Kinematic Character Controller

Walkthrough

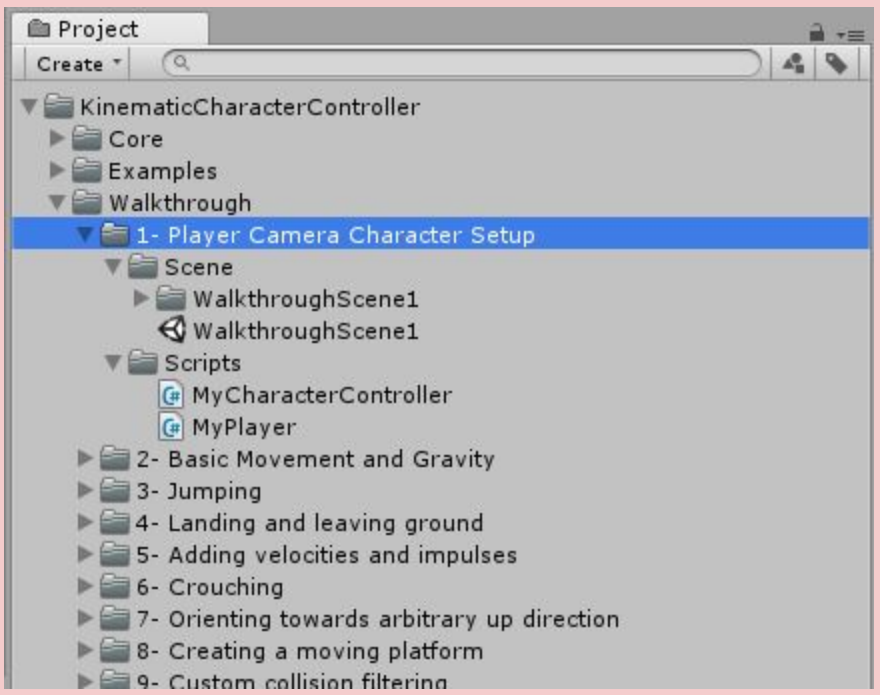
Support email: **store.pstamand@gmail.com**

Table of Contents

Character Controller Creation Walkthrough

This walkthrough will present a step-by-step guide to implementing a complete character controller from scratch using the Kinematic Character Controller system. It can either be followed sequentially or be used as a reference for a specific feature you wish to implement.

How to use this walkthrough:
To follow along, open the “Walkthrough” folder in the project. In each section of this walkthrough, follow along with the scene and the code in the corresponding folder. **The scene in each folder represents the completed version of each section of the walkthrough**.



At every major step of the tutorial, you will be invited to look at specific areas of the walkthrough section code with a highlighted comment such as this one. The comments in the code will explain the rest

Note: The character controller we will be creating during this walkthrough isn’t necessarily meant to be a final game-ready character. It is mostly created for learning purposes. For instance, the swimming mode and the ladder-climbing implementations are very rudimentary and they are mostly just meant to give you a general idea of how such things could be implemented.

Player, Character & Camera setup

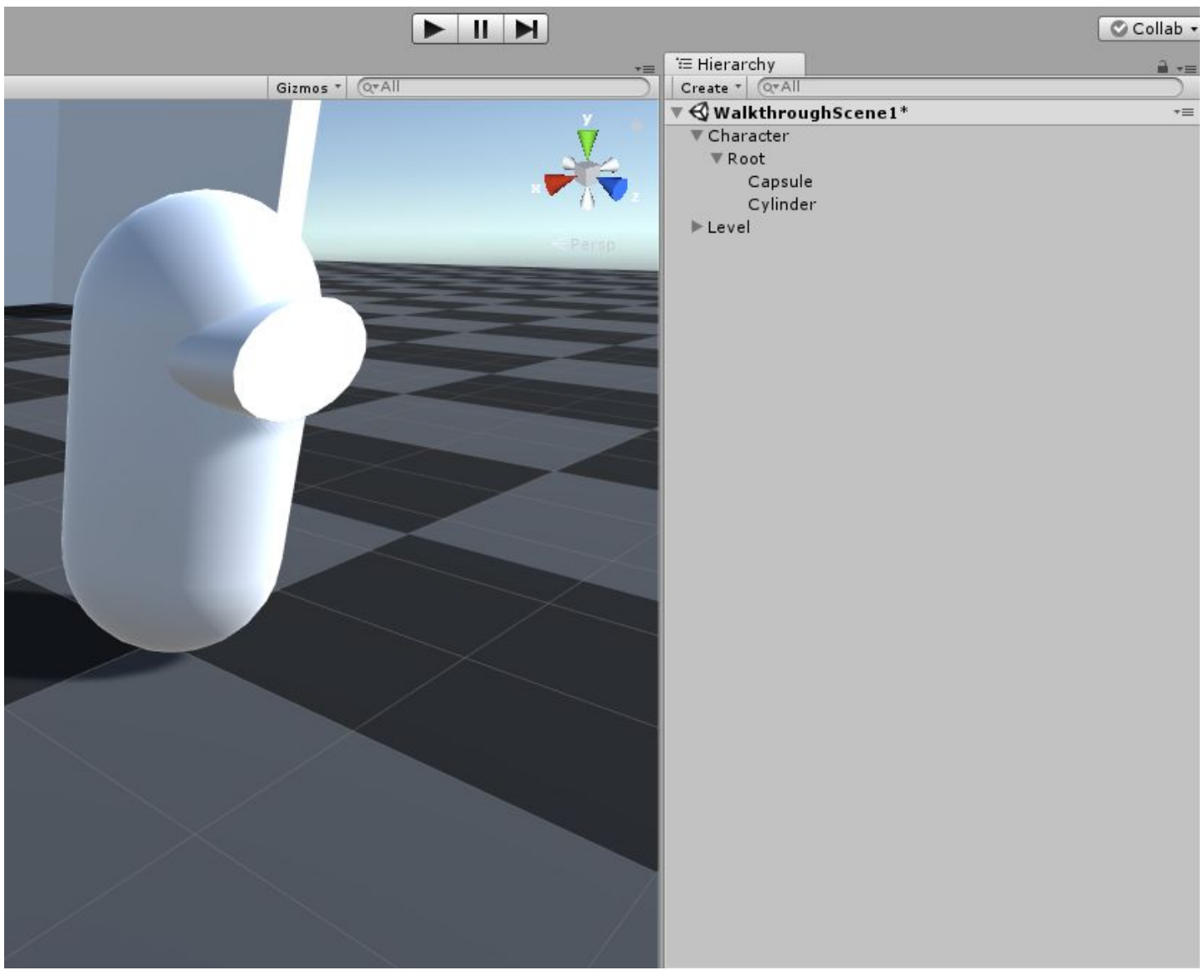
We'll start by creating the general structure for making inputs, characters and cameras work together. Instead of putting input handling and camera control directly into the character controller, we will isolate it in a "MyPlayer" class. The reasoning behind this is that not all character controllers will necessarily be human-controlled. Some will be AI, and it wouldn't make sense for AI characters to handle input and cameras. With this sort of structure, we can easily make certain characters controlled by a human "Player", and others controller by AIs. All of this without requiring two different character controllers.

