OPTIMIZATION OF CULTURAL HERITAGE VIRTUAL ENVIRONMENT FOR GAMING APPLICATION

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ABSTRACT

Serious games are games with a purpose beyond entertainment and are widely acknowledged as fruitful tools for learning and skills development across multiple domains, including specifically educational enhancement. In these last years, the world of serious games has been widely increased. Until now, the purpose that push these phenomena is to educate the alumni of the classrooms. Games have been shown to be powerful complements to classroom-based education, enhancing both learning and motivation to learn. Game design requires significant specialist knowledge and can be very time-consuming and costly. Furthermore, transitions between instructional design and game implementation is acknowledged as lacking methodology. Our challenge was to design a serious game that was an adventure games as well, available on any platform, friendly user and free download on web. To achieve this great goal, it was necessary to overcome the limits and problems due to the virtual environment starting from 3D acquire, finishing to the image stability. In this chapter we show the flowchart and methodology for optimization of cultural heritage virtual environment for gaming application.

Keywords: Serious Game, Cultural Heritage, Virtual Environment

INTRODUCTION

EFFECT TO THE PERSONALITY TO BECOME A GAMER

In these last years, online games have become one of the most popular hobbies among teenagers thanks to their diverse and attractive features. Nevertheless, there is not any educational approach of them. The online game addiction is defined as “excessive and compulsory use of video games that lead to social and emotional problems, and the user, despite the problems, is not able to control this excessive use” [11]. The World Health Organization also announced that online game addiction should be recognized as a disease, as experts agree on the risk of addiction to these games. Although this is said to be due to the widespread expansion of online games, it is more common among young people. Mr. Yasarovich said, “it is still too early to predict the extent of the problem”. On-line game addiction is a relatively new concept and there is still not enough information about the disease and its dissemination factors at the population level.
Scientific psychology research shows that introvert people were more addicted to online games and they were more worried about their identity and more insecure about peers [13]. These concerns about

themselves and others, along with their characteristics can lead these teenagers to avoid real social activities [2]. They may also try to cover their social needs through online games, where they can interact with others remotely and in a superficial manner [19]. The negative consequences of online addiction can be classified into three broad categories: physical problems (fatigue, physical pain, reduced sleep time, eating disorder), personal life problems (conflicts with friends or family, low social participation), and professional failures (loss of work or school, poor performance) [13, 38]. Some psychologists report the link between depression, anxiety, and symptoms of attention deficit/hyperactivity disorder with online addiction. Cognitive distortion structures, introduced by Aaron, Beck and Ellis, are generally defined as false arguments that play an important role in the development of many mental disorders. According to the cognitive-behavioral model, cognitive distortion plays an important role in Internet addiction. Parenting style is defined as the various, normal, and natural behaviors that are used by parents to control and socialize with their children [14, 29].

The results of the research showed that parents of people with Internet addiction do not have the warmth and intimacy, and their children consider their parents (especially their mothers) to be punitive and exclusionary. Narcissistic personality is a type of personality characterized by features such as extreme fantasies about power, beauty and success, having a great deal of sensitivity to criticism, and unparalleled feelings. In fact, high narcissistic personality traits are associated with an increase in online game addiction [37]. This research examines two hypotheses: cognitive distortion, parenting style and narcissistic personality traits have a meaningful relationship with addiction to online games in students; cognitive distortion, parenting style and narcissistic personality traits predict addiction to online games in students (Figure 1).

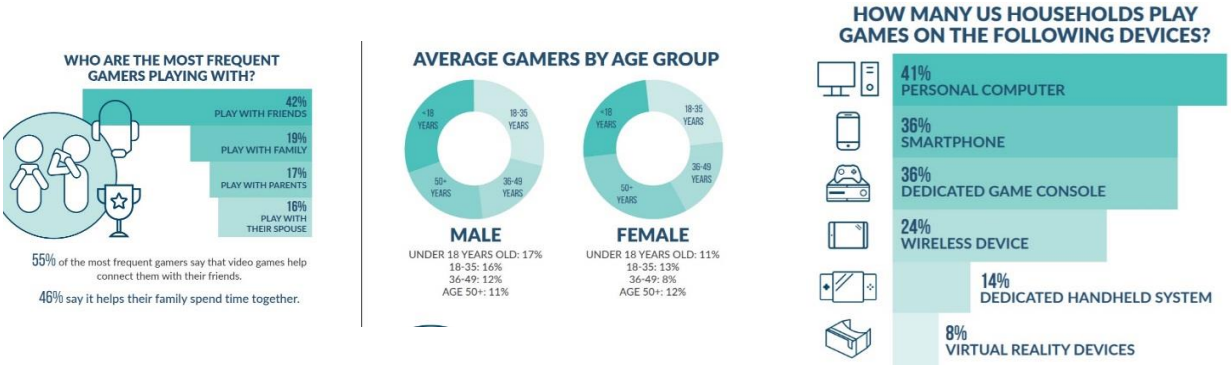

Figure 1. ESA, Entertainment Software Association (http://www.theesa.com)

If this is combined with the effect of violent video games on aggression, the danger in which the young generation is involved can be understood. Playing violent video games was shown to increase the likelihood of physically aggressive behavior, aggressive thinking, aggressive affect, and physiological arousal. Violent video game exposure was also shown result in desensitization/low empathy and a decreased likelihood of prosocial behavior. For example, playing a violent video game can prime aggressive thoughts, increase hostile affect, and create physiological arousal. In turn, internal state variables aired appraisal and decision-making processes [32]. Decision making can result either in impulsive or in thoughtful action, which can be aggressive or non-aggressive. For example, if provoked immediately after playing a violent game, the likelihood of choosing an aggressive response is increased due to heightened arousal and primed aggressive

thoughts and feelings. Factors that increase the accessibility of aggressive thoughts or feelings tend to increase the likelihood of aggressive behavior emerging from the decision process. Once a behavioral response has been chosen, this feeds back into the situation and can influence later thoughts, feelings, and actions. Overtime, the outcomes of each encounter can exert an influence on one's personality (e.g., strengthening habitual patterns of responding), creating a feedback loop. Through this cycle, repeated long-term exposure to media violence leads to the development and rehearsal of aggressive knowledge structures, causing harmful consequences such as more positive attitudes toward violence, greater expectations of aggression by others, hostile attribution bias, and desensitization to violence [4, 3, 6].

To contrast the phenomena described above, has been developed the serious games that are mostly addressed to the educational field but well-being, advertisement, cultural heritage, interpersonal communication, and health care too [30].

The first serious game has been designed in 1970 for academic book by Abt [1]. He coined the first concept of serious games "*We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement."* He used innovative gaming approaches to improve education for the physical and social sciences, occupational choice and training, and planning and problem solving in government and industry (Table 1).

	YEAR	**SERIOUS GAME**	**APPLICATION**
1.	1970	**Serious Games book**	by C. Abt Academic book
2.	1972	**Magnavox Odyssey**	Education
3.	1973	**The Oregon Trail**	Education
4.	1980	**BattleZone**	Training
5.	1981	**The Bradley Trainer**	Training
6.	1982/1983	**Pole Position/Atari VCS 2600 console**	Training
7.	1982	**Microsoft flight simulator**	Military
8.	1996	**Marine Doom**	Military
9.	1999	**A force more powerfull**	Non violent resistance
10.	2002	**America's Army**	Military
11.	2003	**Darwars**	Military
12.	2003	**Tiltfactor laboratory**	
13.	2005	**Vbs1**	Military
14.	2006	**Darfur is dying**	news

15.	2006	**BiLAT**	Interpersonal communication
16.	2007	**Peacemaker**	Government simulator to promote peace
17.	2007	**World without oil**	Environment world
18.	2008	**Foldit**	Puzzle game
19.	2009	**VBS2/Game After Ambush**	Military
20.	2010	**IBM city one**	Educational
21.	2011	**Amnesty the game**	Political
22.	2012	**X-Plane 10**	Training
23.	2012	**Superbetter**	Well being

Table 1. Milestones in the history of games

Furthermore, links between the military and gaming are far from new: during World War II, the US army general staff were the first to use "wargames" and employed them to improve their image with the population. The advertising of one of the world's first commercial home video game consoles, the Odyssey by Magnavox (launched in the USA in 1972), emphasized the device's potential as an educational tool, and thus it might be considered one of the first serious video games [9].
Later, in 1973, educational games such as The Oregon Trail and Lemonade Stand were produced by the Minnesota Educational Computing Consortium (MECC). Lemonade Stand, which was created in 1973, focused on business management, while The Oregon Trail, produced in 1974, intended to teach users about American colonists and was very popular and is still popular today through mobile phones and Facebook. It stands as an example of a successful serious game [35].

THE SERIOUS GAMES

In this scenario, where the games play a role so important, it became more important to design.
In Table 2 there are 23 most popular serious games from 1970 to 2012. Between them there are some serious games that changed the world fighting for a humanity, political, environment and so on, cause.
And at least but not at last, there is the last serious game survey, on the fifth great sites for serious, educational games [16, 20].

	YEAR	SERIOUS GAME	WORLD EDUCATIONAL IMPACT	APPLICATION
1.	1982	**Microsoft flight simulator**	Flight Simulators are the grandfathers of serious games, so it seems only right to mention the most successful commercial flight simulator of them all. Going since 1982 Microsoft Flight Simulator was designed to be a comprehensive simulation of civil aviation and it's one of the few non-combat flight simulators in existence.	Military
2.	2003	**Tiltfactor laboratory**	Established in 2003, serious game research centre, Tiltfactor Laboratory, saw success in the last few years	Social change

			with their innovative card games. The company's motto is "Game Design for Social Change" and with learning games like Pox and Awkward Moment, they teach players about serious topics like the impact of the anti-vaccination movements and avoiding social stereotypes.	
3.	2006	**A force more powerfull**	In 1999, PBS released A Force More Powerful, a documentary about non-violent resistance. Breakaway Games developed a video game based on the series in collaboration with one of the leaders of Serbia's Otpor! Movement. The game was designed to teach nonviolent methods for waging conflict using player-built scenarios.	Non-violent resistance
4.	2006	**Darfur is dying**	Between its launch in April 2006 and the following September, Darfur is Dying attracted 800,000 players. Under the umbrella of 'serious games', it is classified as a new game. In the journalistic spirit of exposing the truth, Darfur is Dying helped to shed a light on the war in Darfur and the consequent humanitarian disaster.	News/information
5.	2007	**Peacemaker**	Originally a university project, PeaceMaker became 'a video game to promote peace', focused on the Israeli-Palestine conflict. In this government simulator, players need represent one of the sides and make social, political and military decisions. The positive and negative consequences of these decisions teach the players about a vastly complex situation.	Government simulator to promote peace
6.	2007	**World without oil**	"Play it – before you live it." So reads the tagline for World Without Oil, an alternate reality game (ARG) that lasted for 32 days in April-June, 2007. The game sought to make players understand how an oil crisis might affect their lives by getting them to describe how the crisis is affecting their area. After the 32 days were up, the game produced a valuable record to help anticipate problems and avoid a worst-case-scenario.	Environment world
7.	2008	**Foldit**	Three years after its release, players of the online puzzle game, FoldIt helped decipher the crystal structure of the Mason-Pfizer monkey virus, an AIDS-causing virus. Although the solution had troubled medical science for the preceding 15 years, the combined efforts of thousands of players produced an accurate model of the enzyme in only 10 days.	Puzzle game
8.	2010	**IBM city one**	With the world becoming more industrialized, IBM's City One provides a comprehensive educational resource. City One is designed to simulate the complexities of urban planning from water management to finance planning. Maxis' Sim City created a similar challenge over 20 years previously. The reason Sim City	Educational

			isn't in this list is that it was primarily designed for entertainment.	
9.	2011	**Amnesty the game**	In this game, players take the role of a Special Amnesty International Agent tasked with convincing populations and governments to abolish the death penalty. While the game does a lot to publicise the work of Amnesty International in general, it also encourages people to consider a politically volatile subject from new angles.	Political
10.	2012	**Superbetter**	Finally, Superbetter is the brainchild of Jane McGonigal – world renowned gamification guru. After she suffered a concussion in 2009, the resulting symptoms left Jane feeling depressed and suicidal. While she recovered, she created Jane the Concussion-Slayer, a game designed to treat her condition (as well as keeping her occupied). Seeing the success of JtC-S, she renamed it 'Superbetter' and developed a gamified application to help people achieve goals and overcome obstacles.	Well being

Table 2. 10 serious game that changed the world

Serious games are making the news almost every day. From teaching children about the cancer in their bodies to helping college students reinforce lessons from their business classes, these educational games take playing to a whole new level. No matter what you may be studying in college/school, there is a good chance that these educational games can enhance your learning or help you teach others. Computer games are effective mean for retaining interest of players (learners) by attracting their attention for much more time than traditional approaches [17].

