GIS AND TERRITORIAL INTELLIGENCE

3D Modeling of Buildings

Outstanding Sites

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Introduction

Traditional topographic databases, usually created from aerial or satellite imagery, provide a simplified three-dimensional (3D) model of our urban environment which can be used for a number of applications, such as town planning, risk prevention and mobility management. However, in the case of representing and analyzing outstanding sites like monuments, works of art or archeological sites, these databases are insufficient and other ways of acquiring and processing data need to be employed. This book presents a state-of-the-art of the methods specifically adapted to outstanding sites and the research currently being carried out in this area. The methods addressed in this text range from lasergrammetry to current dense correlation techniques using images as well as traditional photogrammetry.

These methods allow for the surveying of outstanding sites, permitting the restitution of the structures' form and appearance with a precision and a level of detail agreed upon in advance in a set of building specifications. They are due to takeover from techniques traditionally used for the creation of topographic databases, in the case of specific orders, such as the description of the relief of the façade and the complete 3D survey (interior and exterior) of a monument. In this text, digitization mainly involves 3D geometric rendering, and does not include the inventory, analysis of the construction materials, structural analysis of the building or its history.

First, it is necessary to define what is meant by the term "outstanding site". These are buildings, collections of buildings, monuments or works of art which attract a level of interest to such an extent that any traditional 3D products which currently exist are not able to reproduce the vividness of the original. The size of the sites dealt with in this text is measured from ground level, including structures ranging from a small cellar to an entire district, as well as castles, churches, bridges and towers. Therefore, it is only static objects which will be dealt with in this text.

The aim is to give an overview of the range of current 3D surveying methods. It is neither a theoretical lecture, nor a collection of procedural manuals. The reader will find no detailed algorithms, but instead will find information on all working stages to create a 3D survey of an outstanding site. Advice and recommendations are also given, which the authors compiled paying close attention to produce a result which is as reliable, faithful and precise as the current methods will allow and should, therefore, be used simply as guidelines.

Some building specifications focus more on visual appearance than on overall accuracy. In this case, the demands on the data acquisition phase will be relaxed, while the post-processing cosmetic phases will be lengthened. Therefore, this text is relevant to anyone interested in high resolution 3D surveying, whether they are project managers, surveyors, heritage conservationists, town planners, computer graphics designers, or those who wish to learn about the technical methods available, possible methodologies and the steps to be followed in carrying out a project of this kind.

The text does not aim to provide an exhaustive list of methods or references but instead presents the views of the authors, which is manifestly influenced by their training and profession as photogrammetry engineers.

Contents

1

Specific Requirements for the 3D Digitization of Outstanding Sites

1.1. The current offer for high-resolution 3D data

In France, the IGN (*Institut national de l'information géographique et forestière* or the National Institute for Geographical and Forestry Information) produces and maintains the RGE[1] (*Référentiel à Grande Echelle* or Large-scale reference) over the entirety of the territory, containing four levels of information: a high-resolution orthoimage, an "addresses" database, a georeferenced cadastral map and a 3D topographic database of metric precision containing a description of elements of the landscape, classed according to type. Work is underway on a new-generation RGE, which is more precise and gives better resolution and detail, largely due to the cooperation of a number of stakeholders who collect and manage geographical information throughout the territory.

The IGN is also implementing a semi-automatic production process using high-resolution aerial images (pixel size below 20 cm), which are highly redundant, (significant overlap between images) leading to the production of vector

1 http://professionnels.ign.fr/rge.

databases in line with the LOD2 (*level of detail*) specifications of the CityGML[2] standards. It has been implemented in some large French cities, such as Paris, Nantes, Rennes, Besançon and Marseille. It shows the various districts, roof structures, vegetation and generalized street furniture. This product, Bati3D® [MAI 04], not only contains a survey of the buildings' forms (or groups of buildings if they are connected), but also their appearance, since the volume reproduced via automated photogrammetric processes is textured by aerial images. It is possible to improve the rendering and the precision of the façades and street furniture by adding data acquired in the field by vehicles equipped with stereoscopic cameras, lasers scanners and direct georeferencing devices (GNSS[3] antenna, inertial navigational system or odometer). These devices are rarely self-sufficient in urban environments, but are essential for initiating the georeferencing of images through photogrammetry.

