Behind Livia's Villa: A Case Study for the Devolution of Large Scale Interactive "in-site" to "on-line" Application

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Abstract. This work presents a methodology for designing online web presentations reusing a large scale, interactive and immersive VR installation by mapping assets as well as interactions to a low capability environment. With the emergence of WebGL plugin-free interactive 3D graphics inside limited information processing environments, e.g. browser technologies, becomes reality. However, macro VR worlds typically use large or even out-of-core data sets in order to produce and communicate scientifically relevant content. The major challenge still remains on how we can redesign and optimize applications that have been planned for macro VR worlds and map those to adequate concepts of micro scale worlds. We showcase this in the area of virtual archaeology for the online virtual museum of "Villa Di Livia", part of the bigger project "Flaminia Reloaded", in which several limitations could become crucial. The elaborated workflow could easily be adopted by other VMs and assist in future migrations.

Keywords: Browser Technology, Virtual Museums (VM), Desktop VR, X3D.

1 Introduction

In recent years we experienced a shift from large scale VR worlds to fast and interactive micro worlds in the field of computer graphics (CG) pushed by the huge market of portable devices. Those interactive environments can be accessed even through the smallest mobile platforms. This has been possible also because of the actual power and capabilities given to developers from mature GLSL libraries.

In fact another technology that is currently receiving a lot of attention from major developers, especially from Google, is the WebGL library, whose aim is the creation of high performance plugin-free Web 3D applications [1]. In a perspective of convergence between different technologies, it increases significantly the level of portability of 3D web applications. But since WebGL is a low-level GLSL based API, it is not

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very accessible for the typical Web developer who is used to build Web applications using HTML5 technologies. Moreover as graphic developers we have to deal constantly with large data sets such as large terrains, large textures, and a lot of additional geometry in order to produce and communicate scientifically relevant content, embedding this content inside a complex and interactive environment. This task couldn't be accomplished just using directly raw datasets and the WebGL API providing only limited information structures. So the major challenge still remains on how we can redesign and optimize applications that have been planned for macro VR worlds and map those to adequate concepts of micro scale worlds?

2 Behind Livia's Villa

In this work we present a methodology for designing an online web presentation re-using a large scale, interactive and immersive VR installation and mapping assets as well as interaction to a (yet) low capability environment. We showcase this in the area of virtual archaeology for the online virtual museum of "Villa Di Livia", part of the bigger project "Flaminia Reloaded", in which several limitations could become crucial. In fact, the main goal of this project is to present an articulated environment that could be used to explore digitally reconstructed assets of high scientific value, previously used in a multi-user, on-site application in Rome, called "Virtual Museum of Ancient Via Flaminia" [2].

Fig. 1. The original application: Physical installation (left); views with user avatars into one of the reconstructed interior of the villa

With the emergence of new possibilities for interactive 3D graphics in low capability and web browser technologies, we face a paradigm shift away from macro VR worlds. Thus, one aim of this paper is to showcase the migration process into a web 3D application of some data assets, and the replication of parts of the user experience, from an existing multiuser VR application, in which the visitor had the possibility to explore freely an archaeological site in a cooperative experience, through a narrative and involving approach, switching between actual and Roman ages (see fig. 1) [2].

Unfortunately, the process to convert and optimize already created digital assets is still by far an automatic process. The challenges increase when it becomes necessary to make them available on for the Web or even on mobile devices. The entire workflow is currently using several different approaches and pieces of software, is time consuming, and still most is left to the personal initiative.

2.1 Redesign of Application Logic

Given the intrinsic nature of this and also of the previous work, we looked for a good compromise between pure scientific data visualization and an involving and easy-to-use interface/interaction system, in order to captivate also common users. Given the underling WebGL technology, still facing several limitations, neither original datasets nor the interaction paradigms could be used 1:1. Even the original application concept was inadequate to the new media, e.g. the multi-user aspect.