Creating the Character Controller GameObject

- In a scene, create an empty GameObject
- Add a KinematicCharacterMotor component (this will automatically create a readonly capsule collider)
- Create a script and call it "MyCharacterController". Make it inherit from Monobehaviour and implement the ICharacterController interface
- Add a "public KinematicCharacterMotor Motor;" field to that class
- In the Start() of "MyCharacterController", write "Motor.CharacterController = this" to assign it as the motor's controller
- Add your "MyCharacterController" to the character GameObject
- Assign the KinematicCharacterMotor component to the "Motor" field of MyCharacterController
- Add an empty GameObject as child of your character GameObject, and call it "Root". This will be the container for all the meshes of the character. Having this setup will come in handy later when we will implement crouching.
- Add a mesh as a child of your "Root" GameObject. You can use a capsule primitive for now, **but don't forget to remove ALL colliders that are under the Character GameObject! Otherwise your character will fly off into the sunset because it'll keep trying to de-collide from itself!**
- Set your character's capsule dimensions and physics material (can remain empty) under the "Capsule Settings" section of the KinematicCharacterMotor inspector.
- In the "Motor Parameters" section, you can leave the defaults for now. See the tooltips for more information on what each variable does.

Look at the MyCharacterController class to see what it should look like at this point.

And your Character GameObject should look like this:



Creating the Player

- In a scene, create an empty GameObject and call it "Player"
- Create a script and call it "MyPlayer".

- Add the “MyPlayer” component to your “Player” GameObject

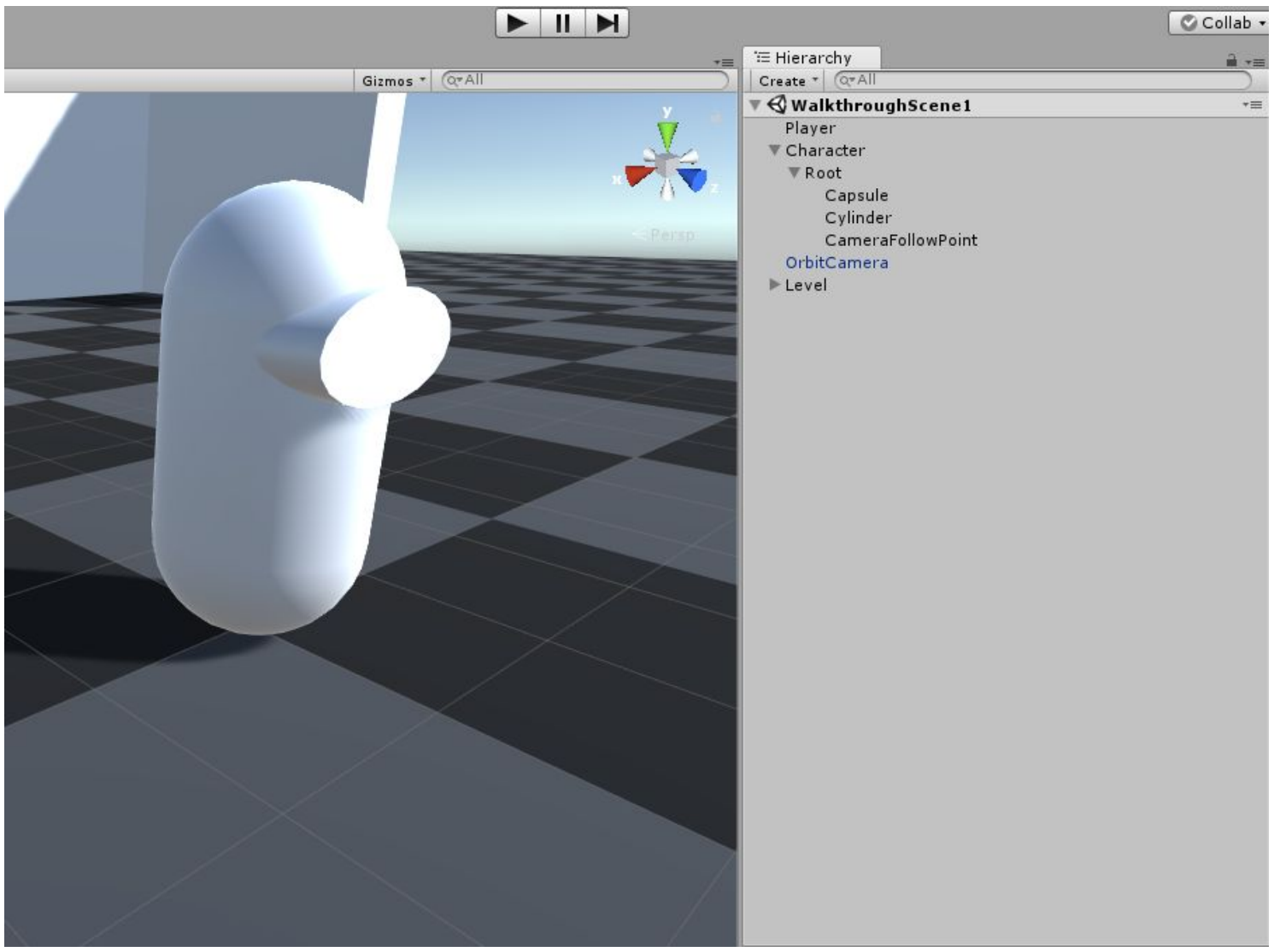
MyPlayer will be where we handle all character and camera input, and make the connections between the camera and the character. For now, let’s just take care of camera handling. On Start(), MyPlayer will setup the camera to follow the character, and on Update(), it will calculate input from mouse movement and mouse scroll wheel, and send these inputs to its assigned OrbitCamera. This will result in a controllable camera that follows the character at all times.

