CULTURAL HERITAGE RECORDING WITH LASER SCANNING, COMPUTER VISION AND EXPLOITATION OF ARCHITECTURAL RULES

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ABSTRACT:

Laser scanning enables to measure a huge number of 3D points in a few time. However, the creation of a 3D model from these data remains an involving work. We introduce a method to get this modeling task easier. Our approach is twofold. On the one hand, a camera is coupled to the laser scanner in order to drive the scan by image analysis. On the other hand, architectural knowledge is digitized in a library of parametric components.

1. INTRODUCTION

Laser scanning holds obvious benefits to architectural recording. Laser scanners just take a few minutes time to scan millions of accurate 3D points. However, it is a huge work to construct a 3D model, containing useful information for heritage documentation, from these measurements. This aspect is certainly a major drawback of laser scanning methods.

The authors are involved in a research project which aims to provide tools in order to create such models more quickly and more easily. Our approach is twofold. The first part is based upon image processing; the second one, upon architectural knowledge modeling.

On the one hand, a camera is coupled to the scanner [1], and used to drive the scanning process. Region of interest found in the image can thus be accurately scanned. Image analysis is also useful for structuring the 3D point cloud, in order to make modelisation easier. The use of both laser scanning and image analysis has attracted more and more attention for the design of efficient modeling systems (see [5, 6, 7, 8] for example).

On the other hand, we want to digitally model *a priori* knowledge on architectural works. In this aim, we create a library of parametric components, and introduce a set of constraints during the modeling step.

The first step of this work consisted in calibrating the camera ant the laser. This step is detailed in the first section. The second section describes the exploitation of the image to help modeling. The last section deals with the use of architectural knowledge for modeling.

2. REGISTRATION BETWEEN CAMERA AND LASER

The GS100 scanner developed by MENSI [1] holds a camera SONY FCB IX 47P, equipped with an optical zoom and with an auto focus system. For calibration, the camera model generally used in computer vision is the perspective projection model, also known as pinhole model. The projection of a point written in any coordinate system is given by a transformation expressing the point in the camera coordinate system (extrinsic parameters) and by a perspective projection modeled by intrinsic parameters. The use of such a model for a camera equipped with a zoom is not direct because a modification of the focal length and of the focus cannot be modeled by just a modification of the camera intrinsic parameters. Indeed, this modification induces a movement of the optical center of the camera, *id est.* a modification of extrinsic parameters, which has to be taken into account [2].

The calibration parameters (extrinsic, intrinsic and distortions) and the repeatability of the zoom lens have been estimated for different values of the zoom. This leads to the knowledge of the projective transformation relating the scanner coordinates to the camera coordinates for a discrete set of zoom commands.

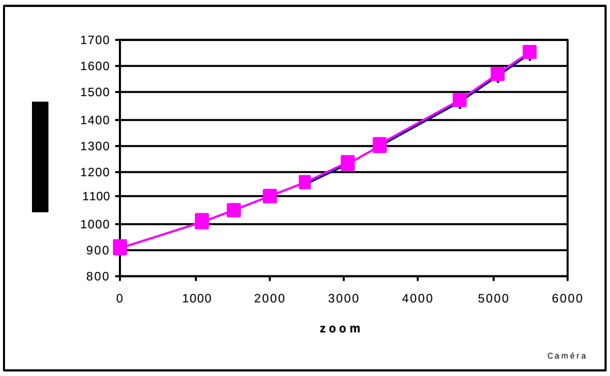

Fig 1. Evolution of focal length with respect to zoom.

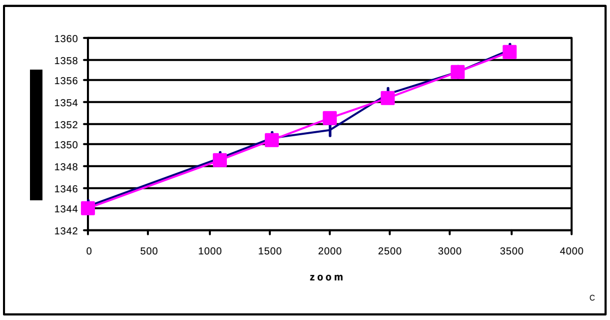

Fig 2. Evolution of the translation in the direction of the optical axis with respect to zoom.

Figures (1) and (2) illustrate this modelisation of both internal and external parameters with respect to the zoom. Several calibration strategies (with different number of parameters in the model) can be considered with respect to the required accuracy. We got a relative precision of about 1%.

3. IMAGE PROCESSING FOR DRIVING THE SCAN

Image analysis is used to drive the scan in order to get, as soon as the measurement step, relevant information for modelisation. It is also used to provide tools to make the modeling process easier.

