Online VT CS Module

Unity Third Person Camera and Character Control

CS 4624 Virginia Tech, Blacksburg VA

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Table of Contents

Deliverables

Video tutorials:
http://www.youtube.com/playlist?list=PLKFvhfT4QOqlEReJ2lSZJk_APVq5sxZ-x

Code: https://github.com/jm991/UnityThirdPersonTutorial

Executive Summary

America's entertainment software industry creates a wide array of computer and video games to meet the demands and tastes of audiences as diverse as our nation's population. Today's gamers include millions of Americans of all ages and backgrounds. In fact, more than two-thirds of all American households play games. This vast audience is fueling the growth of this multi-billion dollar industry *(Essential Facts About the Computer and Video Game Industry, 2006)*.

The Computer Science Department at Virginia Tech has comprised a course to facilitate the future of art and game development. CS 4644: Creative Computing Studio Capstone is an intensive immersion into different approaches of game design and 3D modeling. The course allows students to develop an understanding of the scientific and technological principles associated with the design and development of computer and console games for both entertainment and serious applications. Students are encouraged to use a wide range of game engines as they work in teams to conduct an end-to-end integrative design project, the most popular being Unity.

Unity is a game development ecosystem: a powerful rendering engine fully integrated with a complete set of intuitive tools and rapid workflows to create interactive 3D content; easy multiplatform publishing; thousands of quality, ready-made assets in the Asset Store; and a knowledge-sharing Community.

Unity is free to a large proportion of developers and affordable for the rest. For independent developers and studios, Unity's democratizing ecosystem smashes the time and cost barriers to creating uniquely beautiful games. They are using Unity to build a livelihood doing what they love: creating games that hook and delight players on any platform. It is for this reason that our group decided to work with the Professors of the Creative Computer Studio Capstone to deliver a module that will quickly get students up and running with Unity game development.

Project Overview

The purpose of our project is to create a set of online, cross-disciplinary tutorials for making games with the Unity game engine. The tutorials will cater to both art and computer science students enrolled in the Creative Computing Studio course. The tutorials can also serve as a guide for anyone interested in game development and will be made publically available with the code. Students will gain the knowledge to script game mechanic logic, develop camera devices through which the player views the world, and implement character controllers using preexisting animations through retargeting. By the end of the tutorials students should feel empowered and comfortable enough to begin creating their own games.

The course is aimed at an intermediate level to meet the needs of Virginia Tech students who already know how to program or create 3D art, but don't understand how to apply that knowledge to a game engine. This course is not intended as a step-by-step tutorial series; it takes a troubleshooting-based approach by addressing common pitfalls we encountered taking the gaming capstone in previous semester. Each of the videos can be watched individually to learn the related techniques. Students will learn and apply principles from the course not to a sample file, but to their own game's needs.

Module Overview

When 3D games were made mainstream through titles like *Mario 64* and *Zelda: Ocarina of Time*, game developers revolutionized 3D navigation using a combination of blended animations and automatic cameras. The character control schemes in these games share similar camera and navigation mechanics that are simple, yet extremely robust. This module will recreate the same character locomotion and third person camera used by both games.

