THE DIGITAL ROMAN FORUM PROJECT OF THE UCLA CULTURAL VIRTUAL REALITY LABORATORY

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ABSTRACT:

From 1997 to 2002 the UCLA Cultural Virtual Reality Laboratory created a digital model of the Roman Forum. The model contains the 22 major elements of the Forum. In this paper the project is described, its rationale is given, and the modelling methodology and technology are explained.

1. BACKGROUND

1.1 The Laboratory and Its Mission

The UCLA Cultural Virtual Laboratory was founded in 1997 with the dual mission of creating scientifically authenticated 3D computer models of cultural heritage sites; and of exploring ways of utilizing these models in research and instruction. Thus far, the lab has created models of sites from Lake Titicaca in Peru to Ani in Turkey; and from the Iron Age in Israel to the colonial period in the Caribbean. Our largest project to date is a digital model of the Roman Forum, the civic center of ancient Rome. In this paper we will present a preliminary report on the project, which can serve as an example for the technologies and methodology typically used by the lab in its various projects around the world.

1.2 The Roman Forum

Fig. 1. View of the Roman Forum today (from west to east). Ruins of the Basilica Julia are to the right.

The Forum stood at the literal and metaphorical center of ancient Rome, which at the peak of its development had a population estimated to have been between 1 million and 2 million inhabitants. In the Forum were located from early times some of the major cult centers of the state religion as well as the places where important organs of government, such as the Senate, had their headquarters. The open plaza of the Forum was used at various times for games and spectacles; and it was also the place where a number of important monuments and memorials were erected.

Today, the Forum is largely in ruins (see fig. 1). Thus, very little remains of the two large basilicas, or law courts, flanking its north and south sides. The best preserved structures are the Senate House and the Arch of Septimius Severus, but even these monuments have been greatly damaged with the passage of time. Of the great temples surrounding the plaza of the Forum, only a few columns of the front or side porch survive.

Thus, it is not surprising that many scholars through the ages have tried to reconstruct the Forum and have used two-dimensional views printed in books and engravings or small-scale three-dimensional models made of materials like wood and plaster-of-Paris to do so.

1.3 Rationale for the Digital Forum Model

The UCLA Cultural Virtual Reality Laboratory undertook its model because of the great cultural importance of the site and the equally great limitations of previous modelling attempts in various media. For example, a plaster-of-Paris model is

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* Corresponding author. B. Frischer had the idea for this article, put the team of scholars together, and wrote the drafts. The other co-authors collaborated in the Roman Forum modelling project, which is the subject of this paper, and provided helpful comments and suggestions about the paper's content and structure.

not only made at a small scale, it also must of course leave out the interior spaces of the buildings it represents. Engravings are limited by their two-dimensionality, fixed viewpoint, lack of color and photorealism, as well as by their small scale.

A digital model, on the other hand, can be derived from highly accurate archaeological data. It can depict in color and with accurate lighting the interiors as well as the exteriors of buildings. It can be explored at will in the three dimensions of space and even in the fourth dimension of time. For all these reasons, the UCLA laboratory considered it worthwhile to create a new model of the Forum.

There is a third and final reason that the laboratory began with the Forum: the digital Forum is a subproject of its Rome Reborn project (see Frischer et al., 2000). Rome Reborn's goal is to create a digital model of the entire ancient city within the late-antique walls. Rome Reborn is thus an urban simulation, the purpose of which is less to reconstruct the individual building than to recreate the look and feel of the urban fabric. As the larger model of Rome develops gradually over the years through inclusion of a series of small models, the laboratory's policy is thus to ensure that, to the greatest extent possible, all new models are adjacent to existing models. Thus it was logical for the Rome Reborn model to be initiated with the Roman Forum and to be built up through the addition of new spaces and structures in ever larger concentric circles around the city center.

1.4 Information Provided by the Model

Fig. 2. Detail of UCLA digital model of the Roman Forum. View from east to west. The Basilica Julia is on the left.

In terms of time, the model (see fig. 2) depicts the Forum as it might have appeared at 10:00 a.m. on June 21 of the year 400 A.D. This moment was selected because it comes more or less at the peak of the urban development of the ancient city and represents the period for which the archaeological record is the richest, thus permitting reconstructions that can be based on strong evidence or at least highly probable hypotheses. The time and date were chosen in order to maximize the play of light and shadows across the Forum.

What, exactly, does the digital Forum model represent? Included in the digital Forum model are all architectural features known, or strongly suspected, to have survived as late as 400 A.D. Securely attested plant materials have also been included. When, as is generally the case, evidence is completely lacking, the following features have been omitted from the model: interiors of buildings; furniture; statues; wall paintings; small honorary monuments; inscriptions posted on buildings or on the pavement of the Forum plaza; polychromy of buildings; decorative sculpture on buildings. It goes without saying that the human beings, animals,

movable objects, etc. present in the Forum at the time modeled have also been omitted owing to a complete lack of evidence.

