

## Combining Interaction Design and Gaming Technologies for the Development of Interactive Archaeological Content Presentation Systems

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### Abstract

Our main objective is to produce state-of-the-art edutainment and serious game end-systems, which satisfy the requirements of all three parties involved in the development process: content experts, end-users and application developers. Their requirements are often cross disciplinary, as each party involved in the process requires solutions to a number of problems which need to be answered in a systematic and complete manner. The ultimate goal of this process is to introduce an efficient, extendable and aesthetically pleasing end-system. In order to achieve these goals, we address and attempt to resolve the most common presentation design issues that arise during the process of interaction design. Completion of this process enables the actual system development to commence with a precise and complete specification of content features and system characteristics.

**Keywords:** Interaction design; Multimedia; Gaming technology; Edutainment; Archaeological content

### Introduction

Our previous work [1-5] has demonstrated that it is possible to develop applications and games featuring multiple interactive scenarios, which employ the same set of information markers and triggers in order to cover unique presentation requirements [6]. It was shown how this approach essentially extends the interactivity of a system and provides the capability to offer multiple or scalable interaction scenarios using the same information space [7]. The applicability of the proposed method has already been tested in practice via the development of interactive artwork, games and edutainment applications [8], using state of the art mobile platforms and augmented reality environments [9]. These systems combine real-life and virtual content, cover complex content presentation demands and are designed to adapt according to varying user needs and variable hardware specifications. Note that it is common for such systems to be used synchronously by different user groups, including young [10] and older visitors [11], enabling them to interact with the content using customised narration that suits their personal profile. In addition, users access and interact with the content using personal hardware and network access providers [12].

A requirement for the design of such systems is to first define the information space [8] and decide on system functionality in contrast to intended audience(s). Interaction design is clearly the most important process that affects both end-system quality and user experience. Interestingly, the Association for Computing Machinery (ACM) in 2012 classified interaction design as an autonomous research field, beyond the boundaries of human-computer interaction (HCI). This development identifies clearly that interaction design is not only part of user experience and other human-computer interaction (HCI) fields. Consequently, our research discusses important interaction

design and research issues such as game complexity, interactivity, multimedia content use, storytelling and overall game aesthetics.

In addition, multiple application modes are addressed covering the range between single-player to multiplayer and score-based games. Within the software context, our analysis presents the main game development technologies and platforms available today, focusing particularly on open source software, which may be employed under the intended purpose. Pieces of open source software include HTML-5, Augmented Reality Platforms, Multimedia and Game Authoring Environments, Virtual Reality and Social-Media-based platforms. Ultimately, the use of state-of-the-art hardware is addressed, where we discuss the adaptability of interactive content in order to cover multiple platforms, particularly when user-based hardware is employed in order to cover the presentation requirements and provide a unified game experience.

### Archaeological Content, Data Types and Interaction Requirements

In this work we focus on the design of edutainment and serious games applications [13,14]. In this particular subject-area there exist multiple developmental paradigms [15-17], which are often adapted in order to cover specific content, system and user requirements [18]. Existing methodologies either utilise a generalised interaction design approach for all purposes, or focus system development on the technological platform capabilities [19-32]. Some choose to map learning and game mechanics in order to analyse the performance of the produced application [33], or create models of the end-system in order to predict its end-user performance [34]. In fact some of those approaches suffer from typical software system side effects. Some of those include limited end-system functionality, limited adaptability when new content is introduced, and the lack of flexibility when major changes need to be implemented within the end-system due to content extension and the inclusion of new features. This work presents a novel

methodology, which can simplify the game-design process, specify the desired content aspects and identify precisely the information space that will be communicated to the user. In other words, the process aids content experts (archaeologists in this case) to identify and easily select the desired gamification characteristics of the content, enabling developers to focus their interaction design methodologies on specific content presentation requirements. The implication of this process is that a developer is not limited by technology before the design of the system, enabling the combination of mixed media solutions for the gamification of content, a trend which is quite popular nowadays [35-40]. Clearly, this approach provides content experts with the freedom to design an interactive experience which is not limited by

technological specifications. It also allows developers to choose the most appropriate software/hardware combination. Last but not least, it provides users with an adaptive state-of-the-art interactive experience, instead of a generalised multimedia product.

