THE ORANGE CODER

GPU ECS ANIMATION BAKER

Overview

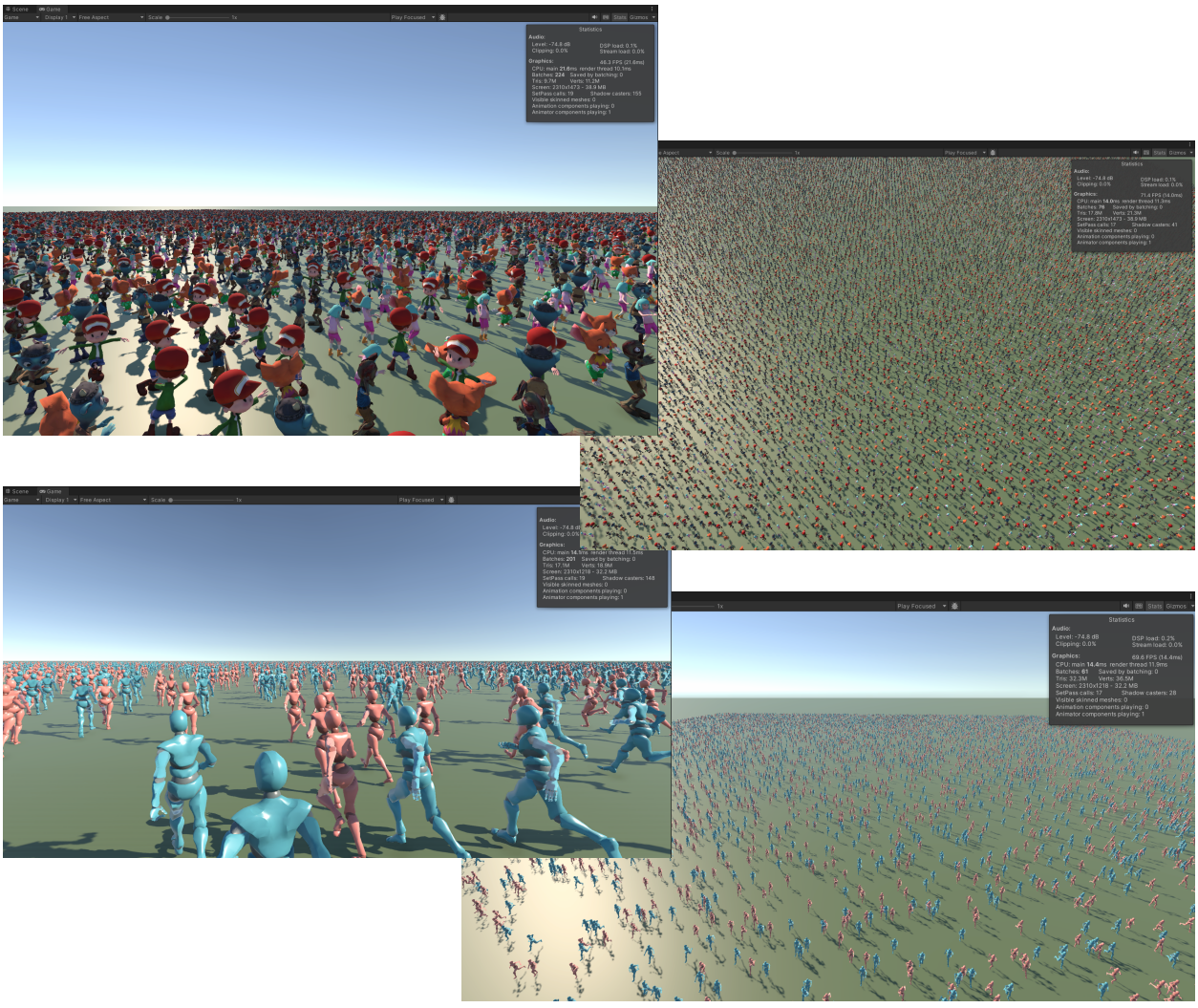
GPU ECS Animation Baker combines the power of DOTS ECS with GPU Animation instancing to allow you to animate tens of thousands of characters at the same time, each with different animations.

It works by baking all vertex bone weights into the UV channels of the meshes (uv1, uv2 & uv3) + baking all the bone transforms per frame into animation textures. A custom vertex shader will take care of the rest. An ECS animation system takes care of updating the shader values each frame.

