Rome Reborn: 3D Digital Modeling and Publishing

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MR.FRISCHER:I would like to begin by thanking the National Endowment for the Humanities for inviting me to participate in this important event and for giving me the opportunity to be here sharing the podium with such illustrious colleagues, one of whom inspired the project I will talk about; another of whom helped us as an advisor.

The Institute for Advanced Technology in the Humanities (or, "IATH") at the University of Virginia was founded in 1992 with the help of a major grant from IBM. From the start IATH's mission has been to study new ways of applying information technology to research in the humanities. Each year we give one faculty member at the university, chosen through a competition process, a two-year grant which involves some course relief, modest funding, and a chance to collaborate with the 15 members of our staff to realize their digital dream. Our projects tend to involve preservation, access, interpretation, and discovery of new facts, ideas, or theories about the objects that humanists typically study, whether they be texts, poems, language, 2D objects like paintings, manuscripts, or 3D objects such as statues, buildings, and even whole cities. The projects of our current fellows run the gamut of humanities disciplines, from classics to religious studies, architecture and art history. It's interesting to note that in recent years, more and more of our fellows' projects have exemplified the "spatial turn" in humanities research.

My focus today will be on "Rome Reborn" (www.romereborn.virginia.edu), a project that certainly exemplifies the spatial turn and which also illustrates many of the fundamental topics that Maurizio Forte has just discussed. This is not surprising. Dr. Forte was one of our project's main advisors all along. Institutionally, Rome Reborn is managed by IATH and is sponsored by UCLA, the University of Virginia, and the Politecnico di Milano.

Rome Reborn started at UCLA in the Cultural Virtual Reality Lab, which I started in 1997 in collaboration with UCLA Architecture Professor Diane Favro. The lab was inspired by the pioneering work in using 3D modeling to reconstruct the tomb of Nefertari, a project that Francesco Antinucci presented to the trustees of the J. Paul Getty Trust in 1992 and which caused quite a stir in the Los Angeles academic community at the time.[1] His pioneering work at Infobyte gave me and my partner, Diane Favro, the idea that there was this new technology out there called "virtual reality," and that we should learn more about it. Within a few years we had launched the Rome Reborn project. Its goal is to create a spatio-temporal 3D digital model of ancient Rome from its beginnings in the late Bronze Age to its decline at the end of the Gothic Wars in the middle of the sixth century A.D.

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[1] See http://www.infobyte.it/vartcollection/contenuto_uk.htm.

The model we plan to make is enormous in scope and will undoubtedly take many years to complete. Indeed, we like to compare Rome Reborn more to a traditional scholarly journal than to a book: like a journal, it is an open-ended and collective undertaking. The only natural way a scholarly journal in an academic field can ever be "finished" (short of mismanagement or a breakdown in the relations of the editors!) occurs when its subject has been exhausted. In fields such as English literature, Asian history, Chemistry, Mathematics, or Physics, this is not likely ever to happen, nor would it be a particularly good thing if it did. Similarly, a model of ancient Rome covering some 1,500 years of urban development and reflecting new discoveries and the evolution of archaeological methodologies is unlikely ever to exhaust the subject of Roman Topography.

In making our model of Rome, we had to start somewhere. At a meeting held at the Institute for Italian Culture in Los Angeles in December of 1996, our board of advisors, which included the superintendents of archaeology in the city of Rome and the curator of antiquities of the Vatican Museums, recommended that we start where the evidence was best and when the city had reached the peak of its development just before Christianity started to leave its mark on the urban fabric. So the model of ancient Rome which I am going to show you reflects the way Rome might have looked in 320 AD, just before the completion of the first great Christian basilica, St. John Lateran. It is the product of a group of very talented 3D modelers and technicians, and it could not have been possible without the help of some leading scholars of Roman archaeology and Roman topography, many of them Italian, at universities like University of Florence, Lecce and "La Sapienza" in Rome. Other major contributions came from scholars from America, Britain and Germany who tend to work in Rome at research centers like the American Academy, the British School, and the German Archaeological Institute. We finished this phase of the model in February of this year, and we unveiled it to the public at an event presided over by the Mayor of Rome, Walter Veltroni, on June 11th of 2007.