Look at the MyPlayer class, and see how we handle sending input to the camera.

Additionally, look at the OrbitCamera class to see how inputs are transformed into movement. Camera handling will not be the focus of this walkthrough, so we will not go into details about this. (the comments in the code should suffice)

Linking everything together

- Drag the “OrbitCamera” prefab from *KinematicCharacterController\Examples\Prefabs* into the scene
- Assign the OrbitCamera to the corresponding field in MyPlayer’s inspector
- Assign the MyCharacterController to the corresponding field in MyPlayer’s inspector
- Under your Character’s GameObject, add an empty GameObject that will serve as the camera’s orbit point. Add this transform to the “Camera Follow Point” field in MyPlayer’s inspector
- Add a floor to the scene (flat cube primitive with (100, 0, 100) scale, for example)
- The final setup should look like this:



Now you can press play and notice you have control of the camera. The initial setup is complete! But you can’t move the character, because we haven’t yet implemented any movement code….

Basic movement and Gravity

Now let's start writing some movement code!

Movement input handling in MyPlayer and MyCharacterController

We need to start by making MyPlayer tell MyCharacterController where it needs look and move to.

First of all, we'll create a struct that represents the inputs that a player can give to its character.

Notice the "PlayerCharacterInputs" struct we define in MyCharacterController.cs

We will then add a "HandleCharacterInput" method in MyPlayer, which will be called on every Update. This method will simply pass on the inputs from the player to the character.

Look at the implementation of MyPlayer.HandleCharacterInputs(), which in turn calls MyCharacterController.SetInputs()

SetInputs()'s goal is to transform these inputs into information that the character can use for its movement and rotation. Here we build a movement vector and a look direction vector based on the camera orientation and the character's up direction (we want to move in the camera's direction, but only on the character's plane).

With this, we have MyPlayer sending movement inputs to MyCharacterController, but we have yet to turn this into actual character movement.

Character controller movement code

Now it's time to make our character controller move with those inputs from the Player.

First of all, we will handle translation movement, which will be done in the "UpdateVelocity" override method of MyCharacterController. **This method is called by KinematicCharacterMotor on every character update and it's basically where you tell your character controller what its velocity should be right now. It is very important to always handle character velocity in this method, because it is called precisely at the right time in the character update loop in order for everything to work well.** You must modify the "currentVelocity" parameter passed as reference to this method in order to set what the velocity should be.

Look at the UpdateVelocity method in MyCharacterController where we implement basic ground/air movement with gravity. See the comments for a more detailed explanation

Next, we can handle character orientation. We will do this in the "UpdateRotation" override method of MyCharacterController. **This method is called by KinematicCharacterMotor on every character update and it's basically where you tell your character controller what its rotation should be right now**. **It is very important to always handle character rotations in this method, because it is called precisely at the right time in the character update loop in order for everything to work well.** Modify the "currentRotation" parameter passed as reference to this method in order to accomplish this.

Look at the UpdateRotation method in MyCharacterController where we implement smoothly orienting towards the camera look direction.

Press play and try out the implemented movement. Feel free to add more geometry to your scene at this point.

Jumping

Simple jumping

To implement jumping, we will first need to handle jump input.

See the “JumpDown” field we’ve added to the PlayerCharacterInputs struct, and see how we set it in MyPlayer.HandleCharacterInput()

And finally, see how we process this jump input in MyCharacterController.SetInputs(). Here we remember that we want to jump, and we start keeping track of the time since jump was requested.

