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Digital epigraphic heritage made simple: an Android app for exploring 3D Roman inscriptions

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Abstract

Spain keeps an exceptional epigraphic heritage, dated from the Roman civilization, that integrates thousands of Latin inscriptions nowadays disseminated along the Iberian peninsula. For many purposes such as education, innovation, cataloging, study and dissemination of this type of historical documentation, a clear demand of placing all this epigraphic heritage into modern 3D graphics, internet and mobile devices is increasing. We present the novel 'Epigraphia 3D' for handheld devices, a native Android app for exploring a total of 60 Roman inscriptions from the National Museum of Roman Art (Mérida, Badajoz). The work emphasizes the 3D nature feature for navigating through the inscriptions, by using Glob3 Mobile, an open source GIS framework for visualizing the 3D inscriptions. Besides, an error analysis of the simplified models is tackled.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Digitizing and Scanning

1. Introduction

Digital revolution is coming very quickly in the Humanities. Recent computing technologies, including hardware scanning [Rem11], software image processing [CCD*11] and new valuable applications [Hed97, EBC16, SLLC15, ZSV*15] have advanced very rapidly in the last decade. The impact for epigraphic surveys is tremendous, especially due to the potential, the low cost and the enhanced usability of many new tools. A previous project that shows 3D digital epigraphies from ancient civilizations on the web can be seen in [BBS12, BBS14]. Although obtaining 3D digital models is still an expensive and time-consuming process that demands a certain amount of technical knowledge, with the arrival of new techniques as image-based reconstruction, the process of completing a final 3D epigraphic inscription may involve taking 32 calibrated photographs and about 30 minutes for editing and processing [RSSCH14].

In the context of artwork conservation, 3D digital models are of great interest, where the aim is to preserve current conditions with the least possible intervention [SLLC15]. The rock deterioration (in the form of detachment, breakage, scaling etc.) of outdoor or indoor stone epigraphies may appear. However, the rate of deterioration of the monuments can be delayed through the detailed inspection by means of cataloging several samples of digital inscriptions. For instance, both digital and real models can be used to control the rock deterioration caused by chemical, biological and physical weathering. The precise digitized records are useful to identify and quantify the magnitude of the deterioration and possible damage. Mobile platforms as Android, the most common mobile OS, offer new opportunities to access our epigraphic heritage. This project presents Epigraphia 3D, an Android app that features a catalog of 3D modeled Roman inscriptions which aims to be a tool for their preservation and study.

Figure 1: *Spatial distribution of the 3D Roman inscriptions from Augusta Emerita (Mérida, Spain)*

2. Epigraphic heritage in Spain

The territory of Spain and Portugal was called Hispania by the ancient Romans. The Roman conquest of Hispania started during the Second Punic War (third century BC), being the Emperor Augustus

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who finished the conquest at the end of the first century BC. Augusta Emerita (actually Mérida) was the provincial capital of Lusitania, which comprises an important territory in the West of the Iberian peninsula. The National Museum of Roman Art, in Mérida, is the most important museum of Roman Archaeology in Spain. The epigraphic collection of this museum has hundreds of Roman inscriptions, some of them being very representative inscriptions of the epigraphic habit in Roman Spain.

The Epigraphia 3D project (`http://www.epigraphia3d.es`) main goal is the digitization and 3D modeling of one hundred Roman inscriptions. This collection is currently the largest in the world and provides access to these digital objects from any device connected to the WWW. The inscriptions are published on Sketchfab platform, which provides a free and fast 3D visualization, embedded in the webpage of the project.

The inscriptions have varied types: from burial inscriptions on limestone altars to marble pedestals of statues. The size of the inscriptions is also very varied: from small inscriptions made in bronze to a monumental lintel which measures 4 m. Besides the geometrical models, the pieces include their discovery location which shows they have been found near their original place of exhibition (see Figure 1).