Before presenting the model, let me raise a fundamental question. Maurizio Forte talked mainly about *how* to make models and how to do so accurately and intelligently. This is where the important concept of ontology comes in. But *why* do we make digital models of a city like Rome in the first place?

Information scientist Colin Ware recently published a very useful book to address this question.[2] He divided the reasons for making them into the following simple categories: facilitating understanding; promoting the perception of emergent properties that were not anticipated; gauging the quality of data that are available to us; and facilitating hypothesis formation.

All these reasons are important, but, for me, it is the last that is perhaps the most interesting. Once we have digital models of our object of study, we are able to ask questions that--short of actually rebuilding the building or city--we could never have asked before. Unfortunately, we humanists usually don't have budgets needed to rebuild a building like the Colosseum just to test the validity of the cliché that it was a good people-mover. An even more fundamental question has been asked many times: how

[2] Colin Ware, *Information Visualization. Perception for Design*, second edition (San Francisco, 2004).

many people could you fit into the Colosseum? If you read the scholarly literature on the building, the range is remarkably wild, but the evidence or reasoning adduced is slight. Respected archaeologists have proposed figures from 38,000 to 75,000 spectators.

But once you have a model of the Colosseum, you can hand it over to engineers to delve into questions such as these, and we were fortunate to find engineers at the University of Zaragoza who were willing to help out. Under the leadership of a brilliant young professor named Diego Gutierrez, they populated our model with Artificial Intelligence figures simulating human beings and smart enough to walk, find their way to a specific seat while not tripping, walking into walls or into each other while doing so. Dr. Gutierrez's team was able to narrow down the estimated carrying capacity of the structure to between 48,000 and 50,000 spectators.[3] This is a major step forward in precision and knowledge.

So you can use these models to do a kind of time travel and to do an empirical study of something that doesn't exist anymore. There are various kinds of models that we use and that correspond to the different kinds of data available to make the model in the first place.

When something doesn't exist or is severely damaged, we can't scan it. Maurizio Forte talked about 3D scanning, and in a moment I'm going to mention it, too. But what do you do when (as is all too often the case in world archaeology) you just have post holes or traces of foundations that survive from a building? In that case, you have to create a model by hand using CAD software on the computer, getting your data from the world's leading experts about the site, if you can recruit them to your project. We therefore call this a *hand-made model*. As an example, I'd cite the Colosseum again. Today it is fairly well intact, but it doesn't look anything today like it did in antiquity. So much has been damaged, demolished, or despoiled that to get a good idea of how it looked and functioned, there is no choice but to create a hand model.

When the object does exist though, you can scan it, and the result is what we therefore call a *scan model*. As an example of scanning in the humanities, I would cite the Digital Michelangelo Project, a famous databank of statues of Michelangelo in Florence created by computer scientist Marc Levoy at Stanford (http://graphics.stanford.edu/projects/mich/). In that project, Levoy and his team scanned the statues with a quarter millimeter accuracy. This kind of detail allows you clearly to see the tool marks left on the surface of the statue by the sculptor. Once you have this kind of information, you can do what David Koller did when he was a graduate student working under Prof. Levoy. Koller used the scan data to work back from the tool marks to the tools themselves that Michelangelo used to carve the statues. Once you reconstruct the tools, you can then start to identify later interventions because you can identify tools that left their mark on the surface that didn't even exist in Michelangelo's day, or if they did exist, which he didn't use in a certain way. David Koller's innovative work exemplifies two of Ware's uses of

[3] See Gutierrez, D., B. Frischer, E. Cerezo, F. Serón. "AI and Virtual Crowds: Populating the Colosseum," *Journal of Cultural Heritage* 8(2), 2007. View Document.

visualization: finding emergent properties that were not anticipated (the tool marks); and forming hypotheses (the reconstructed carving tools).