Remember that all velocity needs to be processed in UpdateVelocity, so this is why we keep track of the fact that that we want to jump and don’t apply the movement right now in some way.

See the jump-handling code that adds velocity at the end of the UpdateVelocity method. This is where the jump velocity is actually applied. **Pay special attention to the call to “KinematicCharacterMotor.ForceUnground()”**. This is required whenever we want our character to leave the ground, otherwise it would keep snapping back on.

Also see the additional jump logic handling in the “AfterCharacterUpdate” method of MyCharacterController, for handling timers and jump states.

Note: The JumpPreGroundingGraceTime and JumpPostGroundingGraceTime respectively represent the extra time before landing where you can press jump and it’ll still jump once you land, and the extra time after leaving stable ground where you’ll still be allowed to jump.

Double Jumping

In order to add double-jumping, we simply have to add a condition when jumping is requested where if we have consumed our first jump and we aren’t on ground, we can jump again.

See the implementation of the double-jump in MyCharacterController.UpdateVelocity, under the “// Handle double jump” comment.

Wall Jumping

In order to implement wall-jumping, we will do something very similar to regular jumping, but only if we are currently moving against a wall. In order to accomplish this, we will need to add code in the “OnMovementHit” method of MyCharacterController that will keep track of if we are allowed to wall-jump, and then we will use that variable in UpdateVelocity in order to perform the actual jump.

See the implementation of the wall-jump in MyCharacterController.OnMovementHit and MyCharacterController.UpdateVelocity. (Look for all the places where the _canWallJump variable is used.)

Detecting landing and leaving ground

Most character controllers will need a way to detect when it has landed, or when it has left ground (for animation, sound effects, etc….). This is very easy to accomplish. All we need to do is to compare the current ground status with the previous ground status of the KinematicCharacterMotor during the “PostGroundingUpdate”, which is called right after the character has evaluated its new grounding status.

See the implementation of this in MyCharacterController.PostGroundingUpdate (“// Handle landing and leaving ground”)

Enter Play mode and try jumping around to see the debug log messages for when you land and leave ground.

Adding velocities and impulses

It is often desirable to have a quick and easy way to add forces and impulses to the character, whether it's for explosion forces, hit impacts, wind zones, etc…. In order to accomplish this, we will create an "AddVelocity" method in MyCharacterController, which will maintain an internal velocity vector to add to the final velocity in UpdateVelocity.

Look for the "AddVelocity" method and all the places where we use _internalVelocityAdd in MyCharacterController

In order to test this, we can simply add some input in MyPlayer that will add a velocity to the character. This is done with the '"Q' key in this example

Notice that we call "ForceUnground" just before adding the velocity. That's because we want the force to launch the character into the air. Without this, the character would always remain snapped to the ground!

Crouching

To implement crouching, we will first need to handle crouch input.

See the “CrouchDown” and “CrouchUp” fields we’ve added to the PlayerCharacterInputs struct, and see how we set it in MyPlayer.HandleCharacterInput()

And finally, see how we process this input in MyCharacterController.SetInputs(). Here we remember our desired crouching state, and apply the capsule rescale if we do crouch

But un-crouching is not handled in SetInputs. That’s because it is possible that the character is in a situation where it doesn’t have enough space to uncrouch. The handling for this is done in MyCharacterController.AfterCharacterUpdate

Look for the “// Handle uncrouching” part of MyCharacterController.AfterCharacterUpdate

This code first tries to determine if we should be uncrouching, and if yes, it’ll temporarily resize the capsule to match the character’s standing height, and do an overlap test with KinematicCharacterMotor.CharacterOverlap. The reason why we do this as opposed to a simple OverlapCapsule is that CharacterOverlap takes all of the character’s ignored colliders and specific collision filtering into account. If it detects that we can’t stand, it resets the capsule dimensions to its crouching size. But if we can stand, it resets the scale of the mesh and assigns IsCrouching to false.

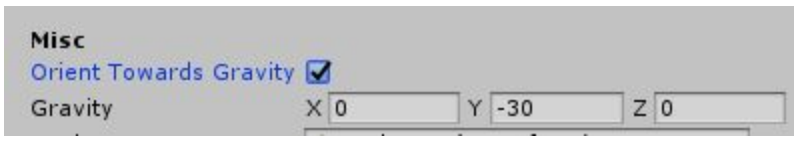
Now try passing under the red module in the scene by crouching with the C key.

Orienting towards arbitrary up direction

In order to demonstrate how you could orient the character towards any direction, we will now implement an option that allows the character to always orient its up direction in the opposite direction of the gravity.

Look for the usage of the “OrientTowardsGravity” variable in MyCharacterController.UpdateRotation

