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Comparative Study on Game Engines

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Abstract. Game engines are platforms that make it easier to create computer games. They allow you to integrate and combine into single unit individual game elements such as animations, interaction with the user, or detection of collisions between objects.

Game engine is a software that facilitates the production of games for platforms such as desktops, consoles, and mobile devices [1]. In addition to specialized editors, game engines provide ready-made functionalities that can be used by users. A great advantage of using the game engine is the possibility of their reuse. Game engines are an example of software isolating rigid logic and game rules, from easily modifiable and expandable components, which can be used repeatedly in a way that does not require great modifications.

This article is an attempt to perform a comparative analysis of three engines to create games: CryEngine, Unreal Engine, and Unity. The criteria for comparison will be technical capabilities and factors influencing the popularity and acceptance of engines by users. The aim of this article is to show the strengths and weaknesses of engines and to present the differences between these tools.

Keywords. Game engines, Unity, CryEngine, Unreal Engine

1. Game engines

The game engine is built with components that provide the necessary functionality to create the game. The most common game engine components are:

- Audio module - the main role of this component is to generate sound effects in the game.
- Rendering engine - the main task of this component is to convert the input data to pixels displayed on the screen. [1].
- Artificial Intelligence Module - a component responsible for providing techniques for defining rules of behavior with characters not controlled by players (NPCs).
- Animation module - performs animation like for example, movement and changes in the shape of virtual objects.
- Network module - the network component of the game engine enables multiple players to play together at the same time, using devices connected to the Internet.
- Game mechanics (logic) - game mechanics (gameplay) consists of elements, i. e. rules governing the virtual world, skills of characters controlled by players, characters led by artificial intelligence, objects in the virtual world, goals and tasks of players. [1].
- Software Tools - Tools that optimize and increase the efficiency of work with the game engine. They provide the ability to add many different types of elements to games, from animation and audio effects to artificial intelligence algorithms.

1.1. Unity

Unity is a game engine developed by Unity Technologies. This software allows for creating 3D and 2D games. The engine was first presented in 2005 at Apple's Worldwide Developers Conference. In the early versions of Unity, the only supported platform was Mac OS; however, along with subsequent releases, the developers consistently increased the number of supported platforms. In version 2018. 1. 5 Unity allows you to create games on many platforms including:

- PC, Linux, Mac OS,
- consoles: PS4, Xbox One, Nintendo Switch,
- mobile Systems: Android, iOS
- virtual reality systems i. e. Oculus Rift, Playstation VR, GearVR. [4].

Unity allows you to write the logic of the game in the C# programming language.

The Unity engine features a component-based, modular system for building objects in games. In this type of system, objects in the game are built from a set of components, where a

component is a set of functionalities. This solution allows you to create objects using a combination of features instead of using inheritance, which is used with a standard object-oriented programming approach. The advantage of the modular approach is the increased flexibility that allows efficient and trouble-free component matching without the need to refectories the inheritance chain at every change in the objects. [3].

1.2. Unreal Engine

The Unreal Engine dates back to 1998 when it was introduced by its creators, Epic Games. Initially, this engine allowed only to modify and add new elements to the game Unreal for the needs of which it was created. The latest version of the engine called Unreal Engine 4 allows you to implement games on many platforms, including Windows, Linux, Mac OS, iOS, Android, Playstation 4, Xbox One, HTML5, and virtual reality devices: SteamVR, HTC Vive, Oculus Rift. Unreal Engine supports writing scripts in C++ language. Unreal engine is equipped with its own BluePrint system, providing the possibility of implementing the logic of the game with the use of graphical diagrams. Logic written using graphical diagrams can completely replace the need to write code in C++ language. The Unreal Engine consists of the following components:

- Sound engine: Sound Cue,
- Physics engine: PhysX,
- Graphics engine: supporting DirectX 11/12, OpenGL, Javascript/WebGL libraries,
- Skeleton of the game: functions controlling the course of the game,
- Post-process effects,
- Artificial intelligence,
- Network module [2].

1.3. Cry Engine

CryEngine is a game engine created by Crytek. The first version of the engine presented in 2002 was supposed to be only a technological demo created for Nvidia. This project finally evolved into a fully-fledged game engine presented in 2004. This year the first game using Cry Engine was created, FarCry. For a long time, the CryEngine engine only allowed you to create FPS (First-person shooter) games, but this changed in 2016 when the latest version of the engine called CryEngine V made its debut. The engine currently allows you to create games for such platforms as PC, PS4, Xbox One, and Oculus Rift. The code of games, created based on the CryEngine V engine, can be written in one of the two programming languages supported by the

engine: C++ language or C# language. CryEngine stands out from the competition due to the high quality of graphical effects and the graphical system Flow Graph, which allows controlling the logic of the game from the level of graphical diagrams.