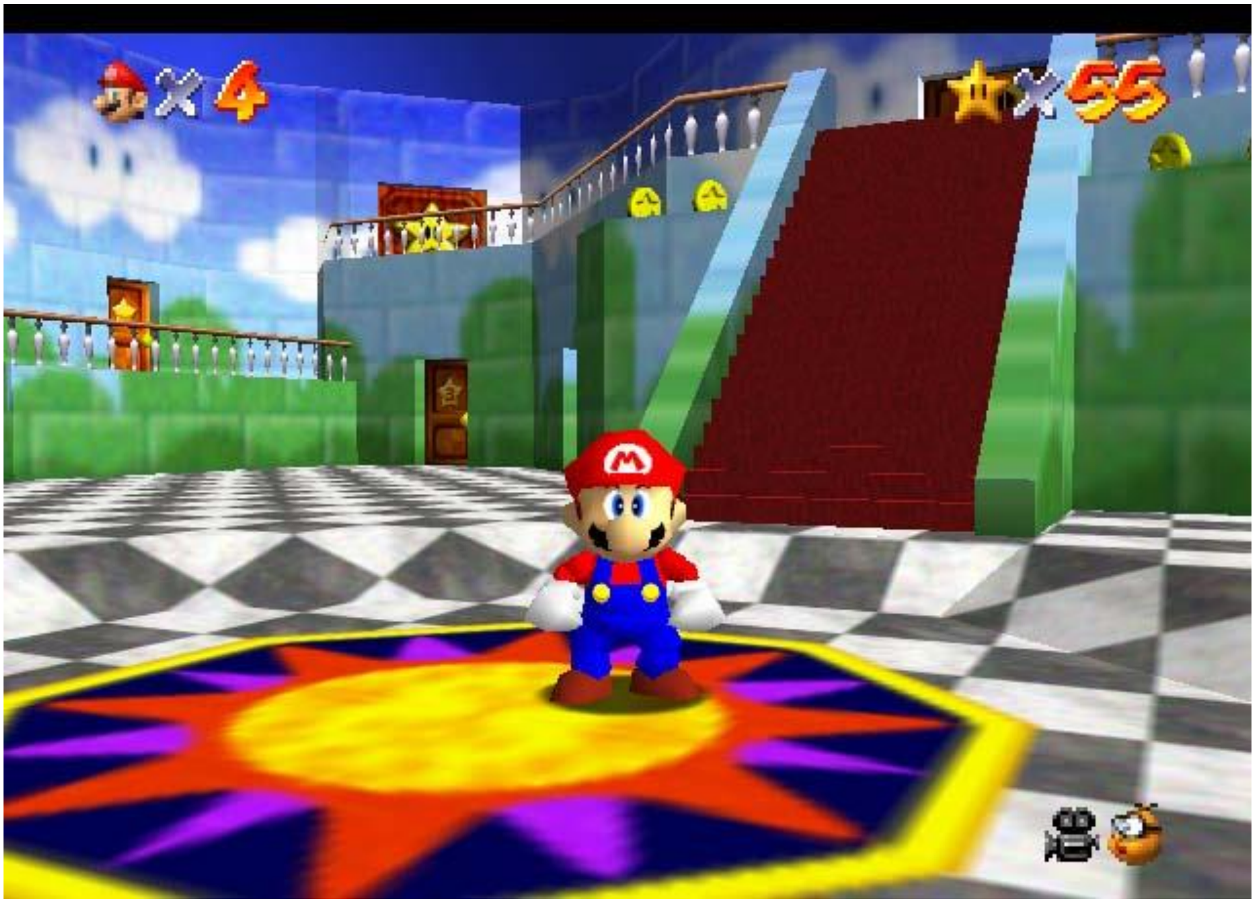


Figure 1: *Mario 64*'s third person camera

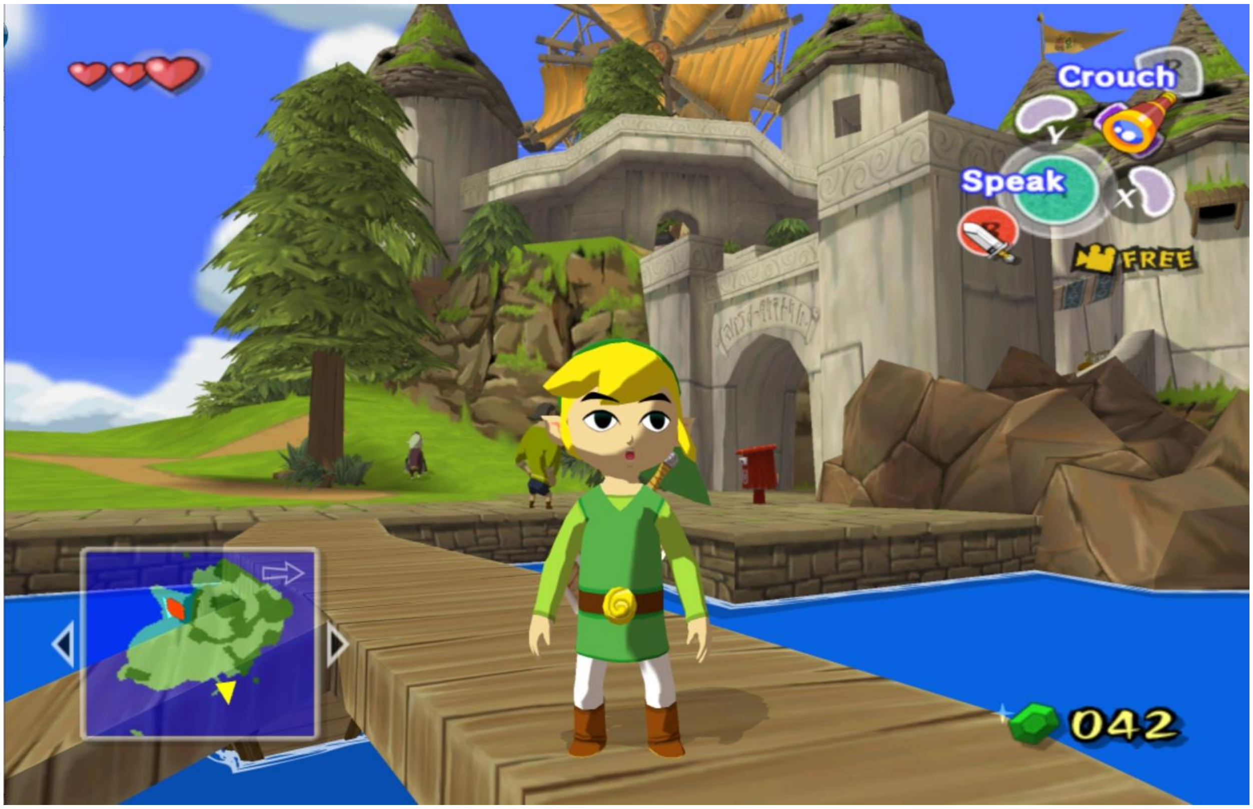


Figure 2: *Legend of Zelda: Wind Waker*'s third person camera

An Overview of Unity

This section introduces the user to the Unity animation system and community services.

Mecanim Animation System

Unity 4.0 includes a rich and sophisticated animation system called Mecanim, which we will be using exclusively for this tutorial series. Mecanim provides:

- Easy workflow and setup of animations on humanoid characters
- Animation retargeting - the ability to apply animations from one character model onto another
- Simplified workflow for aligning animation clips using finite state machines
- Convenient preview of animation clips, transitions and interactions between them. This allows animators to work more independently of

programmers, prototype and preview their animations before gameplay code is hooked in

- Management of complex interactions between animations with a visual programming tool
- Animating different body parts with different logic

The Unity Community and Services

Unity Forums

The forums are the central hub of the Unity community discussions and chatter. Voice your opinion, show what you're working on, and check out the cool things others are doing. The forums are also a great place to contact other Unity developers if you need to build or expand your team.

Link: http://forum.unity3d.com/forum.php

Unity Answers

Unity Answers is the Unity community site for concrete Unity questions and answers. Beginners and experts alike are welcome to post, helping each other out with Unity. The built-in voting system helps finding the best answers quicker.

