CAA2015

KEEP THE REVOLUTION GOING >>>

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

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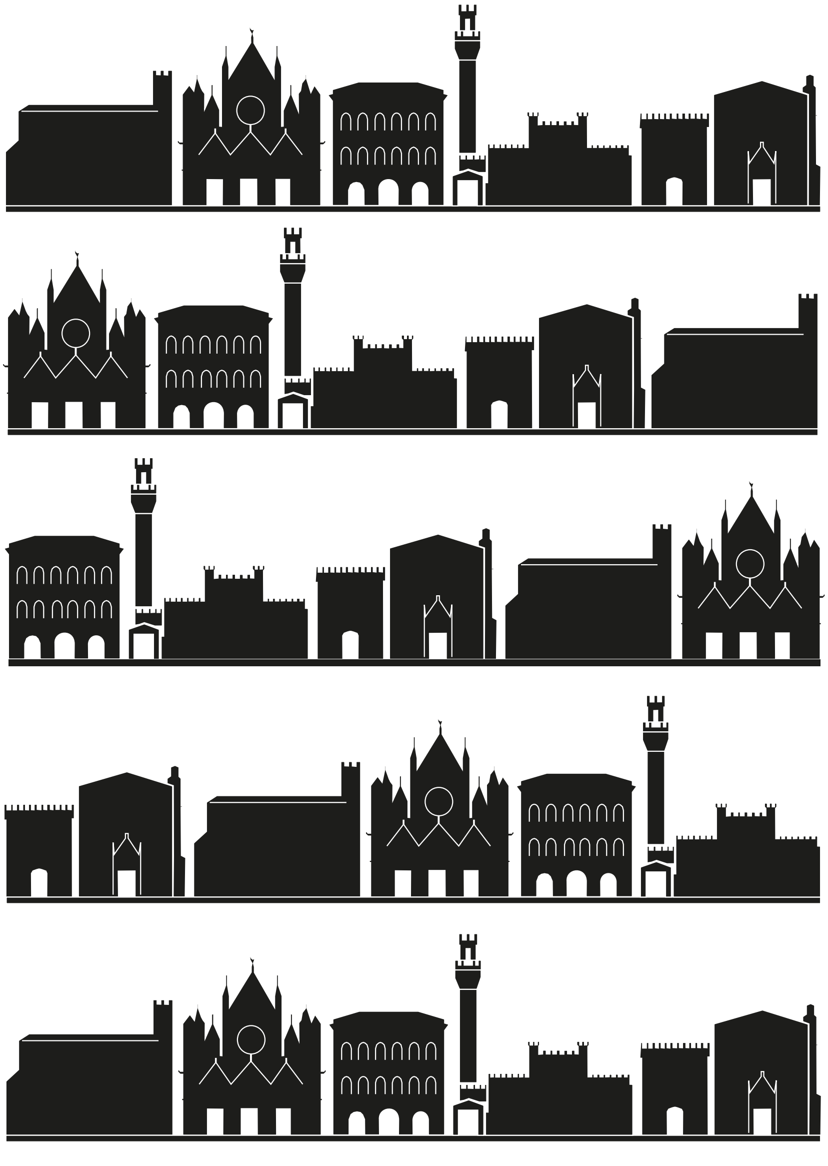
Volumes 1 and 2



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CAA Computer Applications & Quantitative Methods in Archaeology

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Real-time 3D Modelling of the Cultural Heritage: the Forum of Nerva in Rome

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Abstract: 3D modelling and the ability to view and navigate through reconstructions in real time enables people to gain an understanding of what places actually looked like, recreating their form and spatiality.

The case study is a real-time 3D reconstruction of the Forum of Nerva in the central archaeological area of Rome, which has as yet received little attention of this kind. The reconstruction employed the open-source Blender game engine.

Drawing on input from archaeologists and historians for its content, and the expertise with 3D modelling tools offered by specialists in forms of representation, this is the first time that an attempt has been made to reconstruct and explore the Forum of Nerva as it appeared in Imperial Roman and medieval periods.

Keywords: 3D modelling, Real-time 3D, Open source, Communication view

Introduction

Being able to reconstruct places and buildings from the past that are now considered part of the cultural heritage provides exciting possibilities.

3D modelling and the ability to view and navigate through reconstructions in real time enables both scholars and those without a scientific background to gain an understanding of what places actually looked like, recreating their form and spatiality. This opportunity stems from applications conceived for other sectors, and specifically from the software developed for video games. Thus, procedures that have hitherto been used only in the world of video games are transposed to 3D historical modelling and reconstruction. To ensure fluid navigation, the 3D models developed for this purpose must strike an effective balance between solid and surface modelling, using specific textures for historical reconstruction. It is also important to use appropriate algorithms, which make it easier to calculate shading and shadows.

1 Recent solutions

We have considered three 3D modelling and navigation initiatives for ancient Roman and medieval archaeological sites:

- Rome Reborn (http://romereborn.frischerconsulting.com/about.php);
- Virtual Aquileia (http://www.digitalheritage2013.org/virtual-aquileia/);
- The Sainte-Chapelle in Paris (http://paris.3ds.com/en-sainte-chapelle.html).

1.1 Rome Reborn

Rome Reborn (Dylla 2010) is an international initiative, the goal of which is to create 3D digital models illustrating ancient Rome's urban development for the first settlements in the late Bronze Age (*c.*1000 BC) to the depopulation of the city in the early Middle Ages (*c.*550 AD).

The initiative got under way in 1997, when the Virtual World Heritage Laboratory of the University of Virginia (VWHL) joined forces with the UCLA Experiential Technology Center (ETC), the Reverse Engineering Lab at the Politecnico di Milano, the Ausonius Institute of the CNRS, the University of Bordeaux-3, and the Université de Caen in collaborating on the creation of a digital model of ancient Rome as it appeared in late antiquity. The notional date of the model is 21 June 320 AD. Since 2009, the sponsor and administrative home of the project has been Frischer Consulting, whose mission is to apply 3D technologies to the study and dissemination of cultural heritage throughout the world.

