DynaMus: A Fully Dynamic 3D Virtual Museum Framework

Chairi Kiourt Anestis Koutsoudis George Pavlidis
chairiq@ceti.gr akoutsou@ceti.gr gpavlid@ceti.gr

"Athena" Research Centre, University Campus at Kimmeria, Xanthi GR-67100, Greece

Abstract

The evolving technologies of the game engines and the Web have reached a level of maturity that enables them to contribute significantly to the long-celebrated blending of culture and education with gaming. In this work, we present *DynaMus*, an innovative fully dynamic Web-based *virtual museum framework* that relies entirely on users' creativity and on the exploitation of the rich content in distributed Web resources. DynaMus is able to connect to popular repositories, such as Europeana and Google, and retrieve content that can be used in creating virtual exhibitions. It exploits modern Web technologies such as open linked data in an attempt to move towards the semantic Web by exploiting the abundance in data availability. DynaMus provides a complete authoring interface, in which anyone can easily create customised virtual exhibitions, while guaranteeing an engaging experience by relying on modern game engine technologies. The concept easily connects to educational settings as has been illustrated by case studies, one of which is presented in this paper.

Keywords: Dynamic / virtual museum / virtual exhibition / Game-based learning / Distributed data / Cultural resources.

Research Aims

Several research and development efforts have already created a significant amount of works relating to virtual museums and exhibitions. In most cases these efforts produced a very specific outcome, that is, a virtual museum or exhibition for a particular cultural stakeholder. Just a few works (really less than a handful) envisioned more than such specific applications, aiming towards generic systems to encompass more than one stakeholder or application, which, mostly, make use of proprietary technologies. To the knowledge of the authors of this paper, still, there is not a completely generic system that would enable users to easily and freely build a virtual environment (a small virtual world) in which to create and publish virtual exhibitions, even more, with content that is already online on the Web. DynaMus brings this concept to life by providing a totally generic, easy to use, technological framework for VR authoring and open linked data connection that is accessible even by children as has been illustrated by case studies.

1. Introduction

The continuous development of Web services and computer infrastructures complemented by the increasing availability of computer game development platforms (also known as game engines), contribute towards a continuous release of serious games (SG) in diverse fields including entertainment, cultural heritage, education, artificial intelligence, sociology, military and health systems [1]. In a sense, SGs can be considered as an efficient approach for blending domain specific activities, like in cultural heritage and education, with gaming. By utilising contemporary visualisation and simulation technologies SGs enhance the user's experience through photorealistic interactive environments [2]. This form of stimulation is considered to be one of the primary factors for successful user engagement, playing, at the same time, the role of the driving force that promotes concentration in the activity process and user encouragement for further self-improvement. Stimulation is largely considered by the scientific community as a desired mechanism to achieve the desired results [3].

Gaming for educational purposes is a significant and active research domain [4]- [7]. This has taken either the form of game-based learning or serious gaming. As shown in Figure 1, gamification in this sense is the result of serious games based on learning, the content and game design.

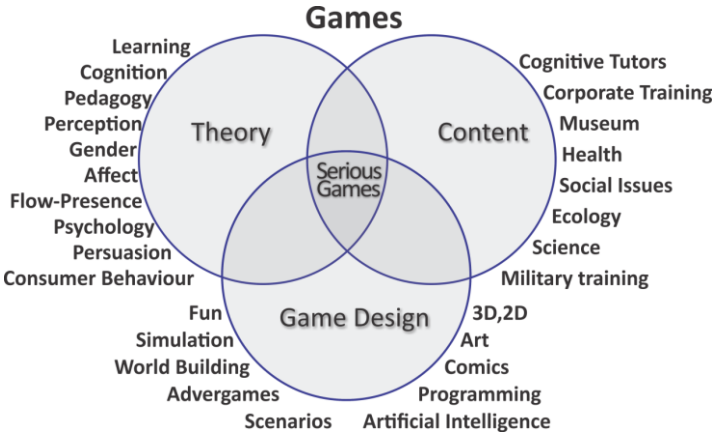

Figure 1. The complex multi-dimensional world of *Gamification*

The importance of *playing* has been emphasized in many studies from various domains. According to [4], playing is an archetypical activity that arises from primordial biological structures existing before the conscience or the capacity for speech; it is not something a person decides to do. According to [5], [6], gamification is nothing more than the use of specific game design approaches and techniques in various environments, in order to attract people in problem solving and to enhance their contribution.

In this paper, we present *DynaMus (Dynamic Museum)*, a novel fully dynamic Web-based SG-based *framework* that is primarily focused on creating and browsing interactive virtual exhibitions. It relies on the rich content of Web-based resources that are not only limited to the cultural heritage domain. Thus, DynaMus follows the current trends of virtual museum dynamic environments by allowing the integration of content derived from any domain using URIs. DynaMus enables users to create their virtual exhibitions by using Web-based cross-platform gaming technologies. The creation of the virtual environment in each user exhibition is totally user-driven and it is enabled through a point-and-click and drag-and-drop interface that does not require programming skills. We created case studies using this framework and tested it in different settings in order to evaluate the functionalities and user adoption and concluded that DynaMus offers a rather user-friendly environment and a functionality that could contribute towards the coupling culture and education through gaming paradigms.

The paper is organised as follows: Section 2 provides a brief review of related works and underlying concepts; Section 3 introduces to the DynaMus system architecture and structure, accompanied by a case study that produced interesting usage results and evaluation. The paper concludes by summarising DynaMus advantages and pointing out future work.

