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Behavior Networks Designer

Behavior Networks Designer is a Unity plugin designed to facilitate the creation of smart interactive characters. Behavior Networks Designer is a tool to create Behavior Networks with a simple user interface carefully thought to simplify the design of behavioral artificial intelligence by non-technical enthousiasts. This document is organized as follows:

Contents

1. Overview

1.1. Introduction

In videogames, Artificial Intelligence (AI) is often created with Behavior Trees, a simple yet robust method to create characters with simple rules, such as the ones needed in first person shooters. Several implementations are available in Unity, some of them remarkably easy to use.

Behavior Networks are an alternative method to solve the same technical problem that Behavior Trees addresses. Arguably, it is a more powerful method, particularly in dynamic and fast-changing environments, which require more reactive and sophisticated behavior.

Behavior Networks are also more intuitive to design. Behavior Networks work by defining Skills and Goals in the interactive character. A goal has a syntax like:

When **x** I want **z**

A Skill is defined in a syntax like:

If **x** and **y** doing **a** has effect **z**

Both for goals and skills, **x**, **y** and **z** are Perceptions that can be quantified by a function returning a value between 0 and 1. Possible examples of Perceptions can be "I am near a fridge", "I have the thermometer", "I do not have ammo", "She is smiling", etc. In addition, in Skills, **a** is an action, which can be performed with a certain intensity, also between 0 and 1.

Decisions In Behavior Networks are taken through an energy spreading mechanism: a certain skill will perform a certain action if its effect is expected to contribute to a goal. Skills also self-organize according to preconditions (in the previous example, **x** and **y**) and its effects (in the previous example, **z**). For example, if character A wants to kill character B, but it needs a gun to do so, a skill such as "pick the gun" will receive a lot of energy. Later on, once the gun is obtained, then the energy will move to a skill such as "shoot at character B", now more likely to contribute to achieve the goal.

1.2. User Interface

Behavior Networks Designer includes a dedicated user interface, which we have designed to:

1. allow non-technical users to create their own skills and goals, and
2. to visualize during game playout the evolution of the character and the Behavior Network

Using this interface, the AI designer can define the relations between Perceptions and Goals by dragging and dropping. During playout, the AI designer can see how the changes in the perception values affect the relevance of a given goal, or affect whether a given action can be performed. For example, in figure 1, a simple diagram corresponding to "When: not Perception0 and Perception1 I want: Perception0 " is shown. The black and gray rectangles show the extent at which a certain perception is true: in this case, Perception0 is true at 83%, and Perception1 is true at 54%. The green and red lines show the relation between the Goal and the Perceptions. The Goal, shown as a blue box, has a Relevance value corresponding to the smallest condition satisfied (in this case, the negation of Perception0, which is true at 17%). During playout, the evolution of the Perception values will in turn affect the Relevance of that particular Goal.

The Relevance of a given Goal will evolve in real time depending on the different Perceptions. In their turn, Perceptions can be defined through dropdown menus, from a set of simple functions that return a value between 0 and 1, and which can also be customized by the end-user (see figure 2). Skills and Actions are defined in a similar way to Goals and Perceptions.

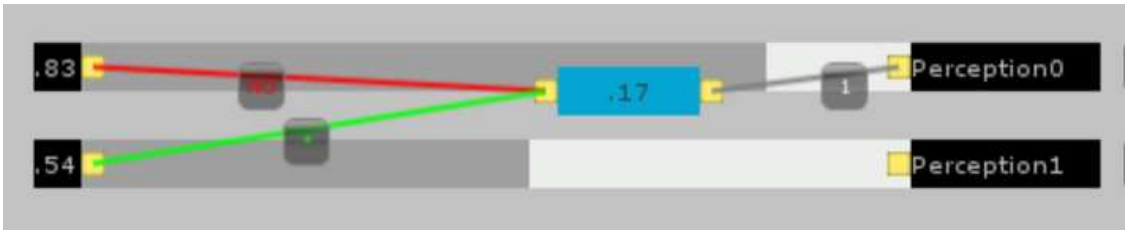


Figure 1: a simple user interface allows visualizing the real time evolution of perceptions and goals during playout

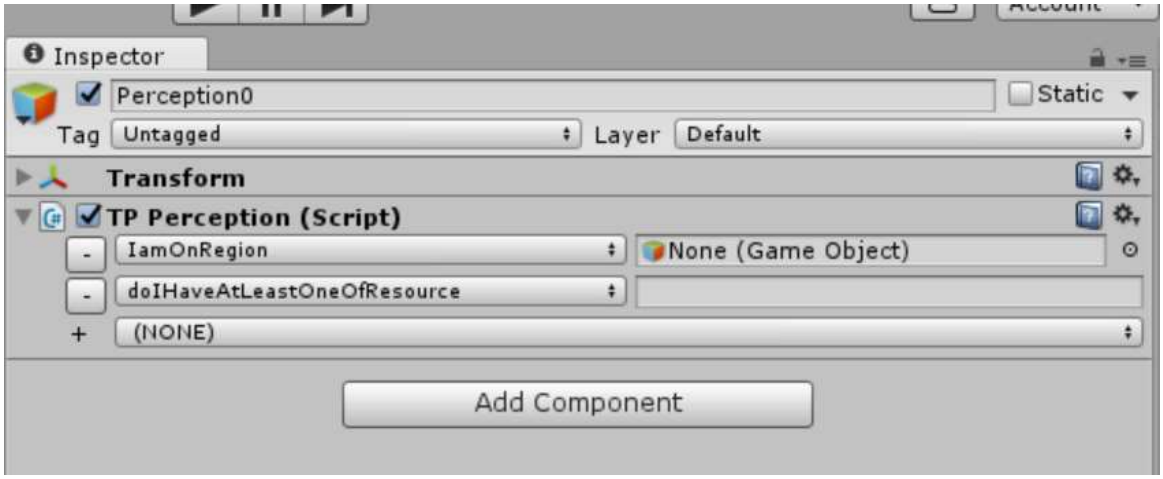


Figure 2: through the Unity Inspector, perceptions can be defined easily from a list of pre-defined and customizable functions.

1.3. Animation Synthesis

Behavior Networks provide a modular way to design smart interactive behavior, based on Goals and Skills. To facilitate this task, this package also includes an innovative method to blend different animations together embodied in a wonderful LGPL library whose online repository is https://github.com/storiesinvr/ADAPT . This library integrates several character animation techniques to create sophisticated behavior, and it is easily extendable. Timepath is and will remain eternally grateful to Alejandro Beacco for pointing out the existence of this library and to Alexander Shoulson and any other relevant contributor for creating this piece of software and sharing it with the world.

The integration of Behavior Networks Designer with Mecanim is also possible.

1.4. Customization and extension

Using this package, Behavior Networks can be defined as prefabs, stored, shared and modified like any other Unity asset. Perceptions and Actions provided can easily be customized selecting built-in functions directly from the Inspector Panel. New Perception and Action functions can also be created through small chunks of code leveraging the power of the Unity3D API. Behavior Networks Designer uses a runtime library compiled for Windows. Version for Android, Mac, Linux, iOS and WebGL will follow, hopefully soon.

1.5. Further information

For further information on how to use Behavior Networks Designer, please go through the Tutorial and the Quick Start Guide sections that follow. The troubleshooting section, at the end, provides a basic list of solutions to practical problems often found when using Behavior Networks Designer.

2. A Tutorial for Behavior Networks Designer

In this section we will follow a progressive, step-by-step approach to the creation of characters which use Behavior Networks to make decisions. The aim is to get you, user of the Unity3D package Behavior Networks Designer, with an acquaintance of the possibilities it offers, and to allow you to use it for your own projects.

Creating characters with interactive behavior requires several additional tasks and decisions to make, before and after each of these steps. However, once you are familiarized with the context of use, the 5 main steps (from a) to e)) are all you need to remember, and which are summarized in section 3. Quick Reference.

If you were to find major difficulties using this package once gone through this tutorial, please check the troubleshooting section and, if this still does not solve your problem, send a precise email, if necessary with the necessary prefabs and code chunks, to support@timepath.io

2.1. Choosing an Animation Controller

To use an artificial intelligence (AI) library effectively –for example, this Behavior Network Designer—requires having an animation controller that can render the actions chosen by the AI. In this tutorial we will use two examples of animation controllers.

The first animation controller will be based on Adapt, a brilliant library for animation control created by Alexander Shoulson (among others) and which is also included in the Behavior Networks Designer in the form of a compiled library. The source code for Adapt is freely available, and it is designed to be easily expandable by the end-user.

The second, Mecanim, is the default's animation controller in Unity3D, and to allow the end-user to rapidly test its use we have integrated some assets from a project tutorial demonstrated by Unity3D at GDC 2013, and freely available at the asset store (https://www.assetstore.unity3d.com/en/#!/content/9896).

2.2. Creating your characters and animation assets

This is the most time consuming part of game creation, the one that requires patient hand-crafted work, artistic skills and a touch of inspiration. We will not address it here.

Please find 2 prefabs in the folder Assets > Prefabs, one called *adapt_body*, and a second called *mecanim_body*. Each of these already contains a rigged character linked to some animations, and some simple behavior scripts. They are each adapted from reference tutorial projects (to further explore these, see links at the end of this tutorial).

These 2 prefabs are already loaded within the starting scene of this tutorial, inside the folder *Assets* > *TutorialScenes*. The scene is called *Tutorial_ready2start.unity.* Once you have opened this scene, we are ready to start creating your first personality.

2.3. Creating a Behavior Network

In this section, we will create a simple autonomous character that picks balls. The use of Behavior Networks Designer involves 5 steps, which are summarized below from a) to e). To use this tool effectively, these are the 5 steps you will need to remember.

a) Create a Personality and the Agent that will use it

The Personality of a character is a set of elements that define its behavior. It is essentially a list of Perceptions, Goals and Skills that, by being related between them, allow the character to make decisions that are appropriate for a given situation. In Behavior Networks, the most demanding task is defining the Skills, which link the personality with the animation controller. However, once the Skills are defined, simple changes in the goals of the character allow for very different behavior patterns, thus favoring recycling of Skills for different purposes.

To create a new personality, go to Assets > Create > Timepath Personality

This will create an empty game object with a TPPersonality component. Before we explain how to define Perceptions, Goals and Skills within this personality, lets see a personality at work.

For this, you will need a personality example. In the folder *timepath4unity > Prefabs* you will find a personality prefab called meteorite_picker. Just dragging it in the scene will instantiate it.

You will also need to create at least one Agent. An Agent is a character which makes autonomous decisions. In this context, this means it has a Personality, and a Body, i.e., a 3D rigged character with an Animation Controller (or an ADAPT Body). To create a new Agent, go to Assets > Create > Timepath Agent. This will create an empty game object with 2 components: a TPMentalBag, which you can ignore for a while, and a TPAgent, which should be the focus of your attention. In the component TPAgent, select the personality that you want that Agent to have. In this case, it should be the personality you just created, meteorite_picker. You also need to select the body you want the agent to have. For this first example, select the gameObject called bodyADAPT, and which is part of the scene hierarchy.

If you want the agent to move along with the body, drag and drop to become part of the hierarchy in the bodyADAPT gameObject. You can now press play and, if everything went fine, your first interactive character should be going to pick some meteorites to bring them all together.

By selecting the Timepath Agent that is walking around in the scene, it is possible to visualize its inspector, where the different perceptions, goals and skills of the character should evolve dynamically with its behavior.

A word of caution is worth taking here: please notice that in Behavior Networks Designer one personality is like a template: at execution time a copy of it will be loaded in the agent. This means that one Personality can be used by several agents independently. However, the body is used immediately, without being copied. Therefore, 2 agents will need to have 2 different bodies in the hierarchy, while only 1 personality may be needed if we want both to have the same interactive behavior.

We can now stop the game execution and take a closer look at a personality, and how to create, copy, store or destroy its building blocks.

b) Create Perceptions, Goals and Skills (or destroy them)

Once we have defined a Personality, we need to create Perceptions, Goals and Skills for it. Select the TPPersonality created. In the Inspector panel:

- To create a Perception, click on the black square with the “+” sign on either side of the Inspector.
- To create a Goal, click on the blue square with the “+” sign.
- To create a Skill, click on the yellow square with the “+” sign.

Creating 2 perceptions, one goal and 2 skills should look closely to Figure 3

- To destroy a Perception, click on the “-” button at the right of its name.
- To destroy a Goal, double click on the corresponding blue rectangle with a number.
- To destroy a Skill, double click on the corresponding yellow rectangle with a name.

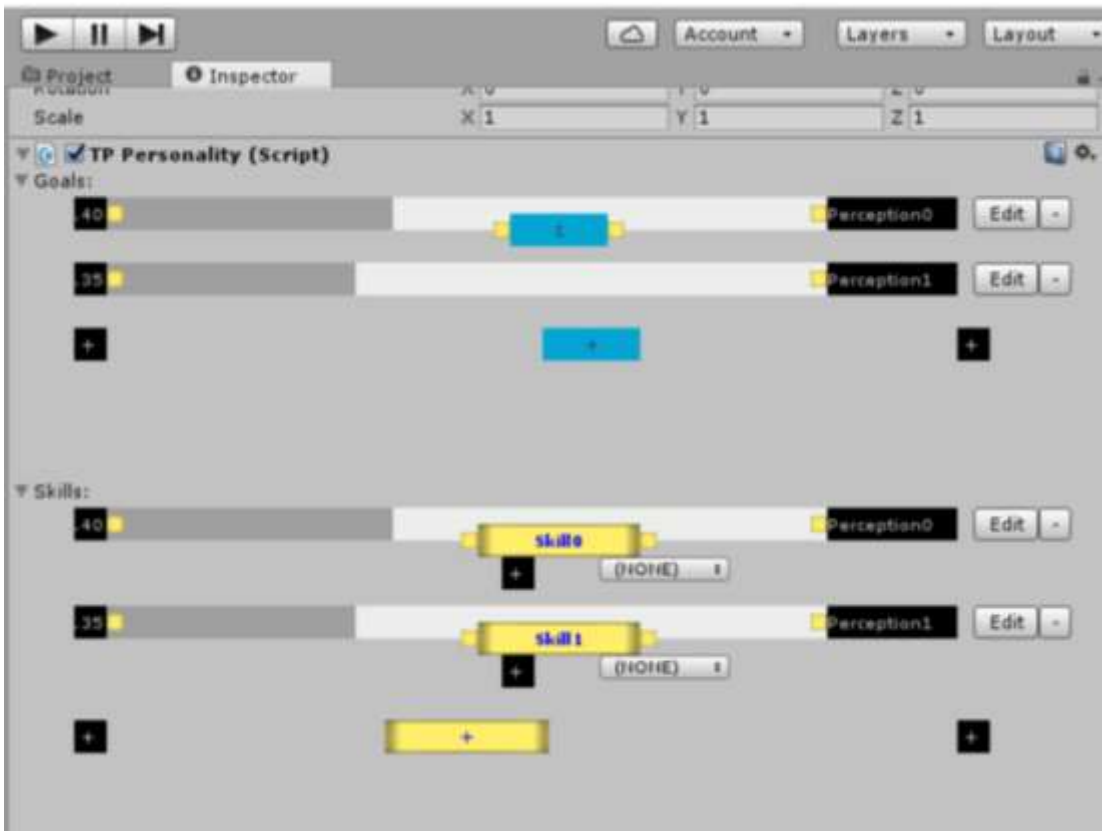


Figure 3 A personality with 2 perceptions, 1 goal and 2 skills

Now you know how to create and destroy perceptions, goals and skills, but you do not know how to use them

c) Define the Perceptions

To define a perception in a personality, click on the corresponding black square with a number (on the left), or on the corresponding "Edit" button next to its name (see Figure 3). This will take you to the appropriate game object in your personality. Once there, in the Inspector, an editable menu like in Figure 2 will appear, perceptions can be defined from a simple dropdown callback menu.