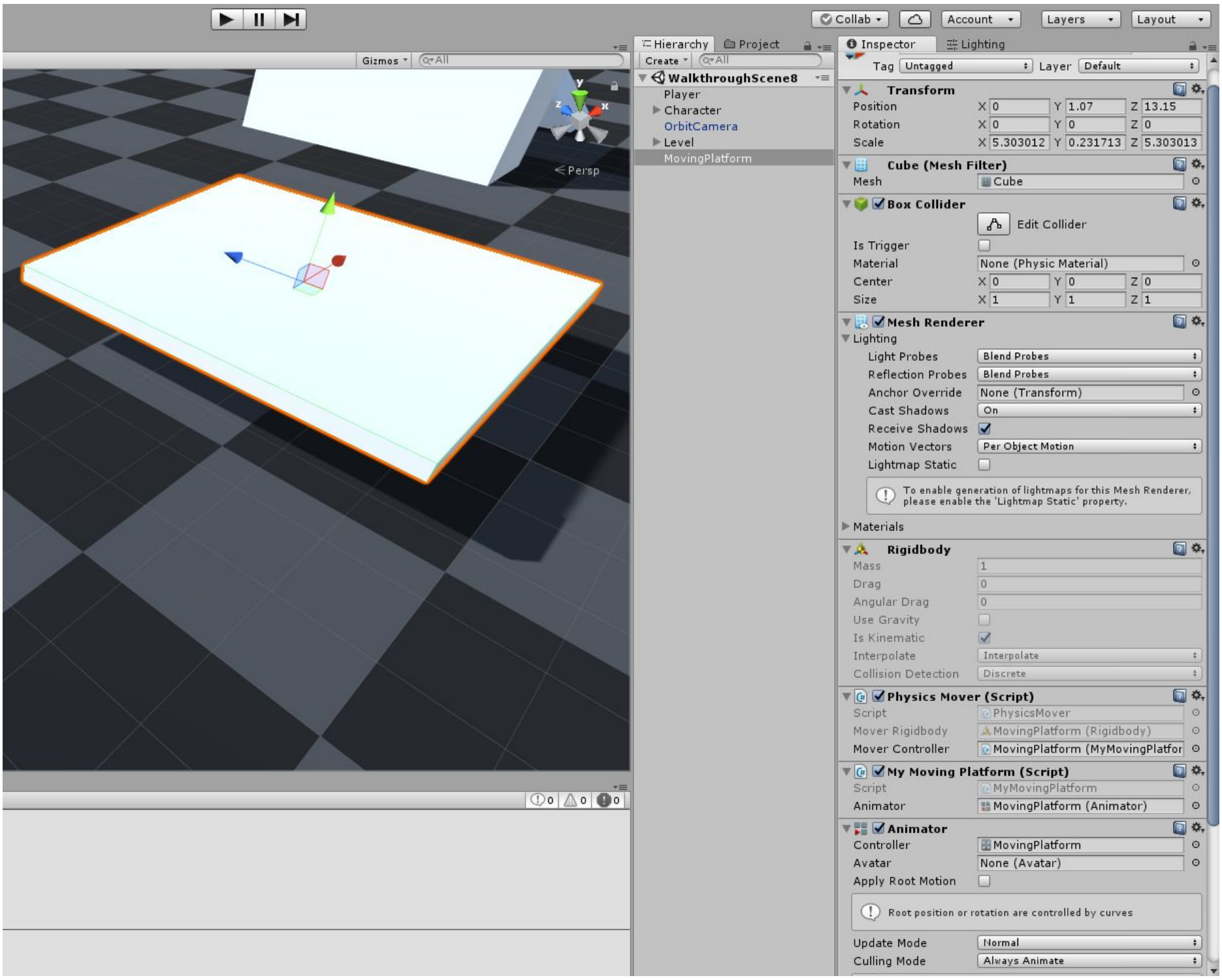
In “UpdateRotation”, which is the method in which you specify what rotation you want your character to have right now, we simply tell the character to rotate from its current up to the inver-gravity direction. This does the trick. Now try to activate “Orient Towards Gravity” in the character’s inspector and play with the character’s “Gravity” vector to see the re-orienting in action.



Creating a moving platform

We will now create a moving platform that you can move through animations. First, let's set up the platform object:

- Create a flat cube in the scene, and call it "MovingPlatform".
- Add a "PhysicsMover" component to it. You should use this component to create any sort of kinematic moving object that the character can stand on, or be pushed by.
- Create a "MyMovingPlatform" script (or take the one in the walkthrough sources). This class must inherit from "BaseMoverController" and implement the "UpdateMovement" abstract method.
- Add the "MyMovingPlatform" component to the "MovingPlatform" GameObject
- Assign the MyMovingPlatform component to the "MoverController" field of PhysicsMover
- Using a PlayableDirector component and the Timeline window, create a playable animation that moves and rotate that platform



The way to use PhysicsMovers is that you tell it exactly what their position and rotations should be in BaseMoverController's "UpdateMovement" callback. When you handle movement through this callback, all of the physics will be handled properly with the character controllers, so it is crucial not to move those PhysicsMovers with anything else. However, this could be a problem if we want to move them with animation….

We will solve this problem by taking total control over the animation evaluation and only update it along with our PhysicsMover's updates (FixedUpdate). To do this, we will make sure our PlayableDirector's update mode is set to "Manual", so we can update it ourselves. We'll then use the Evaluate() method to apply the animation at any time we want

Look at the stopping of the animator's PlayableGraph in MyMovingPlatform.Start

Next we will implement the UpdateMovement callback.

- First we will cache the pose we were in before evaluating the animation,

- then we will evaluate the animation (which will update the transform's pose instantly),
- then we will tell our PhysicsMover where it needs to go over the next FixedUpdate,
- And finally we will reset the transform's pose to where it was before evaluating the animation. This is so that the animation doesn't interfere with the physics

Look at the implementation of MyMovingPlatform.UpdateMovement

With this, we have moving platforms that support animations. Try entering Play mode and jumping on the platform.

Custom collision filtering

In games, you will often need to filter out specific collisions, and it can't always be done elegantly through physics layers. For example, you might want to pass through teammates in an online game, but be blocked by enemies. Here we will create a simple collision filtering example that will give you an idea of how to accomplish this.