2. Comparison of game engines

2.1. Comparison criteria

Unity, CryEngine and Unreal Engine will be compared based on the following criteria:

- Multi-platformity - platforms supported by engines.
- Licenses - types of distribution of available engine versions.
- Programming languages - classic programming languages supported by the engine.
- Development tools - a list of editors and development environments supplied with the game engine.
- Documentation - detail and quality of technical documentation.
- Ease of learning - user-friendliness for beginners, number of official courses and tutorials, as well as support for the community built around the engine
- Multifunctionality - possibility of creating different game genres.
- Artificial Intelligence - modules supporting the design and implementation of the behavior of NPCs
- Physics engine - the capabilities of physics engines.
- Video - design of film interludes.
- Network Modules - Network modes that support multiple players playing simultaneously.
- Scripts - possibility of writing custom game logic elements using programming languages or graphical systems integrated with the engine.
- Sound - possibility of mixing and managing sound effects.
- Level design - tools for designing areas and landscapes.
- Graphic effects - quality of rendered graphics and support for advanced graphics techniques.
- Modeling - modules and editors enabling modeling of three-dimensional objects.
- Texturing - designing textures and materials.
- Libraries and plug-ins - possibility of extending the functionality of development tools with support for external libraries and plug-ins.

- Stores/Markets - comparison of platforms enabling the purchase and sale of ready game elements and entire libraries compatible with the engine.
- Animations - designing computer animation with the use of internal engine tools.
- User Interfaces - possibility of designing advanced user interfaces.
- Performance - comparison of engine performance.

2.2. Licenses

Unity in the free Personal version, allows you to use most of the engine functionality. It can be used by creators whose profits from the game are less than $100,000 a year. After exceeding this threshold, users must purchase one of the paid versions of the engine. One of them is the Plus version costing $35 per month, which is available to creators with revenue of less than $200,000. The second is Unity Pro costing $125 per month. Paid versions of Unity provide automatic reporting of application bugs and performance issues and increase the maximum number of players in online modes to 50 and 200 players, respectively. Also, Unity Pro provides immediate technical support and allows for the use of advanced analytical tools.

Unreal Engine, unlike Unity, is available only in one version with a license allowing for free use of all engine capabilities, if the income from the game created with the use of the engine does not exceed $3,000 per quarter. If this amount is exceeded, the license provides for the transfer of 5% of revenue to Epic Games, the creators of the engine.

CryEngine 5. 5 engine license is very similar to Unreal Engine offer. Using all the possibilities of the engine is completely free even in commercial applications, up to a revenue of more than $5,000 a year. After exceeding this threshold, 5% of the receipt should be transferred to the engine developers.

2.3. Multi-platformity

An overview of all hardware platforms supported by engines is given in Table 1, presented below.

Table 1. List of platforms' compatibility, Source: own elaboration

Platforms	Unity 2018	Unreal Engine 4	CryEngine 5.5
Consoles	Xbox One, Xbox 360, PS4, PS Vita, Switch, Wii U, 3DS	Xbox One, PS4, Switch	Xbox One, PS4
OS	Windows, Mac OS, Linux	Windows, Linux, Mac OS, SteamOS	Windows, Linux
Mobile Systems	iOS, Android, Windows Phone, BlackBerry 10, Tizen	iOS, Android	✗
VR/AR	Oculus Rift, Gear VR, Google DayDream, Cardboard, SteamVR, HTC Vive	Oculus Rift, HTC Vive, SteamVR, OSVR, Google VR/DayDream, Samsung Gear VR	Oculus Rift, HTC Vive
Smart TV	Android TV, Apple TV, Samsung Smart TV	✗	✗
Other	WebGL	HTML 5	✗

2.4. Programming languages and Development tools

Described game engines allow you to write game logic using scripts in the following programming languages:

- Unity – C#, UnityScript (marked as obsolete is no longer supported)
- Unreal Engine - C++.
- CryEngine - C#, C++.

Unity provides the smallest number of editors since some functionality is delegated to the main editor's tabs. Unreal Engine is the only engine with editors supporting the implementation of Artificial Intelligence elements and enabling the design of user interfaces. CryEngine stands out from the rest of the engines with its Modeling tool for 3D object modeling and the Environment Editor for environmental management. It is worth noting that only the editors that are delivered with the engine by default have been indicated. Many engine functionalities, including whole editors, can be added to the engine in the form of libraries or plug-in. Table 2 presents a list of editors per game engine.

Table 2. List of editors per engines, Source: own elaboration

Editors	Unity 2018	Unreal Engine 4	CryEngine 5.5
Basic	Unity Editor	Level Editor	Sandbox Editor
Materials	✗	Material Editor	Material Editor
IDE/Scripts	Visual Studio, MonoDevelop	BluePrint Editor, Visual Studio	FlowGraph, Visual Studio
AI	✗	BehaviorTree Editor	✗

Animations/Video	Animations, Animator, Timeline Editor	Persona Editor, Matinee Editor, Physics Asset Tool. Media Player Editor	Track View, Facial Editor, Mannequin Editor
Graphical Effects	✗	Cascade Editor	Particle Editor, Lens Flare Editor
User Interface	✗	UMG UI Editor	✗
Sound	Audio Mixer	Sound Cue Editor	Audio Controls Editor Dynamic Response System
2D	Sprite Editor	Paper2D Sprite Editor Paper2D FlipBook Editor	✗
3D	✗	StaticMesh Editor	Designer Tool
Other	✗	✗	Environment Editor Terrain Editor

2.5. Documentation

The Unity engine has the best documentation of all compared engines. Most of the engine functions are described very profoundly, the documentation also contains many examples of engine functions, which is very helpful, especially for novice users. The Unreal Engine documentation is written almost as well as the Unity documentation, but some imperfections can be found. The CryEngine engine documentation is the worst. The documentation is deficient, and a large part of it has been written for older versions of the engine and has not been updated since then.