The perceptions that appear in the editor are defined as methods in the class TPPerception, whose source code is included in the package at the folder:

Assets > timepath4unity > TPPerception.cs

A Perception is any method of the class TPPerception which does not take more than one input parameter (a tag, a game object, another element) and which changes the double "value" with a quantity that is between 0 and 1. Combinations of methods can also be selected in the dropdown menu. Several examples are provided in the class TPPerception and in the personality prefab called "meteorite_picker".

These perception methods are fairly easy to define by a computer scientist, but do not hesitate asking a colleague with further programming experience to help you if you do not understand what is required.

d) Define the Goals

The Goals can be very simply defined by connecting the yellow nodes next to the blue boxes with the yellow nodes next to the black boxes (see Figure 1). The logical relation between a Perception and a Goal can be changed by clicking on the small box in the middle of the lines.

In the case of Relevance Conditions, at the right of the blue box, the lines will show either a green "*" when affirmative or a red "NOT" when negated. The number in the blue box will show the relevance values resulting from combining these Perceptions.

In the case of Goal Conditions, at the left of the blue box, the lines will always show a number, but clicking on them will also allow negating the perception corresponding to the goal condition.

The result will correspond to a simple goal definition. For example, in figure 1, the goal defined corresponds to:

```
When:
       not Perception0 and Perception1
I want:
       Perception0  0.89
```

The reason to define these elements visually instead of doing it through direct textual rule writing is twofold:

1. It makes sure the formal syntax required is always preserved, and
2. It makes sure the user understands the visual layout. Indeed, at execution time, when the personality is embodied inside an agent, this visual layout will show how the changes in the perceptions will change the relevance value of the goal in real time, thus helping to debug the overall personality.

Finally, clicking on the blue box will select the game object, corresponding to that goal, and the inspector panel will show the rule created as well as manually allow adjusting the importance of the goal (the small number shown in the Personality Inspector, in the Goal Condition, as shown in Figure 1). This allows defining completely a Goal in a Simple Behavior Network.

e) Define the Skills and the Actions

The definition of the Skills and the Actions is the most difficult part of using Simple Behavior Networks. It involves 3 steps:

1. First, you need to state the logical relations with existing Perceptions, in a way similar to how we did it with Goals. For example, connecting a skill called “pickM” in the same way than the previou goals will generate a structure that corresponds to:

```
If:
       Not Perception0 and Perception1
doing:
       pickM
has effect:
       Perception0 0.89
```

2. The second step to define a Skill corresponds to defining its associated Action, which is done in a similar way than Perceptions, but this time using methods defined in the class TPAction, which can be found in the folder:

   Assets > timepath4unity > TPAction.cs

A method defined in TPAction can be any kind of method that has 1 input field, or combinations of them. The example provided uses the wonderful LGPL library for character animation the source code of which can be found at https://github.com/storiesinvr/ADAPT , and which integrates several character animation techniques to easily create sophisticated behavior. The tutorial to learn its ins and outs is also included in the package.

Alternatively, the freedom to call any class or method within a TPAction method implies that any other animation system can be used, and we wish different users are able to integrate this tool easily with their preferred animation frameworks (please let us know!).

For Mecanim enthousiasts, Timepath can also provide Inspector editable menus to rapidly prototype Simple Behavior Networks using the API that allows changing Mecanim state machines.

3. The third step to define a skill is the likeliness of the effects. For this, click on the corresponding Skill, unfold its corresponding game object. A small hierarchical structure will appear with the following items:

```
1.      When:
2.      DoAction:
3.      Effects:
4.      Using:
```

Under “3.Effects”, the effects created will also have an “effect likeliness” that will be editable, to adjust how likely performing a certain action under certain conditions is likely to have a desired effect.

Depending on your editor settings, the numbered list of items in a Skill might appear disorganized, with item “2. DoAction:” appearing higher than “1.When:” . To correct for this fact, turn on Alphabetical sorting (see Troubleshooting section).

2.4. Extensions with novel Action and Perception Methods

The way novel actions and perceptions are defined is fairly simple in Behavior Networks Designer, it is enough to create a static method within the classes TPPerception or TPAction. These classes can be found in the folder Assets > timepath4unity. To introduce extensions, the programmer only needs to consider a very simple API, common to both the TPPerception and the TPAction classes:

.Me	The TPAgent corresponding to that character
.MyBody (or Me.MyBody)	The GameObject, possibly with a Body component from adapt, or an animation controller from mecanim
.MentalBag	A class that can be defined ad hoc for characters to remember items.

In addition, it is also possible to interact with a given resource with the method:

```
Me.MyPerso.GetResourceByName
```

3. A Tutorial for ADAPT

We now introduce a tutorial of ADAPT. This tutorial is adapted from the original tutorial by Alexander Shoulson. For more information about the underlying mechanics of ADAPT, refer to the links and information on: https://github.com/storiesinvr/ADAPT

Note that these tutorials were written for Unity 3.5, but it has been tested to work up to Unity 5.2. Your screen might differ slightly from the interface screenshots. In addition, this tutorial excludes the use of Parameterized Behavior Trees, which is a part that cannot be easily integrated with Behavior Networks. The tutorial starts from the simplest controller for procedural animation, up to the Body interface, which integrates all the different controllers, and is generally the class used to interface with the behavior networks designer.

3.1. Procedural Animation Blending with Shadows

We will begin by creating a simple character controller and learning how to blend it with one of the included ADAPT shadow controllers. The empty template for this tutorial can be found in the scene `Tutorial1Empty`. Open this file, which begins with a plain scene and nearly empty ADAPTMan character (aside from an animation component).

Creating a "Lean" Controller

Let's create a simple controller that can make the character lean forward or backward. Create a new Unity MonoBehavior called "LeanController". The empty code template should look like this (with some minor formatting differences):

```
using UnityEngine;
using System.Collections;

public class LeanController : MonoBehaviour
{
	// Use this for initialization
	void Start ()
	{

	}

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

	}
}
```

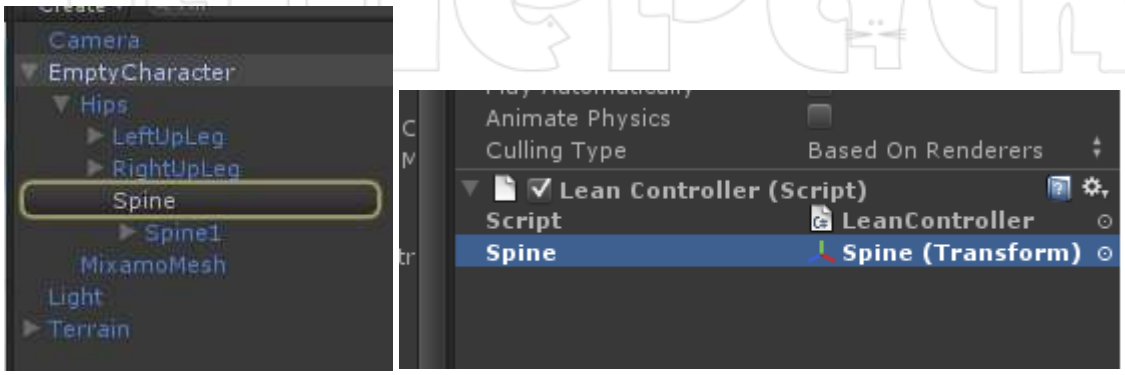
Let's add a parameter called "spine", which will tell the controller where we want the character to bend when we lean forward or backward. We'll assign a value to this field in the inspector in a little bit.

```
public class LeanController : MonoBehaviour
{
	public Transform spine;

	// Use this for initialization
	void Start ()
	{

	}

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

	}
}
```

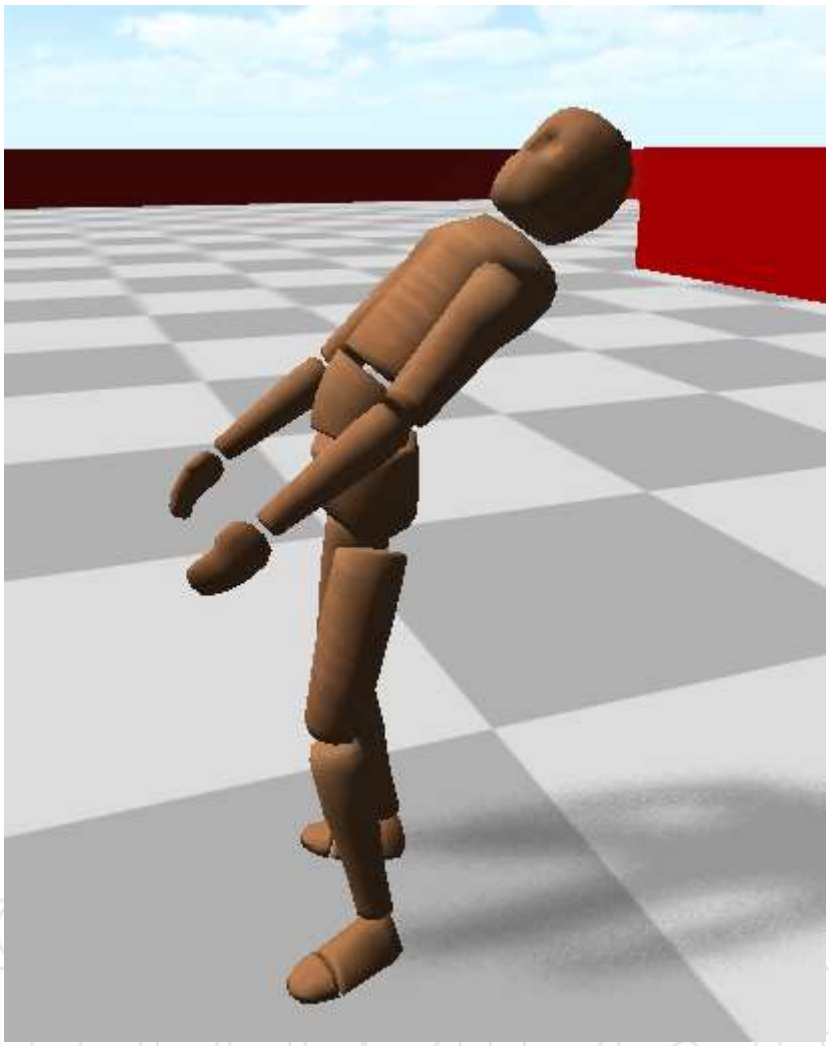
Next, in the update function, we want to rotate that spine bone. We'll use "R" to lean backwards, and "F" to lean forwards. All we're doing is rotating the spine bone along its local x axis when we press either one of these keys.

```
public class LeanController : MonoBehaviour
{

	public Transform spine;

	// Use this for initialization
	void Start ()
	{

	}

	void Update ()
	{
		// Get the current euler angle rotation
		Vector3 rot = spine.rotation.eulerAngles;

		// Detect key input and add or subtract from the x rotation (scaling
		// by deltaTime to make this speed independent from the frame rate)
		if (Input.GetKey(KeyCode.R))
			rot.x -= Time.deltaTime * 50.0f;
		if (Input.GetKey(KeyCode.F))
			rot.x += Time.deltaTime * 50.0f;

		// Apply the new rotation
		spine.rotation = Quaternion.Euler(rot);
	}
}
```

Attach this LeanController script to the EmptyCharacter game object, and drag the "Spine" bone to the spine parameter in the inspector.



Now run the simulation. You can control the camera with the WASD keys, and look around by holding down the right mouse button. Try pressing the R and F keys to make the character lean. (If you'd like, try imposing a maximum and minimum angle for how far the character can lean, but keep in mind that angles wrap around from 359 degrees to zero!)



Making the Controller Work with ADAPT

Now we have a basic character controller in Unity, but this controller currently has nothing to do with ADAPT. We're going to convert it so it can work with the ADAPT system. We need to change a few lines of code:

```
public class LeanController : MonoBehaviour
```

becomes:

```
public class ShadowLeanController : ShadowController
```

```
void Start()
```

becomes:

```
public override void ControlledStart()
```

```
void Update()
```

becomes:

```
public override void ControlledUpdate()
```

Also, change the filename from "LeanController" to "ShadowLeanController".

We're changing the name and inheritance of the class. We're also changing the Start and Update functions from the default functions that Unity automatically calls, to special functions that we will call manually ourselves instead within ADAPT. So our class looks like this:

```
public class ShadowLeanController : ShadowController
{
```

```
    public Transform spine;

    public override void ControlledStart()
    {

    }

    public override void ControlledUpdate()
    {
        // Get the current euler angle rotation
        Vector3 rot = spine.rotation.eulerAngles;

        // Detect key input and add or subtract from the x rotation (scaling
        // by deltaTime to make this speed independent from the frame rate)
        if (Input.GetKey(KeyCode.R))
            rot.x -= Time.deltaTime * 50.0f;
        if (Input.GetKey(KeyCode.F))
            rot.x += Time.deltaTime * 50.0f;

        // Apply the new rotation
        spine.rotation = Quaternion.Euler(rot);
    }
}
```

We need to do one more thing. Remember that `spine` variable we were given in the inspector? Now, a `ShadowController` is given its own shadow to manipulate instead of editing the bones in the displayed character model. When we give the `spine` bone to this component in the inspector, we're tying the component to a bone in the display model, which we don't want to change directly. Instead, we want to edit the corresponding bone in our shadow. So as soon as we start, we need to take the bone we're given from the display model, and find the corresponding bone in the shadow that's been automatically generated for our `ShadowLeanController` to edit. (You can access that shadow using either the `shadow` or `transform` fields inherited from `ShadowController`. Both of them point to the same thing.) We're going to add this line to our `ControlledStart` function to do that remapping:

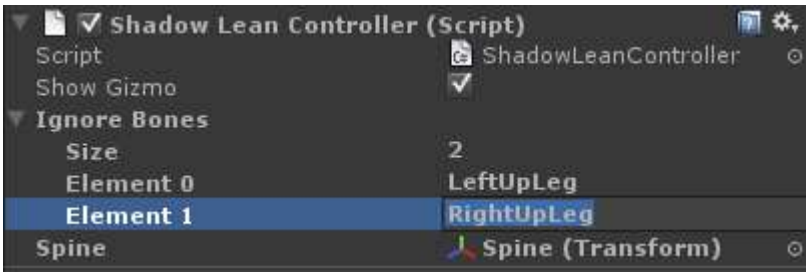
```
    public override void ControlledStart()
    {
        // Find the cloned version of the bone we were given in the inspector
        // so that we're editing our own shadow, not the display model
        this.spine = this.shadow.GetBone(this.spine);
    }
```