First of all, add a public list of colliders to your MyCharacterController that will represent the colliders you wish to ignore:

See the "IgnoredColliders" field in MyCharacterController

The actual filtering will be done in "IsColliderValidForCollisions". The method asks you to return true if you can collide with this collider, or false otherwise.

Look at the implementation of MyCharacterController.IsColliderValidForCollisions

You can try this in play mode by moving against the transparent red cube, which has a collider, but is in our IgnoredCollider list.

You could use this method in any way you want. For example, you could do a GetComponentInParent of any kind of component type on the collider, and filter out all objects that have this specific component.

(Note that this does not make the camera ignore those colliders too. The setup you choose to make both the character and the camera ignore the same colliders in your game will be up to you. But as an example, you could put the IgnoredColliders list in MyPlayer, and the make MyPlayer tell both the character and the camera to ignore these.)

Multiple movement states setup

We will soon reach a point where we'll want multiple movement states for our character controller. To prevent the code from getting too messy, we will take a bit of time right now to re-arrange everything into something much easier to work with. It'll pay off later!

Here's what we're going to do:

1. We will create a "CharacterState" enum representing all the states the character can be in. For now, there's just one Default state.
2. We will add a "CurrentCharacterState" field to MyCharacterController, which will remember what our current state is
3. In all pertinent methods of MyCharacterController, we will add a switch case that'll allow us to write different logic depending on the current state of the character
4. We will add the TransitionToState, OnStateEnter and OnStateExit methods to MyCharacterController to make transitions simpler to manage

Look at the implementation of this in MyCharacterController.

Some of the methods that now have state-dependant logic are:

- SetInputs
- UpdateRotation
- UpdateVelocity
- AfterCharacterUpdate
- OnMovementHit
- AddVelocity
- ProcessHitStabilityReport

We only have one "Default" character state for now, but with this setup, we are ready to add as many movement states as we want!

Charging state

We will now start writing a new and simple movement state that we will call “Charging”. In this mode, the character will keep moving forward at a constant velocity until it hits a wall, or until X seconds have elapsed. It will then pause for some time and go back to the default movement mode.

First, we will add a “Charging” state to the CharacterState enum. Then, we will add some input handling code to call a transition to that state when Q is pressed.

Take a look at the charging input handling in the MyPlayer.HandleCharacterInput and MyCharacterController.SetInputs methods. The actual state transition happens at the beginning of SetInputs()

We are now ready to implement the charging state itself. Here’s an overview of what we want to do:

- In OnStateEnter, for the Charging state, cache a charging velocity based on the character’s forward direction
- In UpdateVelocity, for the Charging state, keep applying the charging velocity every update unless we are in the pause at the end of the charge
- In OnMovementHit, for the Charging state, look for collisions with walls in order to trigger the end of the charge
- In AfterCharacterUpdate, for the Charging state,
    - determine if the charging time has elapsed and if we need to end the charge
    - determine if it’s time to retransition back to the default movement state

See how each of these points were implemented in MyChargingState

In Play mode, we can now press Q and our character will enter a charge that can be stopped by walls or by reaching a certain time. Notice that it does not get interrupted by ramps or steps, and that gravity is only applied when stopped. This is just to show you the kind of versatility you can have with this system.

NoClip state

We will now demonstrate a simple implementation of a “NoClip” mode in order to teach you about the some of the physics activation methods of KinematicCharacterMotor. A NoClip mode is when your character can fly around and pass through all collisions. It’s like a “spectator” mode of some sort.

To do this, follow the same procedure as in last section in order to add a new character state to MyCharacterController (in the CharacterState enum). We will call this one “NoClip”. We will also add an input to PlayerCharacterInputs for when we are requesting a charge.

Take a look at MyPlayer and MyCharacterController to see how the Q input is translated to a transition to the NoClip state in SetInputs()

Now for the implementation of the state’s logic. The most important thing is what happens in OnStateEnter and OnStateExit. Here we control whether or not the character’s custom collision detection code will be bypassed or not with the KinematicCharacterMotor.SetCapsuleCollisionsActivation() and KinematicCharacterMotor.SetCollisionSolvingActivation() methods. When SetCollisionSolvingActivation is set to false, no collision solving is done whatsoever, and the character can go through anything. SetCapsuleCollisionsActivation controls the activation of the kinematic capsule collider itself.

The rest of the implementation of MyNoClipState is just some very basic velocity handling in UpdateVelocity. In order to add a way of moving up and down vertically in NoClip mode, we also added “JumpHeld” and “CrouchHeld” inputs to the PlayerCharacterInputs struct

See how these things were implemented in MyPlayer and MyCharacterController

Try entering Play mode and pressing “Q” to enter NoClip mode. Move around with W ,S, A, D, SPACE, and C keys

Swimming state

Now we will implement a swimming state. Start by adding the “Swimming” state to the CharacterState enum

First we will handle transitions between the default movement state and the swimming state. This will be done in MyCharacterController. We will add a “SwimmingReferencePoint” transform variable to that class, which will represent the point that will trigger the transition to the swimming state when submerged in water. The detection of “being submerged” will be done in the “BeforeCharacterUpdate” callback. We will start with a “CharacterOverlap” test to detect if we are overlapping with any water trigger on the specified water layer. If we’ve found an overlapping trigger, we will use “Physics.ClosestPoint” to determine if our “SwimmingReferencePoint” is inside the trigger collider or not. If it is inside the trigger, we can transition to swimming state.