Speaking of Stanford and relationships with Italy, I just want to mention that there is another great project of 3D data capture that started in Marc Levoy's lab at Stanford and about which David Koller wrote his dissertation: scanning of the 1,200 or so fragments of an amazing map of ancient Rome at a scale of 1 to 240. The map dates to about 210 AD, the time of the Emperor Septimius Severus. We therefore call it the Severan Marble Plan of Rome (see http://formaurbis.stanford.edu/). The good news is that that map was amazingly detailed and showed not only the streets of the city but even the ground plans of all the buildings. The bad news is that the medievals could think of nothing better to do to with this map than to melt it down to make lime. But about 10 percent still survives, and the task of archeologists for the 400 years since it was has been to find joins among those 1,200 fragments. So far, about half the fragments have been integrated. Coming at the end of this long, illustrious tradition, David Koller was still able to make over 20 new joins in a relatively short period of time by using the computer algorithms for puzzle solving that he developed. His achievement is quite remarkable and shows the potential of laser scanning as a tool for discovery in the humanities. There are many more such “puzzles” to be solved! In the meantime, Dr. Koller has come to IATH and our new Assistant Director for 3D Data Capture, and IATH has taken on the responsibility of hosting the database through a new cooperative agreement signed earlier this year between IATH, Stanford, and the City of Rome.

The final kind of 3D model is a *hybrid* of hand modeling and scan modeling. An example of this, as we’ll see, is our Rome model.

To understand how and why we made a hybrid model of Rome, let us by asking a basic question: on the basis of what information can we reconstruct ancient Rome in the year 320 A.D.? That was a long time ago, and almost everything visible then no longer exists. Well, for one thing Rome is the oldest branch of archaeology. It was started by papal secretaries like Poggio Bracciolini and Flavio Biondo in the middle of the 15th century. In the intervening centuries, all the major classes of data have been collected and organized. I don’t mean to suggest that we know everything we would like to know, and in fact new discoveries are being made all the time. My point is that we do have a lot of pertinent information needed for making a model; and that, in any case, such models are representations of the state of our knowledge about a site, allowing us to visualize both what is known and what is not yet known. Thus, a model of a city like Rome in the fourth century A.D. is less an accurate illustration comparable to a photograph and more a working tool that helps scholars to “keep score” of the state of knowledge in their field. So let me go through the classes of data, one by one.

First of all we have texts, including two remarkable texts from the 4th century AD, the period of our model. It seems that the Roman city government periodically made lists of the building stock of the city, district (or “region”) by district. Two of these “regionary catalogues” (the *Curiosum* and the *Notitia*) survive. The important thing to note is that they largely agree. They start by giving the major monuments in each of the fourteen districts of the city and then they go on to give aggregated data about all the main building types in each district. The building types include the apartment buildings, private houses, bath buildings, warehouses, etc.

Now, those aggregated data are very useful. If we want to make a model of Rome, we could make by hand a number of different types of, say, the Roman apartment building, which we know very well from archaeology, and we could populate each district with the right number of apartment houses; and we could do the same with the private houses, warehouses, etc. So even if we didn't have more specific information about individual monuments such as the Colosseum or the Senate House and obelisks, we could resort to the data in the regionary catalogues to make a fairly accurate representation of the ancient city.

But do we have specific individual monuments? Yes, we do. About 265 individual monuments and buildings are known from the ancient city. We know about them from images, starting with the Severan Marble Plan, that ancient map I mentioned earlier. We also have early drawings by artists and architects. Starting in the Renaissance, it was the custom for young architects and artists in Europe to go down to Rome to put the final touches onto their education. These have been collected and studied.

Early photographs are also important. In the 1840s, photography developed and was used almost immediately in Rome, just when major excavations were starting to occur in the city, especially in the center of the city in the area of the Roman Forum. These photographs are useful to us because after the digs were finished, the sites were cleaned up, and the finds were moved around. Today, when you visit the Forum, you find many blocks and architectonic elements lying on the surface, and because the early excavators usually didn't publish reports, you often don't know where they came from unless you're lucky enough to find a picture taken during the excavations.

