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Permalink

<https://escholarship.org/uc/item/1qw6p68f>

ISBN

9781407307213

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Publication Date

2010

Peer reviewed

The final publication is available via BAR Publishing at

https://www.barpublishing.com/?subcats=Y&pcode_from_q=Y&pshort=Y&pfull=Y&pname=Y&pkeyword_s=Y&search_performed=Y&q=Cyber-Archaeology&dispatch=products.search

Please cite this chapter as follows: Lercari, N. An Open Source Approach to Cultural Heritage: Nu.M.E. Project and the Virtual Reconstruction of Bologna. In M. Forte (Ed.), *Cyber-Archaeology* (pp. 125-133). Oxford: Archaeopress, BAR Int. Series 2177.

AN OPEN SOURCE APPROACH TO CULTURAL HERITAGE:

Nu.M.E. PROJECT AND THE VIRTUAL RECONSTRUCTION OF BOLOGNA

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Abstract

Nu.M.E. (New Electronic Museum of the city of Bologna) is a multidisciplinary project involving historiography, museum studies, and computer science. Since the late 1990's it has been answering complex methodological questions with the aim to concentrate, on a single digital platform, the results of many years of research in the field of urban history. The case study of Nu.M.E. is the city of Bologna, in Italy, and its millenary tradition of urbanization. In its 2009 release, the project strives for the definition of new methodologies of cultural transmission for the general public. Nu.M.E. 2009 also adopts a new perspective based on cutting edge, open source technologies. Such choices make it possible to demonstrate that 3D graphics, real-time engines, and interactive storytelling can be useful tools for philological representations of ancient urban landscapes. At the same time, our research evidences that these technologies are fundamental resources for contemporary museology. This paper surveys the problems that emerge in analysis and communication of the medieval urban landscape of thirteenth-century Bologna and will present a new method of interpretation, and visualization of historical data.

Keywords: comparative analysis, sources-based virtual reconstruction, open source, interactive storytelling.

Introduction

The conformation of Bologna's urban landscape is the result of a very long tradition of human activities. Since the Iron Age, when the small village of Felsina was founded by Etruscans in that area, c. 510 BC (Sassatelli 2005), the site of current city has been involved in several phases of historical changes. During the Roman Empire, Middle Ages, Renaissance, and Modern Period many social, political and economic phenomena played a role in the definition of the city's space. This fertile historical context has generated a vast and composite amount of sources and data, most of which are still today available in local archives and libraries.

The Nu.M.E. (New Electronic Museum) project was started in the late 1990s by Francesca Bocchi, professor of Urban History at the University of Bologna. It is an attempt to define a valid methodology for studying Bologna's urban history using a spatial approach and digital technologies. As a decennial research project, Nu.M.E. has adapted to the evolution of computer graphics over time (Diamanti 2007), facing, in every single version, different historiographical issues and technical challenges (Guidazzoli and Bonfigli 1999). The original idea of adopting a rigorous and philological attitude toward virtual reconstruction has never changed, though. During the past decade Nu.M.E. has dealt with the three dimensional

reconstruction of some parts of the historic centre of Bologna with the aim to visualize transformations of urban structure and road networks, from the late Middle Ages to the present

(Put Figure 1 here).

In 2009 new emphasis is given to Nu.M.E.; this happens because some local stake holders, such as municipality of Bologna and *Fondazione Del Monte*, decided to support the creation of the Museum of the City of Bologna (which will open to the public, approximately in 2011 in the medieval complex of *Palazzo Pepoli Vecchio*). The circumstance introduces a new moment of reflection on cultural transmission techniques for the general public. It also opens the way for the beginning of our research, about the communicative aspects of virtual heritage projects.

Nu.M.E. 2009 historical context

This release of the project focuses on one of the most representative moments of Bologna's urban history: the thirteenth century

<Fig. 2 approximately here>

According to Bocchi (2007, 233-241), the death of the Holy Roman Emperor Henry VI, in AD 1197, determined Bologna's independence and had very important outcomes on the city's destiny. The municipality obtained absolute power, and was able to concentrate a great amount of economic resources in the creation of public infrastructures. In AD 1200 a relatively long period of peace began, and an ambitious project of urban development started (Huber 2000, 3-9). It was characterized by the construction, in a temporal range of about a century, of the main urban public space (called *curia Communis*, which corresponds to current *Piazza Maggiore*) and several new buildings (*Palazzo del Comune*, *Torre dell'Arengo*, *Palazzo di Re Enzo*, *Palazzo della Biada*) with political and economic functions, all around it.

