

TECH 3707 - Advanced Mixed Reality



You guys all know the drill by now. Syllabus is [here](#) but always expect changes!

Github is the latest

Most Up-to-date Syllabus:



<https://github.com/ivaylopg/AdvancedMixedRealityStudio>

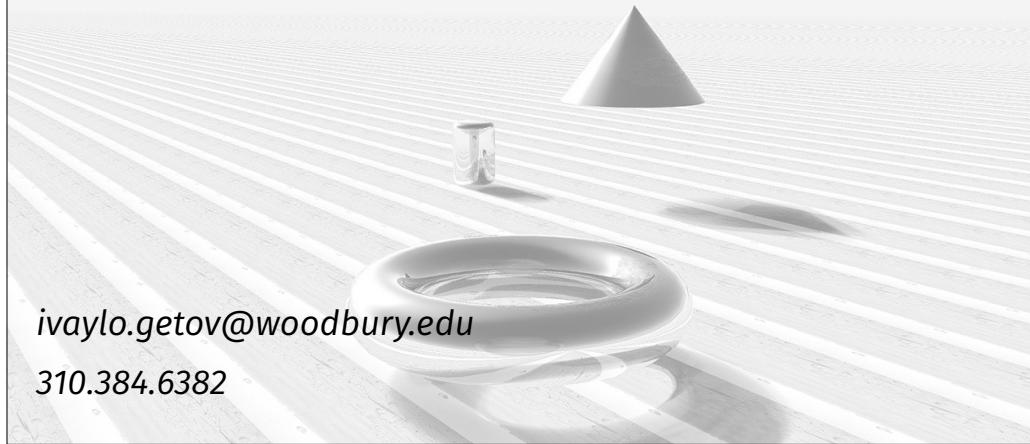
I will do my best to keep the Moodle page updated, but I can promise that most up-to-date class materials will be here:

<https://github.com/ivaylopg/AdvancedMixedRealityStudio>

Contact Me

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What do we mean by “ADVANCED” Mixed Reality



First: What is a programmer?

Broad Understanding About A Wide Range



(Intro) Mixed Reality Studio was about covering a lot of different stuff:

Virtual Reality Hardware

Game Design

UX Design

Project Management



We aspired to this...



...but it's OK if we made this in the end. (It's still a robot!)



Come up with examples on the board range of things we know a little about:

Virtual Reality Hardware
Game Design
UX Design
Project Management

Now we're going to drill down into the specifics of a slightly narrower field. We're going to take our broad knowledge and apply it to a more constrained area.

The horizontal is still important. It's what makes you *better* at the vertical!

(This is called the T-Shaped Designer/Developer/Engineer/Person)

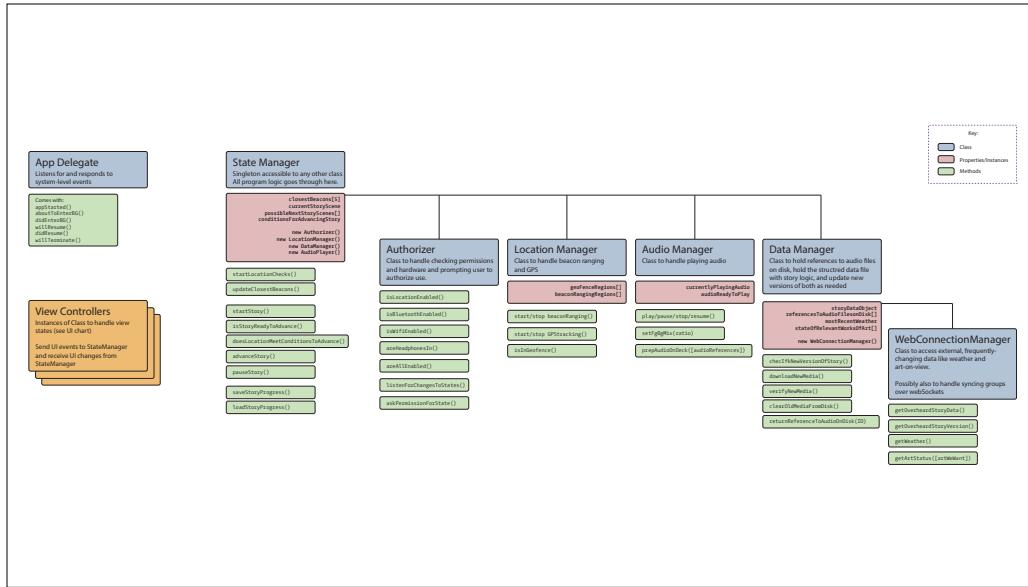
Good Practices

Commented Code

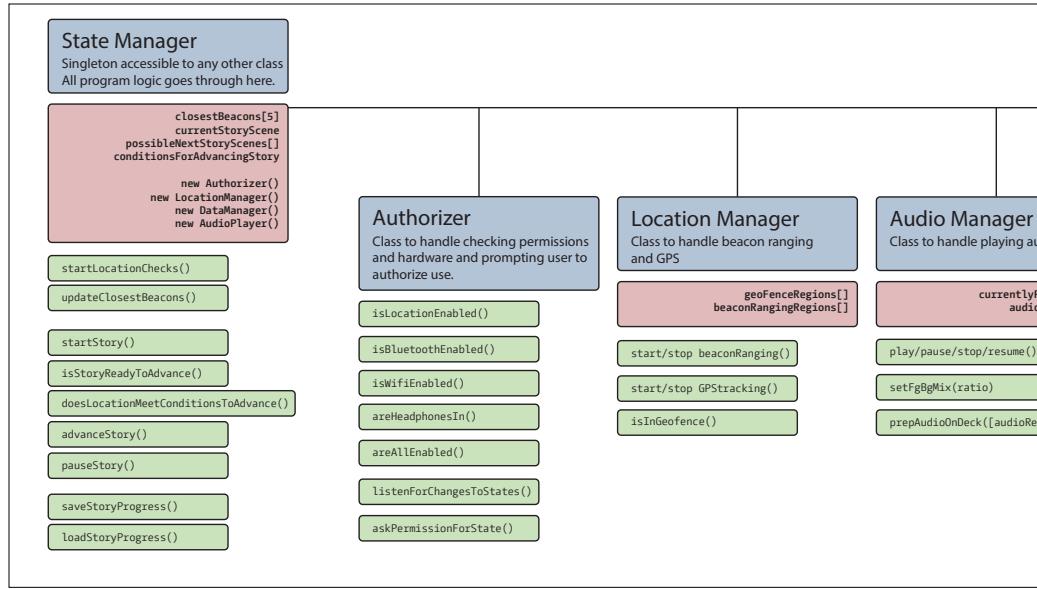
Plan/Pseudocode

The project actually...uh...works.

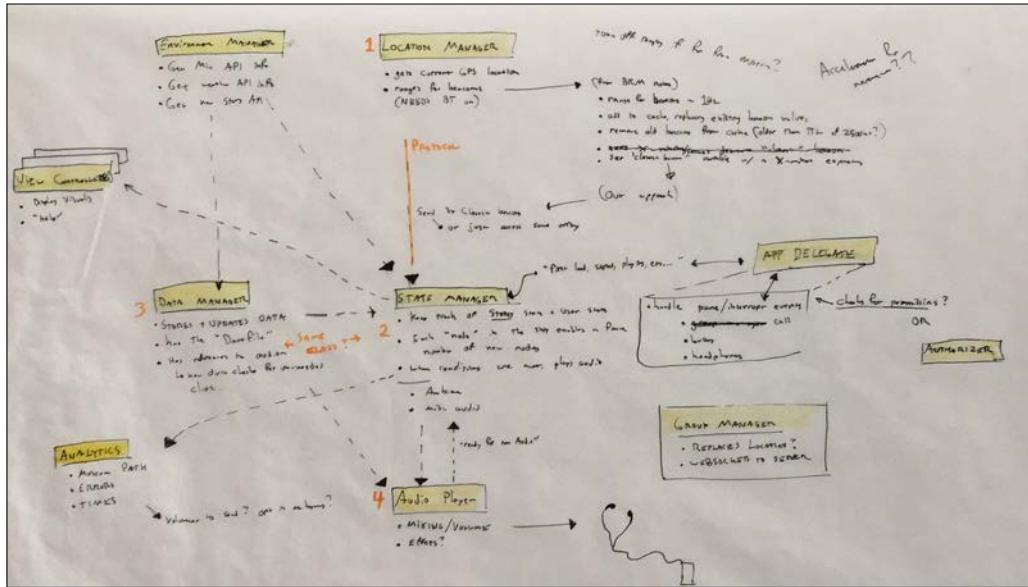
I'm also going to hold you more accountable for good practices



- I'm also going to hold you more accountable for good practices
- PLAN IT OUT
- Here is example of a way to organize an app with lots of components



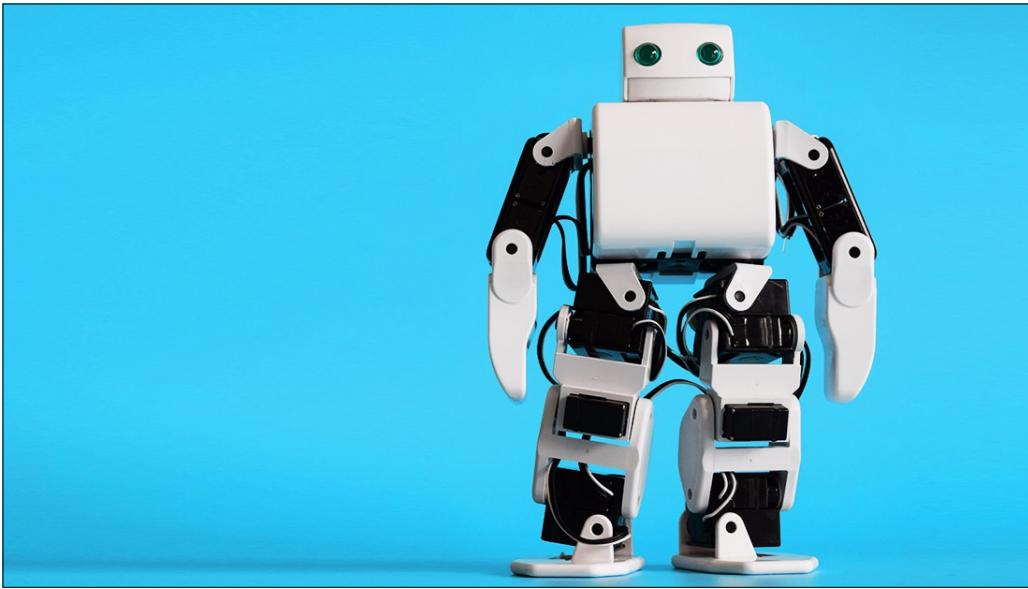
Even for simple programs, helps to organize into well-defined pieces (classes) and the variables & functions that go along with each piece.



- Plan doesn't have to be beautiful.
- Here is the same chart, before it was cleaned up and finalized



So even if we aspire to this and don't quite make it...



...we should still be landing somewhere around here

What are we focusing on?





Mobile AR

Handling real-world coordinate spaces



Then: adding networking.

This could be inter-device communication...



... or interfacing with IoT



Finally: Publishing an app to the app store.

Assignments

First Project - Interactive AR - 20%

Final Project - Shared AR Experience - 30%

Participation, attendance, and classwork - 50%



Format

Chapter 0 Recap Topics

Making sure everyone is back up to speed
and re-familiarized with Unity and C# development.

Course will be organized into chapters



Format

Chapter 1 **Expanding on Fundamentals**

A series of class discussions, speakers, and exercises.
Deep dive into specific concepts and explore techniques.



Format

Chapter 2 **Interactive AR**

We will be developing a mobile AR application
based on the Vuforia framework



Format

Chapter 3 Shared AR Experience

We will build on the previous project
to develop a multi-user mobile AR app



You are not required to have your own computer...