The primary purpose of the project is to spatialize and present information and theories about how the city looked at that time, which was more or less the height of its development as the capital of the Roman Empire. A secondary goal was to create the cyberstructure whereby the model could be updated, corrected, and augmented.

The digital model reflects the sources of our knowledge about ancient Rome, which are of two kinds: archaeological data about specific sites and features ('Class I'); and quantitative data about the distribution of building types throughout the 14 regions (or wards) of the city ('Class II'). Features in Class I are known from archaeological excavations and studies; coins; inscriptions; ancient literary sources; and artists' views from the Renaissance until the nineteenth century. Features in Class II are known from two regionary catalogues (the Curiosum and the Notitia) dating to the fourth century AD.

The digital model as a whole consists of two types of materials: highly detailed models of buildings that can be reconstructed on the basis of reliable archaeological evidence (examples: the buildings in the Roman Forum and the Forum of Julius Caesar, the Flavian Amphitheatre, the Temple of Venus and Rome, etc.); buildings and other features that are known only by type and by frequency in the particular regions of the city. Approximately 200 buildings of the first type and between 7000 and 10,000 in the second category have been modelled.

Around 50 of the 200 Class I buildings that were modelled have been created with the help of scientific advisory committees of experts, while detailing operations are still to be completed for the remaining 150. The Class II buildings have been modelled by a procedure entailing the digitization (Guidi 2005) of the Plastico di Roma Antica created by Italo Gismondi from 1934 to 1974.

As regards dissemination, videos of the digital model have been posted for viewing starting in June 2007. In 2008 the 1.0 version of Rome Reborn was published on the Internet as 'Ancient Rome 3D' in Google Earth. In 2012, this layer was removed. From 2012 to 2013, a number of initiatives surfaced to use Rome Reborn 2.2 as the major asset for educational videos, whether shown in museums or on the Internet. Meanwhile, research was pursued by the leadership of the project on ways of making the model interactively available through a game engine.

1.2 Virtual Aquileia

Aquileia Virtuale is an Augmented Reality Real Time 3D app for Android and iOs tablets and smartphones, designed to provide a better understanding of the city's historical remains.

Aquileia was one of the largest and wealthiest cities of the Early Roman Empire until Attila destroyed it in the mid-5th century. Inscribed in UNESCO's World Heritage List in 1998, it is currently a small town and the ancient Roman buildings, except for the majestic basilica, are mostly unexcavated or buried under more recent buildings. The only way for people to understand what the ancient city looked like is through 3D reconstruction.

Funded by Fondazione Aquileia, the companies Ikon and Nudesign, who specialize in 3D modelling and mobile apps, have created 3D reconstructions and videos of most of the ancient buildings.

The Aquileia Virtuale app, which combines 3D images, videos, and real-time 3D models, allows users to visit Aquileia using their mobile device as a 'time window' and as a multimedia video guide. Walking around town, the visitor receives information on the ancient buildings nearby and, where there is a 3D model available, virtually 'enters' the building to explore it.

The real-time 3D models can be explored both on site (Augmented Reality) and off site (Virtual Tour): the visitor can move the mobile device around him to explore on site, or use the virtual joypads on the side of the screen when off site. This app allows an exploration of the 3D real-time reconstructed buildings using the GPS and the accelerator built in the devices, in an Augmented Reality mode, on the very spot where the original building was. There are also various hotspots inside the 3D models with information about buildings and objects that were present in antiquity.

1.3 The Sainte-Chapelle

With the 3D reconstruction of the Palais de la Cité in medieval times, the Dassault Systèmes Passion for Innovation Institute and the Centre des Monuments Nationaux (CMN) is widening the Paris 3D Saga's collection of monuments. The 3D experience allows credible reconstructions of buildings as they stood in the 14th century, such as the Tour de l'Horloge, the Galerie Mercière, the Trésor des Chartes, etc. With the help of laser digitalization techniques and in addition to the immersive 3D experience, Passion for Innovation Institute teams scanned the Sainte-Chapelle as it is now. The scan was then used as the basis for reconstructing the building in different periods, starting from the Middle Ages.

The model can be navigated in real-time 3D using the link http://paris.3ds.com/en-experience.html?lang=en

The initiative was connected with the *Saint Louis* exhibition, which celebrated eight centuries since Louis IX was born, and ran from 8 October 2014 to 11 January 2015.

2 Proposed solution

The case study is a real-time 3D reconstruction of the Forum of Nerva in the central archaeological area of Rome, which has as yet received little attention of this kind. The reconstruction employed the open-source Blender game engine.

Drawing on input from archaeologists and historians for its content, and the expertise with 3D modelling tools offered by specialists in forms of representation, this is the first time that an attempt has been made to reconstruct and explore the Forum of Nerva as it appeared in Imperial Roman and medieval periods.

2.1 Philology in the reconstruction of the Forum of Nerva

The central area of the Imperial fora in Rome has and continues to be the focus of a number of studies, investigations, and excavation campaigns by the Sovrintendenza di Roma Capitale and the Ministero per i Beni e le Attività Culturali.

The first surveys were carried out by the archaeologist Rodolfo Lanciani, whose investigations in the central portion of the Forum of Nerva in 1882 uncovered portions of the pavement of the plaza and the remains of the perimeter walls at a depth of 5.50 m from street level, enabling him to produce a conjectural layout of the Forum. At that time, the only visible architectural feature was the pair of columns known as the Colonnacce, which protruded from the ground by approximately half their height.

The first excavation campaign took place with the demolition of the Alessandrino district between 1926 and 1934 under the direction of the archaeologist Corrado Ricci. In 1940, the archaeologist Colini began to dig in the area of the Colonnacce and the Temple of Minerva, continuing until 1942 and unearthing the Porticus Absidata and part of the Cloaca Maxima.

Excavations in the Forum of Nerva were resumed in the 1970s, when the German scholar Heinrich Bauer, digging in the area of the west wall, discovered a foundation similar to that of the Temple of Minerva on the opposite side of the Forum, postulating that a temple dedicated to Janus had stood there. It was also suggested that a monument had been located at the centre of the Forum, as the Cloaca Maxima runs off to one side (Meneghini 2007).