Link: http://answers.unity3d.com/index.html

The Asset Store

The Asset Store is a critical time and effort-saving resource when creating a game. Character models, props, materials and textures, landscape painting tools, game creating tools, audio effects and music, visual programming solutions, scripts and editor extensions are all available. You can download helpful learning resources, such as demos, and tutorials for car physics, character customizations, C#, landscape creation and more.

Link: http://unity3d.com/asset-store/

Users' Manual

This section explains everything a user of our module might want to know about the content of our work.

Minimum Skill Requirements

- The user should have a working knowledge of an object orientated scripting programming language, preferably C#
- A basic understanding of vector geometry
- Some graphics programming knowledge is helpful but not required

Getting Started

Unity Technologies offers a free and pro version of Unity. Unity Pro has several additional features some of which include real-time shadows, post processing effects (motion detection, edge detection), and some extra version control features. In the end, Pro is not necessary for creating a quality title, though it will add a polished look to any game. The pro version comes with a $1500 price tag, but first time users have the option of a thirty-day evaluation. Studica.com offers Unity Pro to students at a discounted price.

Installation of Unity

Installation is simple for both Mac and Windows users. Unity download and Installation instructions can be found at the following link:

Link: http://unity3d.com/unity/download/

Installation of GitHub and SourceTree

When working on any team-based projects it is always a good idea to utilize version control. In software engineering, version control is any practice that tracks and provides control over changes to source code. Game developers use version control software to maintain documentation and configuration files as well as source code. This module will take advantage of the GitHub web-based hosting service. To maintain the source code we will utilize the GitHub client (for Windows systems) and SourceTree (for Mac users).

Link: http://sourcetreeapp.com/

Link: http://github.com

Unity Module Cross-Disciplinary Tutorials

This section contains details on our 17 part Unity YouTube video series. A playlist containing all of the videos can be found on YouTube and is approximately 3 hours long.

Tutorial 1 – Introduction

We start the tutorial series by comparing a demo of the final tutorial code and our inspiration, the 3D *Mario* and *Legend of Zelda* series - two popular titles that defined the standard for third person camera control when they were introduced on the Nintendo 64.

YouTube Link: http://youtu.be/b0PvJ4AWvWQ

Tutorial 2 – GIT and Unity (Windows)

There are some quirks to setting up Unity for source control. In the first of the GIT tutorial videos, we cover how to create a new repository, use a .gitignore file, store asset meta data as files, and save binary scenes in the YAML text format for diff'ing in Windows.

YouTube Link: http://youtu.be/sExZ8ft0GSA

Tutorial 3 – GIT and Unity (Mac)

Following the Windows GIT tutorial, this video details the same processes in the Mac operating system.

YouTube Link:

Tutorial 4 – Scene Setup, Creating Test Rooms

This optional tutorial shows our scene setup process, file structure organization, and creation of two new scenes for testing. The first scene is a large, cube-

shaped room for testing locomotion and the second is a more practical example map inspired by Outset Island in *Legend of Zelda: Wind Waker*.
YouTube Link: http://youtu.be/1yOyO06xm34

Tutorial 5 – Mecanim: Creating basic running and idle nodes

In the first Mecanim tutorial, we create a simple animation graph for idling and running. We end with the creation of "Speed" and "Direction" parameters in the character controller.
YouTube Link: http://youtu.be/7-OUZecgXv0

Tutorial 6 – Mecanim: Controller Logic for Basic Running and Idle

After creating the animation parameters, we begin scripting logic for our character controller by supplying values for speed and direction based on player input from the Xbox controller.
YouTube Link: http://youtu.be/MIDt4eIlv8c

Tutorial 7 – Third Person Camera: Basic Follow Camera

We begin the camera tutorials by introducing the most basic kind of third person camera – one that smoothly follows at a fixed distance up and away from the character. This camera has its downfalls, namely that backwards motion on the joystick is handled no differently from forward motion. We will incrementally build from this script in the coming tutorials.
YouTube Link: http://youtu.be/PO5_aqapZXY

Tutorial 8 – Third Person Camera: Player Orbit Camera

The first step to adding more complex interaction between the player and camera is the player orbit camera. In this addition to the camera script, we properly handle backwards joystick movement by mimicking the interaction seen in Mario and Legend of Zelda. In these games, the character's left and right movements orbit around the camera allowing the character to run both towards the camera and away from it.

YouTube Link: http://youtu.be/InguV1v38z4

Tutorial 9 – Third Person Camera: Compensating for Wall Collisions

Instead of clipping through environment geometry, this addition to the script uses a line cast from the character to the camera for collision detection. Using this information, we compensate for these collisions by smoothly repositioning the camera on the wall.
YouTube Link: http://youtu.be/MOoiezkQZmk

Tutorial 10 – Third Person Camera: Targeting/Camera Repositioning

While the player orbit camera is ideal for most situations, sometimes the user wants to reset the camera position to its default position behind the player. We use a custom camera image effect to mimic a widescreen letterbox when the left trigger is pressed to enable this feature.
YouTube Link: http://youtu.be/y97J00tjh_0

Tutorial 11 – Third Person Camera: First Person Look Mode

In adventure games, it's common to need to observe the environment to solve a puzzle or determine the next step in a dungeon. Third person cameras always look at the player, so we fix this problem by introducing a new first person look mode into the camera script.
YouTube Link: http://youtu.be/r8z0wB4YWX8

Tutorial 12 – Third Person Camera: Player Orbit Camera Polish

We improve camera responsiveness by using the dot product (the angle between the camera and player) to determine when the player should be running towards the camera, away from it, or in an orbit around it.
YouTube Link: http://youtu.be/MmTN8OjEZBY