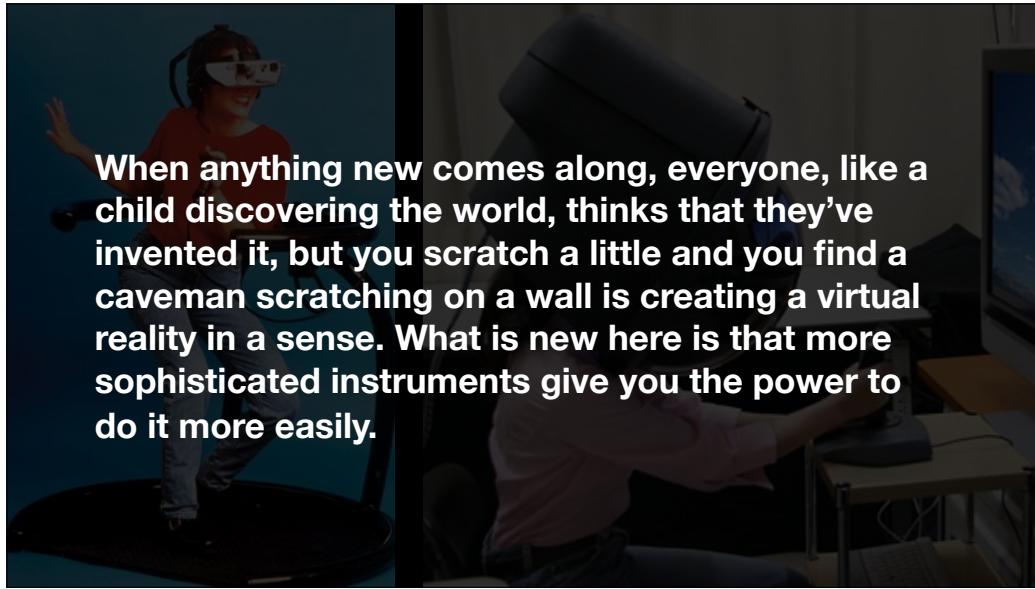


... especially since we'll be doing a considerable amount of work on macOS and iOS once we start building to devices

Let's Go!



Lots of info coming your way today. Should mostly be a recap though...



When anything new comes along, everyone, like a child discovering the world, thinks that they've invented it, but you scratch a little and you find a caveman scratching on a wall is creating a virtual reality in a sense. What is new here is that more sophisticated instruments give you the power to do it more easily.

Morton Heilig (Sensorama and Telesphere inventor)

Augmented Reality



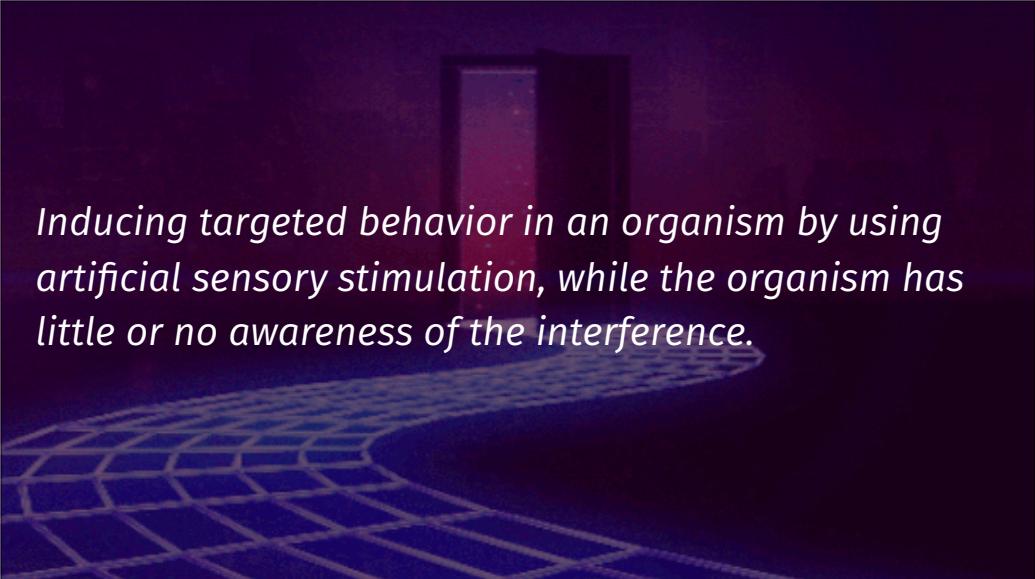
With VR we could create everything!

In AR, we have to (get to?) work as a layer on top of the real world (this is actually *harder!*).

What is AR/VR/MR?



Let's take a look at our old definition again...



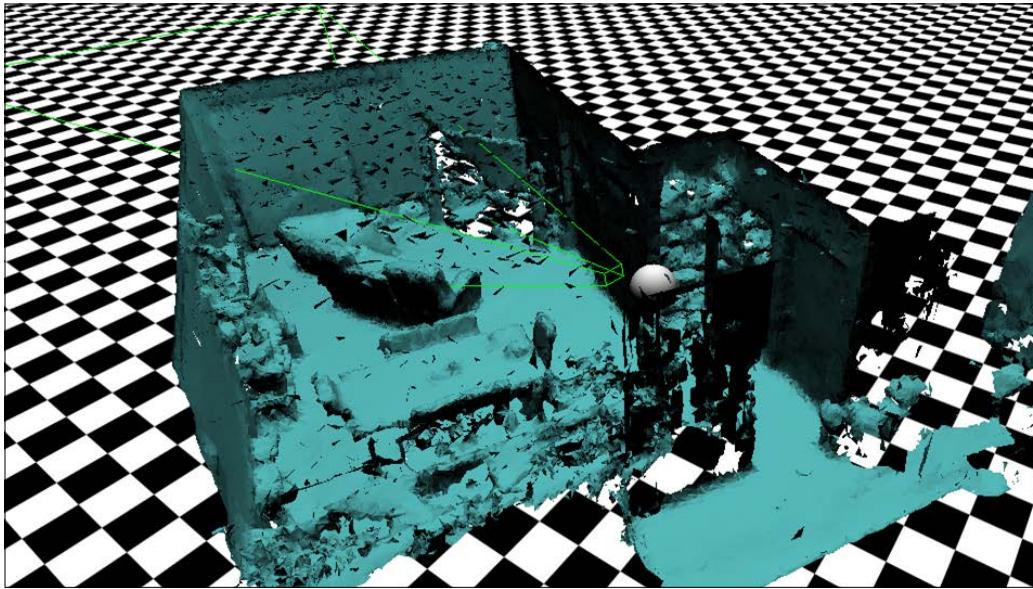
Inducing targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference.

This may need to be revised a bit. AR is generally more actively engaged in that “interference”



Awareness of the world: 3d Sensors (yay occlusion!)

Similar to what a Kinect does - gets a 3D model of what it can see - but the hololens continues to build that model as you move around.



The hololens creates an increasingly detailed model of your space as you move and look around.



Awareness of the world: camera + feature-points.

ARKit/ARCore devices that don't have depth sensors try to lock on to details (features) in the images that they see, and then do complex math in-between each frame to see how those feature points have changed.



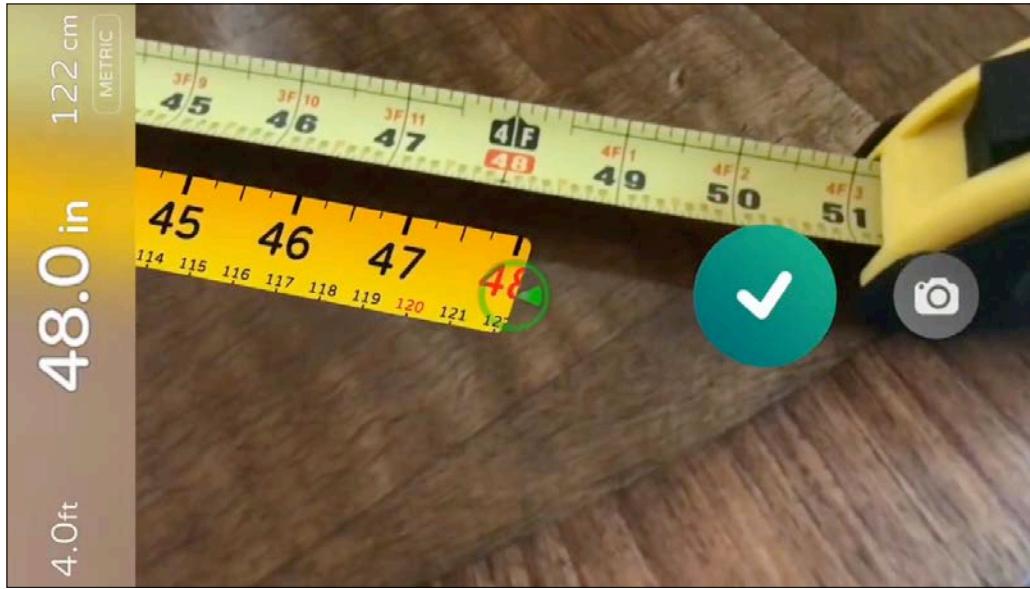
This lets us do some exciting stuff in/to the world.



Games

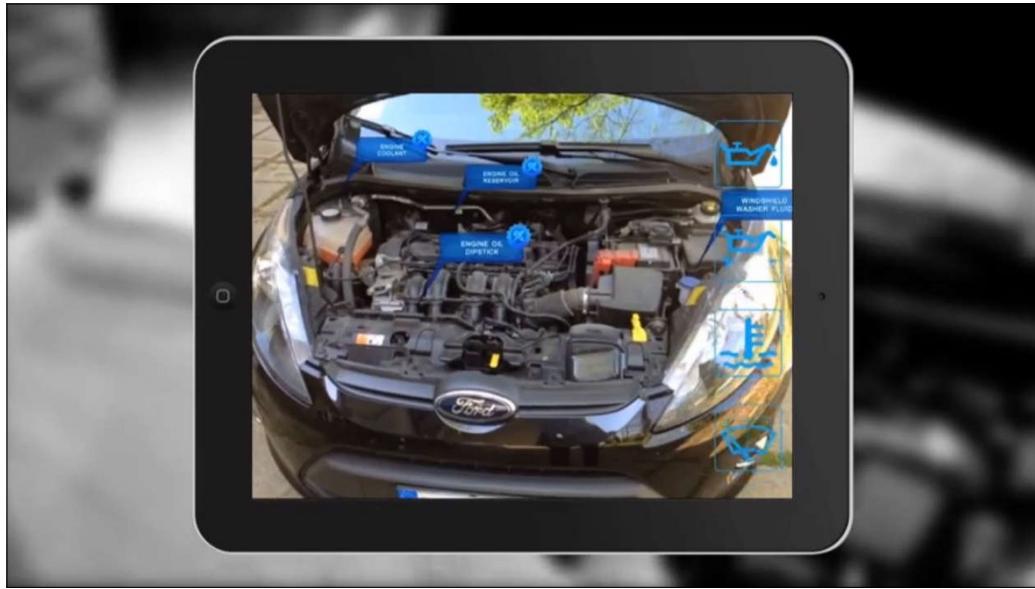


Interactive storytelling.

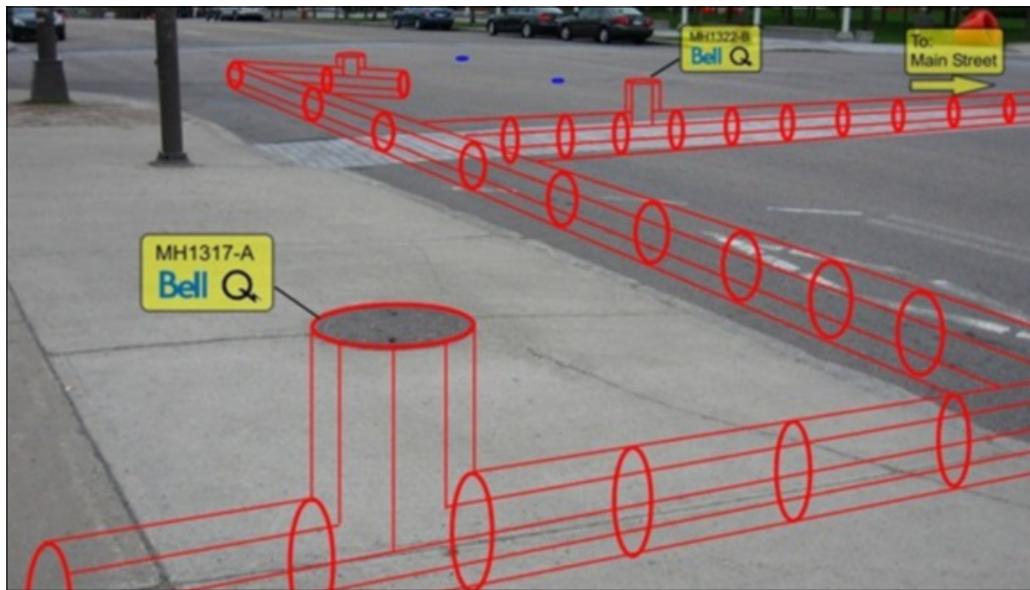


Tools

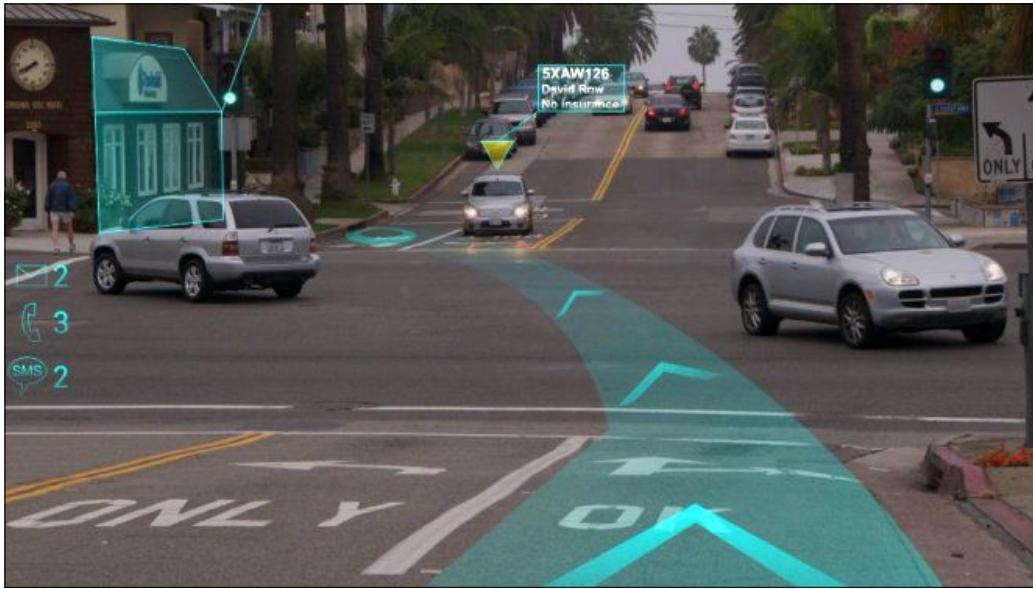
1:1 relationship with real-world scale means AR apps that can measure the environment