2.6. Easy of learning

Due to many factors the most user-friendly and easiest to learn engine for people with programming skills is Unity:

- The C# language seems to be simpler and more pleasant to use than the C++ language used in other engines,
- Very good documentation,
- A large number of ready-made templates and sample projects,
- Simple, clear and easily configurable user interface,
- An active and numerous community built around the engine.

Unreal Engine, in comparison to Unity is more challenging to master engine with a rather friendly user interface, which, however, at the first contact may overwhelm by an excess of

options. Unreal Engine can be a right choice for people without programming skills. The BluePrints graphical scripting system enables the implementation of the whole game logic without the need to write any code in the C++ language. The most difficult engine to learn is CryEngine. Relatively poor documentation, a small number of tutorials, and a smaller community compared to the other two engines can deter newcomers. Flow Graph graphical system, unlike BluePrints with Unreal Engine, does not allow to implement all the logic of the game, so the engine will not be a good choice for people trying to create a game without programming skills.

2.7. Multifunctionality

Unity is a very multifunctional engine enabling the creation of 2D and 3D games belonging to many genres. Unity, thanks to the special Unity2D mode, which is dedicated to creating two-dimensional games, is the best engine for creating 2D games among the compared engines. Unreal Engine also allows you to create two-dimensional games, but creating such games in this engine is less intuitive and more complicated. Unreal and Unity engines are very versatile, and they allow you to create a game of almost any genre possible on many platforms, including mobile platforms. Creating 2D games in CryEngine is highly non-intuitive, and the implementation of more advanced mechanisms may turn out to be complicated or completely impossible to do. CryEngine develops its full potential during the implementation of FPS games. However, this does not mean that you cannot create 3D games of other genres in CryEngine. This engine allows for the implementation of games genre similar to FPS, i. e. third-person games, without causing much difficulty to the users.

2.8. Artificial Intelligence

The only mechanism provided by the Unity engine that supports users in the implementation of NPCs' behavior is the Navigation System. This system allows you to: define the points that non-player characters should avoid, indicate where these characters can move and mark navigation shortcuts. Better in terms of mechanisms supporting the implementation of the behavior of NPCs is Unreal Engine. In addition to the navigation mechanism working very similarly to Unity, Unreal provides tools of Behavior Trees and Environment Query System. The first one significantly facilitates the process of behavior implementation by enabling the design of graphical behavior trees, which is much more pleasant to implement than writing a sequence of conditions in scripts. EQS is a system that allows you to perform dynamic in-game object queries that best match your search criteria. CryEngine, like other engines, has its independent character navigation system, which, in terms of functionality, outperforms other engines' providing solutions with greater freedom in designing areas of movement for

characters not controlled by players. CryEngine, just like Unreal Engine, provides the mechanisms of the behavior tree and Environment Query. CryEngine stands out from the rest of the engines by the AI Territories & Waves system allowing for: manage the number of NPCs in a given area and add more waves of opponents during the game.

2.9. Physics engine

Unreal Engine and Unity engines use a common PhysX physics engine developed by Nvidia. CryEngine uses the proprietary physics engine CryPhisics. PhysX and CryPhisics provide the functionality expected from physics engines, including collision detection, body deformation and external forces acting on objects such as gravity, and wind.

2.10. Video

Unity allows you to design movie interludes rendered on the basis of the engine using the Timeline editor. This editor allows you to create movie sequences with the ability to add sound and graphics effects to your recordings. The Cinemachine tool is a good complement to the Timeline editor. It is plug-in available for download from the Asset Store, extending Timeline's capabilities by dynamic camera position changing the level where the film interrupter is recorded from. Unreal Engine and CryEngine also provide editors allowing you to create movie interludes respectively: Sequencer Editor and TrackView. These editors are in no way inferior to the solution proposed by Unity and do not require downloading any external plugins in order to achieve their full potential.

2.11. Network Modules

Unreal Engine is distinguished by the best network module. The network module of this engine is used by many popular network games such as Fortnite. Games with network modules written in Unity or CryEngine are much less popular, so the optimization of network modules in these engines may raise doubts. Adding multiplayer mode to Unreal Engine games is also the easiest and requires the least modification. The CryEngine engine network module works quite well in FPS games. CryEngine allows you to create only network games based on the architecture with a dedicated server. Creating network modes in Unity, unlike other engines, is limited due to the limits of players that can be supported at the same time. The free version of the Unity engine allows you to support no more than 20 players. The most expensive Pro version raises this limit to 200 players.

2.12. Scripts

The implementation of game logic in all the engines is based on writing so-called scripts. The scripts are written mainly in programming languages supported by the game engine. Some game engines have also introduced the ability to implement the logic of the game using graphical systems, in which code writing has been replaced by combining blocks representing logical operations. The primary motivation for the introduction of such elements was to allow people who are not able to program or do not know the programming languages supported by the engine to use it. Among these engines, Unity is the only tool that does not allow for the implementation of game logic without the need for a programming language. Unreal Engine provides BluePrints system, which enables you to implement the whole logic of the game. At first contact, this system may seem overwhelming and unreadable due to the enormity of graphical nodes and available options. However, after some time spends on reading the documentation and learning how to use the system, it may turn out to be a good alternative to programming languages. The equivalent for BluePrints used in the CryEngine engine is Flow Graph. This system is also an alternative way to implement game logic, but it does not allow you to write all the game logic without the need to using programming languages.

