From a conservationist's point of view.

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Abstract. Although more and more computer-aided technologies are utilised or demonstrated on well-known monuments or archaeological sites, there is - at least for the professionals working in the field - still some lack of clarity about their application. The main idea of our research project is to construct a prototype of a tool that tries to bring new technologies closer to the daily practice. It incorporates recent developments in computer vision and reverse engineering, while at the same time tries to answer the practical concerns from civil servants, architects, topographers, art-historians... who are responsible for the conservation of monuments or archaeological sites. The proposed system covers automatic correspondence analysis and point cloud manipulation to build up a textured 3D model. This model then acts as the central core of a multimedia data structure for the annotation, geometric and thematic interrogation and visualisation of the building or site being studied.

Key words: computer vision, reverse engineering, conservation, monuments

1 Introduction

This paper presents an ongoing research project [2] that uses recent developments in computer vision and reverse engineering to develop a tool for the specific field of conservation of monuments and archaeological sites. The collaboration between three departments from the Faculty of Engineering brings together partners who are working on software development in related fields -computer vision, reverse engineering and CAD - and a partner who represents the users, namely the Raymond Lemaire Centre for Conservation (RLCC),a Postgraduate Training and Research Centre at the same Faculty. The re-search is also actively followed by a small group of professionals in the field -civil servants, architects, topographers, and contractors - who give feedback on the practical application of our developments. This text first describes the particular needs in this domain and afterwards explains our approach to develop a prototype for this tool.

2 Documentation and Conservation

Two excerpts from well-known Charters in conservation focus on important aspects in the conservation of our built heritage relevant for our research.

Venice Charter 1964[3]

Art 9, Restoration.

... The restoration in any case must be preceded and followed by an archaeological and historical study of the monument.

Art 16, Publication.

In all works of preservation, restoration or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs. Every stage of the work of clearing, consolidation, rearrangements, as well as technical and formal features identified during the course of the work, should be included. This record should be placed in the archives of a public institution and made available to research workers. It is recommended that the report be published.

Appleton Charter, Canada[4]

Practice and Documentation.

The better a resource is understood and interpreted, the better it will be protected and enhanced. In order to properly understand and interpret a site, there must be a comprehensive investigation of all those qualities that invest a structure with significance. This activity must precede activity at the site. Work on the site itself must be documented and recorded.

Apart from these guidelines, the conservation of historic buildings re-quires a methodology that includes the following elements: Analysis, Diagnosis, Therapy and Control [5]. This should not be considered as a linear process, but rather as a continuous cycle. A considerable effort is reserved for documentation, which includes the collection and organisation of the information related to the problem being investigated. This does not only serve as justification for the decisions being taken, but also as an archive for future investigations. Although many different visions on conservation of monuments and archaeological sites exist, there is an agreement about the importance of this analytical approach [6].

A crucial part of the analysis consists of recording the object in question. Its aim is to improve the understanding of the building. The measuring techniques used on the site must fit the size of the building, the accuracy needed and the specific requirements of the job (a stability problem, the deterioration of the stone surface, the conservation of a wall painting . . .).

The geometrical recording of the building is of course not the only part of the analysis: research in archives, photographs, chemical or structural tests on materials… also add important information on the building's history and present condition. The recording should act as a reference to situate all this information, e.g. the position of the brick samples… Ideally, all this information can be consulted and updated during the entire work cycle by all persons involved. They must be able to derive information that is important for their specific research, or add extra information and personal interpretations.

3 Present Situation

3.1 Traditional Methods

Today, many architects involved in conservation still work in a rather traditional way. They use hand-measured or instrument-based survey methods and transfer these data to 2D paper drawings. The main drawback of this approach is that all information is distributed in different types of documents (2D drawings, texts, photographs . . .), which makes it often difficult to get an overview of the information available. Moreover, it is very difficult to ex-change this material with other architects or researchers, or for distribution to the public.

Another important aspect is the need to adapt the recording technique to the work that will be carried out. A clear scheme that starts from levels of recording, and relates it to the purpose, recording instruments and accuracy, was published by Robin Letellier [7]. In practice though, architects often do not comply with these obvious rules, and use far too simple measuring methods and idealised drawings for works on important historic buildings, as shown in Figure 1 [8]. Any professional in the conservation field will agree, that it is unjustifiable to use this type of drawings as a base for decisions and interventions on our heritage!