Instruction/teaching



Safety/Survey



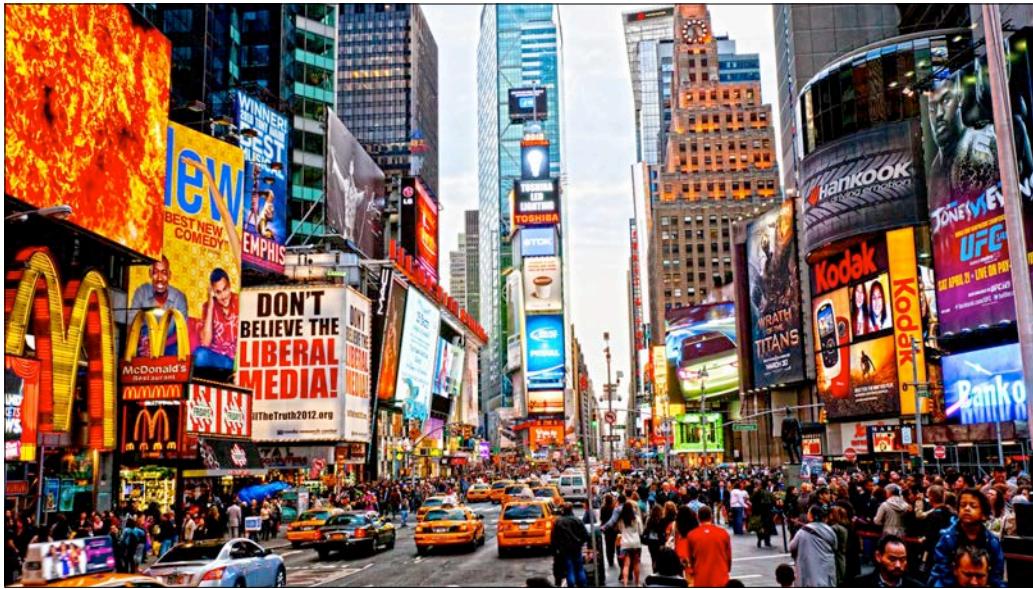
Directions



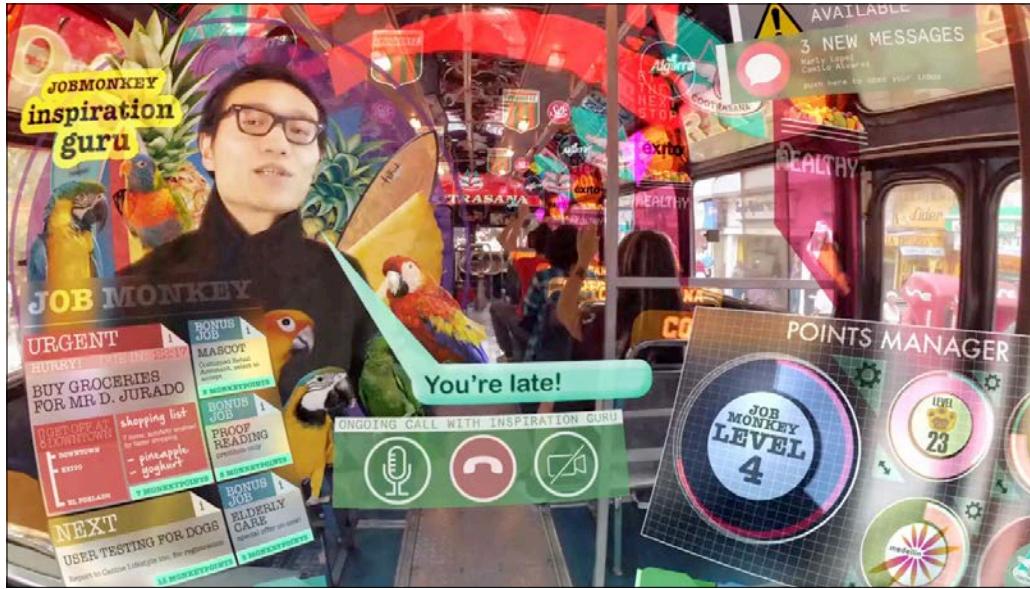
JPL uses Hololens to visualize 1:1 models of rovers, allowing designers to discover relationships and problems before anything is actually built.



You can use Google's Translate app to translate this sign in realtime!



Looking at a slightly darker application. What happens when we go from this...



... to this? (i.e. when Times Square follows a user everywhere they go)

— — —
Keiichi Matsuda

<http://km.cx/projects/hyper-reality>

<https://twitter.com/keiichiban>



VR/AR can be seen as an evolution of **content** (what are we looking at) and an evolution of **platform** (how are we looking at it)

Progression from “usable by a small few” to “usable by everyone”

Vive is expensive. Smartphones are ubiquitous.

Disney says their future is in AR, not VR



Even the idea of a keyboard as input had to be invented - that you could interact with computers using an alpha-numeric alphabet

We can invent new types of interaction.

Maybe it's moving in with your phone while you hold your finger down on screen? Maybe it's drawing a specific shape on your phone?

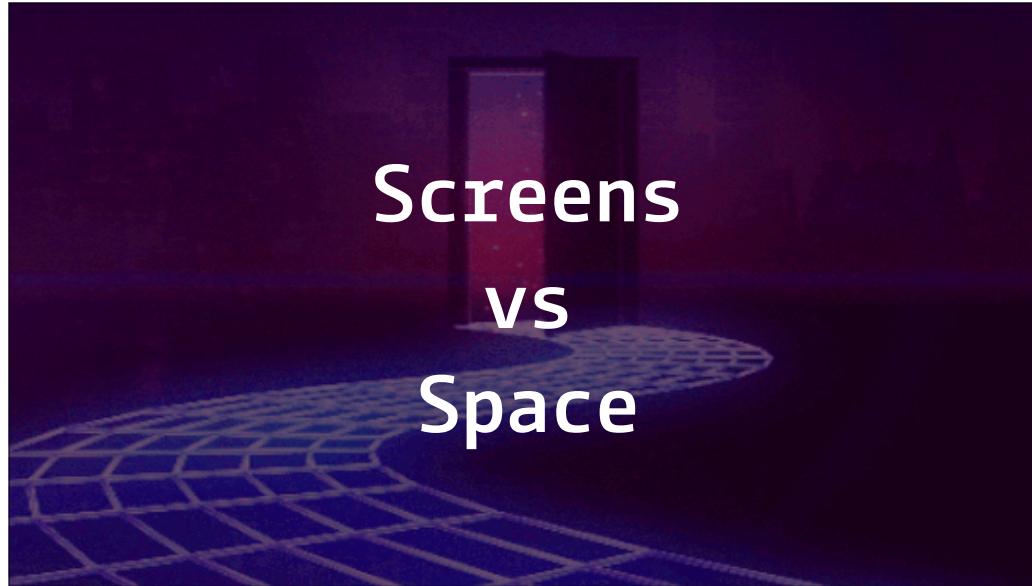
Expectations

With new types of interface, we must teach users *how* to perform new kinds of interactions.



Baby trying to pinch/zoom on magazine after using iPad - 2011

We have to be *taught* the possibilities and limitations



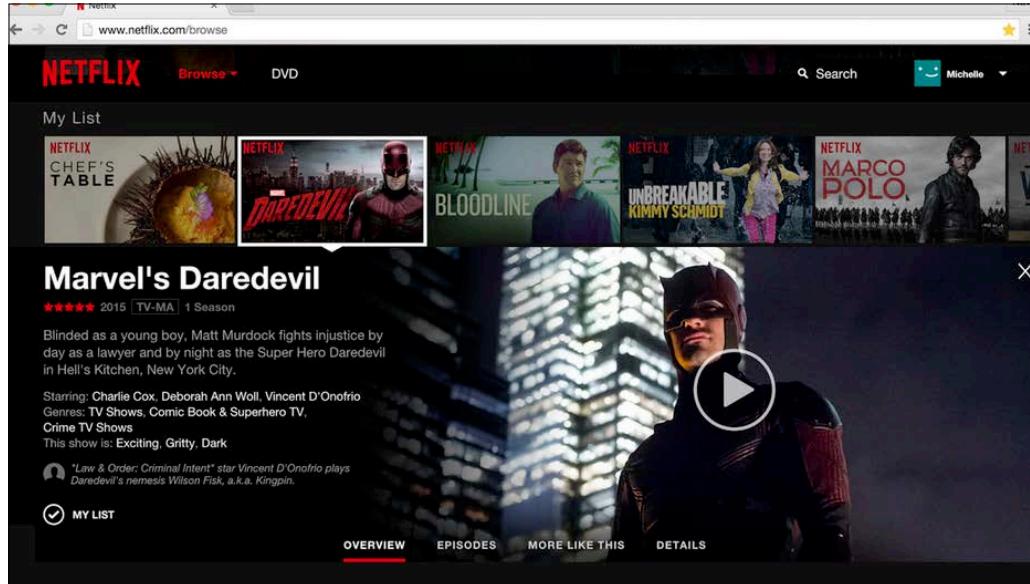
Revisiting some concepts...

Our space just got a lot bigger (and smaller)

All of a sudden we have to think about a spatial context for what we make

We are not limited by pixels or the dimensions of a rectangle, but by the available space.

Designing for Mobile AR, do we have to keep one foot in both?



VR - deals with it by creating new environments

Netflix web interface...



..vs Netflix VR interface

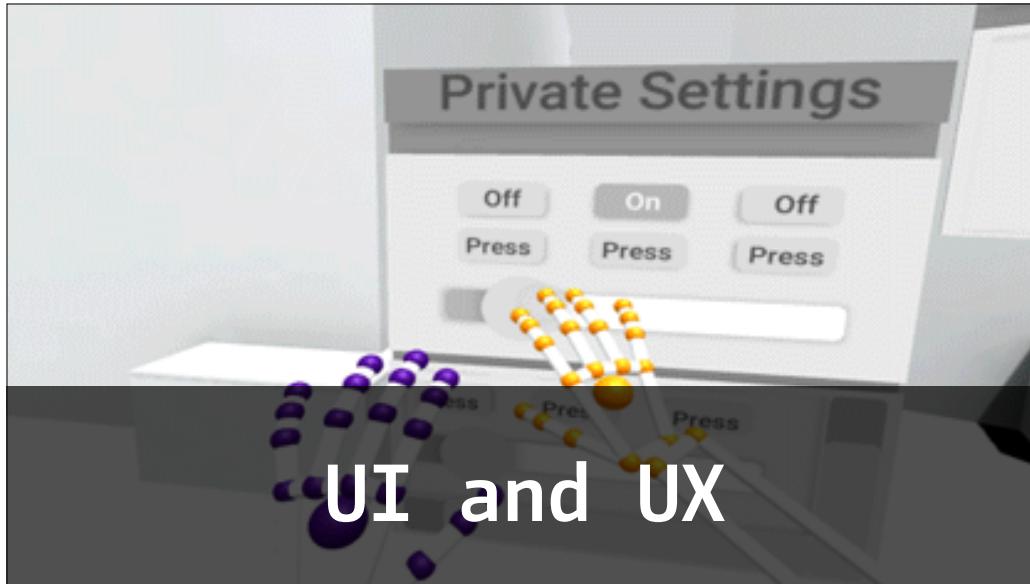
Anticipating a future where we can comfortably sit in VR for a long time, Netflix creates the ideal context in which to watch movies (All of it's existing content is 2D)



Examples:

Pokemon GO - AR does not need to be a headset. Pokemon GO is like a "Lens" into another world.