The policy guiding the project has accordingly been the presentation of the main spatial features of the Roman Forum that are known with certainty or with a high degree of probability; and the avoidance of pure speculation as much as possible. The model thus can be used as a point of departure for a wide range of urban-historical and architectural-historical studies that rely on solid data. That could include, for example, experiential studies involving the alignments of monuments and their impact on the observer, or analytical studies of the statics, acoustics, ventilation, circulation of a building. Since the model is a knowledge representation, it can alternatively be used as the springboard to more speculative studies intended to fill in the enormous gaps that plague the physical record.

The digital Forum includes not only an urban simulation of the city center of Rome; it also includes two user aids that make understanding the Forum easier and more scientific. The first aid is the Navigator, which shows the user his exact location in the Forum by means of a red dot placed onto a plan of the Forum that includes 22 numbered features. The numbered features are linked to a second user aid: the Metadata Window. This window provides basic information about each feature in the digital Forum model. But it also provides information about the scholars responsible for scientific oversight of the model; the elements of the model that are certain versus those that are hypothetical; the reasons for the hypotheses; bibliography; etc. (on the concept of metadata in information science see Borgman 2000, pp. 67-71).

In including metadata, the goal has been to offer transparency to the user in a way analogous to notes, commentary, and bibliography in a traditional academic print publication (on the importance of including metadata, see Niccolucci and D'Andrea 2001; Frischer et al., 2002). The laboratory's philosophy about modelling a cultural heritage site like the Roman Forum is that it is impossible to claim that you have achieved 100% accuracy with respect to the ancient monument's original appearance. But what can and should, on the other hand, be offered is 100% transparency about the modelling data and decision-making process. It is because of such transparency that the laboratory designates its models as scientifically produced and authenticated. The laboratory is currently sponsoring research by a Masters student in Library Science to study ways its approach to metadata can be brought into conformity with the Dublin Core Metadata Initiative (cf. http://dublincore.org/ [accessed Feb. 8, 2003]).

2. METHODOLOGY AND TECHNOLOGIES

2.1 The Scientific Committee

The first step in the production of the digital Forum was the creation of a Scientific Committee of experts whose main task was to supply the archaeological data and to review the progress of the work. The Committee included Prof. Cairoli Giuliani, an expert on Roman building technique at the University of Rome and someone with decades of experience

with the Roman Forum and some key publications to his credit about it. A second committee member was Professor Russsell Scott of Bryn Mawr College. Scott is the only American to have directed excavations in the Forum, and he is currently publishing two volumes on the Regia and the nearby precinct of Vesta. The committee also includes Cultural Virtual Reality Laboratory members Bernard Frischer, Diane Favro, and Dean Abernathy.

2.2 Creating the Individual Models

The second step was to make individual digital models of the 22 structures and monuments in the Forum. This entailed recreating the geometry of each element with the greatest possible precision; and then texturing the geometry with a digital sample of the appropriate material. For both operations, we use MultiGen Creator, a 3D modelling package that produces files in the proprietary "OpenFlight" format (for further information, see http:// www.multigen.com/ support/ dc_files/ CA_creator_. pdf [accessed Feb. 8, 2003]). Creator has been described as an "extensible, multi-purpose, polygon-based authoring system is designed to generate optimized object models, high-fidelity terrain and realistic synthetic environments and other non-visual nodes required by real-time rendering software" (ibid. p. 2). OpenFlight is compliant with Open GL and is optimized to run under Performer on the SGI UNIX platform, and since, as you will see in a moment, we have a SGI reality theater at UCLA, this is the platform for which the Cultural Virtual Reality Laboratory typically authors its models in the first instance.

Once models of individual sites have been vetted and approved by the Scientific Committee, they are rendered with a radiosity solution using the program Lightscape (something MultiGen does not have the functionality to do itself). Equally important, Lightscape also permits our models to be lit in a very precise way according to time of day, day of year, and GPS coordinates of the site.

Once we make a Lightscape version of a model, we reimport it into MultiGen and use the renderings as new textures for the MultiGen model. This is a painstaking process that must, today, be done by hand. Each original MultiGen texture has to be replaced, one by one.

2.3 Individual Model and the Master File

The final step in the modelling process is that the model of each individual structure in the Forum now becomes an "external reference" in a master digital Forum file. The master file is itself quite small. But keeping most of the geometrical and texture data outside a single file, the computer is able to operate more efficiently in generating the frame rate required by true virtual reality.

3. DELIVERING THE MODEL TO THE END-USER

3.1 Delivery Solutions

As mentioned, the Cultural Virtual Laboratory has the two-fold mission of creating scientifically authenticated models but also of studying ways of using these models in real-life applications.

