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## A 3D Web-GIS for the Valley of the Colosseum and the Palatine Hill

*Abstract:* Several computer applications are now available for the management of cultural, archaeological and environmental heritage. These applications allow the user to analyze and interrelate data and meta-data, but more recent computer technologies (mainly information modelling) allow these systems, through dedicated applications, to extend their range for a wider usage, creating new scenarios for a critical investigation of data. The aim of this project is to bring together some specific features of Geographical Information Systems using tools typical of Information and Communications Technology. The core of the project is a traditional GIS with maps obtained by very accurate studies and surveys using advanced technologies such as GPS, photo rectification and DTM constructions. The resulting tool is flexible and can be updated through a very simple interface designed for web use.

### *Area and Periods Selected for the Study*

The area we have selected is situated in the heart of historical Rome. It includes the valley of the Colosseum, the Temple of Venus and Roma, the Velia, the Vigna Barberini, as well as the area around the Arch of Titus. Since 1986, the Chair of Methodology and Techniques of Archaeological Investigation has been excavating using stratigraphic methods near the valley of the Colosseum and the north-eastern slopes of the Palatine<sup>1</sup>. After a preliminary study to assess the state of the ongoing research and the potential for the 3D reconstruction of the monuments, we selected a time span from a moment preceding the great fire of AD 64 to the Severan period. This is rather narrow when compared to the overall history of the city, but quite enough for a meaningful experiment.

### *Choice of the Monuments*

A number of monuments fall within this area. Great urban projects and majestic architecture have followed one another, overlapping and replacing the preceding urban context. In the Julio-Claudian period, the area contained several rich domus, including the aristocratic house situated under the Temple

of Venus and Roma, the domus and tabernae that flanked the road linking the Colosseum with the Oppian hill, the domus recently found at the north-eastern corner of the Palatine, the houses of noblemen that lined the Sacra Via on the northern edge of the Palatine<sup>2</sup>, and the rich house found during the excavation of the French School in the Vigna Barberini<sup>3</sup>. These private buildings follow a pattern of roads and of public and sacred buildings, like the substructures of the Velia and the Compitum Acilii, the Augustan Meta Sudans and the adjacent compitum, the sacred area that has been found near the north-eastern corner of the Palatine (perhaps identifiable as the Curiae Veteres).

For the period under the emperor Nero, we have been able to reconstruct most of the buildings that formed the Domus Aurea facing the valley and the Forum, the great central lake and the colonnades that surrounded it, and the atrium-vestibulum. We have studied and investigated the vaulted road that led up from the valley towards the Forum, the covered alleys along the Sacra Via and those near the crossing between the Nova Via and the clivus of the Palatine<sup>4</sup>.

The reconstructions from the Flavian period include the Colosseum, the square, and the Flavian Meta Sudans, the rearrangement of the atrium-vestibulum and of the covered alleys and road from

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<sup>1</sup> For the results of the excavations, refer to PANELLA 1990; PANELLA 1996; PANELLA / ZEGGIO 2004.

<sup>2</sup> Cf. CARANDINI / PAPI 1999

<sup>3</sup> Cf. VILLEDIEU 2001, 33–58.

<sup>4</sup> For the section of the *Domus Aurea* facing the valley of the Coliseum see MEDRI 1996 and, more recently, MAR 2005, 113–136.

the valley to the Forum, at the top of which we find the Arch of Titus, the restructuring of the covered alleys of the Forum area, and the construction of the horrea of Vespasian and Domitian behind these porticated pathways. The imperial gardens in the Vigna Barberini can also be attributed to the Flavian period<sup>5</sup>.

For the period of Emperor Hadrian, we have studied and reconstructed the Temple of Venus and Roma, and the reshaping of the gardens on the Vigna Barberini, which entailed a radical modification of the substructures, which were expanded towards the north-eastern side. In the same period, the square was radically modified, with the moving of the Colossus into the square and the restructuring of the valley-Forum axis. The whole eastern side of this road was cleared during the construction of the temple of Venus and Rome.

The reconstruction projects for the Severan age and the 3<sup>rd</sup> century AD encompass the sanctuary of

Elagabalus in the area of the Vigna Barberini, with the modified pattern of the substructures on the north-eastern side, and the commercial building, probably an horrea (the so-called *thermae* of Elagabalus), built along the road linking the Colosseum with the Forum area<sup>6</sup>.