2.13. Sound

Unity clearly stands out from other engines in terms of the quality of the tools used to work on the sound effects. The only sound effects editor provided by Unity: Audio Mixer only allows you to manage the basic properties of sounds, i. e. the intensity of sound, the area of audibility, mixing several sound sources, and adding special effects. Unreal Engine provides a much more advanced editor, Sound Cue. It was designed with the use of a graphical system of BluePrints nodes, thus allowing great freedom in editing sound effects. An additional advantage of the Unreal environment is the Dialogue Voices and Waves system, which makes it much easier to add a system of dialogues with NPCs to the game, making it possible to add a full soundtrack to the voices of the heroes. Audio Controls Editor is an editor that allows managing sound effects in a game implemented based on the CryEngine engine. This editor allows you to manage the properties of all sounds in the game and allows you to define events whose one of the results will be to play the sound effect. CryEngine also provides an SDL Mixer editor allowing for basic manipulation of audio effects and the ability to integrate with advanced external sound processing systems such as CRI, FMOD or Wwise.

2.14. Level design

Unity, in comparison to other engines is distinguished by a tree editor that allows you to design a tree model from the root to the crown itself. Unreal Engine and CryEngine, despite the lack of a tree editor, guarantee greater possibilities of land design. Both engines allow you to add layers of land, allowing you to define terrain rules, textures, and landscape elements for each layer separately. CryEngine stands out with its unique Environment Editor, which allows you to set many environmental aspects such as a dynamic day and night system or changing weather conditions. The Unreal Engine's unquestionable advantage is the Level Streaming system, which allows only a part of the game world to be loaded into memory. Only the part of the world loaded into memory consumes hardware resources and is rendered. Correct use of this system allows you to create vast and fluent games that do not require any interruptions to load further areas.

2.15. Graphic effects

CryEngine stands out from other engines by its Voxel-Based Global Illumination system. This system allows you to render realistic dependencies associated with the propagation of light, taking into account the light rays reflected by spatial objects in real-time. Unity and Unreal Engine also provide a global lighting system that only imitates real-time operation. A significant portion of the calculations required for rendering lighting is performed before the first frame is displayed, and the results of these calculations are used later in the execution of the program. All of these engines support a physics-based shading model designed to simulate the interaction between light and surface with regard to their physical properties. It is also worth mentioning other advanced techniques supported by all the discussed engines, i. e. smoothing the edges, real-time reflections, estimation of surface exposure to diffuse light (Ambient Occlusion), depth of field, image blurring, tone mapping or molecular effects. Unreal Engine, in comparison to other engines is distinguished by a very good looking sub-surface shading effect, which allows you to model objects that diffuse light into them. CryEngine handles the generation of natural landscapes best of all engines. This engine is equipped with a particular system supporting the generation of green areas with the accuracy of even single grass blades, each of which reacts dynamically to the interaction with other objects and external forces, adding dynamics to the static scenes in the game. An additional advantage in favor of Unreal and CryEngine engines is very well realized support of effects added to the displayed images after generation, but before showing them (Post-process effects).

2.16. Modeling

CryEngine is the only engine providing a 3D object modeling tool, Designer Tool. It is a high-quality tool capable of successfully replacing external modeling applications, which are the only option to create 3D models that can be used in Unreal Engine and Unity engines. The Static Mesh Editor of the Unreal engine only allows you to manipulate skeletons, i. e. only one of the layers of 3D models. The basic version of Unity does not provide any tools to manage 3D objects. Still, the Asset Store offers plug-ins that extend the engine's capabilities by, among other things, the ability to edit 3D model skeletons.

2.17. Texturing

Unreal Engine stands out from the rest of the engines with the best material design system. This system is based on designing materials with the use of graphic BluePrints nodes, which gives excellent possibilities for manipulating material properties. Content editors provided by CryEngine and Unity allow you to create high-quality resources, but their capabilities are more limited compared to the graphical editor from the Unreal engine.

2.18. Libraries and Plug-Ins

Unity, in comparison to other engines, is distinguished by the highest number of plug-ins and libraries extending the basic capabilities of the engine. Many of the external plug-ins and libraries supported by Unity can be downloaded or purchased directly from the integrated Asset Store. Among the Unity extension plug-ins one can distinguish a graphical system for writing scripts, skeleton model editor, Artificial Intelligence decision tree editor, or VR interface editor. Unreal Engine also has an extensive database of supported plug-ins distributed, among others, through the integrated Marketplace service. Most plug-ins only extend the capabilities of engine editors, less often than in Unity, these are all functionalities with their dedicated editors. Definitely, the smallest database of supported libraries and plug-ins extending engine capabilities has CryEngine. Only a few plugins are available for download in the Marketplace, which is integrated with the engine. However, the engine stands out from the competition due to its ability to integrate with external systems such as Autodesk or Adobe Photoshop.