3. The digitizing pipeline of the 3D Roman inscriptions

In the first step, the main issue is that the object must be located so that it can be photographed all around in 360 degrees. It is also important to have pure white light without falling directly upon the object to avoid shadows, reflections, etc. Bright spots produced by the surface of the object must be avoided. In the case of the Roman inscriptions, it does not suppose a critical problem as the main material is non reflective stone or bronze.

Agisoft PhotoScan was used for reconstructing and modeling these complex 3D models. PhotoScan creates semi-automatically 3D models by combining conventional photographs. In our experience, it is enough to take an average of 32 photographs per inscription, from different angles and preserving the camera-object distance.

The obtained triangle mesh covers most of the original surface of the object, which must be checked to avoid imperfections or holes. In addition, the foothold of the object needs to be covered with a patch mesh because this area could not be reconstructed. This stage is performed manually with the Blender software. The texture of the inscription obtained from the photographs is stored in JPEG format. The image processing consists in adjusting the picture parameters to improve its quality and realism on the model.

4. Development of a native Android app for exploring the 3D Roman inscriptions

The 'Epigraphia 3D' application is intended to show a classification of the pieces and render their 3D models, including related information and their geolocation. The data model is stored using SQLite technology, including the name of the inscription, origin place, current place, inventory number, transcription, references, resources and type. The 3D models files are referenced on this database by their name.

4.1. Compression of 3D models

The size of the 3D model files is also an important issue. Every inscription is composed of two components; the geometry (2 to 8 MB) and the textures, in JPEG format, with a resolution of 4096*x*4096 pixels (1 to 5 MB). All the epigraphies at full resolution need approximately 440 MB of data. This size is not allowed in the Google Play Store, because the maximum size allowed for any app is 100MB.

A server side storage (via private-server or Android Extension Files) of the models would force to download them at least the first time the user wants to see each epigraphy. This solution implies a delay before every new visualization, and a big amount of mobile data consumption. The chosen solution was a lossy compression of all meshes and textures and to embed them in the application package (`https://play.google.com/store/apps/details?id=es.epigraphia3d.android.activities`). Section 5 explains how this loss on precision was quantified and constrained.

4.2. Information of the Roman inscriptions

As can be seen in Figure 2(c), the inscription list are displayed in the main view of the application. This view allows the user to distinguish each monument depending on its category, for instance, funerary, relief or pedestal. Each category header has a specific underline color which is meaningful in the general map of the application.

Once we touch on the desired inscription, the related information is shown (see Figure 2(d)), enabling the buttons *Map* and *3D View*. Map shows a view centered in the geolocated position of the inscription. 3D View opens the interactive viewer of the inscription model.

4.3. 3D rendering on mobile devices

The 3D viewer has been developed on the foundations of the Glob3 Mobile rendering engine [STdlC*12, TSlC*13]. The engine allows to load SceneJS models that combine JSON scenegraphs with external textures. The loaded model is fixed to the center of the scene and scaled to fit the projection of its longest axis in the mobile device screen. This way, the user can have an overview of the whole model right away. In this case, the photographic textures represent the natural illumination of the piece. Therefore, the selected shader [STdlC*15] just maps the textures on the 3D mesh.

Using the spherical object manipulation integrated in the engine, the user can rotate and zoom into the 3D model by using a set of multitouch gestures. These gestures resemble the finger interaction that is commonly provided by virtual globes. In Figure 2(a) we show a capture of the 3D app in action.

4.4. Mapping the geolocated features

In the mobile application we have two kinds of maps: the map with the geolocation as described in Section 4.2 and a general map (Figure 2(b)) with the location of all the inscriptions. On this last one,

(a) Main centered 3D navigating view of 'Lutatia Lupata' Tombstone.

(b) Map containing the location of some inscriptions.

(c) List of Roman Inscriptions ordered by category.

(d) Information view of 'Lutatia Lupata' Tombstone.

