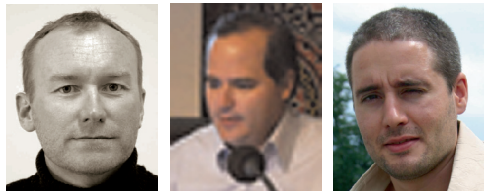# ICT-Supported Learning and Training Tools for Terrestrial Laser Scanning Applications

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Abstract

This paper describes the approach and developments of a project called '3DRiskmapping'. The project aims were to create a 'learning on demand' tool for the use of terrestrial laser scanners in documenting our built environment. The deliverables of the project include a number of 'ICT-supported training tools' that can be used and adopted by academic institutions in their current and future curriculum.

The resulting package consists of a theoretical introduction 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 decision flowcharts for procuring 3D spatial information surveying projects with laser scanning.

The course material is available in five languages: English, Spanish, German, Romanian and Dutch.

Future users will be able to register themselves online at the didactic portal and download all the course material free of charge.

1. Introduction

Terrestrial Laser Scanning (TLS) is a very innovative and useful surveying tool for capturing 3D surface data. Since its beginning in the early 1990s, it has been used in industrial applications, such as piping or in the automobile industry, but it has also emerged in the cultural heritage sector as well as in environmental risk characterization. In spite of these increasing interests, its application has not been fully exploited, among other things, due of lack of appropriate didactic material available at academic institutions and deficiencies in communicating the potential benefits based on real-life case studies.

The aim of the project called '3DRiskmapping' was to create an e-learning platform for utilizing 3D terrestrial laser scanning techniques for risk characterization of our built environment.

The project was launched in autumn 2006 and ran for two years and was co-financed by the European Leonardo da Vinci Project. The project group consisted of eight partners from six EU countries: four academic institutions – KaHo Sint-Lieven Ghent (BE), Universitatea tehnică "GH.Asachi" Iasi (RO), University of Natural Resources and Applied Life Sciences, Vienna (AT) and Universidad Politécnica de Valencia (ES); three surveying companies – Plowman Craven PCA (UK), BnS (BE) and Globe (BE); as well as one engineering company in 3D modelling and simulation – DelftTech (NL) .

2. Didactic approach / Teaching Material

The didactic material of this training course is designed to be used in an e-learning environment. The entire material is available at an online didactic portal on the Internet and consists of *lesson e-books*, *best practice training material*, *decision flowcharts* and an *information hub.* A compiled data set on DVD is available for dissemination to areas with limited Internet access and/or broadband.

The didactic content prepared in this project follow a pragmatic approach, where the following characteristics are present:

- Tutorials cover various applications
- Real data of a measured object
- Use of the most advanced laser scanning tools to address the project needs
- Sufficient case study material to illustrate common problems of TLS in practice

2.1 Lesson e-books

The Lesson e-books are designed to procure an theoretic background on laser scanning, also including:

- the process of procuring technology
- the application of technology for recording three-dimensional spatial information: process of collection and registration

■ the application of software to provide three-dimensional spatial information: process of modelling and visualization

2.2 Training material

Examples of industrial application, heritage documentation and deformation monitoring are available to the trainees. All these tutorials are based on commercial off-the-shelf (COTS) equipment and software. They all follow a strict format, where each processing step is explained in detail and an online evaluation is possible at each stage of the work.

Didactic modules used in the tutorials:

The trainee is guided step by step through the entire workflow of a scanning project; from the problem statement at the beginning to the final visualization possibilities.

■ Interactive instructions: The textual part of the tutorial consists of a verbal description of the procedure and detailed step-by-step instructions to follow up the work flow. Cross-references as well as hyperlinks offer further information on the specific items.

■ Video tutorials: Additionally, the more complex processing steps are explained using short film sequences.

■ "To do" summary: At the end of the chapters a so called "To do" summary is available to recapitulate all steps necessary to achieve the required result.

■ Self test "Question boxes": The trainee is asked to explain the reasons for failures or errors that occurred during data processing. This self test offers the user a possibility to evaluate the knowledge attained of a specific item.

■ Success control using pre-processed data-sets:The trainee can compare the results he/she has achieved with the "correct" results, which are available at different stages of the course.

■ Modular training : The above mentioned pre-processed datasets also offer the possibility to select individual modules for training. Thus, for instance users with experience in data capturing (scanning) can start the tutorial at the section *data processing* or even *3D modelling.*

2.3 Decision flowchart

Interactive flowcharts were developed to find adequate solutions to different questions. These decision-making tools are individually coordinated with the requirements of the respective processes; each stage of the cycle provides

the trainee with information on how to apply this technique effectively and adequately.

