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KEEP THE REVOLUTION GOING >>>

Proceedings of the 43rd Annual Conference on Computer Applications and Quantitative Methods In Archaeology

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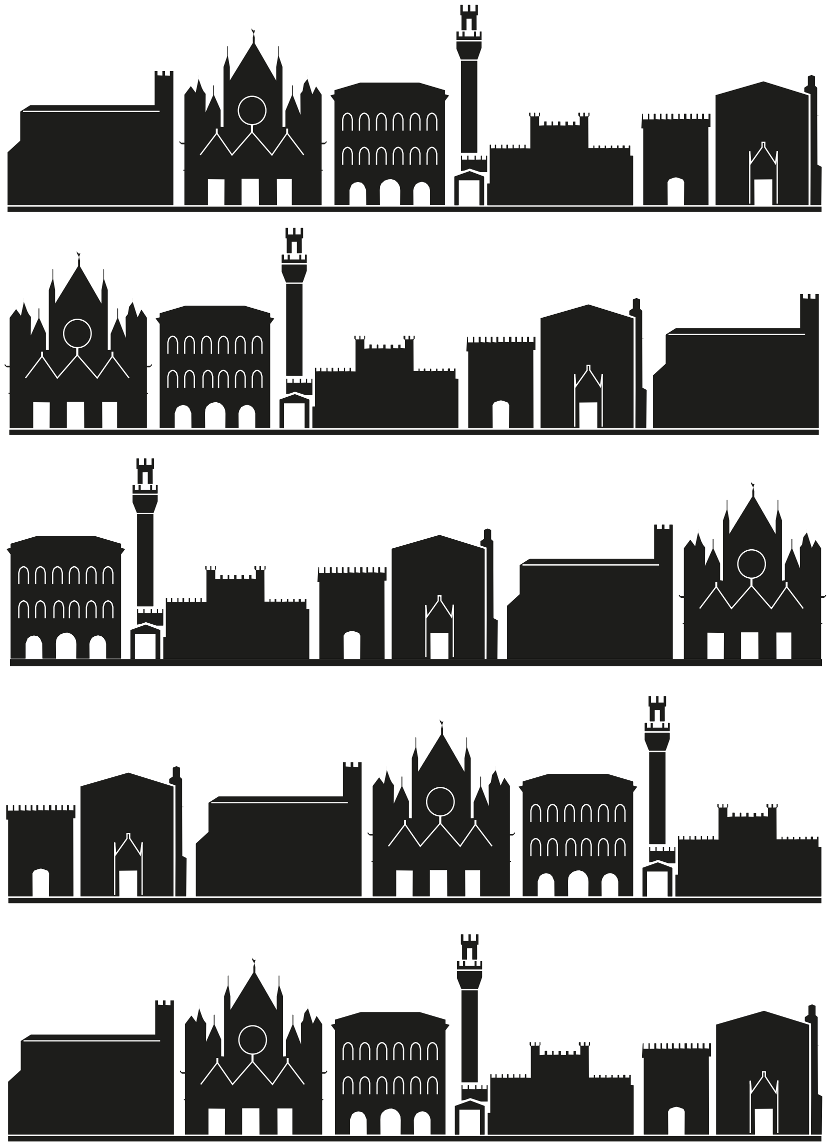

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Computer Applications & Quantitative Methods in Archaeology

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ARIADNE Visual Media Service: Easy Web Publishing of Advanced Visual Media

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Abstract: This paper describes the design and development of a service for 'visual media' files. In the first phase of the ARIADNE project we reviewed the status of visual media resources (2D, RTI, 3D) in the archaeology domain, but there was possibility of publishing visual media resources on the web. To fill this gap we have designed a service aimed at providing easy and unsupervised publication on the web. The service provides a very easy interface (a simple web form) that allows the user to upload the visual media file; the data is then transformed in a web-compliant format, supporting multi-resolution encoding, compression, and progressive transmission. At the end of the data-processing phase the user receives an email containing the URL of the published asset (or, in case he/she wants to store the file locally, a .zip file). Specific browsers for the three types of media have also been developed, based on 3DHOP technology.

Keywords: Visual media, Web publishing and visualization, HTML, WebGL, 3D models

Introduction

One of the major goals of the EC INFRA 'ARIADNE' project[1] is to design, implement, and deliver a number of digital services for the archaeological community, which will be integrated in the ARIADNE web portal. A sub-focus in the ARIADNE project is to provide support for the management of 'visual media'. The concept of visual media can be broadly described as any type of visual representation of archaeological findings or assets, i.e. conventional 2D images (including high-resolution and high-dynamic range, HDR), special images (such as relightable images or panoramic images), 3D models, and videos. The term 'visual data', therefore, encompasses any media that helps archaeologists to represent, document, and communicate the artworks under investigation or study in a better way.