<Fig. 3 approximately here>

A wide suburban area (*Campo del Mercato*) was dedicated to the weekly cattle market, while an extensive system of canals was dug to the benefit of river navigation and textile manufacturing. To defend the city from a potential enemy attack, the construction of an impressive fortification (the so called *Circla*) was started, as well. The date of its completion was AD 1327, but it is very probable that in the late 1220s the whole city was already surrounded by a moat and a palisade (Bocchi 2005, 243-246).

For these reasons, the thirteenth century can be easily seen as a context of a radical process of spatial reconfiguration that completely modified the late medieval structure of Bologna. These historical dynamics shaped the central part of the city so intensely that they even created the basis for the current configuration of downtown. All the mentioned historical events are furthermore documented by an abundant set of both iconographic and documentary sources. Such characteristics make late medieval Bologna an optimal context for doing research on virtual reconstruction techniques; they also give us the opportunity to test different methodological and communicative approaches on a solid informative basis

<Fig. 4 approximately here>

Sources-based virtual reconstruction

While other disciplines that deal with the interpretation of the past and relics take advantage of spatial relations interpretation, the study of history, rarely, has the opportunity to benefit from spatial analysis of data. With this in mind, we reflect on the use of digital technologies in historical research and try to answer the following questions: is the comparative analysis of ancient sources a valid methodology for the virtual reconstruction of early cities? Can iconographic material be a useful resource for the development of a virtual museum on Middle Ages lifestyle in Bologna? The development of Nu.M.E. 2009 helps us find answers. This release of the project demonstrates

that 3D graphics and real-time engines can be useful tools for a philological representation of an ancient urban landscape. Working on three dimensional scientific visualization of a set of historical information, we determined that a traditional historiographical description of an urban place is not sufficient to be used as base of modelling activity. The geometrical representation of historical places, that time has altered or destroyed, needs a very deep knowledge of all urban structural components

<Fig. 5 approximately here>

This circumstance pushes historians to find new relationships between data and sources, in the attempt of gathering very precise information on both architectural elements and construction techniques. At the same time, it requires that 3D modellers be dialectically involved in a discussion on content creation. It is also necessary that computer scientists, while working on visualization of the models, be aware of all the problems and needs belonging to historiographical investigation. The result of the methodology that we used in Nu.M.E. is a multidisciplinary approach that opens new perspective for urban history, and reduces the gap between humanities and information science. Let us take a step back and focus on the description of the specifics of our case study. In Nu.M.E. 2009, the spatial visualization is focused on the most important parts of 13th century Bologna, specifically the area between current *Piazza di Porta Ravegnana* and *Piazza Maggiore*

<Fig. 6 approximately here>

The historiographical survey of this area is based on comparative analysis of documentary and iconographic sources. All the information is recorded in relational databases and, then, connected to a Geographical Information System (Bocchi 1999b, 11-28). This method permits both the development of spatial frameworks for analysing human activities on the urban landscape, and the implementation of a robust grid for virtual reconstruction. To get a scientific

value this methodology follows guidelines and criteria about the study of urban history, issued by The International Commission for the History of Towns (ICHT).

Comparative analysis, in the study of Bologna's past, is a condition that can be effective because the history of the city is evidenced by a very significant documentation; that is because a great amount of historical material has been produced by notaries, religious institutions, and municipality officers since the late Middle Ages. Such a rich data set is constituted of several private and public documents:

- rental contracts of lands between religious institutions and private citizens (*enfiteusi*);
- real estate property contracts;
- medieval cadastre (*Estimi*) held by the municipality since the second half of 12th century;
- early urban planning documents (*Libri terminorum*) that described, in a very precise way, the position of pillars, porches, balconies, and roofs, in order to define the limit between public and private space, both on the ground level, and in elevation.

The work of prestigious Italian artists and cartographers, furthermore, gives our three dimensional representation of Bologna the opportunity to be founded on several iconographic sources. The visual material we used in Nu.M.E. can be subdivided in two different sections. The first consists of a composite set of early matter such as:

- miniatures (e.g. Drappieri Miniature – AD 1523 - Giovan Battista Cavalletto – Civic Medieval Museum, Bologna, Italy);
- frescos situated in Bologna (e.g. *Madonna del terremoto* – AD 1505 – Francesco Francia – *Palazzo Comunale*, Bologna, Italy);
- frescos situated in other cities (e.g. Allegory of Good Government – Ambrogio Lorenzetti – 14th century – *Palazzo Pubblico*, Siena, Italy);
- perspective Renaissance cartography (e.g. The perspective map of Bologna –

Scipione Dattili – AD 1575 – The Pope's apartments, Vatican City);

- topographic maps (e.g. topographic map of Bologna – AD 1833).