Of course, we also have a great deal of archaeological evidence. And, best of all, we have a wonderful six-volume synthetic encyclopedia of Roman topography, written by several hundred experts and edited by Oxford archaeologist, E.M. Steinby.[4]

So if we then take a big step back and ask what kinds of evidence do we have that we could use to reconstruct ancient Rome, we would have to say there are two kinds. There is Class I, which are those buildings and monuments like the Colosseum or obelisks known in great detail. We know their location. We know their shape and their design. Often we know enough even to reconstruct the interior of the buildings, including the décor. Those we can model at a 1-to-1 scale. As I said, they number about 265.

Then we have the other ca. 6,735 buildings that we know from the regionary catalogues, the Severan Marble Plan, and so on. And those we can only model--I think we *should* only model--very schematically to give our users an immediate visual clue that they are seeing an approximation, a guess. We call these the Class II buildings. We don't know

[4] E.M. Steinby, *Lexicon Topographicum Urbis Romae*, 6 vols. (Rome, 1993-2000).

exactly where these buildings were located or how they looked. But we do know the distribution of building types through the individual districts of Rome.

So our basic idea in making this model was to hand-model the approximately 265 buildings in Class I and, for the Class II buildings, to scan and correct the best physical model of the city made in the last century so that we could jumpstart our 21st-century digital model by inheriting all the good work done in the 20th century. The physical model in question is the "Plastico di Roma Antica," which is housed in the wonderful Museum of Roman Civilization. The "Plastico" is itself now a historic monument. It was made at a scale of 1:250 from 1933 to 1974 under the direction of Italo Gismondi, the superintendent of archaeology of Ostia Antica, the port of Rome. Finally, our plan was to geo-reference these two different classes of monuments, combine them, and add online documentation so that the user could instantly understand the evidence behind the part of the model they were looking at as they explored virtual Rome.

We scanned the Plastico di Roma Antica with a Metric Vision LR200 laser scanner. We invited Dr. Gabriele Guidi of the INDACO Reverse Engineering Lab of the Politecnico di Milano to undertake this part of the project. Dr. Guidi's first results, the point cloud, looked pretty promising on the computer screen. As can be seen in **fig. 1**, you can make out the Colosseum, the Temple of Claudius in front of the Circus Maximus, Colosseum, Roman Forum, the Baths of Trajan just to the north of the Colosseum, etc.

But, in fact, it turned out that things were not so simple. From our scan results, you could reverse-engineer the model, but the results were not at a level of quality that was adequate for virtual reality applications. There were distortions all over the results that we got. The semicircular areas between the columns of a colonnade didn't look semicircular; they were oval-shaped. Straight lines were jagged and so on. If we could have afforded to hire an army of helpers, we might have been able to use brute force to clean up the results. But we couldn't.

Instead, we were able to find some very smart students who needed dissertation topics at Prof. Guidi's school, the Politecnico di Milano, and put them to work on our idea of deriving algorithms to go through all the scanned data and infer the underlying geometric forms. It turned out there were thirty-eight simple geometric forms for the buildings (**fig. 2**) and about another twenty for the roofs.

It is the interaction, the permutations and combinations of these thirty-eight building forms and roof forms that give the impression of great variety to the overall model. We then could make those roof and building types by hand, and with the help of six students from the Politecnico di Milano we were able to repopulate all the scan data with the simple clean and crisp geometric forms.

