Video game development Techniques and methods

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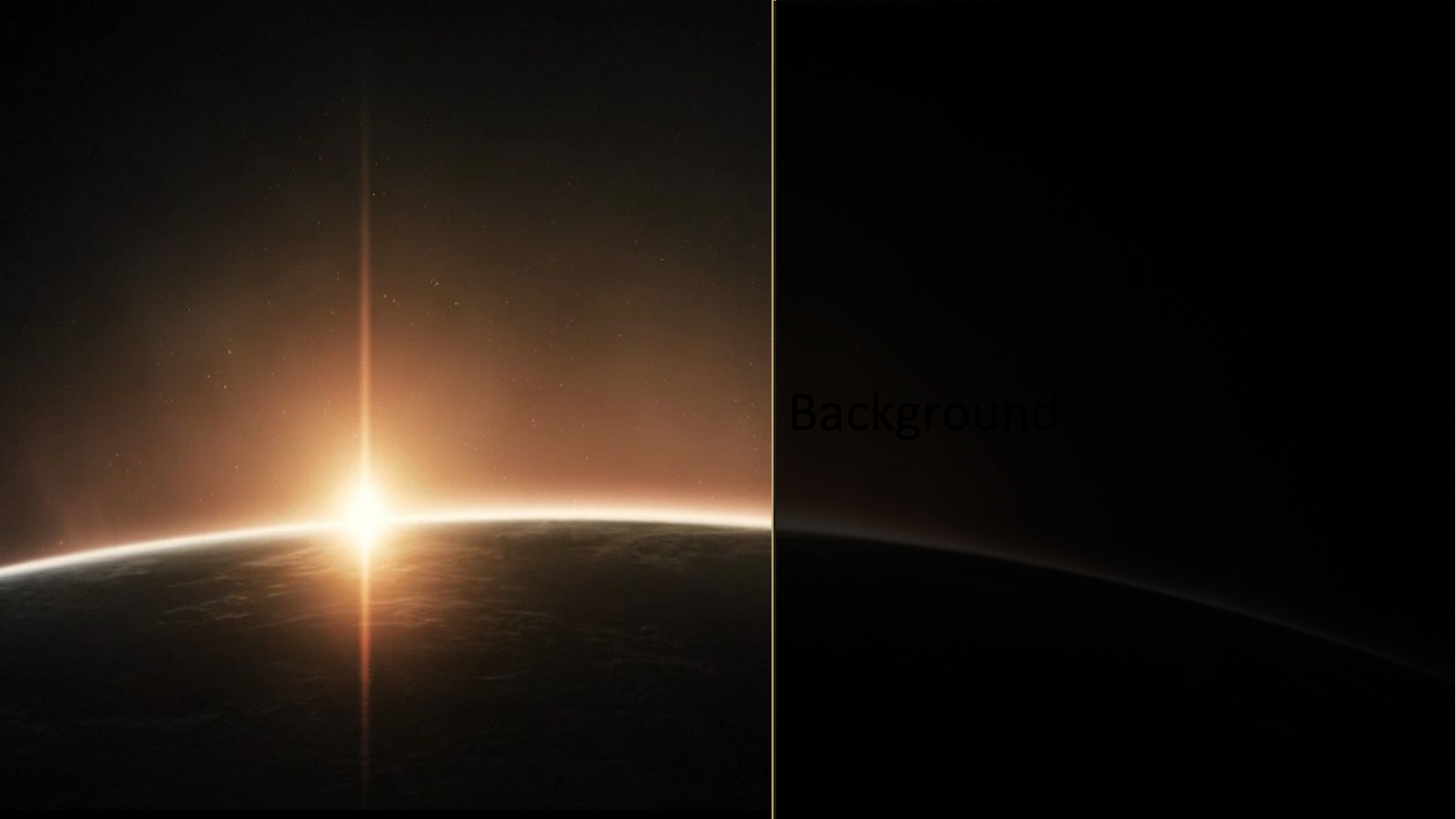
Real time | Good practices | Data driven


Background

Grand Strategy and 4X Games

Game that places focus on military strategy at the level of movement and use of an entire nation state or empire's resources.

- Explore
- Expand
- Exploit
- Exterminate

SEGA Europe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AMPLITUDE
STUDIOS

Amplitude Studios

Amplitude Studios

Amplitude Studios

12 Dev | 20 Dev | 30 Dev | 60 Dev | 80 Dev

2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019

SEGA

Endless Space

2012

Dungeon of the Endless

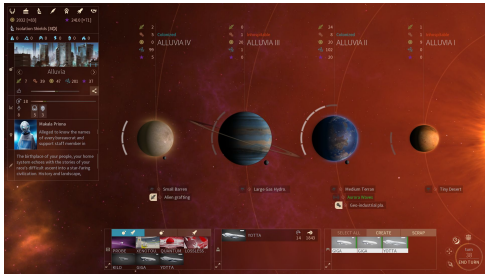
2014

Endless Legend

2014

Endless Space 2

2017




ES2
PATHFINDERS
LAUNCH TRAILER

Humankind

2020


HUMANKIND
ANNOUNCEMENT
TRAILER

Technologies

We use middlewares like Unity and Wwise.

We also develop our own tools and systems in C#:

- Gameplay framework
- User Interface engine
- GPU based particules system
- AI framework

Real time

How to improve performances?

Real Time

Target: 60 frames per seconds (or 120 for VR)

- **16 milliseconds** to compute a frame (for both CPU and GPU).
- Rendering take at least 50% of the CPU time frame.
  - Less than 8 milliseconds to compute the rest of the game (Gameplay, AI, Network, Audio …).

When you have a performance issue, check which processor is slowing down your framerate to know where you need to make optimizations.

What takes time

GPU side

- ~~Vertex count~~
- Fill rate
- Post processes (SSAO, FXAA, …)
- Custom Shaders

What takes time

CPU side

- Algorithms with big complexity
- ~~Arithmetic operations~~
- Allocating memory
- Accessing hard drive data
- Bad uses of your game engine
- Draw calls

How to be more efficient?

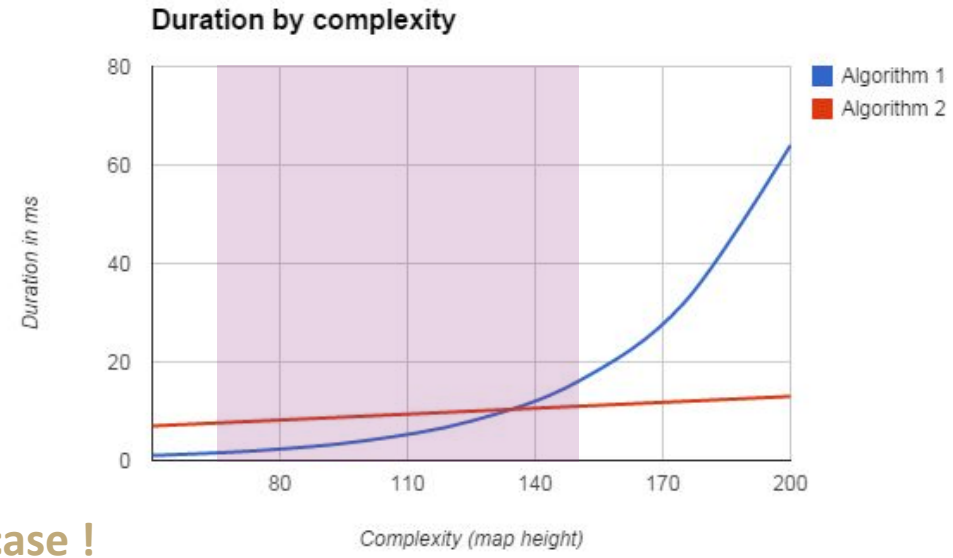
- Instantiate the least frequently you can.
- Adapt your problem to your scope.
- Use the right data structure.
- Try to reduce the algorithm complexity.
- Pre-compute data and store it in memory ...
- … but sometimes it’s faster to recompute data.
- Change to a faster (even if it’s less accurate) algorithm.