Adaptimes (ADAPTIve player-centric serious video gaMES) is a project that aims at investigating how cognitive abilities, psycho-emotional processes and playing style can be used as a basis for efficient and effective player-centric adaptivity in serious games. For understanding how these three mental characteristics of the player are related to game adaptivity, the project will use a novel combination of methods and techniques. Cognitive abilities and processes will be tracked while player performs creative and challenging tasks requiring both divergent thinking (for finding various possible solutions) and convergent thinking (for choosing the best solution) and measured by psychometric tests.

On other side, psycho-emotional status and processes and playing style are going to be accessed by means of non-intrusive behavioral measuring techniques like 3D eye tracking, gestures and interaction patterns, and navigation control. Research findings are expected to address behavioral patterns and correlation between these mental characteristics and will be used for creation of an adaptation control framework using the video engine of Brainstorm Multimedia (host institution) [30].

The framework will be integrated in serious video games targeted to one of the most promising educational areas - that of entrepreneurial education. Video games are chosen due to their impressiveness, attractiveness and visual effects useful for presenting tasks requiring entrepreneurial creativity. Via a field trial of playing the game by students in entrepreneurship, the project will validate the expected efficiency of adaptation control based on the mental characteristics of the player (Figure 2).

Thus, the project plans to produce multidisciplinary and inter-sectoral results which will contribute to European competitiveness and will give the fellow the ideal opportunity to grow professionally and to fulfill a real knowledge transfer and to establish solid ground for a long-term bilateral connection academia-industry.

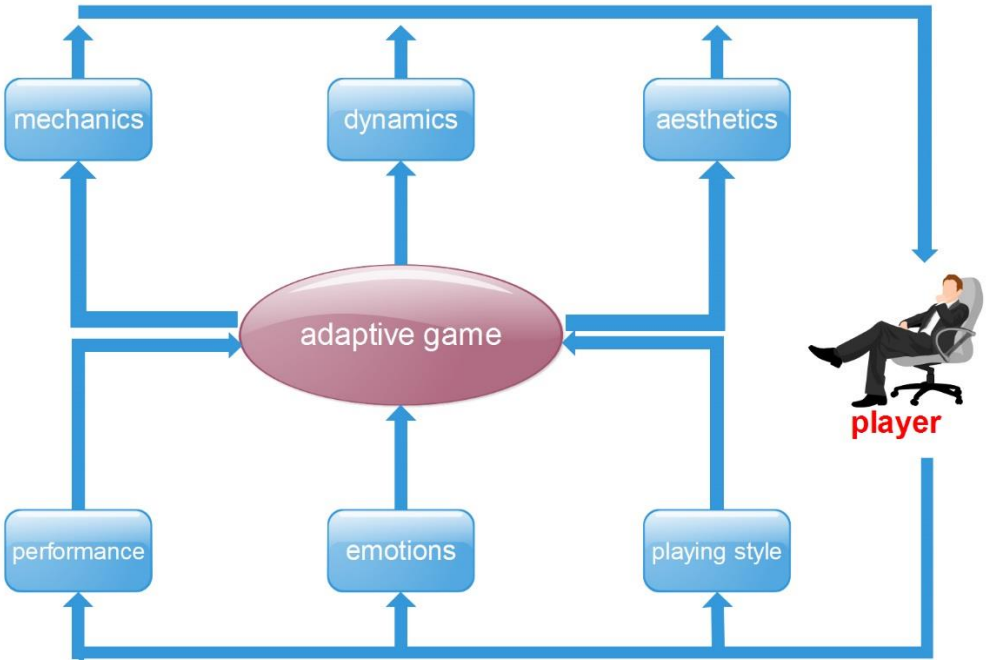

Figure 2. ADAPtive player-centric serious video gaMES

Videogame, creating both tangible and intangible cultural artifacts in highly interactive and dynamic way, should provide a powerful and increasing appeal and engagement for all user ages by possessing an integrated form of fun and play. Nevertheless, sometimes, in the serious game it doesn't happens. The games addressed to the training/educational have more an app- application aspect/function than an adventure game. This means that these games are not widely used among young people (Table 3).

1	Eve online	**Business and Management** From practicing your business skills to learning about bookkeeping in your courses at online colleges for accounting, these games will help you get a handle on your business school lessons.
2	Informatists	
3	Gazillionaire deluxe	
4	Ports of call.	
5	Fistful of dollars	
6	Robo rush	
7	The EIS simulation.	
8	Innov8	
9	Powerup	**Games for Students** These games bring powerful first-hand experience to students with games ranging from early elementary to high school and focusing on everything
10	Nanoquest	
11	Cool school	
12	Lure of the labyrinth	

13	Wolfquest	from science to civic responsibility. Even though these are designed for students, many are worthwhile for players of any age.
14	Quest atlantis	
15	Supreme decision	
16	Betwixt folly and fate	
17	Electrocity	
18	Elections	
19	Global conflicts: latin america	
20	Global warming interactive	
21	America's Army	**Training Games** From the Army to the Navy to handling emergencies to disarming situations non-violently, these games all focus on training for the real deal.
22	CyberCIEGE	
23	Triage Trainer	
24	A Force More Powerful	
25	Fatworld.	**Health and Medical Games** Whether helping young adults get a handle on their diabetes or teaching children about food safety, these games all offer education for secondary students, as well as those in online colleges for healthcare management or just beginning their careers, when it comes to health and medicine.
26	HumanSim.	
27	Food Detectives Fight BAC!	
28	The Magi and the Sleeping Star.	
29	Foldit.	
30	Re-Mission.	
31	Immune Attack.	
32	Darfur is Dying.	**Humanitarian and Environmental Games** Save the world and save the environment with these awesome and inspiring games.
33	Food Force.	
34	3rd World Farmer	
35	LogiCity.	
36	Deliver the Net.	
37	Karma Tycoon.	
38	Stop Disasters.	
39	McDonald's Video Game.	
40	A Tale in the Desert 4.	
41	World Without Oil.	**Political Games** Don't just grumble about politicians, jump in and see what they face every day with these games. Maybe you'll be inspired to go into politics
42	Democracy 2	
43	President Forever 2008.	
44	Ars Regendi.	
45	The ReDistricting Game.	
46	Peacemaker.	
47	Nobel Prize Educational Games.	**Sites with Multiple Games** These sites offer plenty of serious and educational games that touch on a variety of topics from literature to social awareness.
48	Thinking Worlds	
49	Super Smart Games.	
50	Filament Games.	

Table 3. 50 sites for serious/educational games

AIM OF THE CHAPTER

In these last months, we developed a research project to design a serious videogame that is an adventure/educational game as well. It should push the knowledge of the gamer and protects him from the unconscious dangers of video games under an exciting vest. For this reason, we have been moved to improve the serious game world with more sophisticate techniques about the photorealistic virtual model.
The main difficulty of creating a video game, where cultural assets are not a scenario but are part of the game itself, is in photorealism that has become crucial to games. But the design of a photorealistic /adventure game needs the use of optimization techniques and strategies for the gaming useful.
The chapter shows how to achieve it.
From all our senses, vision is the most dominating one. It is estimated that it contributes up to 70% of the information humans perceive. To process this information, we rely on diverse visual cues which all are essential for our orientation and perception. There are several different graphical elements that must be paid attention to while developing a game. Some of them we are considering here are:

- Dimensionality;
- Perspective;
- Color;
- Presentation;
- Realism.

The dimensionality of game graphics (not counting text here) can vary between 2D, 2_D and 3D graphics. 2D graphics is used on most board-based game implementations where a top view of the board displays enough information of the game.
Due to advances in graphics hardware, most games use 3D game engines that display a 3-dimensional world using a perspective projection with proper optical qualities. Quake was such a milestone displaying a fully textured 3D world. Since then, 3D game engines have been applied to nearly every game genre with great success [2].
The Color also plays an important role in establishing an atmosphere. It can convey certain moods with screenshots from Thief – The Dark Project, the world can change from a bright and safe place to a dark and gloomy cave. Further, the sudden change of color can introduce special situations, like switching to b/w for flashbacks.
The presentation defines how the game world and the player himself manifest on the screen. This can vary from pure text to first or third person perspectives, or even being just the top down view on the game's world. It also describes the integration of the user interface and the factor of immersion.
The realism is defined by whether the game is (photo) realistic in look and feel or exaggerate as an example the use of a comic shader and uses a non-realistic game environment. There are several aspects that contribute to the perception of realism like realistic sound, realistic character animation or the believable behavior of objects and characters (which is controlled by the physics-engine or the AI-engine). On a higher level of abstraction, the setting and causality of events or storyline contribute to the user's perception of realism. Many games also incorporate a variable flow of time that allows things to speed up or to slow down. Prominent examples are the bullet time mode in Max Payne or the accelerated time scale in simulation. The software platform for generation of labyrinth games is well described in the flowchart in the Figure 3.
The SG we developed is a learning game and an entertainment game as well where motivation, competitively and learning goals have equal weights (Figure 4).