2. Virtual museums, learning and gaming

Since the early 1990s when really appealing computer game graphics made their first appearances, game engines started to be used as tools in many scientific fields [1],[8], [9]. In this Section, we present an indicative selection of important published works related to virtual museums, exhibitions and game-based learning, concepts that are intertwined with DynaMus.

The notion of virtual museums and exhibitions has been introduced as an approach to overcome the limitations of the physical space and to provide a vivid experience to remote visitors [10]. An overview of virtual museum technologies is presented in [11]. Numerous works utilise various technologies to provide solutions for history teaching and learning, or to enhance actual museum visits. Pavlidis et al. [12], proposed a Web-based 3D digital replicas management system with a dynamic virtual exhibition showroom. In addition, in [13] a more advanced framework for digital museums has been presented, where a non-photorealistic digital replica of a real museum is used to demonstrate educational activities rather its actual exhibition, aiming at increasing the museum's visitors. In [14] an interactive SG is used for the promotion of a prehistoric heritage site. [15] reviewed the state-of-the-art of theories, methods and technologies utilised by SGs as cultural heritage promotion tools by showing case studies that exploit such technologies. Furthermore, works like [16] focus on a generalisation of the task-based learning theory in applications using smart mobile devices. In addition, Koutsoudis & Pavlidis [17], proposed a novel approach for navigating within

complex cultural scenes by exploiting content-based retrieval descriptors. Koutsoudis et al. [18], proposed a content-based navigation framework for a virtual museum, based on metadata that describe the exhibits and thus providing a semantic similarity-based navigation. In [19] a SG is proposed based on scenarios derived from the cultural heritage domain and attempts to enrich the player's knowledge by spreading a mystery in ancient times. In a recent work [20] a multi-user framework for virtual exhibitions that adapts to visitors' preferences has been proposed. In [21],[22] an interactive museum for painting exhibitions with dynamic open data content was introduced as a cultural and educational tool that focuses on user-driven exhibitions.

The Augmented Representation of Cultural Objects (ARCO) [23]-[25] was among the predominant efforts towards a dynamic virtual museum system accompanied by a 3D digitisation technique to provide museums a framework to produce and exhibit 3D digital replicas of their artefacts. It was based on X-VRML technologies [26] and enabled the development of dynamic database-driven virtual scenes composed of 3D exhibits. The system was designed to provide museum curators ways to develop and manage 3D virtual galleries and 2D multimedia representations. The exhibition management was performed through a Web-based application that allowed curators to handle digital exhibits along with their documentation metadata. The information of the exhibition is stored in the databases of the ARCO systems [23]. ARCO was evaluated as an Augmented Reality Interface (ARIF) [27] by focusing on the user experience in relation to the technologies of ARCO.

In 2005, Lepouras & Vassilakis [28] presented the concept of creating virtual museums focused primarily on educational content and related services by using a game engine. This virtual exhibition space took advantage of the high visual quality of modern game engines. Lepouras and Vassilakis also conducted a user acceptance study of their virtual museum prototype, which demonstrated promising results. Sookhanaphibarn & Thawonmas presented a 3D virtual museum developed in the Second Life 3D world engine. The virtual museum was equipped with an innovative intelligent guidance system that was able to provide a customised navigation route based on the visitor's preferences [29]. The route generation was based on tracking the movements of the visitor within the 3D environment. The system automatically produced a user profile adjustment module, which was later used to provide a set of relevant options. Additionally, the museum's content could also be personalised based on the visitor's comments. Papastamatiou et al. [30], presented a dynamic Web-based 3D e-shop system for commercial use, offering a WYSIWYG graphical user interface. The system was build using the Unity3D game engine, whereas the content and the metadata were loaded from external XML files. Through the system's GUI, the user was able to manage not only the e-shop content but also the on-line buyers purchases and activities. A Web-based HTML

editor allowed administrators to add textual information, links to Web resources, images and other multimedia content. Furthermore, Sillaurren & Aguirrezabal [31], presented *3DPublish*, a content management system that was also developed in Unity3D game engine and allowed the generation of dynamic 3D exhibitions. The aim of this project was to create a tool for curators that enabled them to manage 3D environments of virtual museums. The system supported JPEG, PNG, AVI, PPT and PDF file formats to be used as exhibition elements. A Web-based management tool allowed curators to upload their content to a dedicated file server. The exhibitions were stored in XML format, which are stored in the same server while every time an exhibition was loaded all its elements were also reloaded.

Nowadays, a common approach and trend in modern virtual world applications for various domains is to adopt the technology of game development, the game engines; since a game engine is behind the development of the proposed DynaMus framework, a brief reference to the technology and a simple comparison of contemporary available game engines is included in the following paragraphs.

Game engines are integrated software suites that efficiently use 3D rendering pipelines, special data-structures and speed-up techniques for visualising texture mapped 3D objects, scenes and 3D worlds in real-time with modern graphics and interaction capacities [8]. The selection of game engines for building dynamic, realistic, virtual environments was guided by the numerous possibilities and advantages offered by modern game engines [21],[22],[28], [32], not limited to the game engines in this study. Game engines are being extensively tested for usability and performance due to the high demand of the contemporary games. The game engine and computer game developers provide components, algorithms, tools, guides and source code, so that their users can efficiently create new applications. An extensive user support provided by large game development communities makes them even more attractive development platforms. Most of the game engine functionalities are managed and exploited via a GUI for the convenience of developers, providing a more efficient development framework when compared with virtual environment toolkits that often require additional effort to provide functionalities such as user interaction [33], avatar behaviours, collision detection and management, audio management, avatar-based virtual environment interactions, embodied autonomous agents and many other properties [28], [32]. Most of the modern game engines enable cross-platform development. There is a wide selection of 3D game engines available for potential use [34]. In **Table *I*** we summarize our comparison of some of the most popular contemporary game engines, *Unity* [23], [35], *CryEngine* [9], [36] *and Unreal* [9], [37]; we have collected all major advantages and disadvantages regarding these game engines as discussed in [9],[22],[23],[31],[35]-[37] and compiled them into a single table for easy comparison, in which a simple three-level rating for each feature has been followed.