Has both screen (See the UI buttons?) **and** Space



Revisiting some concepts.

What tools do we have open to us? What *don't* we have?



Manipulation

What is the interface?



Moving through an environment to discover content - no direct manipulation.



So what tech will we be using?

...Apple ARKit...



...Google AR Core...



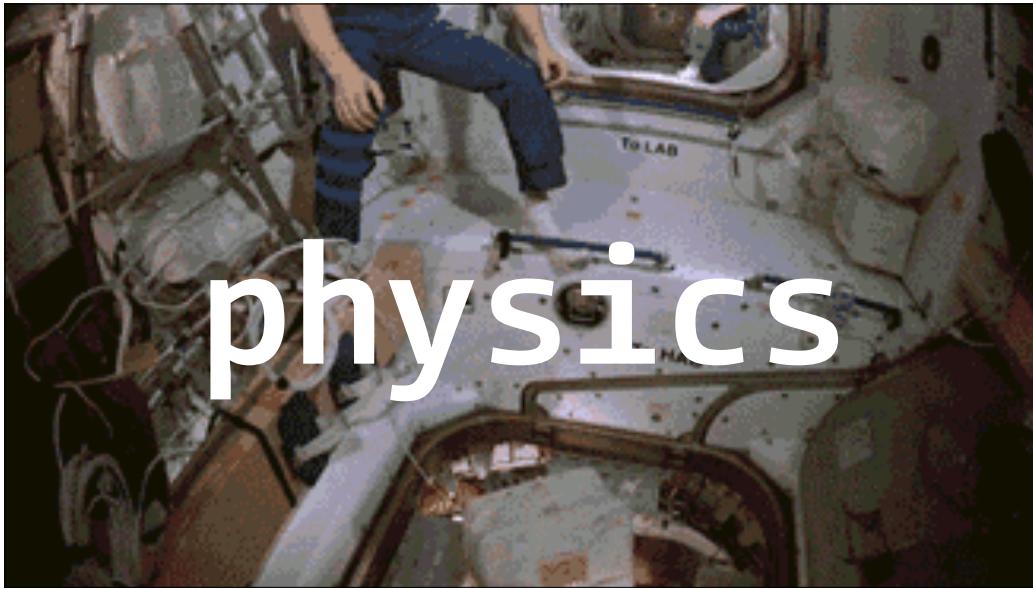
...Vuforia (Built into Unity!)

abstraction

First, let's talk about **Abstraction**:

In software engineering and computer science, **abstraction** is a technique for arranging complexity of computer systems. It works by establishing a level of complexity on which a person interacts with the system, **suppressing the more complex details below the current level**. The programmer works with an idealized interface (usually well defined) and can add additional levels of functionality that would otherwise be too complex to handle. For an example, **a programmer writing code that involves numerical operations may not be interested in the way numbers are represented in the underlying hardware** (e.g. whether they're 16 bit or 32 bit integers), and where those details have been suppressed it can be said that they were abstracted away, leaving simply numbers with which the programmer can work. In addition, a task of **sending an email message across continents would be extremely complex if the programmer had to start with a piece of fiber optic cable and basic hardware components**. By using layers of complexity that have been created to abstract away the physical cables and network layout, and presenting the programmer with a virtual data channel, this task is manageable.

[https://en.wikipedia.org/wiki/Abstraction_\(software_engineering\)](https://en.wikipedia.org/wiki/Abstraction_(software_engineering))



physics

Abstracts the math/physics/graphics away for us and we get to work on a higher level.

Knows about: Mass, gravity, inertia, acceleration...

designing for the real world

It's not that we're making games, its that we're designing for the **real world** so it would be helpful not to have to reinvent the wheel every time.

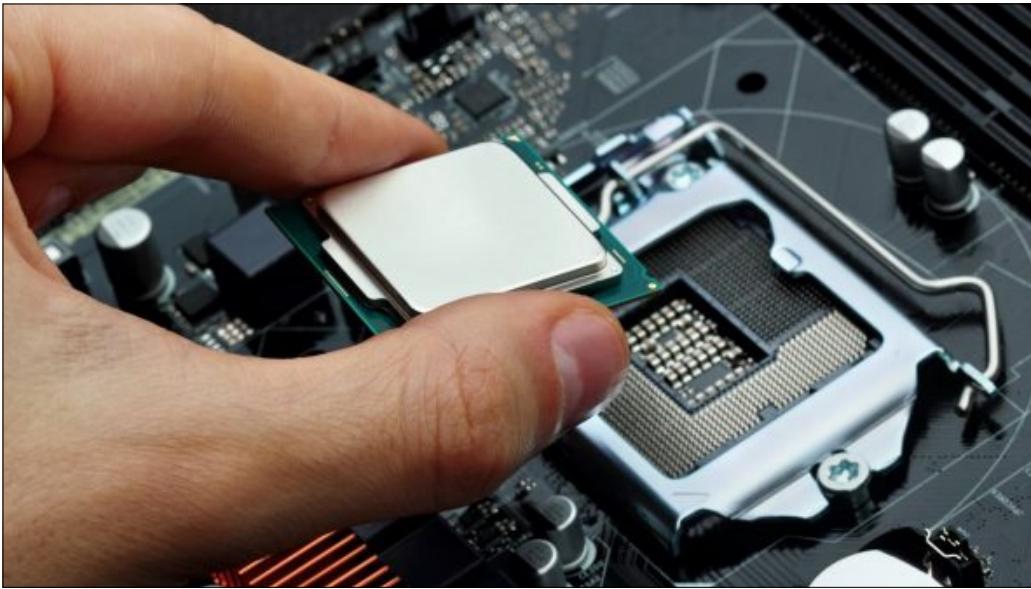
Pros/cons of abstraction

- Find a balance between power and ease
- We'll talk a LOT about this over the next few weeks

abstraction

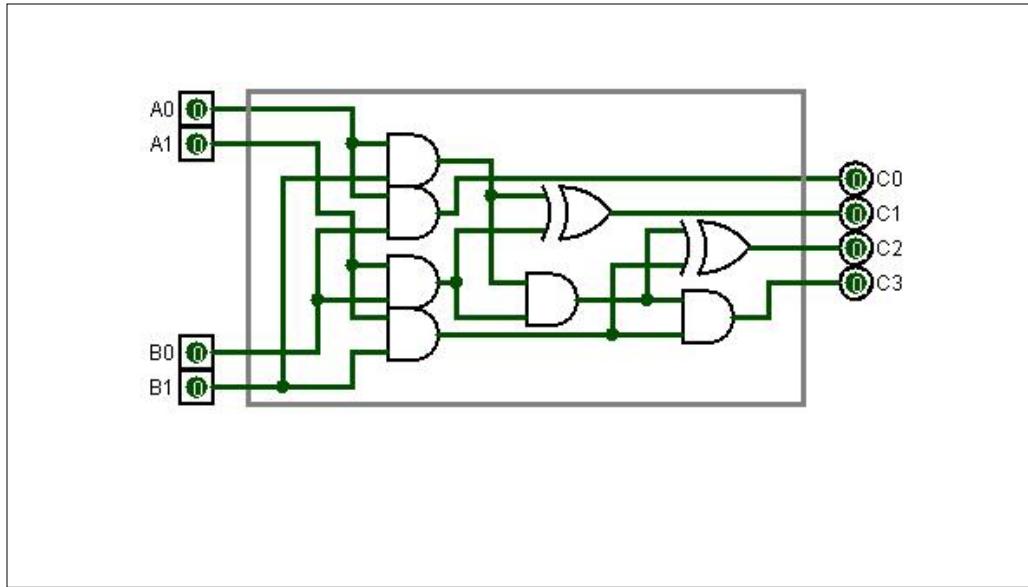
Things are about to get a bit more complex.

Allow me a bit of a tangent...



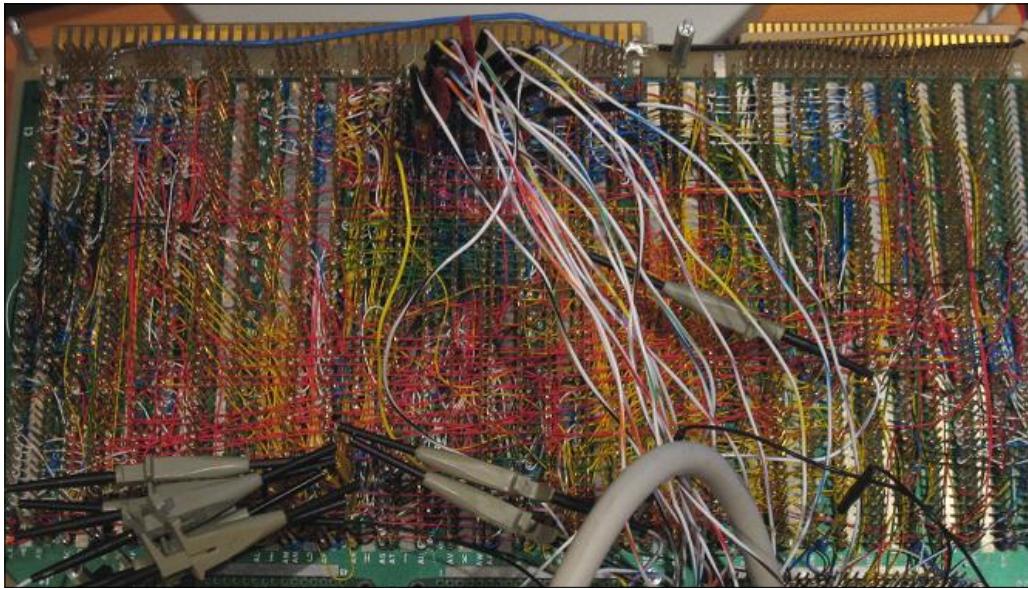
Let's talk about how computers actually work.

What do we really mean by "Computers only understand 0's and 1's"?



Multiply two numbers using **hardware**!

Bunch of AND gates and a couple of XOR (exclusive OR) gates



This is a home-built computer called the BMOW (Big Mess of Wires)

<http://www.bigmessowires.com/bmow1/>

Have you ever thought about how this chunk of metal and wires knows what to do?

```
// UdpPacket provides packetIO over UDP
public class UDPPacketIO {

    private UdpClient Sender;
    private UdpClient Receiver;
    private bool socketsOpen;
    private string remoteHostName;
    private int remotePort;
    private int localPort;

    private string multicastAddress;
    private bool enableMulticast;

    public UDPPacketIO(string hostIP, int remotePort, int localPort, bool enableMulticast=false, string multicastAddress=null) {
        RemoteHostName = hostIP;
        RemotePort = remotePort;
        LocalPort = localPort;

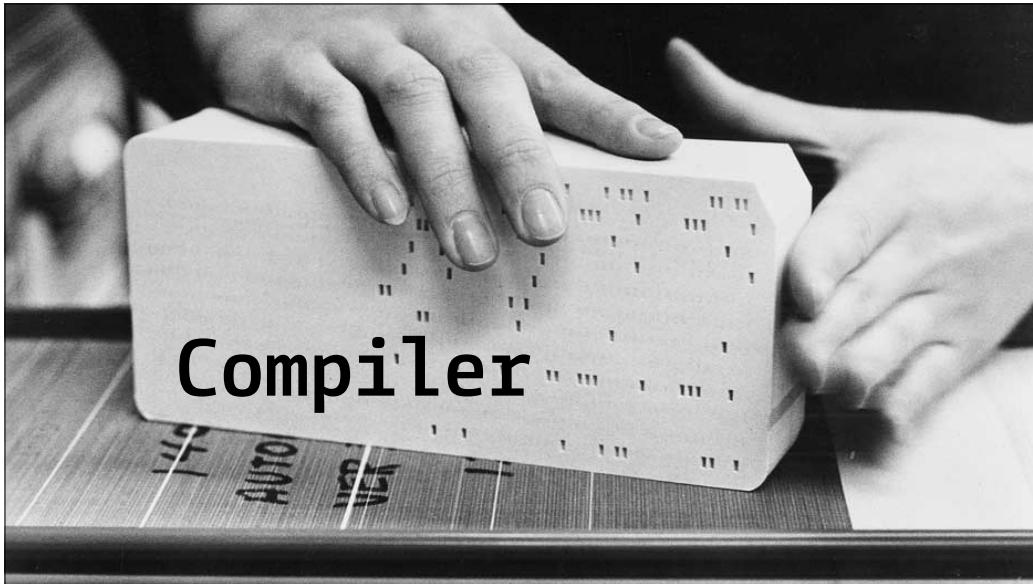
        EnableMulticast = enableMulticast;
        MulticastAddress = multicastAddress;
        socketsOpen = false;
    }

    ~UDPPacketIO() {
        // latest time for this socket to be closed
        if (IsOpen()) {
            BobRemoteControl.BobDebug.Log("closing udpclient listener on port " + localPort);
            Close();
        }
    }
}
```

A programming language is just a text file.