Look at the implementation of the swimming state transitions in MyCharacterController.BeforeCharacterUpdate

Next, we will implement the swimming state logic itself. The first thing to look at is the UpdateVelocity method. In it, we first have a smooth velocity interpolation that is very similar to the one we had in the NoClip mode. But after that, we do a test to see if this velocity would take our SwimmingReferencePoint out of the water on the next frame. If so, we find out what the water surface normal would be using Physics.ClosestPoint, and project our velocity on that plane. This will take care of sticking to the surface of the water even if you’re trying to move upwards out of it.

Look at the implementation of this in MyCharacterController.UpdateVelocity

Finally, we need to make sure the character doesn’t try to snap to the ground while swimming. For this, we will use KinematicCharacterMotor.SetStabilitySolvingActivation(). Setting this to false will skip all ground probing/snapping logic.

Look at OnStateEnter() and OnStateExit() in MyCharacterController

Now enter Play mode and go in the water to try it out

Climbing a ladder

Now we will implement the ability to climb ladders. The end result we'll be looking for is as follows:

- We have ladders in the world that have a start point and an end point, which we can define manually. These points will form a "ladder segment" (displayed in cyan color in scene view).
- When pressing a key (E), if the character is in range of a ladder, the character will "snap" to the ladder on the ladder segment. This will be our ladder climbing state.
- When in ladder climbing state, pressing W and S makes you move up and down the ladder segment
- Once you reach one of the extremities of the ladder segment, your character will automatically snap off of the ladder and return to its default movement state.

The ladder script

We will start by implementing the ladder script, which will serve two purposes: defining the ladder segment, and containing a method that calculates the closest point on a segment from another point. The character will later use the aforementioned method to know where it has to move to when it wants to snap to a ladder.

Take a look at the MyLadder script:

- LadderSegmentBottom and LadderSegmentLength are used to define the ladder segment
- BottomReleasePoint and TopReleasePoint are used to tell the character where to move to when it reaches an extremity of the ladder and needs to return to default movement mode
- ClosestPointOnLadderSegment is the method that calculates where the character must move to when it wants to snap to the ladder segment

Additionally, in the scene, you can find the ladder GameObjects and see that they have a trigger on them. We will use those triggers later for detecting ladders.

Implementing state transitions in MyCharacterController

After adding a "Climbing" state to the states enum in MyCharacterController, we will implement the transition to that state. This will be done in MyCharacterController.SetInputs, when a "ClimbLadder" input is detected. When ClimbLadder is true, we will first do an overlap test. If anything was found, and if the overlapped collider had a "MyLadder" component, we pass a reference to that ladder to our LadderClimbingState, and we will transition to that state. Additionally, if we were already in the climbing state, we will go back to our default movement mode.

Look at MyCharacterController.SetInputs() to see what happens when ClimbLadder is pressed

The ladder climbing state

MyLadderClimbingState itself has three sub-states: Anchoring, DeAnchoring, and Climbing. Anchoring and DeAnchoring are when the character is transitioning in and out of "snapping" to the ladder segment. In this example, this is done through a simple interpolation of the character's position and rotation, but in a real game this would normally be done with specific animations.

Let's take a look at OnStateEnter/OnstateExit first. Here we use KinematicCharacterMotor.SetCollisionSolvingActivation to disable the character's movement and collision solving code. This is because we don't want anything potentially making our character de-collide from the ladder or from the walls while it is climbing. The rest of OnStateEnter is simply caching the position and rotation that we want to snap to. We use the ClosestPointOnLadderSegment method of MyLadder for this.

Look at the implementation OnStateEnter and OnStateExit in MyLadderClimbingState

Next, let's look at UpdateVelocity. If we are climbing, we will set our velocity to a certain speed along the ladder's up direction, depending on if we press up (W), or down (S). When Anchoring or DeAnchoring, we will set a velocity that has the effect of interpolating our character's position from where it was originally to where it needs to go. We use KinematicCharacterMotor.GetVelocityForMovePosition here to make things easier for ourselves. This method returns the velocity required to move to the target position over the next character update frame.

Look at the implementation UpdateVelocity in MyLadderClimbingState

Next, we will look at UpdateRotation. If we are climbing, we will set our rotation directly to the ladder's. If we are anchoring or de-anchoring, we interpolate our rotation from original to target.

Look at the implementation UpdateRotation in MyLadderClimbingState

Finally, let's look at what we do in AfterCharacterUpdate. If we are climbing, we will keep checking if we have reached one of the extremities of the ladder, so that we can de-anchor from it (and therefore transition to the DeAnchoring state). We do this by using the second parameter of the "ClosestPointOnLadderSegment" method, which always returns 0 if we are within the bounds of the segment, and returns the distance from the closest extremity if we are out of bounds. If we are anchoring, we detect if the anchoring phase is finished so that we can transition to the Climbing state. If we are de-anchoring, we detect if the de-anchoring phase is finished so that we can transition back to the default movement state.

Look at the implementation AfterCharacterUpdate in MyLadderClimbingState

Now enter Play mode and try out some of the ladders in the scene.

Root motion example

Now we will demonstrate how to use animation root motion with this character controller. For the sake of simplicity and clarity, we've made new MyPlayer and MyCharacterController classes specifically for this section, which only handle basic root motion movement.

MyPlayer now only handles two input types for the character: moveAxisForward (W and S keys), and moveAxisRight (A and D keys).

