A dynamic web-based 3D virtual museum framework based on open data

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***Abstract*—Continuous developments in the web and computer technologies along with an increasing availability of game engines contribute to an expansion of techniques that bridge culture and education with gaming. In addition, open linked data technologies pave the way towards the semantic web of the future by exploiting the abundance in data availability. In this work we present an innovative and content-dynamic web-based framework, which relies and exploits the rich content of distributed web cultural resources and supports the creation of custom virtual exhibitions for cultural and educational purposes based on gaming technologies.**

***Keywords*—Dynamic virtual museum, dynamic virtual exhibition, game-based learning, distributed data, cultural resources.**

I. Introduction

The notion of virtual museums and exhibitions has been introduced as a means to overcome the limitations of the physical space and to provide a vivid experience to remote visitors [1]. An overview of virtual museum technologies is presented in [2]. Numerous works utilise various technologies to support cultural heritage purposes, such as historical teaching and learning, or to enhance museum visits. In [3], a management system of 3D digital models and a dynamic virtual exhibition showroom was introduced as a dynamic web-based virtual museum framework. In addition, in [4] a more advanced framework for digital museums has been presented with the creation of a non-photorealistic digital replica of a museum that presents its educational activities and not its exhibits, aiming at increasing the actual museum visits. In [5] interactive serious games (SGs) for the promotion of a prehistoric heritage site of the Gargas caves were presented. In [6] a state-of-the-art review was presented for the existing theories, methods and technologies utilised by SGs as cultural heritage promotion tools, showing several case studies representing those technologies. Taking a step further, works like [7] focus on a generalisation of the task-based learning theory with great advantages from smart mobile devices support. In addition, the researchers in [8] proposed a new approach in navigating within complex cultural scenes by exploiting content-based descriptions. Scaling down to a smaller scale, the researchers in [9] propose a content-based navigation framework for a virtual museum, based on metadata that describe the exhibits, thus providing semantic-similarity-based navigation. In [10] an SG is proposed based on a cultural heritage scenario, and tries to enhance knowledge of cultural heritage by spreading a mystery in the ancient world. In a recent work [11] a multi-user virtual exhibitions framework has been proposed that adapts to the visitors preferences.

Differentiating from previous works, we present a novel content-dynamic web-based system primarily focused on creating and browsing virtual exhibitions using the first-person gaming paradigm, which relies and exploits the rich content of web cultural resources (but is not restricted to 'cultural'). This framework aims at empowering users to generate their own exhibitions through the usage of cross-platform gaming technologies on the web. The virtual museum framework is not like any other in that it is not linked with any museum and is not the stakeholder of the exhibits; it is a hosting virtual environment built upon the Open Linked Data concept, thus supporting the creation of virtual exhibitions for cultural and educational purposes by maintaining purely persistent URIs and URLs. The virtual museum framework offers:

- VR-like (first-person game-like) 3D visualisation, navigation and interaction
- Cross-platform functionality
- Purely user-driven dynamic exhibitions
- Interconnection with external resources based on data interoperability standards

II. Related work

Since the early 1990s when high quality computer game graphics started to appear, game engines begun to be used as tools for many scientific areas [12], [13], [14]. Of the many works on virtual museums and exhibitions and game-based learning that have been successfully concluded since that era, we present here only an indicative selection.

The *Augmented Representation of Cultural Objects (ARCO)* [15] 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 models of their artefacts. It was based on *X-VRML technologies* [16] and enabled the development of dynamic database-driven virtual scenes composed of 3D exhibits. The system focused on museum curators to manage the creation of 3D virtual galleries and 2D multimedia representations. Management of the exhibition components is mainly based on a web-based application, through which the curators can add exhibits along with their documentation metadata. The information of the exhibition is stored in databases read from ARCO systems [15]. In 2004, Lepouras and Vassilakis [17] were among the first to present the concept of building virtual museums built upon a game engine focusing primarily on educational content and services. 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 showed promising results. Sookhanaphibarn and Thawonmas in [18] presented a 3D virtual museum developed over the Second Life 3D world[1], equipped with an innovative intelligent guidance system, which produced a navigation root depending on the visitor preferences. Visitor route development was based on tracking the visits of the visitor on the 3D environment. The system automatically created a user profile adjustment module, which was later used to provide the possible visitor options. The content of the museum was also adjusted based on the visitor comments. In overall, the main 3D environment and exhibits were based on the user profile. In [19] a dynamic 3D e-Shop system for commercial use is presented, which is based on a WYSIWYG[2] web-based 3D environment. The 3D environment was based on Unity3D game engine. The objects of the environment are loaded from external XML files with additional metadata. A GUI-based system supports the management of the objects and interactions for the users. Information about the object is added through a web HTML editor, which can be used by the users to add text, links to web resources, images and other multimedia information. *3DPublish* is a 3D content management system developed in Unity3D game engine, which dynamically creates 3D exhibitions [20]. The aim of this project was to create a tool for 3D environments dynamically managed by museum curators. It supports JPEG, PNG, AVI, PPT and PDF file formats as exhibition elements. The curators have the ability to manage the content through a web-based management tool that is used to upload the content to a file server. Exhibitions are stored in XML files, which are stored in a content server. In every load of an exhibition, all the elements are reloaded as internal parts of the game.

