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# C# Jobs System

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# Warning

- This design and feature implementation is not final and will change by the time it is out.

- It still gives you a very good overview of what Unity wants to offer.

# Plan

- Jobs 101
- Changes in Unity
- What is coming in 2017.x
- Best practices to “jobify” some tasks
- AI example

# Jobs 101

Why?

- It is a way for games to use the other cores in a simple manner when they are available

What is a job?

- A job is a function that performs a set of actions on a set of data
  - Data driven / Data centric approach (think SIMD, but spread out)
  - Most efficient when it can be done independently and in parallel

# Jobs 101 - Continued

When to use jobs?

- Not all your systems can be turned into jobs
  - Dependencies
- Some algorithms lend themselves better than others.
  - Repetitive, independent data generally a good target
    - Example: Path Finding, Transformations, Flocks, etc.

# Jobs 101 - Continued

Synchronization

- When executing multiple jobs over multiple processors, need a means to synchronize data.
  - Solution: Fencing
    - A Fence is a primitive that allows you to coordinate jobs and wait for data to be available
    - A main thread kicks off a number of jobs and waits for fence to be cleared
    - Once cleared, results can either be passed on to other jobs / collated.

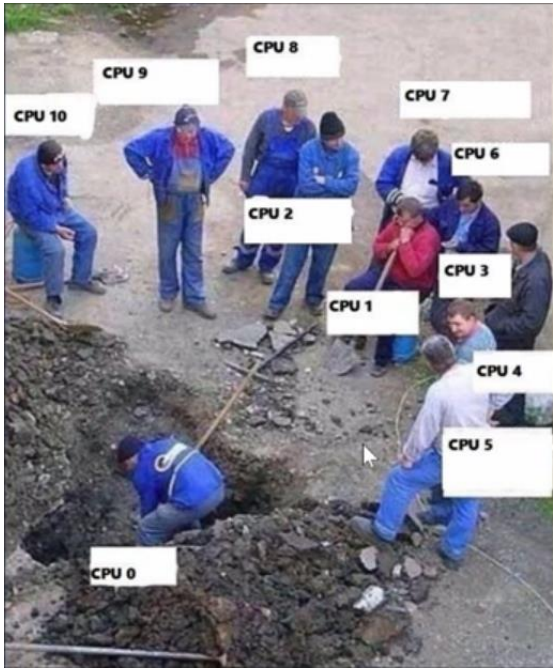
# Jobs 101 - Continued

Internally, Unity already has a job system in C++ that drives a lot of systems.

- With 2017, modularization and the process of exposing underlying systems means we've opened up our internal job system… but made it available in C#
- Using C# it's less difficult to make mistakes
  - Power and  flexibility combined with easy of use!

Targetted in 2017.2, or 2017.3, or 2018.x ☺

# Jobs 101 - Continued



# Jobs 101 - Continued

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# Jobs 101 - Continued

Jobs, or multi-threading an algorithm is a trade off between Effort (how much CPU usage to complete some amount of work) and Latency (how fast you want the result back)

If you build a table, by yourself, it's simpler than coordinating a team... but the team can do it faster

You are making a choice

- To coordinate your jobs, it will cost you memory and time to organize/distribute your jobs