Table I - A simple three-level comparison of various features in popular game engines

Feature	Unity3D	CryENGINE	Unreal Engine
Friendly to User	☺	☹	☹
Components	☺	☺	☺
Object development	☹	☺	😐
GUI	☺	😐	😐
Real time FX	😐	☺	☺
Particles	😐	😐	☺
AI	☺	☺	☺
Physics	😐	☺	☺
Animation Systems	😐	😐	😐
Programming	☺	😐	😐
OpenGL	☺	😐	😐
2D Games	☺	☹	😐
3D Formats	☺	😐	☹
Tools Integration	☺	😐	😐
Assets	☺	☺	☺
Support	☺	☺	☺
Availability	**Free or 4500$ full pack**	**9.90$ monthly**	**5% royalty**

Apparently, we are in an era that a connection of all those technologies and approaches is being explored. Most of the advanced previous works relating to virtual museums focused in providing engaging user experiences within specific frameworks, using specific data and guidance by stakeholders, some of them using game engine or virtual reality technologies. None of these, though, or any other published works (to our knowledge) addresses the concept of an entirely open technological framework, totally disengaged from any stakeholder or presentation scenario, easy to use and based on open linked data, that is able to support the creation of mini virtual worlds and to populate them with Web-based cultural and educational content, readily published on the Web, without requiring technical skills. This is exactly what drove the creation of DynaMus.

3. DynaMus: A novel user-centric virtual museum framework

The scope of this work was to develop a fully dynamic interactive virtual environment as an open technological framework to allow the easy creation of virtual museums and exhibitions using distributed Web content, without the need of any predefined scenarios. In order to be able to implement such a system, open data technologies had to be integrated in order to be available through the 3D virtual environment provided by the game engine. *Unity* game engine was selected due to its low cost, rich development tool arsenal, user-friendliness, cross-platform delivery, and powerful scripting and database connectivity capabilities.

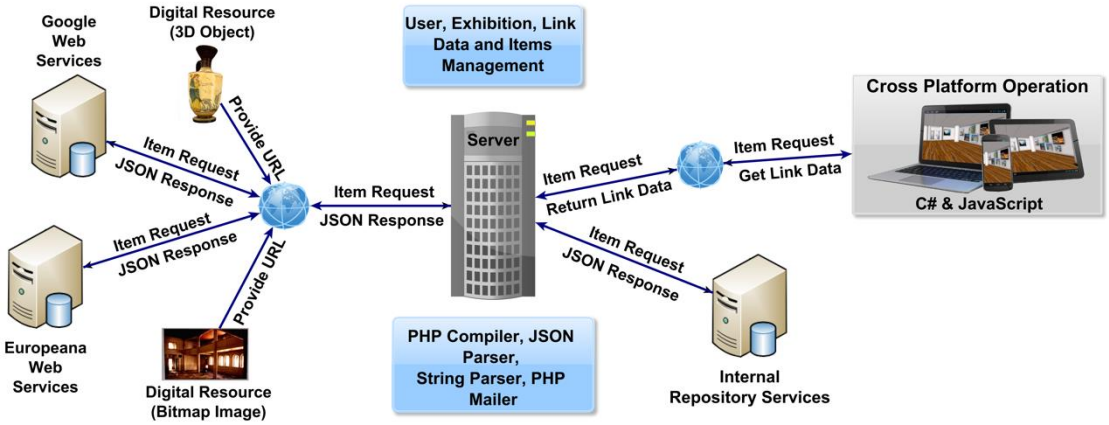

Figure 2. General technological framework of the DynaMus

Figure 2 depicts an abstract overview of the functionalities supported by DynaMus, which can be considered as a 3D content management system (3D-CMS) that offers both back-end and front-end content management functionalities. The current implementation of DynaMus supports exhibitions in the form of:

1. 2D images, which are being mapped onto flat surfaces that simulate painting frames;
2. 3D models, which can be easily manipulated and placed in the virtual environment of the exhibition[1].

Both exhibition visits and exhibition management are performed through a unified GUI in an attempt to provide a WYSIWYG intuitive environment. DynaMus offers user-based access. Hence, user registration is required before using the framework. Each registered user is able to browse and visit published exhibitions and to become an exhibitor-administrator of one or more exhibitions. At the current implementation, all exhibitions are accessible for visiting by all users. The primary 2D image data resources that are already integrated into the framework are *Google Images* and cultural content from *Europeana* (http://europeana.eu), whereas *custom user content* is also supported (Figure 3). There is no limitation in the total number of 3D resources added to the exhibition as the system only stores a URIs (or URLs) that point to remotely stored digital resources. The data interoperability with these resources is guaranteed by the open data technologies that these repositories provide. The data transfer between DynaMus and the external Web-based resources is being implemented using the *JSON data-interchange format*. The overall graph of requests and data interchange is illustrated in detail as a typical *sequence diagram* in Figure 3, which depicts both the visitor's and exhibitor's perspective.

