ON 3D RECONSTRUCTION OF THE OLD CITY OF XANTHI

A minimum budget approach to Virtual Touring based on Photogrammetry*

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Abstract: The old city of Xanthi (Thrace-Greece) is one of the biggest traditional settlements in Greece which has the specialty to exhibit mixed traditional Greek, European and Oriental architectural features. This paper presents a 3D reconstruction of a small part of the settlement. It deals with the idea of using open source systems in 3D graphics in order to produce realistic virtual walkthroughs for culture heritage promotion with a minimum budget and low cost infrastructure.

Keywords: Cultural heritage, 3D Reconstruction, Photogrammetry, Virtual reality, VRML, Architecture

1. Introduction

The promotion of architectural heritage is one of the fundamental elements of tourism development. 3D reconstruction of buildings has been an active research topic in Computer Vision as well as in Digital Photogrammetry for many years. Three dimensional computer graphics are increasingly necessary for the promotion of heritage as they offer alternative possibilities for different kinds of tourist activity [1]-[5].

Extensive research in the fields of photogrammetry, computer vision, and computer graphics has lead to the development of commercial 3D scanning systems that allow effective high-resolution digitisation of heritage sites within a few minutes.

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However, the quality of the final product is determined in many cases by the software that has been used to produce the three dimensional model.

Nowadays, a plethora of *feature rich* open source content creation software has achieved widespread use and this is true even for the particular area of computer graphics and 3D modelling. Open Source systems enable the free production and rendering of 2D/3D graphics. *Blender* is a strong example of such software that allows 3D modelling, animation and rendering. Similar applicable software examples, that follow the open source route, are *The GIMP*, *Wings 3D*, *Hugin* and *Panorama Tools*.

In this project, we attempted a 3D reconstruction of a settlement without the use of any expensive equipment (e.g. commercial 3D range scanners based on techniques like triangulation, modulation or time of flight) or commercial content creation software. We have produced a fully textured 3D model that can be easily accessed from the Internet. Acceptable downloading times have been achieved even for PSTN connections. A low quality sample can be found at http://www.67100.gr/eng.htm

2. The old city of Xanthi

The old city of Xanthi is a masterpiece of traditional mud, brick and stone architecture and a substantial part of our Greek cultural heritage. It is located on the foothill of pine-wooded hills that define the borders of highland and lowland of Xanthi County.

Most of the settlement residencies were completely rebuilt during 1830-40 after two catastrophic earthquakes (March & April 1829). During the 19th century and till the beginning of the 20th, the city thrived as one the greatest centres of tobacco trade. People from different religions and nationalities produced an extremely interesting architectural design fusion. Modern and neoclassical houses were built in a way which betrays the people's close relationships and lifestyle of that era. They share many facade and design characteristics with houses and mansions of Northern Greece. Each building has a unique character but at the same time they all blend smoothly together as they share the same forgotten values of traditional architecture. The basic materials were rocks and woods supplied from the surrounding forests. Their interior decorations are extremely rich in baroque [6]. The design of each mansion is usually dictated by the religion aspects of the owner. In the Muslim regions, one can find single floor buildings with tall surrounding walls to ensure privacy inside the house and the inner yard.

The old city of Xanthi is a prime example of local architecture that allows the visitor to discover its eclectic traditional architectural mix of buildings strongly influenced by 19th–20th century European architecture.

3. Reconstructing Reality

The primary objective of the project was to describe the greatness of cultural heritage with an alternative way such as virtual reality. It has been proved that low complexity 3D models with detailed textures provide enough realism when the main purpose of the reconstruction is promotion of culture and not a scientific study or digital archiving [7]-[9]. A three dimensional reconstruction allows the viewer to freely control the viewpoint of a virtual camera. Thus, the viewpoint restrictions introduced by 2D images and video sequences can be easily overcome. The empirical reconstruction procedure that has been followed can be divided into four different sequential procedures. These are the following:

3.1 Study of settlement and photoshooting

During the first phase of the project, a thorough study of the actual settlement took place in order to identify the basic geometric features. A set of viewpoints has been derived from this study. The number of different viewpoints and the available shooting equipment (digital camera, lenses, tripods, etc) briefly define the amount of time required for the photoshooting procedure. Modern geometry kit lenses allow the coverage of full 360^0 horizontal and 115^0

vertical fields of view in a single shot. The information gathered during this phase played a key role in the degree of realism of the final 3D model. The photos that have been used for the reconstruction contained the maximum possible information that was visible to the visitor of the actual settlement.
In addition, the selection of appropriate viewpoints aimed at minimising the geometric declinations of the building's facades. Those declinations were corrected later on during the photogrammetric reconstruction and texture mapping of the 3D model.

3.2 Image Processing

During the photoshooting phase we have realized that it was very difficult to capture different parts of the building's facades while keeping the same level of capturing quality throughout the settlement. As the project was low budgeted most of the photoshooting was perform without the use of any special constructions (temporary scaffolding, bases, etc). Thus, numerous field of view limitations were introduced by the narrow cobbled roads and the absence of special camera lenses.

Furthermore, some of the most common and noticeable problems between all the images were barrel distortion and trapezoid disfigurement of the building facades due to perspective. Appropriate correction was applied to remove such type of distortion from the whole image set.

Those geometric distortions were not the only difficulties that had to be surpassed. Various obstacles like trees, bushes, fences and other objects block the camera lenses from capturing the buildings. In fact, the phase of removing those obstacles was proved to be very time consuming. The typical procedure that has been followed to produce a corrected image of a single building facade can be summarised as follows:

i. Barrel distortion correction which is caused by the wide angle lenses.
ii. Perspective correction of facades (Figure 1).
iii. Manual image processing for the removal of obstacles and other elements (2D Image Registration Techniques [10] are also recommended).
iv. Further integration of processed images in order to produce a single texture image where all facades of a building are included. The textures were created by combining different images (Figure 2).

We have decided not to process the colour variations of day light appeared on the images as it is proved to be more realistic especially in cases where real shadows are projected on buildings.

[Figure 1] [Figure 2]

3.3 Photogrammetry and 3D reconstruction

The most important feature of image based reconstruction is the fact that none of the objects are being touched. This is a very common requirement especially in digital archiving of ancient delicate artefacts. The technique followed is based on the image to image correspondence [11]-[16].

A set of corresponding points are identified manually by the user and are marked on two or more images that cover the same building from different viewpoints. The 3D coordinates of those points are extracted using principles of photogrammetry [7]-[10]. Polygons are typically created combining these points (vertices) into triangles or quads. Thus, it is possible to restore the basic geometry of the facades of the buildings (Figure 3).

[Figure 3]

These rough outlines of the building's main facades are more than enough as details are preserved mostly within the texture images. More specifically, for the partial reconstruction of a building there are three factors that were taken under consideration:

i. The parts of a building which were visible to the viewer's field of view in relation with the walking restrictions applied by the virtual environment.
ii. The particular characteristics of a building in relation with the walking restrictions applied by the virtual environment.
iii. The contour that describe the building (e.g. rectangle, polygon, etc)

The final model is a three dimensional polygonal mesh object written in VRML (VRML97 ISO/IEC 14772-1:1997) where the texture information is derived from processed and compressed texture images. Thus, it consists of two discrete parts. It was also necessary to include some artificial elements such as a cloudy sky and a panoramic background image in order to improve the realism of the final virtual representation. The figure below (Figure 4) depicts a topographical map of Xanthi and the part of the settlement that has been reconstructed.