The custom vertex shader is implemented as a ShaderGraph Subgraph, so it can be easily integrated in any of your existing ShaderGraph shaders.

The baker supports URP & HDRP, LODs, blend sampling & animation transitions.

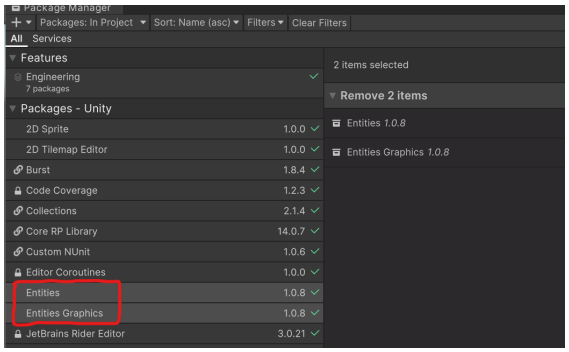
Using this technique, you can easily have tens of thousands individually animated characters on screen.



Installation

Requirements

GPU ECS Animation Baker v.1 requires Unity 2022.2.20f1 or later with ECS 1.0.8 or later.
It requires both the ‘Entities’ as the ‘Entities Graphics’ package:



The asset will be kept up to date to stay compatible with the latest ECS version.

The package fully supports HDRP & URP. However, all sample scenes were made in URP, so it’s best to learn about the package within a URP test project if you are planning to use it in an HDRP project. It’s easy to convert the sample scenes to HDRP though. In the Samples/Shaders folder both the URP & HDRP variation of the sample shaders used in the sample scenes are provided.

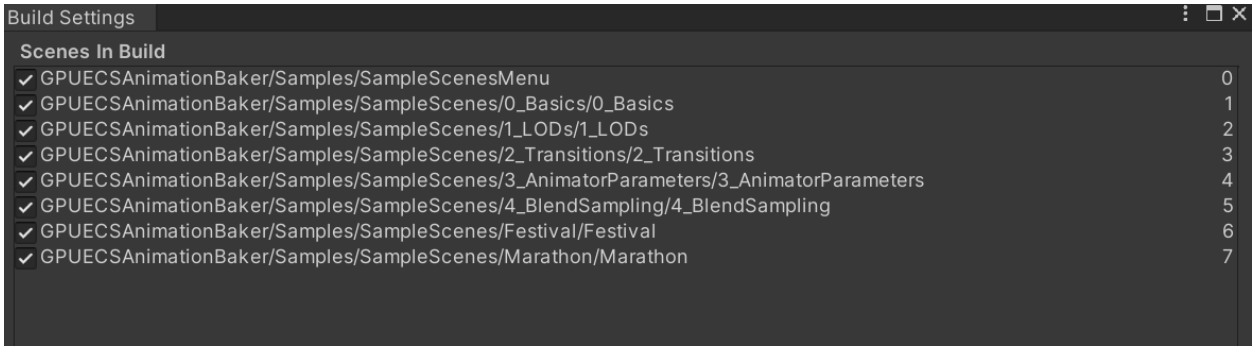
Installation guide

After downloading the asset, make sure you import at least everything from the Engine folder. This is enough to make use of it, although the Samples folder is essential to learn about the tool.

Make sure you have already the packages Entities & Entities Graphics into your project via the package manager.

It’s best to change the rendering path to URP Forward+. Entities Graphics requires this. You will get a warning if you don’t.

If you want to run the sample scenes Menu, make sure you add all the sample scenes to the build menu:



You're now ready to use GPU ECS Animation Baker!

Asset contents overview

The assets consist of the following directories:

- **GPUECSAnimationBaker**
  - **Engine**
    This contains all the code to make the baker work (editor + runtime)
  - **Samples**
    - **Characters**
      All the character models, materials, textures & baked animations objects
    - **SampleScenes**
      Sample scenes are ordered in complexity.
      Festival & Marathon are big crowd demo scenes

    SampleScenesMenu allows you to browse all the sample scenes.

The best way to learn is to follow the tutorials, examine the example scenes & read this documentation for details.