[1] Currently, there is a limitation requiring that each 3D object is described by OBJ files, with a maximum of 10,000 vertices. This limitation is imposed by the Unity game engine, to serve as a guarantee for smooth rendering and fast (real-time) response. There are workarounds for this limitation, which are discussed in the conclusions.

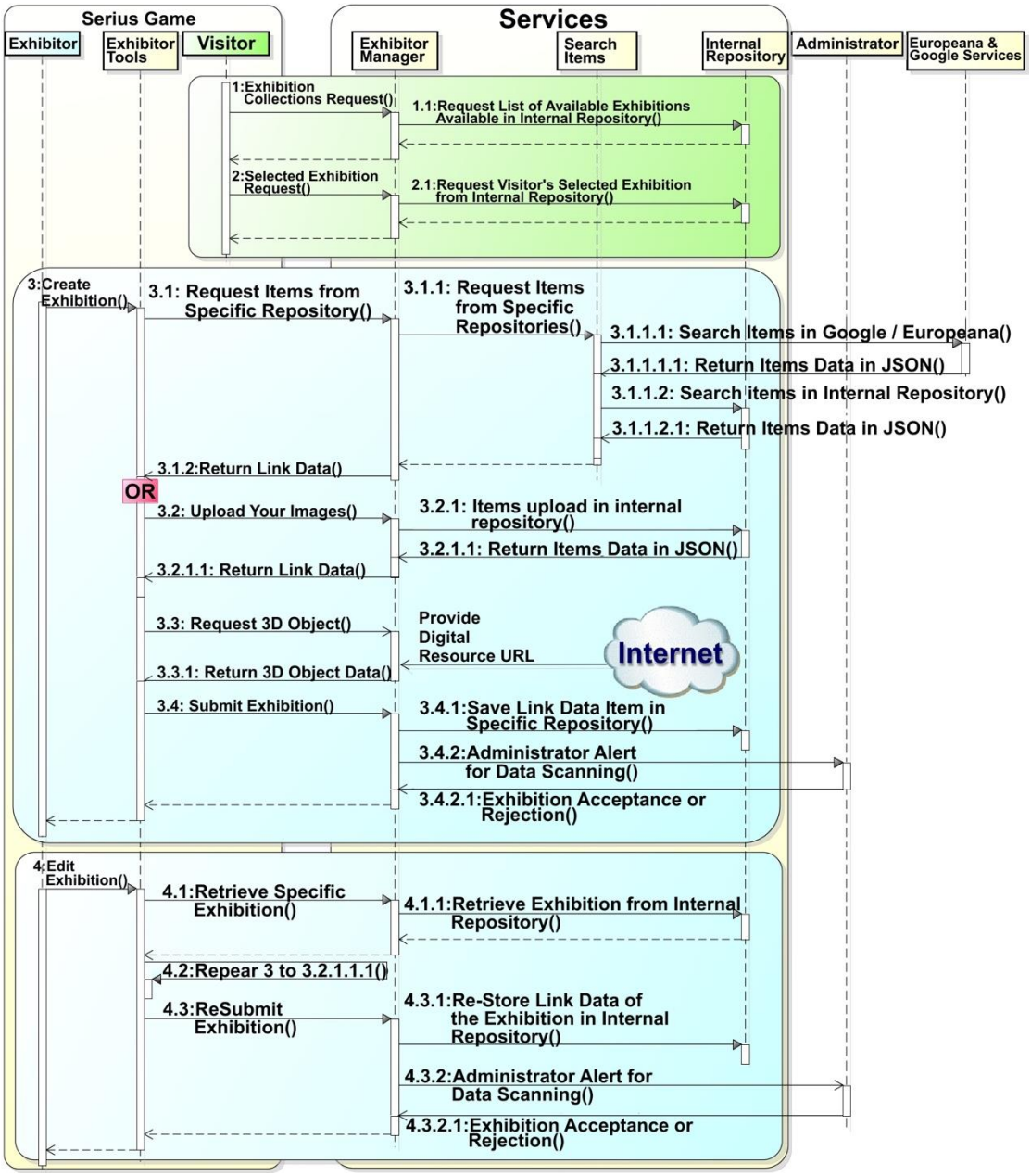

Figure 3. Sequence diagram of the basic activities in the DynaMus

According to this sequence diagram, visitors can browse through the available exhibitions or send a request to explore an exhibition. On the other hand, exhibitors can create a new exhibition or edit an existing one. Exhibition management is also supervised (top level) by the super administration, responsible for activating new exhibitions after performing content compliance verification and testing.

As mentioned before, the data interchange between DynaMus, the Web-based repositories (Google Images, Europeana) and internal repository (considered as the server-side of the system) are based on JSON technology. For each of the repositories a structured query subsystem was built according to the data exchange requirements. Each query subsystem is

able to handle the response data structures. In addition, the server-side of DynaMus is also responsible for handling all the user requests triggered through the 3D virtual environment and related to the development of the exhibitions' environment. More specifically, the server-side of DynaMus provides a number of services in the form of PHP requests. This approach enables to perform all communications using string-parsing functionality. Thus, any user requests are driven through the GUI to the server-side of DynaMus and the server triggers dedicated C# scripts that allow posting (POST) string queries to PHP services that respond with structured string-formatted data. Figure 4 depicts the process of the development and visualisation of the elements found in an exhibition. The 3D object building process is shown on the left side of Figure 4. The operation begins by providing the digital resource remote location (URL or URI). The underlying algorithm parses and analyses all the related files (Step 1) and initiates the real time 3D mesh generation (Step 2). Subsequently, the provided UV texture image is mapped on the 3D mesh (Step 3) using the information stored in the material file that usually accompanies the 3D model files. After the generation of the 3D model the user may annotate it with textual information (Step 4). The interactivity is depicted on Figure 4 (right side). When a visitor selects an object, a pop-up window appears at the bottom of the screen providing the textual information that accompanies the exhibit.