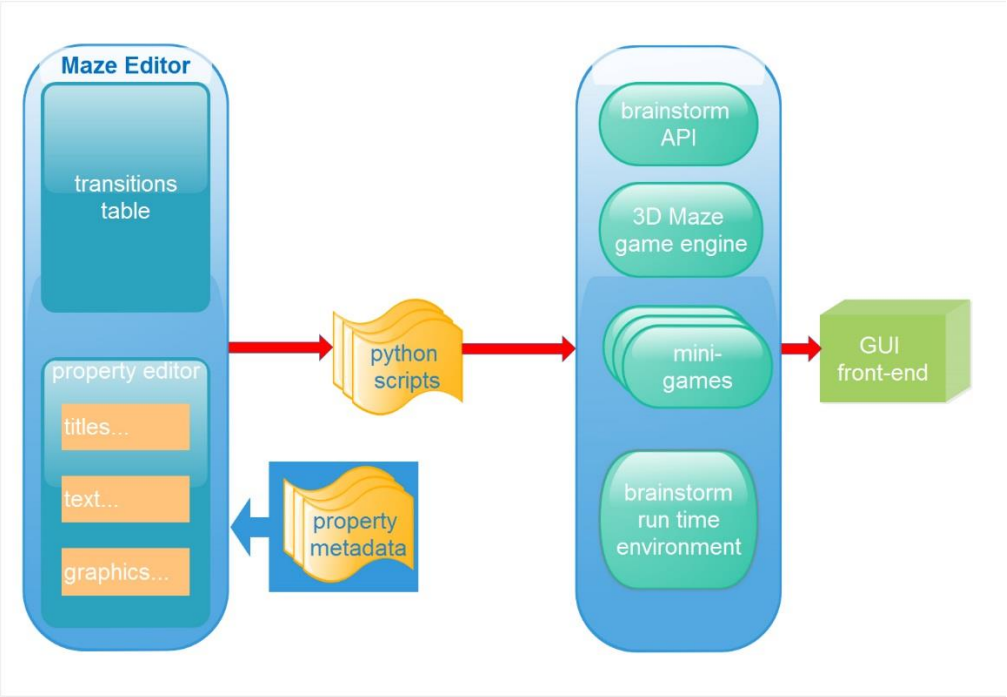

Figure 3. Software platform for generation of games

Figure 4. learning with serious games. The five "W"

STRUCTURAL GAME ELEMENTS

The structural game can be classified as following:
1.form of fun - provides enjoyment and pleasure; 2. form of play - gives intense and passionate involvement; 3. rules – determine structure of the play; 4. goals - provides motivation; 5. interactivity – leads to learning by doing; 6. adaptivity - provides flow 7. outcomes and feedback – serve as a basis for learning 8. win states – provides ego gratification 9. conflicts, competition, challenges and opposition – give more adrenaline 10. problem solving - sparks player's creativity 11. interaction - gives social groups 12. narrative (story) and its representation – both they serve as a source of emotional experience before, during and after gameplay.
When you are working on design a video games there are a lot of choices that you must get. For example: competitive versus noncompetitive games; interactive versus non-interactive games; physical versus non-physical games platforms – personal computers or tablets; game consoles like Microsoft Xbox, Nintendo Wii U, or Sony PlayStation; mobile phones; Playing mode - multi- or single-player; Milieu (social environment) - describes the visual type of a video game - science fiction, fantasy, horror, etc…
Then there are other aspects that must be considered: distribution – paid or free; openness – games with open code or not; Mod's – modified games with altered content; linear vs non-linear gameplay – while linear gameplay provides fixed sequence of challenges, non-linear gameplay poses challenges that can be completed in different sequences; progressive vs emergent gameplay – some games (like 'The Sims') do not have story structure planned in advance and, thus, offer emergent gameplay (Figure 5).
The SERIOUS VIDEO GAMES FOR CULTURAL HERITAGE use the interactive simulation of realistic virtual heritage scenarios; virtual and augmented reality, artificial intelligence – for NPC control and content generation, adaptivity. In the same time, they offer free choice of learning place, choice of learning time and speed, autonomous and self-controlled learning in the game context, problem-solving, willingness for cooperation. The INTERACTIVE VIRTUAL MUSEUMS use gaming technology for both entertaining and educating visitors usually by incorporating some exploration and reassembling tasks and quizzes, examples – "Virtual Egyptian Temple", "Olympic Pottery Puzzle2, "Walk through Ancient Olympia" and "ThIATRO".
The most common problems of the serious games are connected to the higher development cost, lower attractiveness compared to entertainment games, transition between instructional design and actual game design implementation - how Game Mechanics impact and interact with the Learning Mechanics, personalization and adaptation – based on: emotional state, physiological/neurophysiological signals, in-game performance and game progression metrics (Figure 6).
Some supposed solution to problems of SG are the rise of cheap, ubiquitous hardware, the use of robust networks that allow for connectivity without the administrative constraints of the past, making extreme pressure on schools to produce outcomes – too many kids are getting through high school with no meaningful job skills and then, the adoption of brain science software.
At least, we can consider the video games as Cultural Heritage. Video games themselves make part of the human movable cultural heritage. Out-of-date games preserve a snapshot of technological and socio-economic achievements of their epoch and provide evidence of progress in game industry evolution. Due to hardware obsolescence and data degradation most of the first video games might be lost forever.
For the video games museums there the following online archives: http://www.vgmuseum.com/; http://www.archive.org/details/gamevideos; http://www.nationalmediamuseum.org.uk/Collection/New

Media/NationalVideogameArchive.aspx; Museums: the Videogame History Museum - http://www.vghmuseum.org/; Computerspielemuseum - http://www.computerspielemuseum.de/; Museo Games (Paris); The Discovery Tour by Assassin's Creed: Ancient Egypt - https://store.steampowered.com/app/775430/Discovery_Tour_by_Assassins_Creed_Ancient_Egypt/.

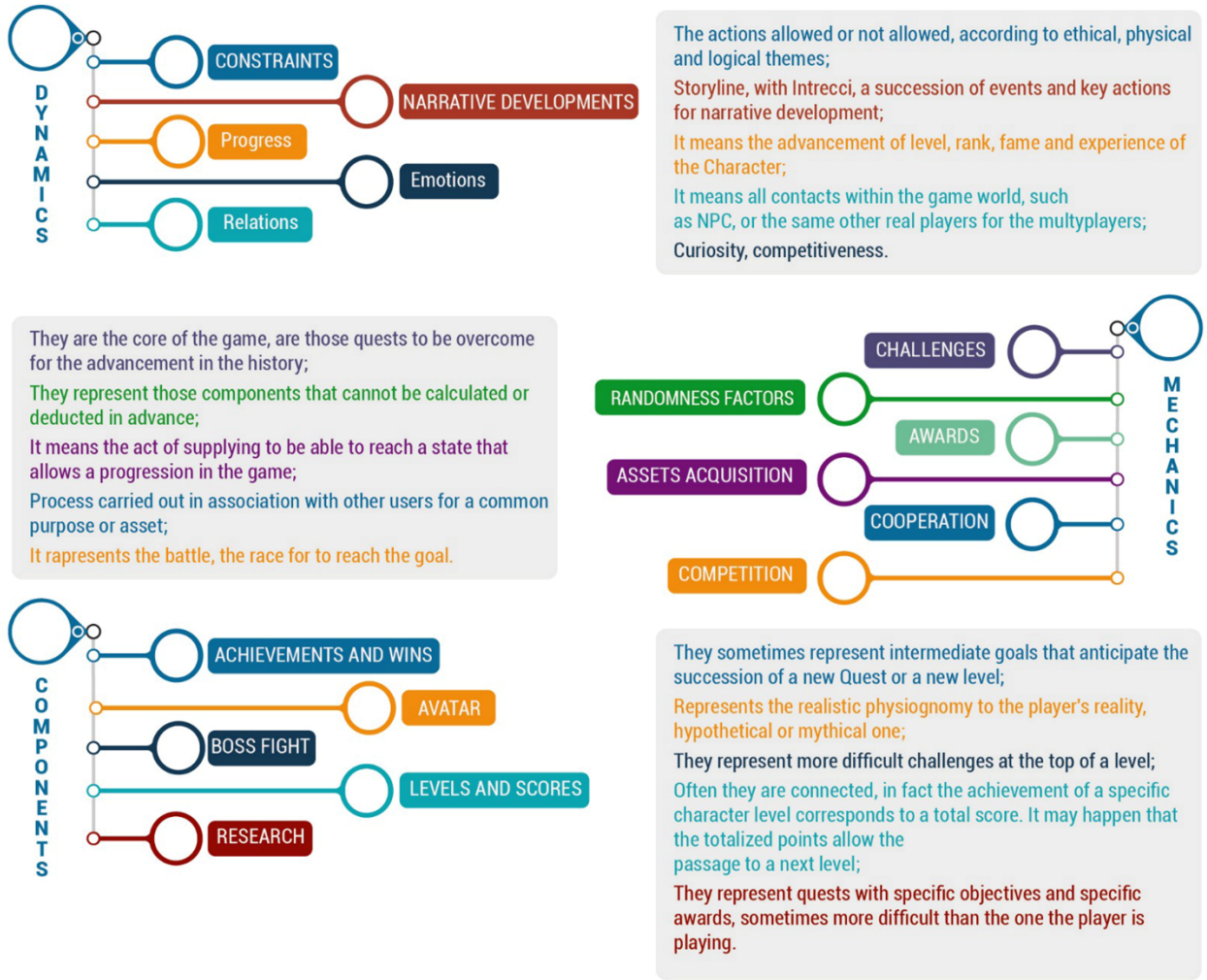

Figure 5. Structural Game Elements

DESIGN AND OPTIMIZATION TECHNIQUES AND STRATEGIES FOR THE GAMING ENVIRONMENT. WORKFLOW AND TOOLS EMPLOYED

In the wide context of Digital Heritage and in this new interpretative scenario just described, the visual communication of a 4.0 cultural experience implies a process of digitization and integration of all the tools to promote, innovative dynamics of the cultural supply, to attract and to involve the user and to create effective multidisciplinary analysis and study platforms.

The technologies of Computer Graphics, Web Design and Gaming and the non-invasive techniques of 3D Scanning (and, nowadays, the photogrammetric techniques) with high-performance devices allow to

generate applications for the high-resolution visualization of three-dimensional environments with the possibility to navigate, to analyze and to query in real time the virtual models.
The research aims at analyzing the actual design strategies of a game structure and to develop procedures to process and to edit 3D data that allow to manage the dedicated platform to the fruition and the knowledge of Cultural Heritage [10].