Tutorial 13 – Mecanim: Pivoting From Idle and Moving States

Sudden changes in direction aren't handled well by our current "Direction" parameter. In this lesson, we fix this by add a third parameter, "Angle", which will

use a quick turn animation for large direction deltas in both idle and locomotion states.
YouTube Link: http://youtu.be/zy9E-w4QM2o

Tutorial 14 – Mecanim: Using State and Transition Information

Values are still sent to the pivot animation during animation transitions, causing inaccuracies due to the angle value becoming smaller during these periods. Using the controller logic script, we fix inaccurate values by detecting the transition states and stopping the values from being sent to the character controller until after the pivot is completed.
YouTube Link: http://youtu.be/0ZCoj79ILAc

Tutorial 15 – Third Person Camera: Free Camera Mode

Another common feature in adventure games is the ability to free the camera from its automatic repositioning and allow the player to position it according to their needs. We extend the camera script to accommodate this.
YouTube Link: http://youtu.be/vOgkxOR1vxo

Tutorial 16 – Mecanim: Blending Blend Trees – Walk, Run, Jog, Sprint

Expanding from the single run animation blend tree using the direction parameter, we blend in walk, jog, and sprint animations based on the speed parameter. More information on blend trees can be found at: http://docs.unity3d.com/Documentation/Manual/AnimationBlendTrees.html.
YouTube Link: http://youtu.be/Or5NgQbOu7s

Tutorial 17 – Mecanim: Jumping and Animation Clip Curves

We create clip curves in the jump animation to manipulate the Y position and collider height on the character model.
YouTube Link: http://youtu.be/AXIJvIanI6Q

Xbox 360 Controls Diagram

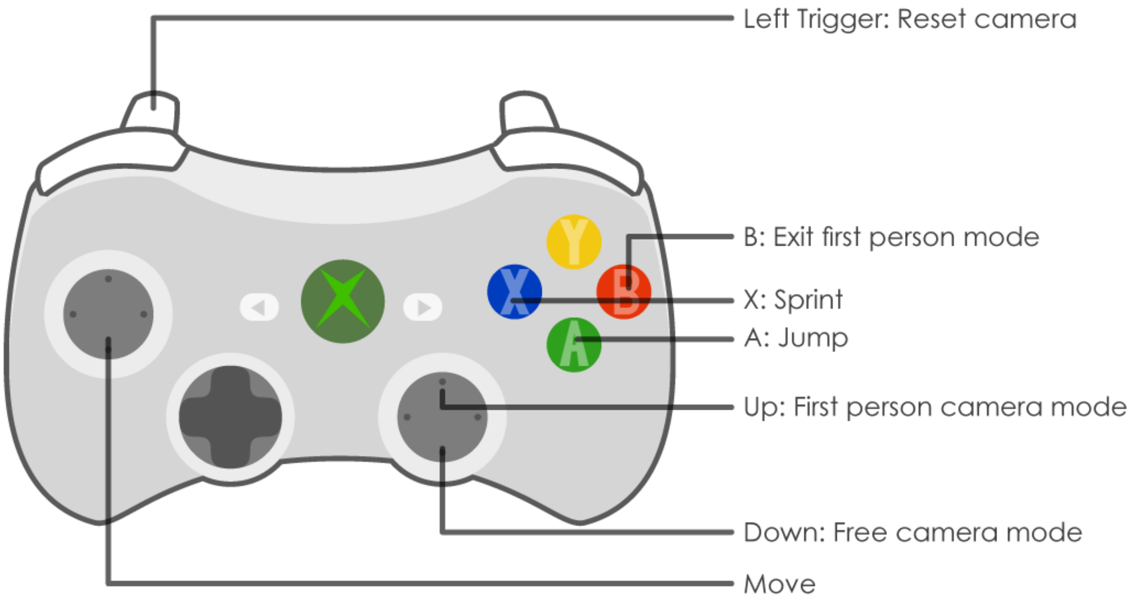

Left Trigger: Reset camera
B: Exit first person mode
X: Sprint
A: Jump
Up: First person camera mode
Down: Free camera mode
Move
Y
B
X
A

Figure 3: Control setup for our demo code

On Windows, these controls correspond to:

3rd Axis:	Reset Camera	**Button 0 (A):**	Jump
5th Axis Up:	First Person Mode	**Button 1 (B):**	Exit First Person
5th Axis Down:	Free Camera	**Button 2 (X):**	Sprint

On Mac, these controls correspond to:

5th Axis:	Reset Camera	**Button 16 (A):**	Jump
4th Axis Up:	First Person Mode	**Button 17 (B):**	Exit First Person
4th Axis Down:	Free Camera	**Button 18 (X):**	Sprint

For more information on controller button bindings in the Unity Input Manager, consult this wiki page.

Developer's Manual

This section contains all relevant information for future developers to easily pick up where our module left off.

GitHub Information

This project is open source and available on the GitHub server:

Link: https://github.com/jm991/UnityThirdPersonTutorial

For read write access add the following address to your GitHub Client:

Link: https://github.com/jm991/UnityThirdPersonTutorial.git

Project Inventory

This is an inventory of some of the data, program, and script files - with explanation of each. Due to the large amount of code required for this project, some of the files have been omitted, but can be found in the GitHub repository. Note: All Unity scripts for this project have been documented and commented.