This line tells our shadow to find the bone that was cloned to correspond the given bone in the display model. We overwrite our spine transform variable so that we'll only ever edit the cloned spine bone instead of the original. Our final class looks like this:

```
using UnityEngine;
using System.Collections;

public class ShadowLeanController : ShadowController
{
    public Transform spine;

    public override void ControlledStart()
    {
        // Find the cloned version of the bone we were given in the inspector
        // so that we're editing our own shadow, not the display model
        this.spine = this.shadow.GetBone(this.spine);
    }

    public override void ControlledUpdate()
    {
        // Get the current euler angle rotation
        Vector3 rot = spine.rotation.eulerAngles;
```

```
        // Detect key input and add or subtract from the x rotation (scaling
        // by deltaTime to make this speed independent from the frame rate)
        if (Input.GetKey(KeyCode.R))
            rot.x -= Time.deltaTime * 50.0f;
        if (Input.GetKey(KeyCode.F))
            rot.x += Time.deltaTime * 50.0f;

        // Apply the new rotation
        spine.rotation = Quaternion.Euler(rot);
    }
}
```

Replace the `LeanController` with the `ShadowLeanController` on the character model and make sure it has a reference to the Spine bone like before. Also, we want to tell the class that this controller only affects the upper body, and to not clone the legs for the shadow. We can set this in the inspector:



Every `ShadowController` has its own Ignore Bones array, so add the names `LeftUpLeg` and `RightUpLeg`. This tells ADAPT not to clone the left leg or right leg bones (and their children) when it's creating the shadow for this `ShadowLeanController`. Since we won't ever write to the legs (we're only changing one spine bone), it's more efficient to make the skeleton as reduced as possible. We could cut off more bones and save even more space, but this is enough for now.
If we run the simulation now, the character won't do anything. This is because nothing is calling the `ControlledUpdate` function, and nothing is applying the skeleton from the shadow to the display model. In order to fix that, we need to create a Coordinator. Let's start with a simple empty class that inherits from `ShadowCoordinator`:

```
using UnityEngine;
using System.Collections;

public class TutorialCoordinator : ShadowCoordinator
{
    void Start()
    {

    }

    void Update()
    {

    }
}
```

Note that we're using the default `Start` and `Update` functions here because we want Unity to automatically update this class, and then this class will update each of the controllers. Now, the `ShadowCoordinator` class has a few built-in functions that we need to call at certain points. First, the `ControlledStartAll()` function automatically calls the `ControlledStart()` function of every attached `ShadowController`. You want to make sure to call this function at the end of your coordinator's `Start()` function. Additionally, the function `UpdateCoordinates()` moves the root coordinates (the hips) of each shadow to match that of the display model. This ensures that the shadows and the display model are all in the same place in the world. You usually want

to make sure to call this in the beginning of your coordinator's `Update()` function. Here's the class with the recommended default function calls.

```
public class TutorialCoordinator : ShadowCoordinator
{
    void Start()
    {
        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        // Move the root position of each shadow to match the display model
        this.UpdateCoordinates();
    }
}
```

Now we need two member fields in our class. The first is a reference to the ShadowLeanController, which we'll set automatically in the Start() function. The second is a ShadowTransform buffer. This is used for storing the position of each bone in a shadow, so we can pass shadow information between ShadowControllers and apply shadows to the display model. We could make new buffers to store these transforms on the fly when we need them, but it's more efficient to pre-allocate the memory for a buffer and just overwrite it each frame.

```
public class TutorialCoordinator : ShadowCoordinator
{
    protected ShadowTransform[] buffer1 = null;
    protected ShadowLeanController lean = null;

    void Start()
    {
        // Allocate space for a buffer for storing and passing shadow poses
        this.buffer1 = this.NewTransformArray();

        // Get a reference to our lean ShadowController
        this.lean = this.GetComponent<ShadowLeanController>();

        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        // Move the root position of each shadow to match the display model
        this.UpdateCoordinates();
    }
}
```

Now, let's set this coordinator up to update the `ShadowLeanController` and apply the shadow it generates to the display model. We're going to add the following two lines to the `Update()` function under the `UpdateCoordinates()` call:

```
        this.lean.ControlledUpdate();
        this.lean.Encode(this.buffer1);
```

These lines will update the lean controller and write the pose for the shadow into the buffer. Then we need to apply this written pose to the display model. We can do that with this function call:

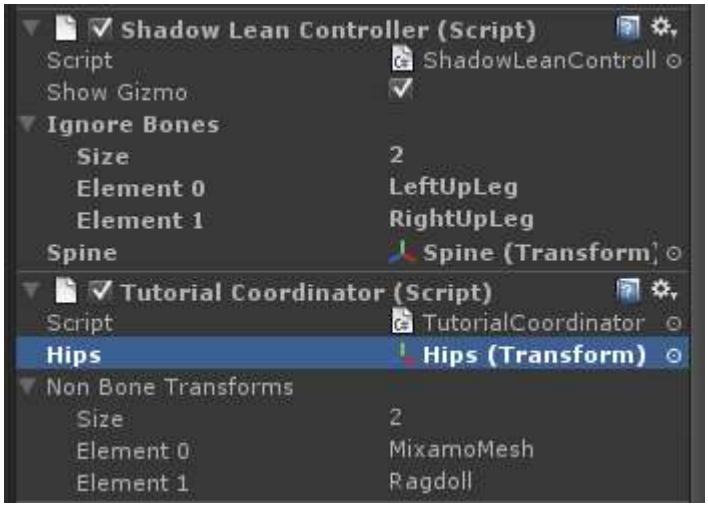
```
        Shadow.ReadShadowData(
```

```
            this.buffer1,
            this.transform.GetChild(0),
            this);
```

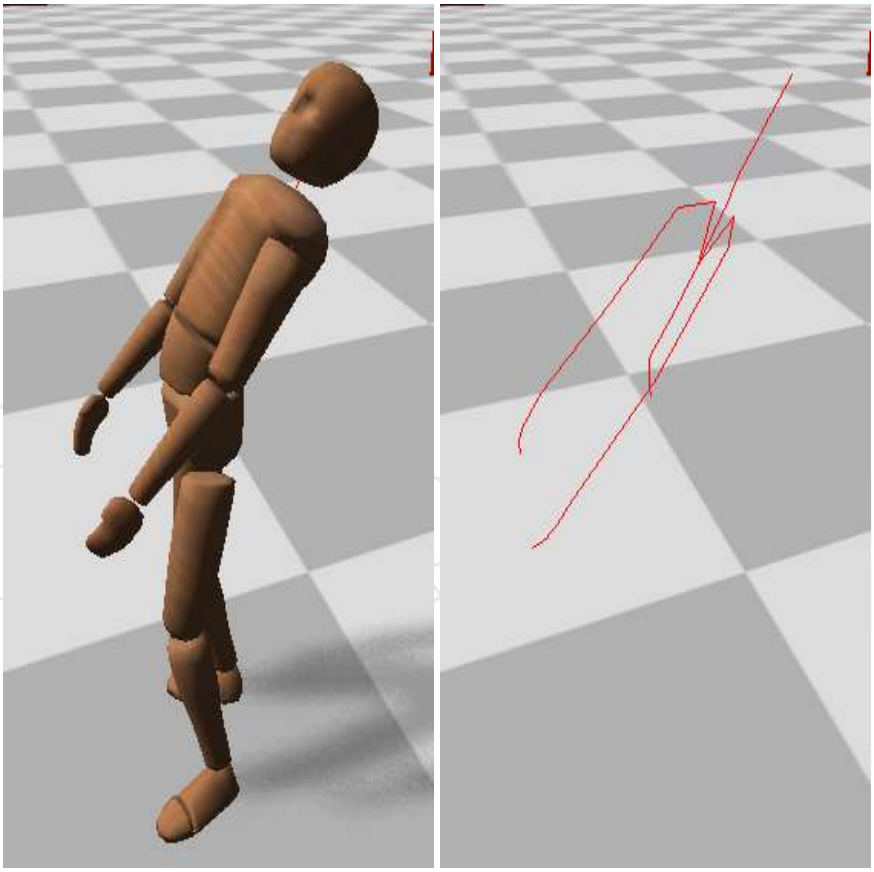
This writes the buffer to the skeleton of the display model, starting at the hips (from `transform.GetChild(0)`). So the final class should look like this:

```
public class TutorialCoordinator : ShadowCoordinator
{
    protected ShadowTransform[] buffer1 = null;
    protected ShadowLeanController lean = null;

    void Start()
    {
        // Allocate space for a buffer for storing and passing shadow poses
        this.buffer1 = this.NewTransformArray();

        // Get a reference to our lean ShadowController
        this.lean = this.GetComponent<ShadowLeanController>();

        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        // Move the root position of each shadow to match the display model
        this.UpdateCoordinates();

        // Update the lean controller and write its shadow into the buffer
        this.lean.ControlledUpdate();
        this.lean.Encode(this.buffer1);

        // Write the shadow buffer to the display model, starting at the hips
        Shadow.ReadShadowData(
            this.buffer1,
            this.transform.GetChild(0),
            this);
    }
}
```

Make sure both this coordinator and the `ShadowLeanController` are attached to the character, and give the coordinator a reference to the character's hips. Then run the simulation.

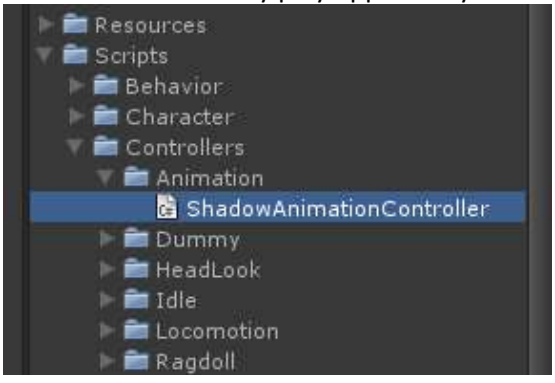


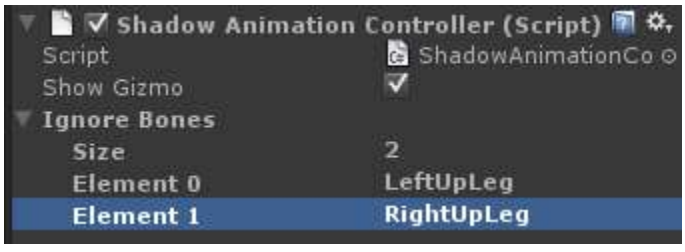
We should be able to lean the character again with R and F. If you enable Gizmos, and press E, you should be able to see the skeleton of the underlying shadow for the lean controller as well.



Adding a Second Controller

Now let's blend this controller with another controller from the ADAPT library. Add a `ShadowAnimationController` to the character. You can find it under `Scripts/Controllers/Animation`. Add `LeftUpLeg` and `RightUpLeg` to the Ignore Bones array like before so that we only play upper body animations.





Add a reference to the animation controller in the tutorial coordinator we've been writing.

```
public class TutorialCoordinator : ShadowCoordinator
{
    protected ShadowTransform[] buffer1 = null;
    protected ShadowLeanController lean = null;
    protected ShadowAnimationController anim = null;

    void Start()
    {
        // Allocate space for a buffer for storing and passing shadow poses
        this.buffer1 = this.NewTransformArray();

        // Get a reference to our lean ShadowController
        this.lean = this.GetComponent<ShadowLeanController>();

        // Get a reference to our animation ShadowController
        this.anim = this.GetComponent<ShadowAnimationController>();

        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        ...
    }
}
```

We also have to update the animation controller and encode its shadow to a second buffer. We'll add that second buffer and perform the update and encode steps like we did for the lean controller. Our class should now look like this:

```
public class TutorialCoordinator : ShadowCoordinator
{
    protected ShadowTransform[] buffer1 = null;
    protected ShadowTransform[] buffer2 = null;
    protected ShadowLeanController lean = null;
    protected ShadowAnimationController anim = null;

    void Start()
    {
        // Allocate space for two buffers for storing and passing shadow poses
        this.buffer1 = this.NewTransformArray();
        this.buffer2 = this.NewTransformArray();

        // Get a reference to our lean ShadowController
        this.lean = this.GetComponent<ShadowLeanController>();

        // Get a reference to our animation ShadowController
        this.anim = this.GetComponent<ShadowAnimationController>();

        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        // Move the root position of each shadow to match the display model
```

```
        this.UpdateCoordinates();

        // Update the lean controller and write its shadow into the buffer
        this.lean.ControlledUpdate();
        this.lean.Encode(this.buffer1);

        // Update the anim controller and write its shadow into the buffer
        this.anim.ControlledUpdate();
        this.anim.Encode(this.buffer2);

        // Write the shadow buffer to the display model, starting at the hips
        Shadow.ReadShadowData(
            this.buffer1,
            this.transform.GetChild(0),
            this);
    }
}
```

Blending Between Two Controllers

Note that we're not actually using that buffer yet. Now we want to be able to blend between the animation controller and our lean controller. First, let's discuss exactly what's happening here. At the beginning of the simulation, the animation controller and lean controller are both given their own clone of the display model's skeleton (we've removed the legs of both so these skeletons are just of the upper body). We need to make sure to manually update each of these ShadowControllers, then we want to extract their shadow skeletons' poses and blend them together. Once we've merged the skeletons, we want to apply the new merged skeleton to the display model so it takes on the combined pose. When we blend, we assign a weight to each skeleton we're blending. The higher the weight (in proportion to every other weight), the more the final skeleton will resemble that given input pose.

