

COMP140-GAM160: Further Programming

## **3: Inheritance and Polymorphism**

# Learning outcomes

- ▶ **Understand** Inheritance in Object Orientated Programming
- ▶ **Understand** Polymorphism role in creating Games
- ▶ **Apply** your knowledge of Inheritance and Polymorphism to programming problems

# **Classes Review**

# Classes

- ▶ Let us look at Classes again
- ▶ Classes allow us to create our own data types
- ▶ They consist of a series of data(variables) and functions that operate on the data
- ▶ Functions and variables inside the class can be marked with the following **access specifiers**
  - ▶ **Public**: Can be accessed directly
  - ▶ **Private**: Can only be accessed inside the class
  - ▶ **Protected**: Acts like private, but child classes can access

# Class Examples - C++

```
class Player
{
public:
    Player()
    {
        Health=100;
    };

    void TakeDamage(int health)
    {
        Health-=health;
    };

    void HealDamage(int health)
    {
        Health+=health;
    };

    ~Player() {};
private:
    int Health;
};
```

# Class Examples - C# Unity

```
public class Player
{
    private int Health;

    public Player()
    {
        Health=100;
    }

    public void TakeDamage(int health)
    {
        Health-=health;
    }

    public void HealDamage(int health)
    {
        Health+=health;
    }
}
```

# Classes vs Structs

- ▶ A **Struct** is pretty much the same as a **Class**
- ▶ The only difference in functionality, by default:
  - ▶ Everything in a **Class** is **private**
  - ▶ Everything in a **Struct** is **public**
- ▶ Difference by convention:
  - ▶ Structs are used for holding related data and tend not to have functions
  - ▶ Classes hold data and functions

# Creating an Instance - C++

```
//Creating on the stack, this will be deleted when it drops out of scope  
Player player1=Player();  
  
//Call take damage function, notice we use . to access functions  
player1.TakeDamage(20);  
  
//Creating on the Heap, please delete!!  
Player * player2=new Player();  
  
//Call take damage function, note we use -> to access functions  
player2->TakeDamage(20);  
  
//Deleting player2 on the heap  
if (player2)  
{  
    delete player2;  
    player2=nullptr;  
}
```



# Creating an Instance - C#

```
//Create a player  
Player player1=new Player();  
  
//Call take Damage  
player1.TakeDamage(50);
```

# Constructor & Destructor

- ▶ **Constructors** are called when you create an instance
- ▶ Constructors can take in zero or many parameters
- ▶ You need to declare different version of the constructor
- ▶ Destructors are called when the instance has been deleted (by the dropping out of scope, or explicitly deleted in C++)
- ▶ Constructors have to be names the same as the class
- ▶ Destructors have the same name as the class but prefixed with ~ (tilde symbol)

# Constructors C++

```
public class Player
{
    public:
        Player()
        {
            Health=100;
            Strength=10;
        };

        Player(int health)
        {
            Health=health;
            Strength=10;
        };

        Player(int health,int strength)
        {
            Health=health;
            Strength=strength;
        };
        ~Player(){};
private:
    int Health;
    int Strength;
};
```

# Constructors C++

```
//Create a player  
Player * player1=new Player();  
  
//Create another player with the one parameter constructor  
Player player2=Player(10);  
  
//Create another player with the two parameter constructor  
Player * player3=new Player(100,20);  
  
delete player1;  
delete player2;
```

# Constructors C#

```
class Player
{
    private int Health;
    private int Strength;

    public Player()
    {
        Health=100;
        Strength=10;
    }

    public Player(int health)
    {
        Health=health;
        Strength=10;
    }

    public Player(int health,int strength)
    {
        Health=health;
        Strength=strength;
    }
}
```

# Using Constructors C#

```
//Create a player with the default no parameter constructor  
Player player1=new Player();
```

```
//Create a player with one parameter constructor  
Player player2=new Player(50);
```

```
//Create a player with two parameters constructor  
Player player3=new Player(120,50);
```