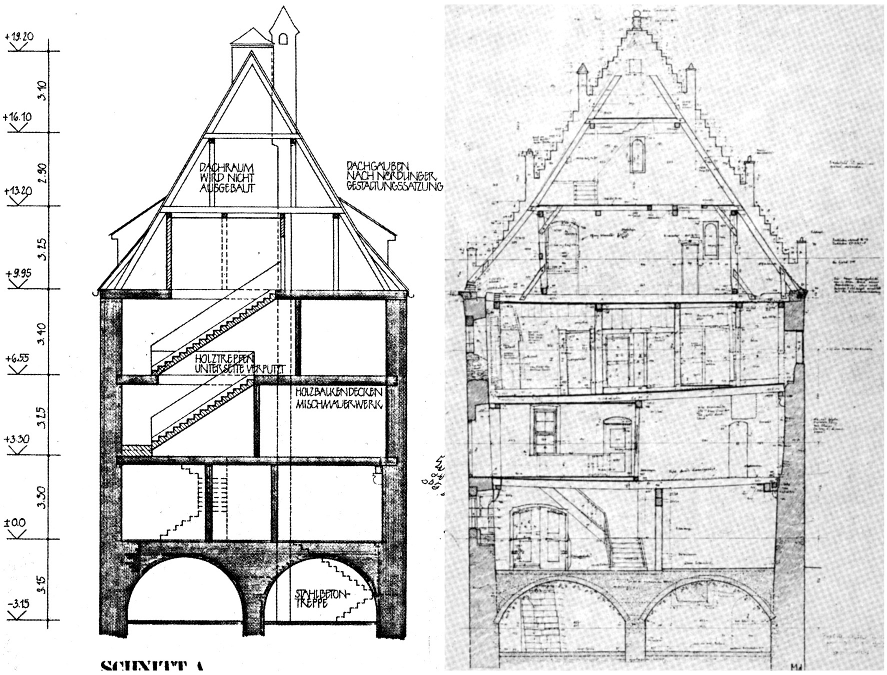

Figure 1 Left: Section used to conduct work on a building dating from 1340; right: emergency recording

3.2 Computer-Aided Methods

Recording Tools.

At the same time, many architects are shifting towards computer-aided design for new buildings, and try to apply these programs to renovation or conservation projects. However, tools to get the existing building into the CAD-program are scarce, and most often translate traditional methods to CAD (automatic import of full station coordinates… Based on the typically limited number of measured points, and the difficulties of drawing irregular shapes in CAD-programs, this often results in an idealised representation. As shown above, this simplification is certainly not a problem of CAD-drawings alone. Apart from programs that import existing measurement data, applications for digital photogrammetry are developed. Research at the RLCC in collaboration with the CAD-lab revealed that this technology can provide accurate 3D surveys [9]. Unfortunately these programs have a rather long learning time and are very labour-intensive. Another approach to raise the amount of measured points is by applying laser-scanning tools for conservation purposes. They allow fast and accurate measuring of a large number of points [10]. The accompanying software provides the processing of the point clouds, export to standard geometrical file formats and conversion to geometrical primitives. So far, the application of digital photogrammetry, laser scanning or similar tools in architectural conservation practice is very limited. The techniques are relatively new, the instruments and accompanying software rather expensive and difficult to learn. Visualisation and Multimedia Tools Simultaneously there is also an increasing use of visualisation programs to display architectural or archaeological sites in their present or previous states. Unlike tools described above, they focus on visualisation techniques rather than geometrical accuracy. Although the effort to build up a reasonable detailed environment should not be underestimated, these models often remain an idealised representation of reality, and are thus restricted in their usability to visual presentations or preliminary studies. Many of these examples are very useful to visualise successive building phases or various interpretations in heritage information systems [11]. Together these emerging trends lead to vague and confusing ideas about what these new technologies can be used for, and to what extent, whereby the discussion between advocates and opponents is rarely focused on the real problems. Every technology certainly can be useful, but it should be clear what is the real aim of its application and to what extent it is a simplification of reality.

4 Our proposal

As can be concluded from the previous part, there is a real need for adapted technology to document and represent historic buildings or archaeological remains in a 3-dimensional way. The tool we are developing really focuses on the requirements from professionals in this field, for a detailed recording and documentation of buildings or sites prior to an important intervention. The principal attention of the project concerns the following topics:

For the objectivity of the information, a consistent 3-dimensional geometric model is to be used. The accuracy of the model must be adaptable to the size of the object and to the specific requirements for the work.

The geometric model is constructed through automatic correspondence analysis and adapted techniques in point-cloud handling, which makes this task less labour-intensive and leaves more time for interpretation.