The second section, instead, is made of recent images obtained through optical instruments:

- early 20th-century pictures collections (e.g. *Collezioni d'Arte e Storia della Cassa di Risparmio in Bologna*);
- aerial photos;
- satellite photos.

Thanks to this great availability of historical sources, the accuracy of 3D models in Nu.M.E. is very high.

<Fig. 7 approximately here>

This goal has been obtained by performing complex methodological tasks such as:

- quantitative analysis of cadastres and legal acts;
- architectonic analysis of building components (e.g. pillars, windows, doors, etc.);
- spatial surveys, about volumes and arrangement, of projecting roofs, balconies, porches and other above ground assets;
- reflections on physical and mechanical properties of materials and buildings;
- ancient cartography analysis;
- comparison between early and recent representations of the city;
- analysis of monumental complexes and geographical landmarks;
- systemic comprehension of urban structures and road network through Geographical Information Systems.

Such a rigorous approach permits us to get a correct and precise virtual reconstruction of the urban space of Bologna. It also defines a standard for representation of early cities through digital technologies. Although it is possible to choose different forms of virtual reconstruction, it has been demonstrated that our methodology can be considered as an effective way to keep a virtual heritage project in balance

between technological dimension, communicative effectiveness and cultural value.

Open source technologies for virtual heritage

The originality of our research project is not only methodological. The technological perspective of Nu.M.E. 2009 brings innovation in the field of cultural virtual environments and can be seen as a mature example of ‘musealization’. We developed a workflow that starts with historiographical investigation on medieval sources, designs a specific communicative process based on them, and eventually implements a complex visualization system based on cutting edge technologies.

<Fig. 8 approximately here>

This is because we decided to focus our research activity not only on the development of historiographical contents for the virtual reconstruction, but also in 3D visualization. In computer science the term ‘open source’ indicates a software released with a type of license that permits the source code to be available to anyone who requests it. In this way developers can take advantage of the collaboration, usually free and spontaneous, of a community of users. The final product of this collaborative process can reach a level of complexity and efficiency that could not be obtained by a single group of programmers.

The model of development we adopted in our project can be defined as open source, as well. The approach of Nu.M.E. 2009 can be described in this way because it pursues a more ethical use of technology. The need to identify effective and alternative models of development is a priority in a field, such as virtual heritage, in which the availability of funding is often limited. An open source approach is particularly effective because it is aimed at obtaining a collective cultural progress based on sharing of expertise between groups of developers and users. This more ethical use of technologies allows for evident advantages such as:

- reduction of software licensing cost;
- sustainability of projects;

- sharing resources and results with other academic institutions;
- extreme portability of file formats;
- quality and usability standards based on community review.

The technological aspect of Nu.M.E. 2009 can be seen as an example of an open source approach in the field of virtual heritage. What follows is a brief overview of all the technical components that are involved in our project. All computers that we used to implement and visualize the virtual environment were running the Unix-like operating system Gnu/Linux Ubuntu. 3D modelling and UV unwrapping texturing have been performed using the powerful open source graphics application Blender.

<Fig. 9 approximately here>

The activity of texture editing and retouching has been achieved using the free software raster graphic editor Gnu Image Manipulator (GIMP). Three dimensional visualization of thirteenth-century Bologna takes advantage of the powerful rendering engine OGRE (*Object-Oriented Graphics Rendering Engine*).

<Fig. 10 approximately here>

Specifically, OGRE is a C++ scene-oriented engine that allows for the development of interactive applications based on hardware-accelerated 3D graphics. Rigid body simulation in Nu.M.E. 2009 is possible thanks to Bullet physics library. Bullet is an open source library that is considered as a standard for video games and film post-production in entertainment industry. It uses multi-threaded 3D collision detection and soft body, and rigid body dynamic libraries

<Fig. 11 approximately here>

To implement realistic shading effects we designed a Spherical Harmonics Lighting system running on CUDA, the cutting edge parallel computing architecture of Nvidia; this powerful tool permitted us to pre-process all the effects of

light directly on special images called light maps, and then display them in real-time using a Nvidia GTX 280 graphic card. In virtual navigation of Bologna, passage of time is simulated using OpenGL shading language and a special module of OGRE called CAELUM. Video capturing for presenting our project to conferences and showing the result of our work online is based on Yukon OpenGL capturing framework. This is a set of libraries and applications that are designed to capture real-time videos of OpenGL applications with high frame rate.