# Encapsulation

- ▶ In OOP, Encapsulation is a key principle
- ▶ This refers to the idea that all data in a class should be hidden by the caller
- ▶ This means that **all** variables should be marked **private** or **protected**
- ▶ And only functions inside the class can operate on the data
- ▶ **Unity - but what about exposing variables to the editor?**
  - ▶ You should still make everything private
  - ▶ Then use the **(SerializeField)** attribute to make the variable visible in the inspector

# Class Examples - C# Unity

```
using UnityEngine;

public class Player : MonoBehaviour
{
    (SerializeField)
    private int Health;

    public Player()
    {
        Health=100;
    }

    public void TakeDamage(int health)
    {
        Health-=health;
    }

    public void HealDamage(int health)
    {
        Health+=health;
    }
}
```



# Inheritance

# Introduction to Inheritance

- ▶ One of the key features of OOP languages is **Inheritance**
- ▶ This allows you to **Derive** a new class from an existing one
- ▶ When this is done, the new class automatically inherits the variables and functions of the **parent** class
- ▶ Advantages of inheritance includes
  - ▶ **Code reuse:** There is no need to redefine functionality, you can just inherit from a base class
  - ▶ **Fewer errors:** If you build on existing class that is bug free then you are more likely to have less errors
  - ▶ **Cleaner code:** because of the increase of code reuse then your code is more modular and reusable.

# Inheritance Example - C#

```
public class Enemy : MonoBehaviour
{
    [SerializeField]
    protected int Damage;

    void Start()
    {
        Damage=1;
    }

    public void Attack()
    {
        Debug.Log("The attack causes "+Damage.ToString()+" damage");
    }
}
```

# Inheritance Example - C#

```
public class Boss : Enemy
{
    (SerializeField)
    private int DamageMultiplier;

    void Start()
    {
        Damage=5;
        DamageMultiplier=2;
    }

    public void Attack()
    {
        Debug.Log("The attack causes "+Damage.ToString()+" damage");
    }

    public void SpecialAttack()
    {
        int totalDamage=Damage*DamageMultiplier;
        Debug.Log("Special attack causes "+totalDamage.ToString()+" damage");
    }
}
```

# Inheritance Example - C++

```
public class Enemy
{
    public:
        Enemy()
        {
            Damage=1;
        };

        virtual ~Enemy()
        {
        }

        void Attack()
        {
            std::cout<<"The attack causes "<<Damage<<" damage"<<std::endl;
        }
    protected:
        int Damage;
}
```

# Inheritance Example - C++

```
public class Boss : public Enemy
{
    public:
        Boss()
        {
            Damage=5;
            DamageMultiplier=2;
        };

        ~Boss()
        {
        }

        void SpecialAttack()
        {
            int totalDamage=Damage*DamageMultiplier;
            std::cout<<"Special attack causes "<<totalDamage<<" damage"<<std::endl;
        }

    protected:
        int DamageMultiplier;
}
}
```

# Overriding

- ▶ You can override functions in the base class by providing a new version of the function
- ▶ You should mark any function that you are going to override with the **virtual** keyword
- ▶ Then in the child class, you have a function with the same signature which is marked with the **override** keyword

# Overriding Example - C#

```
public class Enemy : MonoBehaviour
{
    [SerializeField]
    protected int Damage;

    void Start()
    {
        Damage=1;
    }

    public virtual void Attack()
    {
        Debug.Log("The attack causes "+Damage.ToString()+" damage");
    }
}
```



# Overriding Example - C#

```
public class Boss : Enemy
{
    void Start()
    {
        Damage=5;
    }

    public override void Attack()
    {
        base.Attack();
        Damage+=1;
        Debug.Log("This is the boss attacking");
    }
}
```

# Overriding Example - C++

```
public class Enemy
{
public:
    Enemy()
    {
        Damage=1;
    };

    //Make sure you mark any base class destructor as virtual!
    virtual ~Enemy()
    {
    }

    virtual void Attack()
    {
        std::cout<<"The attack causes "<<Damage<<" damage"<<std::endl;
    }
protected:
    int Damage;
}
```