This geometric representation acts as a central carrier for the layered information linked to the heritage. As such, the users build up a single database including - or linked to - all types of information available, which can be used for distribution towards other professionals or the public.

5 Implementation

For the implementation we decided to build up a stand-alone application that combines the different modules. The integration in an existing CAD-program is not opportune, as such programs do not provide the open structure we need. A disadvantage of this approach is that we cannot directly use the extended drawing possibilities that already exist in these programs, which is solved by providing import and export facilities. In the following text we will describe how we translated our proposal in different technological goals that all together built up the system, see Figure 2. Part one describes the construction of the geometric model, which ends with a meshed and textured representation of the object. The second part is focusing on working with the model, describing the adapted tools to add information to the database, view and query the database… In our approach, a model is the complete collection of structured information about a specific object, c.q. a building or a site. This model can be divided in two main parts: the actual geometry, which is considered objective, and the set of attributes and annotations, which are subjective.

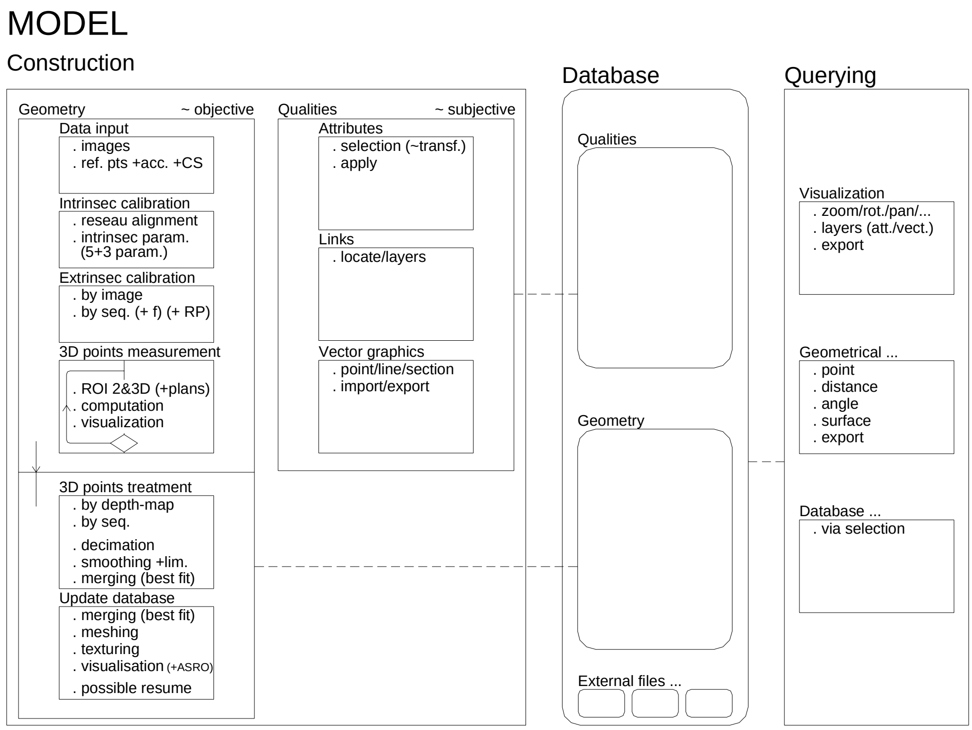

Figure 2 System structure: model construction - database - database querying

5.1 Geometric Model Construction

The input for the construction of the geometric model is a sequence of overlapping images of the considered building. A small number of reference points must be known to locate the geometric model in the world coordinate frame. This is important to allow exchange with other modelling or analysis tools. Furthermore, it constraints the search for additional matches and thus simplifies the automatic matching process. Based on the reference points and the additional matches the intrinsic and extrinsic calibration are computed. An extended camera model, including radial lens distortion, and bundle adjustment are used to achieve optimal and accurate results. The next step consists of obtaining a precise model of the surface of the observed building. The approach is based on the fully automatic 3D modelling approach described in [12]. An important extension consists of streamlining the interaction with a user, who can indicate special regions of interest and can help the system to increase the efficiency, e.g. by manually eliminating trees in front of walls. For every selected image in a sequence, a depth map is calculated, Figure 3. A first rough visualisation helps the operator to get an impression of the results. The separate depth maps are first transferred to point clouds using the camera parameters. From this moment on some typical tools from Reverse Engineering point-cloud manipulation are used. First point clouds from different images in one sequence are merged together, Figure 4. On this level, decimation techniques can be used to reduce the model to a workable size. In an analogue way different sequences can be combined. Every step in the process starts with preset parameters that are typical for the filter. Operators can change them, implying that the result will depend on their needs and interests. It also allows them to construct a model that is in line with the performance of their computer. The result of this component is a meshed model, textured with the images that were used to compute it. Methods to extract the optimal texture from the images are under investigation. It is important to keep track of the accuracy of the results. The outcome of the automatic correspondence analysis already contains information about the accuracy. It is clear that every filter applied to these results must keep the results within the acceptable range. The general structure of this process should be cyclic rather than linear. The system must be able to go back and forth to adapt the results according to the requirements of the user.