A. Game engines

Game engines are powerful software packages that efficiently use rendering pipelines, special data-structures and speed-up techniques for visualising texture mapped 3D objects, scenes and 3D worlds in real-time with incredible graphics and interaction capacities [12]. The choice of game engines for building dynamic realistic virtual environments was guided by the numerous possibilities and advantages offered by nowadays game engines [21], [17]. Game engines are being extensively tested for usability and performance due to the high demand of the contemporary games. The manufacturers and many computer game developers provide components, algorithms, tools, guides and source code, so that end-users can easily create new content. The positive picture is complemented by an extensive support provided by large game development communities. Most of the game engine functionalities are managed and exploited via a Graphical User Interface (GUI) for the convenience of developers, providing greater benefits when compared with virtual environment toolkits that often require additional effort to provide functionalities such as user interaction [22], avatar behaviours, collision detection and management, audio management, avatar-virtual environment interactions, embodied autonomous agents and many other attributes [21], [17]. Last but not least, almost all current generation game engines provide cross-platform development, which ensures their utility. There is a wide selection of 3D game engines available for potential use [23]. We have considered *Unity*, *CryEngine* and *Unreal*. According to the [14], [20], [15], [24], [25], [26], we have collected all major pros and cons regarding these game engines discussed here and show them in Table I as a simplified comparison.

TABLE I. A COMPARISON OF THE MOST WIDESPREAD GAME ENGINES

Feature	Unity3D	CryENGINE	Unreal Engine
Friendly to User	☺	☹	😐
Components	☺	☺	☺
Object development	☹	☺	😐
GUI	☺	😐	😐
FX	😐	☺	☺
Particles	😐	😐	☺
Animation Systems	😐	😐	😐
Programming	☺	😐	😐
Assets	☺	☺	☺
Support	☺	☺	☺
Availability	Free or 4500$ Full pack	$9.90/monthly	5% royalty

III. A NOVEL USER-CENTRIC OPEN VIRTUAL MUSEUM FRAMEWORK

The vision of this work was to develop a completely content-dynamic virtual museum system as a technological framework available to all interested users to be able to easily create virtual exhibitions using distributed or their own content, without any predefined scenario whatsoever. In order to be able to implement this vision, open data techniques had to be applied and supported by a 3D virtual environment provided by a game engine. The game engine of choice was the *Unity* engine, for various reasons, mainly related with the low cost, rich functionalities, user-friendliness, fast development, cross-platform delivery and powerful coding and database connectivity capabilities. Fig. 1 presents an abstract overview of the functionalities supported by the system; in a way the system can be considered as a 3D content management system (3D-CMS), offering both back-end and font-end content management capabilities. The current system implementation supports exhibitions in the form of 2D images mapped onto flat surfaces, like painting frames. Both exhibition visits and exhibition administration are provided through the same, unified, GUI, thus making administration much easier and more intuitively coupled with the end-user experience.

The system requires that all users be registered. Each registered user is able to either browse and visit exhibitions, or become an exhibitor and administrator of his/her exhibitions. All exhibitions are public and viewable by all users. Currently, as shown in Fig. 1, the main image data resources are Google Images, Europeana[3] and the database that is formed by the user content. The data interoperability with these resources is guaranteed by the open data technologies that these repositories support. The exchange of data between the core of the system and the external web-based resources is being done using JSON. Exhibition management is, at a top level, controlled by a system super-administration, who is responsible for activating exhibitions after a typical content verification and appropriate content screening.