Let's start by adding the value we will use for the blend weight. This will be one float value that we'll just interpolate between 0.01 and 0.99. We'll also add code in our Update function to raise and lower this value with Y and H. Here's what our class looks like:

```
public class TutorialCoordinator : ShadowCoordinator
{
    protected ShadowTransform[] buffer1 = null;
    protected ShadowTransform[] buffer2 = null;
    protected ShadowLeanController lean = null;
    protected ShadowAnimationController anim = null;
    protected float weight;

    void Start()
    {
        // Allocate space for two buffers for storing and passing shadow poses
        this.buffer1 = this.NewTransformArray();
        this.buffer2 = this.NewTransformArray();

        // Get a reference to our lean ShadowController
        this.lean = this.GetComponent<ShadowLeanController>();

        // Get a reference to our animation ShadowController
        this.anim = this.GetComponent<ShadowAnimationController>();

        // Set the weight
        this.weight = 0.99f;

        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        // Move the root position of each shadow to match the display model
        this.UpdateCoordinates();
```

```
        // Update the lean controller and write its shadow into the buffer
        this.lean.ControlledUpdate();
        this.lean.Encode(this.buffer1);

        // Update the anim controller and write its shadow into the buffer
        this.anim.ControlledUpdate();
        this.anim.Encode(this.buffer2);

        // Control the weight with the Y and H keys
        if (Input.GetKey(KeyCode.Y) == true)
            this.weight += 2.0f * Time.deltaTime;
        if (Input.GetKey(KeyCode.H) == true)
            this.weight -= 2.0f * Time.deltaTime;
        this.weight = Mathf.Clamp(this.weight, 0.01f, 0.99f);

        // Write the shadow buffer to the display model, starting at the hips
        Shadow.ReadShadowData(
            this.buffer1,
            this.transform.GetChild(0),
            this);
    }
}
```

Now to do the actual blend. This sounds complicated, but is only one function call. Add this right above the `Shadow.ReadShadowData()` function call:

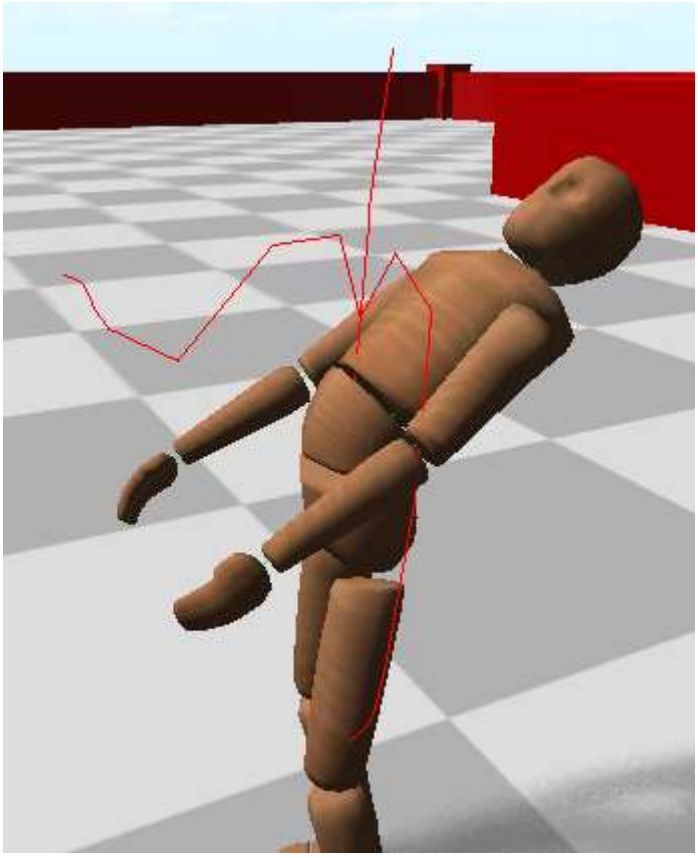
```
        BlendSystem.Blend(
            this.buffer1,
            new BlendPair(this.buffer1, this.weight),
            new BlendPair(this.buffer2, 1.0f - this.weight));
```

This takes the two buffers, blends them using the `weight` value and its inverse, and stores the result back in `buffer1` (this is why it's good to reuse buffers rather than creating new ones). Now, one last thing. Let's make the animation controller actually play an animation when we press the T key. Add these two lines of code right above the `BlendSystem.Blend()` call:

```
        if (Input.GetKeyDown(KeyCode.T) == true)
            this.anim.AnimPlay("dismissing_gesture");
```

Now try running the simulation and play with the R, F, T, Y, and H keys. You should be able to blend into the animation controller, play an animation, and then blend out back into the lean controller. Turn on Gizmos to see the two different skeletons working behind the scenes, too. If you want to keep track of the weight value, put this line of code somewhere in the `Update` function and the value will appear in the console window:

```
        Debug.Log(weight);
```



Fixing Strange Behavior

Now, we've got some problems. First, the animation controller is rotating the hips, which moves the legs of the character when we only want to affect the upper body. Second, when we blend towards the animation controller from the lean controller, the character stands upright again. We want to be able to play animations while still leaning forward or backward, right? Fortunately, we can fix both of these problems with one solution using a `Whitelist` filter. When we call the `Encode()` function, we can give the function a filter to ignore bones in the shadow skeleton we're encoding. We can use two kinds of filters. Whitelists take only the given bones and their children, while blacklists take all bones except the given bones and their children. Since the lean controller bends at the Spine bone, let's have the animation controller cut off right above that spine bone and animate everything above it on the body. We'll create a whitelist starting at "`Spine1`" and use it in the encode function. This is very simple. Replace the following line of code:

```
        this.anim.Encode(this.buffer2);
```

with this:

```
        this.anim.Encode(this.buffer2, new Whitelist<string>("Spine1"));
```

The class should look like this now:

```
public class TutorialCoordinator : ShadowCoordinator
{
    protected ShadowTransform[] buffer1 = null;
    protected ShadowTransform[] buffer2 = null;
    protected ShadowLeanController lean = null;
    protected ShadowAnimationController anim = null;
    protected float weight;

    void Start()
    {
        // Allocate space for two buffers for storing and passing shadow poses
        this.buffer1 = this.NewTransformArray();
        this.buffer2 = this.NewTransformArray();
```

```
        // Get a reference to our lean ShadowController
        this.lean = this.GetComponent<ShadowLeanController>();

        // Get a reference to our animation ShadowController
        this.anim = this.GetComponent<ShadowAnimationController>();

        // Set the weight
        this.weight = 0.99f;

        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        // Move the root position of each shadow to match the display model
        this.UpdateCoordinates();

        // Update the lean controller and write its shadow into the buffer
        this.lean.ControlledUpdate();
        this.lean.Encode(this.buffer1);

        // Update the anim controller and write its shadow into the buffer
        this.anim.ControlledUpdate();
        this.anim.Encode(this.buffer2, new Whitelist<string>("Spine1"));

        // Control the weight with the Y and H keys
        if (Input.GetKey(KeyCode.Y))
            this.weight += 2.0f * Time.deltaTime;
        if (Input.GetKey(KeyCode.H))
            this.weight -= 2.0f * Time.deltaTime;
        this.weight = Mathf.Clamp(this.weight, 0.01f, 0.99f);

        // Optionally, uncomment this to see the weight value
        // Debug.Log(weight);

        // Play an animation when we press T
        if (Input.GetKeyDown(KeyCode.T) == true)
            this.anim.AnimPlay("dismissing_gesture");

        // Blend the two controllers using the weight value
        BlendSystem.Blend(
            this.buffer1,
            new BlendPair(this.buffer1, this.weight),
            new BlendPair(this.buffer2, 1.0f - this.weight));

        // Write the shadow buffer to the display model, starting at the hips
        Shadow.ReadShadowData(
            this.buffer1,
            this.transform.GetChild(0),
            this);
    }
}
```

Run the simulation again and hold H for a second to give the animation controller full blend. Now lean back with R and press T to play the animation. Much better, right? But there's still a little problem. Notice that when the animation ends, it leaves the character's arms and head in a slightly offset position. We want the character to return to a neutral pose when the animation is finished, so that we can replay the animation without snapping. If we blend out when the animation finishes, that pose offset will go away, but we have to blend back in to start the animation again. In short, we need to make blending more straightforward.

This is no problem when we use a `Slider`. A slider is a simple object that smoothly slides a float value between 0 and 1 across several frames. This saves us the trouble of having to manually raise and lower the weight values

ourselves. We can tell a slider to go to its maximum or minimum value, and it will automatically do so after a second or two automatically. Let's replace the weight value with a weight slider, and change the Y and H keys to use it. Change the following lines:

```
protected float weight;
```

becomes

```
protected Slider weight;
```

```
this.weight = 0.99f;
```

becomes

```
this.weight = new Slider(4.0f);
```
(the 4.0f means that we want the slider to go four times as fast)

```
if (Input.GetKey(KeyCode.Y))
    this.weight += 2.0f * Time.deltaTime;
if (Input.GetKey(KeyCode.H))
    this.weight -= 2.0f * Time.deltaTime;
this.weight = Mathf.Clamp(this.weight, 0.01f, 0.99f);
```

becomes

```
if (Input.GetKeyDown(KeyCode.Y))
    this.weight.ToMax();
if (Input.GetKeyDown(KeyCode.H))
    this.weight.ToMin();
```

(the slider automatically handles clamping)

```
BlendSystem.Blend(
    this.buffer1,
    new BlendPair(this.buffer1, this.weight),
    new BlendPair(this.buffer2, 1.0f - this.weight));
```

becomes

```
BlendSystem.Blend(
    this.buffer1,
    new BlendPair(this.buffer1, this.weight.Value),
    new BlendPair(this.buffer2, this.weight.Inverse));
```

(Inverse gives 1.0 – the weight value)

Finally, we need to add this line to the top of the `Update` function:

```
this.weight.Tick(Time.deltaTime);
```

So that the weight slider knows how much to change each frame. The class should look like this now:

```
public class TutorialCoordinator : ShadowCoordinator
{
    protected ShadowTransform[] buffer1 = null;
    protected ShadowTransform[] buffer2 = null;
```

```
    protected ShadowLeanController lean = null;
    protected ShadowAnimationController anim = null;
    protected Slider weight;

    void Start()
    {
        // Allocate space for two buffers for storing and passing shadow poses
        this.buffer1 = this.NewTransformArray();
        this.buffer2 = this.NewTransformArray();

        // Get a reference to our lean ShadowController
        this.lean = this.GetComponent<ShadowLeanController>();

        // Get a reference to our animation ShadowController
        this.anim = this.GetComponent<ShadowAnimationController>();

        // Set the weight
        this.weight = new Slider(4.0f);

        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        this.weight.Tick(Time.deltaTime);

        // Move the root position of each shadow to match the display model
        this.UpdateCoordinates();

        // Update the lean controller and write its shadow into the buffer
        this.lean.ControlledUpdate();
        this.lean.Encode(this.buffer1);

        // Update the anim controller and write its shadow into the buffer
        this.anim.ControlledUpdate();
        this.anim.Encode(this.buffer2, new Whitelist<string>("Spine1"));

        // Control the weight with the Y and H keys
        if (Input.GetKeyDown(KeyCode.Y))
            this.weight.ToMax();
        if (Input.GetKeyDown(KeyCode.H))
            this.weight.ToMin();

        // Optionally, uncomment this to see the weight value
        // Debug.Log(weight.Value);

        // Play an animation when we press T
        if (Input.GetKeyDown(KeyCode.T) == true)
            this.anim.AnimPlay("dismissing_gesture");

        // Blend the two controllers using the weight value
        BlendSystem.Blend(
            this.buffer1,
            new BlendPair(this.buffer1, this.weight.Value),
            new BlendPair(this.buffer2, this.weight.Inverse));

        // Write the shadow buffer to the display model, starting at the hips
        Shadow.ReadShadowData(
            this.buffer1,
            this.transform.GetChild(0),
            this);
    }
}
```

Try running the simulation. The only difference you'll notice right now is that you only have to press Y and H rather than holding it to fully raise and lower the blend weights. It will continue blending even after you release the key until it's either at 0.01f or 0.99f. Lean the character back a bit with R, then press T and H at the same time to blend in and start the animation simultaneously. When the animation finishes, press Y to blend back to a neutral pose. You're manually doing what we want to automate. Let's make this process fully automatic now and wrap everything up.

Simplifying the Interface

What we're going to do is remove the Y and H keys. Instead of relying on those keys, we'll have the animation controller blend in automatically when the animation begins, and blend out when the animation finishes. Begin by removing the if statements corresponding to the Y and H keys. Replace the if statement corresponding to the T key with this:

```
        if (Input.GetKeyDown(KeyCode.T) == true)
        {
            this.anim.AnimPlay("dismissing_gesture");
            this.weight.ToMax();
        }
```

Finally, we want to check and see if the animation is done playing. If so, fade out the animation controller. So add this if statement right under the last one:

```
        if (anim.IsPlaying() == false)
            this.weight.ToMin();
```

The final `Update` function should look like this:

```
    void Update()
    {
        this.weight.Tick(Time.deltaTime);

        // Move the root position of each shadow to match the display model
        this.UpdateCoordinates();

        // Update the lean controller and write its shadow into the buffer
        this.lean.ControlledUpdate();
        this.lean.Encode(this.buffer1);

        // Update the anim controller and write its shadow into the buffer
        this.anim.ControlledUpdate();
        this.anim.Encode(this.buffer2, new Whitelist<string>("Spine1"));

        // Optionally, uncomment this to see the weight value
        // Debug.Log(weight);

        // Play an animation when we press T
        if (Input.GetKeyDown(KeyCode.T) == true)
        {
            this.anim.AnimPlay("dismissing_gesture");
            this.weight.ToMax();
        }

        // Fade out the animation controller if we're finished
        if (anim.IsPlaying() == false)
            this.weight.ToMin();

        // Blend the two controllers using the weight value
        BlendSystem.Blend(
            this.buffer1,
            new BlendPair(this.buffer1, this.weight.Value),
            new BlendPair(this.buffer2, this.weight.Inverse));
```

```
        // Write the shadow buffer to the display model, starting at the hips
        Shadow.ReadShadowData(
            this.buffer1,
            this.transform.GetChild(0),
            this);
    }
```

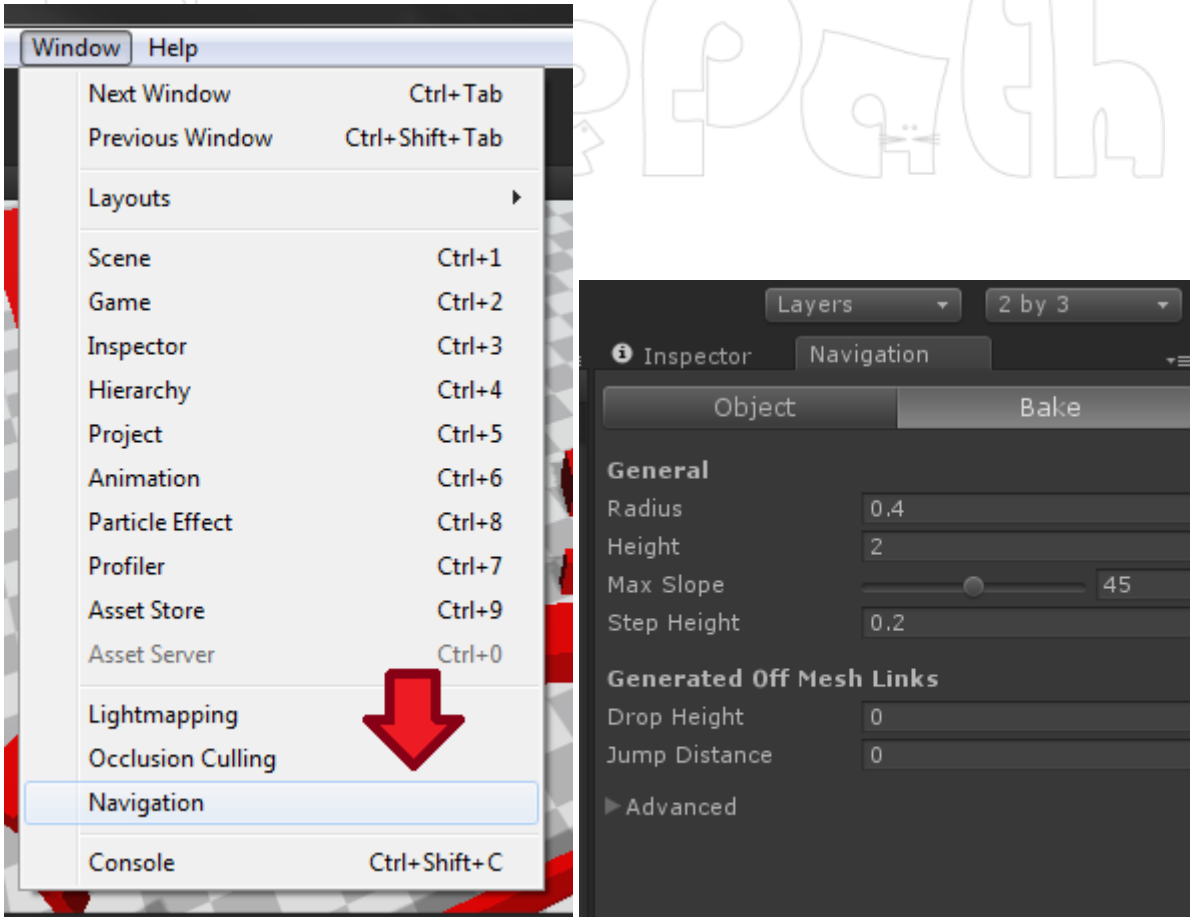
Now you should be able to press T and have the animation controller blend in and out automatically. This should look much better, without any stuttering artifacts or awkward poses. Congratulations, you've successfully created your own character controller and integrated it with a built-in ADAPT controller. In practice, fully-articulated characters are more complex, with multiple controllers like these two working in unison. To see a more complex system with several controllers being blended, look at the `BodyCoordinator` class. The principles here are the same, just applied multiple times to blend at different layers and for different parts of the body.