0100
0011
1001

Heavy Algorithmic Problems

Try to reduce the algorithm complexity but be careful with your context.

- Algorithm 1: O(n) = n^2
- Algorithm 2: O(n) = n



Map height are in [40,150]

→ **Algorithm 1 is more efficient in our case !**

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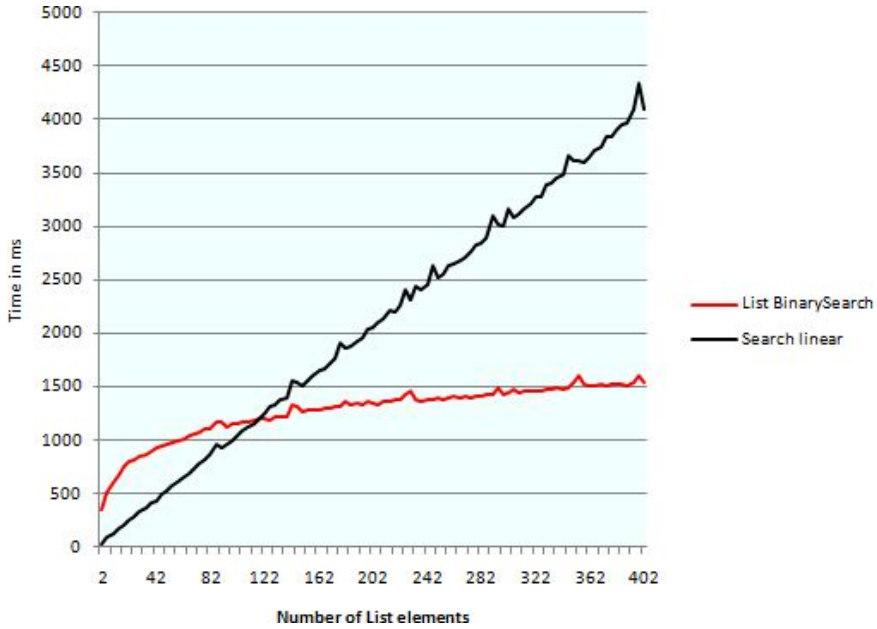
Heavy Algorithmic Problems

Take care of your constraints when you choose an algorithm.

Take care of your constraints when you choose an algorithm.

If you have a less than 100 elements, it's better to have a simple linear search than binary search.

Most of the time, KEEP IT SIMPLE !



Source: http://goo.gl/ub0CUg

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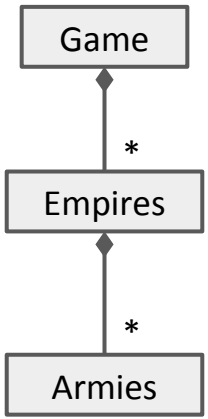
Heavy Algorithmic Problems

Retrieve objects (or components) can be very expensive !

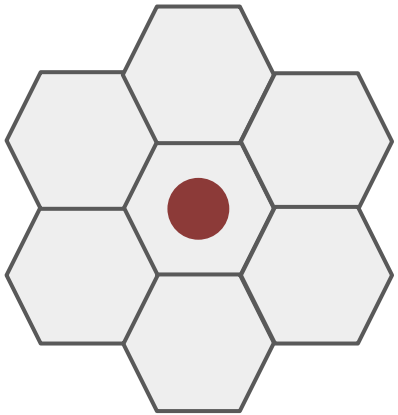



```
Army GetArmyAtPosition(int row, int column)
```

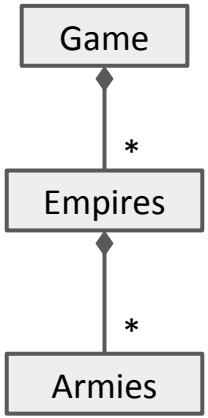
For 50 empires, 10 armies by empire it takes 500 iterations to retrieve this potential army.

```
Army GetArmyNearMe(int distance)
```

For a distance of 1 it takes 6 * 500 iterations.
For a distance of 2, 18 * 500 = 9000 iterations!



Heavy Algorithmic Problems

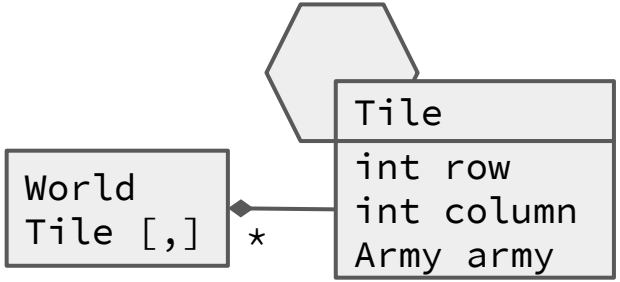


Solution 1

Instantiate a tile data structure with additional informations.

Problem

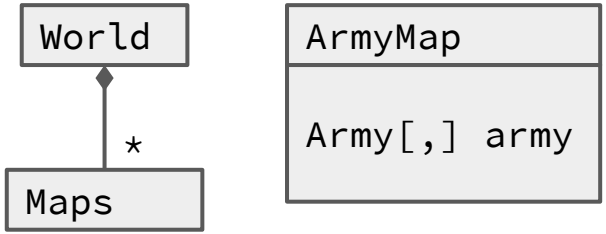
Aggregate data that are not related to each other.



Solution 2

Instantiate a map data structure that contains the informations with a cheap access by position.

A map is a matrix of size rows*columns which contains the armies references indexed by position.



Data Structures

There is a lot of differents data structures that exists for a good reason. Find out what you need and what is the best solution for your problem.

Array	Cannot grow automatically. Very fast assignation speed.
List	Automatically growing array. A bit slower than array but still very fast.
Dictionary	Can retrieve value from key with O(1) to O(n) worst case complexity. Enumerate and insertion are expensive.
SortedList	Sorted generic list. Slowed on insertion.

and many others ...

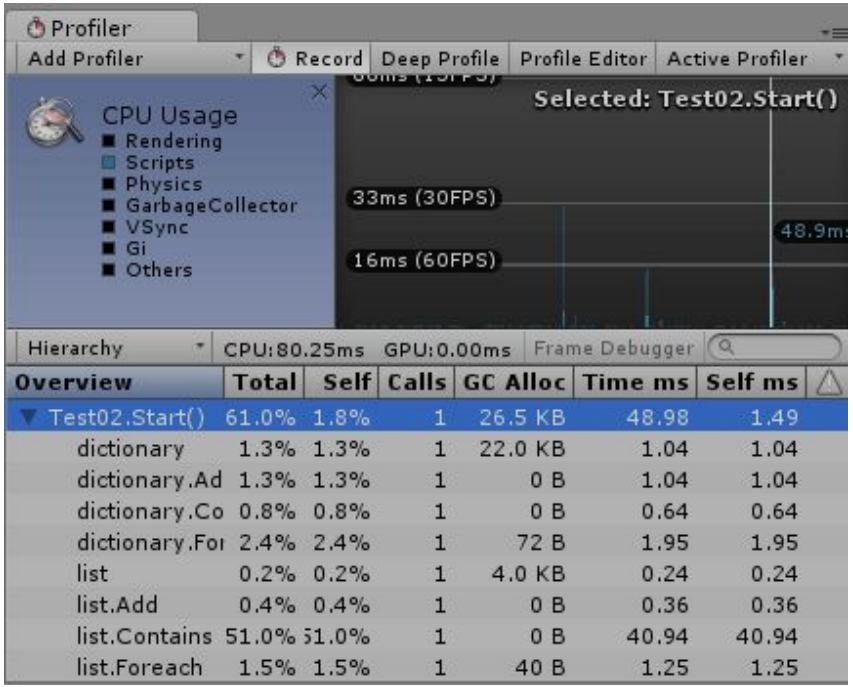
Data Structures

Take care of your constraints when you choose a data-structure.