Between 1985 and 1988, the Soprintendenza Archaeologica di Roma carried out an excavation campaign in order to understand the topography of the area bounded by the Curia, the Forum of Caesar, and the Forum Transitorium. Although these excavations confirmed Bauer's hypothesis regarding the existence of a second temple, the fact that the foundations were found to be badly cracked suggests that construction of this building was abandoned (Viscogliosi 2000).

The latest excavations were carried out between 1986 and 2008 by the Sovraintendenza ai Beni Culturali del Comune di Roma together with the Soprintendenza Speciale per i Beni Archaeologici di Roma (Meneghini 2009). Remains were found from the protohistoric and Imperial period and the Early Middle Ages. Until the 9th century, there are no signs of major changes and despoliation, as had occurred in the other fora. In this period, two-storied houses rose on both sides of a cobbled road that cut diagonally across the Forum, interspersed with vegetable gardens, fruit trees, and farmyards. They are 'Domus Solarate', houses with an upper floor, presumable aristocratic residences or 'curtes'. This group of 'domus' in the Forum of Nerva was abandoned and buried under about 2 m of soil between the 11th and 13th centuries.

2.2 The background for reconstruction

As excavations have proceeded over the years, our knowledge of the structure of the Forum of Nerva has increased, giving rise to a series of hypotheses for reconstruction.

Creating a three-dimensional model of the Forum of Nerva thus entailed a review of the many hypotheses that have been advanced by scholars, seeking a preliminary definition of the areas to be reconstructed through graphic modelling.

Starting from the latest theories deriving from the excavations carried out from 1986 to 2008, as outlined by the archaeologist Roberto Meneghini in his article 'Gli scavi dei Fori Imperiali. Bilancio di un ventennio d'indagine (1986–2008)', the basic structure of the Forum had already been established from the first excavations by Lanciani in 1882, with the raised structures and the position of the Temple of Minerva and of the Porticus Absidata. Later excavations investigated the west side of the plaza more thoroughly, raising questions about the Forum's termination towards the Basilica Aemilia. Another point that is far from clear is the actual course of the 45 columns making up the engaged colonnade. The only section of this colonnade that is still standing, the Colonnacce, shows an irregular intercolumniation, passing from 6.80 to 5.35 m. In this section, there is also a large and asymmetrically positioned architraved doorway, whose function as a passage towards the Forum of Peace has recently been called into question by the historian Alessandro Viscogliosi.

The irregular intercolumniation can be explained by the need to adapt the rhythm of the columns to a series of pre-existing openings giving access to the adjacent monumental plaza. This irregularity, which can amount to as much as 1 or 2 m is not apparent, however, when walking through the Forum, which is too narrow to afford a view of the entire length of the colonnade.

As it was not possible to reconstruct the Forum of Nerva with any certainty, modelling was necessarily based on an interpretation of the latest available information and thus remained at the level of hypothesis. This was especially true of the western part of the forum, which is still being studied. For this reason, the reconstruction drew on the layout postulated by the archaeologist Lanciani in 1882, with the colonnade running around the entire perimeter of the plaza.

Reconstruction of the remaining portion of the Forum was based on the findings of the most recent surveys, using ground plans drawn up by archaeologists, detail surveys of the elevated parts and, as regards the general appearance of the plaza, the testimony provided by classical authors, combining hypotheses and information with the assessments of scholars in the area.

2.3 Three-dimensional reconstruction methodology

The study involved 3D modelling of the Imperial Roman and early medieval periods. A practical outcome of the research is a real-time navigation of the Forum of Nerva, as it appeared in the two periods described, shifting from one age to the other, comparing site changes during the centuries involved.

The team which provide the reconstruction hypothesis comprises Tommaso Empler, Barbara Forte, Emanuele Fortunati, Riccardo Santangeli Valenzani, and Alessandro Viscogliosi.

The reconstruction of the Forum in the Imperial Roman period used the graphical layout proposed by the archaeologist Roberto Meneghini in his book 'I fori imperiali. Gli scavi del comune di Roma 1991–2007', which hypothesizes a possible configuration of the plaza without advancing theories about the parts that are still uncertain, such as the western termination of the Forum.

For the elevated parts, a dimensioned representation from the survey of the Colonnacce was used, and was entered in scale in a CAD application for subsequent vectorialization.

After entering the Forum's ground plan and section in the three-dimensional modelling program, the structural components of the model were constructed. The first operation was the extrusion of the perimeter walls that constitute the Forum's physical boundaries, using the 2D ground plan imported in the program and the section height. The second step was to extrude the columns, which called for more detailed modelling because of the cornices making up the entablature, which projects from the wall behind the shafts, and the capitals.

The colonnade of the monumental plaza was put together from the detailed model of a single column, its capital, the cornices and the projecting entablature. The single column was duplicated using the modeller's array function, which makes it possible to reproduce an object at precise distances along three Cartesian axes. The replicated objects are identical copies of the original and are linked together so that modifying any one of them will modify them all at the same time. The entablature between each column and the next was produced by creating a connecting band, which was then replicated between all the shafts.

In reconstructing the Temple of Minerva, it is necessary to have a knowledge of certain generic features that commonly recur in Roman temples, such as the type of monumental door, the pavement, the roofing, and the probable, though as yet unascertained, presence of acroteria.