[Figure 4]

3.1 Adapting data for the Web

The VRML 3D model can be easily accessed from different Internet browsers using a VRML client plug-in. Even nowadays where broadband connections are becoming a standard for the average home user; there is always a need of organising and compressing data so that they can be efficiently transferred over the Internet. One of the main disadvantages of the 3D reconstruction is the total amount of texture data. The uniqueness of each building facade resulted a large number of different texture images. In fact, the texture images constitute the 80% of the total size of the reconstruction. The realism of the reconstruction mostly depends on the quality of those texture images. Thus, the reduction of texture data size is proportionally reflected on the representation's visual quality. Since now, the only world wide accepted software platform able to integrate some of the possibilities offered by virtual reality is VRML which has now being slowly replaced by X3D. There is no VRML/X3D client that supports fully progressive downloading of geometry data. This is due to the *textual* structure of the source code and the interpreting method that is being used to display geometry. Most of the VRML clients initially load the geometry file and then continue by interpreting the geometry source code. One can split up the geometry code into different files in order to get some basic type of download progression. In our case this approach was considered unnecessary as the total size of the geometry code was less than 40Kbytes.

Textures are loaded progressively in the same order as they appear within the source code of the 3D model. So, in most cases there is only a partial progressive downloading procedure which is acceptable as the user can start interacting with the 3D model while the textures appear one after the other. The total downloading time is further reduced by the ability of some VRML/X3D clients to load the source code as a compressed file based on the lossless compressed data format GNU zip which is described in RFCs (Request For Comments) 1951 and 1952.

In this implementation the texture images are compressed using the standard JPEG and PNG (In cases where transparency was required) compression algorithms. In future versions of the reconstruction, we intend to use the JPEG2000 compression algorithm to speed up downloading times and improve the visual quality in extreme compression levels. At the moment, the JPEG2000 compression algorithm is not supported by the majority of VRML/X3D browser plug-ins nor open source image processing software.

Concluding, with a careful usage of VRML special features like billboards and object cloning a realistic 3D reconstruction for cultural promotion can be experienced over low bandwidth connections such as PSTN. Multiple versions based on different texture qualities can easily serve different bandwidth capabilities, as shown in Table 1.

[Table 1]

4. Conclusions

The three dimensional digital archiving of cultural heritage has been an active research area for many years. Both academic research laboratories and companies are involved in a continuous haunting of new 3D scanning methodologies and data handling in order to provide efficient methods to preserve the past. In this paper we are not presenting any novel ideas on digital archiving. On the contrary a statement is tried to be made on how to run low-budgeted 3D reconstructions projects that still result enough realism for cultural promotion. Although it is fascinating to look at any project from the scientific, technical and realisation points of view, it is absolutely necessary to observe a project from its economic perspective. The 3D reconstruction has been supported by a simple yet informative website that covers the main historical parts of the settlement followed by a photo gallery (Figure 5). The website could be considered as an interactive on-line tourist brochure for the settlement.

[Figure 5]

Interactive 3D representations consist of an important alternative medium for promoting cultural heritage. It is also a fact that 3D reconstructions offer a more data efficient approach than photographs and video sequences. The Virtual Reality Modelling Language still plays an important role in promoting 3D information to the World Wide Web. The use of open source software allows the creation and merging of VRML97 worlds into websites that can be combined with other multimedia elements like video, sound and animation are able to maintain an adequate level of information.

The fidelity and accuracy of the final 3D model is by far inferior to any other 3D models that could have been created by geodetic measuring techniques or terrestrial 3D laser range scanning. However, its limited data transfer requirements allows short download times while giving an acceptable approximation of reality. Nevertheless, modern 3D digitisation equipment can provide rich data sets that can be used for scientific studies like archiving of cultural heritage, architectural studies and restoration projects. The same data sets in combination with sophisticated virtual reality interfaces (HUDs, Active 3D Displays, Caves, etc) can allow a fully immersive virtual reality experience to the user.

As a final point, this attempt of using low cost infrastructure like ordinary digital cameras and freely distributed software proved to be adequate enough to promote cultural heritage over the Internet through a prestigious medium such as Virtual Reality.

