VIRTUAL MODEL OF THE CITY OF LIÈGE IN THE EIGHTEENTH CENTURY – "VIRTUAL LEODIUM"

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ABSTRACT

Virtual Leodium is a project aiming to scan and digitize a master piece of the collection of the University of Liège, the historical model of the city of Liège around 1730 realised by Gustave Ruhl. The two main originalities of the approach are to use a projected-fringes scanning technique and to generate a geo-database as a support for archaeological information. This interdisciplinary project gathers physicists, geomaticians, librarians, and archaeologists.

Index Terms— historical model, 3D model, laser scan, projected-fringes, 3D city model, cultural heritage, 3D information system.

1. INTRODUCTION

The collection of the University of Liège hosts a wonderful model which was built by Gustave Ruhl-Hauzeur (1856-1929) between 1900 and 1910. Titled, « *La cité de Liège vers 1730* », it represents the central part of the city of Liège (scale 1/1200) in the Eighteenth Century [1]. Gustave Ruhl used diverse sources of information such as old maps and plans and also surveys of remaining building of the Eighteenth Century. This impressive master piece got a real pedagogical interest, since it shows the city before the great reshaping provoked by the great industrial upheavals. However, it has been until now, for different reasons, underexploited. It is not easily accessible and needs restoration.

An interdisciplinary team of researchers has decided to work together to create documented virtual models based on Ruhl's master piece. The name of the project "Virtual Leodium" makes reference to the Latin name of the city of Liège.

The aim is to create two models out of the Ruhl master piece; a digital surface model combining geometry and chromatic information (texture) and a geo-info model (or geographical information model) composed of 3D vectors objects on which semantic information can be added. Our methodology and technology are going far beyond the latest realisations in the field (e.g. the Langweil Prague model [2]).

The first model has a double goal: the creation of a medium allowing the publishing in the more accurate way of the studied object; and, even more importantly, the virtual conservation of this object, or, at least, the conservation of the historical information it reveals and preserves. It is based on a new optical inspection technique allowing recording and processing the information that defines the precise 3D shape and chromatic characteristics of an object.

The second model will be derived from the previous one and will be composed of 3D vector objects similar to the ones used in 3D urban reference models. This geo-based model will allow manipulating individual objects (as opposed to a whole surface in the first model) such as buildings, walls, bridges, streets… The main goal of this model is to be the container for archaeological information: a virtual geo-reference where all kind of information could be mapped.

2. PROJECT OBJECTIVES

2.1. Museology

From a museological evaluation point of view, these virtual models generate three types of benefits:

2.1.1. Increased and improved accessibility

The model is currently accessible only on demand. Few people know its existence. Since it cannot be removed from its conservation room, it is impossible to show it to a broader public. Fortunately, when the digital model will be available, this restriction will disappear: thanks to new information and communication technologies, many kinds of visitors will be able to visit the ancient city virtually: this application will be a wonderful tool for teachers, will be a new support for the writing and the diffusion of pedagogical documents describing the past of the city.

Moreover, the quality of the virtual visit will considerably modify the impact of looking at the old model. Where eyes could simply see very little (1cm) houses or bigger (3 cm) monuments, new visitors will have the possibility to perceive doors, windows, or even garden walls. While currently viewpoints are exclusively outside and, in a way, aerial, users will soon have the possibility to walk by narrow streets and to admire the buildings, seen from the ground!

But there is still more: currently, the explanations available for the viewer are very weak: only some pieces of cardboard laid down on the model give the names of some streets or bridges, while things to say are plentiful: the comparison with current city is of course the first to occur, but there are many other aspects to scrutinize: the criticism of architectural restitutions decided by Gustave Ruhl, the description of building material used by the author, the commentaries about damages, and conservation problems e.g. all of them being encountered with Virtual Leodium.