Visual media are not new instruments of work for archaeologists—drawings and images have been used for centuries—and they are part of common working practice. The new issue is how to make proficient use of those media when different digital incarnations are made available with the progress of ICT technology. A number of new, low-cost and commodity opportunities for the easy acquisition of digital visual representations are now available and largely used in the field. Specific to the archaeological domain is the very wide extent of archaeological data, which include representations of small finds (a few centimetres in size) and of an entire archaeological site (hundreds of metres). What is still cumbersome is how to open up those data to the external world (both experts and lay people), and how to publish them in a simple and efficient way. An ARIADNE workshop held in Pisa in October 2013 demonstrated that knowledge and experience with media production technologies was fairly good (with many ARIADNE partners already using 3D scanning and enhanced digital documentation); on the other hand, a critical issue highlighted at the workshop was the lack of tools and experiences for sharing and publishing these visual media on the web, either as independent resources or as part of structured archives (Scopigno *et al.* 2013). Publishing visual media on the web is not easy when someone has rich data and does not want to downgrade them to a size/resolution of insufficient quality. Current sampling technologies allow the production of very complex and high-resolution models (up to Giga-pixels or Giga-vertices). These models allow the faithful representation of even small parts or subtle details of the object of interest,

[1] EC INFRA 'ARIADNE: Advanced Research Infrastructure for Archaeological Dataset Networking in Europe' project, 7th FW; www.ariadne-infrastructure.eu/

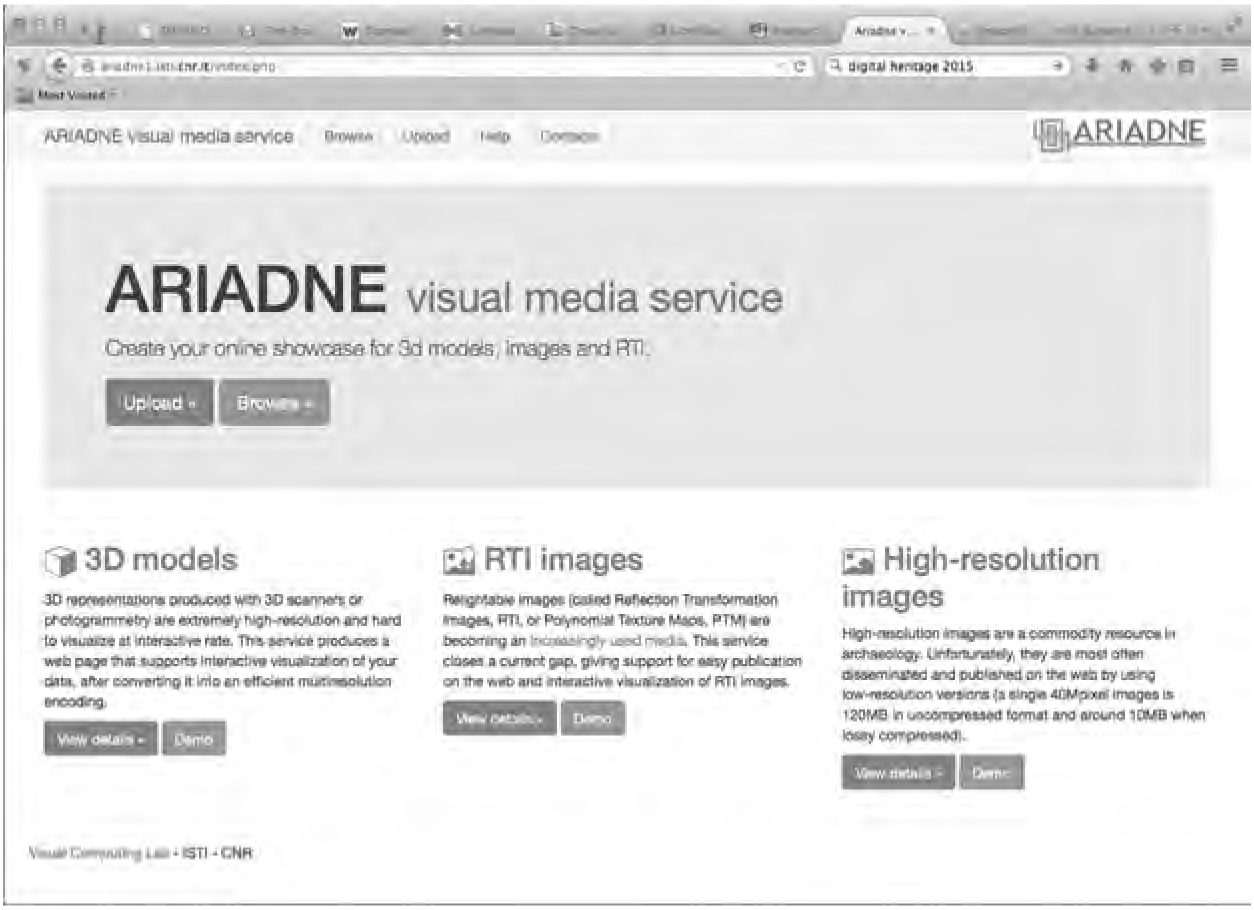

Fig. 1. The ARIADNE Visual Media Service homepage (http://visual.ariadne-infrastructure.eu/).

and the extensive use of sub-sampling or compression (in the case of images) or geometry simplification (in the case of 3D models) is usually not adequate for CH applications. Publishing data on the web invites the question of which format should be used, possibly producing acceptable transmission times, and what type of visualization features should be provided. A very successful web approach has been the one taken by YouTube, providing a simple interface for video data upload and making available to the user all the processing needed to convert and post the data on the web. Sketchfab (https://sketchfab.com/) has taken a similar approach but only for 3D models. The goal at the design stage (2014) of the Ariadne infrastructure was to provide a service similar to the one provided by YouTube (easy publication and presentation on the web of complex media assets), but focusing on media types which did not have an available service: high-resolution 2D images, RTI (Reflection Transformation Images, i.e. dynamically relightable images), and high-resolution 3D models.

