

# Creating Innovative Cultural Heritage Experiences Using Adaptive Game-Based Augmented-Reality and Web Technologies

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**Abstract:** Development of innovative user experiences in museum and cultural heritage sites is a design and cost intensive process. We present state of the art progress on the development of unified systems enabling crowd-sourcing features and particular design characteristics, which permit the integration content presentation, exploration and the implementation of game modes using an open and expandable unified information domains. The advantages of this approach are demonstrated through case studies designed to accommodate the needs of users and content experts, while developers are allowed to dynamically extend system capabilities.

**Keywords:** Edutainment, Cultural Heritage, Interaction Design, Multimedia, Augmented Reality

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## 1. Introduction

The creation of innovative cultural heritage experiences [1] is a multifaceted task. These often rely on state-of-the-art modern mobile technologies [2, 3], where interactive augmentation and virtualization of the environment have shown their adaptive capabilities and potential. In certain case studies [4] technologies are combined allowing visitors to experience dangerous or inaccessible content, such as visiting underwater archaeological sites. The development process often combines existing content with new uses and the end-applications are developed within experimental multimedia environments [5]. Information-enabled real-life environments such as living cities, archaeological sites and museums are ideal candidates for augmentation as they permit linking of physical spaces to knowledge [6]. The generalized innovation movement in the field of experimental multimedia clearly indicates a strong support of the above trends by multidisciplinary research [7], enabling content delivery in a uniform, organized, educative and rewarding manner [8]. The development process of the above systems shares common characteristics that of new cultural products, offering customized content and experiences that cover multiple individual needs. Cultural tourism [9] is a

characteristic area enhanced by those technologies. In order to identify, design and ultimately establish systems capable to deliver adaptive experiences, we focus particularly on user needs. In addition, we track their complexity characteristics and performance, in order to avoid typical problems [10-12] that arise with increased system-content complexities which often introduce end-system inconsistencies, errors and unpredicted behavior. Earlier research [13] has identified a number of user experience factors that govern the so-called experience tourism. The availability of social-based technologies allowing experiences to be captured and shared in global scale, combined with the ease of transport [14, 15], are both important factors that can clearly attract the informed tourist who seeks to be immersed into cultural heritage experiences. The proposed methodology [16, 17] has been used in the past in order to create highly focused advertising campaigns. In our past work [18] we designed a web and mobile-based system that presented users with an adaptive experience ranging from text messaging to fully-featured interactive multimedia games, based on the type of mobile device owned by each participator. Similarly, the proposed methodology discussed in this work, presents a roadmap which can be used to design, develop and expand the knowledge base of such an experience for a real-life

medieval city, that of Corfu, Greece. We present a number of implemented examples, which were used for development and testing through experimentation.

In this work we focus particularly in the interaction design aspects of the experience, designed to unify augmentation and virtualization technologies, in order to provide adaptable navigation into the content. There is strong interdisciplinary research in the area of human factors [19], targeting also user experience [20], satisfaction [21] and learning [22]. Clearly, the resulting master-system is based on the unification of multiple interaction systems under common user experience scenarios. Today this is commonly implemented through the use of dynamic content-delivery platforms, which allow customized scenarios to be implemented, an example being social-media services, delivering personalized content to multiple users which combine user profiles, content and preferences. The deficiency of such systems is the evolution of base-content, used within the interaction systems for the identification of objects, environments and people. When this changes physically, it introduces identification errors, rendering the end-system dysfunctional or in the best-case scenario, disabling some of its features. A similar analogy can be found within the Google Street View application, where the initial mapping of streets requires constant updating in order to record changes made, which may range from simple building restoration, to new building projects and demolitions and traffic changes. What we propose in this work is to create an underlying platform, which can be used to acknowledge changes in the base data and update this information dynamically. When applications request the recognition data, then a fresh version is delivered, updating the content and sustaining the recognition process active. Users in this process are essential as their devices are used to update content and their shared intelligence can be employed to correctly identify changes.

