THREE-DIMENSIONAL RISK MAPPING FOR ANTI-DISASTER RECORDING OF HISTORIC BUILDINGS

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ABSTRACT:

This paper describes a multidisciplinary initiative for the preparation of educational material for the appropriate use of terrestrial laser scanning techniques for risk characterization of our built environment. This project, supported by the European Leonardo Da Vinci project throughout its Flemish Agency involves 8 partners from 6 different countries with members of the industry, as well as academic institutions. The project's website: http://www.3driskmapping.eu.

1. INTRODUCTION

Terrestrial laser scanning offers new challenges for a more adequate risk characterization in anti-disaster recording of historic environment, however its application has not been fully exploited, this is partially because of the lack of appropriate didactic material available at academic institutions and the lack of three-dimensional environment teaching illustrating the potential benefits of using full three-dimensional environments. Currently, laser scanning, being a highly innovating surveying technique, is only sparsely taught and adequate manuals or guidelines are not available.

The project presented in this paper was launched in autumn 2006 and runs for two years. It is aimed at producing a 'Learning on demand' tool for the use of three-dimensional spatial information from laser scanning in risk characterization of our built environment. The deliverables of this project include a number of 'ICT-supported training tools' that can be used and adopted by academic institutions in their current and future curriculum. In addition, the resulting material can be used for awareness and preparedness for anti-disaster mapping. The resulting package will consist of a theoretical basis on laser scanning and laser scanning data processing completed with a number of case studies in the form of online tutorials, lesson e-books and a decision flowchart for procuring 3D spatial information surveying projects with laser scanning.

The project partners consist of a multidisciplinary group of expert users and information and technology providers.

1.1 Assessing user needs

The user assessment is based on analyzing the needs of:

- Several academic institutions in Europe;
- The state of the arts;
- Commercial application of the project.

This is carried out by the combination of the expertise present in the partnership and outreach to other institutions around Europe. The projects has several links with other commercial, governmental and educational institutions

1.2 Risk management and heritage

Risk management in this proposal is associated to the need of identifying and/or characterizing 'hazards' posed by the current state of our built environment. By improving the amount of knowledge gathered using these advanced mapping instruments the characterization of those risks will be improved and a better-informed decision will be potentially taken.

2. LEARNING MATERIAL: PREPARING RELEVANT MATERIAL

The project is currently in both an assessing phase and a development phase. Questionnaires have been prepared and send to all partners to identify their needs and requests considering the laser scanning training material. Quantification and evaluation of existing online and printed educational material is analysed and will be used to generate a reference database and to set up a general template that will be used to develop the general information base and the case studies. Three case studies have been chosen among the industrial partners' projects to develop real life simulation examples considering job planning, scan acquisition, scan processing, up to the generation of final deliverables.

In the upcoming phases the preparation of educational material itself, in the form of books, notes, photos, slides, transparencies, video, etc, dealing with the production of three-dimensional spatial information from laser scanners for risk characterization of the built environment will start. Also a number of flowcharts will be developed that guide the student through the whole process of laser scanning and the processing of the laser scanner data.

The preparation of these training tools will benefit the cultural heritage community, especially in projects aimed at preparing records of historic building using laser scanning. They might also provide grounds for preparing briefings and tenders for projects as well as to carry out the actual recording work.

3. CASE STUDY APPROACH

3.1 Problem statement

The first challenge of the project was to identify the right case studies to illustrate certain problems, benefits, purposes and limitations of the used technique. The importance of the selection resided in the need of sounding examples that show a didactic approach.

The partners evaluated a number of already produced projects by their organizations and decided to concentrate on structures that not only were threatened by disaster, but that also had hazardous environments for surveyors. The chosen case studies include:

- Mapping a Petrochemical plant overseas;
- Measuring a dam in extreme weather conditions, calculation of the water mass;
- Mapping a listed church with several structural decays and weathering for its conservation.

The last example will be described in the following part. This example was prepared in collaboration with Plowman Craven and Associates, a UK surveying firm being one of the first to acquire a laser scanner in Europe.

3.2 The mapping strategy

The case study approach makes use of the SWOT analysis for rapid-assessment in which the extend of the physical survey of the building's fabric can yield preliminary assumptions on cost, time and precision requirements of different measurement techniques available.

Each particular case study in the project has constraints for the adequate survey of its fabric, making them ideal for didactic purposes.