### *The Base Map*

The base map we have used is a digital map obtained from the Municipality of Rome, with a cadastral base and an overlay of a more recent aerial restitution at a 1:2000 scale, in a national projection by the name of Gauss Boaga, drafted by Cartesia S.p.A. Onto this base map we applied two of the most important historical maps of Rome: the “New Map of Rome” drafted by G. B. Nolli in 1748, and the “Forma Urbis Romae” compiled by Rodolfo Lanciani at the end of the 19<sup>th</sup> century.

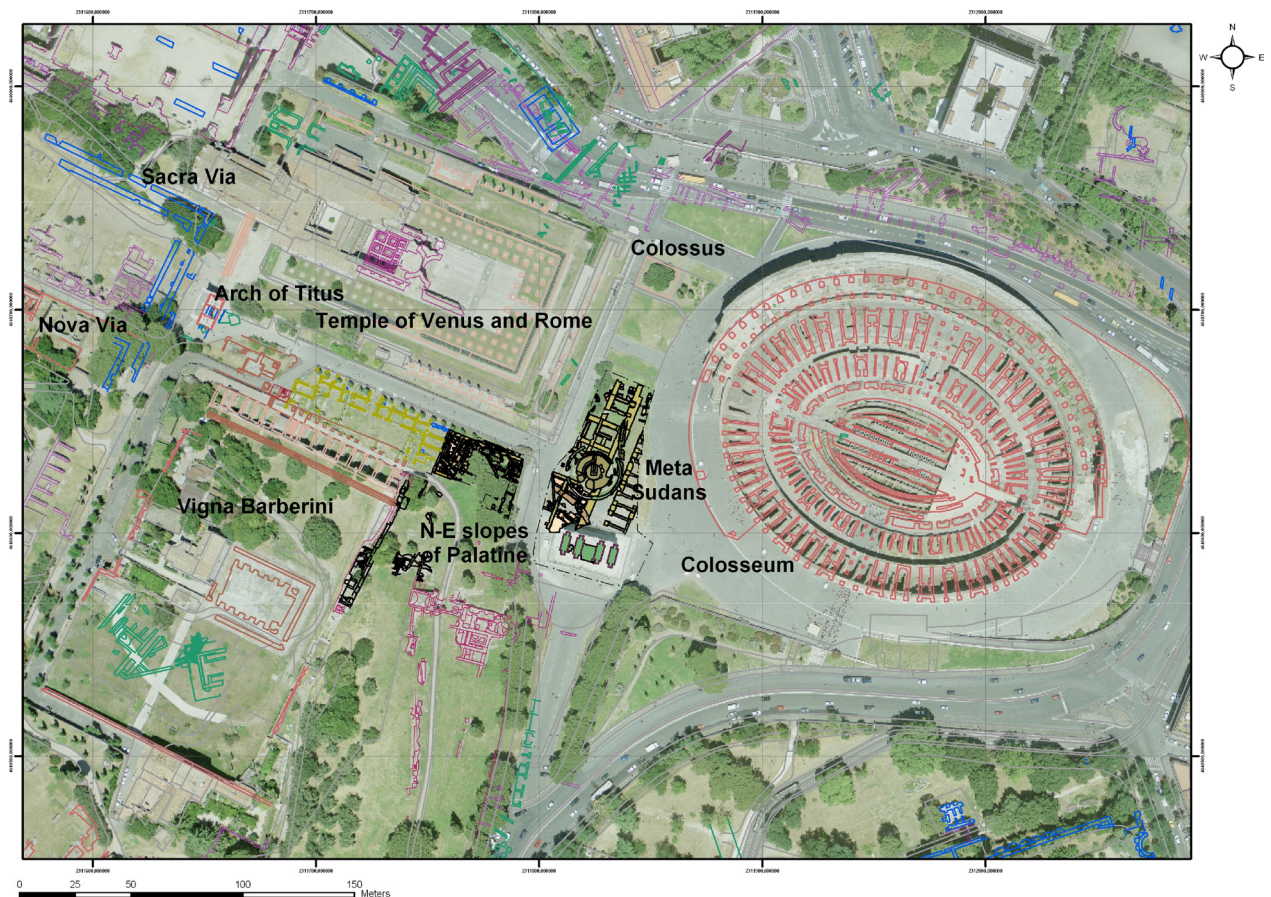


Fig. 1. The base map.