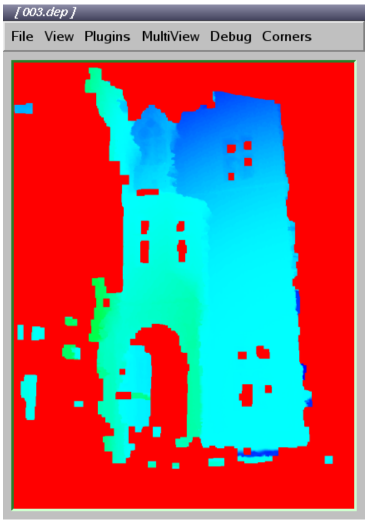

Figure 3 Depth Map

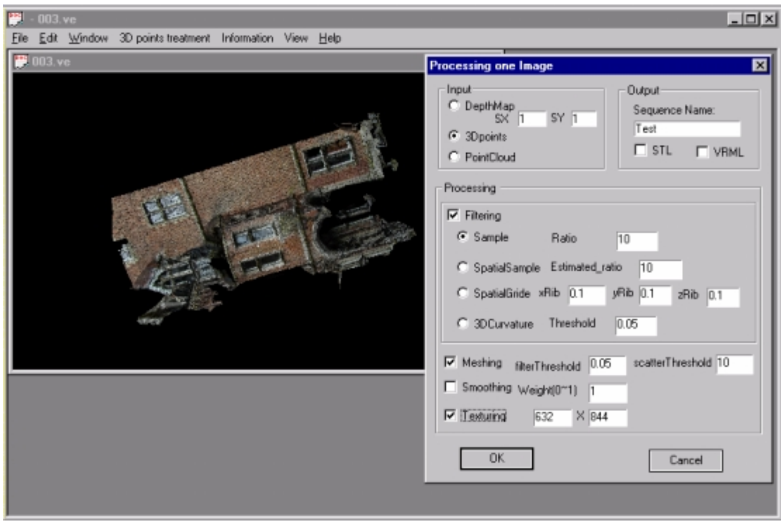

Figure 4 Applying reverse engineering techniques on point cloud data

5.2 Database

This component deals with using the geometric part of the model as the core for a multimedia database. In practice, it allows users to annotate or augment the model with additional information or interpretations in a structured way. To this end a general file structure is established which enables these tasks. As the annotation or linking is coupled to a segment of the geometrical model, general modules for selection are developed. They can be based on geometrical criteria (polygon, rectangle...) as in Figure 5, or on already assigned information in the database, see Figure 6. To allow a structured organisation, we developed a system that can group information on specific themes. Every theme in itself can have multiple layers (for example the theme material can have brick, white stone . . . as its layers). In an analogue way, links to external documents (texts, images, reports, drawings...) can be attached to the model. An icon on the picked reference position is indicating the type of document. These icons are only visible on the themes they are relevant for. A specific type of theme is a vector theme. It is used to draw basic geometric entities (points, lines, triangles) inside our editor, or to import vector graphics from other applications. This module enables us to rely on complex drawing tools from existing CAD-packages, instead of having to implement our own. The linked information must also survive adaptations on the geometrical part of the model. Therefore all filters must conserve indexing and special modules are necessary to fuse overlapping geometrical parts. If necessary, one can go back to the construction of the geometrical model. This may be useful when some part of the geometry is too undetailed to work on for a specific application.

5.3 Database Querying

Selection criteria on an un-annotated geometrical model can use only geometrical constraints, e.g. enclosing polygons. When more information is added, selection criteria can be more elaborate: e.g. select all entities within this polygon that belong to layer X in theme Y. Furthermore, Boolean operations on previous selections can be made. Specific geometrical querying is implemented to measure lengths and areas on the model, including an estimate for the absolute error of the result. A very special type of querying the database is the visualisation. As not all information from all themes can be seen at once, a view on the database can present only a partial view. In a first phase, one theme and numerous vector themes can be visible. The texture colour is changed according to the layer colour of the triangle in this theme. The visible entities and layers in a window can be exported to common formats as DXF and VRML. This widens the possibilities for distribution to the public, as standard browsers can view them. These facilities permit to derive all types of interrelated information from the model.