The introduction of every new technology implies an initial moment of uncertainty before giving effective results; our choice to base Nu.M.E. on open source technologies demonstrated that even these new digital tools have pros and cons. In the first phase of the project we encountered some major technical problems and certain difficulties in handling such experimental technologies. Despite those issues, the good quality of the virtual reconstruction and the excellent results in visualization demonstrate that our choice was brilliant. If we analyse the technological quality of our work on the basis of the cultural and economic goals obtained, we can easily say that our open source approach in virtual reconstruction of early cities can become a good example for forthcoming educational and research projects in this field.

Cultural models for communication to the general public

The main focus of Nu.M.E. 2009 is the implementation of an efficient communicative process for the virtual museum of the city of Bologna. It has been stated (Antinucci 2007, 5-25) that fundamental components of cultural transmission in museums are comprehension and motivation. It has also been proved that digital technologies permit involvement of cognitive and emotional factors in the process of improvement of museum communication (Monaci 2005). In Nu.M.E. 2009 we follow these important principles of museum studies with the aim to help the general public know the history of towns. This attempt pushed us to

confront several theoretical and methodological problems. How can complex historiographical data be communicated to the visitors of a virtual museum of the city? What new models of interaction can improve cultural reception in a real-time simulation environment?

According to Vitali (2000) virtual reconstruction technologies can be defined as 'history commuters' because they invert the regular flow of information within a historical communication system. This condition occurs because, rather than transmitting information through a linear path, 'history commuters' attract people inside the simulated historical context, and involve them in a synesthetic process of communication in which both tangible and intangible elements of the past can be transmitted. The novel informative system that characterized 'history commuters' can be defined as reticular; this because, within this new digital context, the process of meaning creation is based on one side on a net of relations between visualized elements and on the other on a matrix of differences between those components and users. Such a new cultural model allows for communicating to the general public historical memories of specific events or human activities. At the same time spatial relations between places that no longer exist can be included in this process of three dimensional simulation. Thus, causation and spatiality become fundamental factors of cultural virtual environments aimed to communicate historical changes. With this in mind we started to reflect on communicative codes to use in our project. From a communicational perspective, Nu.M.E., being a multi-sensorial digital environment of simulation, can be considered as media, specifically new media. Therefore the comparison of Nu.M.E.'s language with patterns and paradigms of other media is a crucial point of this research about cultural communication in virtual environments. What is the most consistent, tested, and effective cultural model of audio-visual simulation? The first answer we give is cinema. The centenarian tradition of audio-visual simulation that characterized this medium has already become useful matter for new media. It has been demonstrated that cinematic conventions such camera, screen and

spatial editing are cultural interfaces in the field of digital communication (Manovich 2001).

Cinematic formal structures are essentially based on the representation of narratives within time and space. In cinema symbolic systems determine an emotional involvement of the audience; the outcome of this phenomenon is high-motivated spectators who try to comprehend transmitted information. Cinema is not the only cultural model we can take as an example. We want to include in our analysis another contemporary communicational model based on 3D graphics and real-time visualization. In the scenario of computer-based communication video games are one of the few examples of 'native' cultural paradigms (Manovich 2003, 13). The relationship between interactivity and narrativity play a creative role in video games. This very popular form of digital communication uses algorithms to customize in real-time the virtual experience of users. They shape narrative sequences, virtual characters, and virtual worlds according to the evolution of the game. At this point, we try to verify if these cultural models are useful for Nu.M.E. communication. The hypothesis is to transform virtual space of thirteenth-century Bologna in intriguing interactive adventure through historical information. First of all, we have to analyse the semantic role that narratives play in the process of information comprehension within virtual environments. Are the basic functions of any narrative structure, such as causal system, time and space, elements that can be integrated into the interactive structure of cultural virtual environments?