The Temple was modelled on the basis of the historical iconographic sources that have come down to us today, while the portions that have survived were completed using assumptions based on probable similarities and correspondences. This is the case, for example, of the pediment of the Temple of Minerva, the few remaining fragments of which do not permit a definitive reconstruction of the original architecture. The major question in reconstructing the pediment concerned the frieze with the dedicatory inscription and its relationship with the mouldings on the side entablature. After first hypothesizing that the trabeation extended across the entire front of the temple, connecting the two side branches as suggested in a historical document that has come to light, we opted for a 'modus operandi' found in other structures of the same period such as the Temple of Vespasian (De Angelis 1992), where the frieze takes up the entire height, including the trabeated portion, and includes the inscription under a cornice with palmettes. Once this point had been decided, the problem arose of how two resolve the two frontal corners of the side entablature, consisting of several stepped mouldings with the smooth portion bearing the inscription. This issue was clarified by considering the historical representations by Dosio and Palladio (Viscogliosi 2000), which illustrate how the two elements were related, with the trabeation extending to the front of the temple, but only for a small space, thus gracefully connecting the sides without interfering with the inscription.

Interpreting the documentation for the early Middle Ages is more complex because of the lack of urbanistic information in the area of the Imperial Fora. Although the recent excavations brought to light portions of the houses (*domus solarate*) built in the Forum starting in the 9th century, not enough remains to permit us to draw up accurate ground plans which would provide a good overall view.

Combining the information provided by excavations and literary sources makes it possible to interpret structures such as the typical two-storied Domus Solarate, with a lower storey consisting of drafted rectangular blocks — *opus quadratum* — of tuff, and a brick upper storey, but not to establish their real shape and size. Accordingly, three-dimensional modelling was based on a constructional interpretation.

Once again, modelling started from the generic and incomplete ground plans provided in 'I fori imperiali. Gli scavi del comune di Roma 1991–2007' by Roberto Meneghini and Riccardo Santangeli Valenzani, which show the surviving portions belonging to the above-ground structures and offer a hypothesis of how they might have been completed, but do not indicate their precise location in the Forum.

An important reference for modelling the area as it appeared in the early Middle Ages is the reconstructed view produced by Inklink for the Sovrintendenza Capitolina. Another aspect that is of fundamental importance to the 3D model's graphic reconstruction is the presence of vegetation. To achieve an effect that reliably represents the area in the 9th century, it is essential to include natural elements in all parts of the Forum of Nerva, from the packed earth that almost entirely replaced the marble pavement, to the cultivated vegetable gardens and stands of fruit trees, and the invasive plants, such as the ivy clinging to the walls, without forgetting the moss and lichens covering the crumbling stonework. Materials and coverings were checked and evaluated together with scholars specializing in this historical period.

As noted by Felinto (2013) it was also necessary to optimize the modelling techniques to ensure that the application does not slow down during calculation and use. As the intention was to make the application suitable for the widest possible range of users, it was necessary to create a versatile 3D model that does not entail a heavy processing load. Accordingly, the following procedures were used to guarantee a faster program:

- Simplified collision
- Modelling only visible features
- Faked modelling
- Substituting physical models with alpha textures
- Use of power-of-two textures
- Fake reflection

The combined use of these measures at the time of modelling makes it possible to simplify real-time calculation, ensuring the model's fluidity without detracting from the appearance. A low-poly mesh collision model, which can also involve complex objects such as stairways and columns, is created for navigation mesh path finding, and the overly detailed objects in the background are replaced with simplified objects to which high definition textures are applied (Fig. 1).

In the same way, physical objects such as vegetation and the complex details of the architecture are eliminated, replacing them with alpha textures that reproduce their features. Image management during loading was also optimized by using only textures sized in powers of two. Given that it is not possible to recreate the effect of reflection in three-dimensional models intended for navigation, surfaces that were to be reflective were made semi-transparent and a specular model was placed beneath them (Fig. 2).

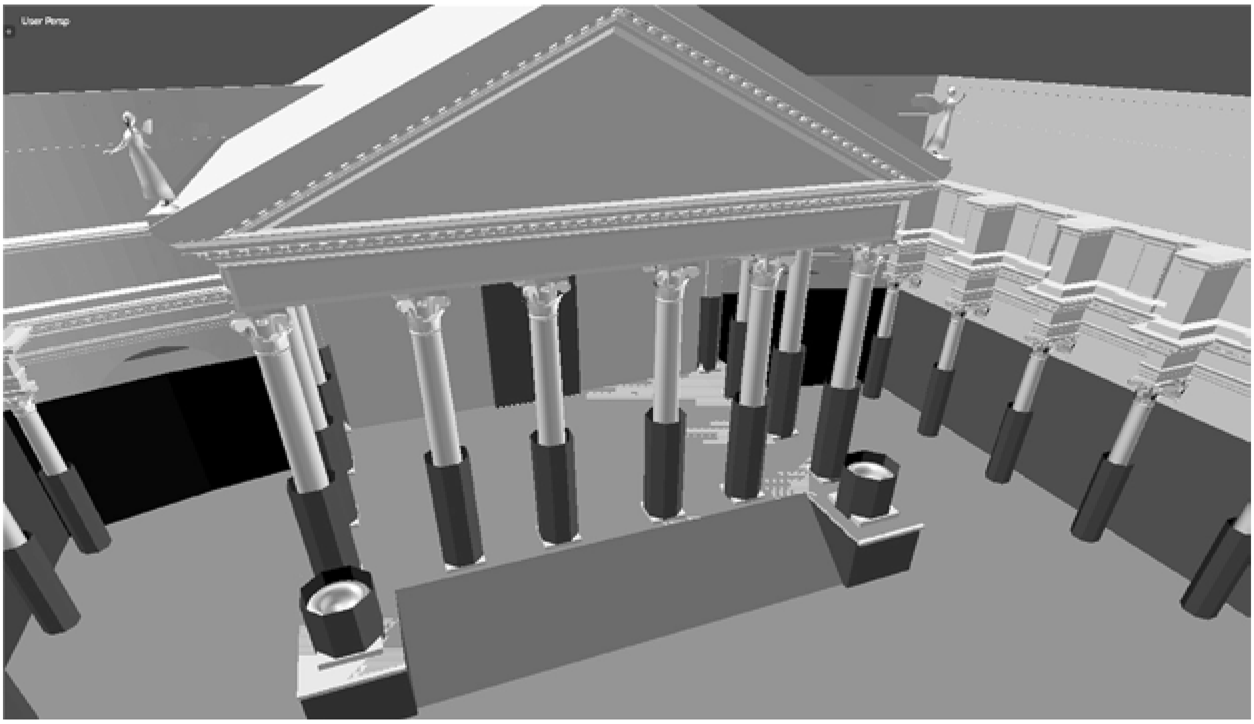

Fig. 1. Objects with high definition textures applied.