Tutorials: https://www.youtube.com/playlist?list=PLerop1JzrAobUF2d8Iafj5waqSq3Ib8k1
Demos: https://www.youtube.com/playlist?list=PLerop1JzrAoa8Vpz1p3Ps8EGRduhaDlP3

Limitations

Disclaimer: The GPU ECS Animation baker is built for performance, and excels in animating many characters at once, but it is in no way as versatile & feature-rich as the existing Unity Animator/Skinned Mesh Renderer solution. There are a few things to bear in mind:

- You can only use UV0 in your meshes. UV channels 1,2 & 3 are used by the baker, so GPU ECS Animation baker doesn't support models that use these channels.
- Your materials need to use ShaderGraph shaders. It would be possible to implement the baker for coded shaders, but this falls outside the current scope of implemented

features. Check out the shader code at /GPUECSAnimationBaker/Engine/Shader if you want to implement this yourself.

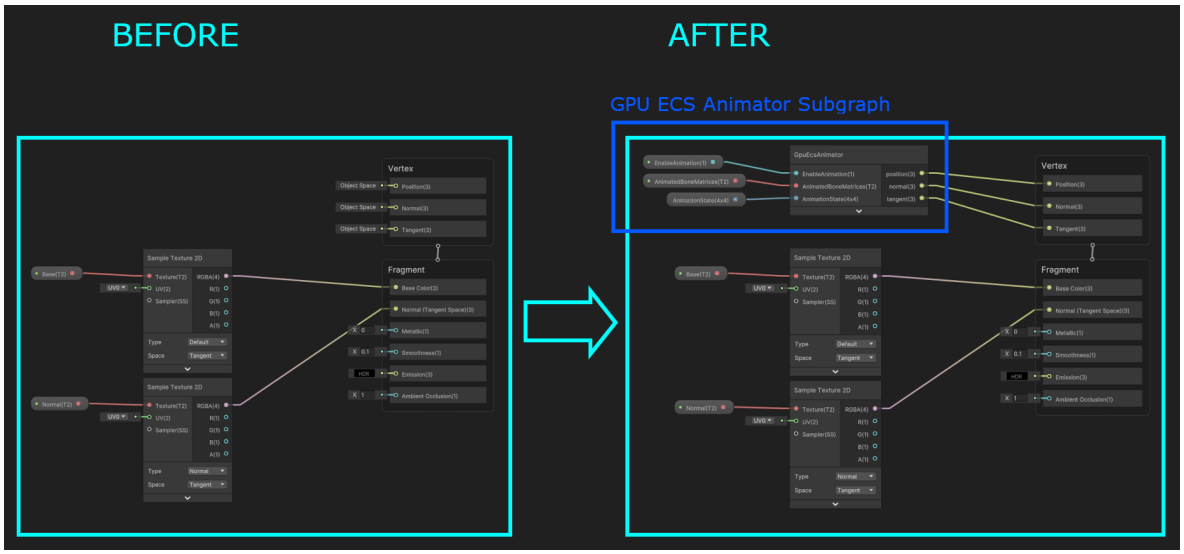
- All classic Animator features are supported insofar as they can be baked and sampled. The classic Animator itself however does NOT run at runtime at all, so be aware of this.
- The package fully supports HDRP & URP. However, all sample scenes were made in URP, so it's best to learn about the package within a URP test project if you are planning to use it in an HDRP project. It's easy to convert the sample scenes to HDRP though. In the Samples/Shaders folder both the URP & HDRP variation of the sample shaders used in the sample scenes are provided.

QuickStart

Everything starts with a classic game object with an animator and 1 or more SkinnedMeshRenderer(s) and optionally an LODGroup. The baking process will start from this object.

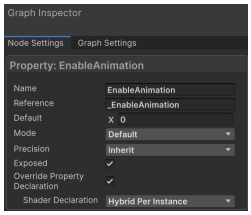
1. Adapt your materials/shaders

The first thing to do is to extend the shaders that are used in your SkinnedMeshRenderer with our special ShaderGraph GpuEcsAnimator Subgraph.
Let's say you have a simple shader URP Lit shader with a base & normal map as input. If you want to make this shader compatible with GPU ECS Animation, you simply have to add the GpuEcsAnimator like this:

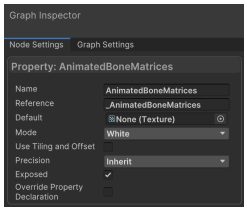


The shader requires 3 extra parameters to be defined on your shader

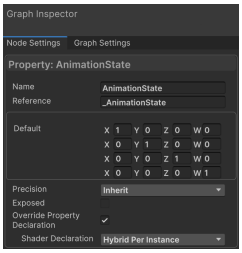
1) **EnableAnimation**
   This is a boolean that allows normal viewing of the original asset by disabling the animation shader on it. Animation will be enabled automatically in the ECS baker/convertor.
   It needs to be exposed & 'Override Property Declaration' must be checked & set to 'Hybrid Per Instance'



2) **AnimatedBoneMatrices**
   This texture contains all the animation data. Each row represents a frame of an animation & each 4 columns represent a mesh bone.
   It needs to be exposed.