In Table 1 are listed the various delivery media used by the Cultural Virtual Reality Laboratory, ranging from the noninteractive 2D rendering up to the highly immersive and interactive 3D reality theater. Each of these delivery media has its strengths and weaknesses. Still images can have high resolution but offer no interactivity. They are appropriate solutions for, e.g., print publications or signs in a museum or on an archaeological site. Urban simulations (by which we mean a series of two or more architectural structures in a city that are adjacent in space and contemporaneous in time and are linked in a single master file) typically have far lower resolution but offer high interactivity and, potentially, high immersivity. When presented in a reality theater. Video fly-throughs can be rendered in formats up to and including high-definition television. The only interactivity they support is the possibility to pause, reverse, or fast-forward through the recording. They are appropriate delivery vehicles for television programs, streaming video on the Internet, or multimedia presentations on CD-ROM. Video panoramas place the virtual camera at a fixed spot, around which a 360^0 photograph of the virtual environment is created. A panorama provides a great deal of visual information about the scene, but lacks all geometrical information Interactivity consists in mobility of the viewing frustum; zoom-in; and zoom-out. Panoramas are appropriate solutions for the media of the Internet and the personal computer. Real-time models can be run on personal computers or served on the Internet in a variety of proprietary and non-proprietary formats (including, e.g., VRML).

| Products | Media | | | | | Degrees of |
	Pr	TV	Int	PC	ReTh	Interactivity
Still images	+	+	+	+	+	none
Video fly-through		+	+	+	+	low
Video panorama			+	+	+	medium
Real-time model				+	+	high
Urban simulation					+	high

Table 1. Delivery of VR models to end-user. Products, Media, level of interactivity.
(Abbreviations: Pr=Print; TV=Television; Int=Internet; PC=Personal Computer; ReTh=Reality Theater).

3.2 The UCLA Visualization Portal

The laboratory's preferred solution at its home base at UCLA is a SGI reality theater (called, locally, "The Academic Technology Service Visualization Portal;" see www.ats.ucla.edu), powered by an Onyx 3400 three-pipe supercomputer with 1 gigabyte of texture memory and 2 gigabytes of RAM (for further information about reality theaters, see http:// www.sgi.com/visualization/onyx/3000/ ir3/overview.html (seen Feb. 8, 2003)]. Data is outputted from the Onyx via three 3-gun Trimension projectors to display images on a 160 x 40-degree spherical screen. The screen is 7.5 meters in diameter by 2.5 meters high. Up to three images can be displayed at the same time - for example, the laboratory's Roman Forum model and the Navigator and

Metadata windows. Alternatively, a single image can be displayed across all three screens at 3840 x 1024 resolution, by blending the edges of the overlapping beams of the projectors. The system also supports stereographics, three-dimensional localized sound, and interactive object manipulation. To navigate models, the laboratory uses VR Juggler, an open-source 3D engine developed by Carolina Cruz-Neira at Iowa State University.

The UCLA Visualization Portal seats 40 people, making it an ideal setting for a lecture, scientific meeting, or a demonstration to potential sponsors. UCLA was the first American university to have such a facility; now several other universities have joined the list. Other universities have related CAVE solutions, where the laboratory's models can run equally well.

4. NEXT STEPS FOR ROME REBORN

The Cultural Virtual Reality Lab has recently received a three-year grant from the Andrew W. Mellon Foundation to enlarge its Rome model by ten-fold. The new areas to be modelled include the continuation of the Via Sacra to the Arch of Titus; the area including the Baths of Trajan and of Titus, the Temple of Venus and Rome, and the Colosseum; the Caelian Hill; and the Circus Maximus. Also funded is the creation of a digital version of the great plaster-of-Paris model of ancient Rome housed in the Museum of Roman Civilization at EUR/Rome. The laboratory's intention is to use this digital model of the entire city as the backbone for its Rome Reborn digital model, which may well take several decades to complete. In the meantime, the digital version of the plaster-of-Paris model will serve as a gigantic placeholder for what is to come. As the laboratory completes new digital models such as the digital Roman Forum, they will used to replace the equivalent parts of the digitized plaster-of-Paris city model.

The project to digitize the plaster-of-Paris model is being undertaken in partnership with Prof. Armin Gruen and his team at the Institute of Geodesy and Photogrammetry at the Swiss Federal Institute of Technology in Zurich. This group will produce a digital version using photogrammetry. At the same time SDS3D of Vancouver, Canada will create a digital scan of the plaster-of-Paris model using the Cyrax-Leica environmental scanner. The Cultural Virtual Reality Laboratory will test both digital representations to determine which better suits its needs, and to test the possibility of creating a hybrid version combining the strengths of the two approaches.

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6. ACKNOWLEDGEMENTS