Thus we had to perform a strong redesign of the application logic and interaction mechanism as well as to establish another production process. The new application logic should allow users to display on the digitized archaeological site several sets of 3d models and provide easy navigational elements. The user should be able to:

- visit the actual remains of the villa acquired in 2007,
- view the reconstruction of the villa in the 2^{nd} century AD,
- switching smoothly between present and ancient times at user request, and
- navigate to points of interests (POI), exploring site, rooms and objects
- query additional information to POIs delivering metadata information [13]

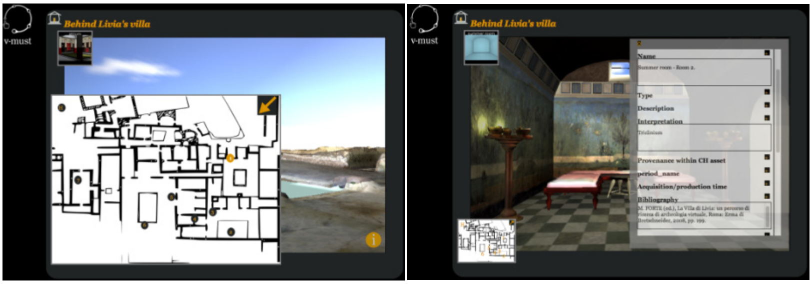

Fig. 2. Some features of the redesigned application. Left: Expandable active navigation map; Right: Example of a query to additional information related to one of the main rooms.

2.2 The User Interface (UI)

For the redesign of the UI, we followed Don Norman's design principles [3] on *affordance*, *visibility*, *mapping*, *feedback*, *constraint* and *consistency*. GUI elements were drafted in order to provide a high level of affordance using simple navigational control (e.g. walkthrough mode), easy to use interaction possibilities (aligned to nowadays possibilities provided by touch displays or classical browser interactions using mouse), guidance (by using map elements) and information (incorporating textual information on linked metadata or the "where-about" within the scene). UI elements are envisaged to be floating and rendered semi-transparently to not constrain the visibility of the site or objects in displays of limited size. Areas of information can be expanded downwards overlaying the 3D scene providing more information on certain assets. We aimed to establish a design that can easily be deployed on any kind of device or application setting, e.g. for tablets, smartphones or desktop based VR environments exposing a high portability (see fig.3 and fig.4).

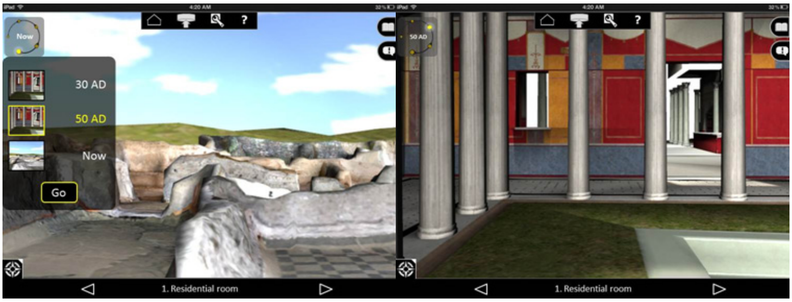

Fig. 3. Redesign of user interface complying with different target platforms; Restricting to low capability environment with only few interaction possibilities (here: tablet design, touch sensitive switching between roman periods); concentrating on affordance, mapping, visibility and consistencies of the user

Fig. 4. UI metaphors for smartphone including navigational (e.g. interactive map exposing POIs) and textual elements (linked metadata (right), “where-about” lower info bar)

In subsequent discussions we focus on a desktop based VR application provided by a simple web browser environment (see fig.5). Here, we have tried to introduce an expert mode that should be aligned to the mode for traditional virtual museum (VM) visitors, yet providing enhanced meta-information on certain assets. In both cases the design required the definition of a simple solution that would not disrupt the user by many explanations, trying to avoid confusion and loss of attention during exploration [3]. We considered two different modalities for interaction: the user could interact within a two-dimensional or three-dimensional space, thereby maintaining consistency to well-known interaction paradigms (e.g. Google Maps, Google StreetView[1]) (*affordance, consistency*). We opted for an expandable active mini-map as a metaphor for navigation support. The map exposes different POIs that represent different viewpoints on certain artifacts within the scene. Triggering one of them zooms the user inside the

[1] Location-based applications, using paradigms such as time-travel, transparency, or advanced query possibilities (`maps.google.com`; `maps.google.com/intl/en/help/maps/streetview/`).