The ARIADNE Visual Media Service approach is to build an automatic service able to transform any media file uploaded by ARIADNE partners into a format that will allow easy and efficient access and remote visualization on the web. The service is based on a simple web interface and currently supports the three types of visual media defined above.

These types of media are still not very common on the web, because their visualization may require the download of an entire file (long transmission times discourage users), and possibly select/install dedicated software (viewers). Moreover, the owner of high-quality data may prefer not to allow visitors freely to download them, in order to protect the ownership of the data.

Conversely, our approach is to design a service that allows inexperienced users to upload any visual media file of interest and (after some processing) receive the URL where the specific data has been stored and can be accessed for efficient visualization. Efficiency of visual presentation is gained by the design of proper GUI (viewers) and also by endorsing efficient data representation schemes. With this setup, even inexperienced users can easily create an efficient webpage to display complex 2D or 3D content. Alternatively, for more experienced users, these basic web pages may be the starting point for the development of more complex visualization, or for the integration of this visualization in existing websites, taking advantage of the features of the 3DHOP platform (www.3dhop.net). Finally, the data structures for remote visualization (multi-resolution for 3D models, image pyramids for images, and RTI web encoding) protect the original data, as the direct download of a multimedia file in single plain format is not straightforward.

We will describe in the next section the types of data that we currently manage in our server; the technical design and the algorithmic solution used are described in Section 4.

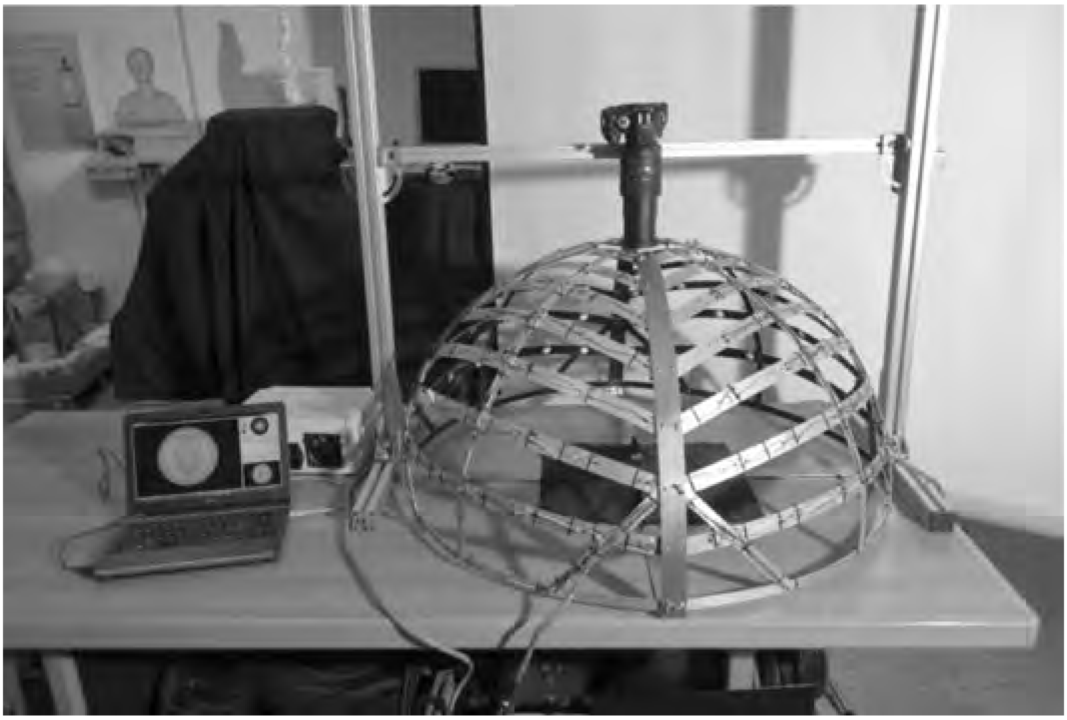

FIG. 2. THE RTI ACQUISITION DEVICE DEVELOPED BY CNR-ISTI.

1 Which type of visual media to support?

1.1 High-resolution Images

Images are the more common visual media, and they have been part of archaeological datasets from the very beginning, originally by means of an analogue, printed version and more recently by means of digital supports (either original digital images or scanned from old prints/slides). These data are what form most digital archives and collections.

While images are a medium that was fully integrated with the web and html from the very beginning, there are a few aspects that lack a standard solution for archival and visualization purposes. Most of the images produced nowadays are high-resolution. High-resolution images are now a commodity resource, with the remarkable evolution of digital photography (as one example, a recent off-the-shelf Smartphone now has a 41 MPix camera) and the wide availability of tools that allow aligning and stitching image patchworks, enabling users to reach huge image resolutions.

When high- or huge-resolution images are available, visualization on the web can be difficult, due to the amount of data that have to be transmitted before the web browser is able to present something visually. This is because standard web browsers must receive the entire file before visualizing it. Another important and critical issue is the need to protect the data.

A possible solution to avoid the problem of waiting for the entire image transmission before being able to provide a visual feedback is the approach adopted by map viewers. For example, Google Maps (http://maps.google.com) handles its huge maps by encoding them in a sequence of decreasing resolutions. Each image of this sequence is split into square tiles of fixed size (usually 256 pixels per side) to allow for the data management at high granularity. The client in the browser 'composes' on the fly the portion of the image selected by the user using the most suitable tiles, according to the size of the portion being viewed. This approach is based on simple multi-resolution encoding that has been demonstrated to be very efficient for visualizing this type of data. A similar approach can be employed to visualize high-resolution images, based on tiling and hierarchical representation schemes.