3.2. The Navigation System

Now we're going to make the character walk around in the environment. The empty template for this second tutorial can be found in `Tutorial2Empty`. Note that this tutorial uses the Unity navigation system, but the Recast navigation system is also available and sometimes produces better results. Refer to tutorial 2b for that technique.

Building a Navigation Mesh

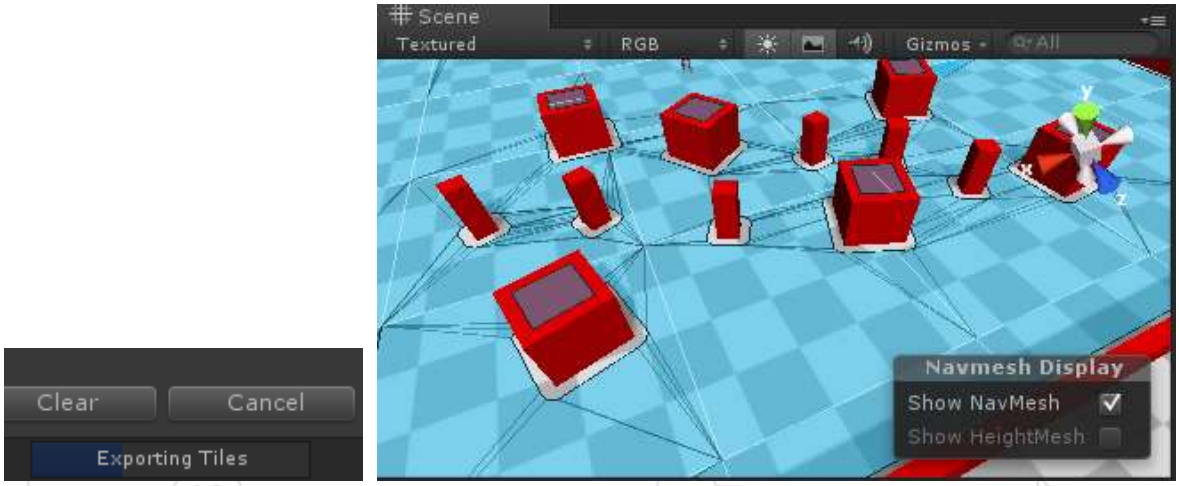
The first thing we need to do, once our environment is built (or in this case, provided to you by the tutorial) is to build the navigation mesh. The navigation mesh (navmesh) is a piece of geometry that contains the information for where the character can walk in the environment. Unity provides the functionality for automatically generating this geometry. You can find it in the Window menu under Navigation. Open this up and you'll see a new tab on your inspector called Navigation. Select that tab, and go to the Bake screen.



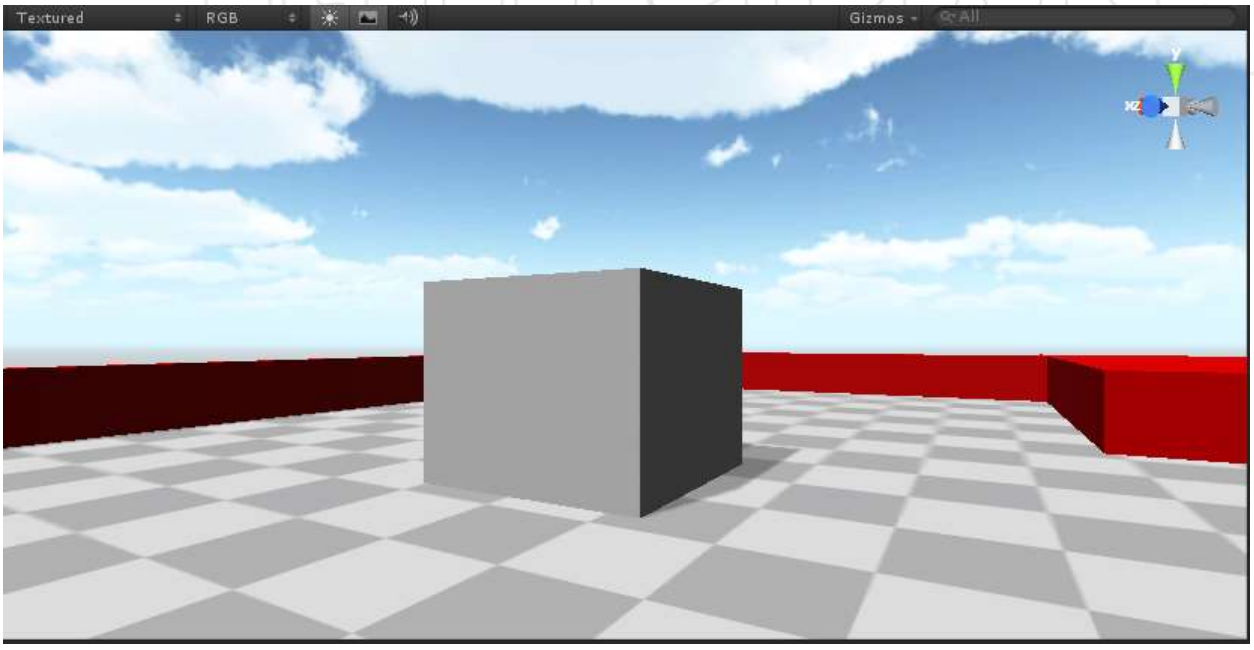
This screen has a few options for tweaking the navigation mesh, which we'll quickly go over:

Radius: The maximum radius of any agent we'll have in the world. For the purpose of navigation, each agent is treated like a cylinder.
Height: The minimum height of any agent.
Max Slope: The maximum incline (an angle, in degrees) that any agent can climb
Max Slope: The maximum step height that any agent can climb

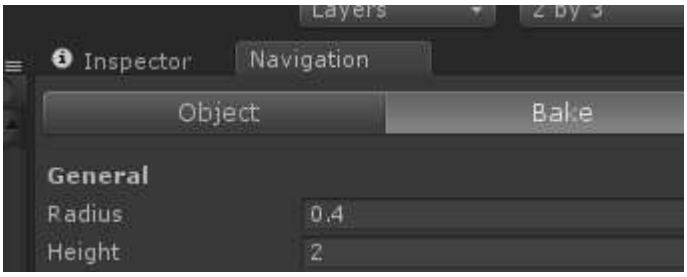
Ignore the others for now. Off-mesh links deal with generating gaps between areas in the navmesh, and the advanced options deal with the detail and fidelity of the navmesh when it's being generated (sacrificing generation speed for quality). Click Clear, and then Bake to create a new navmesh from scratch (this can take a few minutes). You'll see a loading bar at the bottom, and then a blue overlay in the scene view displaying the navmesh Unity generated.

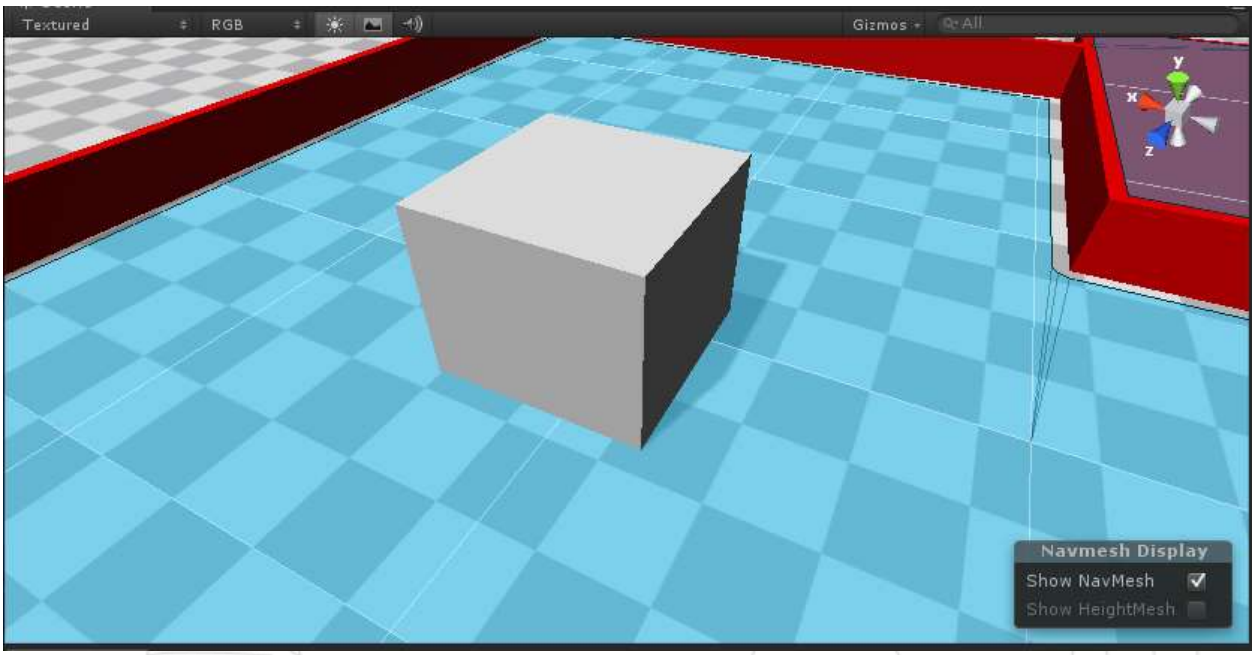


Let's quickly add one more piece of geometry to the environment. Create a new cube gameobject, then scale it and place it somewhere in the scene.

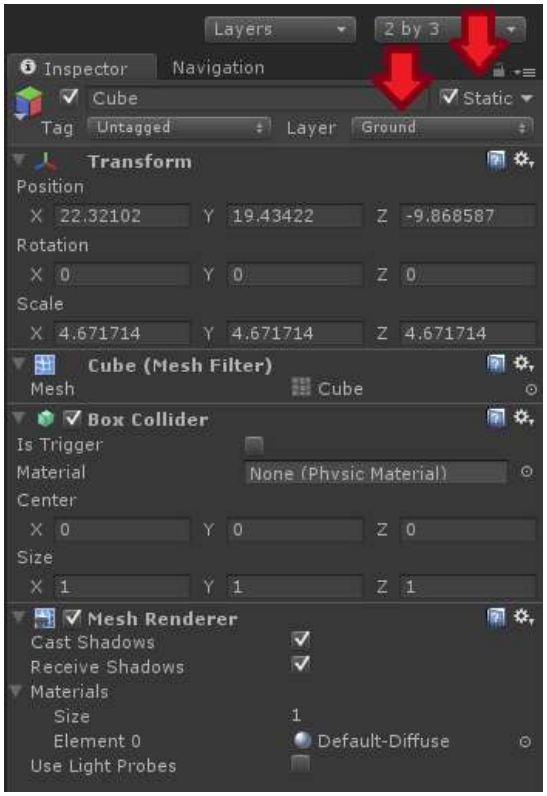


Notice that our navmesh seems to ignore it (if your navmesh isn't visible, go back to the Navigation tab and make sure that that's active):

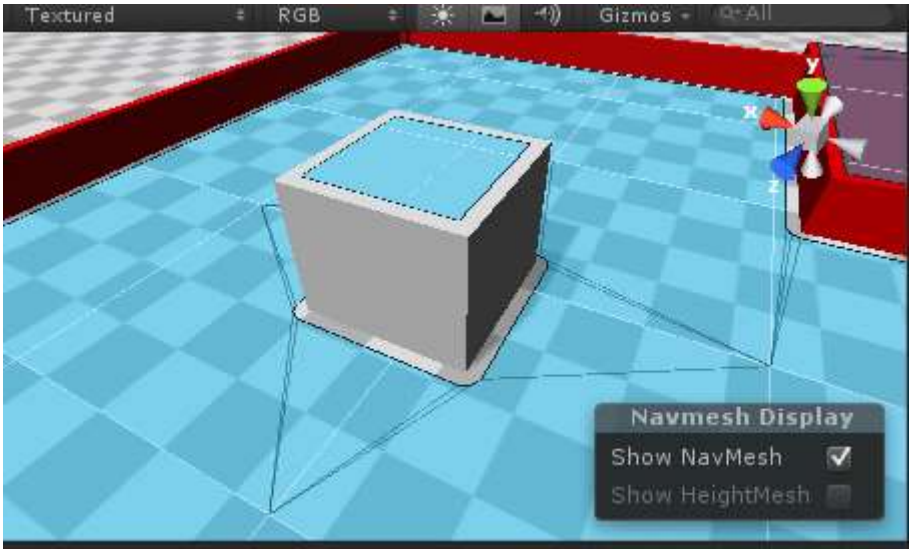




We'll need to generate a new navmesh, but we need to make sure of one thing first. In order for an object to be recognized by the navmesh generator, it needs to be marked as static in Unity. Also, be sure to set its layer to "Ground" (this doesn't affect the navmesh, but other systems in ADAPT will behave better if the ground is annotated). You can do that in the inspector here:



Let's generate the navmesh again like we did before. Make sure that the cube you created is flush with the terrain (or intersects with it a little bit), and that it isn't high enough for an agent to step over.



So, we've generated a navmesh. Let's get an agent to use it. Note that we're going to do this the basic way to show you the underlying mechanics, but Tutorials 3 and 4 talk about much better and more straightforward ways to use the navigation interface (and other components) in a real project.