[1]Second Life at: http://secondlife.com

[2]WYSIWYG: "What You See Is What You Get"

[3]Europeana at http://europeana.eu

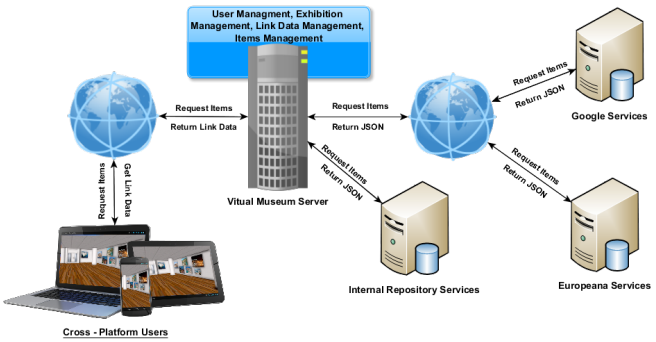

Fig. 1. General technological framework.

The Virtual Museum Server (VMS) (see Fig. 1) is based on JSON data interchange between the core services and the repositories: Google Images, Europeana and the internal repository. For each repository a structured query subsystem was built according to their requirements, which handles the results of the queries with specific string data structure. In addition, the VMS handles the communication between the 3D virtual environment and the repositories. In the case of an image request from one of the repositories, the JSON response is decoded by the VMS and essential data are isolated and stored, including the object location and description, and are forwarded to the framework as structured data to be utilised according to their attributes. In the case of building a new environment/exhibition, the system stores the data of the built environment to the internal repository, where the linked data can be called to rebuild the environment by any authenticated user. A similar workflow is followed for all the services of the VMS throughout the framework, except for the user authentication that is controlled via a dedicated user management system.

In order for the 3D environment to be more realistic, some real-time image effects are being used, which significantly affect the quality and efficiency of the experience and do not impose any additional hardware requirements. Often those image effects are named as *Screen Space effects*. Some of the most widely used and supported by the adopted Unity game engine (version 5) are Ambient Occlusion [27] and Depth of Field [28]. Some additional used effects that are also calculated in real-time are *antialiasing*, *light mapping* and *shadow rendering*.

Currently, we are developing the system as a fully-featured virtual environment with multiple avatars and virtual agents, coupled with artificial intelligence (AI) to support natural and personalised visits or user-defined guided tours, all in a cloud-based storage environment to support custom user content.

A. Case study: The 'Synthesis Museum'

In order to test the technology framework that is proposed, a case study has been conducted. The case study involved the development of the 'Synthesis Museum' a virtual museum that is being used for the purposes of Project 'Synthesis' [4] implemented by *'Athena' Research Centre* in collaboration

[4]Project 'Synthesis' portal is at http://synthesis.ceti.gr/portal and the project facts are presented at http://synthesis.ceti.gr

Fig. 2. Screenshot of the external view of a case-study museum.

Fig. 3. Screenshot of the internal view of a case-study museum.

with *The B & M Theocharakis Foundation for the Fine Arts and Music*. The museum framework is being applied in this project in an attempt to provide a virtual exhibition framework that will be used in activities focused on the education using cultural content. To meet the needs of this case study, the virtual museum framework has been customised to display a virtual world that basically consists of a digital replica of the building of the Theocharakis Foundation. Fig. 2 shows a screenshot of the virtual world at the outside of the virtual building, whereas Fig. 3 shows a screenshot of the interior, at the ground floor where a collection of pictures originating from Google Images are exhibited on a wall of the virtual building.

Preliminary evaluation and testing has been conducted at the *Athens Science Festival 2015*[5] and, a little later, at the *Thessaloniki Science Festival 2015*[6]. At these Festivals more than 200 pupils used the system, with ages ranging between 10 to 14 (there were some younger ones). They were very responsive and creative and, given the time and space limits, some of them developed their own exhibitions. They all thought—and were enthusiastic about it—that it could be a nice game to play at home. A long list of emails from teachers and laymen was collected in order to be updated about the system's readiness level and availability.

[5]Athens Science Festival at http://www.athens-science-festival.gr/en/
[6]Thessaloniki Science Festival at http://www.thessalonikisciencefestival.gr/en/

IV. Conclusion

Building on the Unity 3D game engine and the open linked data technologies we have developed a dynamic virtual museum framework that provides an open system for all users to create their exhibitions made of content that is distributed on the web, either provided by cultural resources and repositories or by the users themselves. The framework provides a first-person virtual world experience for navigation and content manipulation. It can be used both for typical cultural purposes and, more importantly, for educational purposes as demonstrated by a case study that was conducted for the purposes of a related project.

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