A Prototype System for Automatic Design of Virtual Exhibitions Integrating Cultural Assets From Public Repositories

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Abstract. In this work a prototype system for automatic design of cultural virtual exhibitions is presented. The system is designed to make use of digitized cultural heritage assets which are suitable for integration in virtual reality systems and applications. The demonstration system retrieves digital objects and related data from Europeana according to user preferences, creates adaptive virtual exhibitions hosting the retrieved objects and enables users to access the available content. Additionally, the presented system sets the ground for further research on the use of intelligent methods for information retrieval and content personalization towards the enhancement of cultural understanding while drawing guidelines for mixed reality, virtual reality and cloud based solutions for digital heritage.

Keywords: Virtual exhibitions · Digital cultural objects · Adaptive exhibitions · Virtual/mixed reality · Cloud media · Internet of things.

1 Introduction

Virtual museums and virtual exhibitions is an active field of research as shown by the number of publications and projects [10, 11, 15, 19]. They are employed in cultural promotion, aim to enhance cultural understanding, raise public awareness, assist conservation purposes and even raise funding [3, 21]. In the present work the focus is on 3D virtual museums and 3D virtual exhibitions, both terms will be used interchangeably, represented in virtual environments in which virtual visitors have realistic navigation abilities and observation experiences of the presented exhibits.

The research efforts focus on numerous aspects of virtual museums and virtual exhibitions including design approaches, technological challenges, museology approaches, learning issues, navigational issues, interactivity, curatorial aspects, personalization, visitors engagement, etc. Despite the great number of research works and projects in this broad field, little attention is being paid in automating the design of virtual museums and virtual exhibitions.

In this work, automatic design of virtual exhibitions is considered an effective approach for providing a wide audience of diverse preferences and cultural background with access to a constantly growing number of cultural heritage assets. Moreover, virtual visitors should be able to experience these virtual exhibitions in virtual reality systems or they should be able to move virtual exhibitions in a mixed reality environment and experience virtual exhibits into their homes.

In this paper, a prototype system is designed in order to examine the potential of automatically created virtual exhibitions as a solution in enabling future audience to explore public cultural repositories, increase their engagement and enhance societies' cultural understanding. The presented system is designed to retrieve cultural data from Europeana and Europeana's partner organizations according to users' interests. The retrieved digital cultural objects are used for cultural objects' representations and the virtual exhibition instance is automatically designed to host the content while satisfying user's preferences.

The contribution of this paper is threefold. First, models of adaptive exhibition topologies [15] are employed for automatic design of personalized virtual museums and virtual exhibitions. Second, a testbed for examining personalized cultural spaces is provided and third, the prototype system will provide the basis for further research in immersive virtual reality systems and mixed reality systems for cultural knowledge purposes.

In Section 2, the research background is briefly discussed. In Section 3, the system architecture, its functionality and the digital ecosystem in which is hosted are discussed and Section 4 outlines the further research directions which will take advantage of the prototype system.

2 Research background

The research background of this work spreads across numerous fields including virtual environment technologies, virtual museums and virtual exhibitions, personalization techniques, virtual/mixed reality, digital libraries and metadata, etc. In this section, a brief discussion on the most relevant research works is given and the focus is mostly on the field of systems that design virtual museums and exhibitions which host cultural objects derived from open cultural repositories.

2.1 Virtual Exhibitions' Technologies

The term virtual museum is used to describe the presence of museums in the digital world [23]. Virtual Reality Modelling Language (VRML) has been employed for the construction of virtual museums and virtual exhibitions [5, 18]. VRML is considered to provide poor interactivity [4] and researchers have been investigated improved solutions. The use of already implemented multi-user virtual environments, e.g. Second Life, to provide virtual museum activities is proposed in other works [30] but as the authors state there are important limitations.

In order to overcome the aforementioned limitations, the use of game engines is proposed for the creation of virtual museums [17]. Game engines offer the functionality needed for a virtual environment avoiding its time-cost development from scratch. The developed virtual museums then allow users to navigate in their spaces as they would do in reality and also to observe and interact with the exhibited artefacts. The ability of a virtual environment to realistically and efficiently represent virtual cultural heritage is studied in other works. In [14] an approach for dealing with large scale computation issues while maintaining realistic representation of 3D cultural objects of complex geometry is presented.