Creating a Waypoint

We're going to start by making a basic Waypoint object that will tell an agent to approach it when we press a key. Make a new C# file and call it TutorialWaypoint. It should look like this (with some minor formatting differences):

```
using UnityEngine;
using System.Collections;

public class TutorialWaypoint : MonoBehaviour
{
    // Use this for initialization
    void Start ()
    {

    }

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

    }
}
```

The waypoint needs to know two things. First, we want to be able to configure which key it responds to, so we can have multiple waypoints. Second, it needs to know which character it will be controlling. Let's add these two fields to the top of the class above the `Start` function.

```
    public KeyCode code;
    public UnitySteeringController controller;
```

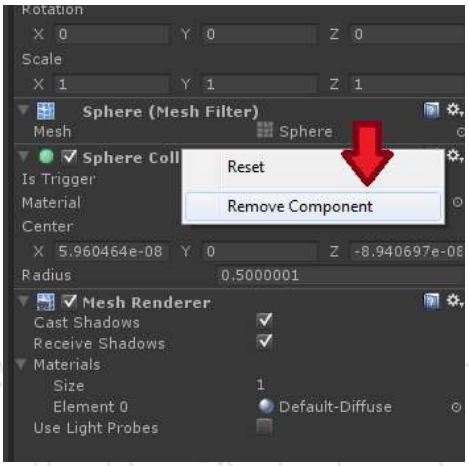
And then the rest is simple. We listen for the key, and if it's pressed, we set the character's navigation target. Just add this to `Update` function:

```
        if (Input.GetKeyDown(this.code) == true)
            this.controller.Target = transform.position;
```

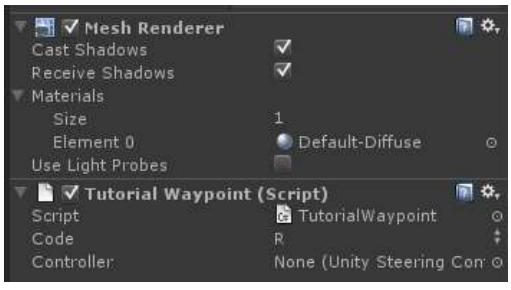
Here's what the final class should look like (you can remove the `Start` function):

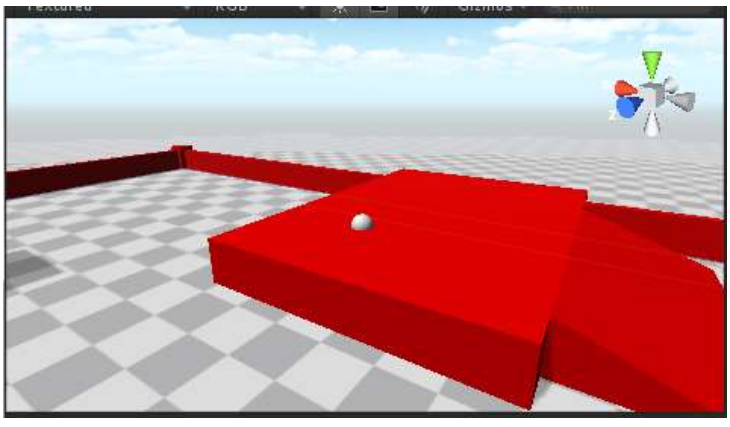
```
public class TutorialWaypoint : MonoBehaviour
{
    public KeyCode code;
    public UnitySteeringController controller;

    void Update ()
    {
        // Listen for the key and set the character's destination
        if (Input.GetKeyDown(this.code) == true)
            this.controller.Target = transform.position;
    }
}
```

Now create a new sphere game object and remove the sphere collider from it.



Now attach our new waypoint class to the sphere and place the sphere somewhere in the world. Make sure that's close to the floor and is somewhere the character could reach. You'll also need to set a keycode for it. I chose the R key and placed the sphere on the big red platform. It's probably best to make the sphere go through the floor somewhat.





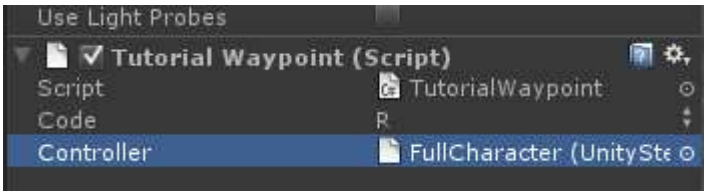
Using the Steering Component

Now let's get the character moving. In order to do so, it needs a UnitySteeringController attachment. Let's drag that onto the character now. You can find it under Scripts/Navigation/Unity.

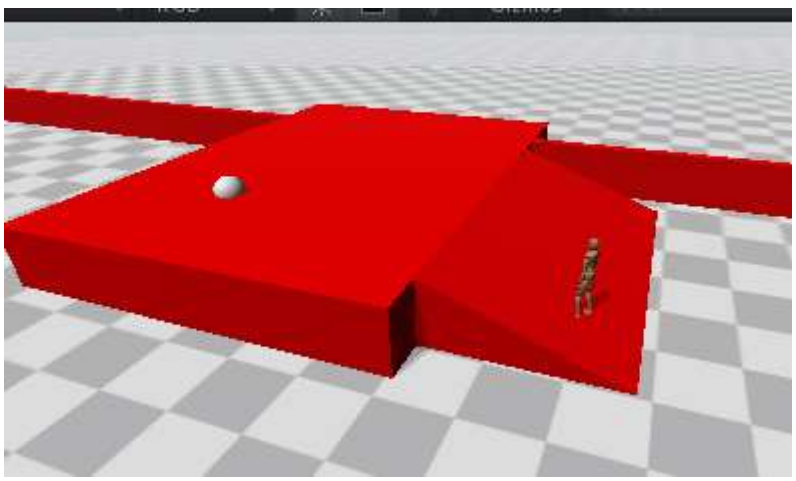
Hopefully most of these parameters are self-explanatory, but let's quickly go over some of the more obscure ones (and ignore the rest for now):

Stopping Radius: When a character is within this radius from the target, it will completely stop.
Arriving Radius: The radius at which the character will begin to slow down before stopping (this is added to the stopping radius). This feature is toggled with the **Slow Arrival** parameter.
Drive Speed: The speed at which we will turn to reorient while walking/running.
Drive Orientation: Turns on or off the ability to turn to face a desired orientation.
Orientation Behavior: Currently we have three options to compute orientation while walking/running. Setting this to "None" allows an external object to set the desired orientation, while any other setting means that the controller will set a desired orientation internally to either look forward or look at the objective.

Now that we've attached a steering controller to the character, let's store a reference to the character in the waypoint we've created. Drag the character into the waypoint's controller field in the inspector.



Now run the simulation and press R (or whatever key you used). The character should glide to the destination and avoid obstacles in the terrain.

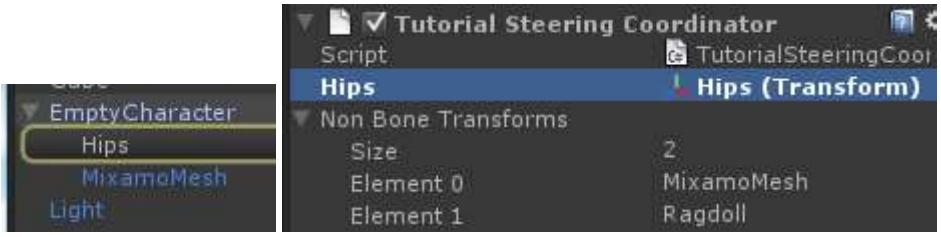


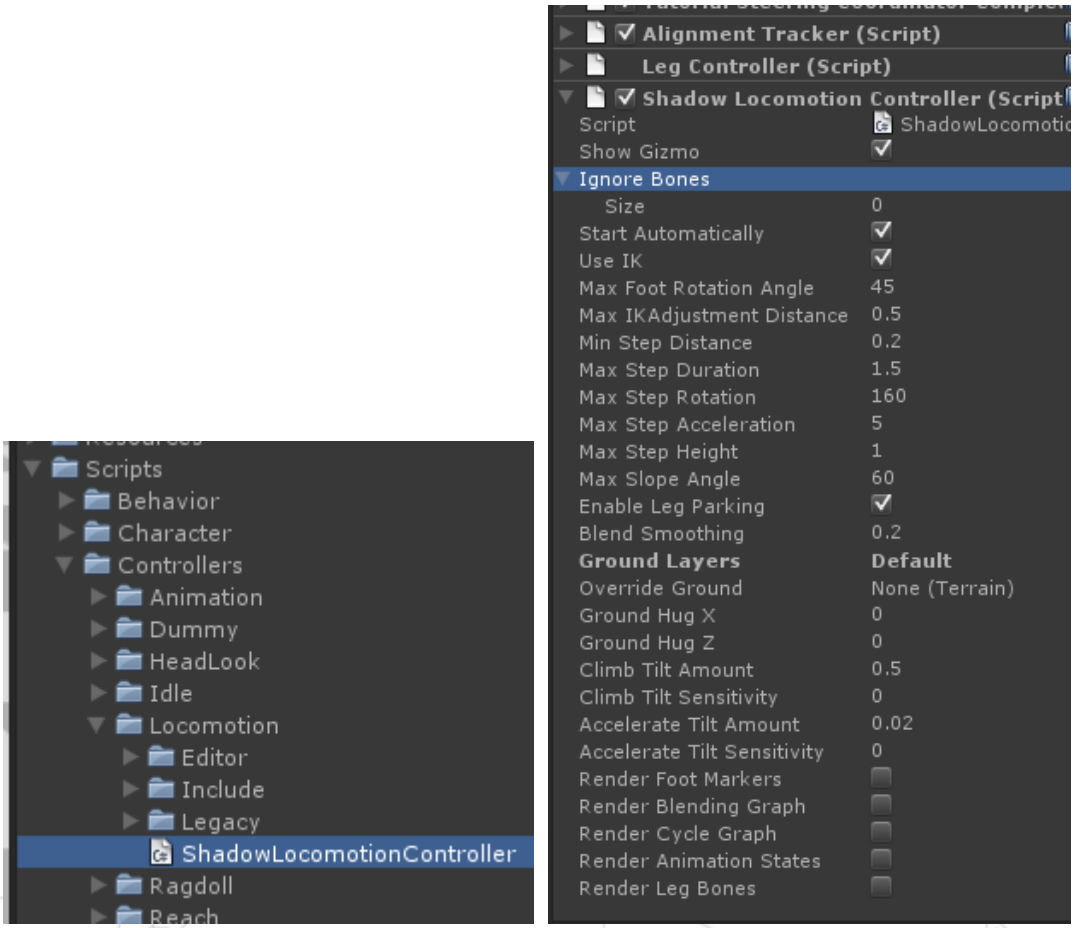
Getting the Character to Walk

Obviously, our job is not done. Surely our character can't be expected to just levitate everywhere. We need to get the character to walk. For this, we're going to use the `ShadowLocomotionController` and a very simple coordinator based on the one from the first tutorial. Let's start with the coordinator. Create an empty C# script called `TutorialSteeringCoordinator`, and use the following code for it:

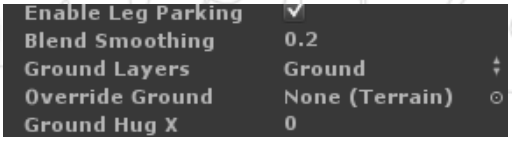
```
using UnityEngine;
using System.Collections;

public class TutorialSteeringCoordinator : ShadowCoordinator
{
    protected ShadowTransform[] buffer1 = null;
    protected ShadowLocomotionController loco = null;

    void Start()
    {
        // Allocate space for a buffer for storing and passing shadow poses
        this.buffer1 = this.NewTransformArray();

        // Get a reference to our lean ShadowController
        this.loco = this.GetComponent<ShadowLocomotionController>();

        // Call each ShadowController's ControlledStart() function
        this.ControlledStartAll();
    }

    void Update()
    {
        // Move the root position of each shadow to match the display model
        this.UpdateCoordinates();

        // Update the lean controller and write its shadow into the buffer
        this.loco.ControlledUpdate();
        this.loco.Encode(this.buffer1);

        // Write the shadow buffer to the display model, starting at the hips
        Shadow.ReadShadowData(
            this.buffer1,
            this.transform.GetChild(0),
            this);
    }
}
```

This is almost identical to first coordinator we made in the first tutorial. Attach the coordinator to the character along with the ShadowLocomotionController, which you can find under Scripts/Controllers/Locomotion. Give the steering coordinator a reference to the hips of the character.Adding this class will automatically add a few others that we need.

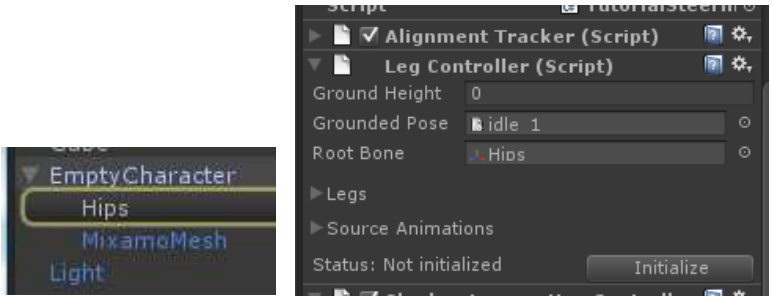




We'll need to configure these components. First, change "Ground Layers" to be "Ground", rather than "Default".

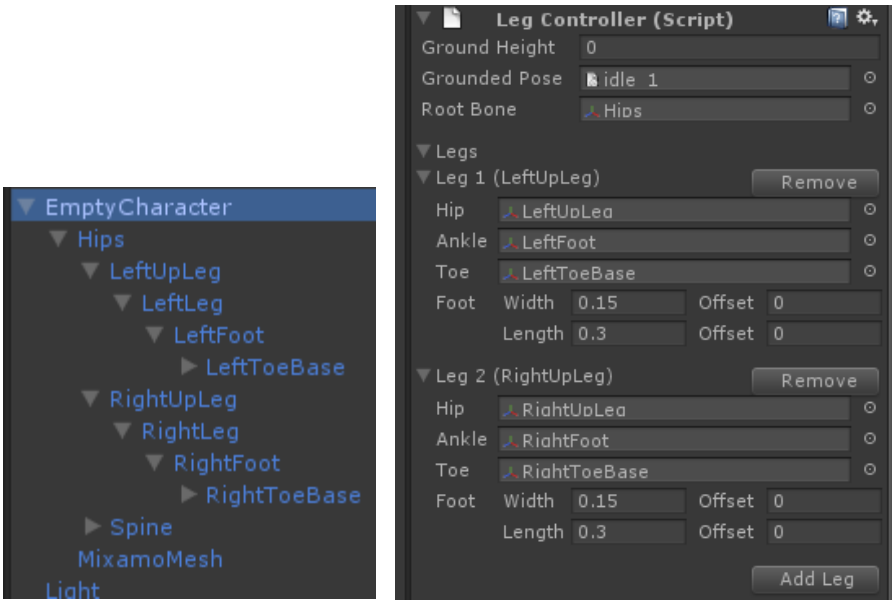


Next, we'll need to tell the leg controller some information about the character. Expand the leg controller component. Set "Grounded Pose" to `idle_1` (use the little dotted circle button to make this easier), and "Root Bone" to the character's `hips` bone.

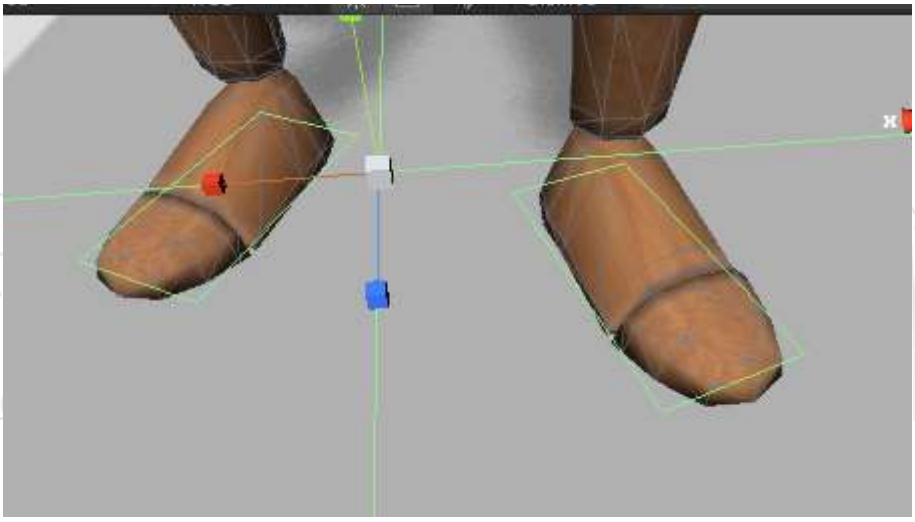


Remember how we had to remap the spine bone in our lean controller to the version in the cloned shadow? The locomotion controller does the exact same thing internally when we give it bone parameters like these as input in the inspector.