Written according to a standard.

It is meant to be HUMAN READABLE. Computer doesn't care if you use C# or C++ or Java or BrainFuck.



```
b8 00 b8 8e c0 8d 36 20 03 e8 fd 01 bf a2 00 b9  
02 00 eb 2b b4 06 b2 ff cd 21 3c 71 0f 84 e5 01  
3c 50 b9 a0 00 74 18 3c 48 b9 a0 00 0f 84 d9 00  
b9 02 00 3c 4d 74 08 3c 4b 0f 84 cc 00 eb d5 89  
3e b5 09 01 cf 89 3e b3 09 e8 87 01 8b 3e b5 09  
b0 20 26 88 05 26 88 45 fe 26 88 85 62 ff 26 88  
85 60 ff 26 88 85 5e ff 26 88 85 9e 00 b0 07 26  
88 45 01 8b 3e b3 09 89 fb 83 eb 02 d1 fb 8a 00  
26 88 45 fe 89 fb 81 eb a2 00 d1 fb 8a 00 26 88  
85 5e ff 89 fb 81 eb a0 00 d1 fb 8a 00 26 88 85  
60 ff 89 fb 81 eb 9e 00 d1 fb 8a 00 26 88 85 62  
ff 89 fb 81 eb a2 00 d1 fb 8a 00 26 88 85 5e ff  
89 fb 83 c3 02 d1 fb 8a 00 26 88 45 02 89 fb 81  
c3 9e 00 d1 fb 8a 00 26 88 85 9e 00 89 fb 81 c3  
a0 00 d1 fb 8a 00 26 88 85 a0 00 89 fb 81 c3 a2  
00 d1 fb 8a 00 26 88 85 a2 00 b0 03 26 88 05 a0  
b7 09 26 88 45 01 e9 0b ff 89 3e b5 09 29 cf 89  
3e b3 09 e8 bd 00 8b 3e b5 09 b0 20 26 88 05 26  
88 45 02 26 88 85 9e 00 26 88 85 a0 00 26 88 85  
a2 00 26 88 85 62 ff b0 07 26 88 45 01 8b 3e b3  
09 89 fb 83 eb 02 d1 fb 8a 00 26 88 45 fe 89 fb  
81 eb a2 00 d1 fb 8a 00 26 88 85 5e ff 89 fb 81  
eb a0 00 d1 fb 8a 00 26 88 85 60 ff 89 fb 81 eb  
9e 00 d1 fb 8a 00 26 88 85 62 ff 89 fb 81 eb a2  
00 d1 fb 8a 00 26 88 85 5e ff 89 fb 83 c3 02 d1
```

Machine-code does not "communicate with the processor".

Rather, the processor "knows how to evaluate" machine-code.

The CPU "looks" at the current instruction. When the instructions are executed side-effects occur such as setting a control flag, putting a value in a register, or jumping to a different index (changing the PC) in the program, etc.

It is the evaluation of each instruction -- as it is encountered -- and the interaction of side-effects that results in the operation of a traditional processor.



Visual Studio and XCode

We can't just finish in Unity anymore! Because these AR devices are running on different processors than our PC, we have to go through another program that will build the final executable for the device.

Some extra nerdiness:

PC/Mac Standalone (and VR):

C# -> IL -> Bytecode -> JIT Compiler -> Machine Code

Using IL2CPP bridge:

C# -> IL -> IL2CPP -> C++ -> Anywhere!

C++ -> XCode -> iOS/Apple A9 processor Machine Code

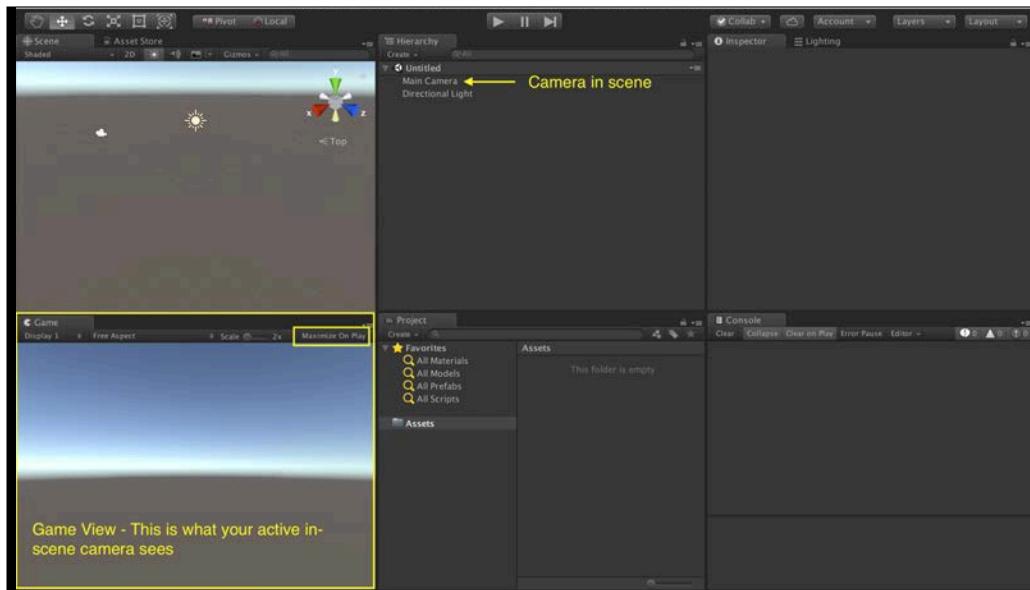


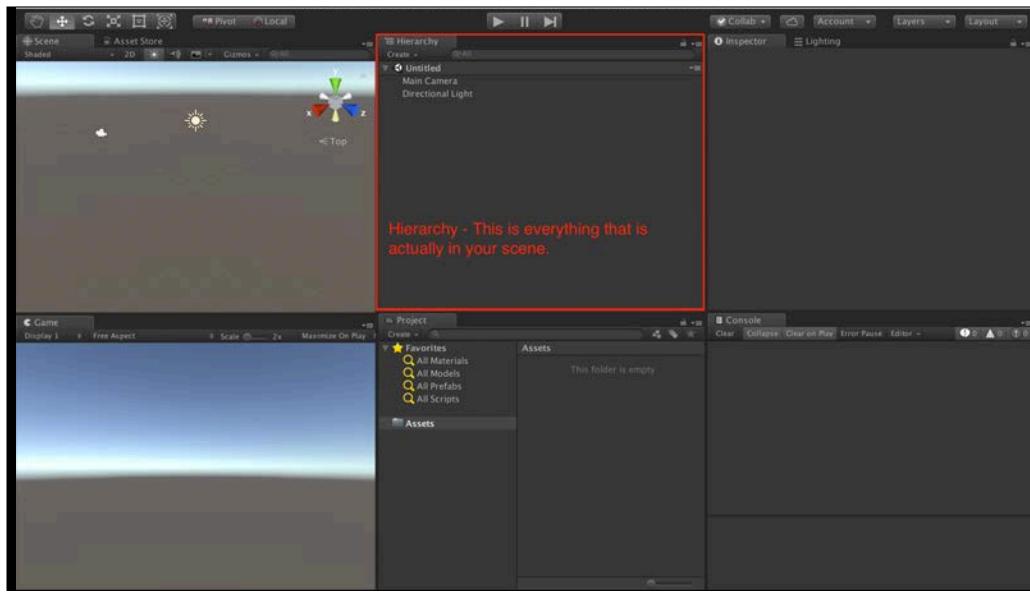
Let's get in to Unity!

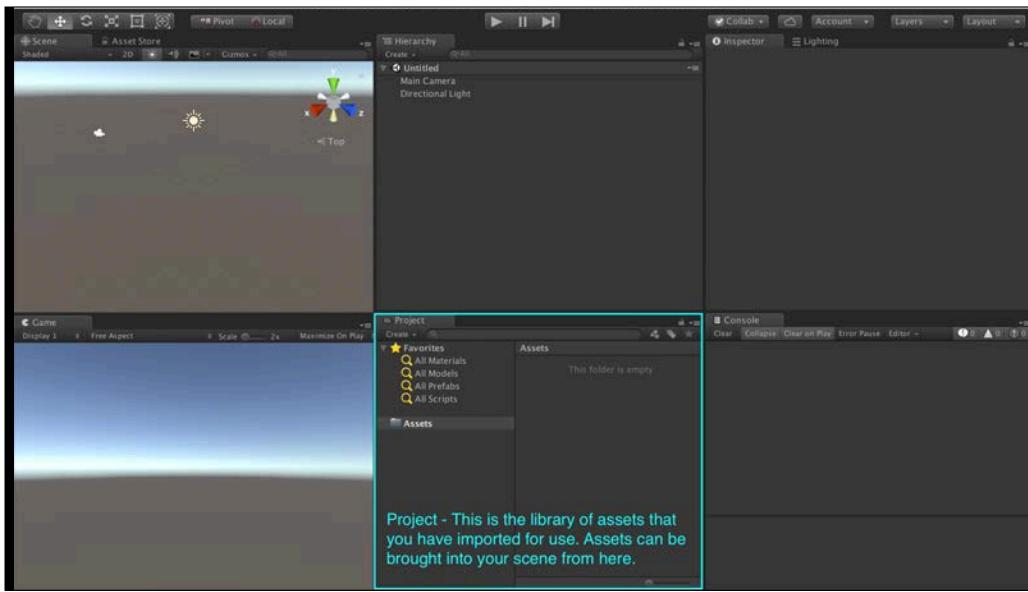


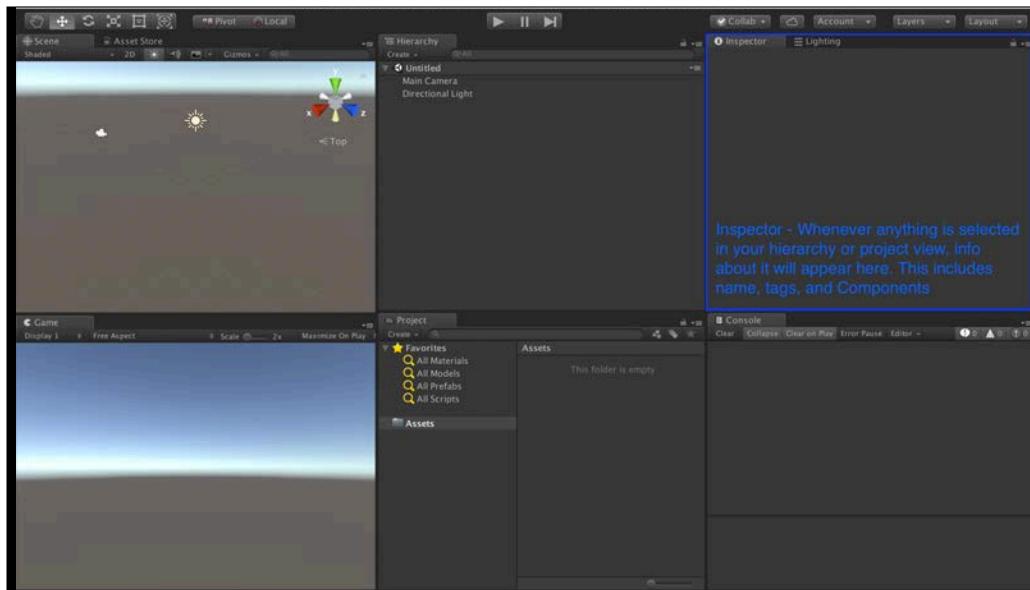


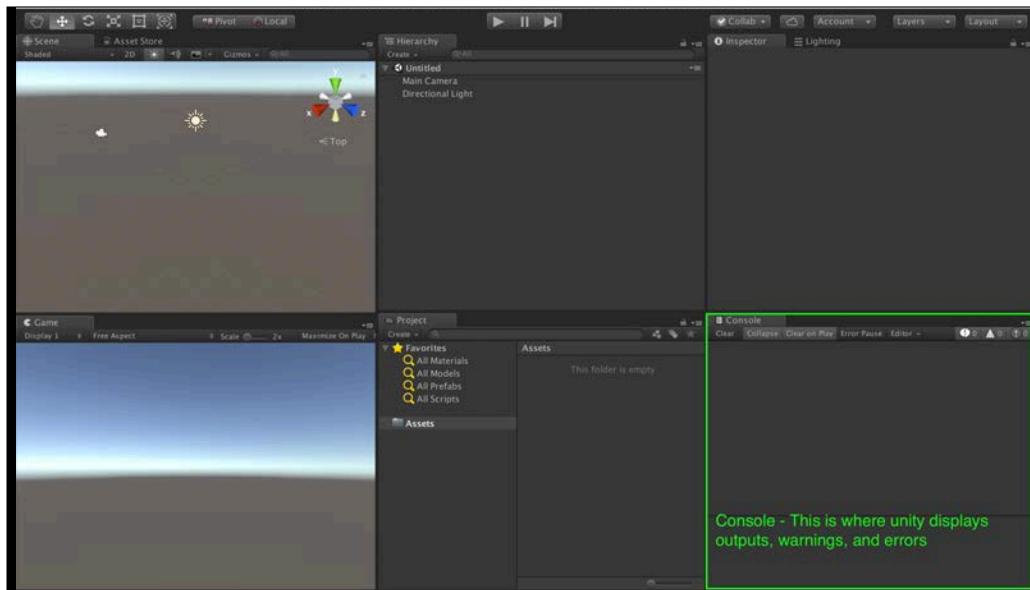
When holding down **Right-Click** inside the scene view, moving mouse along with **W-A-S-D-Q-E** keys will move our point of view.