### Common content characteristics and data types

The majority of archaeological multimedia systems designed to provide an information / learning experience to the user employ a wide range of content data types, similar to those employed by multimedia-based applications such as interactive TV [41-46]. In Table 1 we list the most common data types used in such systems.

Data type	Use	Format	Interaction Requirements Complexity
Text	Content	Plain / Encoded Formats	Low
Text	Labelling	Plain / Encoded Formats	Low
Image	Content	Compressed Image	Medium
Image	Labelling	Compressed Image	Medium
Audio	Content/Instructions/Interaction	Mono/Stereo/Binaural	Low/Medium
3D Model	Content/Effects/Narration	3D formats / motion path	Medium
Video	Content/Effects/Narration	Compressed Video	Medium
Projection Mapping	Content/Narration	Compressed Video	Medium
Augmented Reality	Content/Narration	AR Environment	Medium
Virtual Reality World	Content/Environment Restoration	VR World, CAVE	High

**Table 1:** Media types.

The contents' intended use by the developer is contrasted against the typical formats and most importantly their system handling and processing requirements, which we refer to as "interaction requirements". Low-complexity media such as text, images and audio are considered as the basic building blocks for the more complex data types. However we refer to the content at a higher level, that of a "multimedia frame" [47], each combining one or more of the above content types. Multimedia frames are considered as information entities that can be engineered to refer to real-life entities. For example, in the case of archaeological content, we consider the case of a particular archaeological museum collection in Igoumenitsa, North-western Greece, consisting of excavated items originating from a kitchen in ancient Greece [48].

Each artefact can be represented using a multimedia frame, combining single media and multimedia information that may include: title, item description, history, location found, 3D model, video of the excavation site, images of the original state found, video of the restoration process, how it was used in the past, and all other information available for each particular item. In addition, a multimedia frame can combine direct information linking to lower-order information or higher-order structures - like the collection itself. Clearly, Table 1 lists only the typical data types and not the hybrid combinations that a developer may employ in order to cover special presentation demands. This appears more often with multimedia content which is found in multiple formats: video-based documentaries, animated and interactive 3D models, mixed and virtual reality applications, augmented reality guides and

presentations, projection mapping and immersive experiences utilising many of the human senses in the information/learning process.

### Interaction requirements and instructional design

It is informative to examine the topic of interaction requirements, as the proposed system development approach focuses on the presentation of archaeological content. The development process consists of three distinct roles: content expert, user and developer. Our past research analysed their roles in the process of creating an augmented-reality tour that supports dynamic-dynamic interactive routes [49].

Interaction requirements must cover the demands of instructional design for the content domain. It is evident that instructional design is a key aspect of system development. System requirements analysis is therefore adjusted to cover the learning process. This comprises an integral part of the development process. In the literature it is evident that this also applies for multi-modal systems [50]. The proposed model maps the content in a graph-type structure after the requirements analysis is completed. It is interesting to examine how other instructional design models deal with their design and development stages. Take for example ADDIE, an Instructional Design (ID) model employed for the development of multimedia educational games using mobile phones [51]. In this case, developers employ user-driven evaluation cycles of the end-system. Other instructional design models including the Dick and Carey, Kemp's Instructional Design, Gagné's Nine Events of Instruction, Bloom's Learning Taxonomy,

Kirkpatrick's 4 Levels of Training Evaluation and Cathy Moore's Action Mapping, also connecting the result to the learning process. The main difference between the above and our proposed model is that they include the user responses in their functional learning process, while in our case, the user responses are only embedded into the design process of each system version. Due to the advanced interactive features offered by the produced end-system, the user is able to switch presentation modes, essentially adjusting the learning process to suit their own timing and level, a process that was often found to remove the need for system re-engineering and updates.

The learning effects of such interactive learning modes have been measured and the results are very promising [52]. A content expert can define the learning objectives. In the case of archaeological content learning objectives may vary, depending on each user group. We have shown in previous work how this can be implemented via the selection of information subsets from the complete domain [7] for users with different demands. The system reveals the most appropriate set of information and the user is allowed to interact with it, enabling dynamic adjustment of content access.

From the user perspective, when a specific route is selected, then the starting node of the route is loaded, complete with links to the route's related node(s), and so on. This organisation is commonly described as a graph where nodes represent the information points. Arrows between nodes offer relevant user options that can be displayed at each node. In our work we have already described how multimedia frames can be interconnected [53]. Our past multimedia systems utilise a wide arrange of case studies presenting this technology in action, featuring dynamic interaction within complex multimedia content [54].