List	Dictionary
Retrieve element fast: O(n)	Retrieve element very fast: O(1) to O(n) in the worst case **(75 times faster)**
Insertion is fast. (graph)	Insertion is slow **(175% slower)**
Foreach is fast.	Foreach is slow **(57% slower)**

Unity Profiler

To figure out what takes time. Use the unity profiler!




```
private List<int> list;

public void Start()
{
     Profiler.BeginSample("list");
     list = new List<int>(1000);
     Profiler.EndSample();
}
```

Unity Profiler

You can also use the Unity Profiler to see the GPU usage and the frame debugger to see how the frame is computed.

Bad uses of your game engine

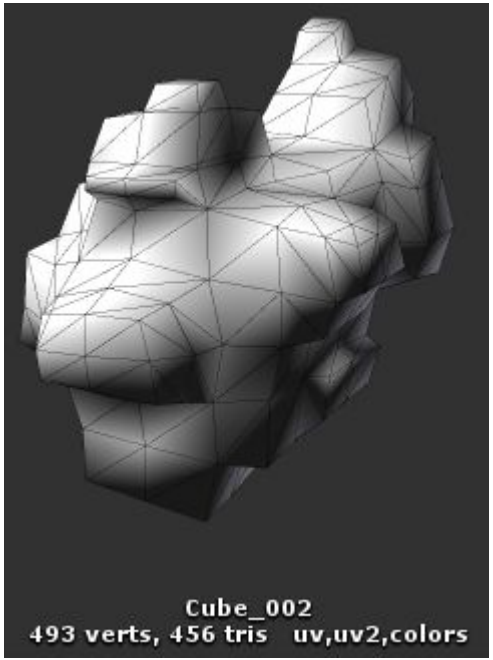
Your algorithms are not the only responsibles.

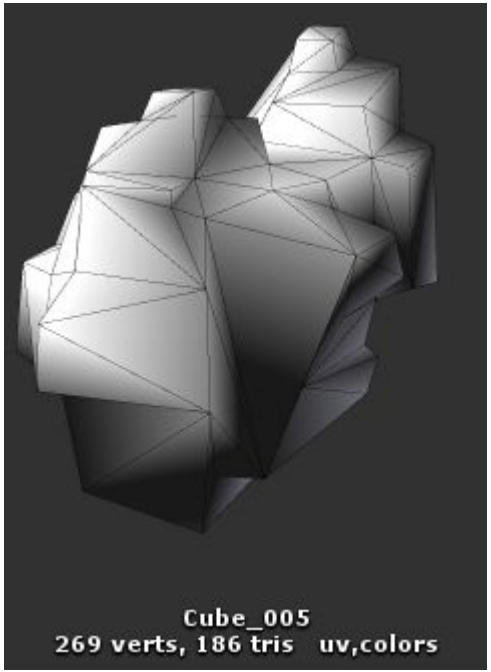
Be careful when you are using some features of your game engine.

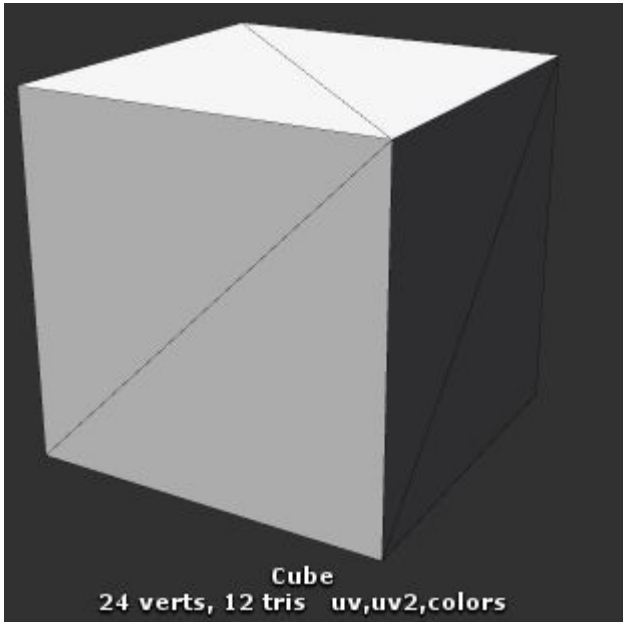
Find out how things works !

The engine tools are designed to be used in a certain way.

Bad uses of your game engine







Bad uses of your game engine

SendMessage and BroadcastMessage are slow. Don’t use this functions!

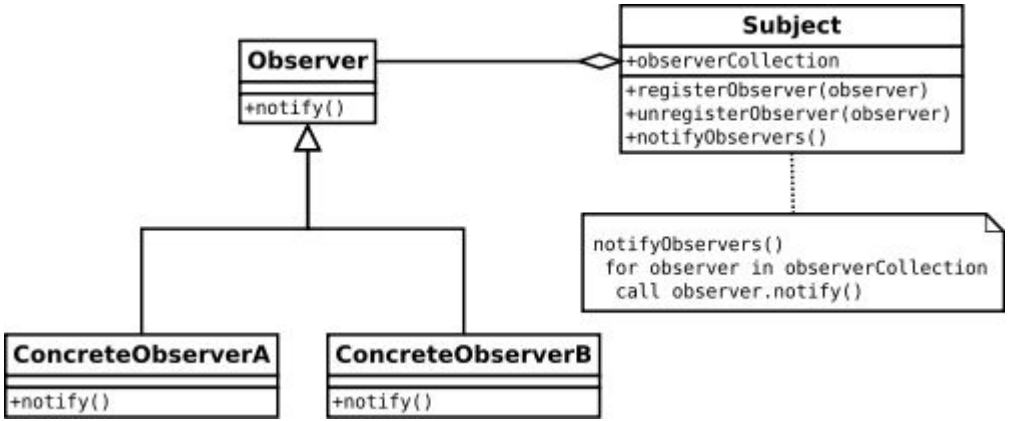
```
public class ExampleClass : MonoBehaviour {
    private void ApplyDamage(float damage) {
        print(damage);
    }

    private void Example() {
        SendMessage("ApplyDamage", 42.0f);
    }
}
```

1000 calls	SendMessage	5.34ms	Direct calls	0.05ms
Tree with 4 levels and 4 children per level	BroadcastMessage	2.32ms	Direct calls	0.07ms

Event C#

Definition: *An event in C# is a way for a class to provide notifications to clients of that class when some interesting thing happens to an object.*

Event is the c# implementation of the **observer design pattern**.



Event C#

Declaration

```
public class MyObservableObject
{
     public event System.EventHandler<System.EventArgs> OnSomethingAppend;

     public void SomethingAppend()
     {
          if (this.OnSomethingAppend != null)
          {
               this.OnSomethingAppend.Invoke(this, new System.EventArgs());
          }
     }
}
```

Event C#

Register and unregister observer

```
public class Observer
{
     public void RegisterObserver(MyObservableObject o)
     {
          o.OnSomethingAppend += this.SomethingAppendDelegate;
     }

     public void UnRegisterObserver(MyObservableObject o)
     {
          o.OnSomethingAppend -= this.SomethingAppendDelegate;
     }

     private void SomethingAppendDelegate(object sender, System.EventArgs args)
     {
          // Do stuff
     }
}
```

Event versus Polling

Definition

Polling, or polled operation, in computer science, refers to actively sampling the status of an external system as a synchronous activity.

Example

```
private void Update() {
    if (UnityEngine.Input.GetMouseButtonDown(0)) {
        // Do Something
    }
}
```

Memory Allocation

Static allocations

```
int n;
int x[10];
double m;
```

The compiler defines that the code requires 4 + 4 × 10 + 8 = 52 bytes on the **stack**.

This space is called stack because as functions get called, their memory gets added on top of existing memory.

As they terminate, they are removed in a LIFO (last in, first out) order.

