject asteroid =
    Instantiate(hazard, spawnPosition, spawnRotation);

asteroid.GetComponent<Rigidbody>().angularVelocity =
    Random.insideUnitSphere * 10;
```

Unlike the bullet instantiation earlier, this time we will also keep a reference to the GameObject that has just been instantiated. As a simple extra effect the new asteroid is given a random angular velocity – rotational movement – so that there is some variation between the asteroids. Obviously this could also be done in a script attached to the asteroid itself.

You may have noticed that every bullet that is fired that doesn't hit an asteroid remains in the hierarchy travelling upwards, and every asteroid that the player does not shoot remains travelling downwards. This is essentially a memory leak – these are unwanted objects that are taking up memory. Create a script component, *DestroyByTime* that calls the Destroy function with a delay.

https://docs.unity3d.com/ScriptReference/Object.Destroy.html

```
void Start()
{
    Destroy(gameObject, 20);
}
```

Here, *gameObject* refers to the Game Object to which the script is attached.

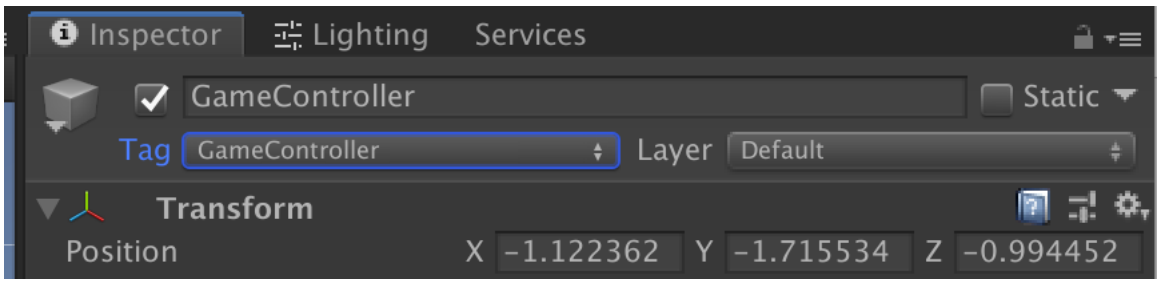
Scoring

The final addition to the game is to keep track of the score in some way. At this stage we will simply print the score to the console. Firstly, add a new variable and a function to the GameController script to maintain the value of the score:

```
int totalScore = 0;

public void AddScore(int score)
{
    totalScore = totalScore + score;
    Debug.Log("Current score:" + totalScore);
}
```

To make use of this function other objects will need to have a reference to the GameController script component that is attached to the GameController object. However, as these objects (asteroids) are instantiated at runtime we cannot set the value of this property via the inspector this time. Instead, when instantiated the asteroids can find objects with a certain tag.

Add the tag *GameController* to the GameController object:



Next, in the DestroyOnContact script, retrieve the object with this tag, retrieve the script component from this object, and keep a reference to the component as a variable:

```
GameController gameController;

// Start is called before the first frame update
void Start()
{
    GameObject gameControllerObject = GameObject.FindWithTag("GameController");
    if (gameControllerObject != null)
    {
        gameController = gameControllerObject.GetComponent<GameController>();
    }
    if (gameController == null)
    {
        Debug.Log("Cannot find 'GameController' script");
```

```
        }
    }
```

Then, when the asteroid is destroyed, we can call the AddScore method on the GameController script and increment the score.

```
    void OnTriggerEnter(Collider other)
    {
        gameController.AddScore(10);
        Destroy(other.gameObject);
        Destroy(gameObject);
    }
```

As an extension, restart the scene when the ship is destroyed using the following function call:

```
    Application.LoadLevel(Application.loadedLevel);
```

Exercises

Experiment with the various parameters:

- Ship speed
- Bullet speed
- Fire rate
- Asteroid speed
- Asteroid waves

At what point is the game the most challenging, but yet still playable?