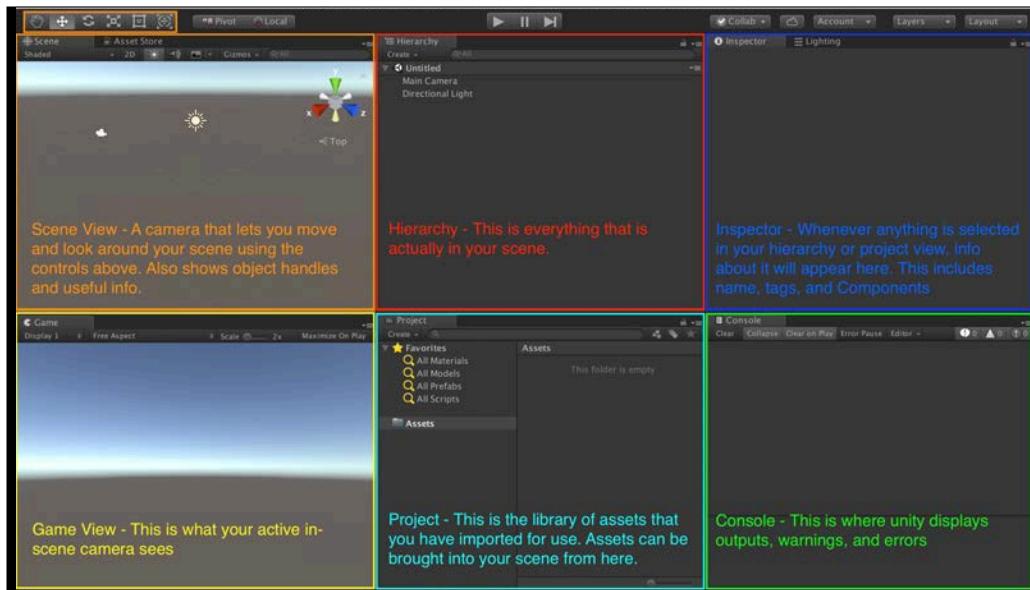


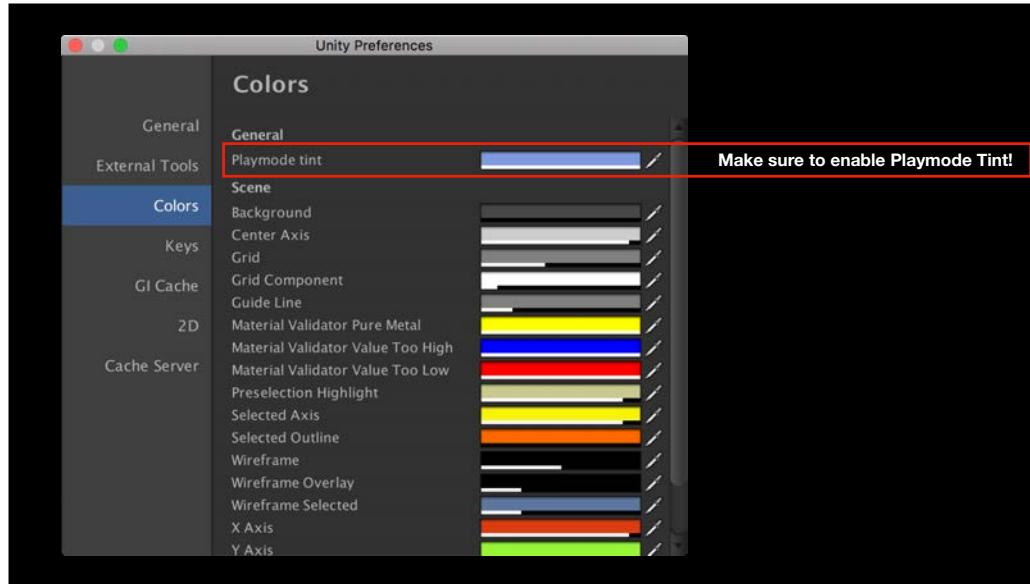






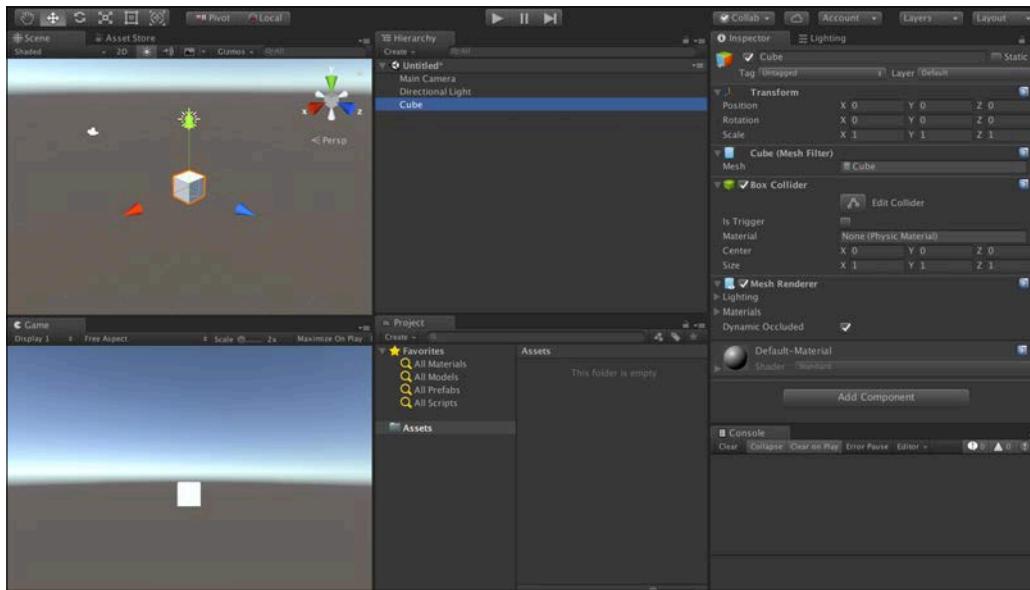




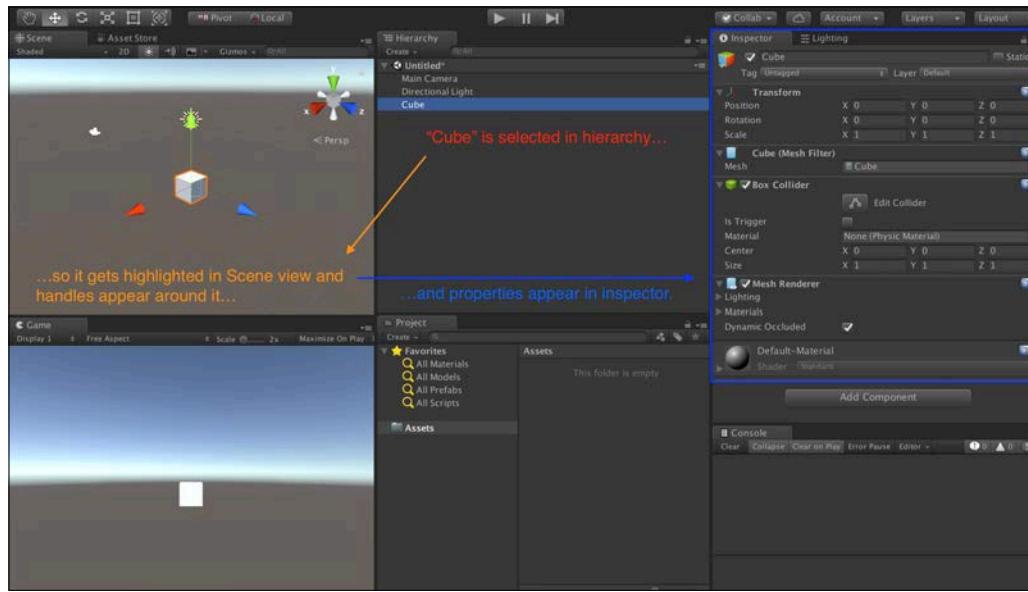


This will save you so much heartache.

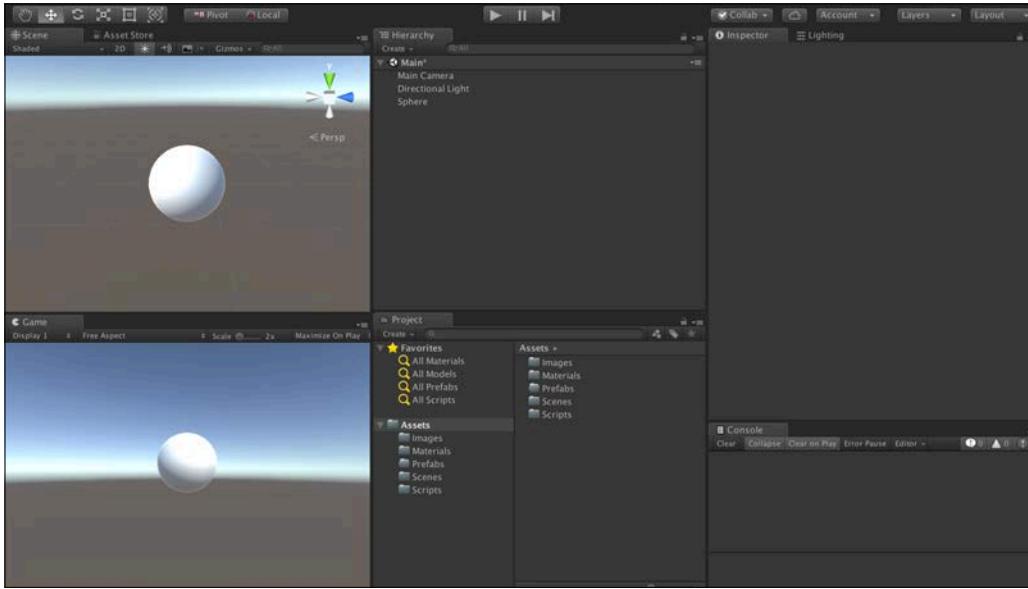
(So so much)



Inspector and **Scene View** change based on what's selected in **Hierarchy**

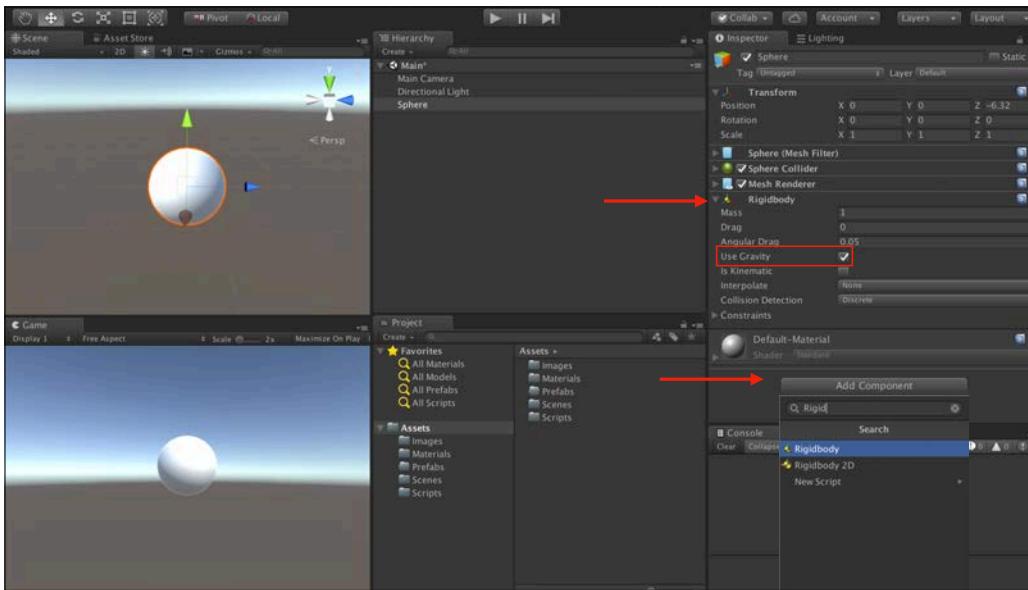


Inspector and **Scene View** change based on what's selected in **Hierarchy**



Working with GameObjects, Components, and Prefabs.