2.2 Virtual Exhibitions' Design

In [31] a system that allows museums to build and manage virtual and augmented reality exhibitions based on 3D models of artifacts is presented where dynamic content creation based on pre-designed visualization templates allows content designers to create virtual exhibitions efficiently. Virtual reality exhibitions can be presented both inside museums, e.g. on touch-screen displays installed inside galleries and, at the same time, are accessible on the world wide web.

[13] presents a web-based virtual museum framework that relies on users' creativity and on the exploitation of the content in distributed web resources. The presented framework is able to connect to popular repositories, such as Europeana and Google, and retrieve content that can be used in creating virtual exhibitions. It provides a complete authoring interface, in which users can create customized virtual exhibitions, while guaranteeing an engaging experience by relying on modern game engine technologies.

In [28] two, almost opposite, layouts are studied: (i) the single sequence layout; and (ii) the grid layout. In the single sequence layout, visitors have to traverse a specific sequence of space components while in the grid layout visitors are able to choose between the available neighboring space components resulting maximized randomness in the pattern of movement and exploration.

In [15] a set of adaptive exhibition topologies for virtual museums and exhibitions is proposed aiming at facilitating user navigation and providing personalized experiences. The concept of adaptive exhibition topologies is also discussed in [2] in which the virtual exhibition's spatial structure derives from the hierarchical structure of the semantic graph based on cultural objects relations.

In [16] the focus is on the interaction functionality of exhibits in virtual exhibitions proposing a set of solutions for enhanced interactivity that serves for effective information communication.

2.3 Digital Libraries and Cultural Repositories

The number of records related to cultural heritage objects that are hosted in accessible repositories drive research teams to take advantage of these sources in order to fill virtual exhibitions. In [12] a dynamic web-based museum framework based on open data is proposed. This framework retrieves content from Google Images, Europeana and an internal repository using JSON data interchange and the exhibition management is controlled by a system administration who is responsible for activating exhibitions after a typical content verification and appropriate content screening.

Other works focus on the aspects of digital libraries and the metadata standards for virtual museums. In [27] a thorough discussion on the available metadata standards is presented but it states that there are considerable gaps in the field of virtual museums metadata. In [9] a study on Europeana's metadata quality is presented concluding that the model provides a limited set of metadata that do not permit classifying digital resources coming from content providers and aggregators according to a specific knowledge domain. Moreover, an interesting point of this study is that the availability of 3D objects is not mentioned, obviously due to the small number of available 3D resources.

3 The Prototype System

The presented system is based on the idea that virtual exhibitions should be designed automatically, with their content beeing selected and placed into exhibitions automatically (System Functionality Requirement 1) and with the ability to adapt dynamically to users preferences (System Functionality Requirement 2). Public accessible cultural repositories are used as content sources and this work focuses on Europeana. Europeana provides access for Europe's digital cultural heritage aggregated from libraries, archives, museums and cultural institutions [26] and it maintains an API which can be deployed for data retrieval purposes. In the presented prototype system the Europeana'a API is used to retrieve Cultural Heritage Objects based on users preferences thus satisfying Requirement 1. The prototype system integrates a mechanism enabling adaptation of the content during navigating in the virtual exhibition thus satisfying Requirement 2.

3.1 Data Providers, Europeana and the Presented System

Data providers, also referred as cultural heritage object providers are organizations and institutions that are responsible for digitization, documentation and (digital) preservation of their cultural heritage objects. Data providers usually are libraries, archives, museums and other cultural institutions.

Europeana collects, maintains and communicates data related to cultural heritage objects which are provided by the partner data providers. Europeana is of crucial importance for the presented system and its functionality as it provides access to the cultural heritage objects that are integrated into a virtual exhibition instance. In this context Europeana is considered a digital ecosystem in which multiple organizations and most important their cultural assets, are connected through contextual relations and descriptive content is developed. Contextual relations are developed by the Europeana Data Model which is described below. Another important feature of Europeana is its interconnectivity capabilities that derive from the provided APIs and which are described in the next paragraphs. The presented system communicates with Europeana by using its API, extracts