1.2 Reflection transformation Images (RTI)

Relightable images (usually called Reflection Transformation Images, RTI) are becoming an increasingly used technology to acquire detailed and interactive documentation on quasi-planar objects (Malzbender *et al*. 2001; Palma *et al*. 2010). This is particularly useful for objects characterized by complex light reflection attributes. The advantage of this representation is the possibility of changing the light direction over the image in real time (i.e. at visualization time), and the availability of using enhanced visualization modes in order to examine fine details of the object's surface.

RTI images have been successfully applied in a number of applications, such as coin collections, cuneiform tablets, inscriptions, carvings, bas-reliefs, paintings, and jewellery. Moreover, RTI images offer the possibility of obtained a digital representation of artworks made of certain materials, which cannot be easily obtained through the usual 3D scanning technologies (highly reflective materials, semi-transparent objects, etc.).

Typically, this type of image is generated from a set of photographs taken with a fixed camera (positioned on a tripod or an acquisition gantry) under varying lighting conditions (see Fig. 2 where an acquisition gantry is holding the camera and providing a set of LED lights in the inside surface of a wire dome). RTI encodes the acquired data in a compact way, using view-dependent per-pixel reflectance functions, which allows the generation of a relighted image using any light direction in the upper hemisphere around the object location. Per-pixel reflectance functions vary between different RTI types. For PTM (Polynomial Texture Maps) the function is a biquadratic polynomial (6 coefficients are required to define it). For more advanced RTI, hemi-spherical harmonics are usually employed (9 coefficients are used). In the latter type of RTI, the image is subdivided into nine layers, one layer for each HSH coefficient, where the i-th layer contains the i-th coefficient of the three RGB colour channels. Then for each layer a multi-resolution quad-tree is created and a tile for each node of the tree is saved in JPG format. To visualize a specific pixel, the nine JPG images that contain its HSH coefficients must be loaded.

As regards the acquisition of this type of image, CNR-ISTI has built an automatic acquisition device (a dome) that allows tens of objects to be acquired in a single day, and produce the RTI images in an automatic way (see Fig. 2). The dome is composed of four aluminium shells that can be easily assembled and disassembled to simplify transportation. It has 116 cold white LEDs (6 Watt, 750 lumen) used to change the lighting conditions and an overhead high-resolution reflex camera (Nikon D5200, 24Mpixel). The dome is computer-controlled to enable a completely automatic acquisition by synchronizing the switching on of each LED with the camera shutter.

The interactive visualization of RTI images can be supported both locally, using freely available tools (e.g. see the desktop RTI Viewer distributed by CHI at http://culturalheritageimaging.org/What_We_Offer/Downloads/View/), and on the web, using a WebGL component (Palma *et al*. 2012). As previously stated for high-resolution images, because RTI images are often at large resolution, this visualization component has to adopt a similar tile-based hierarchical approach.

1.3 3D models

3D representations have also become quite common in archaeology. Two classes of models are produced:

- *Sampled models*, usually produced with active 3D scanning (laser-based systems or systems using structured light) or by adopting recent photogrammetry approaches (production of 3D models from sets of 2D images);
- *Modelled representations* produced using the user-driven modelling systems designed for 3D modelling and computer animation applications (Blender, Maya, etc.).

In the context of professional archaeological applications, sampled models are more common, since those models offer much more control on the *accuracy* of the representation than hand-modelled representations. The latter, conversely, are more common in the applications oriented towards the larger public (e.g. to produce videos or virtual reconstructions).

Presentation on the web of complex 3D models is still a very difficult task to achieve; here with the term ‘complex’ we mean models composed of millions of samples, like those usually obtained by 3D scanning. This is mainly due to two reasons: it is hard to transmit/render such data interactively on commodity platforms; and publishing 3D material on the web is still a task that few developers can undertake. On the other hand, 3D models should not be confined to the single archaeologist’s archive and should be shared with the community, to increase knowledge and stimulate further study.

Publication of 3D models on the web has already been accomplished in several projects; we cite here the work done in 3DCOFORM by Fraunhofer IGD (Limper *et al*. 2013; 2014), who has implemented a web-based archive of 3D-scanned models based on WebGL technology (Khronos Group 2009). But this approach does not yet include an automatic publishing service.

There is a pressing need for platforms supporting easy and free publication of 3D models on the web. SketchFab (https://sketchfab.com/), a recent commercial solution, appeared while we were designing and implementing our system. SketchFab is an excellent system, supporting automatic publishing and a simple and easy to use interface, but focusing on professional use in the CH domain, it lacks flexibility (it only supports 3D models, only provides one layout, users cannot change anything) and does not provide a support for multi-resolution encoding and progressive transmission (thus making the transmission and visualization of very large models very difficult). SketchFab, therefore, requires the 3D model to be fully downloaded on the remote client before it can visualize it.

2 Visual Media Service design

The ARIADNE Media Service aims to provide support for the easy publication and presentation on the web of complex visual media assets. The idea is to build an automatic service able to transform any media file uploaded by an ARIADNE or any external user into a format that will allow easy and efficient access and remote visualization on the web. The goal is to provide a service where the user does not need any knowledge of the issues related to visual media publication on the web, or to the handling of different file types and compression/multi-resolution technologies. Interaction with the service must be very simple and should provide easy-to-use results.