The first section discusses user needs and presents the principal factors that need to be considered during activities and system design. We particularly focus on the organization of the underlying structure, which is designed to support multi-level content delivery, enabling dynamic content re-use and updating, the need for a crowd-sourced involvement and the benefits of such an approach. We focus on the common system practices that through their lack of openness often result in the non-use non-adoption of their content. Within the second section, the complexity of implementation and its sophistication is presented. The third section discusses the organization of the underlying content structure, enabling the delivery of scalable experiences, and their sustainability in an ever-changing environment where information constantly changes and evolves.

## 2. Users, Developers, Content Experts and Content

Those interested to provide innovative cultural heritage experiences for visitors in organizations or archeological sites, focus on the development of specific activities [23],

often in the form of systems targeting the end-user. Those activity-enabled systems may consequently be integrated within larger-scale systems, enabling users to select and employ those either on demand, or as part of the experience planned for them by the content experts and designers [24]. This common approach amongst public bodies and developers, introduces various meta-deficiencies, as they are often developed in an isolated and non-expandable manner that often fails to share their content beyond their intended use. The public bodies and developers who wish to invest into this new domain of interest [25], often find limited information on the process. Previous research [1] indicates that the process requires innovation in product, process, managerial, marketing and institutional level.

Typical examples range from simple audio-based guided tours [26], to the augmentation of the surrounding environment of archaeological sites and cities [20] with additional multimedia material using Augmented Reality technologies (AR). Advanced systems [27] employ Virtual Reality (VR) technologies where in certain instances [28] immersive activities and games are developed where users participate in specific virtual gaming tasks and experiences. Beyond their inability to share content across those different platforms, the majority of case studies presented in the literature, expect users to follow a deterministic approach and go through all the content nodes exhaustively in their attempt to deliver the full experience and content to the user. This clearly limits the user flexibility to transcend through varying presentation modes, enabling cross-media experiences to be developed, as time and cost are the main factors that govern the developmental process of such systems. Usually, the encapsulated information is either limited, or the cost to include more information is significantly high. Recent research [2, 5, 29-31] has shown that this particular system development approach is outdated.

It is informative at this point to discuss the way that human museum guides function and adapt their content and presentation techniques, when they are commissioned to walk through groups of tourists with particular needs and interests such as ethnic origin, knowledge in the domain of interest, mixture of different age-groups such as parents with young children etc. What tourist guides try to achieve is to identify their client's interests, in order to both direct them to the sections of interest and provide a customized and interactive experience that focuses mainly on their preferences. This practically means that the museum guide has the flexibility to skip particular sections of the museum that present no interest to the family, use specific non-linear navigational paths that cover their time-constraints and provide customized information to both the parents and children, mapping their particular interests and answering their specific questions. This approach has already been implemented in small scale case studies [3]. Here, augmented reality is combined with multiple navigational paths within a medieval fortress where users may choose alternative visiting routes [2]. This approach requires modular content organization and delivery in order to allow the visitor to

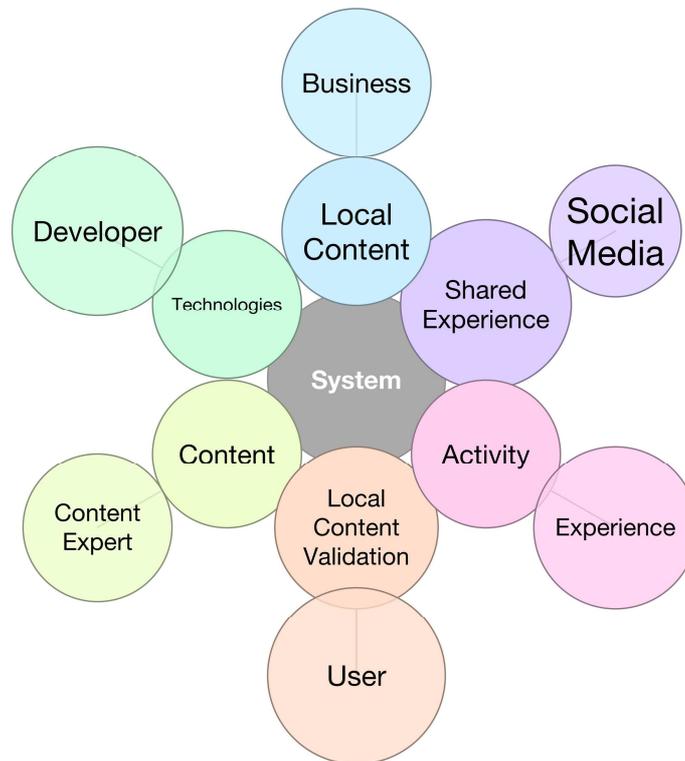
explore areas of interest, while they are allowed to ignore others, and still reach the presentation goals intended for each target group. It is therefore important in such systems to identify content units (nodes), which encapsulate the necessary information, but this is released in a controlled manner and only when the user experience scenario and user choices demand their delivery.