3D scene with adjusted and defined viewpoint (*mapping*). On the upper left corner a small picture depicts the current scene position and orientation displaying the historical period. A floating element suggests a switch between two eras alternatively (*constraint*). Further information is provided by a universal symbolic “i”. Activating this mode triggers a collapsible, half-transparent tab container that encapsulates all the POI/object specific metadata, extracted dynamically from a monolithic XML scheme.

Fig. 5. UI elements of redesigned “Behind Livia's Villa” in desktop mode; Left: Top view of the actual remains; Right: Real-time navigation and transition to the 2nd century reconstructed roman villa supported by help and orientation icons

It is possible to interact with objects directly inside the 3D scene. X3DOM is natively capable to catch click events on 3D objects. However, “walk-through” mode coupled to an interaction on objects querying some information is still not fully developed which leads to a confusion of the user as “on-click” he also moves forward. One workaround was to create transparent objects on the scene that react visually to “mouse-over” and “mouse-out” events, altering their opacity and providing visual feedback. Another problem is related to the persistence of the objects within the scene, when switching between historical periods, a problem that requires further actions on the X3Dom developments. The navigation is currently performed only by mouse interaction and is free in the initial top view. Inside the villa instead, the camera is binded to the y axis of each viewpoint. In this way the user does not take the risk to lose himself inside the virtual environment. A version of the application with free walk mode navigation is currently under development.

2.3 Code Base and Used Technologies

To comply with the portability (and thus reusability) constraints of the new application several solutions require to be HTML5 conform despite limited interaction possibilities. The code base has to be migrated or re-implemented using modern Web technologies like, CSS3, Ajax /JavaScript (JS)/Python, and WebGL. Interactions might be restricted to mouse or mouse generic touch interactions providing limited system interaction and navigation. 3D data should be available plugin-free and being declarative in order to support also web developers without a major CG background.

Therefore, we decided to rely several developments on the open source, high-level WebGL framework X3Dom [4]. It is a JavaScript-based framework for declarative

3D graphics in HTML5, that is based on the open ISO standard X3D [5] describing the scene and runtime behavior. The library provides several different types of nodes, each with its own function. E.g. it provides mechanism to dynamically load external .x3d objects resp. scenes stored as reference within inline nodes [6]. A dedicated viewpoint node allows the developer to define any point of interest and related camera orientation being exposed to the user through simple markup language constructs and thus allowing to implement a guided exploration of the scene. It is easy to customize as the declarative approach provides an XML scheme wrapping 3D assets, thus capable of even providing an automatic way to deliver coordinates and orientation.

In order to allow the user to switch between historical reconstructions (between two 3D scenes), the application has been realized using a preload option for several objects at the beginning of the visit. The management of transparency during era transition uses an ad-hoc reusable JavaScript function chain. The objects are conceptually organized in two arrays of ids. This approach is quite flexible and could be applied using different parameters, but could be also a bottleneck. Here, X3DOM is capable to use also binary and compressed nodes, to increase the overall system performance.

3 Overall Workflow – Production Process

In order to establish a reproducible production process, a flexible and low costs tool chain based on open source software instruments, has been established (see fig.6).

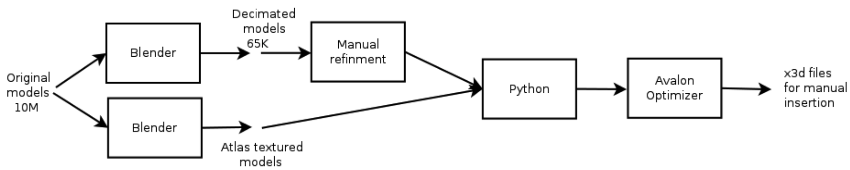

Fig. 6. Overall workflow for the migration of macro to micro 3D worlds; in the end of the process the user is able to embed the assets directly into HTML5

At the beginning of the process we need to convert former assets into the appropriate format. Here, we were reusing 3D Studio Max assets of the former application with typically ~10 million polygons. The complex geometry in some cases was obtained from laser scanning acquisition or using high resolution textures.