Memory Allocation

Dynamic allocation

The function `void* malloc (unsigned int size)` requests `size` bytes of memory from the operating system, and returns the pointer to that location as a result.

This memory is assigned from the **heap** space.

This is called the heap space since it can be selected from any portion of the space that has not been allocated already.

While the stack remains nicely organized, memory in the heap tends to be more messy and all over the place. Hence the name.

Memory Allocation

Static allocation	**Dynamic allocation**
Size must be known at compile time	Size may be unknown at compile time
Performed at compile time	Performed at run time
Assigned to the stack	Assigned to the heap
First in last out	No particular order of assignment

Differences between statically and dynamically allocated memory

Memory Allocation

In C#

- Static allocation > Value type (int, float, struct, …)
- Dynamic allocation > Reference type (class)

A garbage collector takes care of the dynamic allocation.

Unlike in C++ class and struct are very different in c#.

Accessing Data

Retrieve a data from memory can takes time.

1 cycle to read a register
4 cycles to reach to L1 cache
10 cycles to reach L2 cache
75 cycles to reach L3 cache
hundreds of cycles to reach main memory.
Between **0.08 and 0.16 ms** to reach SSD.
Between **0.2 and 0.8 ms** to reach HDD.

Sources: http://goo.gl/uUdiOV - http://goo.gl/5DOUIV

Instantiate is expensive

In Unity:

- **0.04 ms** to compute the arithmetic mean of 15 000 elements.
- **1 ms** to instantiate 15 000 empty classes.
- **3 ms** to instantiate 15 000 classes that contains a float value.
- **1 ms** to instantiate 100 empty prefabs.
- **2.8 ms** to instantiate 100 cube prefabs.

Test processor : Intel core i5-3570K @ 3.4 Ghz

Shoot’em up Project

Project Control instantiation

In the shoot them up project you need to instantiate some objects during game:

- A bullet each time an avatar is firing
- An enemy each time a new one is spawning

If a lot of instantiations are processed at the same time, it could produce some freezing of your game (specially if you run on small device, like smartphone).

You need to handle the worst case ! (spawning of X avatar and Y bullets at the same frame).

You must control the instantiation of your objects.

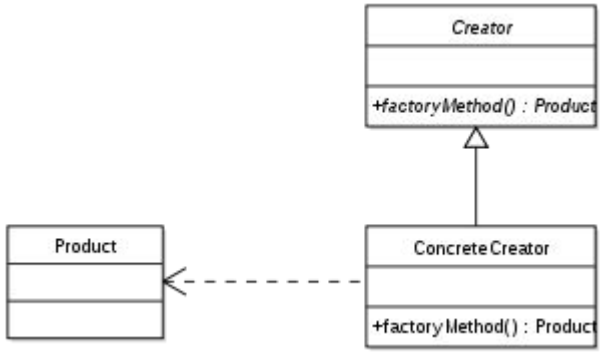
Project Control instantiation

```
public interface IPeople {
    string GetName();
}

public class Villagers : IPeople {
    public string GetName() { return "Village Guy"; }
}

public class CityPeople : IPeople {
    public string GetName() { return "City Guy"; }
}

public enum PeopleType {
    RURAL,
    URBAN
}
```

Project Factory Method Pattern

```
public class Factory {
    public IPeople GetPeople(PeopleType type) {
        IPeople people = null;
        switch (type)
        {
            case PeopleType.RURAL :
                people = new Villagers();
                break;
            case PeopleType.URBAN:
                people = new CityPeople();
                break;
            default:
                break;
        }
        return people;
    }
}
```

The factory method pattern is a creational pattern which uses factory methods to deal with the problem of creating objects without specifying the exact class of object that will be created.



Recycling

When a bullet hit something, don't destroy it. Just disable it and keep it ready to be reused.

This recycling logic can be put in the factory. So you just have to ask for an instance of bullet, the factory will recycle or create a new bullet for you.

Optimization: You can make an estimation of the number of bullets needed in your game and then pre instantiate it while the game is loading.

You can do the same thing for avatars.

Programming good practices

Defensive Programming

Defensive programming is an approach to improve:

- General quality - reducing the number of software bugs and problems.
- Making the source code comprehensible - the source code should be readable and understandable so it is approved in a code audit.
- Making the software behave in a predictable manner despite unexpected inputs or user actions.

You can’t prevent everything ! and if you think you can, you can’t prevent the future!

You must protect your code from errors.

Defensive Programming

- **Intelligent source code reuse**
  If existing code is tested and known to work, reusing it may reduce the chance of bugs being introduced.
- **Secure input and output handling**
  "never trust the client"
- **Low tolerance against "potential" bugs**
  "I'm not aware of all problems. I must protect against those I do know of and then I must be proactive!"

Defensive Programming

Assertions

```
public void Assert(bool condition, string message) {
     if (!condition) {
          UnityEngine.Debug.LogError(message);
     }
}
```

Check your results to test if their values are correct:

```
public float Abs(float number) {
     float result = number < 0 : -number : number;
     UnityEngine.Debug.Assert(result >= 0, “result must be positive”);
     return result;
}
```

Defensive Programming

Exceptions

Check your inputs to test if their values are handled by your code:

```
public float Abs(float number) {
     if (float.IsNaN(number)) {
          throw new InvalidArgumentException(“number”, “The number must have a valid
value”);
     }

     float result = number < 0 : -number : number;
     System.Collection.Generic.Assert(result >= 0);
     return result;
}
```

Defensive Programming

Exceptions

Then, you can catch exceptions when you use your function:

```
public float Abs(float number1, float number2) {
     float result = 0f;
     try {
          result = Abs(number1) + Abs(number2);
     } catch (System.Exception exception) {
          // Handle your error here
          throw; // If your want to forward the exception.
     }
     return result;
}
```

Defensive Programming

Never assume “It cannot happen”

Handle all cases:

```
public void DoSomethingWithStuff() {
     object stuff = CreateStuff();
     if (stuff == null) {
          Log(“Error while creating stuff instance”);
          ManageErrorToAvoidCrash();
          return;
     }

     stuff.DoSomething();
}
```

Code readability

Coding style

It is important to have a common coding style in a project, it makes the code a lot more understandable. Use tools to help you (like StyleCop).

Naming

Be careful when you name your class, methods and variables.
If theirs name are carefully choiced, you'll don't need to read the code to understand what it does.

```
float energyLostPerFiring = 10f      // Better than "float loss = 10f";
```

Documentation

Write documentation, specially when your code is complicated.

Code review

Code review is systematic examination of computer source code.

It is intended to find mistakes overlooked in software development, improving the overall quality of software.

Some web-based source control services like GitHub have integrated a lot of tools to handle code reviews.

Keep in mind that your code will be read by other people.

Architecture / Conception

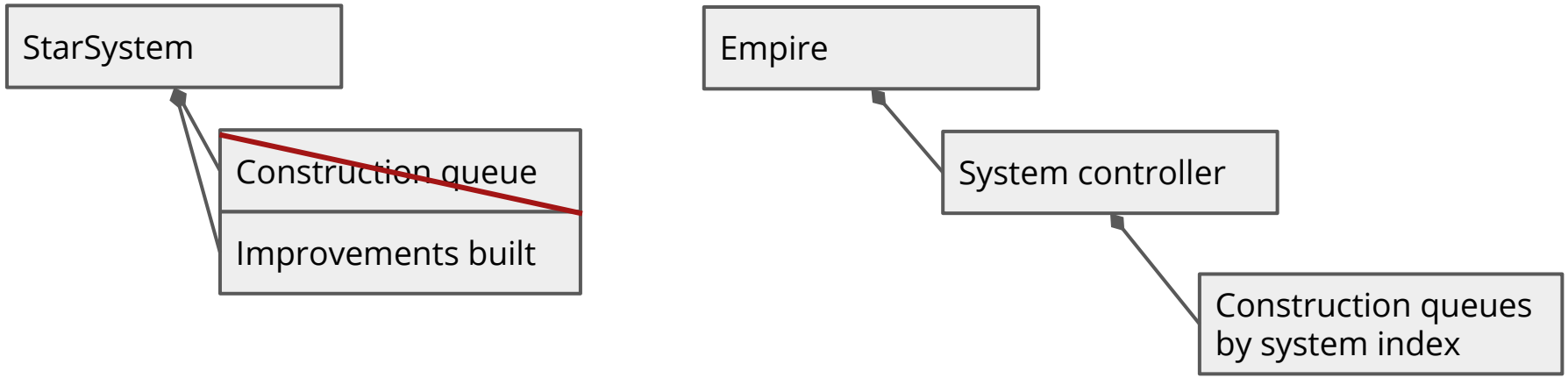
It’s dangerous to start writing complicated code without using solid reflection tools.