Clearly, user needs are unique. In educational and experiential application areas, users are able to customize their experience and receive adaptive content. This is a common characteristic, which is successfully addressed by modern Virtual Learning Environments (VLE's) through the delivery of customized curriculum for each student, adjusted by their accreditation, experience and performance in relation to the optimal learning curve. The main research question here is to invent a method to allow users to find the most appropriate content in a dynamic manner, as this may evolve and change dynamically. Various techniques are employed to overcome those deficiencies within our application area, which is converging towards open content and systems. In

other words, the provision of an open system enabling access to its data and metadata is the key element, offering advanced creative participation and exploration capabilities to content experts, developers and users. Content experts can use it as a research and content-organization tool, developers can employ its organization structure to build their applications, while users may extend and expand it by using their own content or by updating it to reflect their reality.

### 2.1. Transforming Users to Content Providers

Social media and their applications are organized in this manner. Facebook employs users in order to correct their content and provide accurate and updated information, through the "Suggest Edits" option available at the user menu. Google Maps allows users to create content layers, submit photos and local information, which is then made available publicly at various levels and within multiple applications



**Figure 1.** Depicting multiple shared interests, linked to the proposed content management system.

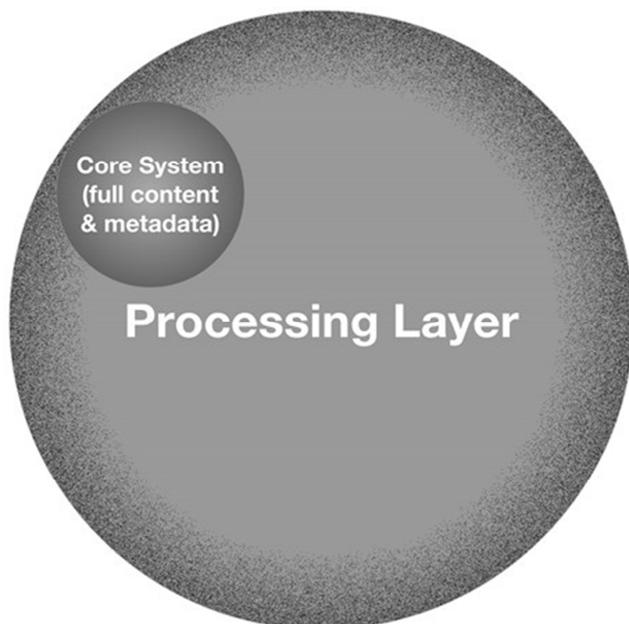
In most cases, social software systems prove the validity of the common saying: "if you do not pay for the service, YOU are the product...". In essence, one of the characteristics of the proposed methodologies is to outsource the updating effort to the users at varying levels: enabling standard user to validate the correctness of the content and identify changes that have occurred to the environment used for recognition; allowing standard users to publish their content within the system, with the provision that content uploaded may be employed also by others in recognition processes; and

ultimately, allowing a user to develop an application which sources content from the general database, which may use social-sourced content to update its links and information. Figure 1 is used to depict interaction between the key players in the process. Note that here various scenarios are supported, and this is the reason that directional information is not strict. Those parties on the outside of the diagram may instigate development, which when completed will result into content, metadata, interaction design and methods to be stored centrally within the system, enabling other users to

explore, view and reuse those resources in an iterative or recursive manner, creating “*semantic mashups*” [32]. While existing Content Management Systems (CMS) can clearly be employed to support this structure, we choose to use the underlying platforms for social media management following well-established practices [33], as those developmental platforms allow personalization and control over content to be passed to the users themselves.