For example, a *quality control flowchart* describes the processes for the correct acquirement of the built environment using laser scanning (Fig. 1)
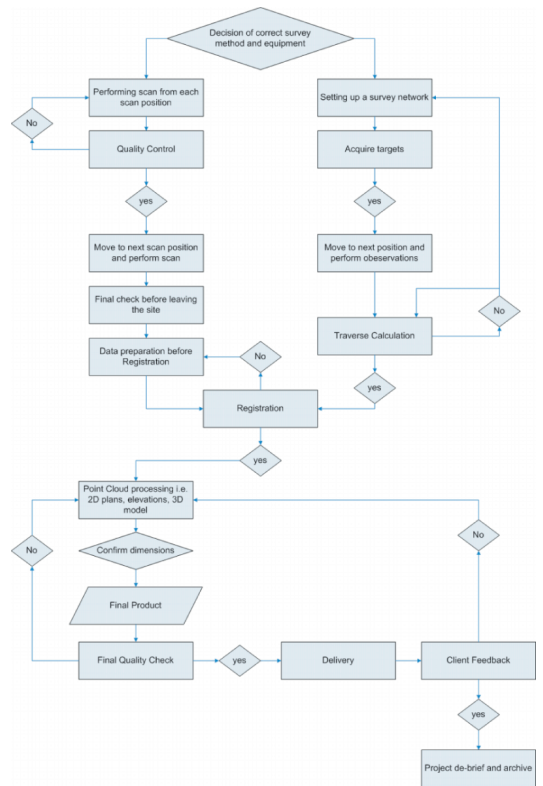

Fig. 1: Decision flowchart "quality control"

2.4 Information hub

A resource hub – compiled by the partners – with relevant information and links for the target group beneficiaries in the application of these technologies. A first version including further reference material and subject specific organizations around the world is available at: http://www.3driskmapping.org/site/

3. General description of the tutorial

The course developed within this project consists of two main parts, a theoretical part and a practical part, or so called hands-on tutorial, based on real-life case studies.

3.1 Theoretical part

The first part of the course is dedicated to the theory on TLS and is divided into 4 chapters:

Chapter 1 serves as a general introduction to laser scanning and the applications for which it can be used. The following topics are discussed:

- What is risk assessment?
- What is laser scanning?
- Static and dynamic laser scanning
- Applications of laser scanning

Chapter 2 is a theoretical exposé of various laser scanner types and how they work. It also explains the different metrological aspects that need to be taken into consideration when scanning. Topics discussed:

- The electromagnetic spectrum and light
- Lasers
- Important properties of laser light
- Laser safety
- Measuring using light
- Metrological aspects: error analysis
- State of the art laser scanner equipment

Chapter 3 explains the process of performing a laser scanning job. Every step of the process is explained in detail, providing tips and tricks based on expert experiences. Topics discussed:

- Survey planning
- Field operation
- Data acquisition
- Data preparation
- Registration & geo-referencing
- 3D point cloud processing
- Quality control & delivery

Chapter 4 provides a view on the problem of data management. A set of meta-data tags that are important for the dissemination and archiving of laser scanner data were defined. Topics discussed:

- Laser scanner data formats
- Scanning metadata
- Project metadata
- Registration information
- Storage media

3.2 Best practice training examples

The practical part of the course is designed as a hands-on training part based on real-life case studies. This tutorial contains 3 case studies, each

chosen to illustrate certain problems, benefits, purposes and limitations of the recording technique utilized. Each of the case studies also focuses on different aspects of the laser scanning process:

Heritage Case Study (St. James Church)

The heritage case focuses on both the registration phase and post-processing of data. The dimensions of the church and the inside-outside relationship of the scanned surfaces provide an excellent challenge for linking scans taken from different positions. On the other hand, the level of detail requested and required deliverables require a time-consuming post-processing phase using highly specialized software (Fig. 2).
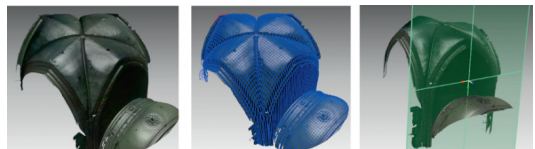

Fig. 2: Cupola of St. James Church

Industrial Case Study (FPSO vessel)

This case study explains the possibilities of using laser scanning in surveying industrial sites. An extensive overview of possible uses of the processed data during the engineering phase is given: it also tackles the actual scanning itself, using a software tool that simulates a laser scanner, providing insight into how to set up the scanner and the correct parameters (Fig. 3).

