

COMP140-GAM160: Games Programming

7: Memory

Learning outcomes

- ▶ **Understand** Memory in modern object orientated languages
- ▶ **Compare** memory models in managed and unmanaged languages
- ▶ **Understand** the role of the profiler in measuring performance in games

Memory

Memory Refresher

- ▶ Recall that:
 - ▶ Dynamic memory, allocated on the **Heap** and is **growable**
 - ▶ Static memory, allocated on the **Stack** and is **fixed size**

Stack Memory

- ▶ When you allocate value types (int, float, short, char etc), these are allocated on the stack
- ▶ Values allocated on the stack are local, when they drop out of scope they are deallocated
- ▶ Values passed into functions are copied onto the stack
- ▶ The stack is of fixed size
 - ▶ C# - **1MB**
 - ▶ C++ Visual Studio - **1MB**

Stack Memory Example 1

```
void Update()  
{  
    int x=10;  
    int y=10;  
  
    Vector2 pos=Vector2(x,y);  
} //<-- x, y and pos drop out of scope here
```

Stack Memory Example 2

```
class MonsterStats
{
private:
    int health;
    int strength;
public:
    MonsterStats()
    {
        health=100;
        strength=10;
    };

    void ChangeHealth(int h)
    {
        health+=h;
    }; //<- h drops out of scope here

    void ChangeStrength(int s)
    {
        strength+=s;
    }; //<- s drops out of scope here
};

void main()
{
    //Create an instance of the class on the stack
    MonsterStats stats=MonsterStats();
    stats.ChangeHealth(10);
    stats.ChangeStrength(-2);
} //<-- stats drops out of scope here
```

Heap Memory

- ▶ Otherwise known as dynamic memory
- ▶ Types allocated with the **new** keyword are allocated on the heap
- ▶ The new operator returns a reference to the type and can be allocated to a pointer (C++)
- ▶ This heap is managed by the programmer in C++ (see **delete** keyword) or the garbage collector in C#
- ▶ In C++ is very important that you delete anything allocated on the heap
- ▶ **for every new, you need a matching delete**
- ▶ In the Unreal Engine objects can be Garbage Collected

Heap Memory Example 1 - C#

```
public class MonsterStats
{
    private int health;
    private int strength;

    public MonsterStats()
    {
        health=100;
        strength=10;
    }

    public void ChangeHealth(int h)
    {
        health+=h;
    }//<- h drops out of scope here

    void ChangeStrength(int s)
    {
        strength+=s;
    }//<- s drops out of scope here
}

void Start()
{
    //Create an instance of the class on the Heap
    MonsterStats new stats=MonsterStats();
    stats.ChangeHealth(10);
    stats.ChangeStrength(-2);
}
```

Heap Memory Example 2 - C++

```
class MonsterStats
{
private:
    int health;
    int strength;
public:
    MonsterStats()
    {
        health=100;
        strength=10;
    }

    .....
}

void main()
{
    //Create an instance of the class on the Heap
    MonsterStats * stats=new MonsterStats();
    stats->ChangeHealth(10);
    stats->ChangeStrength(-2);

    if (stats)
    {
        delete stats;
        stats=nullptr;
    }
}
```

Data Types in C#

- ▶ Value types are primitives such as int, bool, float etc
- ▶ Structs are custom value types (see example)
- ▶ Reference types are anything declare with the **class**, **interface** & **delegate**
- ▶ In addition to this strings are also reference types
- ▶ Value types are allocated on the stack
- ▶ Reference type are allocated on the heap

Struct Example - C#

```
public struct MonsterStats
{
    private int health;
    private int strength;

    public MonsterStats()
    {
        health=100;
        strength=10;
    }
}

void Start()
{
    //Create an instance of the struct on the stack
    MonsterStats stats=new MonsterStats();
    stats.ChangeHealth(10);
    stats.ChangeStrength(-2);
}
```

Passing Types

- ▶ In C#, when we call a method and pass some data as a parameter we either pass by value or we pass by reference.
- ▶ We can mark a parameter with the **ref** or **out** keyword (see example)
- ▶ Reference types are always passed by reference
- ▶ In C++, we can pass by value or reference. In addition to this, we can also pass in a pointer
- ▶ We can mark parameter with **&** to pass by Reference
- ▶ Larger data types should be passed by Pointer or Reference