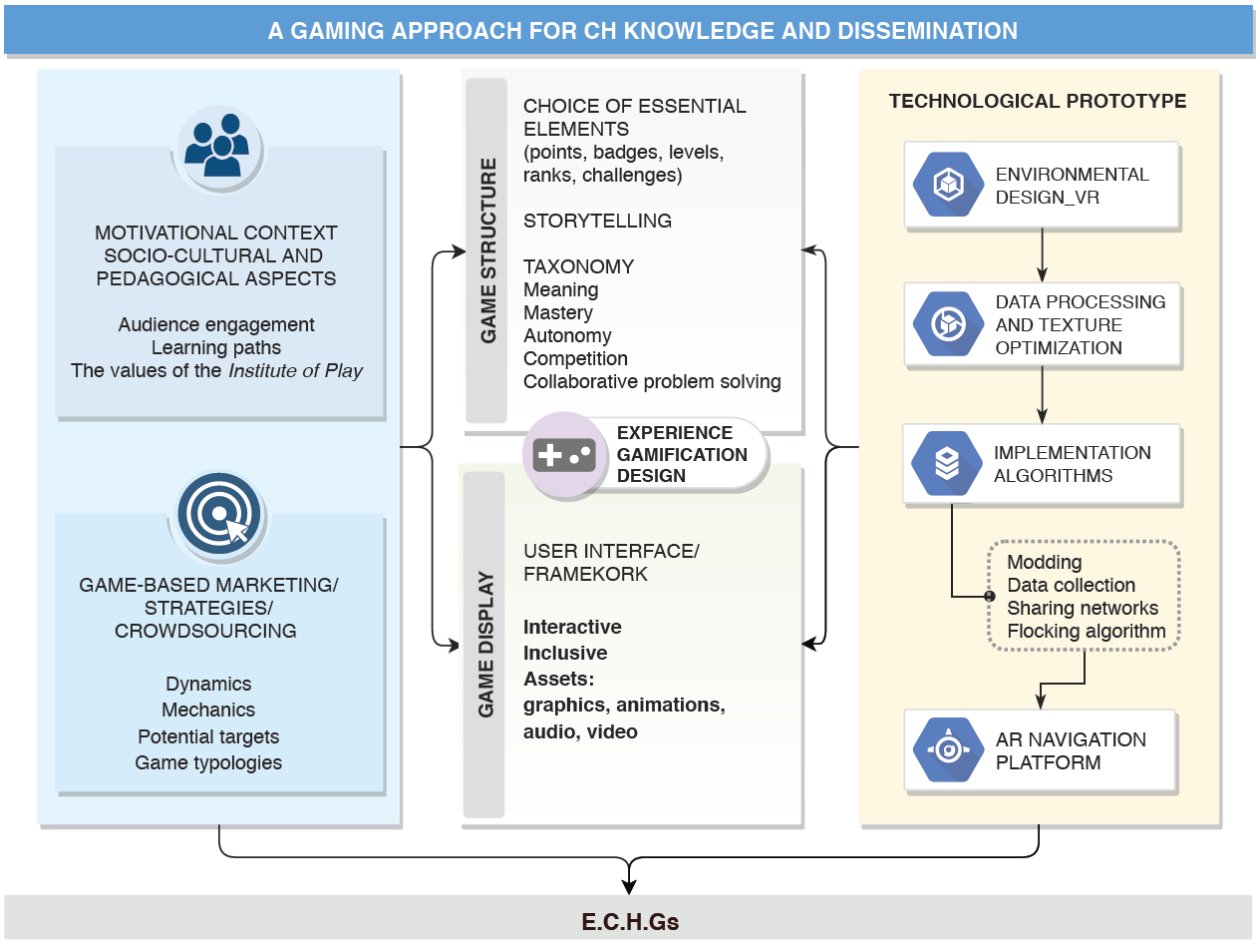

Figure 6. Flow chart of the pipeline of the Entertainment CH Games design structure

The workflow submitted explores and tries to overcome a variety of operative issues that are common in a 3D digital acquisition process of complex objects, such as archaeological artefacts, works of art, decorative or architectural elements. At this point, the applications created, to be placed in an environment with game peculiarities, must have special characteristics, in terms of polygonal weight, quality of texture applied, geometric topology that, obviously, can deeply change in accordance with the kind of digital model created. It highlights the value to develop and manage suitable design, implementation and development strategies for 3D content pipelines in order to visualize cultural photorealistic environment gaming, effectively with today's devices in commerce [25, 29].
For instance, the texture quality is a crucial issue to investigations in the field of Architecture, Civil Engineering, Design, Cultural Heritage, Archaeology and, nowadays, even more than in the past, gaming.

Usually the texture on the 3D model is often worse than that of 2D images mainly because: the individual texture on the 3D model comes from different image sources; there are many camera and environmental parameters or, the logistical problems due to data acquisition (under/over-exposed areas, low ambient lighting) [23, 27]. These aspects could produce several issues that give us a result that doesn't correspond to the real object with regards to the geometry and the texture mapping [5, 7, 12].

The set pipeline allows you to obtain the architectural scenario furnished with all the elements that characterize it for the creation of a virtual tour in gaming mode that allows the user to immerse himself and navigate the museum environment involving it with a series of infographic information that emphasize the virtual visit. In order to test and evaluate the management and optimization process, it was decided to develop a prototype of a museum setting in game mode, determining the precise design and operational choices described below (type of software in terms of reliability, accuracy and simplicity; software implementation tools; export mode; criteria for baking and packing of 3D models, etc..).

The methodological process was carried out in three different phases.

The first phase required the 3D modeling of the architectural-environmental context, based on the 2D documentation found (photographic survey, design drawings, direct survey, planimetric setting).

The second phase involved the digital acquisition with non-invasive photogrammetric techniques of *Reverse Modeling* (*SfM* technique and, where needs, *structured light* technique) of the decorative apparatus and the collections of the museum artefacts. As will be described later, in this step it has been possible to optimize the models acquired with mesh reduction amount and sculpting techniques and the meshes and textures applied to them [22, 24, 26].

The last phase of "coding" was involved: the coding of the game structure within the *UnReal Engine 4* platform (by *Epic Games*) and the creation of new and specific addons and parametric-procedural algorithms in dedicated programming languages (*Python*), scripts that have made more productive some steps of the workflow editing.

Returning to the description of the first phase, we describe some of the salient aspects that have characterized the strategic choices adopted. One of the fundamental concepts for *CGI* (Computer Graphic Imaging), applied to the world of videogames, is the management of *LODs* (Level Of Details), which determines the real playability and an effective real-time and interactive display of a game. The acronym establishes, in relation to the position of the player from an object on the scene, the level of detail that is represented of it.

The use of appropriate LOD management criteria implies an effective game navigation, correctly exploiting computational resources and hardware performance. In particular, the hardware component that manages this process is the Video Card, which must generate in real time the context around which the character moves. Therefore, the level of detail must not and cannot be the same for each object, and for each distance of the player from it.

The usual procedure to manage this aspect and reduce the load on the *GPU* (Graphic Processor), is called multi-resolution technique and involves loading, within the game engine, two or more meshes with a different number of polygons. This happens, for instance, when, with a very low poly polygonal load mesh, the player is tens of meters away from the object and the software loads the next mesh (*high poly*) to approach the player. However, as will be described below, for the model with high polygonal load, it is not meant a mesh with the same number of polygons obtained with the photogrammetric techniques used, but these data must be optimized and corrected for subsequent processing.

For the creation of the prototype game presented here, the LOD technique was not used for all the objects on scene, but for some the polygonal load was simply lowered exponentially but using high resolution procedural textures.

This procedural choice has allowed to satisfy the requirement to contain the final weight of the whole project to visualize and to interact with the models also through devices with more limited hardware resources.

The whole architectural structure has been modeled, textured and rendered within the *Blender* work environment (stable version 2.79 and beta version 2.8). The latter is a cross-platform open source software, distributed under the GPL license. One of the strengths of this software is the presence of modifiers, in other words, specific non-destructive effects parametrically applicable to a mesh, such as subdivision or deformation. The modifiers most used for the creation of the three-dimensional scene have been: *Subdivision Surface*, *Bevel Modifier*, *Smooth Mesh*, and *Mirror Modifier* (Figure 7).

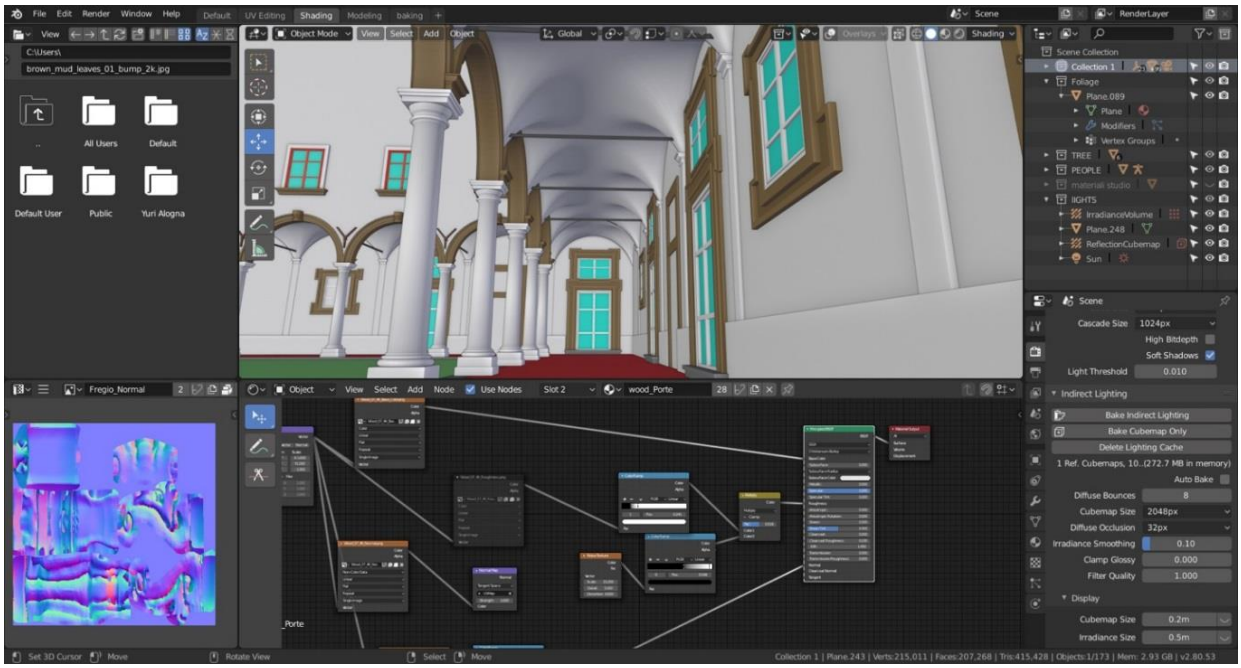

Figure 7. Game environment design using Blender 3D sculpture tools and modifiers

In addition, using proprietary 3D sculpture tools, the architectural elements (arches ashlars, moldings and friezes) have been modelled, adopting some methodologies that have allowed to obtain a graphic rendering very faithful to the reality, preserving, at the same time, the computational load of the processor manageable (Figure 8).

With this aim, the processes of *Retopology* and *Remeshing* (software used: *MeshLab* and *Instant Meshes*) on polygonal models have been started. These two processes replace a mesh with a new one that reflects certain characteristics. The rebuilt mesh with a reduced number of polygonal faces (low poly) is required to conform to two fundamental requirements: it must maintain the shape of the original mesh (high poly) and it must have a topology which conforms to the aims of the project.

However, when the geometry is organic, many details are lost during the *Retopology* phase, but they are also displayed using procedural textures, during the phase called *Baking*. These procedural textures are

specially created to store information in 2D maps without adding geometry to the model, such as the *Displacement map*, the *Lightmap*, the *Cavity map*, etc. (Figure 9).

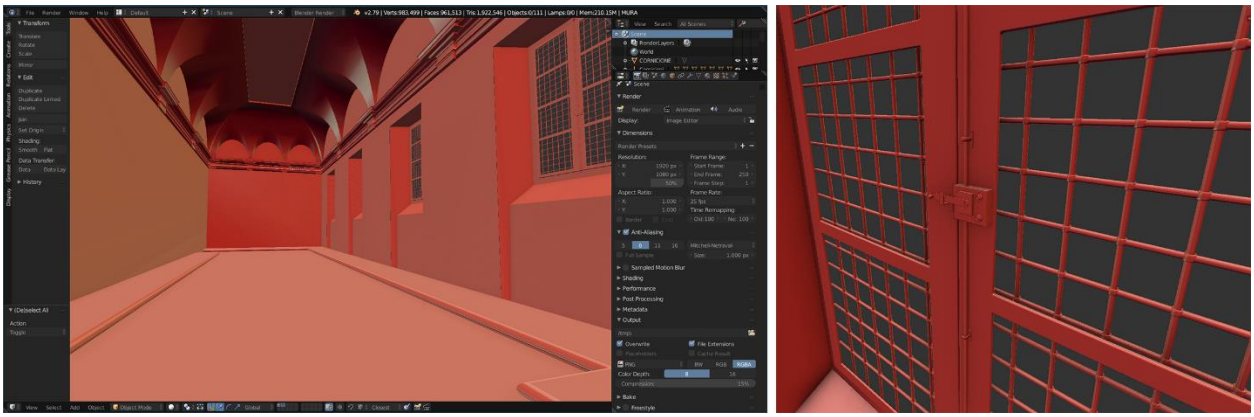

Figure 8. Game environment in Matcap display

Figure 9. The Retopology phase on an architectural element and the Baking one by procedural 2D maps

About the setting of the parameters of the *Lightmap*, a series of tests were carried out in order to establish which were the best resolution values, from a computational point of view, for the export from the *Blender* environment to the *Unreal Engine* platform. The result of the tests showed that, with the same number of polygons, two meshes with *Lightmap* with a resolution of 512 are more efficient than a single *Lightmap* of 1024 (Figure 10).