3.3 Choosing a heritage sample

Plenty of material already exist about the application of laser scanning for conservation of heritage places, however most of these papers felt short in describing why this mapping technique is chosen in relation with the approach and requirements of the project.

In the case of this project, the St James church in Leuven (Belgium) was chosen to be an appropriate case study because it offers a unique example of a heritage place with serious weathering and structural problems preventing it to be utilized by the community.

In addition, the church is part of an ongoing research project in which the structural safety and historic background are being investigated. This means a lot of different users work on the same subject, each of them trying to gather the information they need. Using laser scanning a full 3D recording can be achieved that can be used as a central dataset for all these users. Each user can then filter this dataset to acquire the data needed for their research.

Figure 1: Outside the church: strengthening of buttresses, author.

3.4 SWOT analysis

Issues	Heritage place	Didactic example
Strengths	The church is an important enlisted monument with serious decay problems	The condition of the building makes it a good example, relevant for ante-disaster mapping
Weaknesses	The condition and stability problems are complex and require careful mapping	The didactic material derived from this example might be too complex to the student, it requires careful explanation and clear goals
Opportunities	The church is	The use of a complex

	empty, but if it is repaired it will offer the community a potential meeting point, will help strengths this area's quality	example and important provides the definition of clear needs and therefore helps defining the mapping strategy and the relevance of using devices as laser scanning
Threats	The list is threat not only by its complexity, but also by the lacking of funding that can undermine the repair of the building	The didactic material can become very extensive and lack the effective level of recording due to the lack of means

Table 1: SWOT analysis on the St.-James church

4. ANTI-DISASTER LASER SCANNING - A HERITAGE CASE STUDY

The final goal of this case is to prepare a full record of the current state of conservation (geometrically speaking) for identifying necessary maintenance works on the church to allow an alternative use of this important historic space in the community of Leuven.

Since the church is enlisted as a priority in Belgian's cultural heritage, it is also the purpose to create a historical record of the building containing its geometry and a number of thematic analyses (pathology, historical building phases,)

To upgrade the physical condition of the church, a complete structural condition of the building is needed, meaning that an accurate 3D model should be made with an extensive level of detail and accuracy.

4.1 St James church

The church of Saint James is situated in Leuven, Belgium. It dates back to the year 1220 when the construction of the western tower began. During several subsequent building phases, the Romanesque church has been replaced and extended by a church in early Gothic style. The wooden roofs in the central and side naves were replaced with masonry vaults, and flying buttresses were added.

Because it is constructed on a former swamp, the load-bearing capacity of the subsoil is limited, causing large differential settlements. At several occasions in the past, restoration works took place. However, due to the excessive cracks observed, it was decided in 1963 to close the church for service, in fear of its structural collapse. During many years, a number of structural supporting shorings were placed to stop the church from degrading. In 1995 the city of Leuven decided to restore the church into its original state and to valorise it as a multi-cultural space.

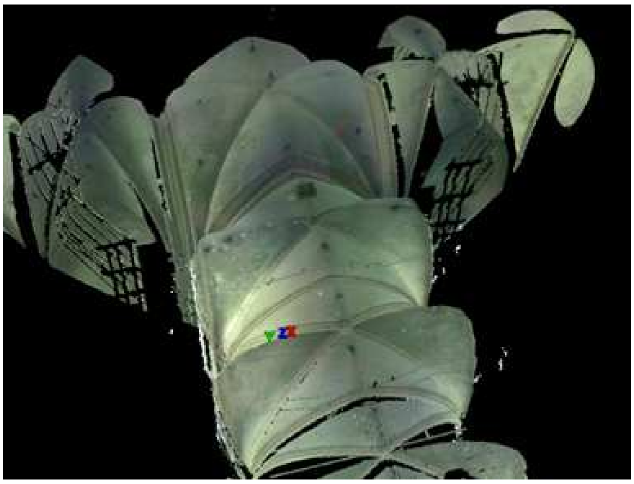

Figure 2: Scanned point cloud of the vaults from the inside of the St.-James church, PCA and author.

To be able to commence with conservation interventions for upgrading the condition of the church, a number of actions should be taken.