# Overriding Example - C++

```
public class Boss : public Enemy
{
public:
    Boss()
    {
        Damage=5;
    };

    ~Boss()
    {
    }

    void Attack() override
    {
        Enemy::Attack();
        Damage+=1;
        std::cout<<"This is the boss attacking"<<std::endl;
    }
protected:
    int DamageMultiplier;
}
```

# Polymorphism

# Introduction to Polymorphism

- ▶ Polymorphism is another key feature of OOP languages
- ▶ The basic idea is that instances of a derived class can be treated as objects of the basic class
- ▶ They can be used as parameters for functions and in collections
- ▶ We then call the functions on these objects and our code will call the 'correct' version of the function
- ▶ This is best illustrated by an example

# Polymorphism example C#

```
class Enemy{/*This has been defined in previous slides*/}  
class Boss : Enemy{/*Again see previous slides*/  
  
    //This function will be in monobehavior  
    void DoAttacks(Enemy enemy)  
    {  
        enemy.Attack();  
    }  
  
    //We probably have grabbed these from other game objects  
    Enemy goblin=new Enemy();  
    Enemy orc=new Enemy();  
    Boss ogre=new Boss();  
  
    //Call DoAttack on each one of these  
    DoAttack(goblin);  
    DoAttack(orc);  
    DoAttack(ogre);  
  
    //This even works if each instance is in a list  
    List<Enemy> enemies=new List<Enemy>();  
    enemies.Add(goblin);  
    enemies.Add(orc);  
    enemies.Add(ogre);  
  
    foreach(Enemy e in enemies)  
    {  
        DoAttack(e);  
    }
```

# Polymorphism example C++

```
class Enemy{/*This has been defined in previous slides*/}
class Boss : Enemy{/*Again see previous slides*/}

//This function will be in monobehavior
void DoAttacks(Enemy *enemy)
{
    enemy->Attack();
}

//We probably have grabbed these from other game objects
Enemy goblin=new Enemy();
Enemy orc=new Enemy();
Boss ogre=new Boss();

//Call DoAttack on each one of these
DoAttack(goblin);
DoAttack(orc);
DoAttack(ogre);

//This even works if each instance is in a list
std::vector<Enemy*> enemies;
enemies.push_back(goblin);
enemies.push_back(orc);
enemies.push_back(ogre);

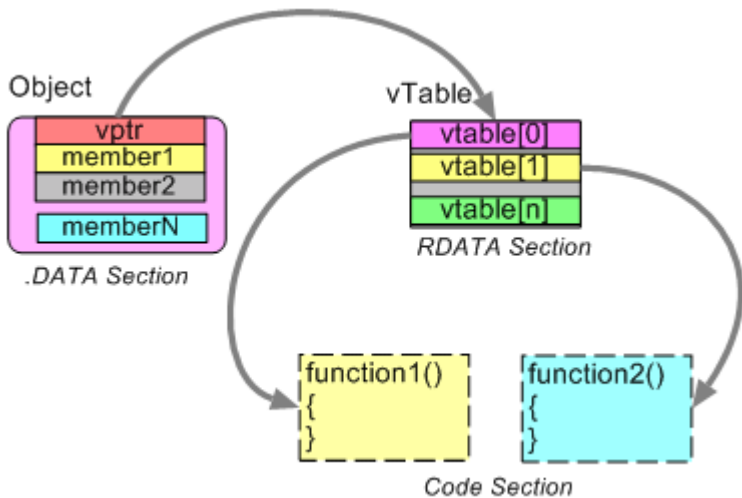
for(Enemy * e : enemies)
{
    DoAttack(e);
}
```

# Polymorphism: Some details

- ▶ This is known as runtime Polymorphism and it works by making use of a construct called a virtual function table (a.k.a vtable)
- ▶ A compiler builds up a vtable during compilation
- ▶ Basically a hidden pointer to the vtable is added to the object and is used to call the correct version of the function
- ▶ Another thing to note, this has a cost so please don't overuse Polymorphism!