2.19. Stores/Markets

Described engines have dedicated services with ready-to-use resources for use in games. On this type of service, for a fee or completely free of charge, users can offer to the rest of the community their resources, plug-ins, or libraries. In such shops, a predetermined percentage of

the profit from each transaction is kept by the engine developers. At the Unity Asset Store, engine developers take 30% of the profits from each purchase at the Unreal Engine Marketplace 12%. At the CryEngine Engine Marketplace, the rate is set for each item separately. The platform with the most significant number of exhibited items is the Unity Engine Asset Store, and the smallest platform in terms of assortment offered is the CryEngine engine service.

2.20. Animations

Unity in terms of animation stands out from the rest of the engines, allowing only basic animation of 3D objects, without the ability to perform skeleton animation. CryEngine and Unreal Engine in their basic versions provide editors allowing to design skeleton animations. However, more control over animations is provided by Unreal Engine thanks to the graphical system SkeletalControl. This system will enable you to control every single bone of the skeleton model. Thus making this system a tool for creating procedural, dynamic animations in which changing the position of one bone drives the movement of other surrounding bones. CryEngine is distinguished by the fact that it is the only engine with a specialist editor dedicated to animating the facial expressions of virtual characters, Facial Editor.

2.21. User Interface

Unreal Engine is the only engine with a dedicated user interface design editor, UMG UI Designer. Unity allows you to create user interfaces not with a special editor, but with a component added to the scene. The solution proposed in Unreal Engine, which is easier to integrate with the rest of the game elements, seems to be more effective in use. CryEngine is the only game engine that does not have an editor for designing user interfaces. The only way to model such tools is to use external tools such as Vectorian Giotto, recommended by the engine designers [4].

2.22. Performance

In order to examine the criterion of performance, a 3D game has been implemented with the use of each of the discussed engines. A virtual world in each implementation of the game has the same size: 1. 048km^2 and is filled with elements of nature such as trees, grass, uneven terrain. In each implementation of the game, all advanced techniques provided by engines enabling the generation of realistic nature areas were used. The experiment consists of measuring the average time needed to load and display a single frame. The tests will be carried out using the following parameters:

- Graphics quality - all engines have default profiles defining the quality of the displayed graphics. In experiments with the use of these engines, profiles with graphics in low, medium and highest (ultra) quality will be used.
- Average tree density - this parameter means how high is the average density of trees in the virtual world. This parameter will take one of three values: low (2000 trees), medium (4000 trees), high (8000 trees).
- Resolution - the number of pixels displayed simultaneously on the screen. The parameter takes values: 1600x900, 1280x800 and 800x600.

All experiments were carried out using the following hardware configuration:

- Intel Core i5-4210M 2.60 GHz,
- 12GB RAM,
- NvidiaGeforce 940M,
- Windows 10 64bit.

A total of 81 experiments were carried out. The results are presented in the form of bar charts on the Fig. 1-9.

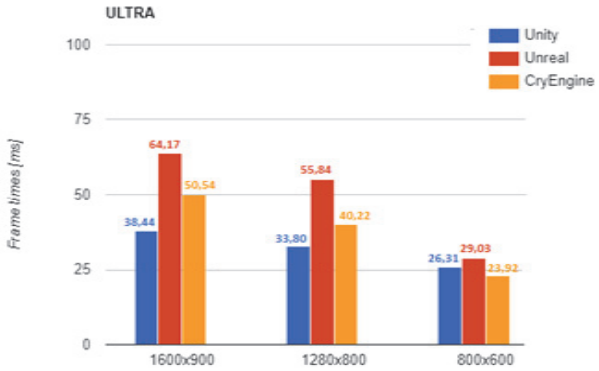


Figure 1. Results at low tree density and ultra graphics quality, Source: own elaboration

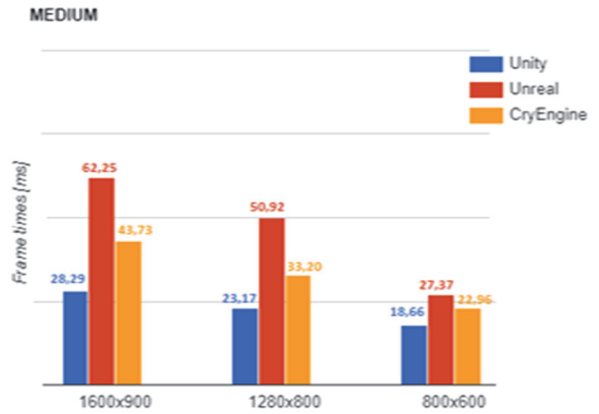
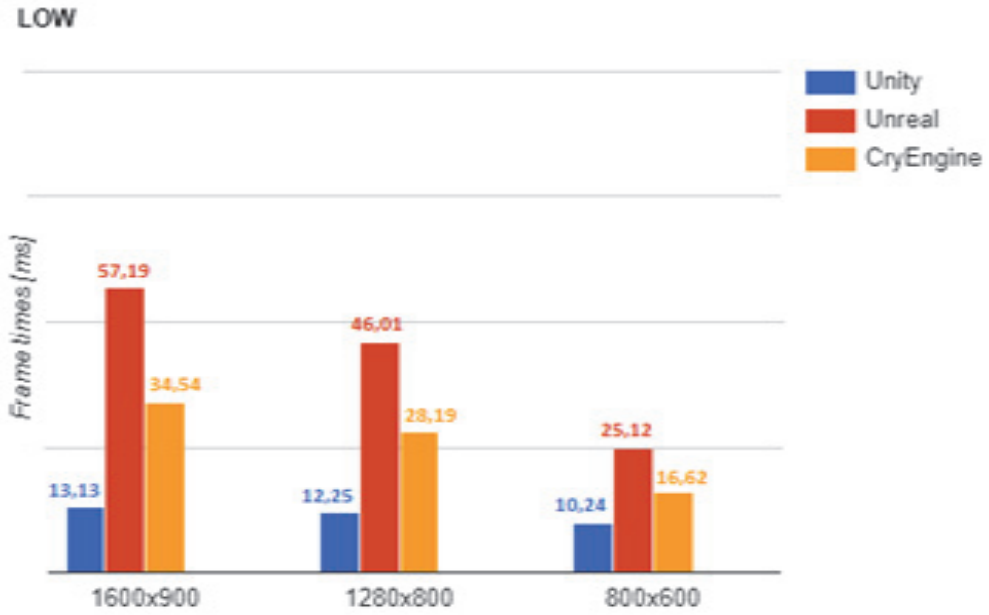