- Since the church has suffered alterations through-out the time, an as-built plans and sections should be made, this requires the church being fully surveyed, providing relevant information to get a set of measured representation in 2D;
- The structural condition assessment is also needed. In particular the masonry vaults and some wall pieces that may have deformed during the years. To measure the deformation, we want to compare these building elements to the geometrically ideal shape. Therefore a full 3D model of these elements is needed for a finite element analysis. Using this data, appropriate structural supporting and/or reinforcement techniques can be chosen to keep the church from detoriating any further.
- The foundations of the church should also be checked and reinforced to keep the church from moving and to assure ….

4.1.1 Deliverables

The following deliverables are prepared for the online tutorials, providing an efficient learning material set of different products from laser scanning, the products consist of:

- Creation of a 2D measured dataset of as-built plans, elevations and sections of the church, containing the inside and outside measurements of the building with an accuracy that is used in architectural drawings, meaning +- 3 cm. To make sure the whole structure of the church can be clearly understood from these drawings we suggest creating:
- at least 4 floor plans (1.20m, 8.70m, 13.00m and 19.00m)
- 2 cross sections (1 longitudinal along the main axis, 1 through the transept)
- 3 elevations (of the facades that are not obstructed by trees)
- Creation of a full 3D meshed model of the masonry vaults with very high accuracy (+-1/2 cm)

- Creation of a full 3D meshed model of the side wall of the transept to be able to check it's inclination angle

Next to these primary deliverables the laser data can also be used for tourism as to provide virtual walk-troughs and illustrating the measures that have been taken to renovate the church. Other possibilities are monitoring the deformations of certain structures like the masonry vaults in time, as to assure structural safety once the church will be put back in use.

Figure 3: Meshed point cloud from interior, PCA and author.

4.1.2 Didactic approach

St James has been chosen for being a relevant case study for didactic purposes because it represents both the complexity and the needs required for using laser scanning.

In this case study we focus on the problem of connecting inside scans to the outside scans. This means that we will need some kind of a reference system that connects the inside and the outside measurements. For this purpose we suggest using a total station to setup a closed polygonal reference system that allows us to reduce errors by traverse network adjustment. From each of the total station setup points, we also measure a number of target points (natural or artificial) on the building itself, which will provide the necessary means to connect all the measurements.

A second problem that will be tackled is the minimization of the scan positions. The church is a large structure, so we want to get as many measurements as possible from as few positions as possible.

And last but not least, the processing of the data will be handled. Even today with high-end computer technology, one of the biggest problems still remains working with very large datasets (up to 300 million points). Final deliverables in the form of 2D floor plans and sections and a full 3D model of certain parts of the church are required for use in structural computations using finite element analysis. This data processing step will also be handled in the tutorials by explaining state-of-the-art software and algorithms and looking ahead at possible future developments in this field.

Of course accuracy and resolution play an important role when talking about surveying, these topics will also be handled into full depth and a comparison will be made between laser scanning and other surveying techniques.

Figure 4: inside St.-James church in Leuven, scanning using a phased-base scanner provided by Plowman Craven and Associates, author.

4.2 Risk minimization by using laser scanning

In this case study we minimize certain risks by using the laser scanning surveying technique. Because laser scanning is a distant measuring technique, we do not need to make contact with the structure. This minimizes the risk of further detoriation.

For the same reason we have no need for scaffoldings to measure the ceilings. This is good because scaffoldings might damage the structure and they create a possible safety risk for people working on it.

By scanning the structure more than once over a certain time frame, conclusions can be made about the structural safety without having to perform destructive testing. The benefit of this type of monitoring is also that not only stresses or deformations in sparse points can be measured, but the deformation of the structure as a whole will be assessed.

Figure 5: Example of a meshed point cloud from one of the inner vaults, PCA and author.

5. CLOSING REMARKS

In the long term, this project will improve the capacity that ‘spatial information’ is acquired by adapting advanced three-dimensional recording techniques, such as laser scanning. Spatial information is a very important component for improving decision making processes, especially in studying the built environment. In addition, the project seeks to link the needs for risk awareness in studying the built environment and the development in high precision measurement.

6. FUTURE WORK

The project presented here is currently under development. The case studies are in process of being finalize, the coming phases foreseen the preparation of the didactic material, based on the first hand experience provided by the cases.

This project’s contribution will be significant, not only from the point of view of the use of laser scanning, but to establish a close link between mapping for risk characterization of our built environment, ensuring safety and quality of living.

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