Expose your ideas to other people
Confront your ideas to another brain is a strong way to ensure that your are on the right way (even if the other people don’t know what you are talking about -> canard en plastique).

Pen & paper or blackboard
Make schema and write your ideas, you may discover that it is stupid before beginning to implement it.

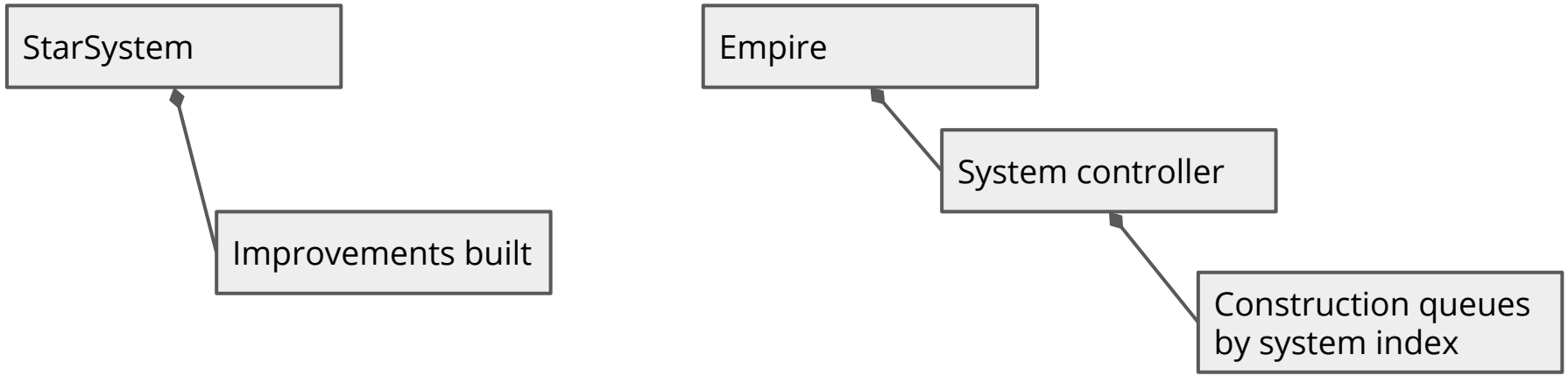
UML
Very useful tool to talk about architecture with other programmers (because it’s a common description language). You can try StarUML.

Endless Space construction queue



Architecture / Conception

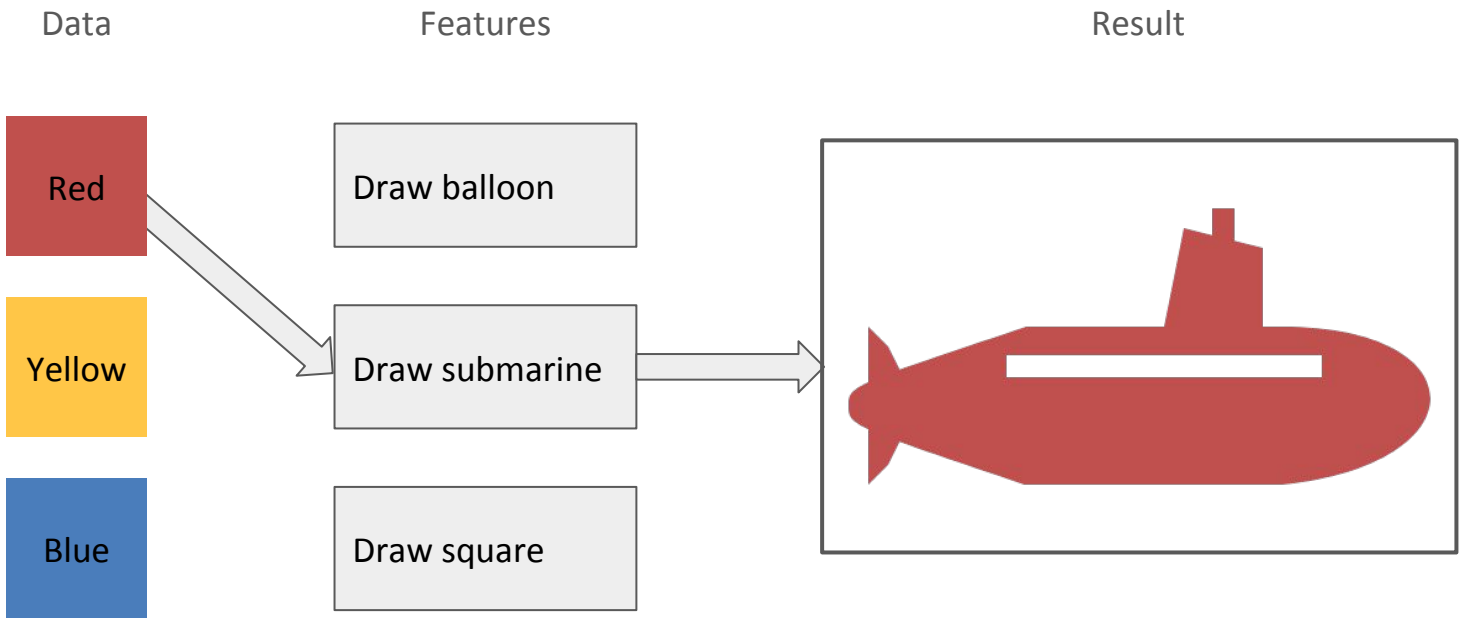
- Define who is really in charge of a specific functionality.
- Split your functionalities (and remove dependencies if possible).



Endless Space 2 Data Driven Simulation

Data Driven

A data-driven game is a game that exposes a large amount of functionality outside of code and lets the data determine the behavior of the game.