Causality, in a virtual environment, means possibility of constructing a specific exploration path through the composite matrix of information that is recorded in historical databases. Our objective is to determine if users of virtual museums can be guided along the process of the creation of historical meaning. We can achieve this goal using communicative techniques able to focus users' attention on systemic comprehension of the relationships that exist between 3D objects. The consequence of this improved learning process is an enhanced comprehension of historical data. We think this makes it possible to provide the general public

with a deeper knowledge of cultural contents. The causal system can, furthermore, be used to mitigate the impact of virtual experience, especially when it is based on immersive virtual environments. We consider such a condition as a necessary method to avoid a cognitive overload in the audience of these complex simulation systems. Narrativity can, also, be considered as an attempt to guide users' cognitive efforts along the main goal of our virtual museum: the allocation of a specific historical meaning to the components of reconstructed virtual space. In the summer 2009 we tested our urban simulation system with the general public and noticed that the possibility of a progressive lack of interest is very high if users are not guided along themed pathways; if this undesirable circumstance happens, visitors of virtual museum, immediately, decide to stop their cultural fruition, causing the communicative system to fail. Analysing the concept of space in virtual environments it is easy to verify that 3D simulation systems attribute many different meanings to spatial relations. Space is the interface through which users communicate with the system. At the same time, it is the medium that allows communication of information between people involved, simultaneously, in the process of simulation. Specifically virtual space, as a navigable space, is a key element in our perspective. It is the digital framework in which we can enact interactive storytelling. It becomes a path to follow, during this type of historical simulation. Users of interactive storytelling systems can express their subjectivity dealing with the virtual space (Blom and Beckhaus 2002). They can also be emotionally involved in the narrative structure describing events of the past. Thus narrativity, giving to virtual spaces a new psychological value, enriches the use of 3D models with a new emotional dimension. Spatial structure can, therefore, be exploited to give a specific shape to navigation. This can be done with specific stylistic choices that transform the concept of space; from an initial state of mere digital information virtual space becomes an emotional resource. Emotions influence users' expectations and motivation, and therefore, historical comprehension as well. Narrative structure has another important feature that can

enhance the simulation of historical changes. Interactive storytelling introduces in the virtual world a temporal variable. Such a new feature determines the end of the hegemony of the spatial dimension in the production of cultural meaning within virtual reconstruction. Temporality, in cultural virtual environments, can be considered a convention that establishes chronological progression of the simulated historical events. The indefinite time of virtual worlds can, eventually, be declined in functional structures that help to enrich user experience. The outcome of this new feature is that temporality is able to describe how historical places have been transformed over time.

Using a narrative structure in cultural virtual environments creates the opportunity to intervene on simulation in order to generate a specific chronological meaning in represented historical events. We believe that the relationship between the opposite formal structures of interactivity and narrativity can open new communicative scenarios in the field of virtual heritage.

After this theoretical preamble, we want to describe, in brief, the attempt of enacting interactive storytelling in Nu.M.E. 2009. Our integration of the language of cultural virtual environments with the communicative codes of video games and cinematic language is pursued in the creation of themed pathways based on historical information. The final goal is to help users handle the interactive environment of the virtual museum of Bologna and decode complex historical information. Said decoding takes advantage of the simplification that storytelling and spatial-temporal structures give to virtual reconstruction. Although they can be perceived as simplistic features in virtual environments aimed at historical interpretation, we strongly believe that these formal structures are not a limit. Interactive storytelling enriches the communication of cultural heritage to the general public of museums, or virtual museums. This happens because the 'narrative-interactive model' stimulating users' emotional spheres and, helps their cognitive system in the learning process of represented historical data. This is a key point in our research project about Nu.M.E.'s communicative aspects. Even though user

experience of the simulated medieval space of Bologna is, primarily, a matter of perception and interaction, we try in the 2009 version of the project to describe scenes of medieval daily life or historical memories of important events that characterized thirteenth-century Bologna.

<Fig. 12 approximately here>

Our effort is focused on the representation of a cloth market of that was held in *Piazza di Porta Ravegnana* since the late Middle Ages.

<Fig. 13 approximately here>

This economic activity was so relevant for the city that the municipality assigned to it the square just below the Garisenda and Asinelli Tower; this central location is one of the most significant and symbolic places of mediaeval Bologna, (De Angelis 2000).

<Fig. 14 approximately here>

Thanks to information we can get from the fifteenth-century *Drappieri Miniature* is possible for us to create an accurate themed pathway between market stalls, and involve users, especially young students, in a stimulating process of comprehension of production activities that characterized the Middle Ages.