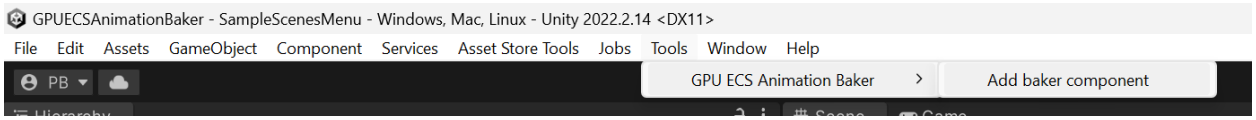
3) **AnimationState**
   This will drive the animation state at runtime
   It needs to be exposed & 'Override Property Declaration' must be checked & set to 'Hybrid Per Instance'



Note: The simplest way to do this is to simply copy paste the 3 parameters & the subgraph from one of the sample shaders found in /GPUECSAnimationBaker/Samples/Shaders.

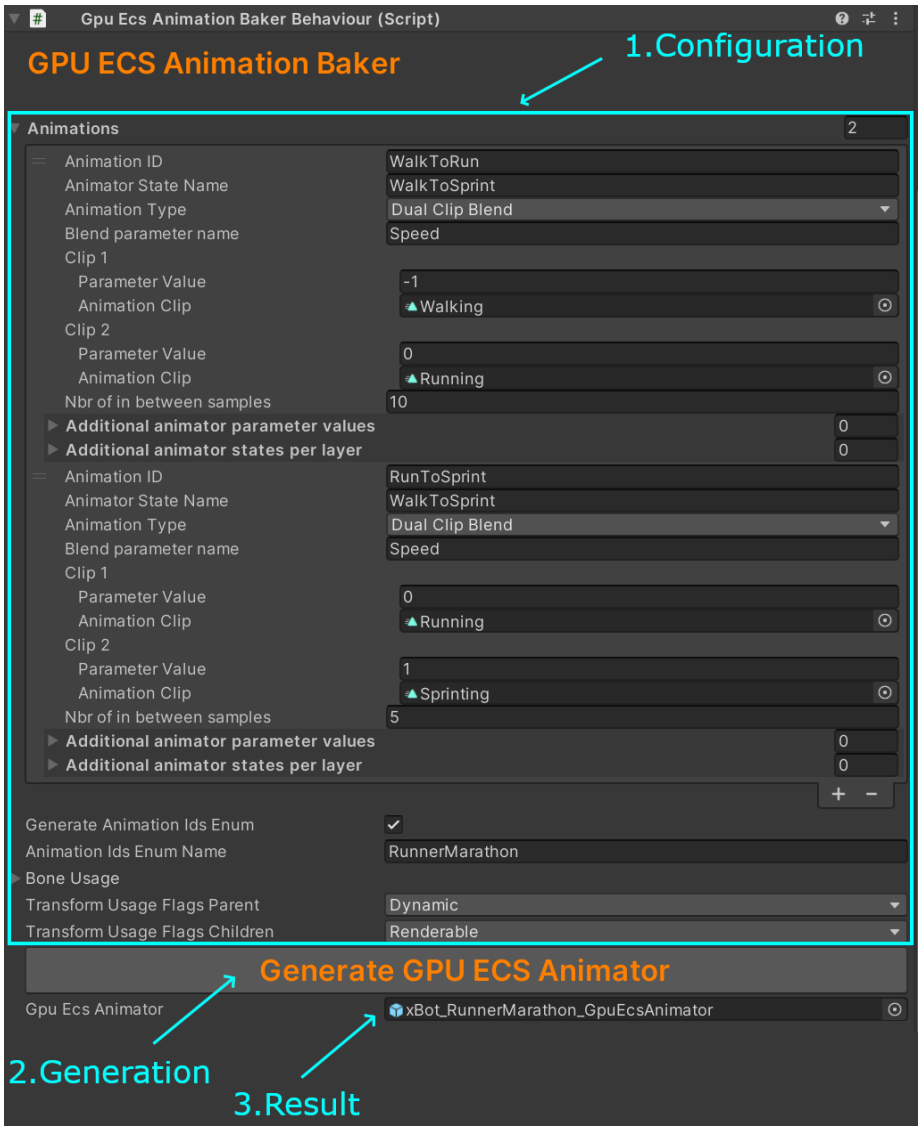
2. Attach baker component

Attach the baker component through the menu when the Animator game object you wish to bake a GPU ECS Animator for, is selected.