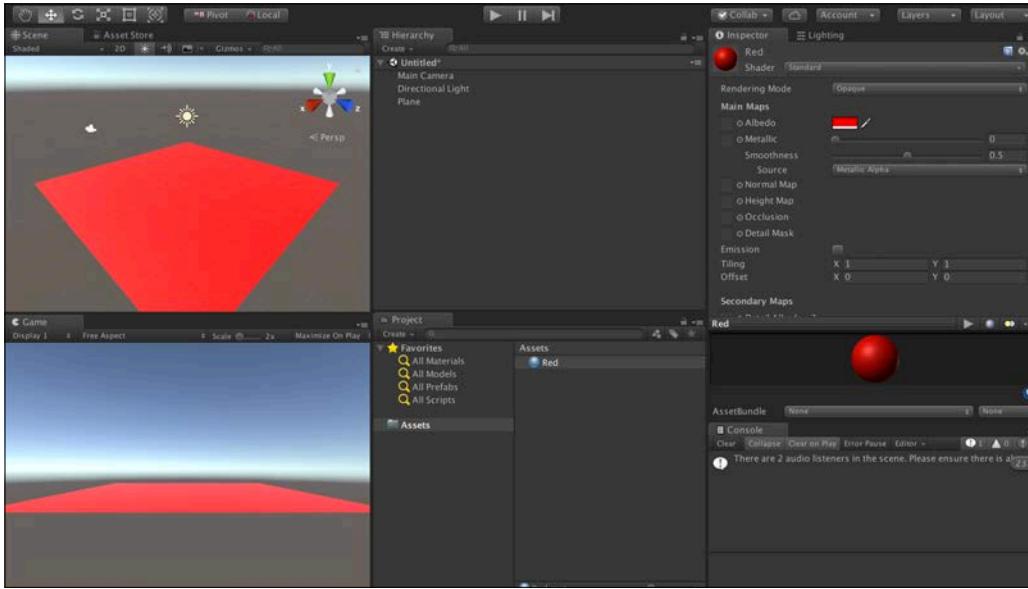
Create a new **Sphere** inside your scene (i.e. create it in the **Hierarchy**)



Back to our **sphere**.

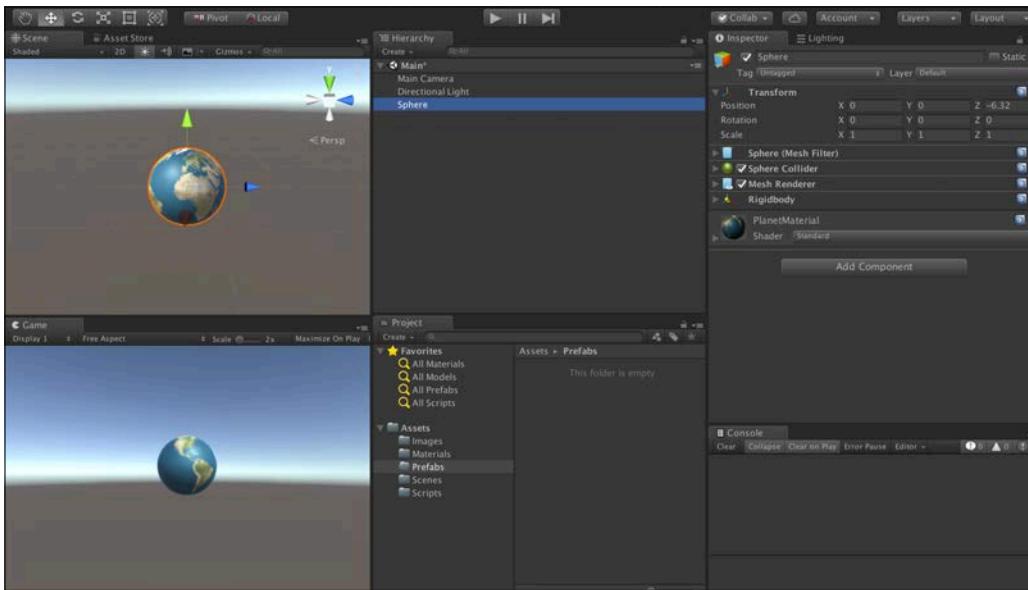
Make sure it is selected and use the “Add Component” button in the inspector to add a **Rigid Body**.

Now you have physics! Yay, thanks Unity!

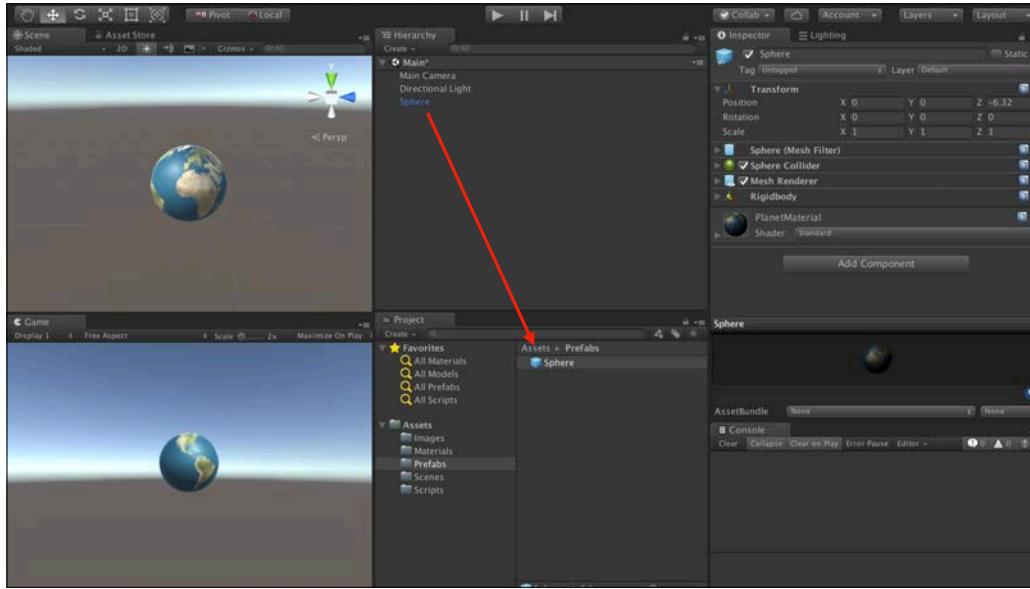


Materials are a bit weird - they're kind of like a *Component* of a Component

Lots of ways to add them but easiest is by dragging. (This actually works for a lot of components, but materials are clearer: easy to see what you're adding to, everything else I prefer adding via the inspector, like we did with RigidBody)

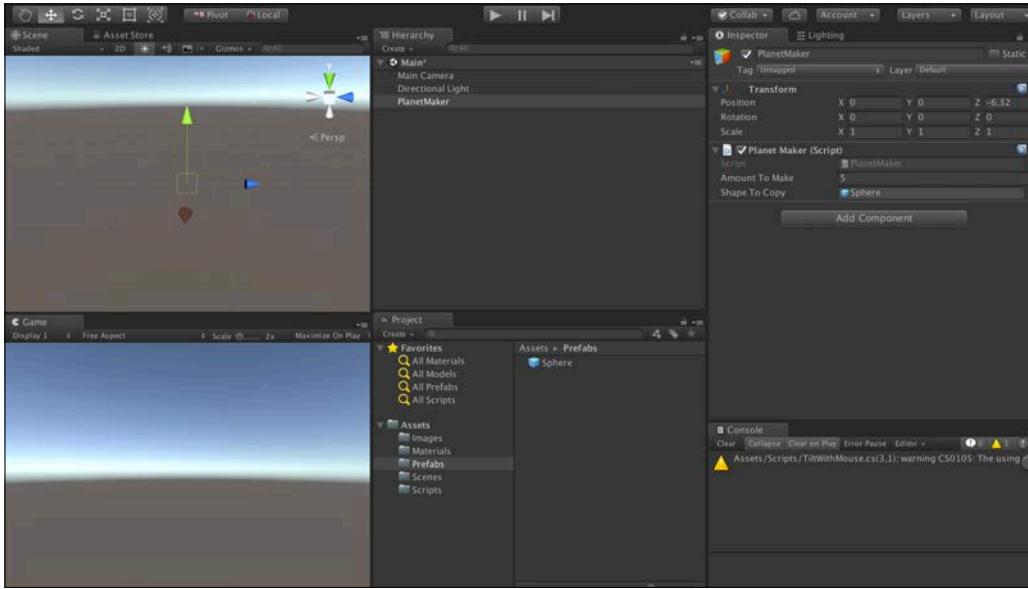


Prefabs! So, we've started with a simple shape, but now we've added stuff to it. Cool textures, useful components.



We can drag things from the hierarchy **back** into the assets in the project view!

This creates a reusable object called a **Prefab**.



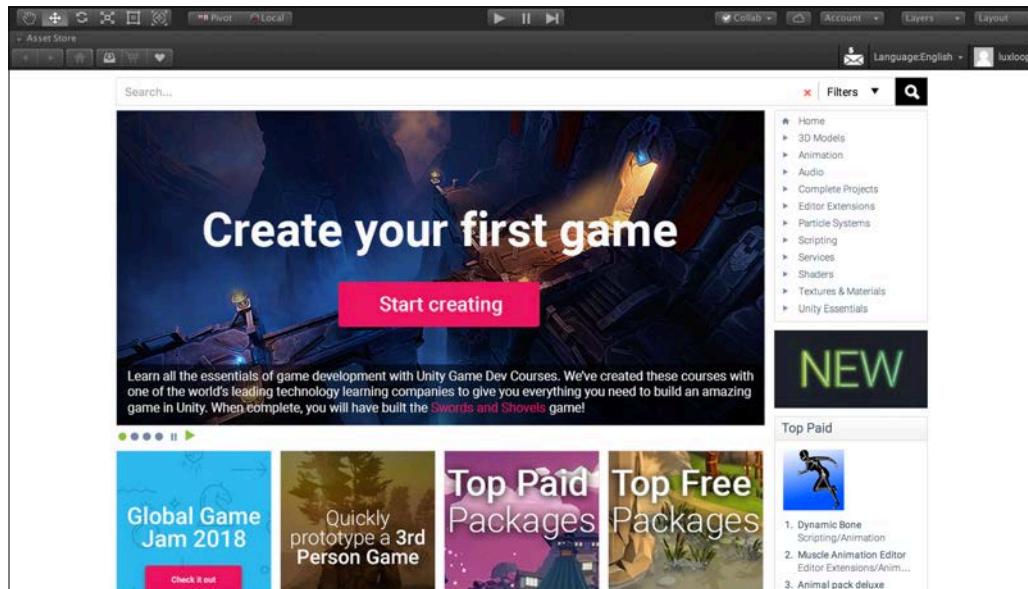
Adding **Scripts** to GameObjects is the same as anything else (We'll cover making our own scripts next time)

Scripts have to live somewhere in your Hierarchy (just because they are in the assets does not mean they are active yet).