<sup>5</sup> Cf. VILLEDIEU 2001, 59–72; MAR 2005, 171–174.

<sup>6</sup> MAR 2005, 208–217; 241–292.

The documentation has been enriched by the inclusion of the contour lines derived from the cartographic atlas by Professor Reina, dated 1911. The document is especially relevant since it includes the topographic details of that part of the city that was removed by the earthworks in the Fascist period. This basic cartography has been enriched with orthophotomaps based on aerial photographs rectified on the basis of land points obtained through a differential GPS campaign (Fig. 1).

### *Location of the Monuments*

To locate with due precision the different monuments and for a more detailed analysis of the land – all essential elements for the reconstruction of the ancient environment – we carried out a topographic campaign using total-stations and differential GPS. The measurements began with the set of polygonals defined during the excavations on the north-eastern slope of the Palatine and the Meta Sudans as a basis. We also made use of the reference points set in place for the drafting of the Cartesia map, and of the geodetic points used in the project of the “Nuova Forma Urbis Romae”. The topographic campaign covered the above mentioned excavations, the Vigna Barberini, the eastern slopes of the Palatine, the so-called Baths of Elagabalus, the temple of Venus and Roma and the Forum area.

### *Materials and Methods*

The project itself grew from a basic set of ideas that were revised and modified during the project’s realisation. The final product is based on an open architecture client/server system, designed to be used via the internet. It has been designed following some principles specific to current software. The overall system is built around several interlinked and integrated subsets:

- A database organized in MySQL that contains the tables with all the metadata and part of the data;
- A GIS developed in ArcView 3.2 used to relate plans and alphanumeric data;
- Several digital terrain models that represent the morphology of the land at different periods;
- Software developed using Java to visualize the 3D models in real time; the models built with techniques that optimize the number of poly-

gons, and connected to the database with a Java-based program communicating with the MySQL server;

- The web site, which is the “container” that uses dynamic techniques such as HTML, XML and PHP to enable the management of a great deal of interconnected data.

### **The Database**

MySQL is a relational database management system (DBMS) with an open architecture built around a client with a text-based interface and a server. We chose to use this DBMS because of its open-source nature and hence the possibility of wide-ranging portability. The open architecture allows for the management of the data through a very transparent procedure, creating a data management system with dynamic content. The use of forms designed with XML allows for a constant and direct feed to the MySQL server and the possibility of controlled access through an account system.

For greater control and standardization of data entry we prepared fields with drop-down menus linked to predefined glossaries. For the chronological fields, like period of existence and destruction, we made use of a table in which every chronological period has a simple numerical code and an acronym made of letters. The values are used for the selection and display of plans for a certain period and the selection of the pertinent 3D reconstructions. These act as mathematical operators within the code of a selection query. For example, if we know that the value for an unidentified period is 0, while the Julio-Claudian period is 10, the query for the data extraction would be  $([Period] <> 0)$  and  $([Period] \leq 10)$  and  $([Destruction] > 10)$ .

The criteria for the application of the formula are applied in succession, in the following order:

- Exclusion of all the structures of an unidentified period;
- Extraction of all the structures of or preceding the Julio-Claudian period;
- Exclusion of all the structures destroyed before the chosen period.

### **The GIS**

The maps drawn and retrieved were organized with the ArcView 3.2 software. The general plan of the monuments was linked with the tables in the database. In the same way, we have ensured the connec-

tion with the graphic documentation, photographs and bibliography. Different queries have been developed on the basis of the attributes contained in the database. It has been possible to produce period maps, typology of architecture, and the level of reconstruction from the available data. Thematic maps can be produced on the basis of chronology or typology of buildings.