Data Driven

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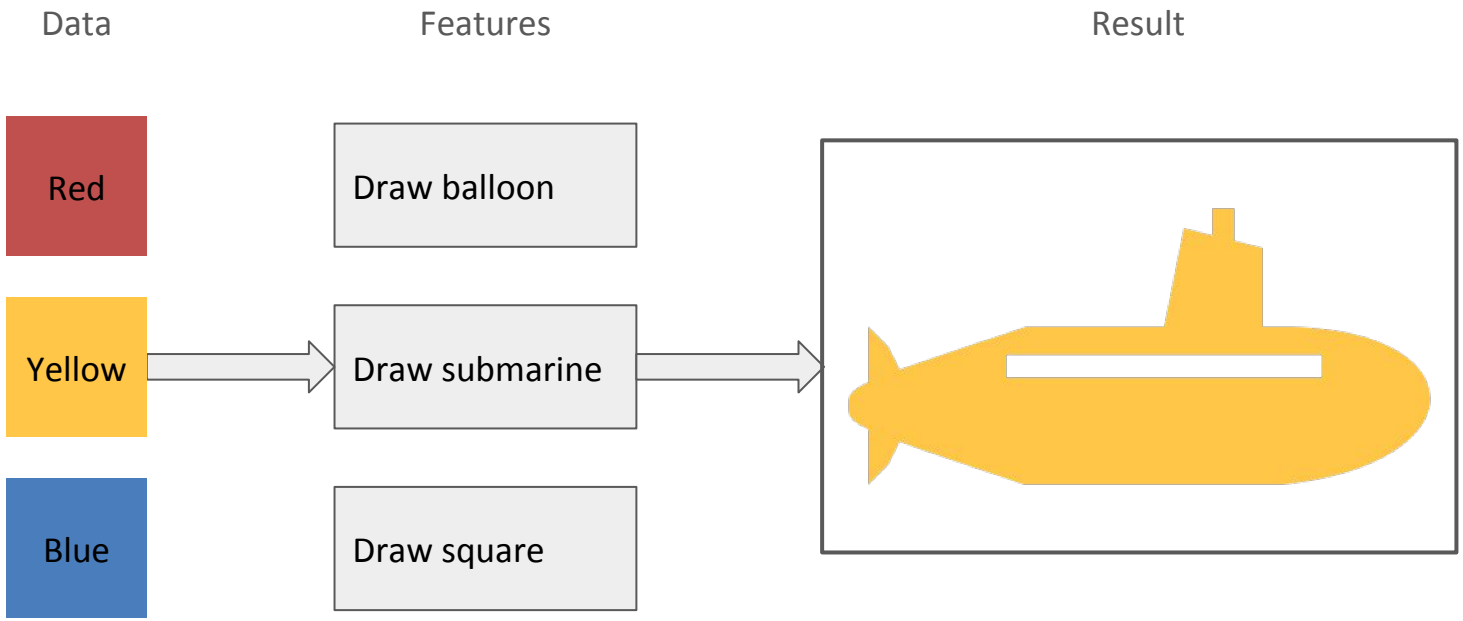


Data Driven

A data-driven game is a game that exposes a large amount of functionality outside of code and lets the data determine the behavior of the game.

Pro

+ Re-Use
+ Job Specialization

Cons

- Data management layer cost
- Abstraction cost

Source: http://goo.gl/Or51IO and http://goo.gl/xtVdSA

Endless Space 2

Empire

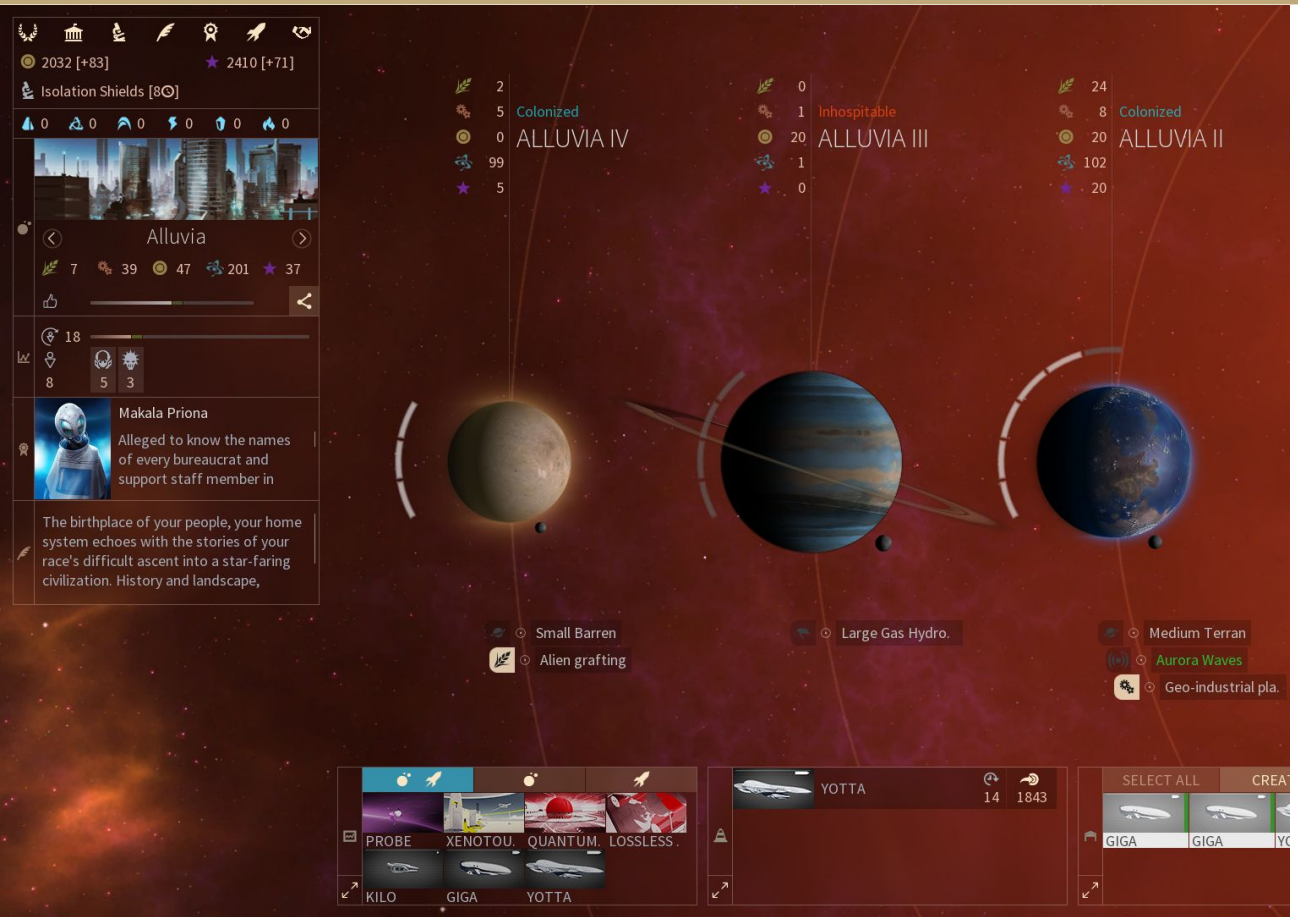
Systems

Fleets

Global bonuses

Researches

Endless Space 2



Systems

Ressources

Population

Improvements

Garrison

Endless Space 2

Ships

Type

XP and Level

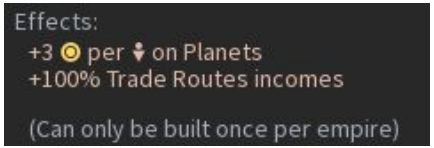
Attributes

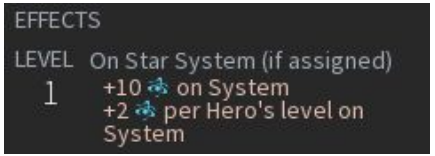
Modules

Capacities

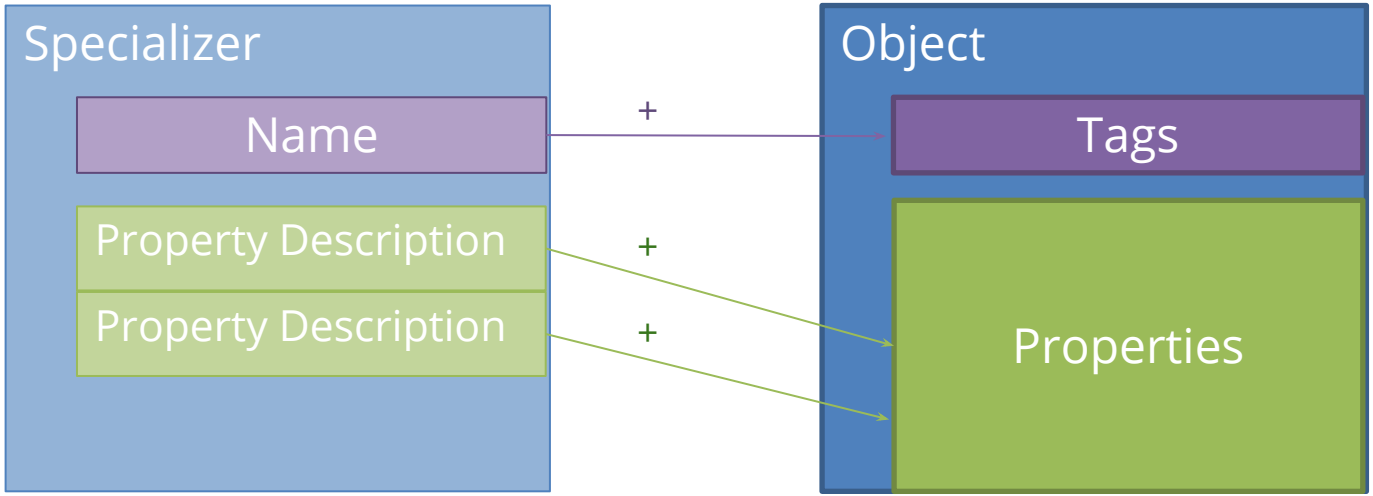
Endless Space 2

- Describe objects (systems, fleets, empire, …) with properties (float values)
- Properties values can be linked by some mathematical relations.
- We want to write all rules in text files (XML).
- Give the power to designers by exposing the gameplay rules in data files.