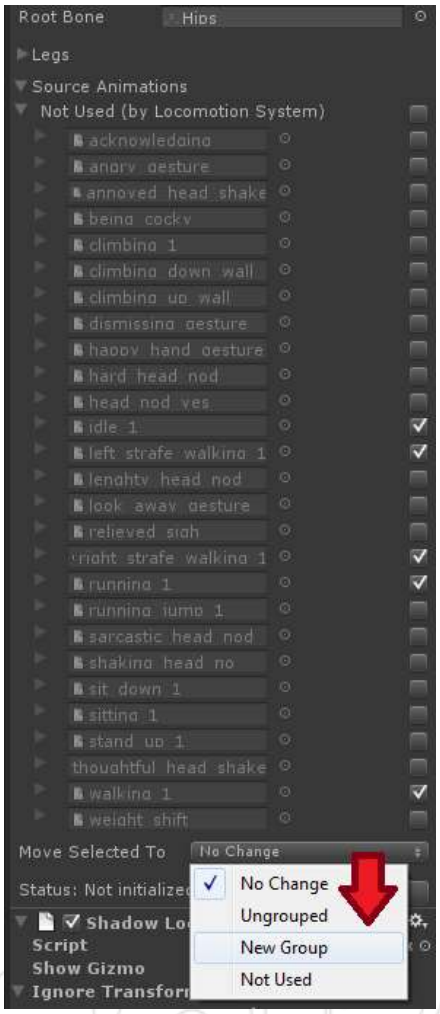
Now, let's tell it what bones refer to the legs, and where the feet are. Expand the "Legs" dropdown, and add two legs. Configure them like so:



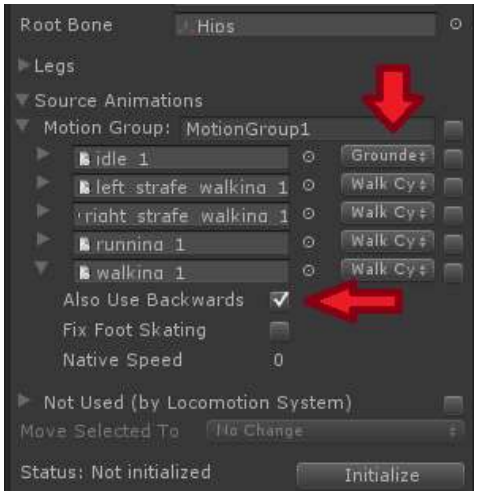
You should be able to see the bottoms of the character's feet in the scene view:



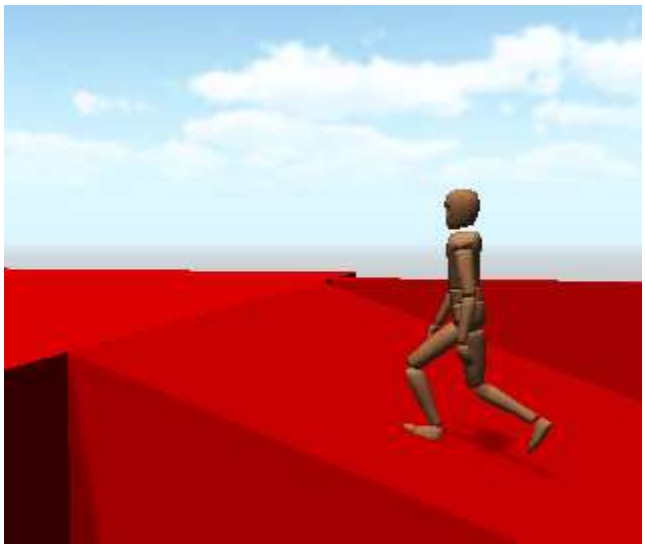
Now, we need to tell the leg controller what animations to use. The locomotion controller works by analyzing these animations and picking a blend of the animations depending on the velocity of the character. Higher speeds will cause the character to play the running animation, or lateral movement will cause the character to use a sidestepping animation. We use a modified version of a locomotion system provided by Unity and developed by Rune Johansen. You can find out more about the system here: http://runevision.com/multimedia/unity/locomotion/. For now, expand the Source Animations pull-down menu. Select "idle_1", "left_strafe_walking_1", "running_1", "right_strafe_walking_1", and "walking_1". With these animations selected, pull down the "Move Selected To" option and pick "New Group". This tells the system that these animations are the ones we want to consider when walking or running around.



Change `idle_1` from “Walk Cycle” to “Grounded”. This tells the system that the idle pose should be played when we aren’t moving. Also, expand the `walking_1` field and check “Also Use Backwards”.



Finally, click Initialize, and run the simulation. Press R, and watch the character properly walk to the destination waypoint.

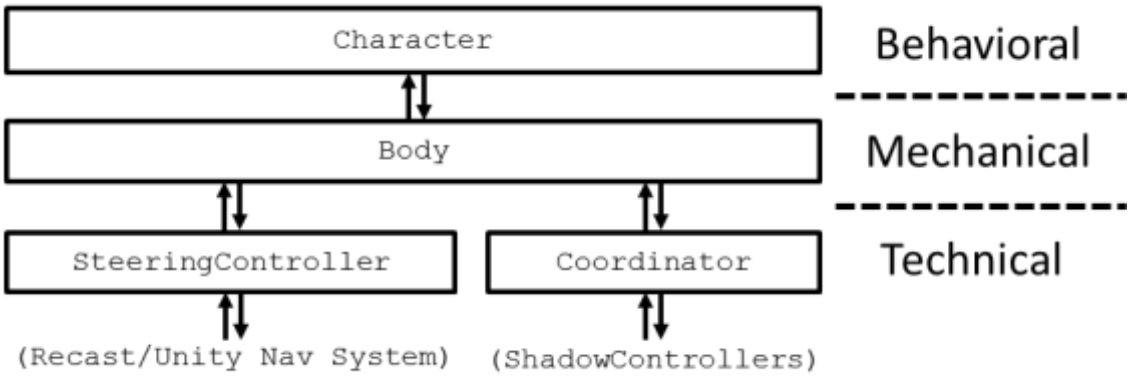


Congratulations! You've gotten a character to successfully walk to a destination in ADAPT. Try experimenting with different waypoints in different parts of the environment (using the configurable key code to give different waypoints different keys).

3.3. The Body Interface

Up until now, we've been controlling the character at a very low mechanical layer, effectively re-implementing parts of the character coordinator and navigation/locomotion system. In practice, when using ADAPT for a bigger project, we don't want to manually integrate these components. For this reason, ADAPT provides a default character capable of locomotion, reaching, gaze tracking, gesture animations, sitting, and physical response to collisions. Each of these features stems from a shadow controller dedicated to that function, which we blend together using a more advanced version of the coordinator discussed in Tutorial 1.

The provided default character is organized into layers, with different interfaces offering more intuitive or more specific control of components:



The bottom layers are the "technical" controls of the character. Usually an external component would interact with these systems directly only if it wanted to very specifically modify the behavior of the blending system or a particular choreographer. In general, this would be considered an advanced technique and probably wouldn't be best to start off with.

The middle layer, the "mechanical" layer, contains a set of commands for activating and de-activating shadow controllers, and sending messages to the coordinators to change their targets or behavior. Some of the functions in the `Body` interface include:

```
ReachFor(Vector3 target)
ReachStop()
HeadLookAt(Vector3 target)
HeadLookStop()
AnimPlay(string name)
SitDown()
StandUp()
NavGoTo(Vector3 target)
NavStop(bool sticky = true)
NavSetDesiredOrientation(Quaternion desired)
```

There are also more advanced commands for finer control and feedback. These commands are translated into messages that are sent either directly to the shadow controllers, or to the coordinator itself to know when to blend controllers in and out. The actual commands within the `Body` class are very simple, and should shed some light on how this layer actually performs. Generally, external modules would interact with a character on this layer if they wanted very specific control of the mechanical actions the character performs, as well as being able to handle failure states (can't navigate to a point, too far away to reach for something, etc.) manually. Smart Objects mostly interact with a character using the `Body`, as discussed in Tutorial 5.

The top layer, the behavior layer, is an abstraction of the `Body` that is more suitable for use in behavior trees. Unlike the commands in the `Body`, which occur instantly, the `Character` functions are designed to "block" until the action either succeeds or fails. All functions in the Character class return a `RunStatus` enumerator, which is discussed more in Tutorial 4. Behavior trees interact with a character at the top layer, as well as any external module

which wants to direct the character without having to deal with details like detecting the failure of specific tasks. All commands in the `Character` class use the commands in the `Body` class, but with a more simplified interface.

With the discussion out of the way, this will be a simple tutorial on flexing some of the muscle of the `Body` and using some of its functionality. The empty template for this tutorial can be found in the `Tutorial3Empty` scene file.

Navigation, the "Right" Way
Like before, we will begin by making a waypoint destination for the navigation system. We can edit the waypoint class from before to make a dead simple class for this. Call it TutorialWaypoint2:

```
public class TutorialWaypoint2 : MonoBehaviour
{
    public KeyCode code;
    public Body body;

    void Update()
    {
        if (Input.GetKeyDown(this.code) == true)
            this.body.NavGoTo(transform.position);
    }
}
```

This is almost exactly the same as before, except instead of taking a `UnitySteeringController` and setting its `Target` property, we take a `Body` and use the `NavGoTo` command. We've provided a sphere (with no `SphereCollider`) like the one used in the prior tutorial called `NavWaypoint`. Attach the new `TutorialWaypoint2` script to the `NavWaypoint` game object, and give it a reference to the `EmptyCharacter` and a key to use (such as "R") as we did in Tutorial 2. Run the simulation and test out the waypoint.

Look and Reach
Like navigation, using the `Body` class to perform other activities only requires a few lines of code. We're going to make two more classes very similar to `TutorialWaypoint`. They'll look like this:

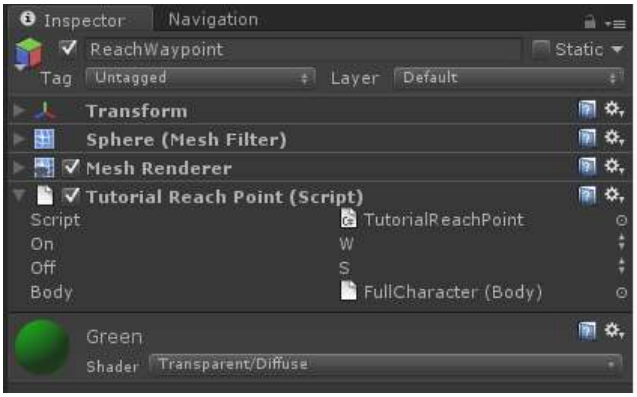
```
public class TutorialLookPoint : MonoBehaviour
{
    public KeyCode on;
    public KeyCode off;
    public Body body;

    void Update()
    {
        if (Input.GetKeyDown(this.on) == true)
            this.body.HeadLookAt(transform.position);
        if (Input.GetKeyDown(this.off) == true)
            this.body.HeadLookStop();
    }
}
```

and

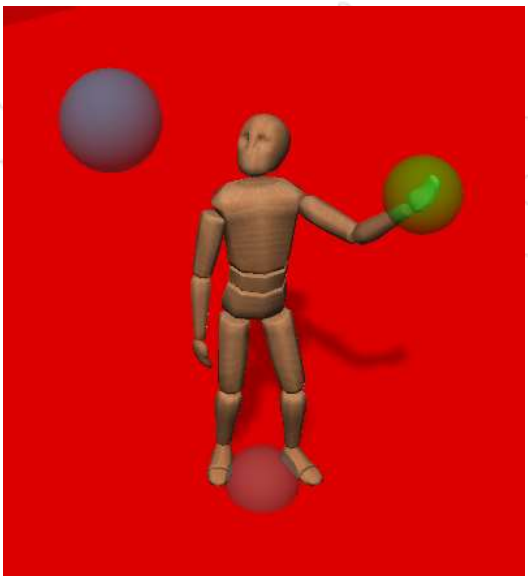
```
public class TutorialReachPoint : MonoBehaviour
{
    public KeyCode on;
    public KeyCode off;
    public Body body;

    void Update()
    {
        if (Input.GetKeyDown(this.on) == true)
            this.body.ReachFor(transform.position);
        if (Input.GetKeyDown(this.off) == true)
```

```
            this.body.ReachStop();
    }
}
```

The two main commands here are `HeadLookAt` and `ReachFor`, which both just take a Vector3 for input. Note that `ReachFor` will try to reach as close as it can to the target point. Attach the `TutorialLookPoint` script to the `LookWaypoint` gameobject, and the `TutorialReachPoint` script to the `ReachWaypoint` gameobject. Give each component a reference to the FullCharacter and set the on and off keycodes for each script, such as "T" and "G" to turn looking on and off, and "Y" and "H" to turn reaching on and off.



Run the simulation, send the character to the navigation waypoint, and try turning looking and reaching on and off.



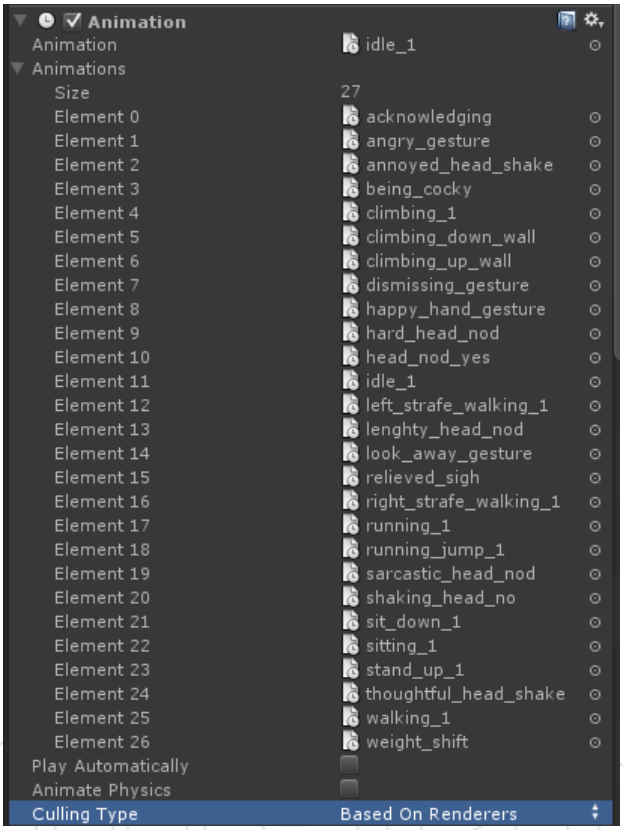
Gestures

Finally, let's make the character play some gestures. We'll make another class to attach to the `FullCharacter` object called `TutorialGestures`. We'll start it out by giving it a `Body` reference and having it fetch the character's `Body` component at the start of the simulation:

```
public class TutorialGestures : MonoBehaviour
{
    protected Body body;

    void Start()
    {
        // Get a reference to the body component
        this.body = this.GetComponent<Body>();
    }

    void Update()
```

```
    {
    }
}
```

Now, we want the character to play a few upper body animations. If you select the FullCharacter object, you'll notice it has an `Animation` component with a handful of animations provided (your exact list may differ slightly):



Let's pick two of the more noticeable gestures: "dismissing_gesture" and "being_cocky". We'll bind these to the 1 and 2 keys. Fill in the `Update` function of `TutorialGestures` like this:

```
    void Update ()
    {
        if (Input.GetKeyDown(KeyCode.Alpha1) == true)
            this.body.AnimPlay("dismissing_gesture");
        if (Input.GetKeyDown(KeyCode.Alpha2) == true)
            this.body.AnimPlay("being_cocky");
    }
```

Now run the simulation and press the 1 and 2 keys, as well as the other keys we used earlier to control setting a destination, reaching, and gazing. You can do all of these things simultaneously and the movements should blend with one another.