### The DTM

The necessary basis for a 3D reconstruction of the area is the definition of a reliable model of the terrain, or rather of a sequence of models of the terrain that reproduce the changing landscape throughout the centuries. There was not much data available. For the model of the terrain of the present day we used the maps of the municipality of Rome (Cartesia) and the older map prepared by the Office of the Historical Centre, completing the information with data derived from campaigns connected with recent excavations. For the period that precedes the radical urban modifications of the Fascist period we used Reina's 1911 topographic data from the School of Engineering, which has the only reliable information on the Velia hill. These basic models were subsequently modified using excavation data and explorative borings so as to define a set of hypotheses regarding the periods preceding the construction of the huge substructures of Vigna Barberini and Venus and Roma, when the levels at the bottom of the valley (Colosseum square, San Gregorio Avenue, etc.) lay about six metres below the present or Flavian levels. For these reconstructions, and for another reflecting the situation at the time of the foundation of Rome, we made large use of the studies and reconstructions of Antonia Arnoldus. The interpolations between known elevation points were traced using ArcGIS. We then defined some procedures to translate the resulting formats into others compatible with the CAD instruments used in the application (.dxf or .dwg). The results of this work are four sets in chronological sequence, which cover an area somewhat larger than the one occupied by the study area, including the Capitoline Hill and covering a good share of the Oppian Hill (Fig. 2). The resulting digital terrain models are quite adequate as a basis for the different 3D reconstructions, and the same method can be applied in the future to modify and refine some details or to extend the area covered by the model.

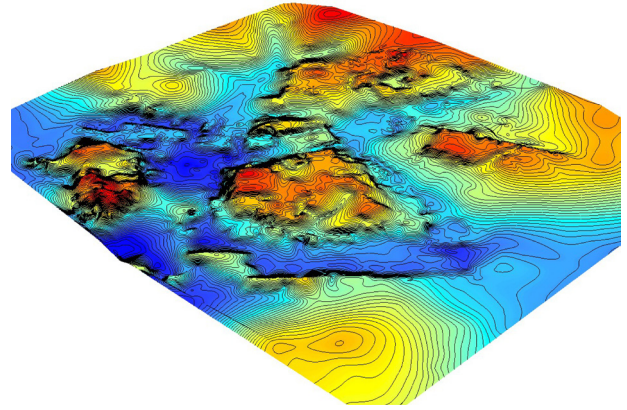


Fig. 2. DTM of Rome after the time of Nero (*post AD 64*).

### Java Software for Real-Time Visualization and the 3D Models

Reconstructing an ancient building through the tools of computer graphics, starting from the few known remains and documents, is already a common experience. Very often these models are meant as scenographic representations and do not pretend to represent true digital reconstructions.

A digital model is a very different thing from a mathematical model. A mathematical model is a set of algorithms, logical and mathematical expressions, which through a certain degree of approximation tend or try to represent a real phenomenon within a theoretical space and time, a virtual re-enactment. The possibilities of modern-day information technology allow us to build complex models, based on a large amount of data and metadata. The more the structures and relations between the various parts of the model become complex and sophisticated, the more we can consider the system an intelligent one.

In our work, we decided to optimize the nature of the 3D models according to the needs of



Fig. 3. High poly 3D model.

the presentation, and the times of response to the navigation instructions of the user. When building a model that has to respond in real time, the representation needs to be simplified, the model more “agile”, which reduces the lag but translates into a coarser representation of the different objects. This representational technique is known as low poly, and entails a very accurate selection of the polygon resources. The advantage obtained is a higher speed in the response and a reduced amount of data that has to travel over the internet, and consequently reduced streaming times. These models can be used to verify positions and relationships at the urban scale but cannot be used to analyze details and architectural styles. Because of this, every low poly model is related to a set of more detailed sections that are accessed according to need, zooming of a detail, and proximity to the screen surface. These sections can be layered to different scales of detail, and contain 3D models with varying degrees of accuracy according to the level of knowledge we have about each individual monument. In the event of very detailed analyses, the models can reach a high level of realism, both in shape and in the aspect of materials, using complex rendering techniques that can simulate non-linear natural phenomena, such as light diffusion, chromatic interferences, reflectivity of surfaces, etc. In these cases, the model used will be a high poly construction, which allows for stylistic comparisons, architectural and technical analysis (Fig. 3). The procedures used are those developed by architects Stefano Borghini and Raffaele Carlanì, called the “method at generative levels and queried elements”. This method forces each reconstruction to record not only the data and metadata accessed