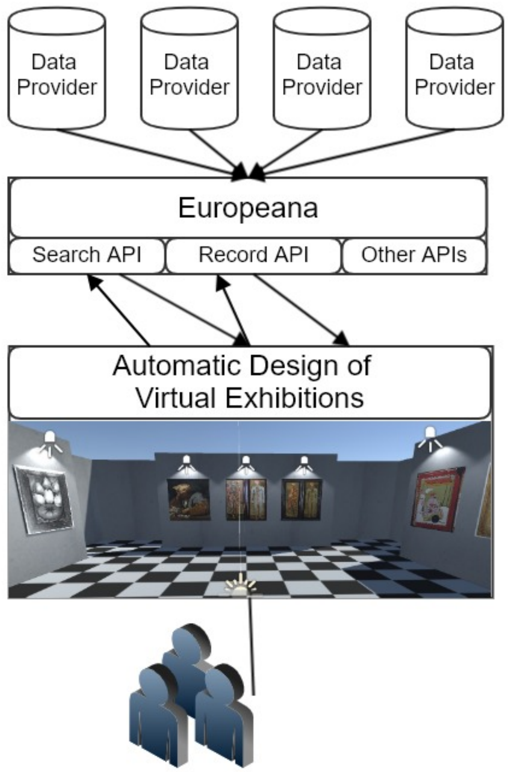


Fig. 1: System's overall architecture.

metadata about the cultural heritage objects published by data providers and retrieves the digital objects representing the cultural heritage objects.

Europeana Data Model To organize and structure its data, Europeana has defined a data model named Europeana Data Model (EDM) [6]. A detailed description of EDM is beyond the scope of this work. However, the properties and classes used by the presented demo application are presented. In EDM cultural assets are organized in records. A record refers to the package of data about a cultural heritage object, comprising the information which connects the metadata and the digital representations together. All records when delivered to Europeana are assigned a unique identifier (IRI) with the following structure: `http://data.europeana.eu/item/DATASET_ID/LOCAL_ID` For simplicity, many of the Europeana APIs use a field named Record ID as a shortened version made out of just the variable parts of the IRI: `/DATASET_ID/LOCAL_ID`. Each record has a title (dc:title) which is a literal property used to provide the name of the cultural heritage object. Also, each record has also a property instance (edm:isShownBy) defining a media file related to the specific object.

Europeana API Europeana provides API access that enables integration of Europeana's assets into other contexts [26]. Europeana uses REST (REepresentational State Transfer) technology taking advantage of HTTP (Hyper-Text Transfer Protocol) methods which are widely deployed and supported.

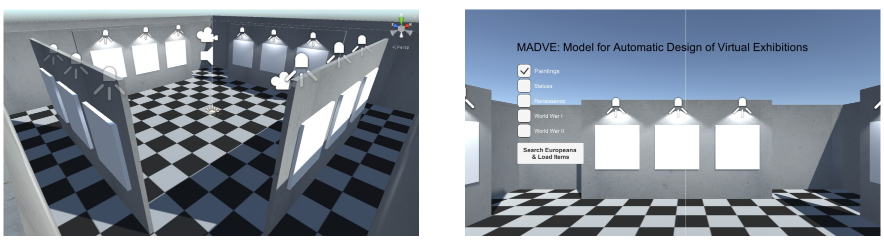
Europeana provides a wide range of specialized APIs for searching entities, metadata analysis and contribution to Eureopeana's assets. In this work the Search API [8] and Record API [7] are mostly used. Search API provides the ability to define search terms and also to apply content specific parameters. Search terms are defined by users' interaction and the following content specific parameters are used: (i) parameter 'media', requires a media file to be available; (ii) parameter 'edm:Type' is used to define the required media type, e.g., 'image', '3D', etc.; (iii) parameter 'reusability', the demo application requires that the provider allows the reusability of media for the the specific asset. A request to Europeana's Search API results a collection of items meeting the search criteria. The resulted collection comes in JSONP (JavaScript Object Notation with Padding) format. Each item of this collection has an ID, a Title and a Link property instance (read more about in 3.1). The link value is then used in order to retrieve the cultural object's data using Record API. The Record API provides direct access to the Europeana data, which is modeled using EDM. A request to the Record API results a JSONP object containing the link to the media file (edm:IsShownBy) representing the cultural asset.