The service is based on a simple web interface and currently supports the three types of visual media mentioned above: high-resolution images, RTI images, and high-resolution 3D models. These types of media are still not very easily found on the web because their visualization may need to download heavy files and possibly select/install dedicated software.

Our approach with the ARIADNE Visual Media Service is to provide a platform that makes it very simple to publish and share those media; at the same time, we also offer some (limited) protection over the data, since we do not send the remote browser the entire file in plain format. The adoption of a multi-resolution and compressed encoding makes stealing the file slightly more complicated than the usual save-as option provided by clicking on the right button in a standard web context.

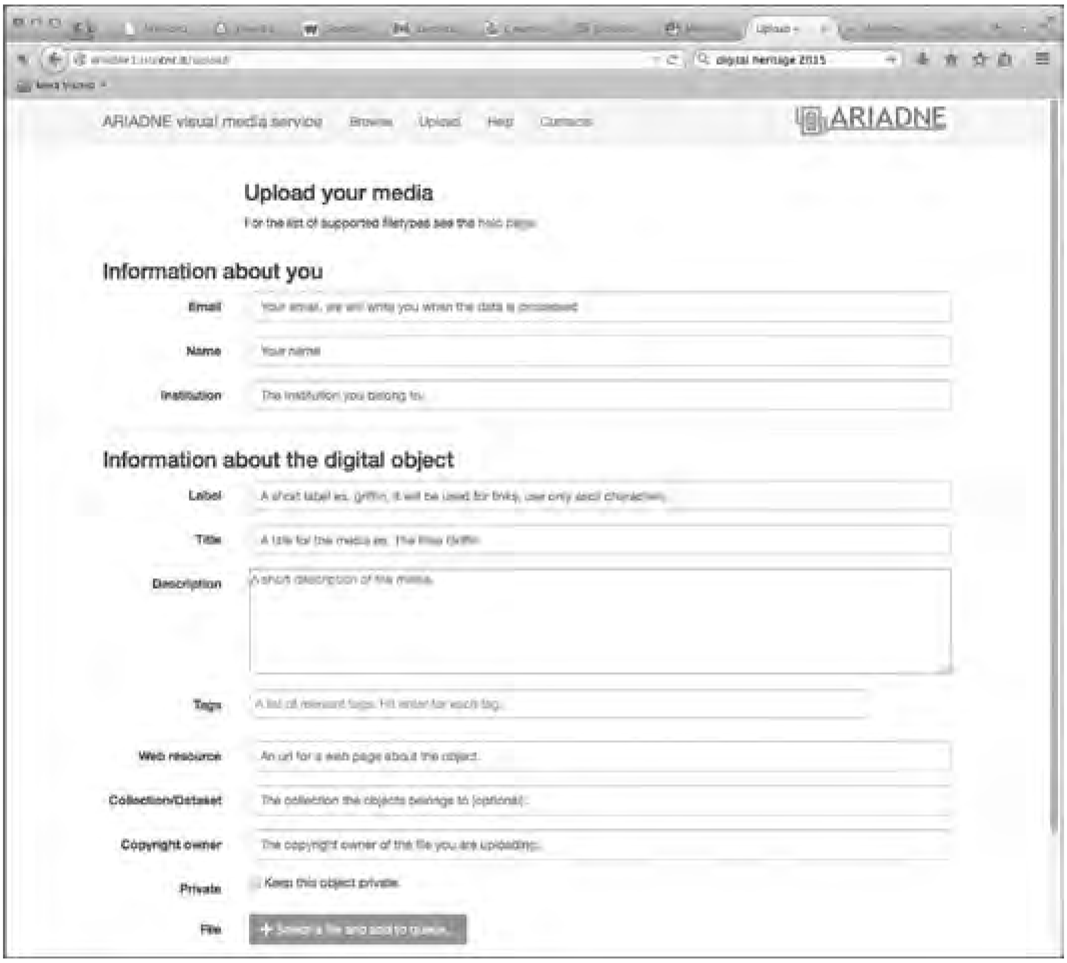

FIG. 3. THE ARIADNE VISUAL MEDIA SERVICE UPLOAD WEB PAGE (HTTP://VISUAL.ARIADNE-INFRASTRUCTURE.EU/UPLOAD).

We will first describe how to use the service, then give some details on the technology and algorithms used.

After accessing the service, the user finds a simple web form (http://visual.ariadne-infrastructure.eu/upload) that allows him/her to upload his/her own data (3D model, hi-res image, or RTI) and provide some basic information about the file and the represented artwork. The service processes the input data automatically and creates an online page. At the end of the processing and format conversion phase, the user receives an email containing a link to the visualization page (hosted on the Ariadne web-service and open to any external user) and to an admin page, where the associated data can be modified. It is also possible to download the created page (html code + processed 3D Model or 2D image) in order to store and integrate the content on a user's local server or archive. The user may also keep the image private, in which case it will be accessible only if the user provides a direct link.

High-resolution images are transformed into a multi-resolution format, supporting progressive streaming. The service transforms each image in a web-compliant format: similar to Google maps, the high-resolution image will be regularly divided into tiles and a hierarchy of images at different resolutions will be produced from these tiles; a rendering webpage is then created where it will be possible to navigate the image in a WebGL frame (see an example of the *image browser* in Fig. 4).