Passing Example 1 - C#

```
int x=10;

void Adder(ref int value,int v)
{
    value+=v;
}

Adder(ref x,10);
//x would now be 20 after this
```

Passing Example 2 - C#

```
void SetupMonster(ref MonsterStats stats, int health, int strength)
{
    //if we use the ref keyword MonsterStats has to be initialised
    stats.health=health;
    stats.strength=strength;
}

void CreateMonster(out MonsterStats stats, int health, int strength)
{
    //when we use out, it means we can initialise inside the function
    stats=new MonsterStats();
    stats.health=health;
    stats.strength=strength;
}

//Calling code
MonsterStats goblinStats=new MonsterStats();
SetupMonster(ref goblinStats,10,2);

MonsterStats orcStats;
CreateMonster(out orcStats,20,4);
```

Passing Example 1 - C++

```
int x=10;

void Adder(int &value,int v)
{
    value+=v;
}

Adder(x,10);
//x would now be 20 after this
```


Passing Example 2 - C++

```
void SetupMonster(MonsterStats &stats, int ↵  
    health, int strength)  
{  
    stats.health=health;  
    stats.strength=strength;  
}  
  
//Calling code  
MonsterStats * goblinStats=new MonsterStats();  
SetupMonster(goblinStats,10,2);
```

Strings

Strings

- ▶ Strings act like value types but they are actually reference types (C#)
- ▶ This means we need to be careful in allocating new strings
- ▶ **And** doing any operations using strings such as concatenation using +
- ▶ In C# you should use the **StringBuilder** class
- ▶ In C++ you should use the **stringstream** class

String Builder Example - C#

```
//We need to use the namespace - System.Text  
using namespace System.Text  
  
//Create the string builder with a capacity of ↵  
1024  
StringBuilder sb=new StringBuilder(1024,1024);  
  
//Append some text  
sb.Append("Name: ");  
sb.Append("Brian");  
sb.Append(" Health: ");  
sb.Append(100);  
  
//Get the String from the String Builder  
string s=sb.ToString();
```

String Stream Example - C++

```
//We need to include the sstream header file
#include <sstream>

//Create String Stream
std::ostringstream stringStream;

//Append some text
stringStream << "Name: ";
stringStream << "Brian";
stringStream << " Health: ";
stringStream << 100;

//Grab the constructed string from string stream
std::string s=stringStream.str();
```

Memory Management

Garbage Collection in C#

- ▶ In C# there is an inbuilt Garbage Collector which will walk through the Object Graph
- ▶ It will check to see if the object is still allocated, if not, the Garbage Collector will cleanup the object
- ▶ This process is automatic and is tuned for maximum performance
- ▶ <https://unity3d.com/learn/tutorials/topics/performance-optimization/optimizing-garbage-collection-unity-games>

Memory Management in C++

- ▶ In C++ there is no Garbage Collection, you have to manually delete objects when no longer needed
- ▶ Worth repeating **for every new, you need a matching delete**

Memory - General Good Practices

- ▶ Never allocate or deallocate during game update (this includes Instantiate)
- ▶ Use Memory Pools to recycle objects
 - ▶ Unity - <https://unity3d.com/learn/tutorials/topics/scripting/object-pooling>
 - ▶ C++ - <http://gameprogrammingpatterns.com/object-pool.html>
- ▶ Cache frequently used objects

Coffee Break

Exercise

Exercise - All Students

- ▶ Complete exercise from last week
- ▶ Then move onto this weeks (on next slides)

String Exercise - All Students

- ▶ Download one of the following Projects
 - ▶ BA Students - `https://github.com/Falmouth-Games-Academy/GAM160-Exercises`
 - ▶ BSc Students - `https://github.com/Falmouth-Games-Academy/COMP140-Exercises`
- ▶ Replace all string processing with `StringBuilder` if using C# or `StringStream` if using C++

Debugging Exercise - BA Students

- ▶ Watch the following video - <https://unity3d.com/learn/tutorials/topics/scripting/debugging-unity-games-visual-studio>
- ▶ Open DebugExercise from the GAM160 Exercises Repository
- ▶ Use the debugger to find answers to the questions which are shown as comments within the Start() function

Debugging Exercise - BSc Students

- ▶ Read the following - <https://tutorials.visualstudio.com/vs-get-started/debugging>
- ▶ Open DebugExercise project
- ▶ Use the debugger to find answers to the questions Q1 and Q2 which are shown as comments within the main function