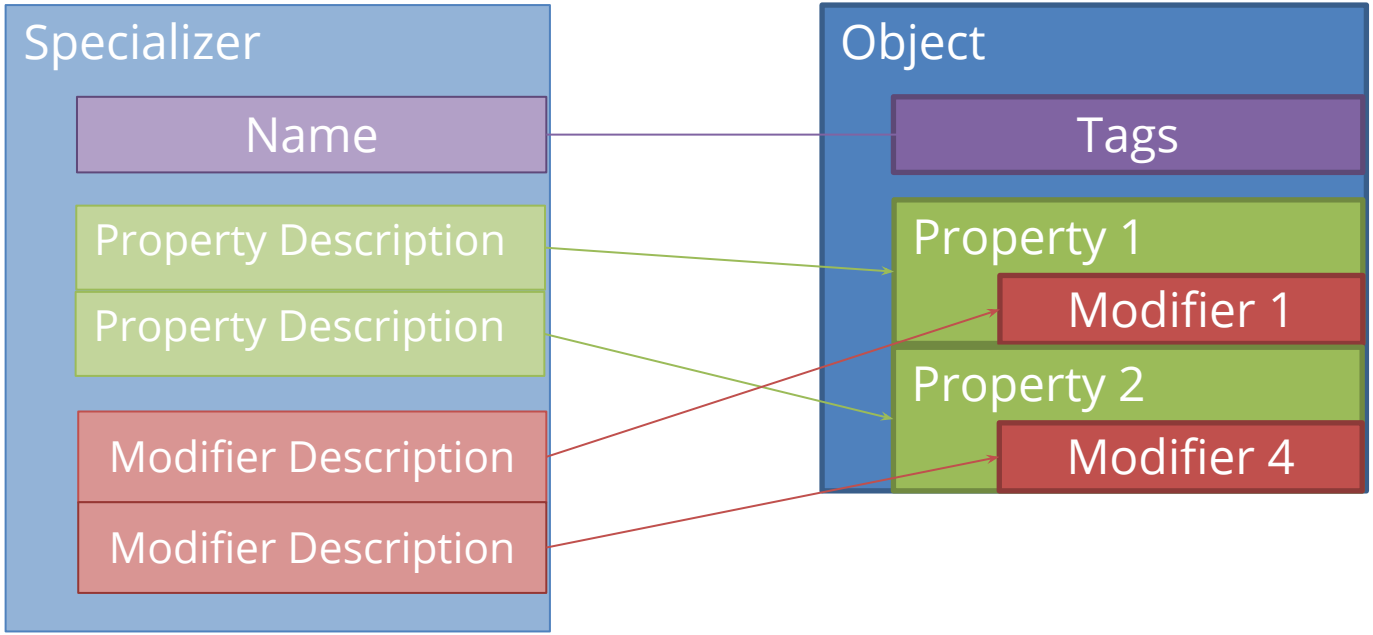




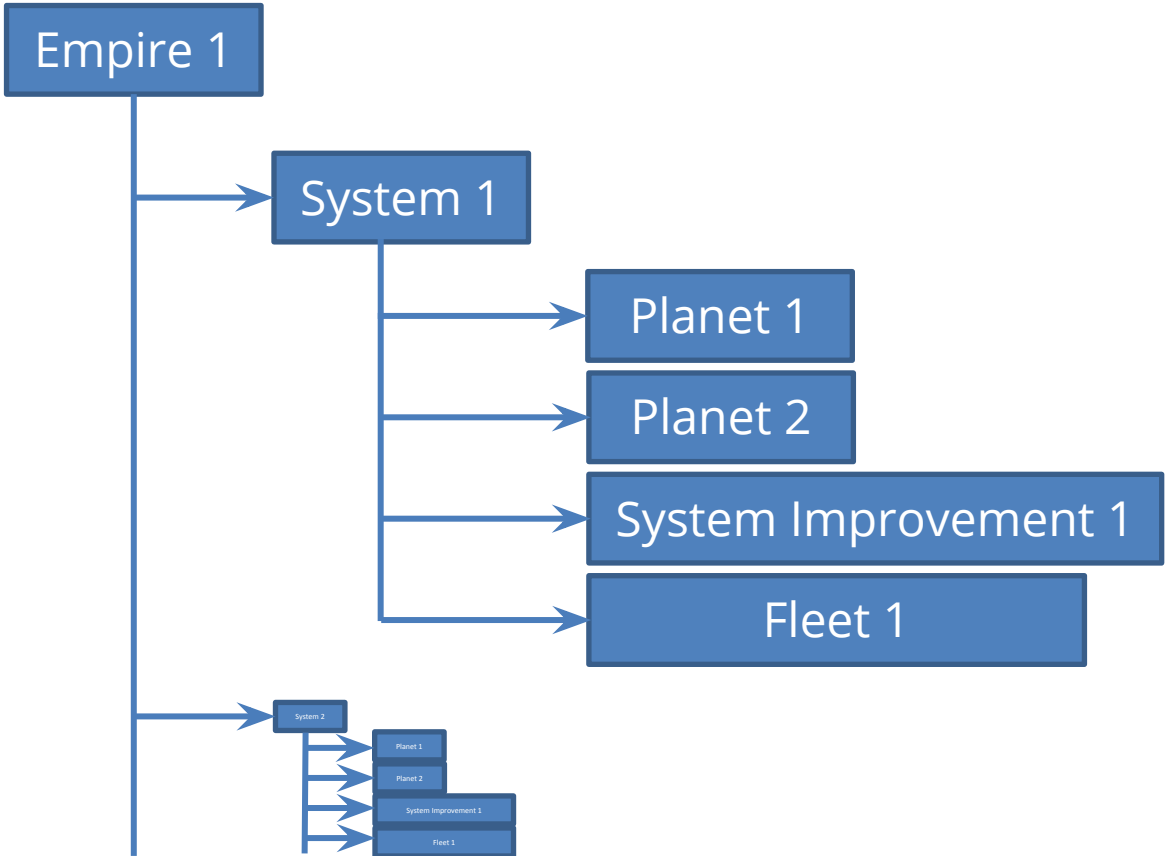
Describe an object



Describe an object



Objects architecture



Data format

```
<Descriptor Name="ClassPlanet" Type="Class">
      <Property Name="Industry" BaseValue="0"/>
      <Property Name="Food"     BaseValue="0"/>
</Descriptor>
```

```
<Descriptor Name="FoodImprovement1" Type="Improvement">
      <Modifier TargetProperty="Food" Operation="Addition" Value="10"/>
</Descriptor>
```

```
<Descriptor Name="FoodImprovement2" Type="Improvement">
      <Modifier TargetProperty="Food" Operation="Multiplication" Value="2"/>
</Descriptor>
```

Shoot’em up Project

Data driven level design

We want to describe our level in XML files.