RTI images are managed in a similar way to hi-res images, even if the encoding for web streaming is a bit more complex, and WebGL rendering also takes care of the input and calculation of the variable-lighting (see an example of the RTI image browser in Fig. 5). The way we process and encode RTI images to provide web-based visualization is described in detail in Palma *et al.* (2012).

In the case of *3D models*, the geometry is processed, converting the 3D model into a multi-resolution format. We adopt the *Nexus* format, http://vcg.isti.cnr.it/nexus (Ponchio *et al.* 2015). This multi-resolution structure is streaming-friendly, and is used to create a visualization web page using the *3DHOP* web presentation tool, based on WebGL (Khronos 2009). An example of the browser for 3D models is presented in Fig. 6.

3DHOP (*3D Heritage On-Line Presenter*, www.3dhop.net) is a set of templates and components for the development of a Virtual Museum or effective presentations on the Web of digital 3D assets (Potenziani *et al.* 2015). Its main features include: easy presentation of different types of multimedia

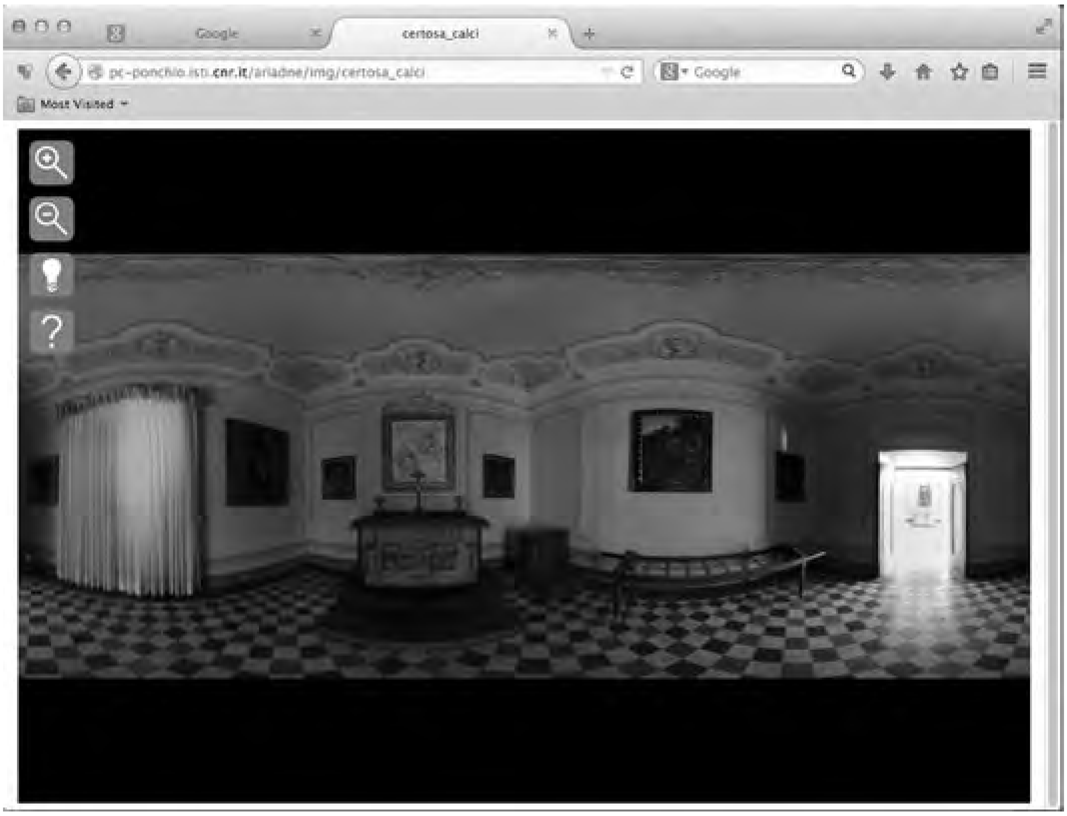

FIG. 4. A VISUALIZATION PAGE AUTOMATICALLY GENERATED BY THE VISUAL MEDIA SERVICE, FOR BROWSING A 2D HIGH-RESOLUTION IMAGE.