Figure 2. Results at low tree density and medium graphics quality, Source: own elaboration



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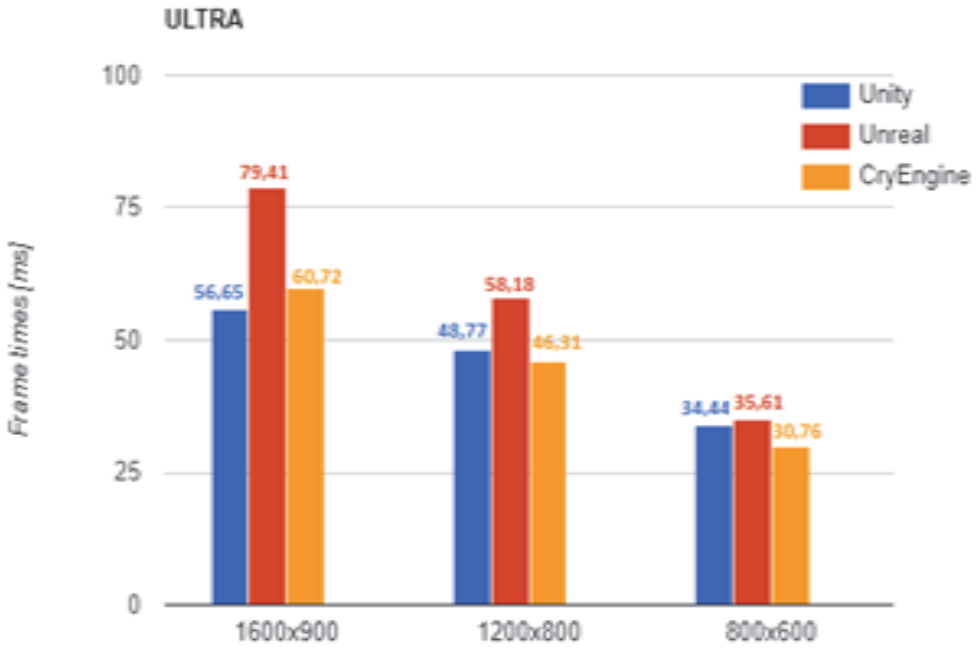

Figure 4. Results at medium tree density and ultra graphics quality, Source: own elaboration

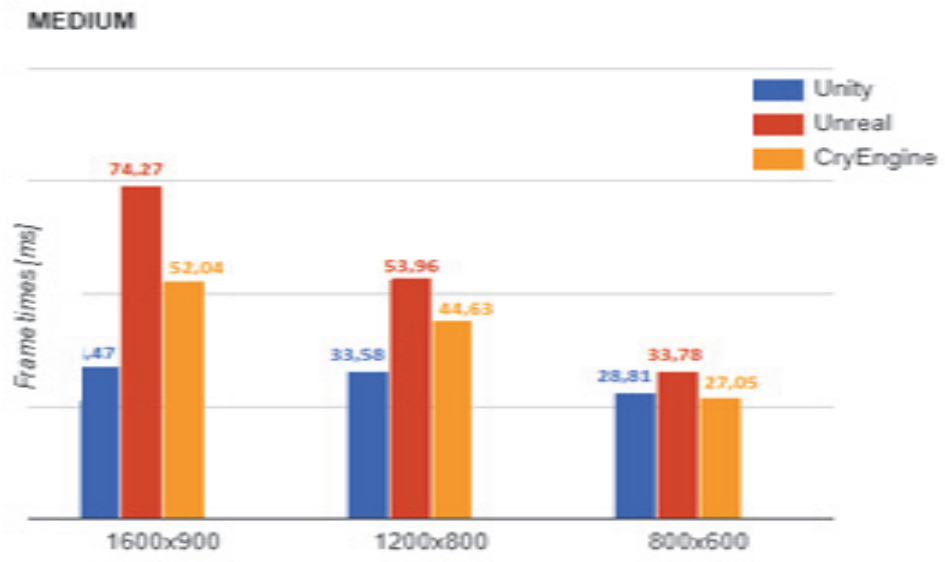

Figure 5. Results at medium tree density and medium graphics quality, Source: own elaboration