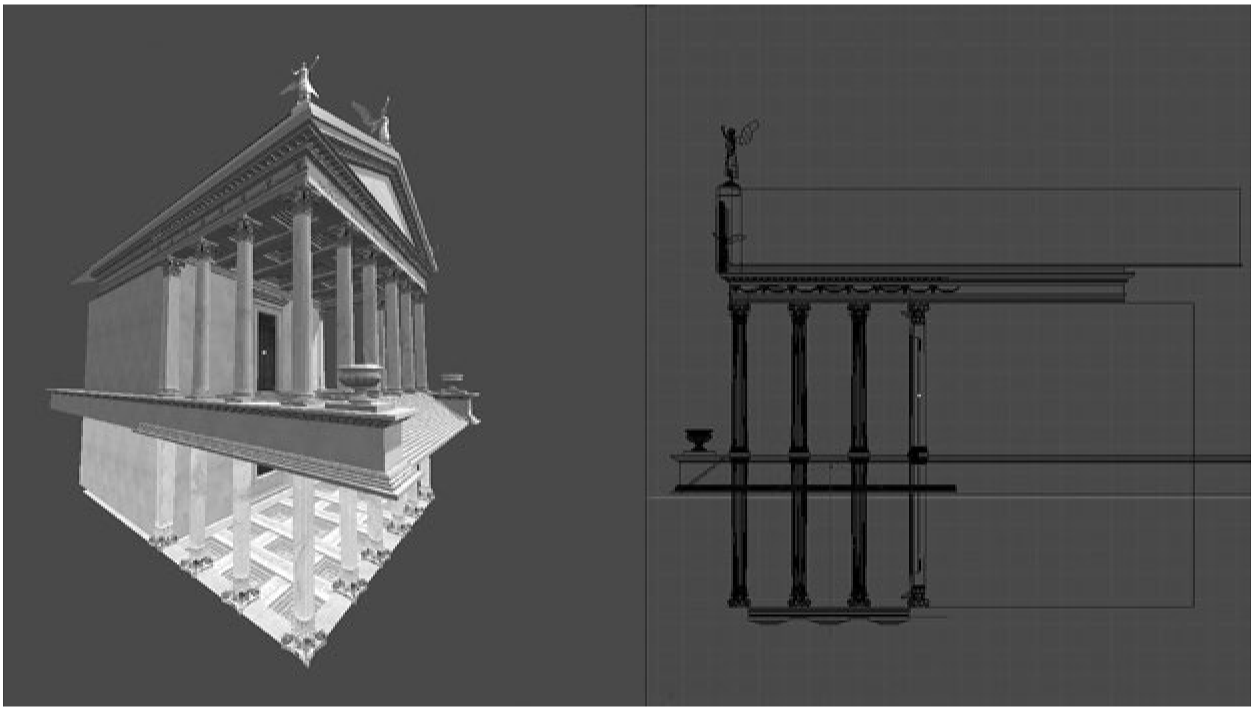

Fig. 2. Surfaces that are to be reflective are made semi-transparent and a specular model is placed beneath them.

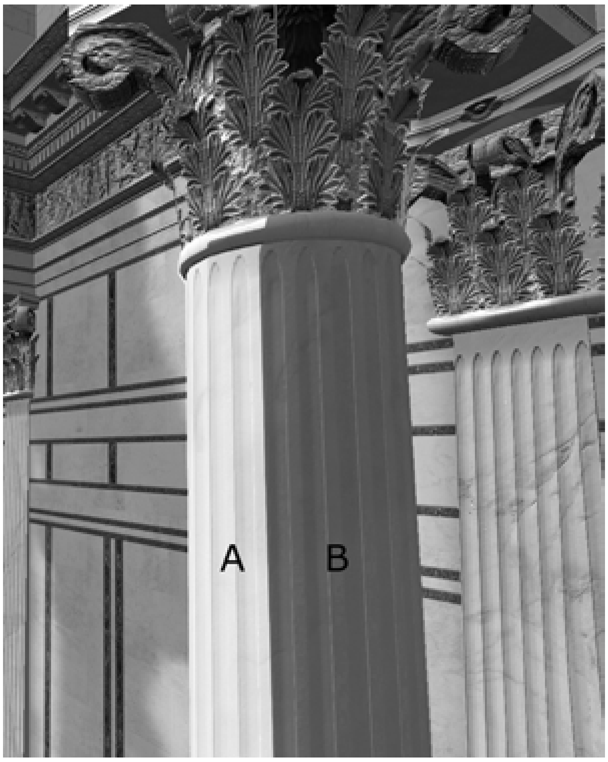

Fig. 3. Texture mapping procedure to simulate fluting on the columns.

Fig. 4. Texture mapping procedure to simulate fluting on the columns.

To ensure that three-dimensional models are complete and realistic, it is essential to apply photorealistic textures which can evoke (in the case of archaeological sites) or present (in the case of architecture) the atmosphere and sensations that the visitor experiences or would have experienced at that particular site. Consequently, it is important that the quality of the applied images is very high, and that the current features — or those that existed in the past — are reproduced as accurately as possible.

Texture mapping used a stack of texture layers, such as Diffuse, Bump, Specular, and Normal Mapping. Layering textures provided a very high level of photorealism while at the same time simplifying the texturing operation and the program's calculation operations. To circumvent some of the specific problems associated with the faked modelling of certain objects, we used nodal materials, which combine different basic materials on the basis of the light striking the object to which the material is assigned. For instance, since in our case the fluting on the columns was simulated with normal maps rather than modelled, this detail was lost in the shaded part but was restored thanks to a nodal material that blended together the specific material for the illuminated part of the column and a specific material for the shaded part, with much more evident fluting (Figs. 3 and 4).