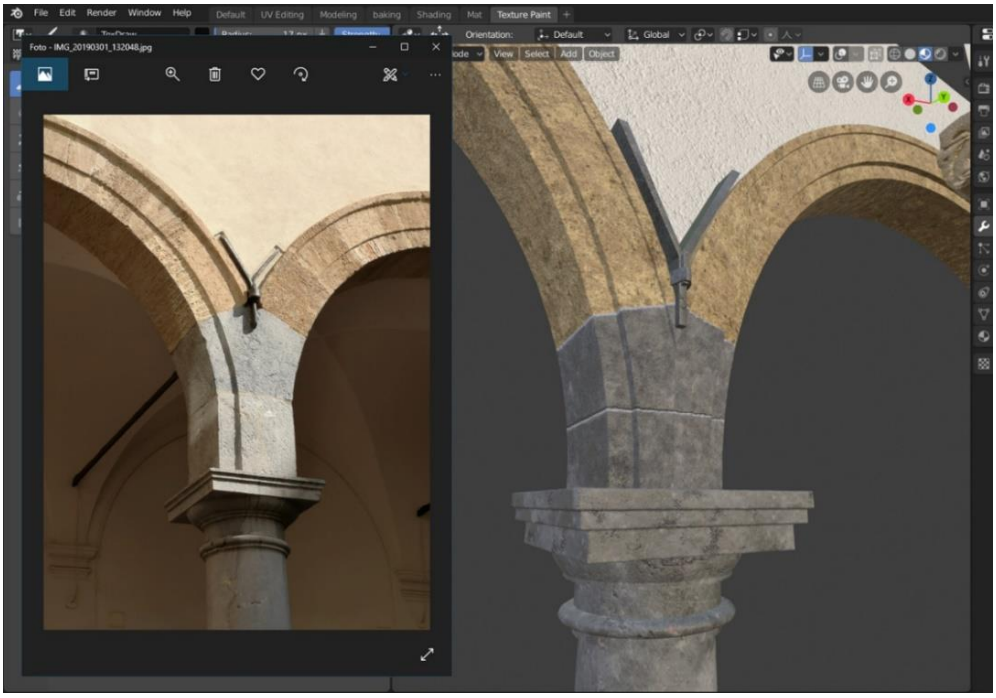

Figure 10. The procedural textures created to store information in 2D maps without adding geometry

About the setting of the parameters of the *Lightmap*, a series of tests were carried out in order to establish which were the best resolution values, from a computational point of view, for the export from the *Blender* environment to the *Unreal Engine* platform. The result of the tests showed that, with the same number of polygons, two meshes with *Lightmap* with a resolution of 512 are more efficient than a single *Lightmap* of 1024 (Figure 10).

Another optimization strategy in order to obtain a real time photorealistic visualization was to represent with visual devices the areas of the scene not accessible to the player. For instance, the windows placed on floors higher than 10 meters or the areas not accessible by character, were geometrically built through a flat rectangular surface, which was then calculated with the technique of *Baking* the mesh containing the details shaped with image-based methods (Figure 11).

The textures, which reproduce the scene's cladding materials, have been reproduced in procedural mode, using the node editor available within *Blender*. The various procedural maps used were subsequently combined with each other through mixing tools, following specific logics.

The nodes are basically constituted of three types of sockets:

- “Color node” (in yellow), color information is transferred with *RGB* channel values (not including the *Alpha channel*).
- “Numerical” (in grey), numerical information is displayed, in the format of a floating variable, using sliders that go from 0 to 1. The values are converted to grayscale (e.g. *Alpha Channel*, *Ambient Occlusion*).
- “Vector” (in blue), coordinate information is displayed, in general, vector type information (e.g., *Roughness_Amount*).
- “Shader node” (in green), contain information about the internal operation, recognition and conversion within the *Blender Rendering Cycles engine* of the previous nodes connected to it (for example, *Principled BSDF node*) (Figure 12).

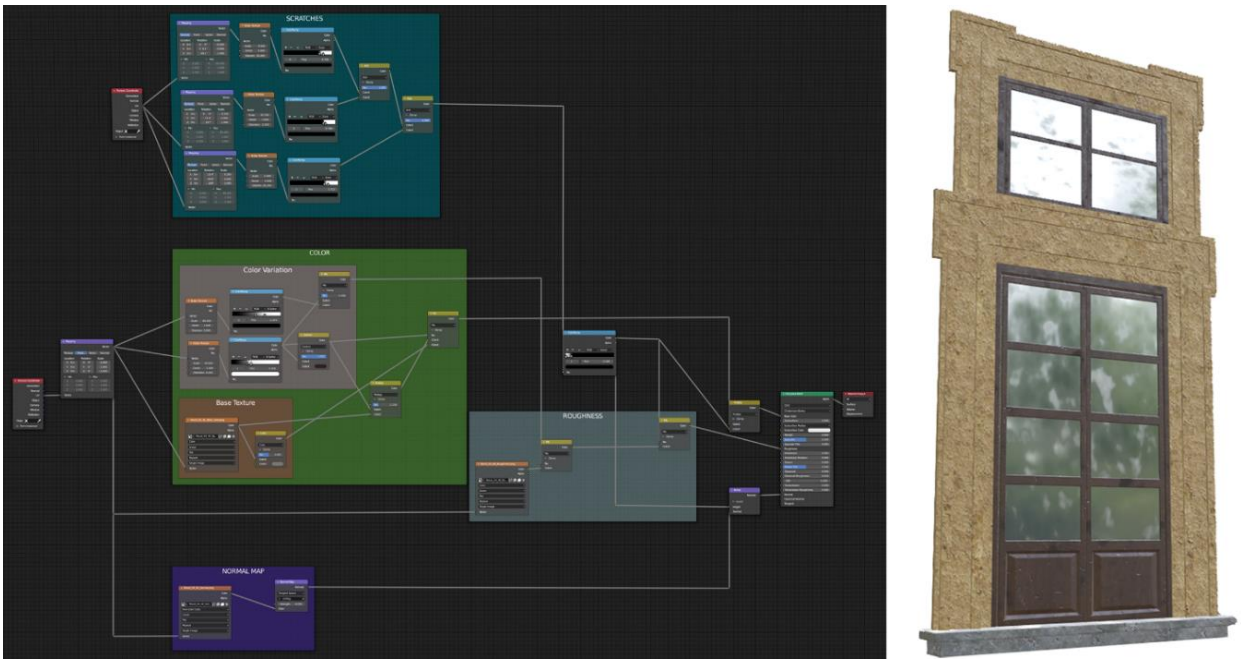

Figure11. The procedural texture creation which reproduce game architectural elements within the Blender node editor

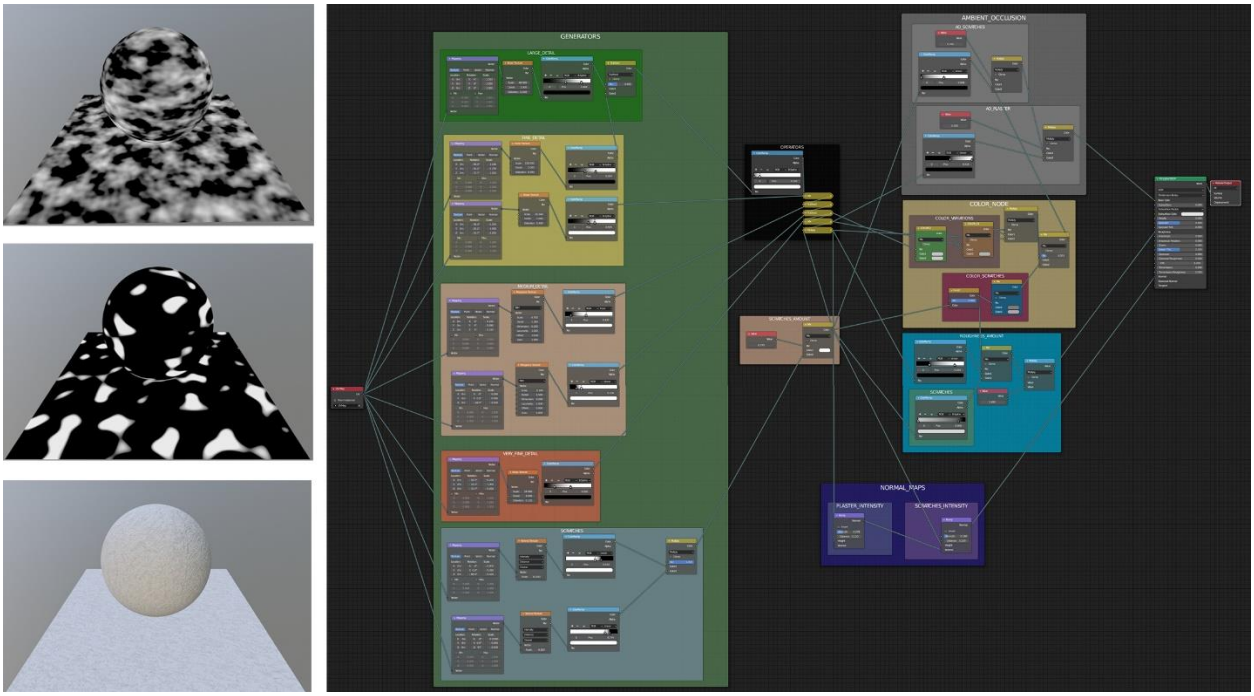

Figure 12. The procedural texture creation which reproduce the scene's cladding materials within the Blender node editor

SCULPTING AND MESH REDUCTION AMOUNT

After the3D acquire of the work arts, that has been made using by the photogrammetric techniques and structured light scanner, the part that optimizes the geometry and texture of the objects starts [15, 28].
From literature and from experience it is known that in the texture mapping, the most common issues are: the low texture resolution; the missing color in some mesh portions and photo inconsistencies that usually appear along the boundary of the various groups of meshes; the topological errors due to formal geometric complexity; the integration with different acquisition technologies (Figure 13) [31, 33].
The tested process aims to overcome these critical issues. This defined texture optimization workflow includes multiple steps: Mesh collision detection/re-meshing/mesh correction; Polygonal mesh parameterization; *Model quality/final user*; *Mesh segmentation unwrap*; *Project island* and *UV Map layout optimization*.