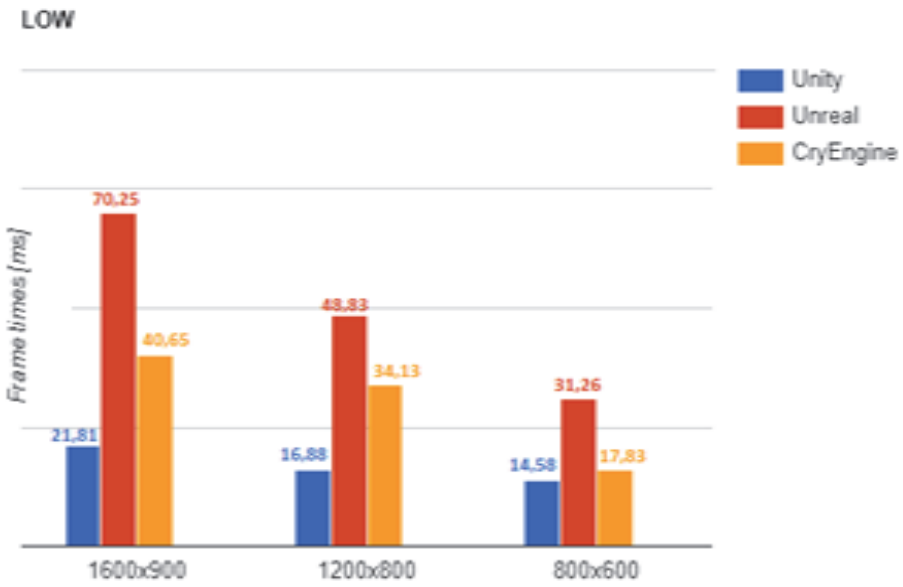

Figure 6. Results at medium tree density and low graphics quality, Source: own elaboration

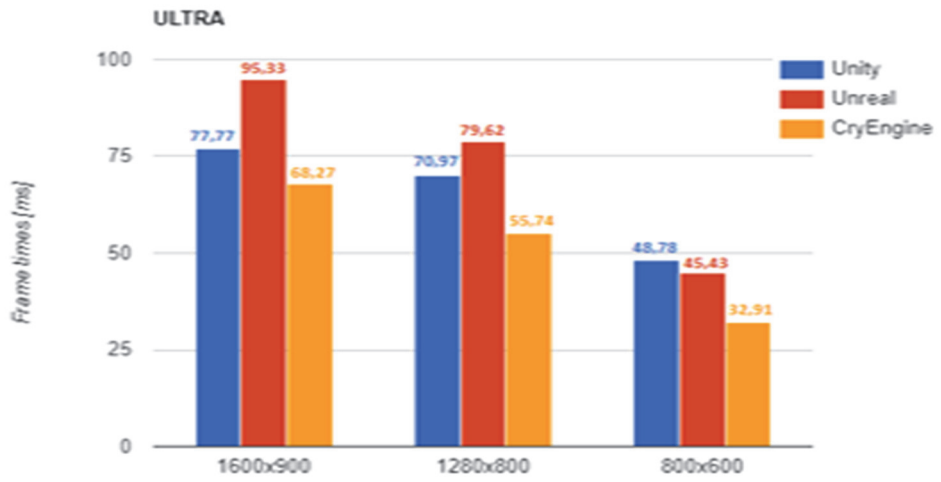

Figure 7. Results at high tree density and ultra graphics quality, Source: own elaboration

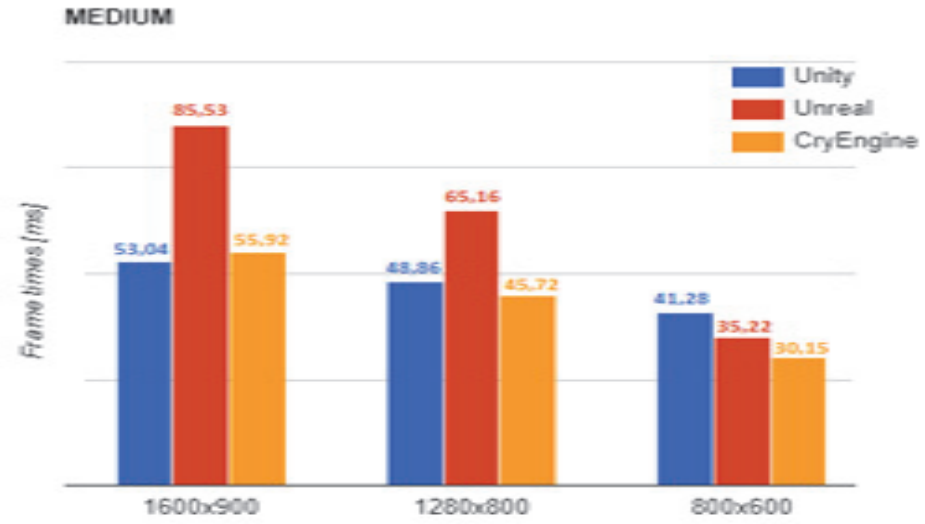

Figure 8. Results at high tree density and medium graphics quality, Source: own elaboration