Unity Assets

- **Beta Character:** Downloadable from Mixamo's animation site
- **Fairy Forest Scene:** rebuilt from Legend of Zelda: Wind Waker

Unity Scripts

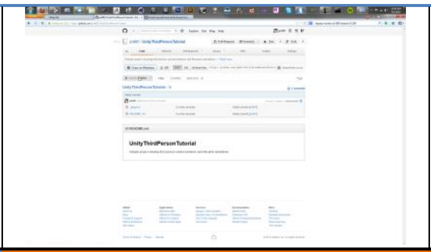
- **SceneViewCameraFollow.cs:** Debug script to allow multiple scene view cameras in the editor to be setup to follow game objects. Author - Joshua Berberick. Found on the Unify Wiki.
- **BarsEffect.cs:** Contains the logic to support the targeting bars effect camera feature.
- **ThirdPersonCamera.cs:** The main camera script that controls the three camera features: Behind the back, First person look, and third person free cam.
- **CharacterControllerLogic.cs:** Supplies the character control logic, information and parameters to the Mecanim character animation controller.

Video Storyboard

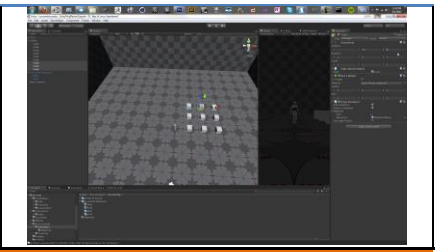
The tutorials have been color coded so that users can find relevant information quickly, rather than watching the entire tutorial series from start to finish:
Setup, introduction
GIT
Mecanim

Camera

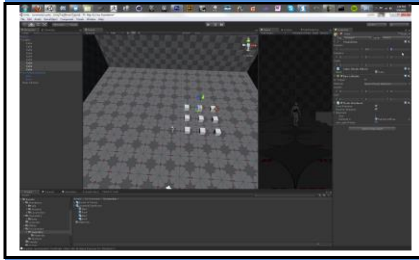
Tutorial 1 - Introduction



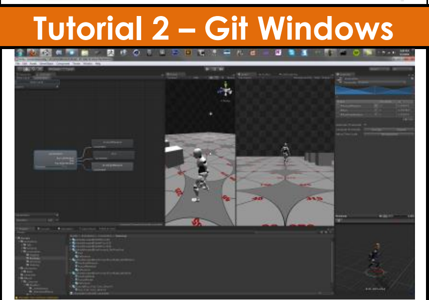
Tutorial 2 – Git Windows



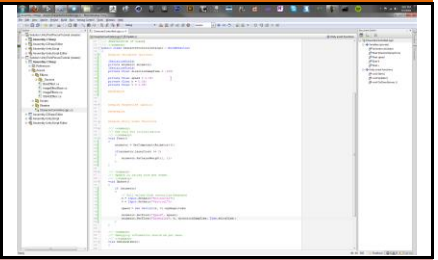
Tutorial 3 – Git Mac



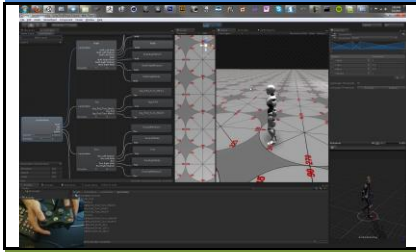
Tutorial 4 – Scene Setup



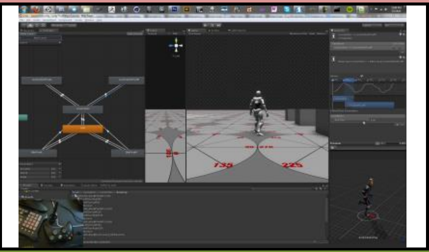
Tutorial 5 – Mecanim Nodes



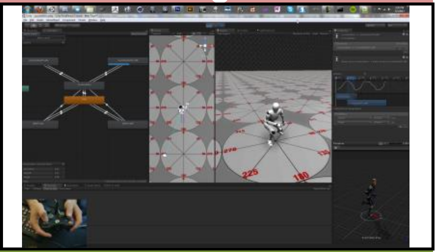
Tutorial 6 – Mecanim Logic



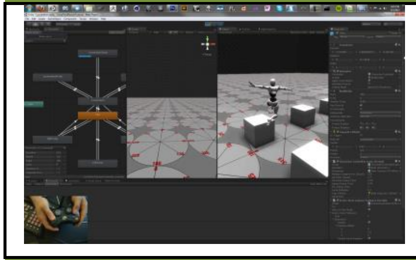
Tutorial 7 - Follow Camera



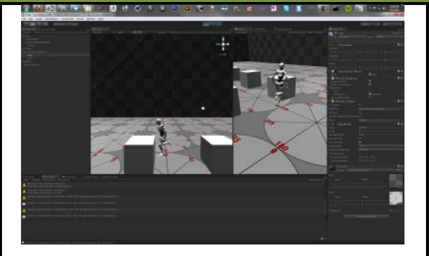
Tutorial 8 – Orbit Camera



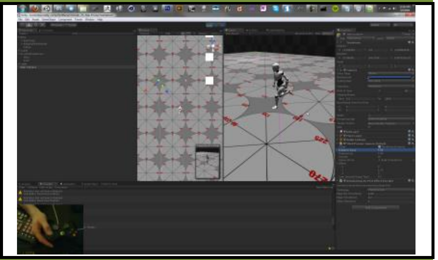
Tutorial 9 – Camera Collision



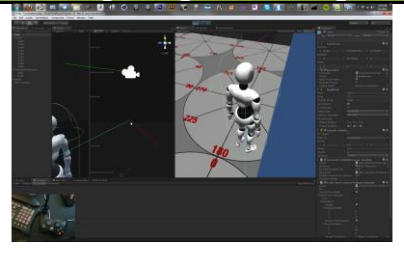
Tutorial 10 – Camera Targeting/Resetting