3. Configure & Generate

You can now configure all baking settings, and when done generate the GPU ECS Animator object.



Configuration Settings

1. Animations

Configuration of all animations you want to bake

- **Animation ID**
  Only used when generating enum code file to identify animations (see below)
- **Animator State Name**
  The Animator state name that will be used during sampling (regardless what layer it is on)
- **Animation Type**
  This can be either of these 2:
  1) Single Clip
     A single clip animation just plays a single (non-blended) animation
     - **Animation Clip**
       Only used to determine the length of the animation**(*)**
  2) Dual Clip Blend
     Dual clip blends will allow you to blend between 2 animations controlled by an animator parameter. The baker will sample this animation across a range of values for this parameter
     - **Blend parameter name**
       The animator parameter that will be used to blend
     - **Clip1, Clip2**
       - **Parameter Value**
         The animator parameter value to blend from or to
       - **Animation Clip**
         Only used to determine the length of the animation**(*)**
     - **Nbr of in between samples**
       The nbr. of samples to take. More will result in better results, but larger baked animation textures
- **Additional parameter values**
  Any additional Animator parameters that will be used during sampling (independent of blending)
  Specify name, type & value for each.
- **Additional animator states per layer**
  Any additional Animator states that need to be set on different layers
  Specify layer index & animator state name for each.

(*) It's important to realize that what matters for the generation of the animation textures is not the actual animation clips that are set, but rather the animator state (+ additional animator states per layer). The animation clip just needs to be provided as a reference to determine the length of the sample to be baked.

2. Generate AnimationIds Enum

It can be handy to use an enum file to control animation from code in a more user-friendly way.
If you don't generate an enum, you will have to control which animation to play by its index (see below)

3. Bone Usage

You should specify a default number of bones per vertex to take into account. More bones will yield better results but requires more from the GPU at runtime.
You can override the amount of bones per LOD to further optimize performance.

4. Transform Usage Flags Parent & Children

These flags will be used in the ECS entity baker for both the Animator (parent) as the children (Meshes). Check documentation for TransformUsageFlags enum in the Unity ECS Baking documentation.

Generation process

The generator will create a new directory (if it doesn't already exist) with the prefix 'BakedAssets_'+ the animator gameobject name. Inside it will generate a bunch of files:

- The enumeration C# file to identify animations (optional)
- Animation textures
- Copies of the original materials with the animation textures assigned to it
- Mesh copies with the vertex bone weights baked into UV coordinates uv1, uv2, uv3
- The GpuEcsAnimator object, which can be baked by the Unity ECS baker into an entity

3. Use the GpuEcsAnimator object

If you examine the GpuEcsAnimator you will see that it will mirror the structure of the original Animator gameobject. All SkinnedMeshRenderer components will have been replaced with regular MeshRenderer components with the generated materials & meshes assigned to them.
Any LODs will have been converted. Monobehaviours with ECS conversion bakers will be attached.

The simplest way to use the entity is by putting it in a Subscene (which will tell Unity it needs to be converted to an ECS entity). In most real game use cases though, you will use them as prefabs for ECS entity spawner systems.

The animation will be controlled by 2 systems:

- GpuEcsAnimatorSystem
  This system will prepare the data to be sent to the shaders
- GpuEcsAnimatedMeshSystem
  This system will populate all material overrides with the prepared data

The only thing you need to do as a user to control these animations is to set the GpuEcsAnimatorControlComponent component on the entity you want to animate:

```
using Unity.Entities;

namespace GPUECSAnimationBaker.Engine.AnimatorSystem
{
    public struct GpuEcsAnimatorControlComponent : IComponentData
    {
        public AnimatorInfo animatorInfo; // All info about the animation you want to play
        public float startNormalizedTime; // An option to start the animation from an arbitrary
position (0 to 1)
        public float transitionSpeed; // The transition speed that will be applied when switching
to another animation
    }

    public struct AnimatorInfo
    {
        public int animationID; // the unique animation ID, can be assigned from the generated
enum file
        public float blendFactor; // From 0 to 1, going from clip1 to clip2
        public float speedFactor; // <1 to make the animation go slower, >1 to make it go faster
    }
}
```

Typically you will set this component whenever you want to transition to another animation or when you want to change the parameter of a running animation (blendFactor or speedFactor).