Using Blender as open source tool the model has been automatically reduced to ~1 million polygon which is still too large. The mesh structure is still not optimized for web-based rendering (e.g., indexed rendering using WebGL requires having geometry chunks of at most 2^{16} vertices). Given the aim of the application a further reduction has been performed using the Blender bullet physics engine to simulate the fall of a detailed mesh, with velvet-fabric parameters, on the model. Coupling this idea with the use of the shrinkwrap modifier, to force an object being aligned to another one in a parametric way we obtained a new model made of just 65K polygons, without losing too many particularities or introducing unwanted artifacts. At the end of this process a quick manual refinement has been performed to correct several remaining minor issues. The architecture of the original application contained many objects, each one with its own texture. Thus, we faced a general lack of homogeneity in the ratio between the size of the textures and the objects visual relevance. To proceed with the optimization we established a per-room set of texture-atlas, redistributing the pixel ratio. It allowed us to enhance the correct perception of each room.

Together with the XML correction scheme, the system performs image conversion from different formats automatically and eventually creates different sets of textures in different resolutions (according to the specifications within the correction scheme). This was particularly useful to set up different versions of the same application, i.e. the deployment on different devices. This part has been realized using Python as scripting language in association with "imagemagick"[2] for image processing. After visual appearance optimization, the built-in exporter of Blender was used to get X3D.

The final step in this process pipeline deals with the data transcoding to X3Dom. Here we use the *aopt tool* from InstantReality [7] (see [8] for details). The process of integration of the obtained models into the web application is performed manually.

4 Evaluation

We conducted an evaluation of the new Villa of Livia in order to elevate the degree of user experience with the new redesign. This evaluation has been conducted during the Archeovirtual 2012[3] which offers showcases of various VMs from all over the world and should complement first endeavors in [9]. We have been evaluating the final 3D online application, with full scientific metadata access about the Livia's Villa at Rome (Prima Porta). The methodology follows the general evaluation strategy exposed in [10]. Here, we concentrated on selected (non-)instrumental qualities of User Experience aspects according to the model of [11]. We therefore investigated *Utility*, i.e. to examine, if the VM supports all required and desired functions, *Learnability*, in order to derive conclusions on ensuring easy learnability of the interface (quantitative parameter is *Perspicuity*), *Efficiency*, as the subjective perceived efficiency of user interactions based on the users' satisfaction, and last but not least, *Stimulation*, elevating to which extend excitement and joy captivate the user.

Several quantitative results were mapped onto a scale between -3 and 3. The neutral interval contains values between -0.8 and 0.8. Extreme values at the end of the scale either smaller than -2 or bigger than 2 are rated as "very poor" or "very good".

Following the evaluation in [10] we received 23 written survey and 10 interviews with following results: *Learnability* of this VM is less good as many participants found it either challenging to use the VM in the beginning or hard to use for the whole duration of interaction even though the perspicuity reached a good level. It is decreased by too small visual navigation elements and a no obvious function for changing the perspective inside a room. Both are hardly noticed by the users.

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2 `www.imagemagick.org/script/index.php` (aof February 2013).

3 Archeovirtual – Embedded within Mediterranean Expo for Archaeological Tourism, in 2012: 15th-18th of November, Paestum, Italy, www.archeovirtual.it (aof February 2013).