Create a new **Empty** game object (Just like you created a Sphere) and add the *PlanetMaker* script to it (Just like you added a RigidBody)

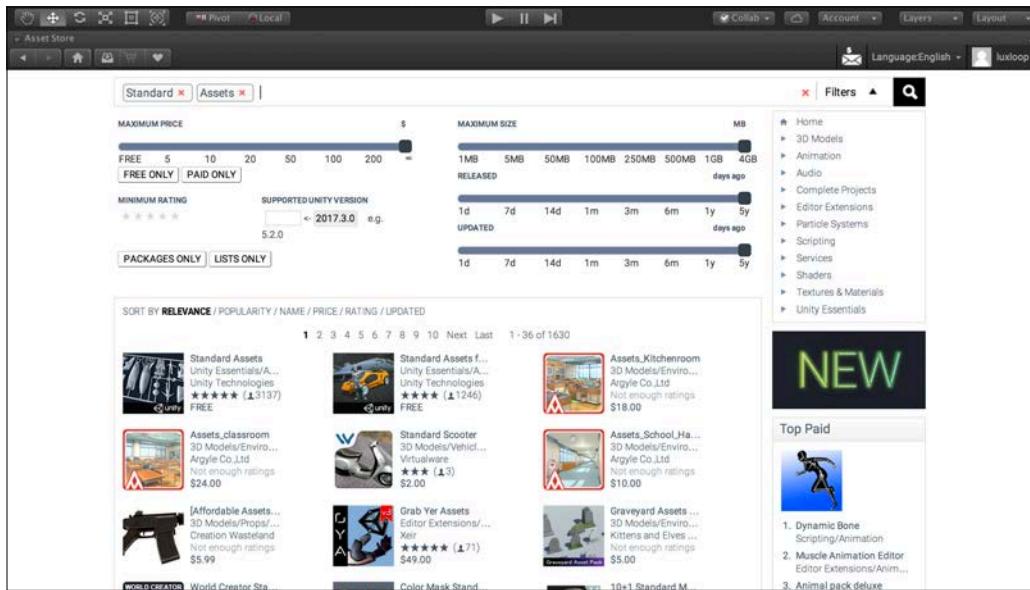
Notice that this particular script has an empty slot in it called “Shape to Copy” and in parenthesis it’s saying that this slot takes a **GameObject**. Drag the **Prefab** we made earlier into this slot.

Also notice the “Amount to Make” slot - this is a **public script variable** (more on that later).

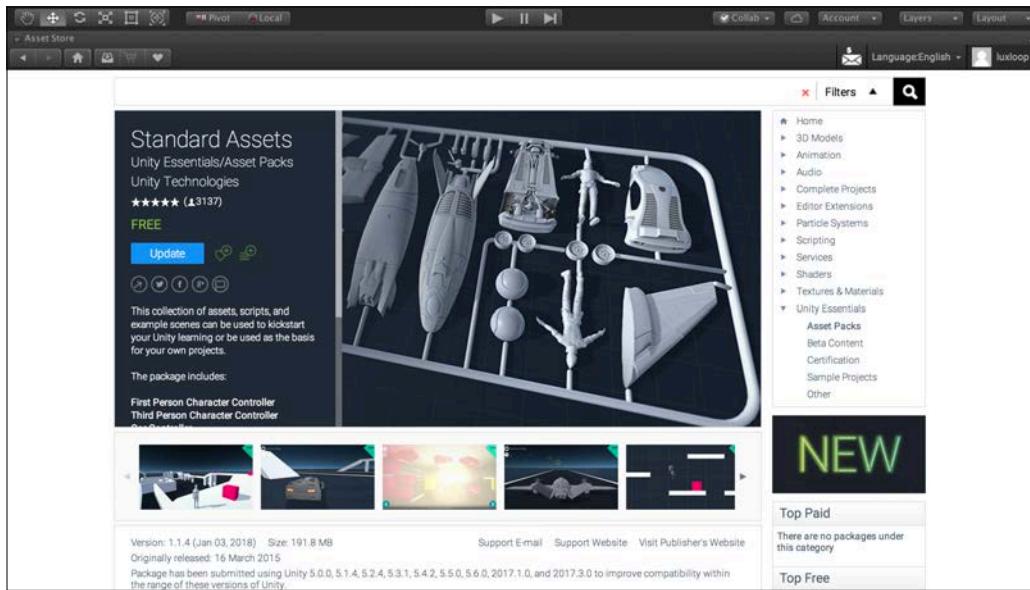


Asset Store

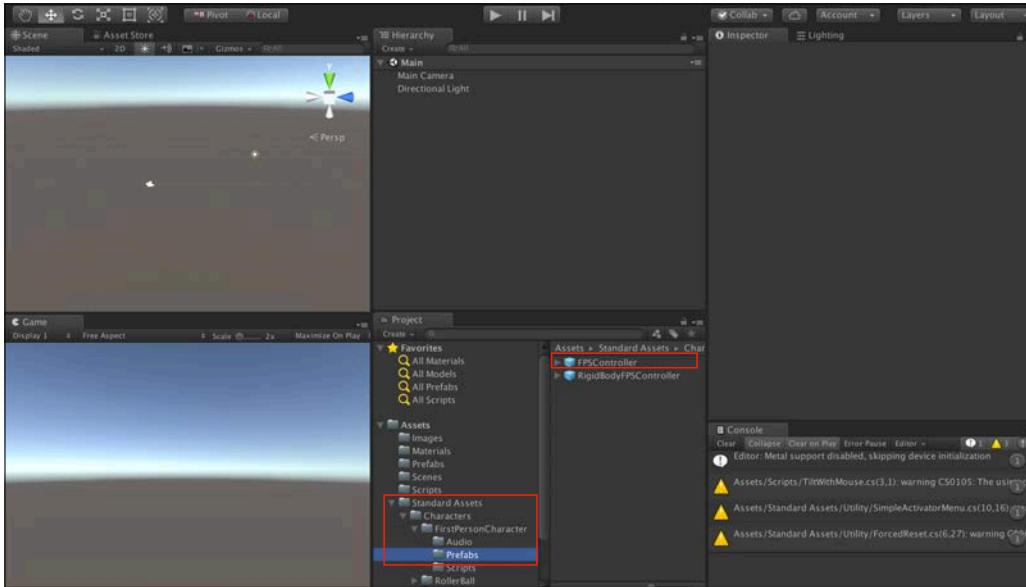
Window > Asset Store



Search for Standard Assets



Search for **Standard Assets**



Find the FPS Controller under

Standard Assets > Characters > FirstPersonCharacter > Prefabs

This is the first thing we will use to give ourselves agency inside the scene. Very simple:

- There must be some kind of “floor” for the character to walk on
- The floor must have some sort of **collider** as a component (most Unity primitives already come with collider components)

When in play mode, FPSController will move with WASD keys



Back into Unity

- Is everyone on Visual Studio 2017?

Vectors

In programming terms, you can think of Vectors as a way to store 2, 3, or 4 values in one easy-to-use package:

```
Vector2 someNumbers = new Vector2(1.0, 2.2);
Vector3 someOtherNumbers = new Vector3(5.3, 2.6, 12.0);
Vector4 evenMoreNumbers = new Vector4(7.4, 2.1, 12.0, 9.8);
```

Vectors

We can use vectors to:

- Store multiple numbers in one variable
- Describe the position of something in our world
 - For example: (2.1, 8.9, 7.4) represents the point in space 2.1 units along the X-axis, 8.9 units along the Y-axis, and 7.4 units along the Z-axis.

Vectors

We can use vectors to:

- Describe a direction

- For example: $(0.0, 1.0, 0.0)$ represents a point 1 unit directly above (along Y) the origin.
- If we drew an arrow from the origin to this point, it would point straight up.
- It doesn't matter how long the Vector is:
 - $(0.0, 1.0, 0.0)$ and $(0.0, 5.2, 0.0)$ are different points, but they both describe the same *direction* (straight up).

Vectors

Unity has some built-in direction shorthands:

```
Vector3 example = Vector3.up;
```

is the same as:

```
Vector3 example = new Vector3(0.0, 1.0, 0.0);
```

Vectors

Other shorthands:

- `Vector3.up` (pointing along Y-axis)
- `Vector3.forward` (pointing along Z-axis)
- `Vector3.right` (pointing along X-axis)
- `Vector3.one` (Equal to `(1.0, 1.0, 1.0)`)

RayCasting

RayCasting is when we shoot an invisible line into our scene to see if we hit something in that direction.

To understand RayCasting, you must understand **Vectors**.

RayCasting

`Physics.Raycast()` is a function built in to Unity.

There are many, many different forms it can take. Here is the easiest:

```
Physics.Raycast(Vector3 originOfTheRay, Vector3 directionOfTheRay);
```

All this function actually does is return `true` or `false` to answer “did this Ray hit anything?”

See the example script on the github for more details:

<https://github.com/ivaylopg/Tech421Tech3706/blob/master/Session17/ScriptExamples/RayCaster.cs>

RayCasting

To store information about *what* was hit, and more importantly *where* the hit is in space, we have to do two things:

1. Declare a variable of the type `RaycastHit` to store the information about the hit point.
2. Use a slightly different version of `Physics.Raycast()` to pass the hit info out of it:

```
RaycastHit hitInfoVariable  
Physics.Raycast(Vector3 originOfTheRay, Vector3 directionOfTheRay, out hitInfoVariable)
```

See the example script on the github for more details:

<https://github.com/ivaylopg/Tech421Tech3706/blob/master/Session17/ScriptExamples/RayCaster.cs>

RayCasting

So if wanted to Raycast from a GameObject (for example a Vive tracker or the user's headset POV):

We want to shoot a ray from:

`gameObject.transform.position`

in the direction of:

`gameObject.transform.forward`

(`gameObject.transform.forward` is the local Z-axis of the *object*, which may be different from the *world* Z-axis, which is `Vector3.forward`)

See the example script on the github for more details:

<https://github.com/ivaylopg/Tech421Tech3706/blob/master/Session17/ScriptExamples/RayCaster.cs>

RayCasting

```
void Update() {
    RaycastHit hit;
    if ( Physics.Raycast(gameObject.transform.position, gameObject.transform.forward, out hit) ) {

        Debug.DrawLine(gameObject.transform.position, hit.point, Color.red);
        Debug.DrawRay(hit.point, hit.normal, Color.green);

    }
}
```

RayCasting

the **hit** variable that stores information about the result of the Raycast has a few useful properties:

`hit.point` (The coordinates of the collision as a `Vector3`)

`hit.normal` (A `Vector3` direction that describes the direction coming *straight out* of the face of the `hit` object)

See the example script on the github for more details:

<https://github.com/ivaylopg/Tech421Tech3706/blob/master/Session17/ScriptExamples/RayCaster.cs>

RayCasting

These visual Debug functions help you see what's going on.
They will draw lines in your *Editor*, but never in the
actual *Game* view:

```
Debug.DrawLine(Vector3 lineStartCoordinate, Vector3 lineEndCoordinate, Color color);  
Debug.DrawRay(Vector3 lineStartCoordinate, Vector3 lineDirection, Color color);
```

See the example script on the github for more details:

<https://github.com/ivaylopg/Tech421Tech3706/blob/master/Session17/ScriptExamples/RayCaster.cs>

**ARx Designers: The Future Kings and
Queens of Silicon Valley**

<https://goo.gl/dfWGeA>

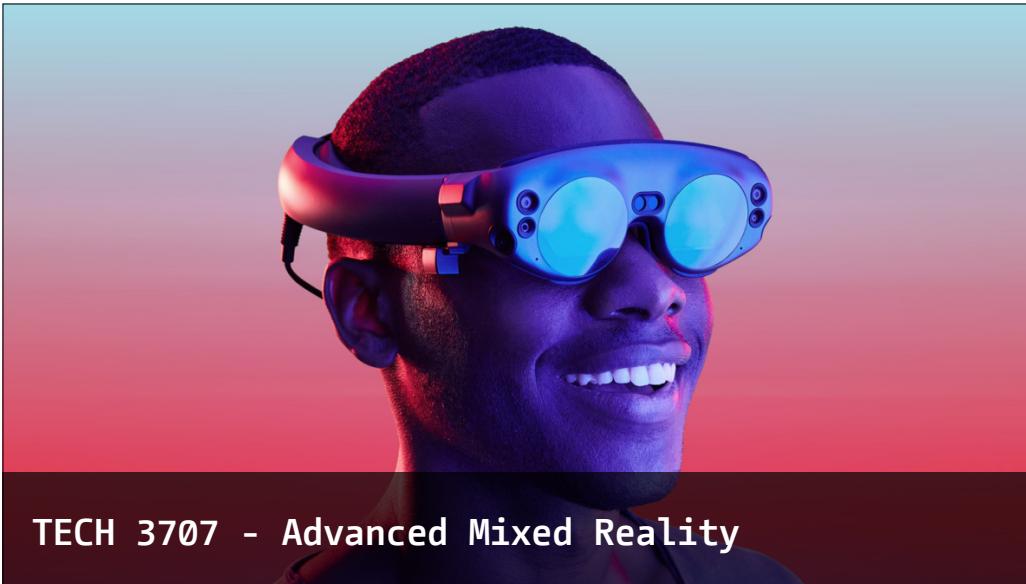
**Bob Iger Says AR, Not VR, Is the Way of
the Future for Disney Parks**

<https://goo.gl/Jv5EFZ>

Reading assignment:

<https://medium.com/the-mission/arx-designers-the-future-kings-and-queens-of-silicon-valley-9c2a7a208fdb>

<https://augmented.reality.news/news/bob-iger-says-ar-not-vr-is-way-future-for-disney-parks-0176733/>



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