## 2.2. Content Delivery Evolution

Various activities [34] designed to attract the interest of the visitor in worldwide scale may be traced in the literature, each implemented through its own content organization approach [35]. The availability of multiple, yet distinct systems each with different content requirements, implies that it is imperative for the proposed underlying content delivery mechanism to cover diverse end-application content adaptation and delivery through flexible adaptive and transparent methods.



**Figure 2.** System-content organization and access using client-specific content transformations.

In order to achieve this goal, further to the core content-encapsulating system, we implemented a second layer in order to provide adaptive content access to external applications. As a result, the core shown in Figure 2 holds complete information (image data, coordinates, camera direction & angle, date, time, content owner details etc.), while developers may create specific delivery options that suit their particular applications.

The first time content is requested by external applications, the delivery process performs the following actions: first the application requests specific content items to be delivered. A copy is passed to the secondary processing layer from the core, which transforms it to the application-specific format and stores it on the proxy server, marking it with a versioning

system, which relates back to the original item. The application uses this customized copy for its delivery stored within the proxy server. This intermediate version is only updated when the core system information detects a physical change to the environment, and the end-system needs to be updated in order to function properly.

It is interesting to describe the mechanism and conditions under which the core information is updated. Clearly, when this information is used within Augmented Reality environments for recognition of the environment, and the environment changes, it is imperative to be updated and replaced, in order to restore the application’s functionality. The proposed method in order to function in a fully automated manner requires two-way communication between the application and the core system. When the user is located near the augmented environment and the process fails to produce a result, then the application requests a new version of the sampled environment which is delivered and replaces the original. If this succeeds then there is no need to perform further actions. If the process fails, then the application enters a sampling mode, which prompts the user to scan their environment, and the system detects changes in it. Fitting algorithms are used to identify the changes in the environment and update the information, which is appended to the system, enabling temporal changes to the environment to be recorded and used further, while the latest version is always visible to all applications.

## 3. From Linear to Highly Adaptive Systems

In this study we discuss the process of design and development of two parallel main modes of content access: virtual museums and augmentation of the user’s experience within the setting of a museum or in open spaces such as archaeological sites. The combined development of those modes begins at the content design level, which is described using appropriate content-context relations and metadata. This approach is designed to cover the needs for interactive exploration, furnishing the needs of wide audience ranges, which are allowed to explore and experience the content, both in real life and remotely by switching between pre-determined and dynamic presentation paths. The advantages are manifold and range from the development of multiple application-systems using the same content base, to the minimization of the cost aspects of the process and the reusability and extendibility of the content.

It is interesting to point out that today the majority of multimedia-based applications for museum visitors, ranging from audio-guides to Augmented Reality and to Virtual Reality realizations utilize hierarchical content access models [36] where the systems focus mainly on the user experience [37]. Although it is possible to support these applications and allow them to access the content, in this work we suggest that new applications that wish to automatically update and adjust their content must be designed and implemented to do so. We

have implemented this task using two alternative interaction design approaches.

The first case employs fixed augmented reality presentation systems that cannot adjust dynamically their content. We employed the proprietary AR-application *Aurasma*, that allows developers to recognize and dynamically augment information into real-life objects and images. This application employs a multimedia database featuring basic object recognition items (called trigger-images) each used to identify a real-life object that is linked to an instance of multimedia information. Successful recognition of the object by the application software triggers the display of this digital information through the application.