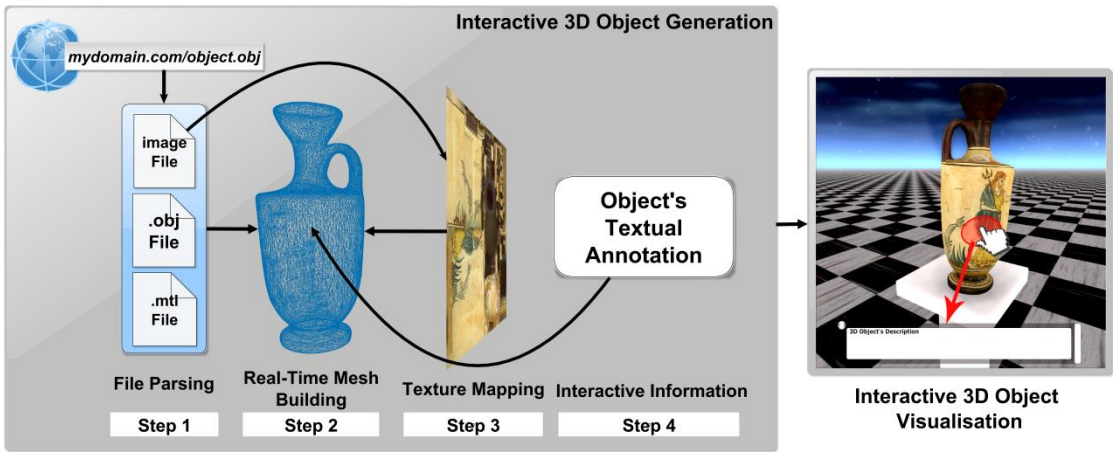

Figure 4. Workflow for reading and presenting interactive 3D models in DynaMus

In order for the 3D environment to be more realistic, some real-time screen space effects such as *Ambient Occlusion*, *Depth of Field*, *Antialiasing*, *Light Mapping and Shadow Rendering* are being used. These can significantly affect the quality and efficiency of the experience but impose some additional graphics card hardware requirements, which, nowadays, are considered common. More specifically, *Ambient occlusion* [38] is a sophisticated ray tracing calculation, which simulates soft global illumination by faking darkness perceived in corners and at mesh intersections, creases, and cracks, where light is diffused (usually) by accumulated dirt and dust. *Depth of field* [39] is a common post processing effect that

simulates one of the most notable properties of a camera lens: the limited depth of focus. *Antialiasing* [40], gives smoother appearance of the graphics based on the difference of coloured areas of the image. *Light mapping* [41], by which point, area, directional and spotlights shine upon every pixel displayed on the screen space. *Shadow rendering* [41], which is based on the light mapping and tries to simulate environment shadows that are associated to the light sources. Figure 5 depicts the difference by using these real-time effects.

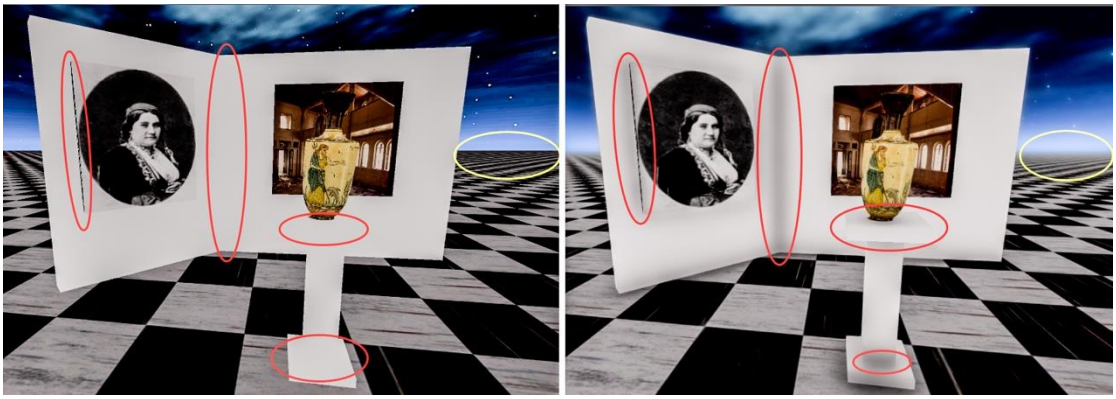

Figure 5. Real-time screen space effects for enhanced visual realism

3.1. The 'Synthesis Museum' case study

In order to objectively evaluate the performance of DynaMus, we conducted a number of case studies by implementing various virtual exhibitions in different settings and frameworks (high school, science festivals and technology fairs). We present here a specific case study, which involved the generation of the *'Synthesis Museum'*, a virtual museum that was created for the purposes of the 'Synthesis' Greek National Funded R&D project [42].

The Synthesis project attempted to bridge culture and education through technology and to provide means for tutors to enhance their everyday teaching with alternative approaches that derive and reuse cultural content as an integral part of their courses. The specific virtual museum consisted of artworks (mainly paintings) of Spyros Papaloukas, an esteemed early 20th century Greek painter. To meet the required specifications of the case study, a digital replica (3D model) of the *Theocharakis Foundation for the Fine Arts and Music* building was created to host all the exhibitions. Screenshots of both the interior and the exterior of the 3D model are depicted in Figure 6. Apparently, in this case we have created the virtual world that would host the exhibitions and the outcome was separately given to users for use and evaluation (this case study is available online at http://synthesis.thf.gr/portal/applications-en/virtual-museum-en/).