# Jobs 101 - Continued

Not all algorithm works well

You might have to redesign a naive design to organize the data so it works

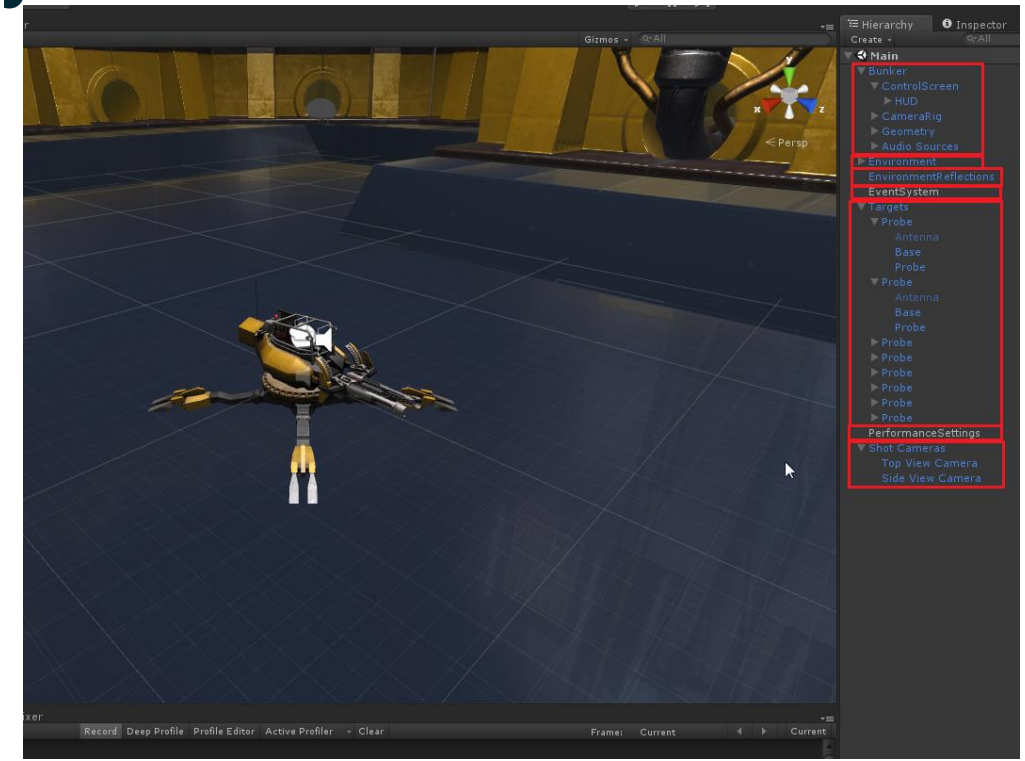
iPhone 5S : has two threads, one for main, one for rendering ... if you add 6 more threads, then you may impact the performance and reduce it

# Changes in Unity

# Changes in Unity

Internal changes

- TransformHierarchy
- TransformChangeDispatch



# What is coming in 2017.x

# What is coming

- Jobs
- New C# attributes
- New types
  - Intrinsic (float3 for instance)
  - NativeArray are new VALUE type. It's a struct.
    - The data is actually in native and the handle enforces threading restriction and allows access from native of C# without marshaling
    - Accessible on both sides (C++ and C#)
    - And you will need to dispose of them
- New compiler
  - Only used on jobs

```
public class JobifiedBehaviour : MonoBehaviour
{
    public struct JobifiedData
    {
        [ReadOnly]
        public NativeArray<float> inData;

        public NativeArray<float> outData;

        public void Execute(int index)
        {
            outData[index] = inData[index] + 1.0;
        }
    }

    void Update()
    {
        JobifiedData jobData = new JobifiedData();
        jobData.inData = new NativeArray<float>(100, Allocator.Persistent);
        jobData.outData = new NativeArray<float>(100, Allocator.Persistent);
        jobData.Schedule(100, 2).Complete();
        jobData.inData.Dispose();
        jobData.outData.Dispose();
    }
}
```

# Why is the new compiler so much faster?

- Works with intrinsic types
- Knows about vectorization
  - SIMD
- Using math asm calls
  - C# is just a VM…

Trade off between performance and precision

SIN -> lookup table, other math optimizations

Mono compiler to IL -> IL to internal domain model -> optimize -> send to LLVM -> write executable code in memory

# What it is NOT for

- Jobs over multiple frames
- Algorithms that may not converge
- Call the Unity API or .NET API on other threads

# Comparison

| | Async/Tasks | C# Job System | Native multi-threading |
|---|---|---|---|
| .NET libraries | X | - | X |
| Transform, Mesh, Textures manipulations | - | X | - |
| Unity API | - | - | - |
| Standalone algorithm | X | - | X |

# Best practices to jobify

# Best practices

- Data Oriented Design (DOD)
  - Mainly used to optimize data layout for a physical architecture

    Be careful, it might not be true for all hardware...