Figure 2: *Different views of 'Epigraphia 3D' app.*

we can easily relate each epigraphy with its category as its pushpins shares the color code given by its category. Interacting with a pushpin reveals the name of the inscription and its related data. Figure 2(b) shows some pushpins on the map of Mérida city. A semi-transparent light brown polygon is also displayed on the map, showing the intramural Roman city.

5. Digital quality assessment of 3D Roman inscriptions

Due to the limitations of the graphics hardware of mobile devices and the limited storage space available, the original models had to be reduced. Such simplification decreased the number of triangles and the resolution of the textures to a level that enables the graphics hardware present on most Android devices to render on real time smoothly.

However, that kind of reduction generates losses in the model detail, which motivated us to conduct two different experiments in order to analyze the impact of those detail losses in the visualization of the 3D models.

5.1. Mesh geometry comparison

The mesh vertex reduction scales the models to a 25% of their original size preserving their form by using the decimation algorithm, as implemented in Blender. On this experiment, we consider the Hausdorff distance [CRS98] between the models as error metric. Both meshes of a representative model of each one of the 11 defined epigraphy categories are processed, as in [Con08], relying on the Meshlab software tool [CCC*08].

The results have shown that, for most of the models, average difference between points in both meshes is around 0.1% of the diagonal of the model bounding box. Moreover, maximum difference is always below 3.5%. A visual representation of the results can be seen in Figure 3. There, a heatmap was drawn over the simplified model, showing that the Hausdorff difference between the models is rather low.

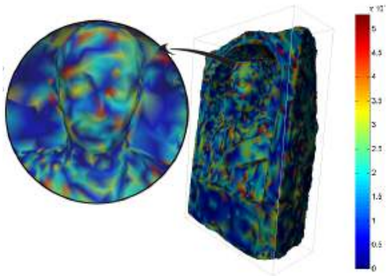

Figure 3: *Distance heatmap image for the sample 1 inscription: 'Epitafio de L. Antestius Persicus'.*

5.2. Texture comparison

The scale reduction of textures lowered the initial resolution to a factor of $1/4$. Each pixel is encoded on RGB255 color space, therefore all metrics on this section refer to this colorspace. In this second experiment, screenshots of the app viewer were taken in a prefixed camera position for both original and simplified versions of all the sample models from the first experiment. Pixel difference between both renderings was studied. From the set of scaling algorithms (Resampling, Linear, Cubic and Sinc (Lanczos 3)), it was selected the cubic interpolation , which provides the best results (2.35 mean error) at the expenses of a longer execution time.

A graphical representation of the visual differences can be seen in Figure 4. The average difference ranges from 1 to 3 color units for all samples which experimentally is not noticeable. Biggest differences are present close to the model edges and in detailed areas, e.g. the inscriptions. The improvements in performance and usability outweigh the small quality losses that were detected during

Figure 4: *Heatmap representing root of sum of squared differences image for the sample 2 ('Epitafio de Atimetus').*

the experimentation. In this regard, a set of 10 random interviewed users declared not noticing the difference between high quality and low quality models.

6. Conclusions

The added value of new technologies for professionals and researchers in the Roman Epigraphy is increasing. In addition, the dissemination to a broad audience is of particular interest, where users can access to a selection of 3D Roman inscriptions just with a smartphone and an internet connection.

A novel Android app for handheld devices is presented for exploring a total of 60 Roman inscriptions from the National Museum of Roman Art (Mérida, Spain). We use the engine Glob3 Mobile to explore the Roman inscriptions and their original location. A brief quality assessment study of the mesh geometry and photo textures concludes that the simplification process does not noticeably affect the models rendering. Ongoing work is focusing on including in the app 37 new Roman Inscriptions from the Archeological National Museum in Madrid, already digitized and published in the web of Epigraphia 3D. This involves modeling the new content without deteriorating the app performance and the quality of the digitized epigraphic heritage.

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