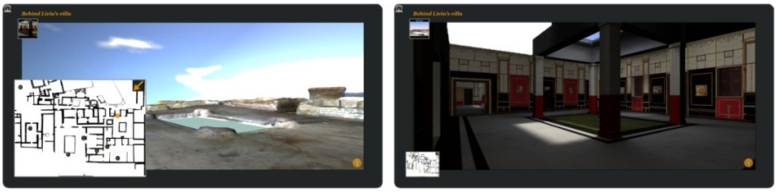
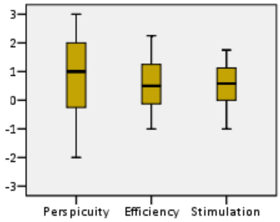


Fig. 7. Behind Livia's Villa - Left: Present state with enlarged map, Right: Past state with downsized map

Table 1. Livia's Villa - Scales

		Perspicuity	*Efficiency*	*Stimulation*
N	Valid	21	21	20
	Missing	2	2	3
Median		1.0000	.5000	.5833
Std. Deviation		1.46517	1.18838	.71812
Rating		Good	Neutral	Neutral



The participants were satisfied with the *efficiency* of the VM. Yet, remarkable that the result on the scale is less well manifested than in other obtained results. Only an average result was achieved for *stimulation* supported by an enjoyable interaction that allows inspecting the evolution over time of the villa. Yet, it is lowered by the less perceived novelty in interaction or content and some annoying navigational problems. For *utility* within the written survey 70% found all available functions useful and interesting. Within the interviews one participant said that it needs to be a further division between general and specific information. Another two participants stated that the information is hard to find. Suggestions for enhancements: General information about the archaeological site, audio explanations and move inside the environment on a guided path.

5 Discussion

It becomes clear that this first version of the redesigned Villa di Livia cannot cope with the narration and storytelling framework we were establishing in the original version. This is due to the fact that it is a very early prototype using a very new prototypical framework for declarative content on the web. Thus, during the Archeovirtual 2012 it became clear that especially for *Desktop VR applications,* the narrative thread, which lied beyond the content architecture of some VMs, was extremely appreciated by users, while metadata and content modeling systems (like ours) were not. The evaluation revealed in fact problems of affordance on certain information, visibility issues in GUI design. Especially Livia's Villa content was hard to find, also due to the reduced dimensions of icons and maps, as well as the absence of aesthetical features. Accordingly, the general experience of it was badly affected since users felt frustrated with the limited interaction possibilities and got quickly bored. Especially functionalities addressing the different scopes of users and the envisioned aims need to be improved. Moreover, the choice of language, the way of presenting data and the level of system complexity (multiple unclear functions) inevitably influenced them.

Nevertheless, the presented workflow (though not purely automatic) offers an alternative and systematic methodology to easily adopt this kind of migration. The process actually is not fully automated, but the elaborated methodology provides a faster way to implement migrations from macro to micro VR worlds. It is especially meant for modellers and entry-level web developers. Eventually, there are no evident constraints from the original data-assets point of view, and our case study already depicted a quite complex situation. The objects generated could be quickly inserted in a web page. Using our final application scaffold as template allows even advanced functionalities, such time-shift capabilities, and viewpoints navigation to be used by web developers, as they are easily accessible through provided JS modules.

6 Conclusion

The “Behind Livia's Villa” application at the current development stage, allows the user to explore a low cost VR environment in which both the actual and the reconstructed models could be visited and switched between present and past eras. The user is guided by a collapsible map which contains a list/map of point of interests. An expert mode might allow the retrieval of metadata information for certain objects.

During the start of this migration, we performed several tests. The first attempt to convert the model and build the first version of the application, took two months including an initial learning phase. For the second release, the whole process took only few weeks. Other functionalities originally derived from this experience are currently under development, such as the creation of semi-automated processes that might be exposed to the community by web services. Specific “application templates” might support web developers and users alike to embed converted assets in on-line virtual museums being deployable on different devices. The creation of online services for model conversion, optimization and automatic generation of basic web 3d pages as resented within the Common Implementation Framework [12] has been built up as early prototype, to which this work contributed by providing best practices.

We hope that an improved process and an automatic tool chain can be finally adopted (not exclusively) for other on line virtual museums. Any application domain relying on 3D models (e.g. automotive, aerospace, AEC) might benefit from this experience as well as the envisaged next generation version of automatic transcoding services filling different application templates.

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