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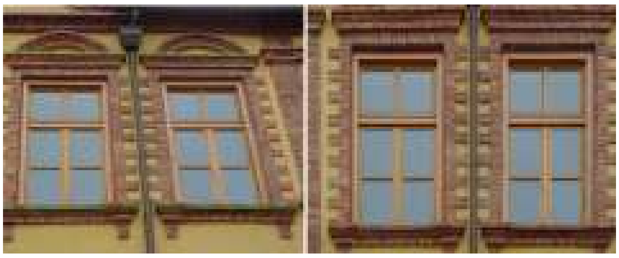
Tables

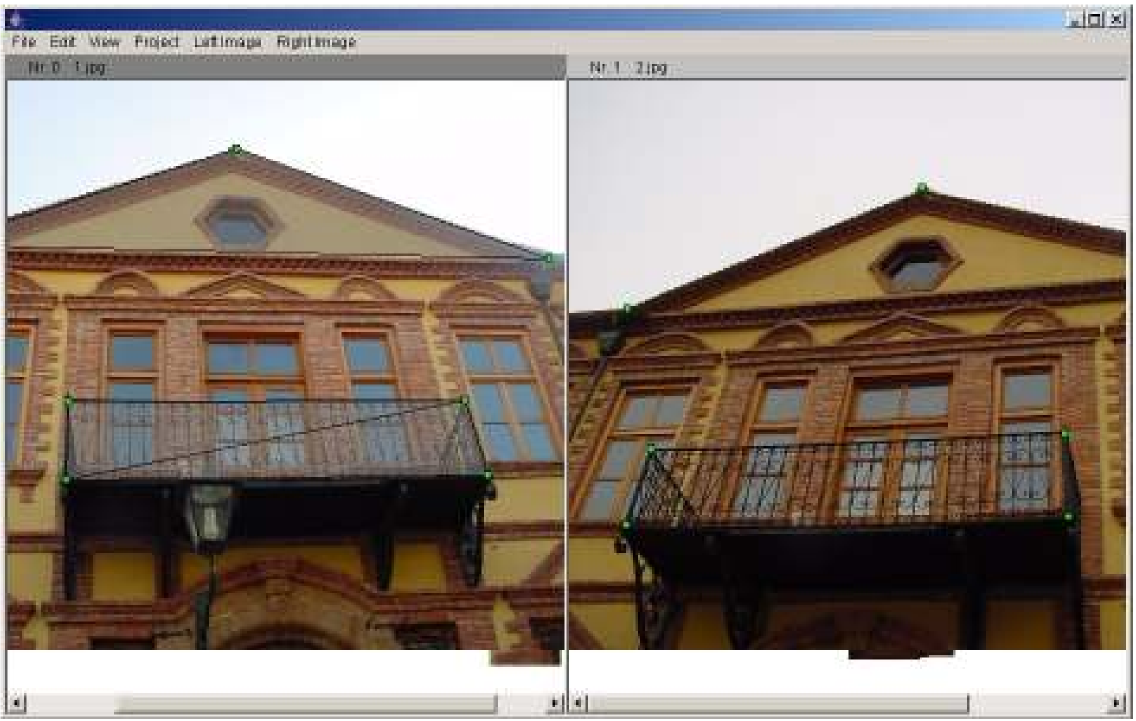
Table 1 – Downloading Times with an Overhead of 20%