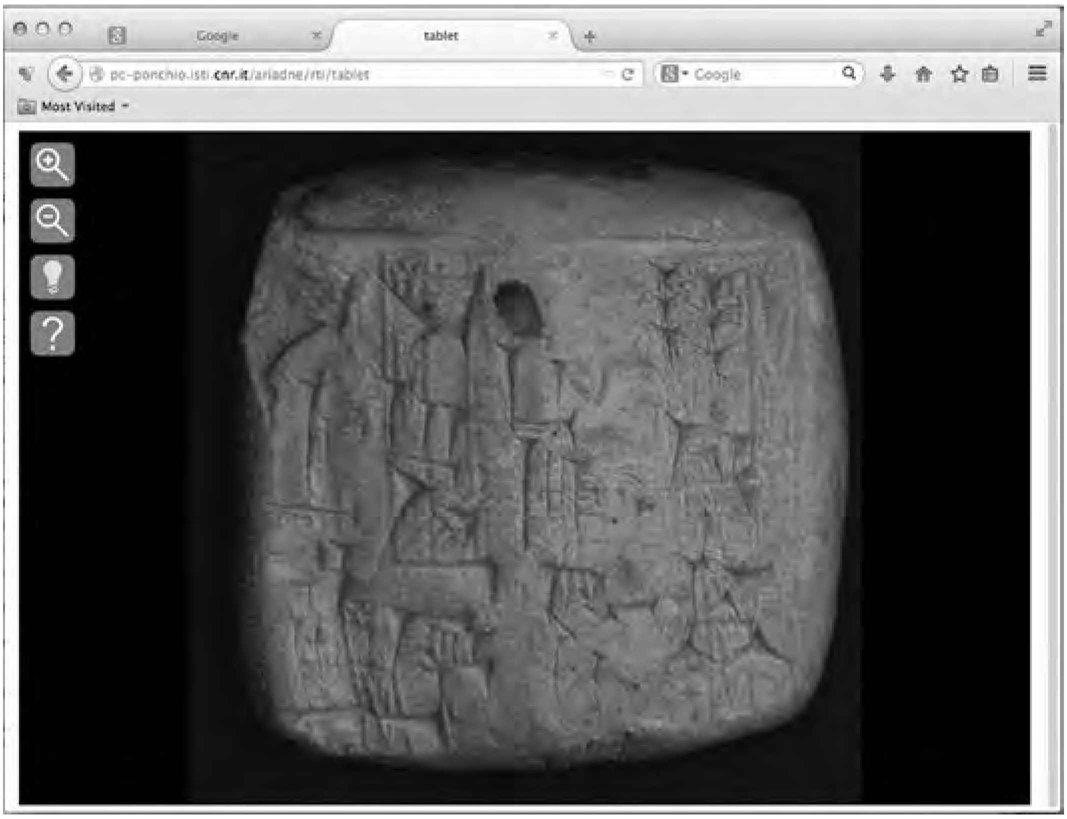

FIG. 5. THE VISUALIZATION PAGE AUTOMATICALLY GENERATED BY THE VISUAL MEDIA SERVICE FOR BROWSING AN RTI IMAGE.

FIG. 6. THE VISUALIZATION PAGE AUTOMATICALLY GENERATED BY THE VISUAL MEDIA SERVICE FOR BROWSING A 3D MODEL.

content, sophisticated customization capabilities for the Web presentation, seamless integration with the rest of the Web page allowing integration of different multimedia data. 3DHOP is designed to be easy to learn and easy to use. Its modular structure allows users with different levels of expertise to use it effectively, even when the user has very little or no knowledge of Computer Graphics and Web Programming. The framework also provides terrain visualization, different navigation/ interaction modes, and picking and camera controls. Many of these components are designed to answer the needs that are often encountered in the development of Cultural Heritage applications (for example, it is particularly easy to build a web page showing a collection of objects).

The visualization of high-resolution 3D models is based on a WebGL and Javascript implementation of the *Nexus* multi-resolution framework: the model to be visualized is pre-processed and converted into a collection of small fragments of a few thousand triangles, at different resolutions. These fragments can be assembled together to approximate the original surface. Depending on the perspective, an optimal set of fragments is selected to minimize the rendering error, given an ideal number of triangles to be rendered for each frame. Thus, only the fragments effectively viewed by the users are required to be sent through the web for each frame.

This approach is optimal for a number of reasons:

- It minimizes the CPU usage, as the assembling algorithm is quite simple. This is especially important since the client side is running in Javascript.

- Using a collection of fragments naturally supports an out-of-core approach, which allows us to start rendering as soon as data is incoming, and tile-based data processing to minimize the effects of network latency.

- It is possible to optimize the rendering quality for each given bandwidth value.

- Automatic pre-fetching is implemented to hide latency as much as possible.

- There is no need for special server support: data transmission just requires the basic http protocol. In other words the browser itself handles both the data streaming and rendering tasks.

With this setup, inexperienced users can easily create an efficient webpage to display complex 2D or 3D content. Alternatively, for more experienced users, these basic web pages may be the starting point for the development of a more complex visualization layout, or for the integration of this visualization in existing websites, taking advantage of the features of the 3DHOP platform (www.3dhop.net). Finally,