3.2 Prototype System Design and Architecture

The main purpose of the prototype system is to act as a platform for automatic design of 3D virtual exhibitions which will enable exploration of content provided by interconnected cultural repositories. The prototype system supports content retrieval from Europeana's partner organizations. The prototype system is implemented in Unity3D [29] game engine, makes use of Europeana's APIs and integrates mechanisms for content management, content personalization and adaptive space structure which are further described below.

User Functionality Requirements: an initial user requirement analysis is performed resulting that user functionality consists of three important tasks: (i) users are able to choose categories and cultural heritage objects (User Requirement 1, Figure 2b); (ii) users can easily navigate in virtual exhibitions (User Requirement 2, Figure 2a); and (iii) users can observe and interact with objects (User Requirement 3). The system's interaction methods and the corresponding interfaces are separated in three categories: (i) dialogue based 2D user interfaces used for initial system configuration and content selection; (ii) virtual environment interactions used for navigation and observation of the virtual exhibits; and (iii) exhibits interactions which consist of methods for interacting with the objects using virtual environment based interactions [16].

Implementation platform: Unity3D game engine is used for the implementation of the prototype system. Unity3D is an efficient game engine used in video games and cultural heritage applications [14]. Unity3D provides the ability to create 3D scenes according to predefined plans or even dynamically create scenes based on multiple criteria [15]. The designed 3D scenes can be rendered in real time in high quality photo-realistic graphics. Due to its game engine origin it provides tools for designing interaction mechanisms while allowing designer to extend functionality by programming. The available interaction mechanisms include character controller used for navigating in the 3D scenes as well as user interface components for information communication and user data input. Unity3D is executed on the MONO framework [20] providing access to its functionality while maintaining cross-platform compatibility. One of the advantages of Unity3D is that provides libraries for submission of HTTP requests and handling of the corresponding responses that are used for communicating through Europeana's APIs. Unity3D has an easy to use editor and interoperates with advanced integrated development environments (IDEs), e.g. Microsoft Visual Studio, providing developers the ability to write code effectively and to perform debugging sessions. Moreover, Unity3D can build projects for numerous platforms, e.g. PC, MAC, mobile devices, webGL, game consoles, and numerous operating systems, e.g., Microsoft Windows, macOS, iOS, Android, etc.



(a) Virtual exhibition space design. (b) User interface design.

Fig. 2: System design.

System Components The presented system consists of several software components in which a set of purpose specific operations are performed. The components are: (i) system state controller; (ii) content retrieval; (iii) content management; (iv) user interface; (v) interaction design; (vi) exhibition design; and (vii) exhibit controller.

System State Controller performs system initialization, manages its states and mediates between components. Five states, and their transitions (Figure 3), are defined below:

1. Initial state: system has not received user information, no data request to Europeana has been submitted and the virtual exhibition is not designed.

2. Parameterization: user selects the categories of interest and configures certain aspects of system's functionality and interactivity, e.g., camera position, volume level, etc.
3. Navigation state: user has submitted information, requests to Europeana and data providers have been performed, exhibition is designed and user navigates in it.
4. Exhibit interaction state: user interacts with exhibits, while in this state navigation is paused and interaction is focused on actions which affect exhibit's state, e.g. rotate, scale, etc.
5. Terminate: user terminates the system.

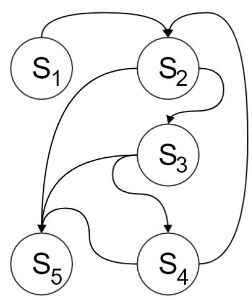


Fig. 3: System's state diagram.

Content Retrieval Component gets input from the User Interface mechanism (through the system state controller) and performs the required operations in order to provide the information. Once a user has defined the thematic category she/he is interested in through the user interface, the content retrieval component submits a request to Search API (Figure 1). The content retrieval component receives Europeana's response in JSONP format, it decodes the received data and extracts the required information (record id, title and link). For each one of the resulted cultural heritage objects a Record API call is submitted in order to retrieve the URL reference of the media file representing the cultural heritage object that is hosted on a cultural repository.