2.1.2. Conservation

The ancient model is a very fragile document. Built with organic elements, it suffers a lot from light, temperature, and hygrometry changes. In the course of time, some bell towers and trees began to lean, some houses lied down. Of course, digital reproduction is never a perfect surrogate since only the visual aspect is preserved and since the scanning team cannot anticipate the futures scientific needs. Nevertheless, scanning the Ruhl's model offers several conservation advantages: first, it can permit to avoid numerous manipulations from the specialists interested in the work of Ruhl or in the architectural past of Liège. This opportunity is especially welcome since a heavy showcase surrounds the model and that frequent removals of this showcase can be destructive. Second, it allows conservation professionals to visualize in a very detailed way the damages that need to be fixed. Third, this scan may be considered like a first step of monitoring, since, in the future, a new scanning operation would bring to light potential new problems or damages and give curators the possibility to measure the evolution of the situation between the different scans.

2.1.3. Providing new scientific discoveries

Scanning the model, but above all, building around it a 3D geo-info data base will be a wonderful way to provide a new tool for archaeologists, historians, and art historians specialising on the city of Liège. This will be a system to store, to share, to compare, to update all the documents linked with the model or even, why not, linked with the current city. This multi format information will then be available to entertain spatio-temporal analysis providing new scientific understandings about the evolution of the so called "*Cité Ardente*".

2.4. Laser scanning

Besides the interest in archaeology and cultural heritage conservation, the many technical problems related to the recording of the 3D Ruhl's model constitute a true challenge that we wanted to take up. The geometric and structural complexity, the multitude of details, the texture and the size of the objects to be scanned are so many difficulties to be overcome. They will require special methodologies but at the same time they will allow one to test the capacity limits of the tool, and are appropriate to improve its features, performances, and conditions of use.

2.5. Geographical information science

3D urban modeling is a key research topic in geographical information science. New standards have been adopted to improve interoperability between 3D city models. It is worth mentioning that moving to 3D geo-info is much more than providing fancy images; it is a complete change of frame of reference, from traditional 2D maps to 3D maps. The challenge is currently to propose models and supporting systems allowing the recording of information on 3D maps possibly with temporal information. This project is strongly grounded in geographical information science as it aims to provide a 3D city model (derived from the scan of the Ruhl's model) with associated semantic information (provided by the archaeological partners).

2.6. Others objectives

Beyond already mentioned research and technical objectives, it is rather obvious that such a model could be valorized in many different ways, such as in the game and movie industries. At this stage of the project, such outcomes have not been fully explored.

3. PROJECT WORK PACKAGES

3.1. Documenting the model

Before building the 3D geo-info data base, Ruhl's model must be the subject of several scientific investigations. How worked this erudite? What were his sources? Is he reliable? Is it possible to improve his work? Extending the investigation on Ruhl's work implies to find the remaining traces of Ruhl's work (papers, pictures, sketches, plans, etc.) and to synthesize all the discoveries made on the shape of the ancient city since the completion of the model. This will be a huge, but very exciting challenge whose first step will consist in building a database system dedicated to organise the way to store all the data recorded. This data is mainly information about real buildings of the city and their evolution, urbanism changes, historical events, but also preservation operations made on the old model, bibliography, iconography, people involved in the construction, etc. Once that stage will have been completed, the data will be gathered and then encoded. To obtain a complete data gathering, a deep sorting through numerous publications will be necessary, followed by a last very thorough review of the data.

3.2. Scanning the model

In order to obtain a digital surface model, a specific technique called projected-fringes is going to be used. It is among the preferred approaches for measuring shape, surface profile, and displacement of usual size objects. Furthermore, it benefits of the well-established procedures developed for interferometric systems such as phase-shifting and phase-unwrapping algorithms. The HOLOLAB team has developed an original monolithic device that allows fringes generation and phase-shifting without any moving part. Simplicity, robustness, insensitivity to vibrations, and low-cost are among the principal qualities of this device [3]. The main characteristics of the techniques are described below.

In a typical way, one or multiple structured light patterns are projected on the surface to be analyzed. They are usually characterized by a periodic variation of the intensity in such a way that a specific phase can be associated with every illuminated points of the object. By recording the scene with a camera, it is possible to compare the phase distribution of the image points to the linearly growing phase of a non-distorted grid. This phase difference contains the information required for a computation of the surface height variations based on triangulation formulas.

The required features for a good projection pattern are a perfect sinusoidal irradiance function, a very high contrast, high irradiance, and a large depth of field. The problem of contrast is especially critical when ambient light cannot be shut off, for instance in outdoor conditions.