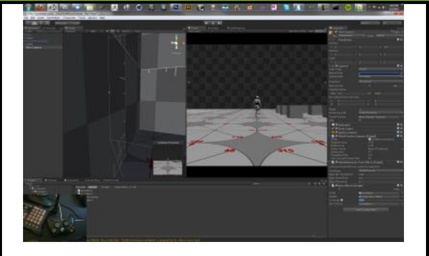
Tutorial 11 – Camera First Person



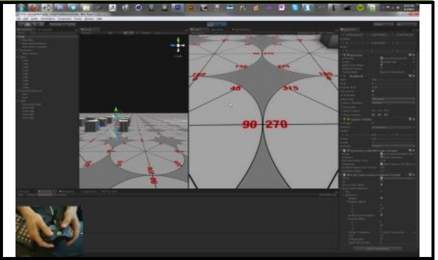
Tutorial 12 – Orbit Camera Polish



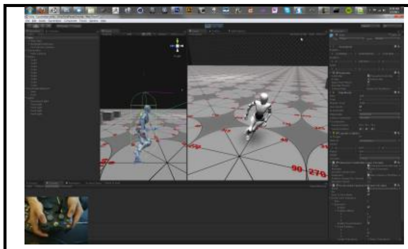
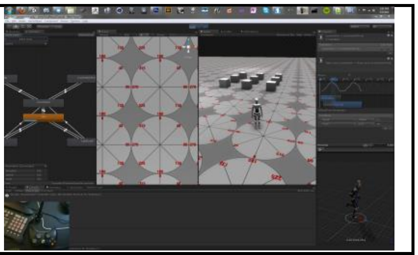
Tutorial 13 – Mecanim Pivoting



Tutorial 14 – Mecanim Transition Info



Tutorial 15 – Free Camera

	
Tutorial 16 – Mecanim Blend Trees	Tutorial 17 – Mecanim Clip Curves

Potential Features for Future Developers

If future developers wish to continue our module we would encourage them to implement and create tutorials on the following features:

Mass Effect Over the Shoulder Camera

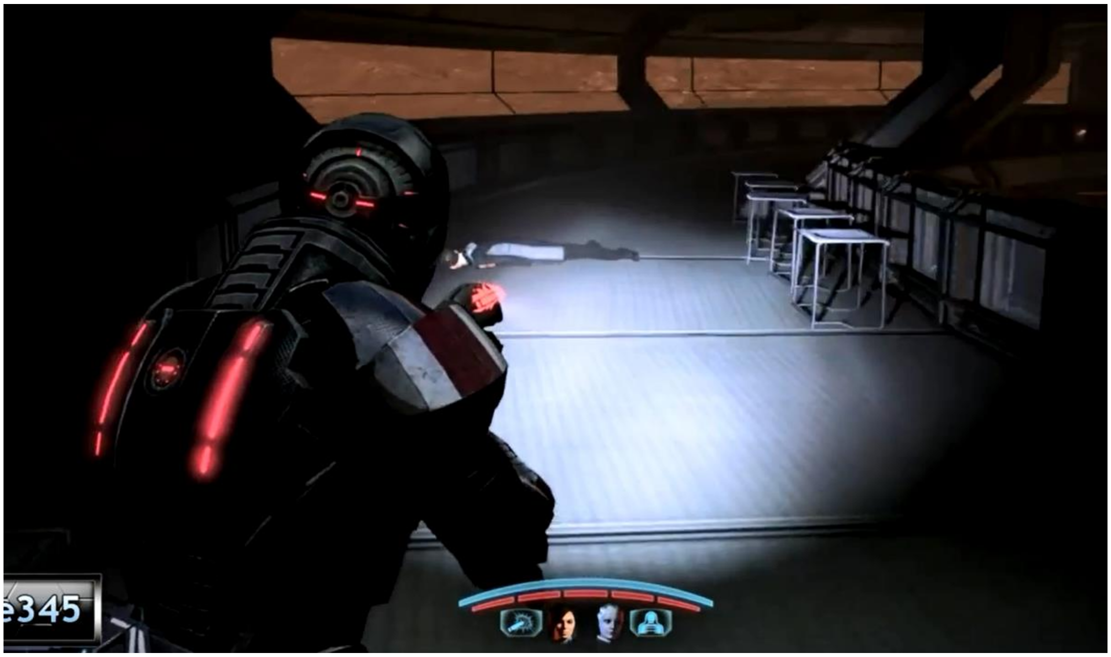


Figure 4: *Mass Effect* "over the shoulder" style camera

Weapon Crosshair Targeting Camera

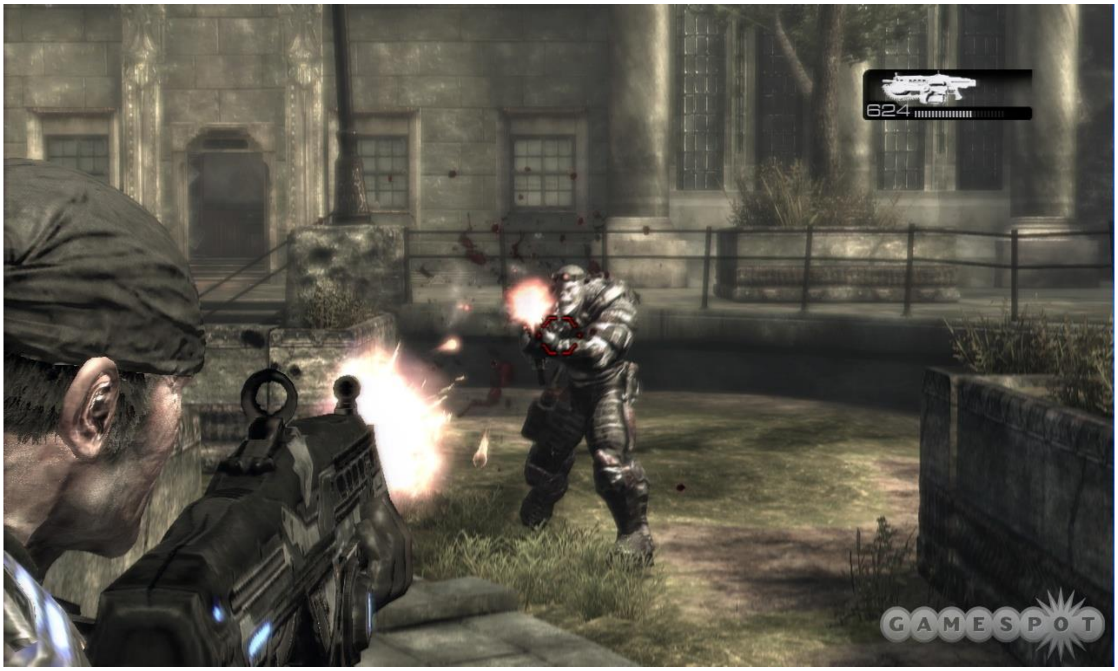
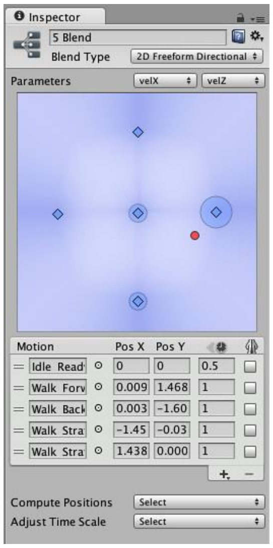


Figure 5: *Gears of War* camera crosshair for targeting

The Animated Soldier (incl. movement scripts) is a fully rigged 3D model with complex camera scripts. This is a great reference for implementing both the Targeting Camera and Over the Shoulder Camera. It is available for free on the Unity Asset Store. *Link: https://www.assetstore.unity3d.com/#/content/1727*

Advanced Mecanim Blend Trees

In Unity 4.1, 2D blend trees were introduced to clean up blended blend trees like the ones found in Lesson 16. Additionally, since two parameters can be sent to these trees, strafing, walking backwards, and walking forwards is easily achieved using a blend tree similar to the one below:



5 Blend

Blend Type: 2D Freeform Directional

Parameters: velX, velZ

Motion	Pos X	Pos Y		
Idle Read	0	0	0.5	□
Walk Forv	0.009	1.468	1	□
Walk Back	0.003	-1.60	1	□
Walk Stra	-1.45	-0.03	1	□
Walk Stra	1.438	0.000	1	□

Compute Positions: Select

Adjust Time Scale: Select

Figure 6: 2D blend tree for strafing

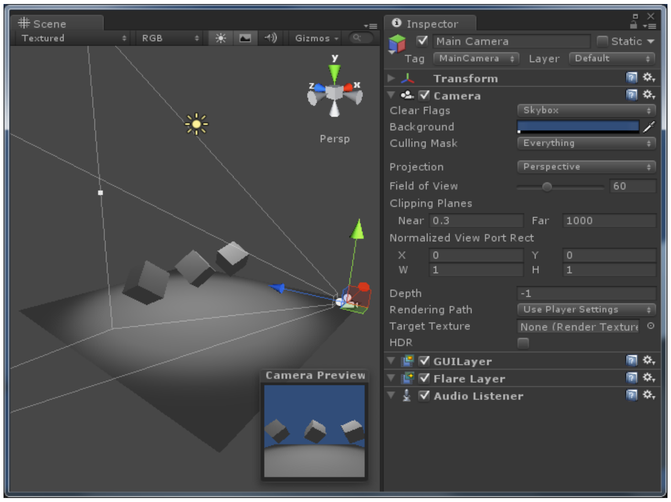
We encourage future developers to explore the possibilities of this new type of node in Mecanim in conjunction with the targeting camera mode.