So to summarize, the new digital model of Rome has three components. We have the born digital Class I hand-made models of 31 buildings in Rome. We didn't have time or money enough to do all the rest, but we do have a plan for getting them done, which I will mention later. For the moment, the other (ca. 234) Class I buildings are included in

Class II, the schematically represented buildings not known in any detail. These buildings were made first by scanning the "Plastico di Roma Antica," then by reducing the scan data to a library of basic geometric types, and finally by hand modeling these types. Hence, we can classify our overall city model as a *hybrid meta-model*. It is hybrid insofar as it was made by a combination of hand and scan modeling. It is a "meta-model" insofar as it was inspired by the physical model of Gismondi, making it (in part, at least) the model of a model.

As Maurizio Forte suggested we should do, we offer the end-user transparency as a third element. We allow you to see through the model back into the underlying documentation giving rise to what you're seeing on the screen. And to do that we use Google Earth. We have created our own layer for Rome in Google Earth, and all throughout the city we have put place marks with links to the key archaeological documentation for the specific sites around the city. So at any point in navigating through our model, you can click the "d" (="documentation") key on your keyboard, and a window with Google Earth opens up, showing you your current position in the modern city and providing you links to our database of documentation.

In the printed version of this talk, I can only illustrate the model with a still shot (**fig. 3**), but readers can check out our project web site for more still shots and some video fly-throughs (www.romereborn.virginia.edu). One should bear in the mind that what we actually created is a "real-time" model, and if you come to visit us in Charlottesville (which readers of this are hereby invited to do!), you can see it the way it was intended to be used: in an immersive space with a large screen with rear projection and stereo.

Of course, we are also eager to publish the model to the Internet, and I conclude by communicating the good news that we have just received a grant from the National Science Foundation that will enable us to start the world's first peer-reviewed, online journal where scholars can publish their 3D models or add new features to already published models. The journal will be called SAVE, which stands for "Serving and Archiving Virtual Environments." And now I can explain how we plan to fill in the missing ca. 234 Class I buildings in the ancient Rome model. The answer is simple: using the power of collaborative research on the model of the Wikipedia but with the important addition of peer-review, we will invite qualified scholars to submit the missing pieces of our city model, first for the period of ca. 320 A.D. and then for the earlier and later phases of Rome's urban history. We have already added two important pieces this year: the colossal statue of Constantine from the Basilica Nova. It was created by the German digital archaeological company, Arctron.[5] And we have also added a stunning model of the Circus Maximus made by a team of scholars from the CNRS in Bordeaux, France and the Archaeological Superintendency of the City of Rome (cf. fig. 3).[6] These and, we hope, many other models of important Class I features of Rome will be included in the first release of SAVE, which is expected to occur by the time Computer Applications to

[5] See http://www.arctron.com/3D_Surveying/3D_Laser_Scanning/Examples/Constantine/index.php .
[6] http://archeovision.cnrs.fr/fr/archeogrid/index.htm .

Archaeology meets in Williamsburg, Virginia from March 22-26, 2009.[7] I hope everyone here will be able to attend CAA to help us celebrate![8]

Figures

Fig. 1: The point-cloud resulting from scanning the Plastico di Roma Antica. Clearly seen are the Circus Maximus, Colosseum, Temple of the Divine Claudius, Baths of Trajan, etc. When, in the next step of postprocessing, the mesh was made, it turned out that these

[7] http://www.iath.virginia.edu/virtual_williamsburg/CAA2009TestPage.html (October, 2007), which after January 1, 2008 will become http://www.iath.virginia.edu/virtual_williamsburg/CAA2009.html.