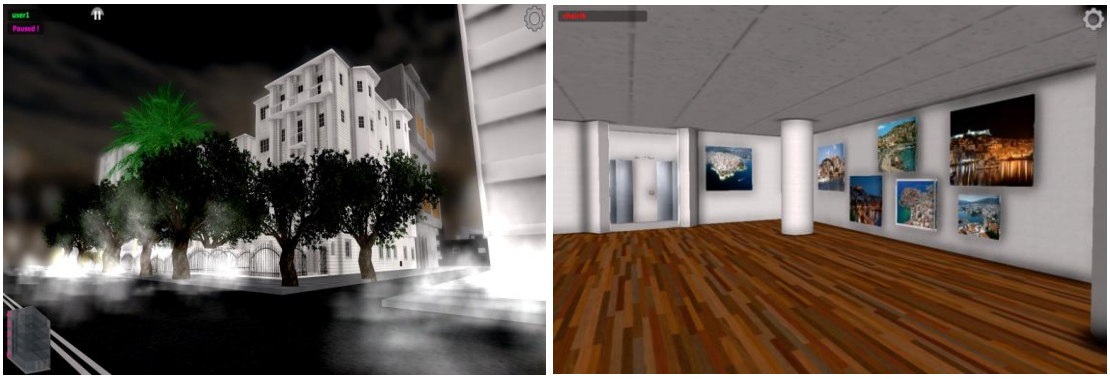

Figure 6. Screenshots of an external and an internal view of the 'Synthesis' virtual museum

To evaluate the functionality, along with the impact, the adoption and user satisfaction on this technology, the system has been given for use to a number of secondary education school pupils, teachers and parents. The evaluation was based on a questionnaire that included questions targeting various aspects of the general technology adoption, the gamification aspect adoption and the specific technology impact. Some of the most interesting results are being summarized in Figure 7 and Figure 8. The results show that, although, the technology adoption and expectation is high and the exposure to it is considered highly positive, there is still some scepticism on the ability and willingness of the tutors to successfully adopt the technology and integrate it in everyday educational practice, which is actually the case. Nevertheless, the adoption of the technology offered by DynaMus is really high by both the tutors and the pupils/students, the latter, of course, being more exposed to VR-like environments and technologies.

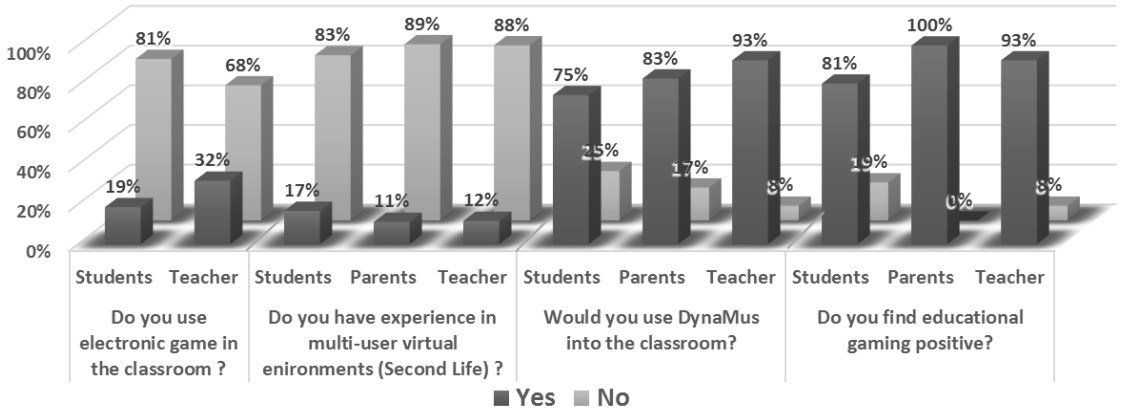

Figure 7. Dichotomous scaled questions-answers

It is evident in Figure 7 that although there is almost no classroom electronic gaming, the prospect of it becoming possible and the adoption of DynaMus is highly anticipated. Figure 8 reveals some of the controversies still in effect, like in the first question, in which most students do not expect that tutors will be up to the challenge of incorporating DynaMus in the daily practice. The intermediate three questions revealed that the experience offered by

DynaMus was highly pleasing, easy to use and joyful, whereas the final question revealed the significant differences in the exposure to VR-like environments by the various implicated groups of users. In overall, the evaluation revealed a significant lack in gamification approaches in education and that DynaMus like similar game-based approaches are highly anticipated as considered positive additions to the educational practice.

