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Original article

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.

However, the quality of the final product is determined in many cases by the software that has been used to produce the 3D 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

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hills that define the borders of highland and lowland of Xanthi County. Most of the settlement residencies were completely rebuilt during 1830–1840 after two catastrophic earthquakes (March and 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 3D 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 and are listed below.

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° horizontal and 115° 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 (Fig. 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 (Fig. 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.

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