The game will then read these files to create the real levels and run the game.
A level design can contains many informations:

- **Enemies**
  - Type
  - Position
  - Spawn time
- **Obstacles**
- ...

Project XML Serialization

Serialization is the process of converting an object into a form that can be readily transported.

The central class in XML serialization is the `System.Serialization.Xml.XmlSerializer` class, and the most important methods in this class are the `Serialize` and `Deserialize` methods.

XmlSerializer serializes only the public fields and property values of an object into an XML stream, use it when the XML stream is expected to conform to a known XML Schema (else you can use XmlWriter and XmlReader to manually serialize/deserialize your data).

Sources: https://goo.gl/j85m99

Project XML Serialization

C# class

```
public class OrderForm
{
    public DateTime OrderDate;
}
```

XML file

```
<OrderForm>
    <OrderDate>12/12/01</OrderDate>
</OrderForm>
```

Project XML Serialization

With XmlSerializer you can:

- Serialize classes that implement ICollection or IEnumerable.
- Generate a XSD schema files from your code, then check if your data files are well formed.
- Specify whether a field or property should be encoded as an attribute or an element.
- Specify the name of an element or attribute if a field or property name is inappropriate.

A class must have a default constructor to be serialized by XmlSerializer.

Sources: https://goo.gl/j85m99

Project XML Serialization

```
[XmlRoot(“Order”)]
public class OrderForm
{
    [XmlAttribute(“Date”)]
    public DateTime OrderDate;

    [XmlElement(“Value”)]
    public float FloatValue;
}
```

XML file

```
<Order Date=”25/09/2015”>
    <Value>42</Value>
</Order>
```

Sources: https://goo.gl/614Oo0

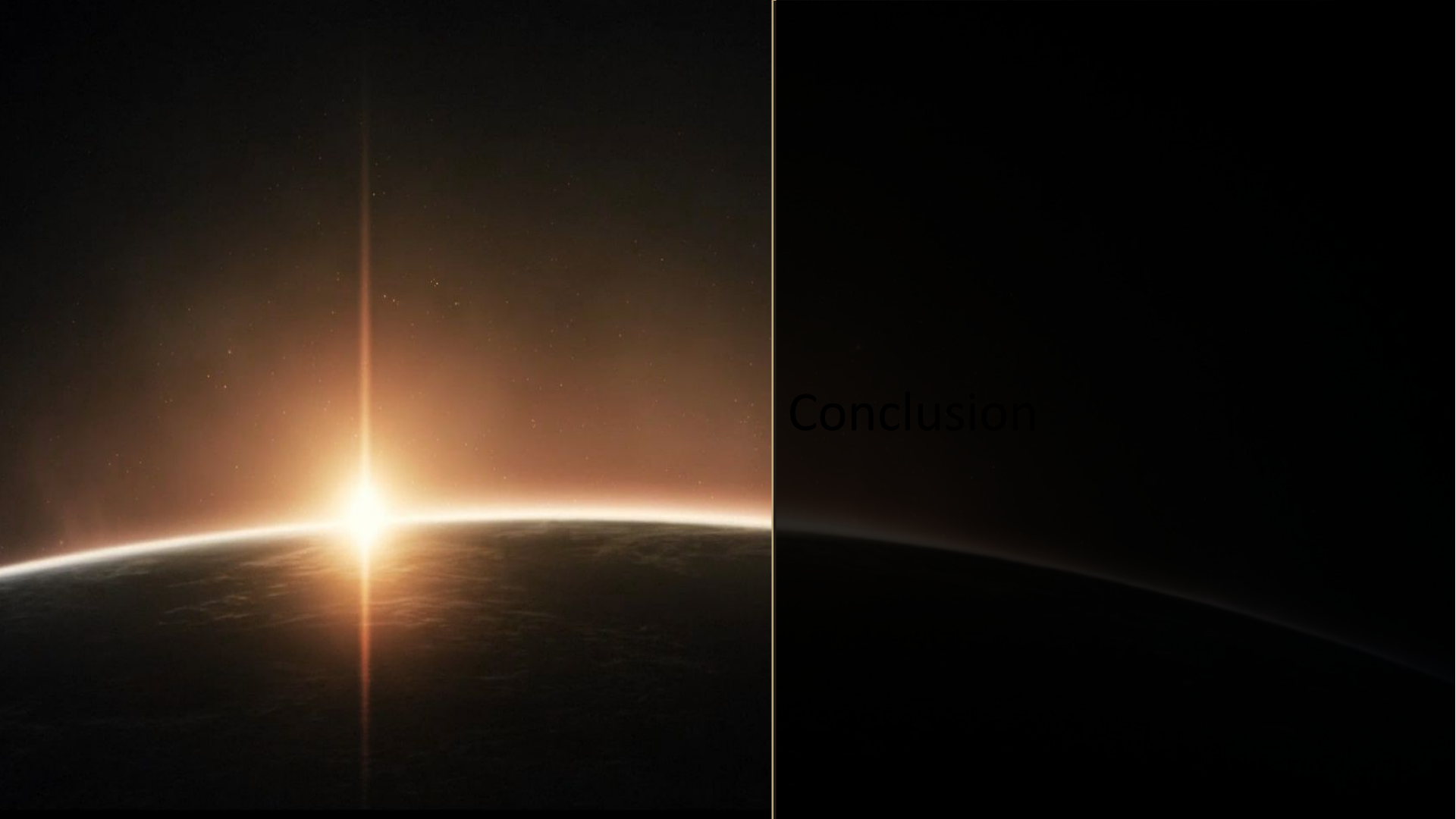
Project Shoot’em up

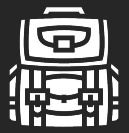
Code features needed:

- Ability to spawn an enemy with specific attributes.
- Create a “Game Manager” to manage level and progression.
- Meta-game system that check if the current level is finished and launch the next one (keeping score and other persistent infos).

Then …

… Just add some XML files to add more content to your game !


Conclusion



Takeaway

- Keep your code as simple as possible.
- Learn how to use your game engine.
- Beware of performances. Do not assume! Try and measure!
- It’s always CPU vs Memory problem.
- Data driven is good!
- Keep your code as simple as possible. (It’s very important!)
- Practice programming!

Questions & Answers

THANK YOU!

Questions?

Annex - Documentation

C#

http://www.codeproject.com/Articles/375166/Functional-programming-in-Csharp
http://www.codeproject.com/Articles/286255/Using-LINQ-Queries
http://msdn.microsoft.com/fr-fr/library/ms173109.aspx
http://www.dotnetperls.com

Unit testing

http://blogs.unity3d.com/2014/07/28/unit-testing-at-the-speed-of-light-with-unity-test-tools/

Algorithmics

http://www.redblobgames.com/

Data-Driven design

http://gamearchitect.net/Articles/DataDrivenDesign.html
http://www.cs.cornell.edu/database-OLD/games/

Annex - Documentation

C# Memory management for Unity

http://www.gamasutra.com/blogs/WendelinReich/20131109/203841/C_Memory_Management_for_Unity_Developers_part_1_of_3.php
http://www.gamasutra.com/blogs/WendelinReich/20131119/203842/C_Memory_Management_for_Unity_Developers_part_2_of_3.php
http://www.gamasutra.com/blogs/WendelinReich/20131127/203843/C_Memory_Management_for_Unity_Developers_part_3_of_3.php

Memory hierarchy

http://en.wikipedia.org/wiki/Memory_hierarchy
http://www.sisoftware.co.uk/?d=qa&f=mem_hsw
http://www.gdcvault.com/play/1014645/-SPONSORED-Hotspots-FLOPS-and

0100 0011 1001 Annex - Code samples

Shoot'em up game with Unity:

https://github.com/Tichau/Schmup

Tetris game (standalone/web/android) with Unity:

https://github.com/Tichau/Tetris

Contact

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Slides > https://tinyurl.com/ampjin2019

Humankind > https://tinyurl.com/humankindgame