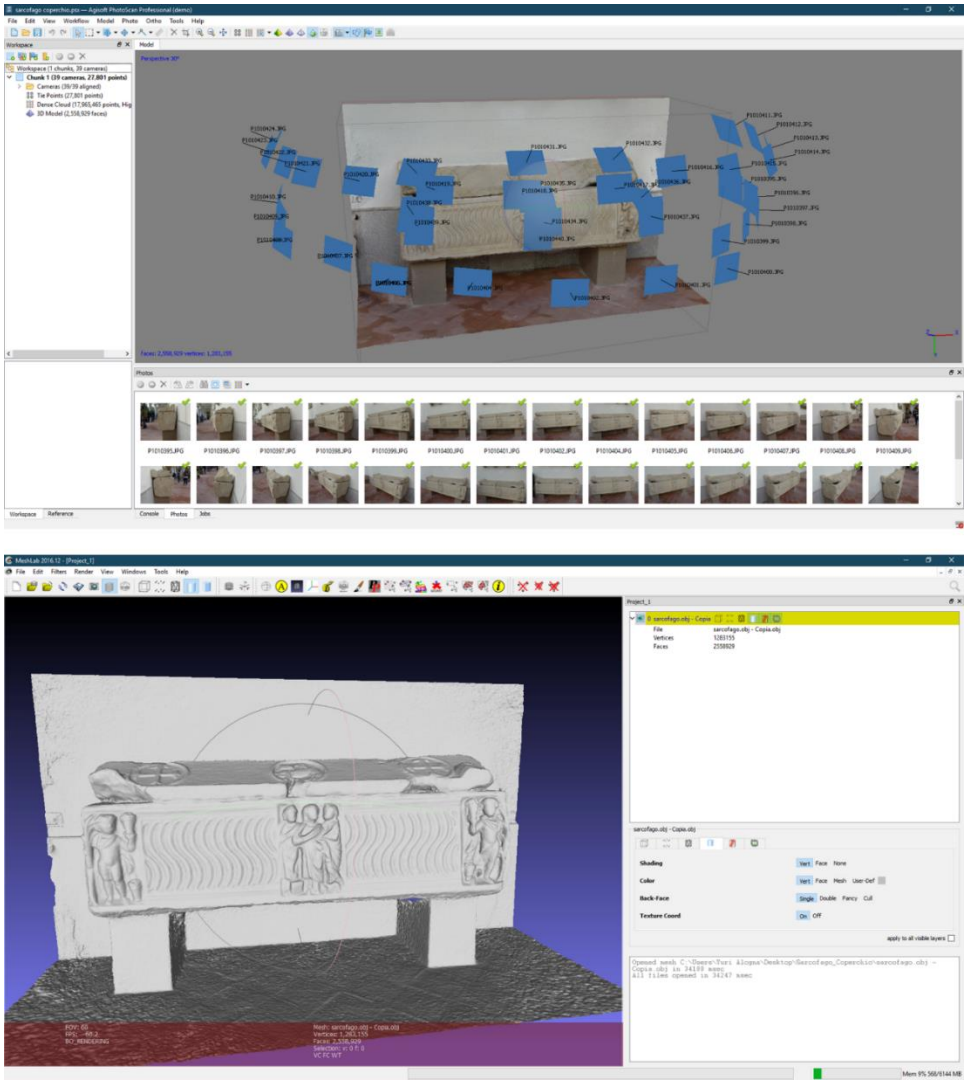

Figure 13. Digital acquisition with non-invasive photogrammetric techniques of Reverse Modeling (SfM technique)

The *UV Mapping* phase can be conceptually associated with the "flattening" phase of a solid that is represented in two-dimensional mode according to logical and mathematical criteria.
Before proceeding to the mesh segmentation, "unwrap", it is required to check for topological errors to optimize the mesh structure. Indeed, often, by exporting a model acquired with *Reverse Modeling* techniques, the resulting mesh may have vertices that are overlapped, or not connected to each other. Sometimes, further, by reducing the polygonal weight, there are visualization problems due to the removal of the vertices necessary for the visualization, which are wrongly classified by the software as not relevant. Therefore, in order to correct any errors in the structure of the mesh, through a specific tool for the detection of superfluous vertices, they are eliminated, thus lightening the polygonal load and the visualization of the mesh without altering the geometry (Figure 14) [34, 36].

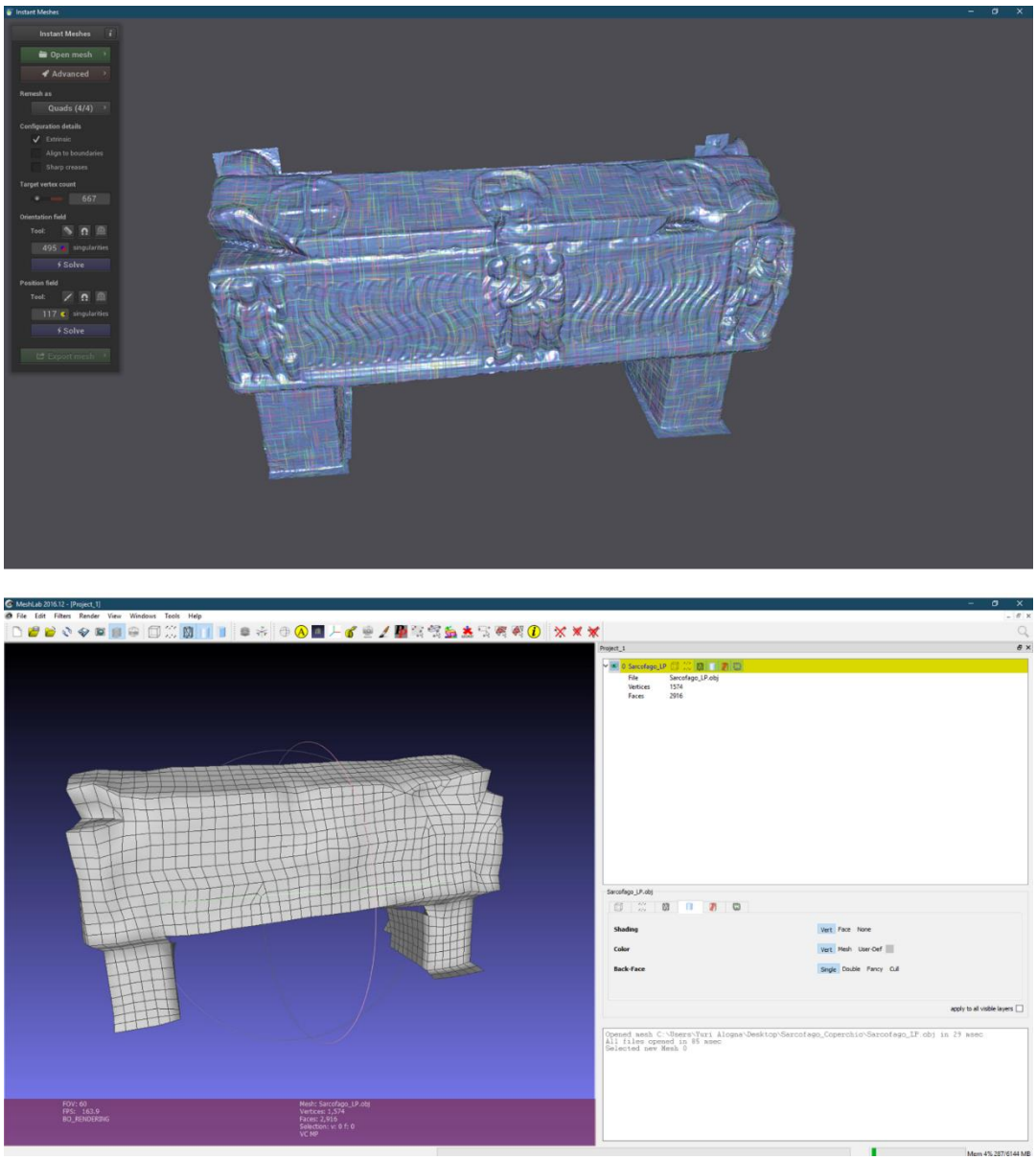

Figure 14. Mesh collision detection, Re-meshing and polygonal weight reduction

MESH AND APPLIED TEXTURE OPTIMIZATION

After, according to the application field: conservation or real-time visualization and gamification, it is necessary to establish which path to follow. The paths could be essentially of two types: to continue working on a model with full polygonal load, to engage in further multidisciplinary research, or lighter for a real-time display.

At this point, the study focuses attention to the “mesh partitioning” that assigns a weight to each mesh, to create the *UV MAP*.

The libraries available within the *Blender* software use an automatic procedure for creating *UV Maps* and islands segmentation; the tool is called *Smart UV Project*. Thanks to this tool, it is possible to create a very disjointed map of triangle patches.

During the texturing process, the latest software technology uses tools dedicated to generating vertex maps, known as UV vertex maps, to assign the texture to a numerical model with a complex geometric shape.

As the texture is a planar 2D figure, the UV vertex maps establish a strict biunivocal correspondence between the vertexes of the 3D polygonal mesh and the pixels of the image.

The calculation of the vertices on the 2D domain is based on the approximation of the minimum squares according to mathematical formulas that minimize the distortion of the triangles along the perimeters of the patches. In *Blender*, it is possible adjust the “Angle Limit” in the operator menu to try to minimize distortion, but, often, the mesh unwrap isn’t compatible with the geometrical-formal features of an object, or the unwrap obtained does not optimize the 2D domain, leaving entire portions empty (Figure 15).

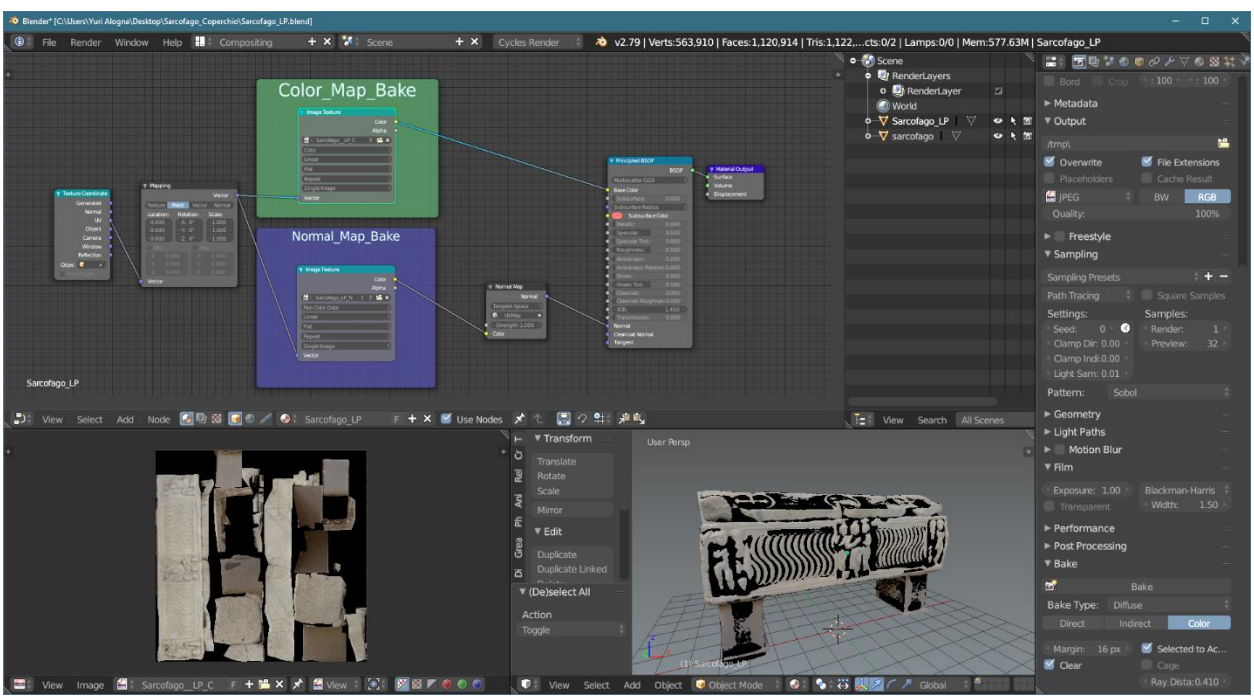

Figure 15. Baking node System, UV-remapping and texture optimization. Mesh with final baked UV-Map disposition

Hence, the aim is to segment the resulting meshes into patches and unwrap them onto a 2D planar surface, according to semantic criteria imposed by the user that consider (for instance: topological relationship; colour variation; display mode, specific shape of the object).
The aim of the pipeline developed is also to determine controllable solutions of the "UV vertex project" that allow to occupy the entire perimeter of the UV Map of the bitmap optimizing the high resolution of the image associated with the model.
Following the phases of the set method, for each of the acquired 3D models the following steps have been developed: Removing Doubles Vertices from the acquired Mesh and closing seam, and edges connections review; *Mesh partitioning* process for better *UV-Mapping* Working process; *Mesh marking seams* process for manual unwrapping mode.
These steps allow to optimize the polygonal weight of the object compared to the initial acquired mesh, dividing the geometry in a custom way (Figure 16) [8].