A further texturing technique that was used is Vertex Painting, which is a way to paint meshes manually, directly manipulating the colour of vertices that make them up through a colour gradient. This makes it possible to map a large surface such as the packed earth that serves as the background for the early medieval forum, and add dirt to all the other surfaces, producing a different effect for each feature.

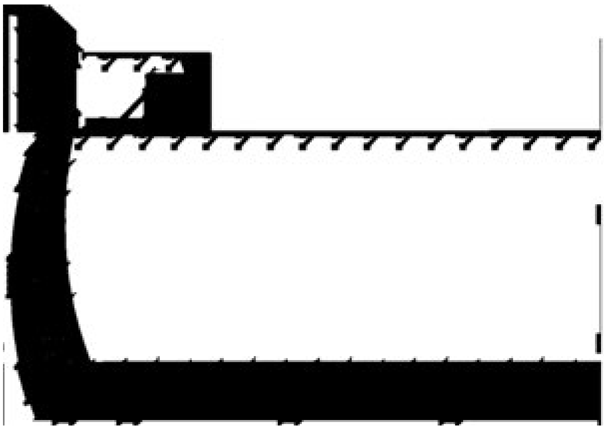

Fig. 5. Pre-calculated shadow mapping in the 3D modelling.

Shadow mapping, which is also called projective shadowing, is a process whereby shadows are pre-calculated in three-dimensional modelling applications (Fig. 5). The technique is not restricted to rendering (static images), but is also used in real-time images, video games, and cinema. Shadows are generated on the basis of whether or not the portion of the surface is visible from the light source: this information is projected to the camera and depth is compared to check whether a given point is illuminated or not, colouring it accordingly. Starting from the principle that the side of an object that is visible from a light source is illuminated and, conversely, the parallel and opposite side is necessarily shadowed, the view from the light source is rendered by deactivating all other

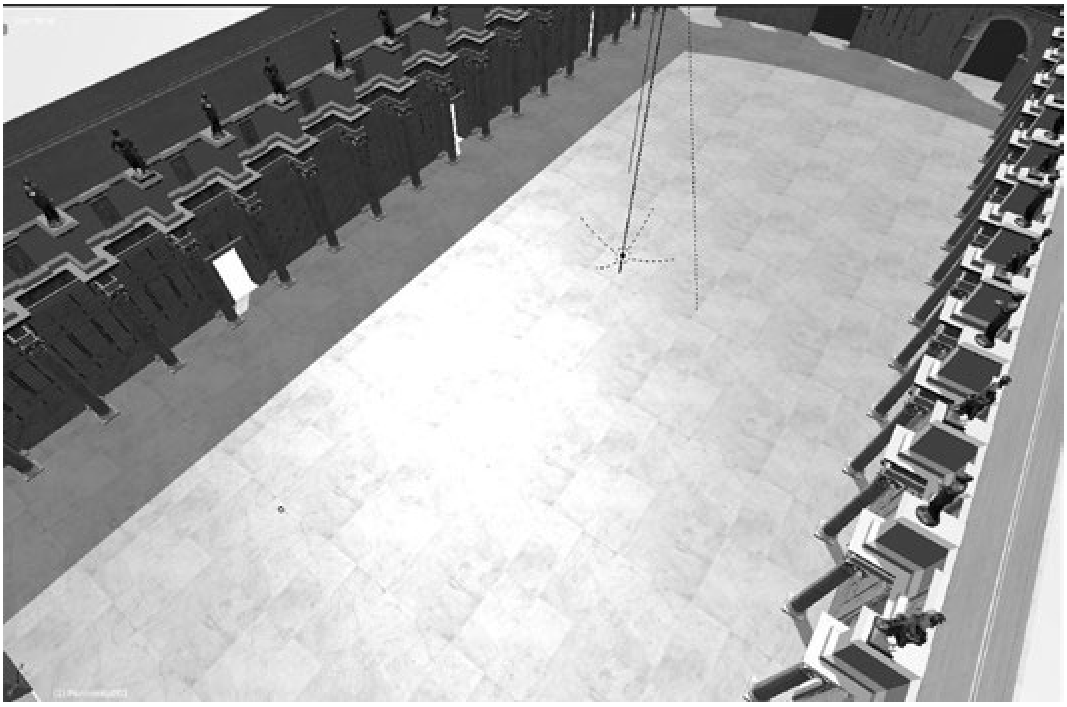

Fig. 6. The shadow mapping technique, especially when working with real-time images, is a valid and significantly faster alternative to computing shadows continuously with the graphic processor.

unnecessary factors, including the texture colour component. That done, all of the parts of the scene are rendered, comparing the depth of each point with the shadow map projection in the camera view space: if a point is behind the shadow map, it is shadowed. The shadow mapping technique (Fig. 6), especially when working with real-time images, is a valid and significantly faster alternative to continuously computing shadows with the graphic processor. In addition, it is not like 'dirtying' the material, in other words a level that darkens the object and cannot be changed, but it reacts to the addition of new light sources and thus produces the effect of a real shadow.

3 Experimental results

3.1 Real-time visualization

Three-dimensional modelling was performed with Blender, an open-source 3D modelling application whose programming structure features a game engine which is capable of managing simultaneous multiple events that permit real-time visualization, including:

- Scene rendering with texturing and light effects
- Physics engine
- Management of sound events
- Management of source code scripts
- Animations

Together, these characteristics permit 'subjective' movement simulation, which is achieved with single images produced in a short periods so as to have between 30 and 60 fps (frames per second), thus providing a smooth visualization.

A navigable model must achieve an effective trade-off between the number of polygons in the 3D model and the processor's ability to run a sufficient number of frames per second to ensure that movement is always smooth. The model must thus be optimized from the viewpoint of the 'virtual camera' located at about 1.70 m above ground level.