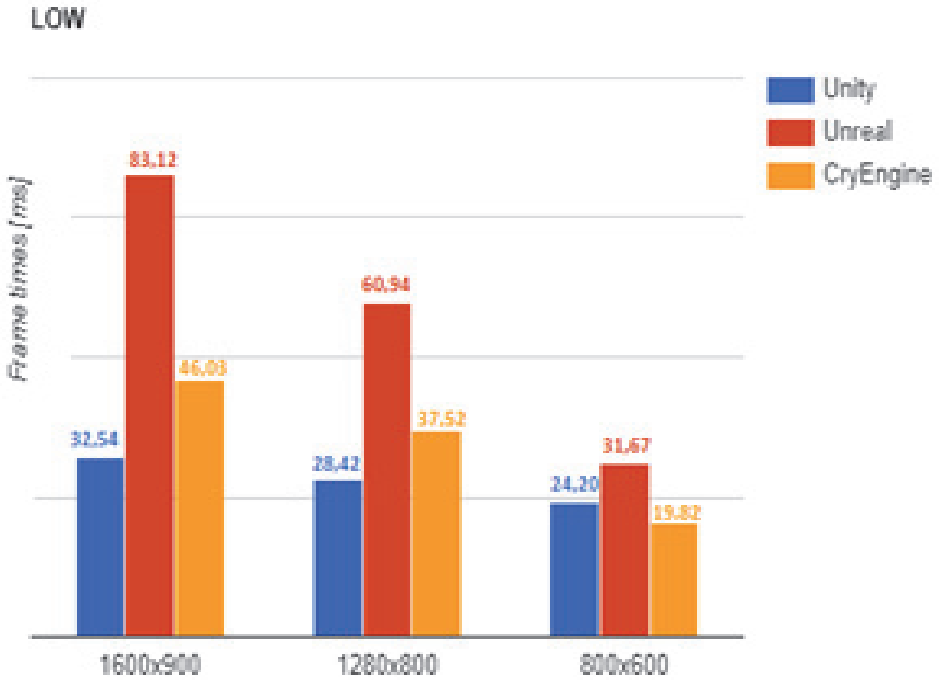

Figure 9. Results at high tree density and low graphics quality, Source: own elaboration

3. Summary

The Unity engine will probably be the best choice for beginners. Very well written documentation, many courses, and ready-made templates allow you to get to know all the most important engine functionalities quite quickly. Besides, the largest number of supported platforms and great versatility of the engine allows you to implement any genre of games. Unity is the only engine with dedicated 2D mode, so it will be the best choice for users who want to create a two-dimensional game. The disadvantage of this engine is undoubtedly the relatively small number of specialized editors. Modules enabling animation, creation of video interludes, or adding audio effects in comparison to the competition allow only for basic operations. The engine can be expanded using plug-ins and libraries, but many of them are paid, which may discourage potential users. In terms of graphics quality, the Unity engine seems to be the weakest of the compared engines. Of course, its' possible to create great looking games with this engine, but the Unreal and CryEngine engines are better suited for rendering breathtaking graphics. The test game implemented in the Unity engine did quite well during the performance tests. The implementation of the game in this engine benefited the most from the decrease in graphic quality, which was greatly influenced by the default developers' settings' policy. In the Unity engine, along with decreasing graphics settings, some graphics mechanisms are entirely disabled, which is not the rule in the case of other engines where the approach consisting in reducing the detail of graphic effects generated by these mechanisms is preferred. The game

implemented in the Unity engine lost most of its performance with increasing forest cover, which may indicate that the engine may not be suitable for the implementation of games with a large and complex world. Problems with Unitys' performance are also confirmed by the fact that the average frame rate decreases relatively slightly with the decrease in screen resolution.

Unreal Engine, unlike Unity, will not necessarily be the right choice for beginners. The vast range of options and editors available can be overwhelming when first contacting this tool. Unreal Engine gives more freedom to programmers, and thus this type of operation must be handled by the engine users themselves. However, Unreal Engine can be a good choice for users without programming skills. BluePrints authorial tool allows you to write the whole logic of the game with the use of graphic diagrams, which can completely replace the need to write code in C++ language. Unreal Engine is distinguished from the competition by its support for many target hardware platforms, the ability to generate high-quality graphics, a proven and relatively easy to use network module, a great editor of materials, the ability to create advanced skeleton animations, and systems supporting the implementation of artificial intelligence behavior. In performance tests, Unreal Engine did not perform well. In most experiments, the game implemented in this engine was the least efficient. It should be noted, however, that with the increase in forestation, the game written in Unreal Engine lost the least amount of performance. Proper optimization of this engine is also evidenced by the biggest increase in performance as the resolution of the graphics displayed decreases. Relatively poor results obtained during experiments may indicate that the engine is not well adapted to weaker hardware configurations.

CryEngine is a tool that certainly cannot be recommended to people without experience in creating games. A small number of tutorials and rather poorly written documentation are unlikely to help attract new users. In comparison to other engines, it is also a rather insignificant universal tool, focused mainly on the creation of FPS games, possibly games of related genres. Turning a blind eye to the imperfections of CryEngine, it is a tool that enables you to generate the highest quality graphics, providing many unique functionalities i. e. great terrain editor, author's system of animation of virtual characters'; faces, high quality systems enabling implementation of NPCs' behaviors and editor allowing for designing three-dimensional objects directly in the engine. In performance tests, the game implemented in the CryEngine engine with the highest graphics settings and the highest forest cover worked the most efficiently.

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