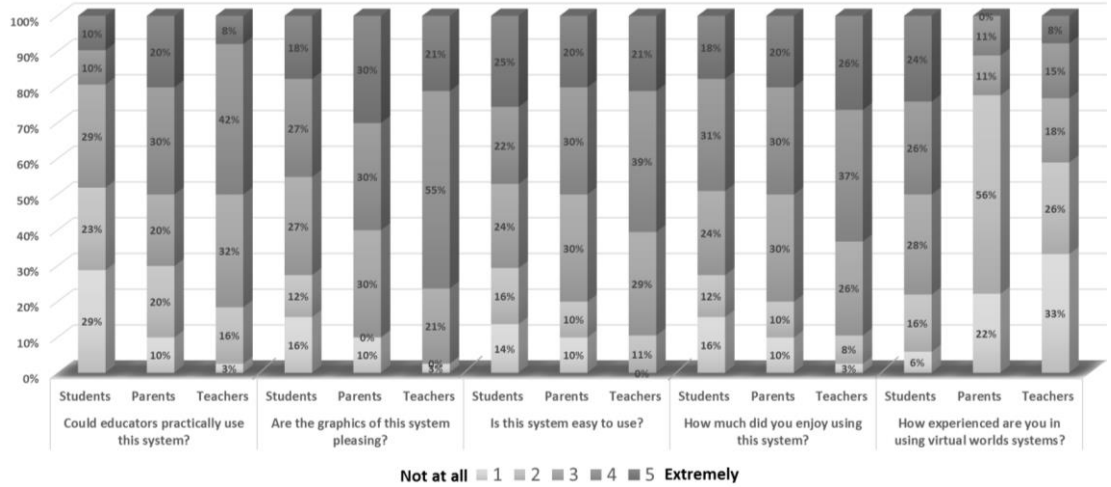

Figure 8. Five-point scaled questions-answers

4. Conclusions

In this paper, we presented *DynaMus*, a *dynamic virtual environment authoring framework* that composes an open system for everyone interested in creating virtual 3D environments that exhibit their own content or content in Web-based repositories. The framework is built upon the virtual world paradigm and provides a first person virtual world navigation and content manipulation experiences. It can be used to provide cultural heritage content visualisation coupled with educational activities intertwined with VR technologies, based on game engine software. We presented one of the case studies created with DynaMus technology that demonstrated its functionalities and user adoption aspects. We are currently working towards integrating virtual agents to serve as exhibition guides that will be coupled with artificial intelligence (AI) to either support natural and personalised visits and user-defined guided tours, or to build socially trained agent-based collaboration between agents and humans. In addition, we are working on bringing cloud-based storage connectivity to support the user content. Last but not least, we are exploring various workarounds to the limitations imposed by the selected game engine, such as the 3D model limits.

DynaMus clearly differentiates from all previous similar works in the sense that it is a generic and online free technological framework (not a specific virtual museum) that it is not paired to a specific real-world museum and at the same time does not play the role of a stakeholder. Thus it is considered an Open Linked Data hosting virtual environment that maintains purely

persistent URIs and URLs in order to support the generation of virtual exhibitions focused on cultural heritage and education (http://dynamus.ceti.gr). In summary, DynaMus offers:

- VR-like first-person 3D visualisation, navigation and interaction
- Cross-platform functionality
- Interactive 3D exhibits
- User-created dynamic virtual environment
- Connection with external resources using data interoperability standards, such as JSON structured data exchange

References

[1] J. Breuer and G. Bente, "Why so serious? on the relation of serious games and learning," *Journal for Computer Game Culture,* vol. 4, no. 1, pp. 7-24, 2010.

[2] R. Van Eck, "Digital game-based learning: It's not just the digital natives who are restless," *EDUCAUSE,* vol. 41, no. 2, pp. 16-30, 2006.

[3] A. Rogers, Teaching Adults, 2nd ed., Buckingham: Open University Press,, 1996.

[4] S. Brown and C. Vaughan, Play: How it changes the brain, Opens the Imagination, and Invigorates the Soul, J P Tarcher/Penguin Putnam, 2010.

[5] S. Nicholson, "Making the Gameplay Matter: Designing Modern Educational Tabletop Games," *Knowledge QuesT,* vol. 40, no. 1, pp. 60-65, 2011.

[6] S. Nicholson, "Strategies for meaningful gamification: Concepts behind transformative play and participatory museums," in *Presented at Meaningful Play 2012*, Lansing, Michigan, 2012.

[7] G. Pavlidis, "Towards a playful education," in *International Workshop on Virtual Archaeology: Museums & Cultural Tourism*, Delphi, Greece, 2015.

[8] L. Harrison, Introduction to 3D Game Engine Design Using DirectX 9 and C#, Apress, Berkeley, 2003.

[9] J. Craighead, J. Burke and R. Murphy, "Using the unity game engine to develop sarge: A case study," in *Simulation Workshop at the International Conference on Intelligent Robots and Systems*, 2008.

[10] D. Tsichritzis and S. Gibbs, "Virtual museums and virtual realities," in *International Conference on Hypermedia and Interactivity in Museums,*, 1991.

[11] S. Sylaiou, F. Liarokapis, K. Kotsakis and P. Patias, "Virtual museums, a survey and some issues for consideration," *Journal of cultural Heritage,* vol. 4, pp. 520-528, 2009.

[12] G. Pavlidis, N. Tsiafakis, G. Provopoulos, S. Chatzopolos, F. Arnaoutoglou and C. Chamzas, "Momi: A dynamic and internet-based 3d virtual museum of musical instruments, June 5-9," in *Third International Conference of Museology*, 2006.

[13] G. Pavlidis, C. Makarona, F. Arnaoutoglou, A. Koutsoudis and C. Chamzas, "Museums In The Virtual World," in *International Symposium Information and Communication Technologies in Cultural Heritage*, Ioannina, Greece, 2008.

[14] D. Djaouti, J. Alvarez, O. Rampnoux,, V. Charvillat and J. Jessel, "Serious games and cultural heritage: A case study of prehistoric caves," in *15th International Conference on Virtual Systems and Multimedia,* 2009.

[15] E. Anderson, L. McLoughlin, F. Liarokapis, C. P. Petridis and S. Freitas, "Developing serious games for cultural heritage: a state-ofthe- art review," *Virtual Reality,*, vol. 14, no. 4, p. 255–275, 2010.