Now you're really starting to flex some of ADAPT's animation muscle! Experiment with looking and reaching, as well as the other commands in the `Body` class. You can see some demos of the Reach and HeadLook systems in action in the Demos folder.

Some other controllers like Sitting and the Ragdoll controllers are demonstrated in the Demos folder, though they are more complicated to use.

4. Quick Reference

This quick reference is intended to be used as a reminder for people already familiar with Behavior Networks. If this is not your case, we advise you first go through the tutorial document.

The creation of a Behavior Network involves 5 steps, which are summarized below from a) to e). If you were to find major difficulties using this package once gone through this quick start guide, send a precise email, if necessary with the necessary prefabs and code chunks, to support@timepath.io

4.1. Create a Personality and the Agent that will use it

To create a new personality, go to Assets > Create > Timepath Personality

To create a new character with a personality, go to Assets > Create > Timepath Agent. In the component TPAgent, select the personality that you want that Agent to have. Upon pressing play, it will be possible to visualize in real time the dynamic evolution of the behavior network (see example in the sample scene provided).

4.2. Create Perceptions, Goals and Skills (or destroy them)

Select the TPPersonality created. In the Inspector panel:

- To create a Perception, click on the black square with the "+" sign on either side of the Inspector.
- To create a Goal, click on the blue square with the "+" sign.
- To create a Skill, click on the yellow square with the "+" sign.

Creating 2 perceptions, one goal and 2 skills should look closely to Figure 3

- To destroy a Perception, click on the "-" button at the right of its name.
- To destroy a Goal, double click on the corresponding blue rectangle with a number.
- To destroy a Skill, double click on the corresponding yellow rectangle with a name.

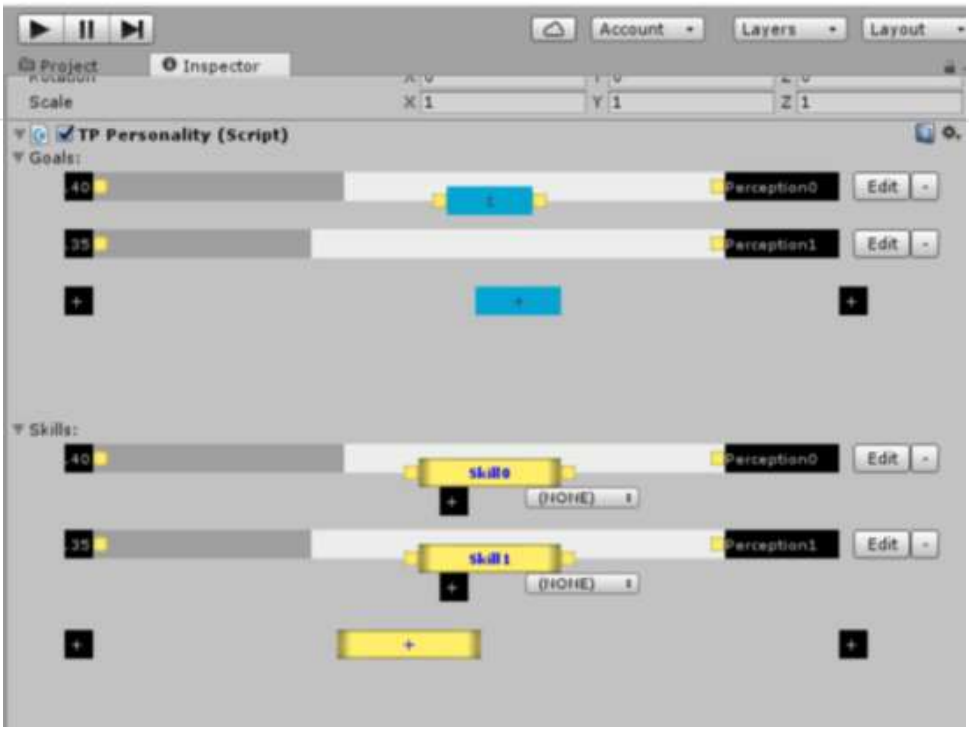


Figure 4 A personality with 2 perceptions, 1 goal and 2 skills

4.3. Define the Perceptions

To define a perception in a personality, click on the corresponding black square with a number (on the left), or on the corresponding "Edit" button next to its name (see Figure 3). This will take you to the appropriate game object in your personality. Once there, in the Inspector, an editable menu like in Figure 2 will appear, perceptions can be defined from a simple dropdown callback menu.

The perceptions that appear in the editor are defined as methods in the class TPPerception, whose source code is included in the package at the folder:

Assets > timepath4unity > TPPerception.cs

A Perception is any method of the class TPPerception which does not take more than one input parameter (a tag, a game object, another element) and which changes the double "value" with a quantity that is between 0 and 1. Combinations of methods can also be selected in the dropdown menu. Several examples are provided in the class TPPerception and in the personality prefab called "meteorite_picker".

These perception methods are fairly easy to define by a computer scientist, but do not hesitate asking a colleague with further programming experience to help you if you do not understand what is required.

4.4. Define the Goals

The Goals can be very simply defined by connecting the yellow nodes next to the blue boxes with the yellow nodes next to the black boxes (see Figure 1). The logical relation between a Perception and a Goal can be changed by clicking on the small box in the middle of the lines.

In the case of Relevance Conditions, at the right of the blue box, the lines will show either a green "*" when affirmative or a red "NOT" when negated. The number in the blue box will show the relevance values resulting from combining these Perceptions.

In the case of Goal Conditions, at the left of the blue box, the lines will always show a number, but clicking on them will also allow negating the perception corresponding to the goal condition.

The result will correspond to a simple goal definition. For example, in figure 1, the goal defined corresponds to:

```
When:
       not Perception0 and Perception1
I want:
       Perception0  0.89
```

The reason to define these elements visually instead of doing it through direct textual rule writing is twofold:

3. It makes sure the formal syntax required is always preserved, and
4. It makes sure the user understands the visual layout. Indeed, at execution time, when the personality is embodied inside an agent, this visual layout will show how the changes in the perceptions will change the relevance value of the goal in real time, thus helping to debug the overall personality.

Finally, clicking on the blue box will select the game object, corresponding to that goal, and the inspector panel will show the rule created as well as manually allow adjusting the importance of the goal (the small number shown in the Personality Inspector, in the Goal Condition, as shown in Figure 1). This allows defining completely a Goal in a Simple Behavior Network.

4.5. Define the Skills and the Actions

The definition of the Skills and the Actions is the most difficult part of using Simple Behavior Networks. It involves 3 steps:

4. First, you need to state the logical relations with existing Perceptions, in a way similar to how we did it with Goals. For example, connecting a skill called “pickM” in the same way than the previou goals will generate a structure that corresponds to:

```
If:
        Not Perception0 and Perception1
 doing:
        pickM
 has effect:
        Perception0 0.89
```

5. The second step to define a Skill corresponds to defining its associated Action, which is done in a similar way than Perceptions, but this time using methods defined in the class TPAction, which can be found in the folder:

   Assets > timepath4unity > TPAction.cs

A method defined in TPAction can be any kind of method that has 1 input field, or combinations of them. The example provided uses the wonderful LGPL library for character animation called ADAPT [1], and which integrates several character animation techniques to easily create sophisticated behavior. The tutorial to learn its ins and outs is also included in the package.

Alternatively, the freedom to call any class or method within a TPAction method implies that any other animation system can be used, and we wish different users are able to integrate this tool easily with their preferred animation frameworks (please let us know!).

For Mecanim enthousiasts, Simple Behavior Networks can use the API that allows changing Mecanim state machines. However, this option is not the most recommended, since the hierarchical structure of state-machines in Mecanim could cause trouble when integrating with this library. Timepath can also provide code to rapidly prototype Mecanim integration with drop-down menus, if this is of your interest please send an email to support@timepath.io.

6. The third step to define a skill is the likeliness of the effects. For this, click on the corresponding Skill, unfold its corresponding game object. A small hierarchical structure will appear with the following items:

```
5.      When:
6.      DoAction:
7.      Effects:
8.      Using:
```

Under “3.Effects”, the effects created will also have an “effect likeliness” that will be editable, to adjust how likely performing a certain action under certain conditions is likely to have a desired effect.

Depending on your editor settings, the numbered list of items in a Skill might appear disorganized, with item “2. DoAction:” appearing higher than “1.When:” . To correct for this fact, turn on Alphabetical sorting (see Trouble-shooting section).

[1] the source code of which can be found at https://github.com/storiesinvr/ADAPT

4.6. Optional: refinement with Resources

The previous combination of building blocks –Perceptions, Goals and Skills- already allows defining quite complex character behavior. However, the user can also extend personalities with Resources, which will appear under the item “4.Using:”

Resources are useful when defining Skills that compete for a limited amount of world, such as typically “Energy”, “Stamina”, but also anything, like “Rocks”, “Spaghetti” or any other resource that in a given environment is scarce enough to not be available at the same time for all the Skills that might want to use it.

To define Resources, select the personality, and under the appropriate skill select an item in the small menu that appears under the yellow rectangle, either an existing resource or by creating a new one. Once selected, clicking on the name will select the appropriate gameObject and show the options available for editing. The prefab “meteorite_picker_resources” contains an example of a personality using Resources.

5. Troubleshooting

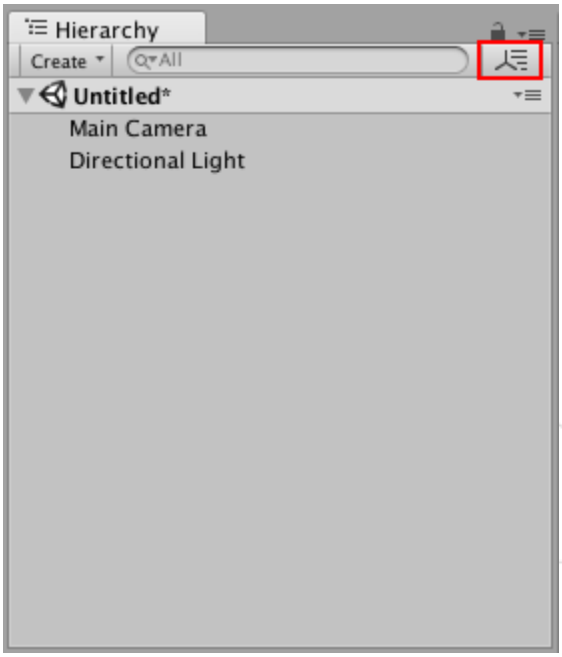
5.1. The order of objects in the Hierarchy window does not seem right.

You might need to turn on Alphabetical sorting.

To turn on Alphabetical Sorting, we can turn to the Unity3D Manual:

The order of objects in the Hierarchy window can be changed to alphanumeric order. In the menu bar, select **Edit > Preferences** in Windows or **Unity > Preferences** in OS X to launch the **Preferences** window. Check **Enable Alpha Numeric Sorting**.

When you check this, an icon appears in the top-right of the Hierarchy window, allowing you to toggle between **Transform** sorting (the default value) or **Alphabetic** sorting.



Source: https://docs.unity3d.com/Manual/Hierarchy.html

5.2. My character does not perform the action that I expect it to

If your character does not perform the action that you expect it to, you can try the following options:

1. Write in your action a log message to make sure the action is not being excuted (you can use Debug.Log("my message");)
2. If at a given time a character is not performing an action, use the visualization to clarify why this could be the case. Concretely, this implies:
    a. Check the activation value (the small number in the box), and confirm it is among the ones with high activation
    b. Check if the action contributes to a relevant goal (check the expected effect of performing the skill contributes to a Goal with high relevance value)
    c. Check if the preconditions of the skill are satisfied (i.e., low values for negated items, and high values for non-negated items)
    d. Check the lack of resources needed for the action is not a blocking factor
    e. If it is a Skill that will satisfy a Precondition for another Skill, check whether the relations between Perceptions satisfying successive Preconditions of Skills do end up contributing to a Relevant Goal.
3. Once you have understood why it is not doing the behavior you want it to for that moment, stop the playout, change the Relevance conditions of a Goal, and/or the Preconditions of a Skill, and test it again to check if the behavioral performance of your character to go in your desired direction possible when you want it to.

If importing the package generates this error:

https://forum.unity3d.com/threads/unityengine-ui-dll-is-in-timestamps-but-is-not-known-in-assetdatabase.274492/#post-1942214

try right click, reimport all, and say YES to the warning.

TODO:

in timepath4unity, TPAction and TPPerception, which are part of the package, are already existing in the tutorial. These files are where the action and perception methods are defined, and there are custom definitions for the demo.Therefore, in the import process they are renamed as

TPACtion 1.cs

TPPerception 1.cs

the simplest is to delete the, and keep the previous files,

since the tutorial version contains custom method definitions apropriate ofr hte demo.

TODO: THIS IS CORRECTED; RIGHT? RECHECK

-the locomotioneditor shuold not give errors

-the body picker should not allow for prefabs, only scene elements.

-defining personalities with prefabs causes trobule when we press play:

Setting the parent of a transform which resides in a prefab is disabled to prevent data corruption.

UnityEngine.Transform:set_parent(Transform)

timepath4unity.TPSkillList:GetSkillContainer(TPPersonality)

timepath4unity.TPPersonality:get_Skills()

timepath4unity.TPPersonality:removeSpacesInNames(TPPersonality)

timepath4unity.TPAgent:CreateMind()

timepath4unity.TPAgent:Start()

6. Further reading

6.1. References

K. Dorer, (2004). Extended behavior networks for behavior selection in dynamic and continuous domains. In *Proceedings of the ECAI workshop Agents in dynamic domains, Valencia, Spain*.

A. Shoulson, N. Marshak, M. Kapadia, and N. I. Badler (2014) ADAPT: The Agent Development and Prototyping Testbed. *IEEE Transactions on Visualization and Computer Graphics (TVCG)*

J. Llobera, R. Boulic (submitted) A tool to design interactive characters based on embodied cognition IEEE Transactions on Computational Intelligence and AI in Games

6.2. Unity Projects

ADAPT code and tutorial https://github.com/storiesinvr/ADAPT

Mecanim tutorial https://www.assetstore.unity3d.com/en/#!/content/9896