After the 3D models for the Imperial Roman and early medieval periods were created and the necessary simplifications were made in terms of polygons and applied textures, the Blender Logic Editor was used to set up and edit the game logic for the objects present on the scene in real-time. The logic for the objects created and selected in the 3D panel consists of logic bricks, which are shown as a table with three columns, indicating sensors, controllers, and actuators. The links joining the logic bricks conduct the pulses between sensor-controller and controller-actuator and permit the physical actions that take place in the scene, indicating the direction of the logical flow between objects. The properties of the game are the variables used to store and access the data associated with each modelled object (Fig. 7). The models for the two historical periods were exported in a standalone .exe player file which allows the models to be run without having to load the program that generated them, in this case Blender.

The structure of the navigation interface was also developed with the Blender Logic Editor. Its objectives are to guarantee smooth navigation mesh movement through the keypad and joypad (such as the Dualshock4 wireless controller for PS4), to make it possible to pass quickly between the Imperial Roman and early medieval models, and to provide interactive

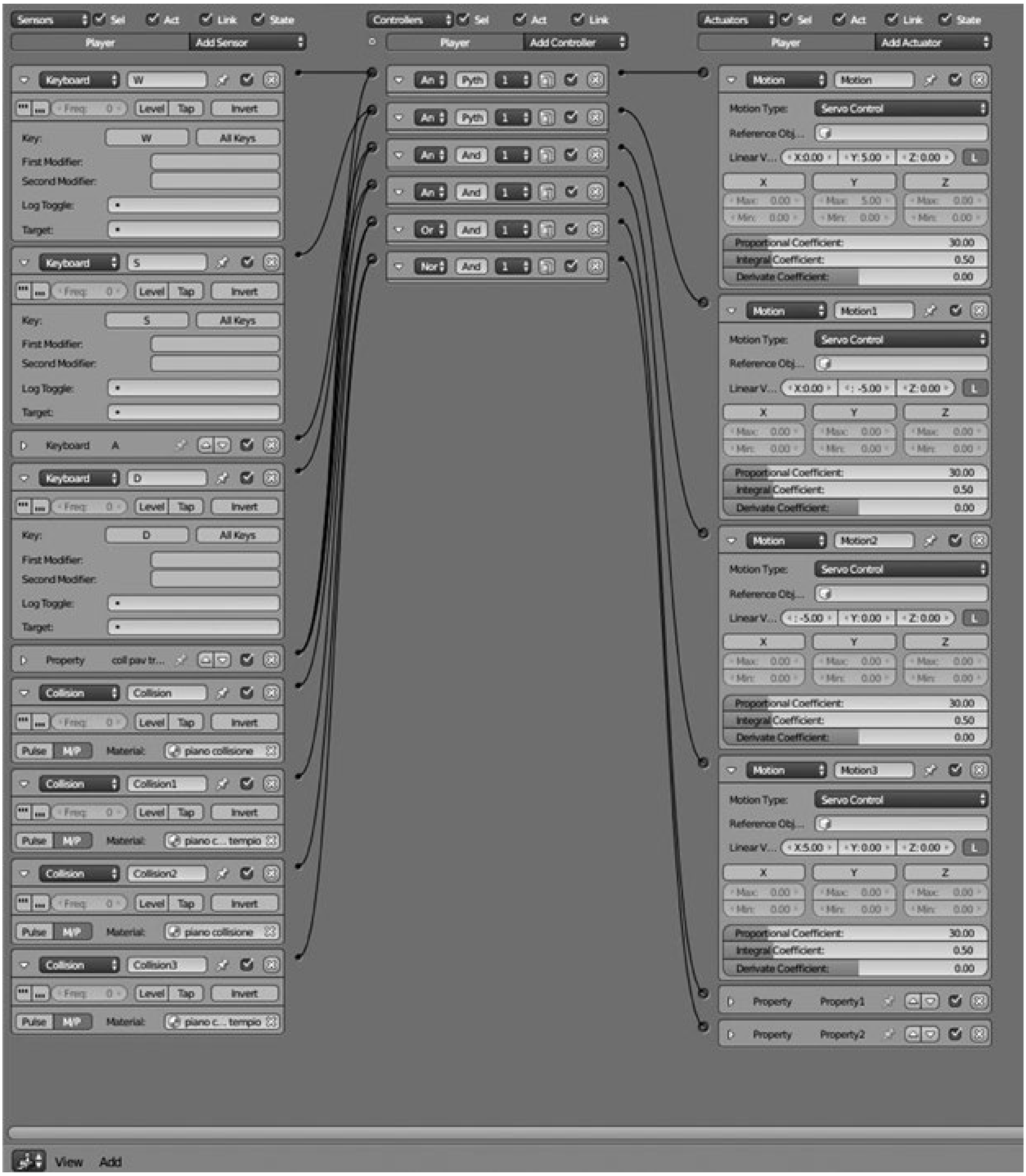

Fig. 7. The logic for the objects created and selected in the 3D panel consists of logic bricks, which are shown as a table with three columns, indicating sensors, controllers, and actuators.

information hotspots that can be accessed for all parts of interest in the 3D models. Hardware controls can be interfaced with input commands with the aid of several logic diagrams and scripts (Fig. 8).

The system with which the end user interfaces with the application includes a main menu, where the user can chose to begin navigating in person in one of the two historical periods, two models in axonometric view with the information hotspots that can be found while navigating through the model, and a screen with a map of the commands that can be used (Figs. 9–11).