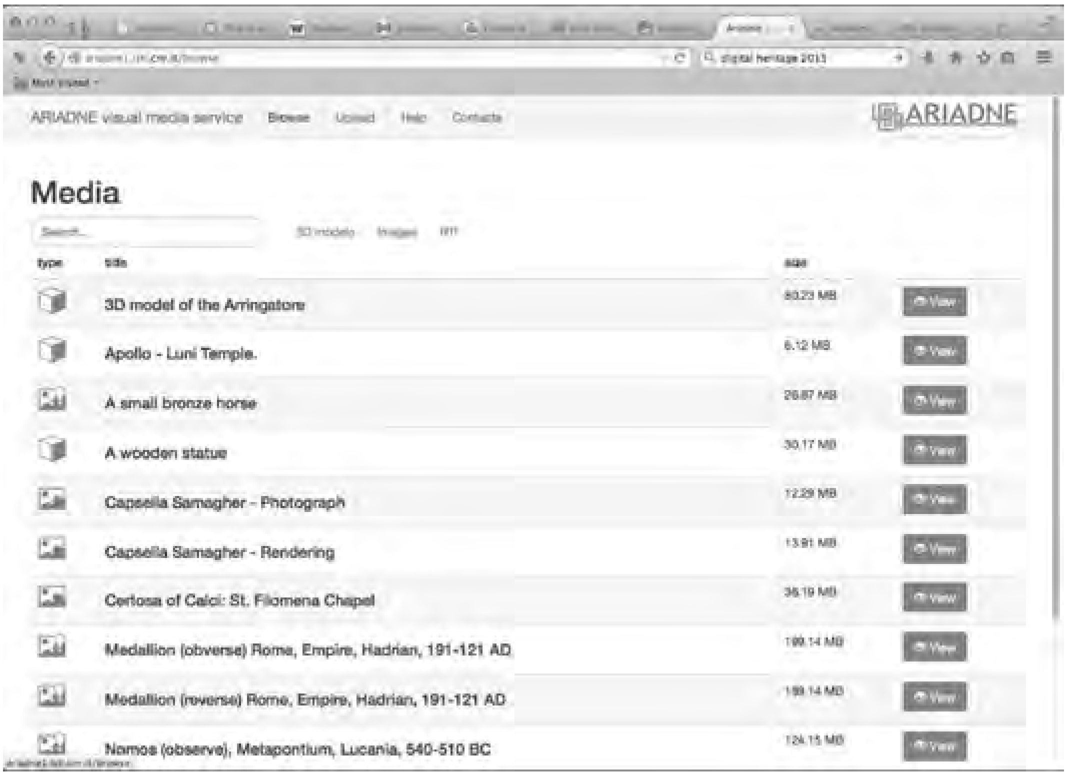

Fig. 7. The ARIADNE Visual Media Service browsing web page, that provides access and a search of the uploaded Visual Media data (http://visual.ariadne-infrastructure.eu/browse).

the data structures for remote visualization (multi-resolution for 3D models, image pyramids for images, and RTI web encoding) protect the original data, since direct download of the multimedia encoding in a single plain file is not possible.

In Section 3.3 we mentioned SketchFab as the current main competitor for our Visual Media Service. We have to underline that SketchFab focuses only on 3D models, while the Visual Media Service also supports other media types. To cross-compare the efficiency in data transmission and visualization, we did a test comparing the speed of SketchFab and other web-based browsers with the performances of the 3DHOP platform; this is reported in Potenziani *et al*. (2015). The results obtained on large models are largely in favour of our multi-resolution-enabled approach.

3 Conclusions

The Ariadne Media Service represents a first step toward a full integration of visual media in the context of archaeological datasets. Initial testing started on selected datasets provided by ADS, Discovery Programme, and other partners of the ARIADNE project. The results of a first preliminary user evaluation have been quite positive so far. A more detailed and structured user evaluation will be made in the fourth and final year of the ARIADNE project and results will be published soon.

Concerning future extensions, we are planning to upgrade the current version with a new one supporting:

- Increased flexibility: the uploading form will allow the selection either of a default browser layout or the specification (by means of simple check boxes) of the browser features. It will be possible to customize the browser layout and features, following the flexible tools provided by the underlining 3DHOP platform.

- The management of other media, such as High Dynamic Range images (HDR). We will allow the direct publication of the original HDR data and the automatic conversion on the fly to LDR format (driving the HDR to LDR to fulfil an optimal conversion focusing on a specific image area selected by the user).

Acknowledgements

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Bibliography

Khronos Group, Webgl - OpenGL es 2.0 for the web. 2009, http://www.khronos.org/webgl/

Limper, M., Wagner, S., Stein, C., Jung, Y., Stork, A. 2013. Fast delivery of 3d web content: A case study. In *Proceedings of the 18th International Conference on 3D Web Technology. Web3D '13*: 11–7. New York, ACM.

Limper, M., Thoener, M., Behr, J., Fellner, D. W. 2014. SRC - a streamable format for generalized web-based 3 data transmission. In N. F. Polys, A. Chesnais, E. Gobbetti, J. Doellner (eds.), *The 19th International Conference on Web3D Technology, Web3D '14*, *Vancouver, Canada, 8-10 august 2014*: 35-43. New York, ACM.

Malzbender, T., Gelb, D., Wolters, H. 2001. Polynomial texture maps. In *Proceedings of the 28th annual conference on Computer graphics and interactive techniques (SIGGRAPH '01)*: 519-28. New York, ACM.

Palma, G., Corsini, M., Cignoni, P., Scopigno, R., Mudge, M. 2010. Dynamic Shading Enhancement for Reflectance Transformation Imaging. In: *ACM Journal of Computing and Cultural Heritage*, 3, 2, n. 6. ACM.

Palma, G., Siotto, E., Proesman, M., Baldassarri, M., Baracchini, C., Batino, S., Scopigno, R. 2012 Telling The Story Of Ancient Coins By Means Of Interactive RTI Images Visualization. In *CAA 2012 Proceedings of the 40th Conference in Computer Application And Quantitative Methods in Archaeology*, Southampton, UK, 26-30 march 2012: 177-85.

Ponchio, F., Dellepiane, M. 2015. Fast decompression for web-based view-dependent 3D rendering". In *Proceedings of the 20th International Conference on 3D Web Technology*, Heraklion, Crete, Greece, 18-21 June 2015: 199-207. New York, ACM.

Potenziani, M., Callieri, M., Dellepiane, M., Corsini, M., Scopigno, R. 2015. 3DHOP: 3D Heritage Online Presenter. In *Computer & Graphics* 52: 129-41. Elsevier. doi: 10.1016/j.cag.2015.07.001

Scopigno, R., Dellepiane, M. 2013. Ariadne infrastructure for Multimedia data: Matching technologies and user needs. Report of the first meeting of the *ARIADNE SIG on 3D & Visualization,* 7-8 october 2013.