Young's interference pattern is a theoretically perfect sinusoid that can have a very high contrast. In addition, interferometric fringes are non-localized which means that the irradiance function and contrast remain unchanged whatever the projection distance so there is no depth field problem. The use of monochromatic laser light is also a beneficial approach for filtering the relevant signal from ambient light. Note that the use of a polarizing beam splitter is necessary to get dynamic interference pattern projection. Spatial splitting and amplitude splitting of a wavefront are then the two ways for producing stable interference patterns.

The key element of the common path dynamic fringes projector that we develop is a glass prism coated on its hypotenuse with a Bragg grating [4]. This process creates two orthogonally polarized spherical waves that propagate in the same direction but that are spatially sheared. Then the two beams pass through a liquid crystal variable driver whose fast and slow axes, are respectively parallel to the TE and TM axes.

In front of the acquisition camera, different filters can be set in order to improve the image quality. The most frequent cause of signal disturbance is the ambient light. Classical structured light projection systems are unable to work correctly under daylight conditions because of the poor fringe contrast. Laser light has the advantage of a very narrow spectral band (< 1 nm). Using an interferential spectral filter adapted to the laser frequency, one can reduce drastically disturbing light while preserving the fringe image.

Beyond to the accurate reproduction of forms and volumes, the exact restitution of texture and especially the visual color restitution as realistic as possible, is a highly important parameter. First the acquired 3D pictures were color mapped with an image recorded by a RGB camera. The results can be very good ones but we want more precision. In order to improve the technique and to provide more accurate information, a spectral characterization is added to the set-up. Adding the spectral information to the 3D measurements provides a highly realistic and exceptional color mapping to the pictures. More than 30 spectral images can be recorded in the visible field (400 - 800 nm) to build the color information.

The spectro-photo-colorimeter set-up has been designed to be integrated in the 3D scanner device.

3.3. Building a 3D geo-info database

The following step of the project is the creation of 3D vector objects, indeed geo objects, based on the CityGML format [5]. It is a new standard of geographical information, originally developed to improved interoperability between 3D city models. In our project, we are dealing indirectly with 3D city objects as the Ruhl's model is a representation of an ancient urban fabric.

Using the digital surface model and pictures of the Ruhl's model, we will create vector objects with a 3D editor (e.g. 3D studioMax, TerraScan or AutoCAD). The object's exterior envelope will be modeled with faces (boundary representation model) accordingly to CityGML geometric primitives. The model will then be organized semantically as proposed within CityGML specifications. Geometry and semantics links will be recorded in a spatial database management system (DBMS) (e.g. PostGRESQL or Oracle). At this stage, we will get a 3D city model of the Ruhl's model. From that point, several extensions can be envisaged. First, by adding texture to it, this model could be used for navigation or animation and basic City model queries (e.g. visibility analysis). Second, this model will be enriched by semantic information (coming from the documentation work package). Third, the model could be scaled to its "real" dimension by linking the objects of the model with their corresponding ground truth (mostly remaining buildings).

Stepping back to the second extension, the enrichment of the model with semantic information: it represents a major improvement in cultural heritage management and more globally in archaeology. As mentioned among the objectives, the way geo-info is referenced is changing: 4D spaces (3D + time) will become the standard way to structure geo-info in what is now called “micro spaces” (cities, buildings, archeological sites, etc.). The major improvement is in fact the way other types of information (archaeological in this case) can be mapped on these geo-structures. This mapping or linking can be realized by different means: new attributes, extensions of the structures, mapping of ontologies [6], etc. Therefore, archaeological information can be accessed through a strong spatio-temporal framework allowing performing complex queries which were impossible to do in the past.

4. CONCLUSIONS

Compared to other historical models scanning projects, Virtual Leodium presents two main characteristics: the use of projected-fringes scanning technique and the development of a geo-database as a support for archaeological information. It is a huge improvement in the way historical and patrimonial information can be recorded and analyzed. Beyond “simple” 3D visualization, it is a rich information system which is going to be set up. Archaeologists hope to generate new information and new knowledge about the model itself but also about the historical evolution of the city of Liège.

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