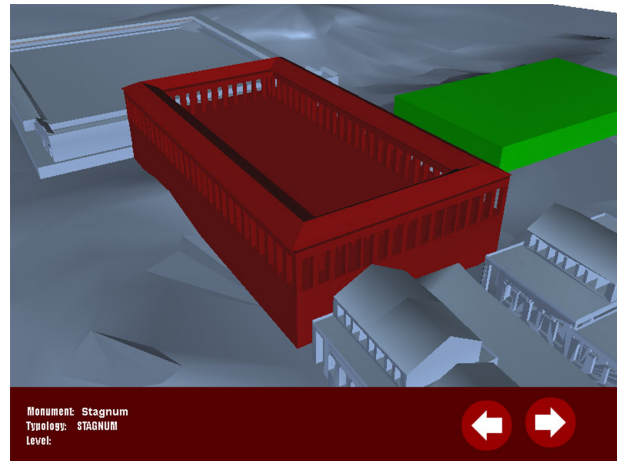


Fig. 4. Real-time 3D model.

during the process but also the generation processes underlying the models through the use of grades assessing the reliability of the reconstructions.

### The Website

The overall system that contains and connects the different components we have described is formed by a set of web pages built in HTML, XML and PHP, according to the role they have to fill within the system.

The main area is where the user navigates within the 3D model (Fig. 4) and queries the database. The queries are constructed by selecting metadata from a set of drop-down menus with standard contents (Fig. 5). We chose this method to simplify the level of interactivity, with a little less liberty of choice but a simpler and friendlier interface. This area was de-

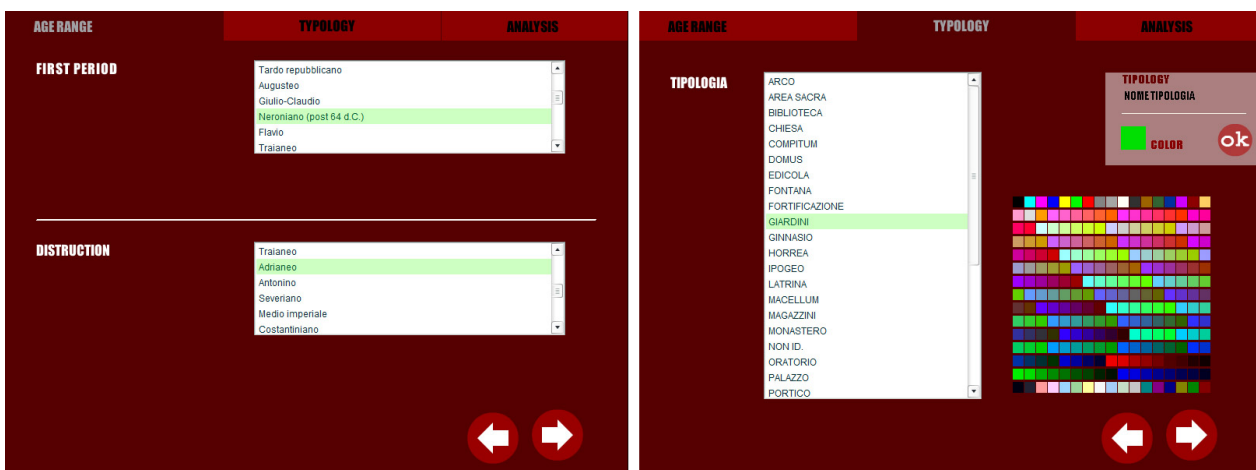


Fig. 5. Pull-down menu for query.

veloped in XML, and contains the java applications compiled for the management of the real time actions. Upon selecting a model, the user can access a description with all the relevant data compiled in HTML. The amount and quality of the information included in these descriptions depend on the amount of information available on the monument. It is possible to include excavation reports, papers, other 3D models, reconstructive renderings (both static and dynamic), photos, films, and a bibliographic list including scientific and other documentation, such as archaeological or tourist guides, which can be linked on the web with sites where they can be bought online.

Through an account system, the whole project could be implemented and updated following rules established by the site administrators. The entire code has been built with a modular and parametric system, which can be extended both horizontally (by the addition of new 3D models) and vertically (by inserting new details and information on an existing model) through update forms.

### *Future Developments*

The possibility of visualizing reconstructed monuments in real time is a function of technologies readily available to the average user. It is certain that the evolution in the graphic technologies and the rendering engines (on OpenGL and DirectX) will allow for more and more spectacular and convincing real-time navigation. This is the reason why the system includes a further development phase that will include a dedicated (proprietary) rendering engine developed within a C++ environment, which will be able to enhance the interpretative and informative experience.

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