[8] I would like to thank the following people and institutions for their indispensable help in creating Rome Reborn 1.0: project assistant director Diane Favro (Dept. of Architecture, UCLA); the following members of our Scientific Advisory Committees—Dean Abernathy (University of Virginia), Carla Amici (University of Lecce), Heinz Beste (German Archaeological Institute, Rome), Diane Favro (UCLA), Fulvio Cairoli Giuliani (University of Rome "La Sapienza," Paolo Liverani (Vatican Museums, University of Florence), Lynn Lancaster (Ohio University), Mark Wilson-Jones; our financial sponsors—the Creative Kids Education Foundation, Intel, Mr. Kirk Mathews, the Andrew W. Mellon Foundation, Microsoft, and the National Science Foundation; and our institutional sponsors—the Politecnico di Milano, UCLA, and the University of Virginia. Important contributions were also made by many individuals, among whom I would like to give special thanks to Monica De Simone for research assistance; to Kim Dylla and Bob Kuehne for developing our user interface; to Janez Donno and Ignazio (Politecnico di Milano) for their work on the Class II models; and to our Class I modeling team led by Dean Abernathy (University of Virginia) and including Renee Calkins, Steve Guban, Chris Johanson, Chad Keller, Rebeka Vital and Itay Zaharowitz. Finally, we thank Clotilde D'Amato, Eugenio La Rocca, and the Museum of Roman Civilization of the City of Rome for granting us permission to scan Gismondi' Plastico di Roma Antica.

and the other features of the physical model were randomly distorted and so the scan model of the Plastico di Roma Antica was not suited to virtual reality applications. Image courtesy Dr. Gabriele Guidi, Politecnico di Milano.

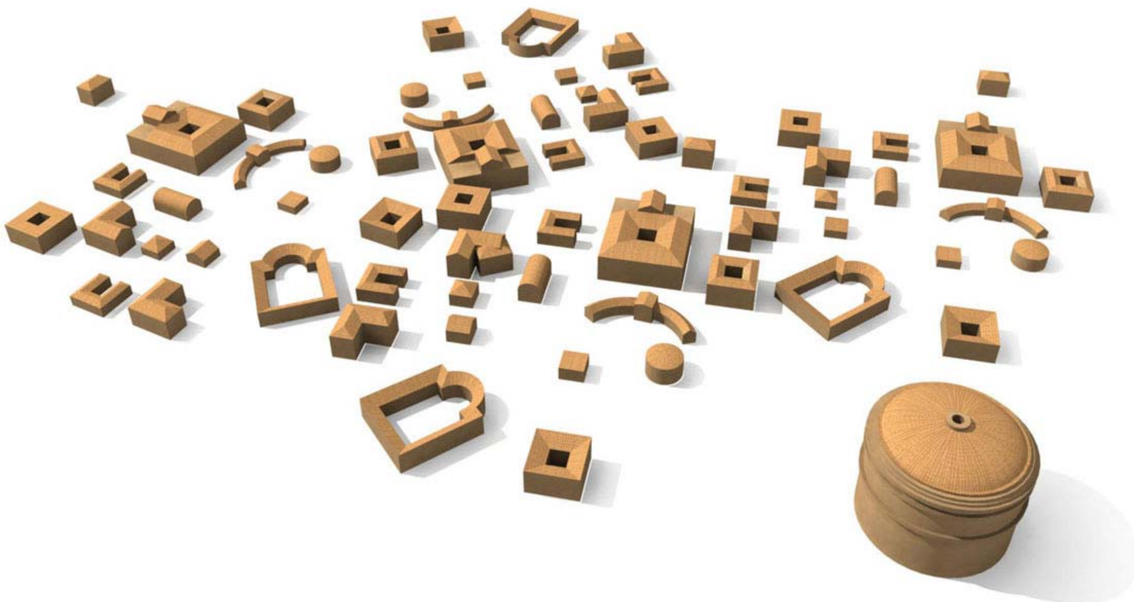

Fig. 2: Graphic showing the 38 repeated geometric forms used in the Plastico di Roma Antica; based on the research of Dr. Janez Donno (Politecnico di Milano).

Figure 3. View of Rome Reborn 1.0 from above and from the south. In the center is the Colosseum; to the left, the Temple of the Divine Claudius to the right, the Baths of Trajan. The Baths of Diocletian are seen in the upper right. At the top is the Tiber River. Running through the middle ground of the image is the Claudian Aqueduct. Model copyright by The Regents of the University of California 2007. All rights reserved. Photograph of the model copyright by The Board of Visitors of the University of Virginia 2008. All rights reserved. Rendering courtesy Barry Minor, IBM