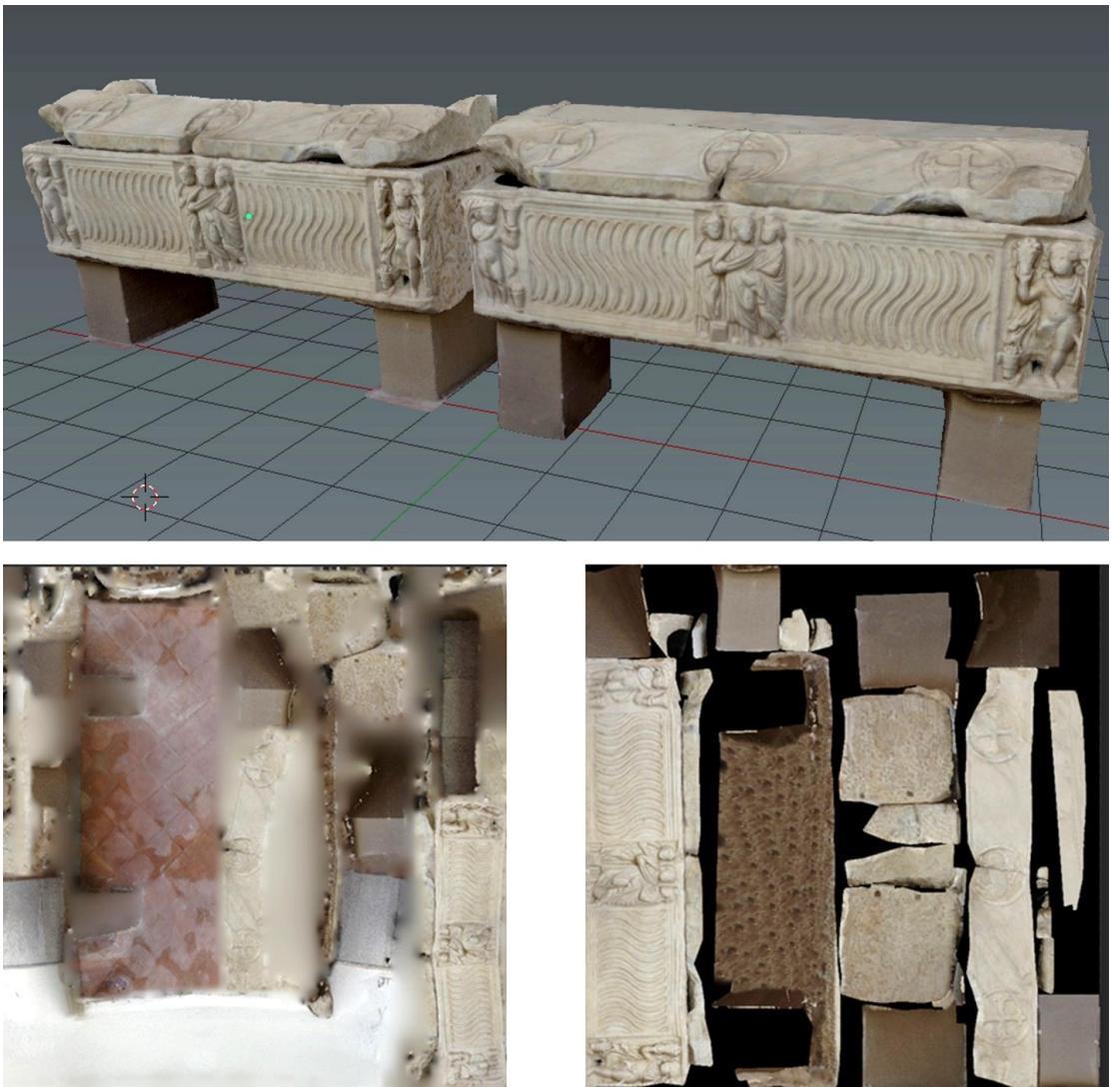

Figure 16. Optimisation process of polygonal load and baking, from the "original" UV-Map to the final one with the assigned blank image

One of the most used tools in *Computer Graphics* applications is *Baking*. It is particularly useful for managing models with high information density and a high polygonal load (*high poly*).
This procedure defines a UV vertex map and it collect the data of the acquired model in high resolution and "cook" them in a low-poly model: morphological data (onerous calculation of the simulation of the light/matter ratio, global illumination, radiosity); displacement maps; normal maps of the RGB type (normal map) [18].
In the final phase of texture optimization after baking, some areas of interest have been selected with the *Texture Painting mode* tool and emphasized (by creating masks) editing some parameters such as: saturation, contrast and brightness.
Following this process of editing and optimizing the geometry and texture applied, each model is assigned: the initial mesh with original *UV-Map* Arrangement; the *Matcap Visualization* with final *UV-Map Arrangement* and the final Mesh, with the final baked *UV-Map disposition*.

DESIGN OF SPECIFIC ADDONS IN SPECIFIC SCRIPTING LANGUAGES: PYTHON

The proposed mesh partitioning technique essentially assigns a weight to each mesh. The tool used is the "Weight Paint Mode".
In the *Blender* environment, there are two methods to use this tool: in manual mode and in automatic one.
In automatic mode, with the aim to achieve a semantic and automatic selection of the polygonal mesh, using the color variation, the study presents an implementation of this tool with the *python* language [21].
The specific addon is described in detail below.
The weight is translated into shades of color using red, yellow, green and blue (Figure 17).

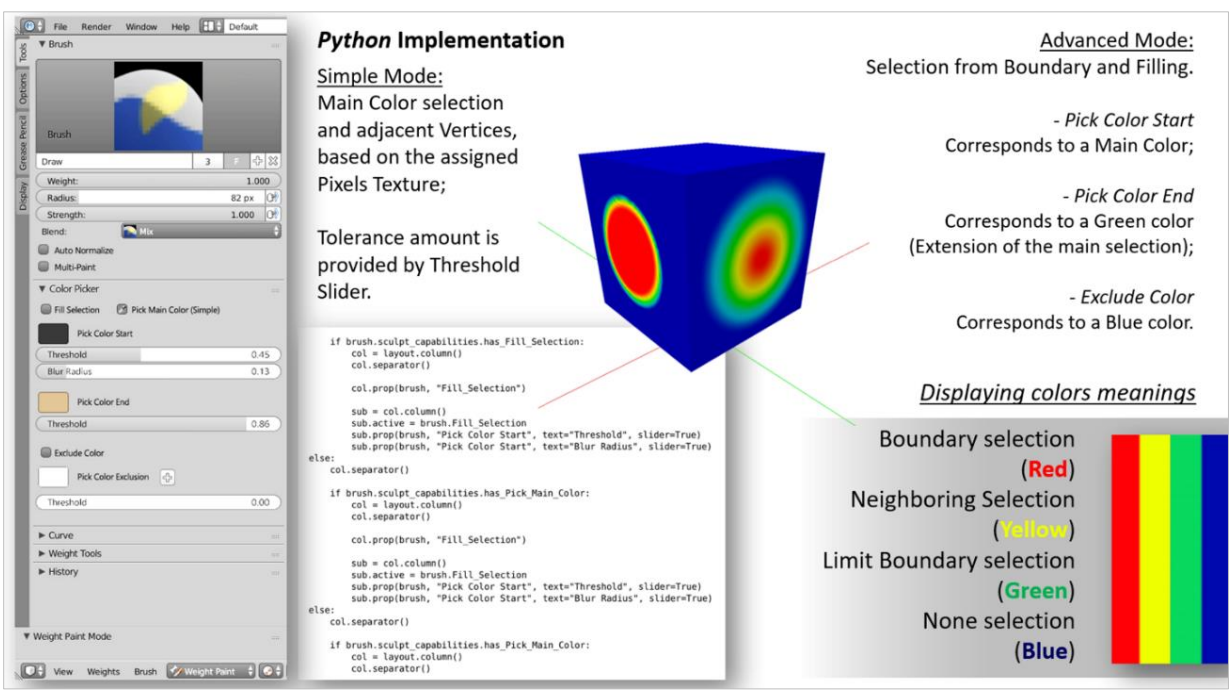

Figure 17. "Weight Paint" Mode, automatic selection, with the implemented Color Picker tool. Python implementation Addon