Figure 5 Geometric manipulation

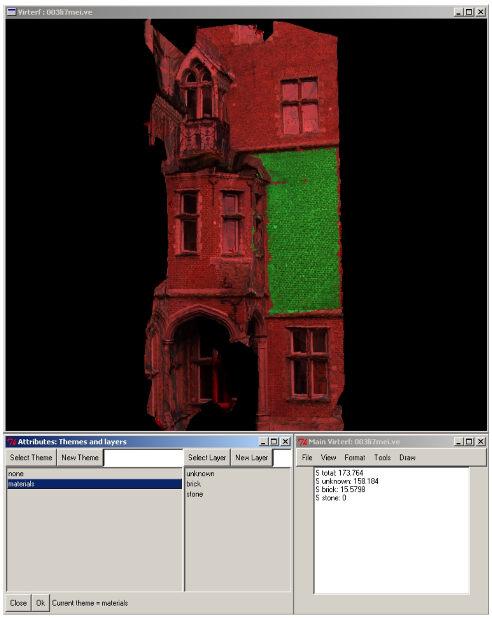

Figure 6 Annotation using themes and layers

6 Conclusions.

Regular meetings with the user group show that our initial ideas are in line with the needs in the sector, and that our approach still seems to be achievable. The major problem concerns the incorporation of existing libraries with the constraints of indexing. Visualisation of large meshes still remains a privilege of powerful computers with special graphics boards. Keeping in mind that we are currently working on a prototype, we already foresee future hardware developments. As the mesh complexity is adaptable by the user, the actual use of our prototype is not limited to high-end workstations. We expect our project to proof that information technology can provide interesting tools in a field that is often unwilling to accept these developments in daily practice. To test the practical utilisation in the field, the last months of the project are devoted to selected case studies in collaboration with the user group. Depending on the outcome of these tests, we hope to be able to continue in this direction, which in the end should lead to an additional and useful tool to document and conserve our heritage.

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References

1. Contact information: ir.arch. Kris Nuyts, Dept. ASRO, Kasteelpark Arenberg 1, 3001 Leuven, Belgium; tel 0032.16.321769, fax0032.16.321984 e-mail: kris.nuyts@asro.kuleuven.ac.be; project website: http://virterf.asro.kuleuven.ac.be
2. Sponsored by IWT (www.iwt.be) as an STWW project.
3. http://www.icomos.org/docs/venice charter.html
4. http://www.icomos.org/canada/appleton charter.html
5. Searls, C. L., L. Binde, J. F. Henriksen, et al., Group Report: How Can We Diagnose the Condition of Stone Monuments and Arrive to Suitable Treatment Programs? Saving Our Architectural Heritage: the Conservation of Historic Stone Structures. Eds N. S. Baer, and R. Snethlage, pp. 199-221.
6. B. Palo Torsello, La Materia del Restauro, techniche e teorie analitiche, Venezia pp 131-132
7. Letellier R., Computers in Conservation: Toronto, Quebec City, and Afterwards, in APT Bulletin Vol XXVI n1, 1994, pp.6-10.
8. G.T.Mader, Angewandte Bauforschung als Planungshilfe bei der Denkmalinstandsetzung, in Kirschbaum J., Erfassen und dokumentieren im Denkmalschutz (Schriftenreihe des Deutschen Nationalkomitees fur Denkmalschutz,16), 1980, pp 42.
9. Van Balen K., Nuyts K., Smars P., et al., Optimisation of models for the evaluation of the stability of vaulted gothic structures using deformation measurements and crack analyses, research report RLCC KULeuven, 1995

Nuyts K., Van Balen K., Cathedral of Antwerp, Preliminary investigation façade restoration, research report RLCC KULeuven, 2000.

10. Alonzo C.Addison, Virtualised Architecturel Heritage- New Tools and Techniques for Capturing Built History, VMSS98 FutureFusion, p.17-22
11. D.Pletinckx, D. Callebaut, A.E.Killebrew ea, Virtual Heritage Presentation at Ename, IEEE MultiMedia, april-june 2000, p45-48
12. M. Pollefeys, R. Koch, M. Vergauwen, L.Van Gool, Automatic Generation of 3D Models from Photographs, VMSS98 FutureFusion, p.128-133.