The developer focuses in a number of points: system functionality, ensuring that each navigational path is complete and informative; information accuracy, where each user is presented with the correct information at each stage; interaction adaptability, enabling the system to switch presentation modes when that is required, without repeating information which was presented before; and finally, usability and presentation aesthetics, a process enabling users with different backgrounds to employ the end-system and maximise its performance.

## System Development

The process of system development demands the interaction requirements process to be completed and the main navigational routes through the content, including narration, to be decided. The outcome of the customised requirements-analysis approach described above (section 2.2) is used as a developmental basis. This information set encapsulates the essence of the end-system: the content organised in "multimedia frames", the interaction rules, its intended functionality in the form of pre-determined or open-ended scenaria and narratives. This structured multimedia graph is actively employed in order to cover multiple user requirements, a process which in some instances has allowed the automatic deployment of such systems directly from specification [49]. Uniformity of representation in frames is particularly important for archaeological content, as the resulting specification possesses a number of highly desirable characteristics. First, it is evident that the information space is well defined, as research information complements the archaeological findings. Secondly, many researchers may be active in information spaces, which are often complementary, offering different perspectives on the same archaeological findings. Therefore developers may collectively use content from different sources in a constructive manner, in order to

provide multiple interactive learning experiences or educational games which re-use content and location-based triggers, featuring innovative scenaria. Multimedia databases are commonly employed for content organisation, enabling direct access by the end-system.

## Platforms and implementation

Typically, web-based tools and time-based multimedia authoring environments are employed for the development of the end-system application. Today HTML-5 and Shockwave are the usual formats in which the content is delivered. HTML-based solutions as opposed to proprietary software offer more flexibility, particularly due to their standardization and accessibility in a wide variety of platforms. However the specification does not limit the developers to specific environments.

The process may be summarised as follows: the content expert organises the content and creates digital entities in the form of "multimedia frames" which will later be used as the information access points by the user. As the same information points can be employed for multiple purposes, in order to reduce developmental delays, it is important to include all the information that is available at the time. Then, user interaction requirements come to play. The content expert creates a set of rules, which enable the system to identify if a specific node can be accessible from all presentation states. Imagine the starting point of a guided tour where the user is presented with three different paths. The content expert chooses at this point to enable access to a "multimedia frame" containing each route starting point, complemented by a short description and a video presenting a summary of what the user will experience.

Take for example the guided tour case study of the Old Fortress Corfu, Greece [7]. Here, the augmented reality platform "Aurasma" was utilised in order to implement interaction using mobile phones and tablets. Multimedia frames containing historical information were linked to easily recognizable markers that the device's camera detects and displays the following information: directions to the next information points, historical information regarding the specific location, panoramic views of the location, map, old photographs and video, full archaeological information for that specific point.

Verification is a process that today requires extensive testing and effort, particularly when non-linear narrative paths are supported. Depending on the complexity of the implementation, a developer may choose to verify system performance using multiple methods. Real-user testing in the field is the most common method, where practical problems can also be revealed such as limited lighting for image recognition used in augmented reality, or the change of shadows in buildings that alters the stored image. Other issues that commonly arise include the audio performance in noisy environments, the lack of network connection that requires content caching to be supported, the GPS reception errors that provide erroneous readings and can cause to system underperform and the lighting conditions which affect what the user sees on screen. Finally, issues of usability and aesthetics are important, as those applications apply to wide audiences with a wide range of abilities. In order to provide acceptable interaction environments, we choose to employ the standard conventions for accessibility used in different environments, regarding access to audio-visual information, subtitles, the size of graphical objects and their contrast.

## Conclusion and Future Research Directions

In this work we have presented a number of issues that relate to interaction design for archaeological content. Our experience has shown that it is possible to design multimedia-enabled interactive systems featuring dynamic information switching, dynamic navigation, adjustable presentation of content, via the use of multimedia frames used to encapsulate both content and interaction design. There are many future research directions that we wish to pursue. These include the need for automatic system authoring based on the specification, a development that reduces the need for developers and can provide rapid prototyping methods that can be directly utilised by content experts. The issues of automatic interface production and aesthetics are also highly important, as those are the parts of the content that the users experience. Ultimately, we aim to reach a point where archaeological information will be standardised, enabling content experts to select and compile presentations dynamically.

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