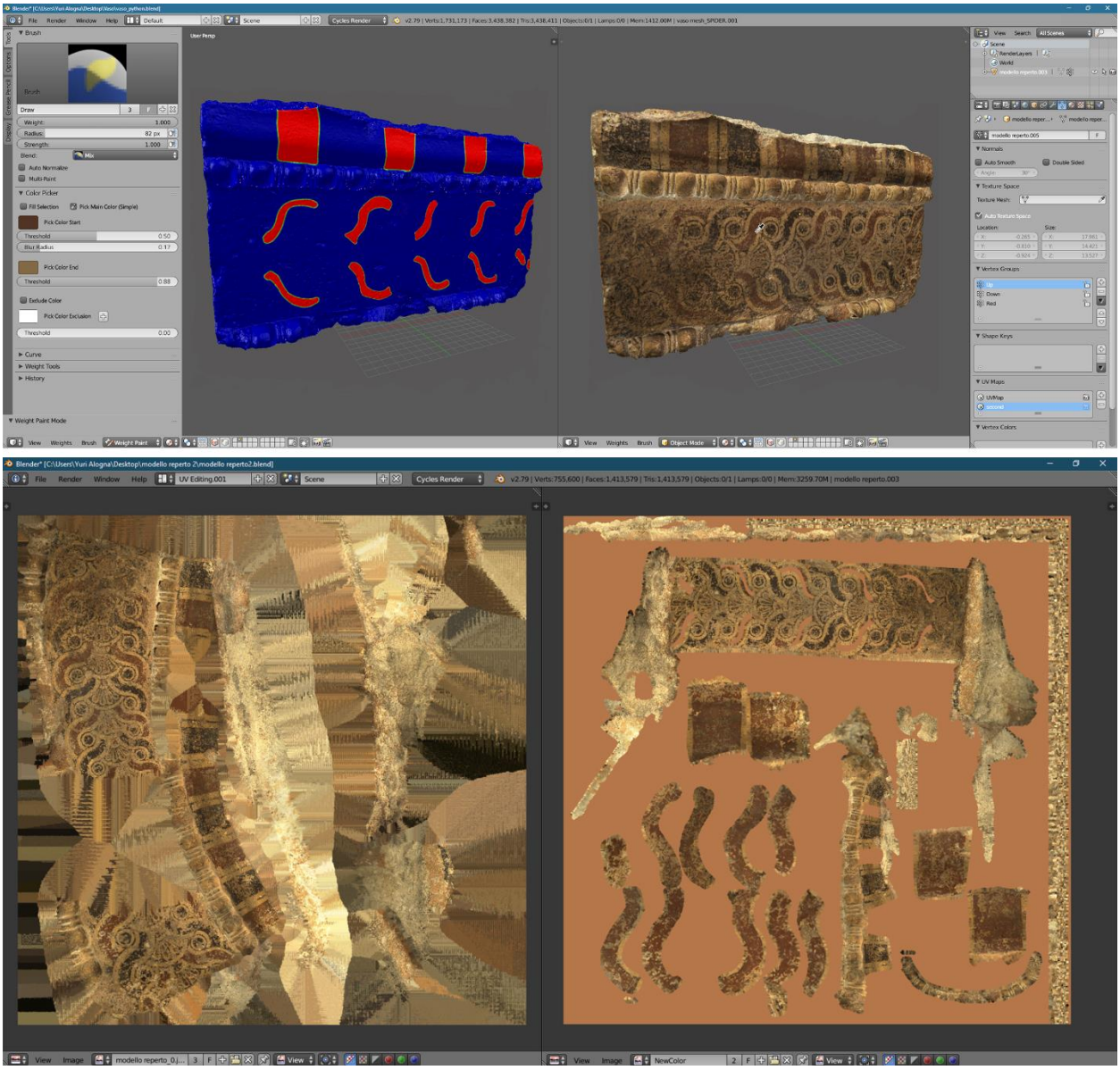

Figure 18. Automatic boundary selection by "Weight Paint" Advanced Mode, Blender Environment (above); comparison between the automatic and custom UV maps (down)

Each color has a specific meaning.

- The *Red* colour is decoded by the tool as a user defined selection and represents the boundary selection.
- The *Yellow* colour is decoded by the tool as an extension or expansion selection.

This happens after having selected and chosen inside the box color "pick color start" the selection color tonality.

- The *Green* colour identifies the end of the selection that is chosen by the box color "pick color end", the slider threshold manages the visibility as well as the extension.
- The *Blue* colour indicates that no selection (or exclusion) of pixels and, consequently, of mesh vertices has been made.

The algorithm has been defined according to two modes of automatic interaction (Figure 18).

The first is the simple mode via “pick main color selection”.
This mode selects a main color and automatically also the adjacent vertices corresponding to the pixels of the texture assigned to the object. The chosen color is displayed inside the “Pick Color Start” Color Box.
The parameter that manages the Pick function and the selection tolerance is the “Threshold” slider, while the “Blur Radius” function manages the selection blur. Modifying the “Threshold” and “Blur Radius” parameters the extension changes on the adjacent similar pixels, and therefore parametrically the vertices below.
The second mode is called “Advanced Mode”, selection by boundary “Weight Paint”.
After having selected the boundary through “Weight paint mode”, the command will fill the mesh area within this.
The Color picker modes are two: “Pick Color Start” Function (Pick the vertex with the primary color assigned to it) and “Pick Color End” function (Pick the vertex with the primary color assigned at the end of the selection).
Finally, “Exclude Color” and “Pick Color Exclusion” function have the role to select the vertexes with assigned the “external” color to the selection criterion. It applies if within the selection area the vertices with different colors are automatically selected.

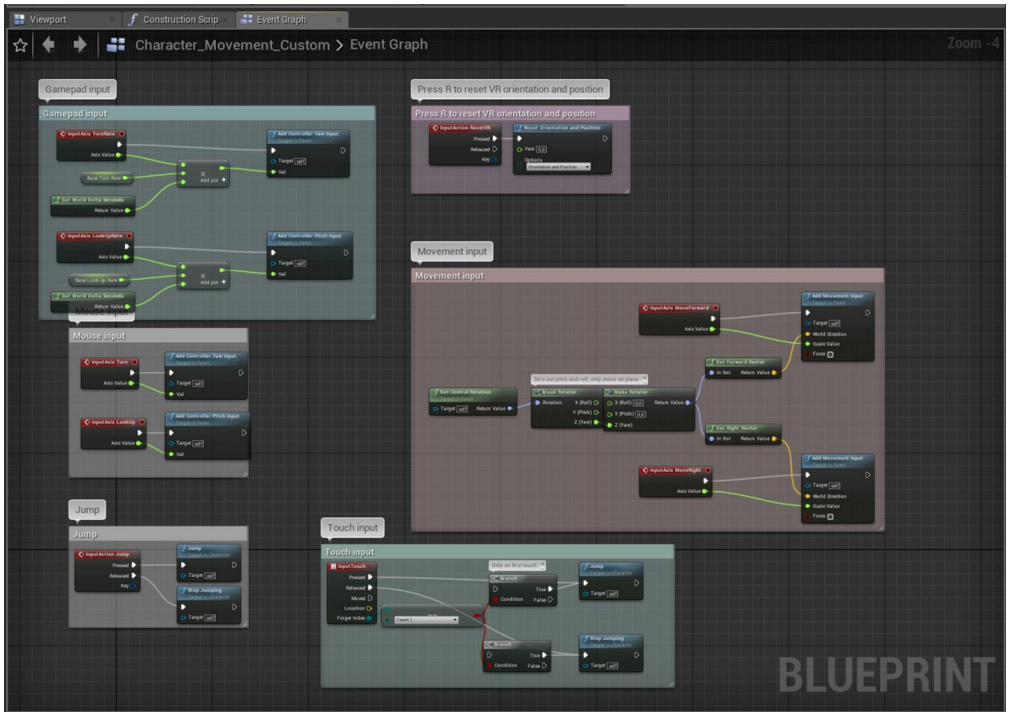

Figure 19. Setting the Unreal Engine 4 Blueprint Visual Scripting node interface

CONCLUSION

Some games for fun will continue stay open for modifications with means of adapting and evolving the original game, which creates opportunities for adding didactical and cultural elements to them like SGs. Applied games for cultural heritage with non-linear and interactive storytelling will be used more and more

for immersive cultural presentation, teaching, assessment and training. In the big world scenario, our research is well correlated and overcome some problems that, until now, have been reduced the application and dissemination of SG games.

By employing the proposed workflow there is great potential in producing high resolution textures associated to models with different resolutions (*high poly/low poly*) in relation to the final use (conservation or real-time 3D visualization and gamification).

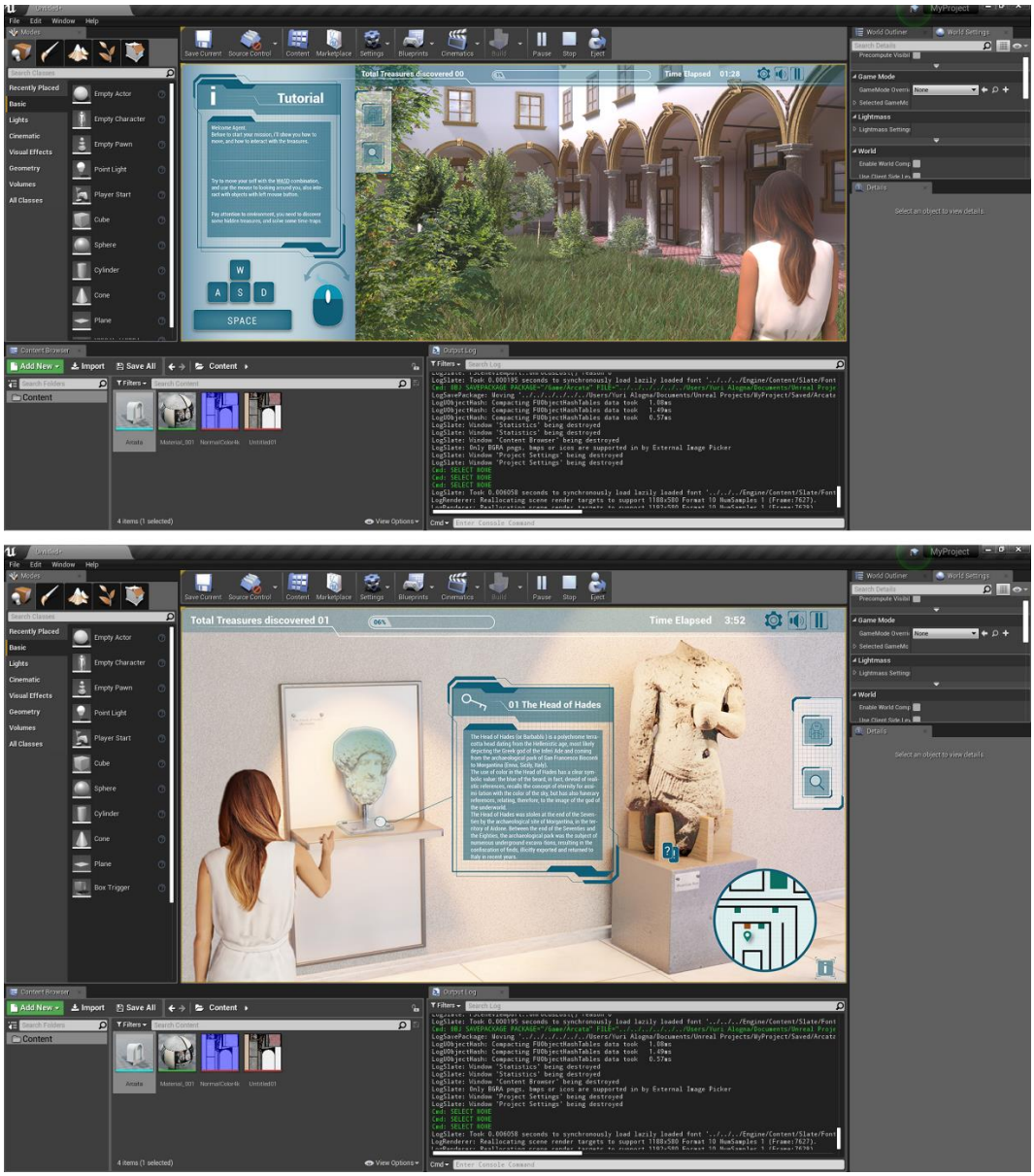

Figure 20. Game environment, configuration of the context and of the player's paths within the UnReal Engine 4 platform (above). Design of the selection and interaction modalities of the contents within the UnReal Engine 4 platform (down)

Some advanced surface segmentation methods were used to reconstruct the texture, used in the *Blender* environment. Alternative methods were also proposed, defined by implementing an algorithm, written in *Python*. These alternative developed methods create a mesh unwrap that is more compatible with the geometric-formal features of a complex photorealistic environment and with other custom user-defined semantic criteria (Figure 19-20).
The results present design and optimization techniques and strategies for the gaming environment

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