Many local authorities (well-known examples include Monaco[4], Geneva[5] and the urban community of Lyon whose model is now available to be consulted on-line) have financed digital 3D models of their territory, believing that the traditional products available were not able to meet their requirements. In general, specific teams manage the production of Digital Elevation Models (DEMs), orthoimages and vector models representing buildings, street furniture and vegetation, with the use of aerial images and adapted lidar technology. Large internet-based companies are also working on 3D representations of towns, offering navigation

2 http://www.citygml.org/.

3 Global Navigation Satellite System.

4 http://www.gouv.mc/Action-Gouvernementale/La-Qualite-de-Vie/La-Prospective/Actualites/La-maquette-3D-de-Monaco-presentee-par-la-DPUM-a-Imagina.

5 http://ge.ch/sitg/cartes/3d.

services in the most realistic reproductions of our environment. An example of this is Google, which offers detailed reproductions of entire districts. A number of different methods are used to achieve this from traditional photogrammetric stereoplotting, through to pure infographics and the production from multi-images available to every Internet user[6]. This range of processes gives rise to questions regarding traceability of data and the amount of confidence which can be invested in it.

The quality of aerial images and the ever more automated computerized tools allow for the large-scale production of urban databases with increasingly detailed resolutions. However, the majority of these databases solely aim to show towns from an external view-point, without looking into the buildings or going underground.

On the other hand, the architect's digital model, or Building Information Modeling (BIM), is exhaustive, showing the building or the district from all angles: internal, external, underground and from above. Either this precedes the construction phase and gives an architect's view, or it is used in urban restoration projects (modernizing old buildings), and it meets the requirement of providing a model "as-built".

The methods of digitization discussed in this text provide a description of a particular building, which is more applicable than that given by other products available in terms of better spatial resolution or greater comprehensiveness. The text refrains from examining computer-aided design (CAD) processes, which concentrate more on the image than the accuracy of the survey. Here, the focus will be on geometric methods which, while keeping up-to-date, are able to remain objective and render a building as it really is and not as it may be imagined.

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6 http://www.google.com/earth/learn/3dbuildings.html#.

1.2. Statement of requirements

The digitization methods which are addressed in this text involve the following stages [BAR 11]:

– presentation of requirements;

– choice of techniques to be applied;

– data acquisition in the field;

– data processing;

– quality control;

– layout and delivery.

1.2.1. *Potentials*

Drawing up the statement of requirements for digitization, prior to the production of building specifications for the contractor, is a challenging exercise. A comprehensive, precise and well geolocalized digitization of an outstanding site may be requested in the case of an inventory, a restoration or an archeological dig, or with the aim to make it accessible to everyone everywhere with a digital model that can be consulted online (virtual tourism). Requirements regarding content, resolution, precision or up-to-dateness obviously vary depending on the context. However, the statement of requirements is often initially summarized in an idealistic manner: the 3D model of everything at the highest resolution. Budgetary constraints tend to bring project sponsors back down to earth. The reasons motivating digitization, in terms of potentials, should, therefore, be highlighted. The following examples can be given:

– Understanding the monument:

- establish a model of movements;

- recover the history of its construction;

- analyze its distortions.

– Providing a collection of measurements:

- count openings;

- measure the surface of the roofs;

- display different sections of the structure;

- study the stability of the monument.

– Locate the monument in time and space:

- superpose elevation to previous or future surveys;

- create an evolving 3D model;

- visualize the site and its positioning within its environment;

- view installations and existing equipment;

- show future projects or constructions.

– Communicate, broadcast and exchange:

- broadcast the model online;

- consult the model online;

- be interoperable with a cadastral plan or other traditional geographic information system (GIS) layers;

- provide a 3D immersion.

– Administrate:

- take decisions on strategic projects;

- re-develop the building to enable visits from the public;

- visualize and present projects during the planning permission applications;

- allow tracking of town-planning regulations.