Content Management Component is used by the system in order to convert the retrieved data in a format usable by the system according to the employed technologies and its purposes. API requests results when received are formatted in JSONP and their properties are not directly usable by system's functionality thus are parsed and the data are used to instantiate appropriate object classes with their instances beeing directly accessed by system operations. When content retrieval component retrieves media files, the content management component associates the received media files with the previously retrieved metadata. In addition, content retrieval component responds to requests received by other components by providing the required information.

User Interface Component is the visible mechanism of the presented system, or better described, the system's elements that are visible and usable are part of the user interface mechanism. Users makes use of the user interface services in order to configure the system, interact with the virtual exhibits and receive information (Figure 2b). Every user activity on the system is a request from a user interface element to a user interface method which is then proceeded to the system controller and then to the appropriate component.

Interaction Component, user interface describes what users see and it is responsible to receive users input and forward it to the appropriate component, e.g. content retrieval. On the other hand, interaction component describes the actions that users are able to perform, e.g., navigation, observe objects, interact with objects, change system state, etc. and it is responsible for communicating these actions to the appropriate components. Among the numerous actions that are enabled by interaction the most important are those of navigation and interaction with the exhibits.

Exhibition Design Component provides exhibition designs which are adapted on users preferences. The exhibition design is based on the concept of adaptive exhibition topologies [15] aiming at providing exhibitions designs which are easy to navigate and navigation's overall distance will be kept under a certain limit. A major functionality of the exhibition design controller is the expansion of the exhibitions as users move forward thus meaning that they are willing to view additional exhibits.

Exhibit Controller, exhibits are virtual elements representing through the available media files cultural heritage objects. Exhibits should be accompanied by information, this information should be available in the virtual environment and users are able to interact with the exhibits.

3.3 System Tests

The system is tested in order to confirm that basic system functionality requirements (Section 3) and basic user functionality requirements (Section 3.2) are satisfied. System tests are based on the initial use case scenario (Section 3.2: user functionality) requiring users: (i) to select a thematic category, (ii) to navigate in the virtual exhibition and; (iii) to adapt the exhibition's content.

Early tests show that users are able to choose thematic category by using the user interface but the set of choises is considered to be limited. A major functionality aspect that is revealed by the system tests is the time needed each time the application load a new dataset, either due to change of thematic category or due to exhibition expansion as user moves forward. The time needed in these cases is considered to be long (approximately 20-30 seconds) and varies

(a) User interface and system state controller test.

(b) Content retrieval, exhibition design and user interaction test..

Fig. 4: Content retrieval, exhibition design and user interaction test.

depending on the network capacity and the computational power. Exhibitions' space adaptation is considered to be sufficient but the resulted exhibition spaces are considered to be monotonous as they are based on the sequential layout [15] thus not providing alternative routes. Regarding the exhibits' information that the system provides it is considered to be limited but this due to the fact that the metadata provided by the content providers are limited as it is also stated in [9]. Overall it is concluded that the tests are successfully completed and the system is proposed as the case for further research which is described in Section 4.

4 Conclusions and Further Research

In this paper a prototype system for automatic design of virtual exhibitions is proposed. The purpose of the prototype system is to demonstrate the ability to create personalized and adaptive exhibitions for content derived from public cultural repositories. In particular, the content is derived from Europeana, user is given a set of thematic categories to choose and the exhibition size and space expands as users explore the exhibition. Sequential topology is employed for automatic design of the requested exhibitions showing that the approach provides sufficient exhibition spaces. In future work, additional exhibition topologies [15] will be deployed which will be evaluated for their effectiveness. The content of the exhibitions is retrieved from public cultural repositories and it is possible to consist of large amounts of data thus the network connection and the computational power and memory capacity of users' computer machines is an important factor. Regarding network issues future work will focus on the employment of future network technologies (5G) [32] in media rich applications. Regarding the computational limitations, cloud computing [34] and its descendant cloud gaming [24] provide interesting approaches. The *Internet of Things* concept is also promising on providing enhanced user experience as new application models can be designed to take advantage of smart sensor networks for data communications or processing services. Such networks can provide access to cloud infrastructure [33] in mobility scenarios or even deploy the edge infrastructure [25]. Moreover, sensor networks can be deployed by virtual or mixed reality applications for user input, context awareness and other purposes related with the concept of ubiquitous multimedia applications.

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