Alternatively, for convenience there is also an GpuEcsAnimatorAspect aspect class that you can use to control the animation:

```
namespace GPUECSAnimationBaker.Engine.AnimatorSystem
{
    public readonly partial struct GpuEcsAnimatorAspect : IAspect
    {
        private readonly RefRW<GpuEcsAnimatorControlComponent> control;

        public void RunAnimation(int animationID,
            float blendFactor = 0f, float speedFactor = 1f, float startNormalizedTime = 0f, float
transitionSpeed = 0f)
        {
            control.ValueRW = new GpuEcsAnimatorControlComponent()
            {
                animatorInfo = new AnimatorInfo()
                {
                    animationID = animationID,
                    blendFactor = blendFactor,
                    speedFactor = speedFactor
                },
                startNormalizedTime = startNormalizedTime,
                transitionSpeed = transitionSpeed
            };
        }
    }
}
```

There is also another convenient initializer monobehaviour script that allows you to initialize the correct animation at baking time:

```
namespace GPUECSAnimationBaker.Engine.AnimatorSystem
{
    [RequireComponent(typeof(GpuEcsAnimatorBehaviour))]
    public class GpuEcsAnimatorInitializerBehaviour<T> : GpuEcsAnimatorInitializerBehaviour where
T : Enum
}
```

If you define a new behaviour that subclasses this GpuEcsAnimatorInitializerBehaviour with the correct animation enum type, you can attach it to the animator object and select the animation to initialize at design time, so it will be initialized already during baking.

Best way to learn how to control the animations is to look at the samples provided with the asset where each of these methods described above are used.

Advanced topics

Blending

The classic Unity animator does blending via interpolation of the bone structure relative angles. This is however not possible when using GpuEcsAnimationBaker, because each vertex position is calculated in the shader based on bone matrices that are pre-baked per frame. Interpolation instead happens between vertex positions. It's important to note that this can cause unwanted mesh deformations when the difference between the 2 blended poses is large. Let's examine the 3 scenarios where vertex interpolation blending will be applied:

1) **Transitions**

   Transitions between 2 different animations typically don't last more than half a second or so. In this case, the deformation is not easily spotted, especially in a context where many characters are on-screen.

2) **Dual Clip Blends**

   When blending between 2 poses, for example between a walk & a run cycle, the blend is continuous so a simple vertex interpolation between the walk & run pose will not look ok. However, we can fix this by sampling enough in-between poses during the baking process. Vertex interpolation will then occur between 2 very similar poses and will look just fine.

3) **Frame-to-frame interpolation**

   Frames are sampled & baked at 30 FPS. This means that in a game, running at 60+ FPS, interpolation will occur between pre-baked vertex positions in time. These 2 poses will by definition be very similar, so again vertex interpolation will work just fine.

GPU Instancing

As all animation shaders will be based on ShaderGraph shaders, GPU instancing is supported by default. All you have to do is enable it in the material.

Using baking services from your own editor code

Instead of attaching the baker component to your animators and configuring baker settings manually in the editor + starting the process via the 'Generate GPU ECS Animator' button, you can also automate this process via your own editor code by calling the following function:

```
namespace GPUECSAnimationBaker.Engine.Baker
{
    public static class GpuEcsAnimationBakerServices
    {
        public static GameObject GenerateAnimationObject(string assetPath,
GpuEcsAnimationBakerData bakerData, string generatedAssetsFolder, string targetAssetPath,
string targetEnumAssetPath)
    }
}
```

- **assetPath** : the asset path of the source prefab asset you want to generate a GPU ECS Animator from
- **bakerData** : all the baker Configuration data. This structure is equivalent to what you see in the editor when you attach a baker component to a prefab
- **generatedAssetsFolder** : the folder that will contain all the generated assets during baking. When you use the editor UI to generate the GPU ECS Animator, this will be a subfolder in the folder of the source prefab called 'BakedAsset_*{name of asset}*'. Using this function will allow you to choose your own folder
- **targetEnumAssetPath** : the asset path of the enum file that will be generated (if applicable)

This way you can write your own generator for multiple animators in your project at once, sharing all or part of the configuration and deciding yourself where all the assets end up.

Support

http://www.headfirststudios.com/theorangecoder
https://discord.gg/DnBzvMC2uG

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