# Vtable



# Abstract Classes & Interfaces

- ▶ An **Interface** is very similar to an abstract class, the only difference is that every function in an Interface is marked as pure virtual
- ▶ If you then inherit from an interface, you have to provide an implementation of all pure virtual functions
- ▶ The difference between Abstract classes and Interfaces, is that in C# you can only inherit from one class (include abstracts)
- ▶ But you can inherit from multiple Interfaces

# Abstract Classes & Interfaces

- ▶ An **Interface** is very similar to an abstract class, the only difference is that every function in an Interface is marked as pure virtual
- ▶ If you then inherit from an interface, you have to provide an implementation of all pure virtual functions
- ▶ The difference between Abstract classes and Interfaces, is that in C# you can only inherit from one class (include abstracts)
- ▶ But you can inherit from multiple Interfaces

# Abstract Class Example C#

```
public abstract class BaseEnemy
{
    public abstract void Attack();

    public void Jump()
    {
        //Do jump code
    }
}

public class Orc : BaseEnemy
{
    //we have to implement attack but no need to implement Jump
    public void Attack()
    {
        //do attack
    }
}
```

# Interface Example C#

```
interface Jump
{
    void DoJump();
}

interface Attack
{
    void DoAttack();
}

public class Orc : Jump, Attack
{
    //we have to implement Attack and Jump Interface
    public void DoAttack()
    {
        //do attack
    }

    public void DoJump()
    {
        //do Jump
    }
}
```

# Abstract Class Example C++

```
class BaseEnemy
{
public:
    //Make sure we have a destructor defined!
    virtual ~BaseEnemy(){};
    virtual void Attack()=0;
    void Jump()
    {
        //Do jump code
    };
}

class Orc : public BaseEnemy
{
public:
    //we have to implement attack but no need to implement Jump
    void Attack()
    {
        //do attack
    }
}
```

# Interface Example C#

```
class IJump
{
public:
    //We must provide a virtual destructor
    virtual ~Jump() {};
    void DoJump()=0;
}

class IAttack
{
public:
    virtual ~Attack() {};
    void DoAttack()=0;
}

class Orc : public IJump, public IAttack
{
    //we have to implement Attack and Jump Interface
public:
    void DoAttack()
    {
        //do attack
    }

    void DoJump()
    {
        //do Jump
    }
}
```

# Interface Discussion

- ▶ You can think of an Interface as a contract
- ▶ The derived class must implement the Interface's function
- ▶ I can leverage Polymorphism to work with interfaces
- ▶ This means that I can consume derived classes in a function that takes in pointers (in C++) or references (in C#)
- ▶ Or I can process a collection of instances that implement the Interface



# Interface Discussion

- ▶ Lastly, Interfaces a great tool for working with others. We as a group could create the interface together
- ▶ Then another programmer can write Classes which implement the Interface
- ▶ While another writes code which consumes instances of the Interface
- ▶ `https://stackoverflow.com/questions/4456424/what-do-programmers-mean-when-they-say-code-aga`

**Coffee Break**

# Exercise

# Exercise 1 - Inheritance

- ▶ Please use one of the following projects as a starting point
  - ▶ C# Unity -
  - ▶ C++ -
- ▶ You are creating an Fantasy RPG create a class hierarchy which represented the following Ranged Enemies, Melee Enemies, Healer Enemies
- ▶ Implement some functions for these classes
- ▶ Have you consider having a common base class?

## Exercise 2 - Polymorphism

- ▶ Now add a pure virtual attack function to the base class
- ▶ Change how attack is implemented in each derived class
- ▶ Add a few instances of each class to a collection
- ▶ Iterate through the collection and call the Attack function on each instance. This should be triggered off by a key press

# References