Using the Camera Frustum for Better Wall Collision

While the collision we implemented in Lesson 9 was an improvement, it still allowed the user to see outside of the world. One way to fix this is to cast rays from the camera's viewport along each of the four corners of the viewing volume in order to check for collision. If there is no collision at a corner, the camera can be smoothly moved in from the wall in the direction of the corner. Some sample code to calculate rays from the frustum can be found below:

```
private void CompensateForWalls(Vector3 fromObject, ref Vector3 toTarget)
    {
        UpdateFrustrumPlanes();

        Vector3 point = Vector3.zero;
        Vector3 direction = Vector3.zero;
        PlanePlaneIntersection(out point, out direction, planes[(int) Frustrum.Left],
planes[(int) Frustrum.Top]);
        Debug.DrawRay(camera.ViewportToWorldPoint(new Vector3(0, 1,
camera.nearClipPlane)), -1f * direction, Color.yellow);
        PlanePlaneIntersection(out point, out direction, planes[(int) Frustrum.Top],
planes[(int) Frustrum.Right]);
        Debug.DrawRay(camera.ViewportToWorldPoint(new Vector3(1, 1,
camera.nearClipPlane)), -1f * direction, Color.yellow);
        PlanePlaneIntersection(out point, out direction, planes[(int) Frustrum.Right],
planes[(int) Frustrum.Bottom]);
```

```
        Debug.DrawRay(camera.ViewportToWorldPoint(new Vector3(1, 0,
camera.nearClipPlane)), -1f * direction, Color.yellow);
        PlanePlaneIntersection(out point, out direction, planes[(int)
Frustrum.Bottom], planes[(int) Frustrum.Left]);
        Debug.DrawRay(camera.ViewportToWorldPoint(new Vector3(0, 0,
camera.nearClipPlane)), -1f * direction, Color.yellow);

        Debug.DrawLine(fromObject, toTarget, Color.cyan);
        // Compensate for walls between camera
        RaycastHit wallHit = new RaycastHit();
        if (Physics.Linecast(fromObject, toTarget, out wallHit))
        {
            Debug.DrawRay(wallHit.point, Vector3.left, Color.red);
            toTarget = new Vector3(wallHit.point.x, toTarget.y, wallHit.point.z);
        }
    }

    private void UpdateFrustrumPlanes()
    {
        planes = GeometryUtility.CalculateFrustumPlanes(this.camera);

        for (int i = 0; i < planes.Length; i++)
        {
            DrawPlanePoints(planes[i], i);
        }
    }

    /// <summary>
    /// Find the line of intersection between two planes.
    /// The inputs are two game objects which represent the planes.
    /// The outputs are a point on the line and a vector which indicates it's
direction.
    /// </summary>
    private void PlanePlaneIntersection(out Vector3 linePoint, out Vector3 lineVec,
Plane plane1, Plane plane2)
    {
        linePoint = Vector3.zero;
        lineVec = Vector3.zero;

        // Calculate position of planes' "centers" in space using normal and distance
        Vector3 plane1CenterPosition = -plane1.normal * plane1.distance;
        Vector3 plane2CenterPosition = -plane2.normal * plane2.distance;

        // We can get the direction of the line of intersection of the two planes by
calculating the
        // cross product of the normals of the two planes. Note that this is just a
direction and the line
        // is not fixed in space yet.
        lineVec = Vector3.Cross(plane1.normal, plane2.normal);

        // Next is to calculate a point on the line to fix its position. This is done
by finding a vector from
        // the plane2 location, moving parallel to it's plane, and intersecting
plane1. To prevent rounding
        // errors, this vector also has to be perpendicular to lineDirection. To get
this vector, calculate
        // the cross product of the normal of plane2 and the lineDirection.
        Vector3 ldir = Vector3.Cross(plane2.normal, lineVec);

        float numerator = Vector3.Dot(plane1.normal, ldir);

        // Prevent divide by zero.
        if(Mathf.Abs(numerator) > 0.000001f)
        {
            Vector3 plane1ToPlane2 = plane1CenterPosition - plane2CenterPosition;
            float t = Vector3.Dot(plane1.normal, plane1ToPlane2) / numerator;
            linePoint = plane2CenterPosition + t * ldir;
        }
    }

    private void DrawPlanePoints(Plane p, int i)
    {
        Color myCol = Color.white;
        switch (i)
        {
        case 0:
            myCol = Color.blue;      // left
            break;
        case 1:
            myCol = Color.red;       // right
            break;
        case 2:
            myCol = Color.magenta;   // bottom
            break;
        case 3:
            myCol = Color.yellow;    // top
            break;
        case 4:
            myCol = Color.cyan;      // near
            break;
        case 5:
            myCol = Color.green;     // far
            break;
        default:
            break;
        }

        Vector3 pCenterPos = -p.normal * p.distance;
        Debug.DrawRay(pCenterPos, Vector3.up * 0.1f, myCol);
    }
```



☑ Main Camera □ Static
Tag MainCamera Layer Default
Transform
☑ Camera
Clear Flags Skybox
Background
Culling Mask Everything
Projection Perspective
Field of View 60
Clipping Planes
Near 0.3 Far 1000
Normalized View Port Rect
X 0 Y 0
W 1 H 1
Depth -1
Rendering Path Use Player Settings
Target Texture None (Render Texture
HDR □
☑ GUILayer
☑ Flare Layer
☑ Audio Listener

Figure 7: View frustum and volume

Lessons Learned

This section is a reflection on our experiences with the project.

Timeline/schedule

At the outset of our project, we had a hard time deciding what it was we wanted to teach in the tutorials. At first, we had decided on Mecanim and ShaderLab, the lighting and shading language in Unity. We then moved to trying to code an entire game prototype. With guidance from our sponsors, we settled on the 3rd person camera and Mecanim character control idea that led to this project by the midterm. Our rough schedule was as follows:

3/27 – 4/3

- Polish camera and character control scripts

3/31

- Record GIT intermediate tutorial

4/2

- Edit GIT intermediate tutorial

4/3 – 4/10

- Testing scripts and bug fixes

4/10 – 4/17

- Record Character Control and Camera tutorials

4/17 – 4/24

- Edit Character Control and Camera tutorials

4/24

- Present final product to clients

Problems and Solutions

The biggest challenge for us was deciding on what we wanted to focus our tutorials on. As discussed above, the numerous changes to the original proposal led to some randomization. However, once we reflected on the work we had done at the midterm, it was much easier to properly scope the project and have a compelling final product.

Our largest technical challenge was the Orbit Camera, which had bugs up until the final days of the semester. Once we realized we needed to rotate the character model along with changing its direction and convert the joystick axis movement to the character's coordinate system, the project continued on at a smooth pace.

Our recording process also suffered from a few problems. We invested in a Yeti microphone, but it gave out during the 4th tutorial. We had to improvise and used a cheaper Logitech dynamic USB microphone. It took some getting accustomed to, but by the 7th tutorial, our audio sounded high quality again. We also had some issues exporting 3 hours' worth of tutorials from Camtasia, but using the export setting that treated each marker as a separate video helped. We could not use lossless due to the huge size of the 1080p recordings, so we settled for h.264 MP4 files set to 100% quality as our intermediary step before taking the tutorials into Premiere Pro for editing.

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