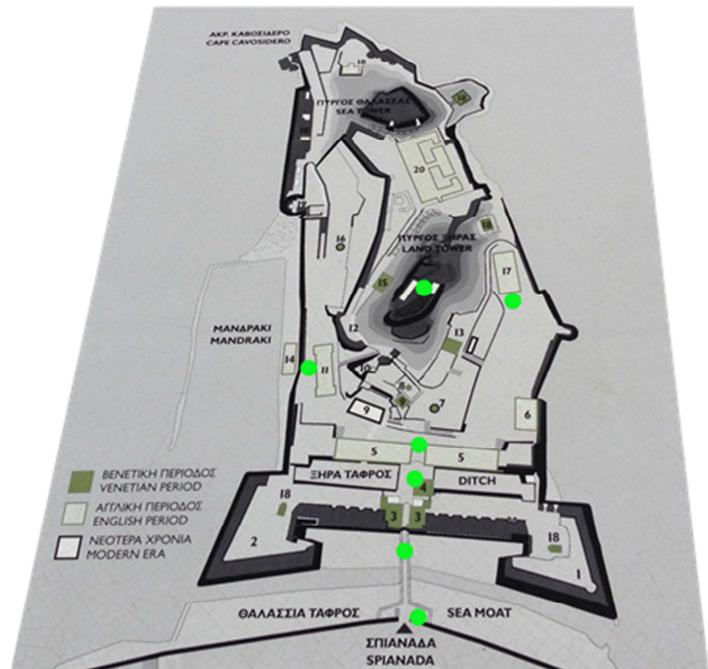


Figure 3. Alternative walking paths allow adjustment of the content, the base story and hence the user experience.

Selecting the clockwise or the anti-clockwise path activates different channel selection offering visitors inherently different experiences, despite the fact that they use the same visible markers for recognition of their location within the archaeological site. Developers are also able to create further experiences for particular user groups such as schoolchildren, by developing new “*information channels*” that employs the same points of interest to present different content domains.

#### 4. Further Work

We have already designed and presented dynamic-adaptive systems for the exploration of complex information domains including research, art, edutainment and entertainment [5, 38-40]. It is evident that in order to provide an adaptive user experience a number of user and systems factors need to be met. The constant availability of content and metadata ensures that the end-user will be able to dynamically scan and select through the available content-context options,

Collection items can be categorized within channels, grouping this information together. So, a user visiting a cultural heritage site or a museum must subscribe to a channel in order to experience the augmentation. In order to create innovative and complex interactions with object featuring multiple layers of exploration, we designed the scalable experience which in an instance extended in physical space [29], and in an other instance revealed different levels of information for different user types for the same objects [2]. Figure 3 displays the topological interest of this cultural heritage monument, featuring a selection of interactive paths, which are dynamically adjusting according to the path choice of the user.

adjusting the experience in a dynamic manner. This Web-like accessibility of multimedia content is also common under interactive TV research, enabling users to explore the content based on their evolving needs and interests [41-49].

Large public thematic collections including the Europeana project funded by the European Committee provide open data and metadata specification, search and retrieval standards, allowing interested parties to furnish such a system with content on a crowd-sourced basis. Our current research focuses into this particular aspect. Furthermore, an appropriate application implementation integrating the interaction design/mechanism and the performance/aesthetics of the system into an appropriate application format is needed. As we have already implemented a number of such case studies in museums and archaeological sites [3, 50] and we actively explore the use of content-context multimedia constructs that will allow us to store the data and allow complex interaction scenarios to be implemented dynamically, without the need to repeat the interaction design phase for each instance.

## 5. Conclusions

Developing innovative and adaptive cultural heritage user experiences through reusable augmented reality systems is a multifaceted process where the end-system is affected by a number of interdisciplinary factors. From the content expert's perspective the availability of content, its quality and the supported access/delivery methods are important for the development of useful experiences that meet the end-user requirements. The target-user experiences are based on either scenario-driven access methods featuring interactive adaptive behavior, or can be implemented into an open information domain where users are allowed the flexibility to dynamically access content instances.

System developers who deal with the implementation of such complex interactive scenarios featuring dynamic content inclusion and frequent scenario and content updates, rely on strongly typed data databases combining structured information and its contextual linking for the realization of the interactive scenarios and game-like activities. This is not a content-representation issue as we have shown that those systems already exist. Information representation must be addressed at the application-level where individual multimedia instances are connected into useful interactive systems featuring narration and adaptable behavior that covers the content expert presentation demands.

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