Fig. 3: Petrochemical installation of the FPSO

Civil Infrastructure Case Study (Hydroelectric Dam)

This case study describes the use of laser scanning data for monitoring deformations over time. Special emphasis is placed on determining the optimal laser scanning and target locations and on comparing different datasets for monitoring purposes (Fig. 4).
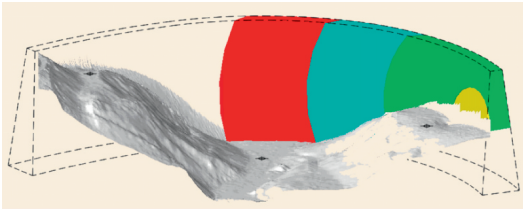
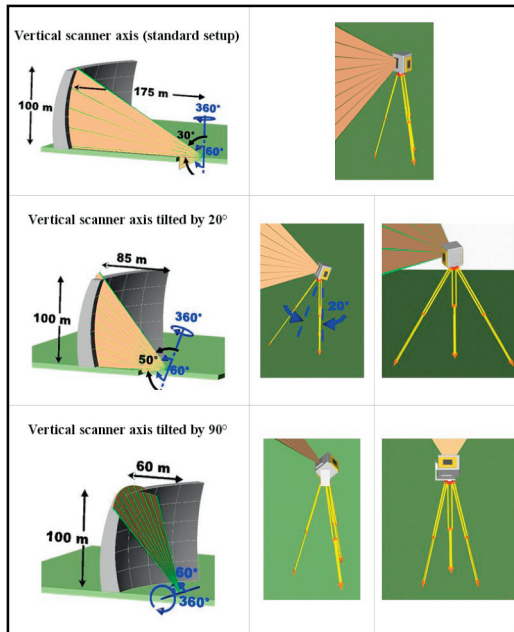*Fig. 4: Model of arch dam of "Kops" reservoir*

Fig. 5: Scan distances at different scanner set-ups

4. Exemplary excerpt of the tutorial
4.1 Determining the optimal scanning position

In case of scanning an object with a height of 100 m under a field-of-view of $\pm 30°-$ (Figure 5a), the Trimble GX 3D scanner requires a horizontal distance from the object of:

Solution 1: $l = 100\,m/\tan(30°) \approx 175\,m$

However, it is possible to decrease this distance by tilting the laser scanner a few degrees (e.g. 20°, Figure 5b):

Solution 2: $l = 100\,m/\tan(50°) \approx 85\,m$

To reduce the distance between scanner and dam even more, it is necessary to use a totally different mounting for the scanner. An orthogonal mounting bracket can be used to turn the scanner by 90°. In this case, the vertical scan direction

becomes the horizontal one and vice versa. So the resulting field of view of the scanner is 360° vertical by 60° horizontal (Figure 5c).

With this adjustment, it is possible to come closer to the object. To avoid the appearance of low intersection (sharp) angles, we keep an angle of 30° between the object's surface and the laser beam:

Solution 3: $l = 100\,m/\tan(60°) \approx 60\,m$

4.2 Registration – Finding errors

Open the *Registration menu* and start the *register* command. When this procedure is finished, the error column is filled and an error vector column has been added. The constraints can be sorted in descending order based on the error value by clicking the header of the error column. In this way, the constraints can be analyzed (see video *"registration_interior_part6.avi"*).

> *To Do: Sort the error column and check the error values.*

In the error column, the first *4 (reduced dataset: 2)* constraints have an error measure of more that 2 meters; *Target 17* is also involved in all these constraints. By double clicking on a constraint, *Cyclone* opens both *ScanWorlds* involved in the 2 viewers below (Fig. 6).

> *Question 1: Double click the second constraint matching ScanWorld 5 and ScanWorld 6 and zoom to target 17. What is wrong with target 17?*

Answer to Question 3 (remark: The answers are located at the end of the tutorial): "We can see that Target 17 in ScanWorld 6 (the right viewer) is not well-defined in the point cloud."
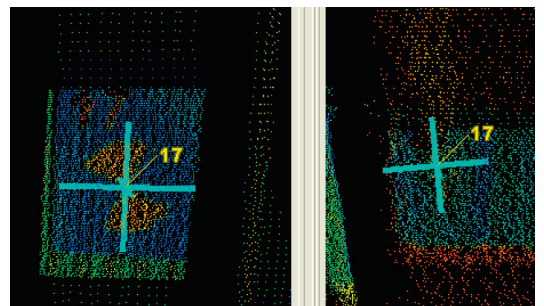

Fig. 6: Target 17 in ScanWorld 5 (good position – left) and in ScanWorld 6 (bad position – right)

5. Conclusion

These training tools will benefit the surveying community as well as the laser scanning industry by making people more aware of this new technology and its possible applications. Besides an introduction to laser scanning, its processing and decision flowcharts help the trainee to decide which recording technique is best for a certain situation. The final outcome of this project is not meant to be a commercial advertisement for laser scanning, but rather an in-depth analysis of the possibilities and limitations of using this technique for recording the built environment on the one hand, as well as a manufacturer-independent, quality-oriented tutorial for the application of terrestrial laser scanning.

References

[1] *Lerma García J.L, Santana Quintero M., Heine E. (eds), 2007:* Applications of terrestrial laserscanning for risk mapping. Polytechnic University of Valencia, Spain. 115 p.

[1] *Lerma García J.L, VanGenechten, B., Heine E. and M. Santana Quintero (eds), 2008:* Theory and practice on Terrestrial Laser Scanning. Training material based on practical applications. Polytechnic University of Valencia, Spain. 261 p.

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