4 Conclusion

Being able to use open-source tools to create real-time navigable 3D reconstructions opens up new and interesting prospects for communicating the cultural heritage, thanks to lifelike and photorealistic visualizations of objects and sites from the past. This enables scholars to verify hypotheses

```
        ### Mouselook System ###
        if self.props['mouselook']:
            if not self.features.get('mouselook', None):
                self.addMouselook()

        ### Staticmove System ###
        if self.props['static']:
            if not self.features.get('static', None):
                self.addStatic()

        ### Dynamicmove System ###
        if self.props['dynamic'] and not self.props['static']:
            if not self.features.get('dynamic', None):
                if self.own.parent:
                    self.addDynamic(self.cont)

    def main(self):
        # Refresh properties
        self.props = self.getProperties('mmc')
        self.controls.main()

        cursor = self.props['cursor']
        if cursor in [True, False]:
            render.showMouse(cursor)

        for i in self.features:
            if self.props[i] == True:
                self.features[i].main()
            elif self.features[i].ready == True:
                self.features[i].deactivate()

    def create(self, key, object):
        features = {'mouselook':Mouselook, 'static':StaticMove, 'dynamic':DynamicMove}

        if key in self.features:
            msg('Core Feature "', key, '" already created! Returning None')
            return None

        newFeature = features[key](self, object)
        self.features[key] = newFeature

        return newFeature

    def addMouselook(self, object=None):
        self.setProp('mmc.mouselook', True)
        return self.create('mouselook', object)

    def addStatic(self, object=None):
        self.setProp('mmc.static', True)
        return self.create('static', object)

    def addDynamic(self, object=None):
        self.setProp('mmc.dynamic', True)
```

FIG. 8. HARDWARE CONTROLS CAN BE INTERFACED WITH INPUT COMMANDS WITH THE AID OF SEVERAL LOGIC DIAGRAMS AND SCRIPTS.

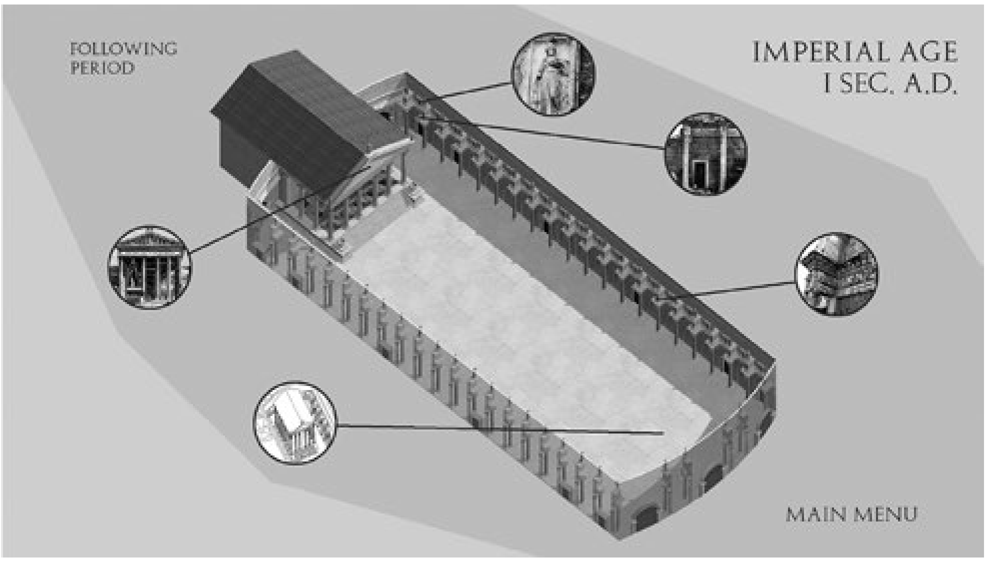

FIG. 9. IMPERIAL AGE MODEL IN AXONOMETRIC VIEW WITH THE INFORMATION HOTSPOTS THAT CAN BE FOUND WHILE NAVIGATING THROUGH THE MODEL.

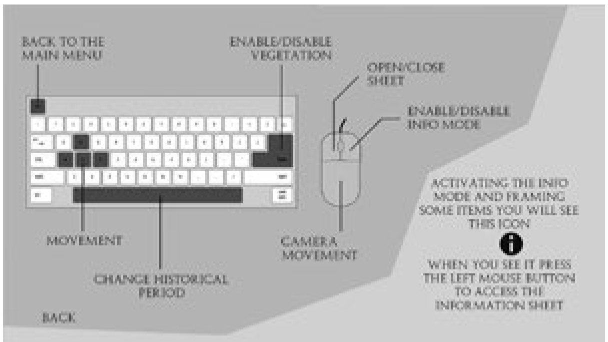

Fig. 10. Screen shot with a map of the keyboard commands.

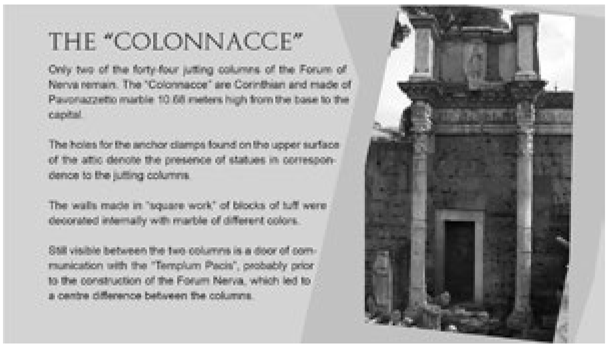

Fig. 11. One of the hotspot fact sheets of the Imperial Rome Age model.

Fig. 12. Real-time image of Imperial Rome Age. View from the west.

Fig. 13. Real-time image of Rome in the Middle Ages. View from the west.

Fig. 14. Real-time image of Imperial Rome Age. View from the south.

Fig. 15. Real-time image of Rome in the Middle Ages. View from the south.

regarding reconstruction and/or modify them in real time, while visitors can gain an understanding of what a site actually looked like in the period of its greatest splendour (Figs. 12–17).

The next stages of the research are in two main directions. The first will contemplate on the reconstructions of the Forum of Nerva in the Baroque period, late 19th century, and before the 1930 demolition. The second plans to extend the 3D reconstruction and the real-time navigation to the entire area of the Imperial Forums and the methodology can be applied to other sites of archaeological interest.

Furthermore, as visualization systems are evolving towards less powerful computing tools, such as smartphones and tablets, while maintaining an effective level of photorealism, the use of tools like blender4web and unity will allow the use of the real-time methodology described, including the shifting procedure from one age to another, directly on portable devices.

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Fig. 16. Real-time image of Imperial Rome Age. View to the north side [looking north?].

Fig. 17. Real-time image of Rome in the Middle Ages. View to the north side [looking north?].

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