Look at the new input handling in MyPlayer.HandleCharacterInput

First, let's see how we can gather information about root motion. There is an Animator component on the same GameObject as MyCharacterController, which means we can use the "OnAnimatorMove" callback of Monobehaviours. In OnAnimatorMove, we accumulate root motion position/rotation deltas every frame while we wait for the character update to process that motion. We need to do this because since the character update runs on a FixedUpdate, it's entirely possible that we'll get multiple OnAnimatorMove callbacks between two character updates.

Look at the implementation of OnAnimatorMove in MyCharacterController,
And see how they are only reset in AfterCharacterUpdate

The next important thing to notice in MyCharacterController is the handling of animation parameters in Update(). Here we smooth out input values and apply them to the "forward" and "turn" parameters of the Animator, which makes the character run.

Look at the animation handling in MyCharacterController.Update

At this point, we've implemented the requirements for a character that is animated with input and tracks root motion deltas. All we need to do now is to apply that root motion as a velocity. In UpdateVelocity, if we are grounded, we calculate the velocity from the root motion position delta, reorient it on the ground slope, and set "currentVelocity" to that. This takes care of moving with root motion. If we're not grounded, the movement handling is the same as in the previous sections. Note that it is extremely important that we translate the root motion to a velocity and apply it in UpdateVelocity. Otherwise, if we simply let the root motion move the transform directly, the character's movement solving code would not be taken into account.

Look at UpdateVelocity to see how root motion position is applied as a velocity.

Next, we handle root motion rotation in UpdateRotation. Here we simply rotate our current rotation by the root motion rotation delta.

Look at UpdateRotation to see how root motion rotation is applied

Now you can try out root motion movement in Play mode.

Frame Perfect rotation

Due to the interpolated FixedUpdate nature of the movement of the character, you may notice a certain delay in the character's rotation even if you give it no rotation smoothing at all. This can become a problem in several cases, such as in the context of a First Person Shooter where the gun (a child object of the character) needs to follow your camera perfectly.

Start by entering the scene in play mode, and look around with the camera. You should be able to clearly notice that the object representing the "gun" in your screen is lagging behind. Now, under the MyCharacterController component, activate "Frame Perfect Rotation" and try moving the camera again. You should see that the problem is solved. Let's see how this is done....

The general strategy is this: the character controller will keep rotating on FixedUpdate like it always had, but on top of that, we will also rotate the child transform of the character object that contains all the mesh on every frame. In other words; the physics representation of the character will keep rotating on FixedUpdate, but the visual/mesh part will now rotate on Update.

Look at how this was set up in MyCharacterController:

- We created a "PostInputUpdate" method, which is called on every frame after all inputs have been set. It sets the rotation of the "MeshRoot", which is the child transform of the character that contains all meshes
- We created a "HandleRotation" method that is used by both "PostInputUpdate" and "UpdateRotation" to make sure they both process rotation in the exact same way

And finally, look at the "Update" method in "MyPlayer". This is where we call "PostInputUpdate" after we're done applying all inputs.

Now press play and try to rotate your view around. Now try to change the activation of the "Frame Perfect Rotation" field in the inspector. When it is deactivated, you should notice the lag from interpolation.

Tips

Navmesh usage

In order to make a KCC use a navmesh:

- Bake a navmesh using agent parameters that fit your character's capsule radius, step height, etc….
- Calculate path queries using your Navmesh solution of choice
- Give your KCC a velocity that goes towards the next point on the navmesh path that was calculated. You are free to make this behaviour as simple or as complex as you want it to.

Networking

Kinematic Character Controller was made with an authoritative server networking architecture with lag-compensation and client-side prediction in mind. This means that it has the following characteristics:

- Simulation can be ticked manually

  This is done in **KinematicCharacterSystem**
  - Make sure to set KinematicCharacterSystem.AutoSimulation to false via script at runtime
  - Call KinematicCharacterSystem.Simulate(deltaTime) from your game code. This is what "Ticks" the character simulation

- Movement is close enough to determinism for client-side prediction (although you should not assume complete determinism over long periods of time)
- Character state can easily be saved and applied

  This is done in **KinematicCharacterMotor**
  - Call KinematicCharacterMotor.GetState() to get a struct containing all the necessary info about the current state
  - Call KinematicCharacterMotor.ApplyState() to apply an existing state instantly

- Input handling is left to you (not handled internally/automatically inside the character class)
- Default interpolation can be turned off in order to let you handle your specific network interpolation

  This is done in **KinematicCharacterSystem**
  - Set KinematicCharacterSystem.Interpolate to false via script at runtime

Specific details on implementing a good network architecture, or on implementing KCC into existing network architectures is outside of the scope of this project. However, here are some good learning resources on proper fast-paced game networking in genereal:

- "*Fast-Paced Multiplayer*", by Gabriel Gambetta (read all 4 parts of the series)
  http://www.gabrielgambetta.com/client-server-game-architecture.html
- "*The DOOM III Network Architecture*", by J.M.P. van Waveren
  http://mrelusive.com/publications/papers/The-DOOM-III-Network-Architecture.pdf
- "Source Multiplayer Networking", by Valve
  https://developer.valvesoftware.com/wiki/Source_Multiplayer_Networking
- "*Making Fast-Paced Multiplayer Networked Games is Hard*", by Mark Mennell
  https://www.gamasutra.com/blogs/MarkMennell/20140929/226628/Making_FastPaced_Multiplayer_Networked_Games_is_Hard.php
- "*Snapshot Interpolation*", by Glenn Fielder (most of his other articles are very pertinent too, but just this one will do for now)
  https://gafferongames.com/post/snapshot_interpolation/