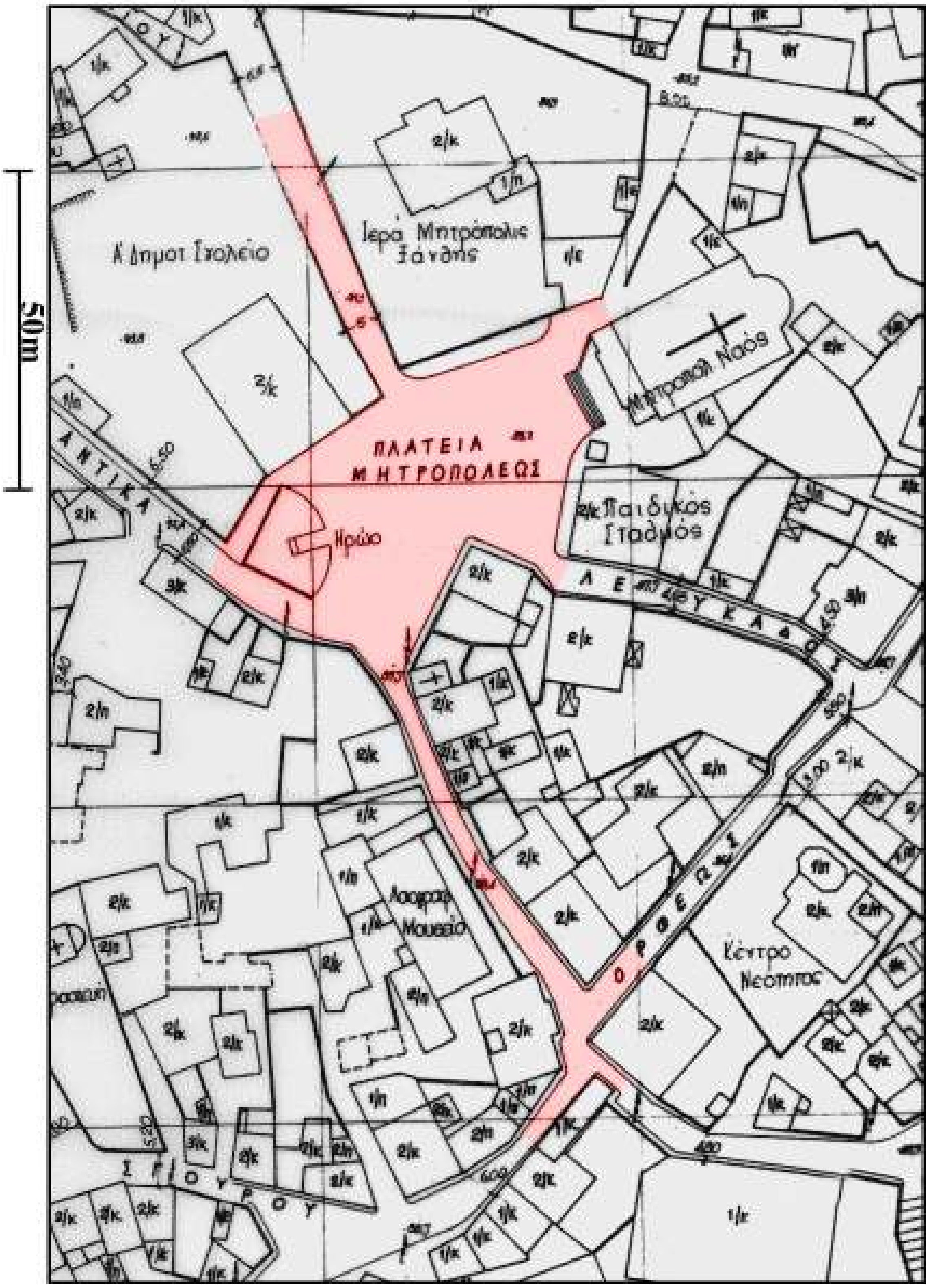
Connection Type	Geometry Data Size (bytes)	Texture Data Size (bytes)	Downloading Time (Overhead 20%)	Subjective Quality
PSTN (56Kbps)	36,980	878,419	2 Min. 36 Sec.	Low
ISDN (128Kbps)	36,980	2,007,814	2 Min. 33 Sec.	Medium
ADSL (512Kbps)	36,980	4,497,504	1 Min. 25 Sec.	High
ADSL (1Mbps)	36,980	5,994,521	0 Min. 56 Sec.	Ultra

Caption of Figures

Figures




File Edit View Project Left Image Right Image
Nr. 0 1.jpg
Nr. 1 2.jpg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Λαογραφ.
Μουσείο
Κέντρο
Νεότητος