    You may even want different data org for different tiers of hardware
    -> Use our Device Intelligence!
- Design for cache coherency
- Group data physically in memory

    In C# that means struct in arrays
- Forget MonoBehaviour based designs

# Best practices

TLDR; You want to put things in arrays and process them in order

Note : This also works with single threaded architecture

# Best practices – Steps

1 – Old school MonoBehaviour design

2 – Move Functionality to Component System

3 – Change simple data to IComponentData

Manager containing NativeList of that data is automatically created for you

4 - Switch to Multithreaded updating using C# job system

# Best practices – Step 1

```
public class RotatorOnUpdate : ScriptBehaviour {
	[SerializeField]
	float 				m_Speed;

	public float speed
	{
		get { return m_Speed; }
		set { m_Speed = value; }
	}

	protected override void OnUpdate ()
	{
		base.OnUpdate ();
		transform.rotation = transform.rotation *
			Quaternion.AngleAxis (m_Speed * Time.deltaTime, Vector3.up);
	}
}
```

# Best practices – Step 2

```
namespace ECS
{
public class RotationSpeedComponent : ScriptBehaviour
{
        public float speed;
}

public class RotatingSystem : ComponentSystem
{
        // NOTE: InjectTuples scans all [InjectTuples] in the class
        // and returns the union of objects that have both Transform and LightRotator
        [InjectTuples]
        public ComponentArray<Transform> m_Transforms;

        [InjectTuples]
        public ComponentArray<RotationSpeedComponent> m_Rotators;
[...]
```

# Best practices – Step 2

```
[...]
        override protected void OnUpdate()
        {
                base.OnUpdate ();

                float dt = Time.deltaTime;
                for (int i = 0; i != m_Transforms.Length;i++)
                {
                        m_Transforms[i].rotation = m_Transforms[i].rotation *
                                Quaternion.AngleAxis(dt * m_Rotators[i].speed, Vector3.up);
                }
        }
}
}
```

# Best practices – Step 3

```
// New light weight component is a struct.
// The data is stored in a NativeArray owned by a LightWeightComponentManager<>
//
// * Data is stored in tightly packed array (Good for performance and also allows for
//   safe jobification)
// * Allows for light weight components to live without their game object,
//   enabling massive scale lightweight simulation (Think 2M instances in certain games)

[Serializable]
public struct RotationSpeed : IComponentData
{
        public float speed;

        public RotationSpeed (float speed) { this.speed = speed; }
}
```

# Best practices – Step 3

```
public class RotatingSystem : ComponentSystem
{
        // NOTE: InjectTuples scans all [InjectTuples] in the class
        // and returns the union of objects that have both Transform and LightRotator
        [InjectTuples]
        public ComponentArray<Transform> m_Transforms;
        [InjectTuples]
        public ComponentDataArray<RotationSpeed>        m_Rotators;

[...]
```

# Best practices – Step 3

```
[...]
        override protected void OnUpdate()
        {
                base.OnUpdate ();

                float dt = Time.deltaTime;
                for (int i = 0; i != m_Transforms.Length;i++)
                {
                        m_Transforms[i].rotation = m_Transforms[i].rotation *
                                Quaternion.AngleAxis(dt * m_Rotators[i].speed, Vector3.up);
                }
        }
}
```

# Best practices – Step 4

```
public class SystemRotator : ComponentSystem
{
          // NOTE: InjectTuples scans all [InjectTuples] in the class
          // and returns the union of objects that have both Transform and
LightRotator

          [InjectTuples]
          public TransformAccessArray                m_Transforms;

          [InjectTuples]
          public ComponentDataArray<RotationSpeed>    m_Rotators;
[...]
```

# Best practices – Step 4

```
[...]

        protected override void OnUpdate()
        {
                base.OnUpdate ();

                var job = new RotatorJob();
                job.dt = Time.deltaTime;
                job.rotators = m_Rotators;

                job.Schedule(m_Transforms);
        }
[...]
```

# Best practices – Step 4

```
[...]

        struct RotatorJob : IJobParallelForTransform
        {
                public float dt;
                [ReadOnly]
                public ComponentDataArray<RotationSpeed>      rotators;

                public void Execute(int i, TransformAccess transform)
                {
                        transform.rotation = transform.rotation *
                                Quaternion.AngleAxis(dt * rotators[i].speed,
Vector3.up);
                }
        }
}
```

# Boids - bird-oid object simulation

- Lets’s look at the code…

# Example of AI for an RTS

# RTS

- Rethink your normal A* algorithm
  - Tiling system
  - Influence map
  - Hierarchical Graph were you calculate nodes in jobs and then do a simpler traversal of the graph
- If you use a BlackBoard as a knowledge database
  - It is easy to create small jobs on a per unit/squad basis
  - You can precalculate multiple jobs in parallel that are then going to be used as knowledge sources for the BlackBoard

Automated planning

# Thank you!

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