Conclusions

Technological evolution and new cultural paradigms push museology to find different models for museums of the future. Just five years ago the majority of virtual museums were only websites in which users could just experience a digitized version of artwork and collections. Today's cultural communication can take advantage of several new methodologies and tools that, in the recent past, were confined to 'techno-scientific imaginary' of sci-fi movies. 'Multiuser online metaverses', collaborative virtual environments, and embodied learning processes open new horizons for contemporary museology (Forte and Bonini 2008). Nu.M.E. challenges virtual heritage methodology in the attempt to contribute to this cultural debate with a decennial tradition of research and innovation.

In the 2009 release of the project we try to give an example of sustainable communication processes that might become useful for forthcoming initiatives. The purpose of our research is to test open source technologies for the communication of historical contents. In this way we try to define a novel paradigm for museums which want to use 3D graphics and simulation technologies. We reflect also on interactive storytelling in order to introduce new formal structures in the communicative context of Nu.M.E. Our final aim is to involve visitors of the virtual museum of Bologna in an emotional and intriguing experience of the past of the city. The outcomes of these new features are the possibility to aim our virtual reconstruction to the general public. The use of reconstructed historical context in early versions of Nu.M.E. consisted of 3D navigation in the first person where users could just use 3D objects to perform simple actions. The introduction of a narrative structure enriches this system of cultural communication. It gives the user an active role in the process of the creation of meaning based on the simulation of significant scenes and events of late Middle Ages life. The great realism and historical accuracy of 3D models allow for obtaining scientific validation and enlarge our project perspectives and goals. Nu.M.E. 2009 becomes a useful tool for both historians and general public. Experts of urban history can take advantage of our virtual reconstruction in the interpretation of spatial-temporal relations and attribute a precise meaning to the urban landscape. Tourists, youth, and students can find in Nu.M.E. 2009 a non-conventional, intriguing, but at the same time historically correct, way to get in touch with the past of Bologna and comprehend its long history.

The final result of our methodology can be, therefore, defined as a 'sources-based virtual reconstruction' of thirteenth-century Bologna that is both philological and emotional. Thus, we can finally say that our goals of improving communicative aspects of Nu.M.E. and keeping decennial scientific and cultural value of the project have been achieved. We are, also, aware that the relationship between cultural heritage and technology is today related to their social dimension. A contemporary virtual museum

cannot exclude dealing with what is radically changing user experience and new media communication. Therefore, we considerate Nu.M.E. 2009 not the end of our investigation on communicative aspects of virtual museums, but the starting point for a new release of the project

focused on the collaborative aspects of cultural reception. It will be released approximately at the beginning of 2011, and will conclude this research project about thirteenth-century Bologna, adding educational, social and communicative values to virtual reconstruction.

The final publication is available via BAR Publishing at

https://www.barpublishing.com/?subcats=Y&pcode_from_q=Y&pshort=Y&pfull=Y&pname=Y&pkeyword_s=Y&search_performed=Y&q=Cyber-Archaeology&dispatch=products.search

Please cite this chapter as follows: Lercari, N. An Open Source Approach to Cultural Heritage: Nu.M.E. Project and the Virtual Reconstruction of Bologna. In M. Forte (Ed.), *Cyber-Archaeology* (pp. 125-133). Oxford: Archaeopress, BAR Int. Series 2177.

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Captions and Figure formatting

Figure 1. Part of thirteenth-century Bologna urban landscape around *Piazza di Porta Ravegnana*. (1 column, in-line).

Figure 2. Thirteenth-century porches. (1 column, in-line).

Figure 3. Thirteenth-century buildings. (1 column, in-line).

Figure 4. View of the no longer existing *Artenisi* and *Guidozagni* towers. (1 column, in-line).

Figure 5. Detail of the no longer existing *Riccadonna* tower. (1 column, in-line)

Figure 6. East view of Via Emilia. (1 column, in-line)

Figure 7. Detail of *termini* and porches in *Piazza di Porta Ravegnana*. (1 column, in-line)

Figure 8. Spherical Harmonics Lighting technique in OGRE 3D graphics engine. (1 column, in-line)

Figure 9. Low polygon Bologna 3D model in Blender. (1 column, in-line)

Figure 10. Bump mapping technique in OGRE 3D graphics engine. (1 column, in-line)

Figure 11. Virtual characters in OGRE 3D graphics engine. (1 column, in-line)

Figure 12. Scene of medieval daily life in *Piazza di Porta Ravegnana*. (1 column, in-line)

Figure 13. View of *Cappella della Croce* in *Piazza di Porta Ravegnana*. (1 column, in-line)

Figure 14. View of *Garisenda*, *Asinelli*, and *Artenisi* towers. (1 column, in-line)