[16] F. Bellotti, R. Berta, A. D. Gloria, A. D'ursi and V. Fiore, "A serious game model for cultural heritage," *ACM Journal on Computing and Cultural Heritage,* vol. 5, no. 4, p. 17, 2012.

[17] A. Koutsoudis and G. Pavlidis, "Content-based search and retrieval within complex 3d scenes - an application to cultural heritage," in *16th International Conference on Cultural Heritage and New Technologies,*, 2011.

[18] A. Koutsoudis, C. Makarona and G. Pavlidis, "Content-based navigation within virtual museums," *Journal of Advanced Computing Science and Technology,* vol. 1, no. 2, p. 73–81, 2012.

[19] A. Doulamis, F. Liarokapis, P. Petridis and G. Mialous, "Serious Games for Cultural Applications," *Intelligent Computer Graphics. Springer Berlin Heidelberg,* p. 97–115, 2012.

[20] B. Bonis, S. Vosinakis, I. Andreou and T. Panayiotopoulos, "Adaptive virtual exhibitions," *DESIDOC Journal of Library and Information Technology,* vol. 33, no. 3, 2013.

[21] C. Kiourt, A. Koutsoudis, F. Arnaoutoglou, G. Petsa, S. Markantonatou and G. Pavlidis, "A dynamic web-based 3D virtual museum framework based on open data," in *Digital Heritage,* Granada, Spain, 2015.

[22] C. Kiourt, A. Koutsoudis, F. Arnaoutoglou, G. Petsa , S. Markantonatou and G. Pavlidis, "The 'Synthesis' Virtual Museum–an open virtual exhibition creation tool," in *International Workshop on Virtual Archaeology: Museums & Cultural Tourism*, Delphi, Greece, 2015.

[23] M. Patel, M. White, K. Walczak and P. Sayd, "Digitisation to presentation: Building virtual museum exhibitions," *Vision, Video and Graphics,* 2003.

[24] M. White, N. Mourkoussis, J. Darcy, P. Petridis, F. Liarokapis , P. Lister, K. Walczak , K. Wojciechowski , W. Cellary, J. Chmielewski, M. Stawniak, W. Wiza, M. Patel, J. Stevenson , J. Manley, F. Giorgini , P. Sayd and F. Gaspard, "RCO - an architecture for digitization, management and presentation of virtual exhibitions," in *Proceedings Computer Graphics International*, Crete, Greece, 2004.

[25] K. Walczak and W. Cellary, "X-vrml for advanced virtual reality applications," *IEEE Computer magazine,* p. 89–92, 2003.

[26] R. Wojciechowski, K. Walczak, M. White and W. Cellary, "Building virtual and augmented reality museum exhibitions," in *Proceedings of the ninth international conference on 3D Web technology*, 2004.

[27] S. Sylaiou, K. Mania, A. Karoulis and M. White, "Exploring the relationship between presence and enjoyment in a virtual museum," *International Journal of Human-Computer Studies,* vol. 68, no. 5, pp. 243-253, May 2010.

[28] G. Lepouras and C. Vassilakis, "Virtual museums for all: employing game technology for edutainment," *Virtual Reality,* vol. 8, p. 96–106, 2005.

[29] K. Sookhanaphibarn and R. Thawonmas, "A content management system for user-driven museums in second life," in *International Conference on CyberWorlds*, 2009.

[30] N. Papastamatiou, T. Alexandridis, K. Tsergoulas, A. Michopoulos and N. V. Karadimas, "Virtual reality applications with user interface for dynamic content development," in *CEA'10 Proceedings of the 4th WSEAS international conference on Computer engineering and applications,*, 2010.

[31] S. Sillaurren and P. Aguirrezabal, "3dpublish: A web-based solution for building dynamic 3d virtual museums," *International Journal of Heritage in the Digital Era,* vol. 1, p. 147–152, 2012.

[32] D. Trenholme and S. P. Smith, "Computer game engines for developing first-person virtual environments," *Virtual Reality,* vol. 12, no. 3, p. 181–187, 2008.

[33] D. Bowman, E. Kruijff, J. J. LaViola and I. Poupyrev, 3D user interfaces: theory and practise, USA: Addison Wesley, 2005.

[34] M. Lewis and J. Jacobson, "Game engines in scientific research," *Communications of the ACM,* vol. 45, no. 1, p. 27–31, 2008.

[35] Unity3d, "U. Technologies," in *[Online]. Available: http://unity3d.com/*, 2015.

[36] Crytek, "Cryengine.," in *[Online]. Available: http://www.crytek.com/cryengine*, 2015.

[37] E. Unreal, "Inc., E. G.," in *[Online]. Available: https://www.unrealengine.com/*, 2005.

[38] K. Vardis, G. Papaioannou and A. Gaitatzes, "Multi-view ambient occlusion with importance sampling," in

ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games, 2013.

[39] X. Yu, R. Wang and J. Yu, "Real-time depth of field rendering via dynamic light field generation and filtering," *Computer Graphics Forum,* vol. 29, p. 2099–2107, 2010.

[40] T. B. Mathew, "Edge Based Antialiasing: Quality without Compromise," *International Journal of Engineering Science and Research Techonology*, vol. 2, no. 6, pp. 1627-1631, 2013.

[41] G. Guennebaud, L. Barthe and M. Paulin, "Real-time soft shadow mapping by backprojection," in *17th Eurographics conference on Rendering Techniques*, 2006.

[42] S. Project, (last time accessed at 25/1/2016). [Online]. Available: http://synthesis.ceti.gr/portal.