3.1 Estimation of vanishing lines to scan relevant profiles

Some recent results of research in computer vision [3] lead to accurate and automatic estimation of vanishing points (figure 3). Servoing the laser on vanishing lines enable to accurately scan the frontage of buildings along interesting profiles. These profiles will give precious information during the modelisation step (see next section).

The algorithm used for searching vanishing points can be divided in 6 steps:

1) edge detection;
2) approximation of edges by line segments;
3) grouping of line segments into two groups corresponding to horizontal and vertical directions;
4) computing intersection points of the base lines;
5) computing the most significant intersection points and the corresponding lines;
6) refining the estimation of vanishing points by using a statistical criterion.

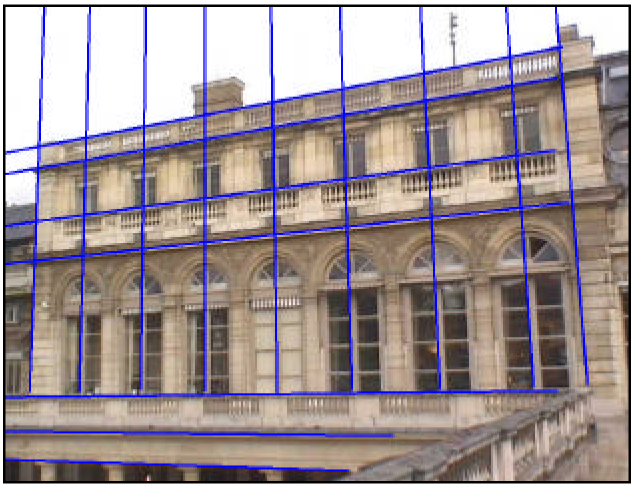

Fig 3. An image of the PalaisRoyal (Paris) and some of the estimated vanishing lines.

Let us note that it is possible to calibrate cameras when three vanishing points, in orthogonal directions, have been estimated [3].

3.2 Rectification of frontages

Furthermore, knowledge of camera calibration and of vanishing points enables the rectification of the image, *i.e.* the correction of perspective distortion of planar structures in the image. We thus compute perspective corrected images of buildings, where the frontage geometry is that which would be seen, had the original photograph been taken with the camera fronto-parallel to the frontage (figure 4). We thus get back, in the image, the initial geometry of the front plane (distance ratio, angles, parallelism). These images are more intuitive to process for an operator, and make further computer processing easier.

Fig 4. Rectified Image of a frontage of the Palais Royal

3.3 Structuration of the point cloud

To structure the point cloud, we propose to search for repetitive elements in the rectified image. The user can select a window in the image of figure 4 and find all the identical ones (figure 5). Our approach is a robust method, based on the correlation of gradient vector in the search window. This approach is more efficient than a simple texture correlation which would not enable, in our example, to get the window with the closed curtain. Nevertheless, the geometry of the window being the same afer the rectification, our approach has found every window back.

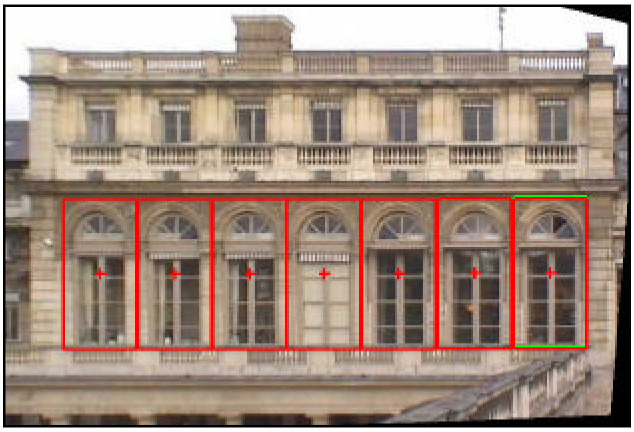

Fig 5. Result of automatic search of repetitive elements. The window in the right was manually selected. Similar windows are automatically found in the image.

The aim of this search of repetitive elements is to make their positioning in the point cloud easier, when one of them has been modeled. We want to extend this technique in order to detect in the image, elements given by a library of architectural components described by their wireframe model.

3.4 Neural approach

We study an other approach for searching architectural elements. We applied a RBF (Radial Basis Functions) neural network on the edges extracted from the different windows, during a learning step.

Then, on a pattern which has not been previously learnt, the system can detect and recognize a window element. The demonstration is completed by a tricky case which detects an area which is not a window.

We show an example of this approach (Fig 6 and 7). The system recognizes a window of the same kind that the one it learnt, while discriminating windows of an other kind.

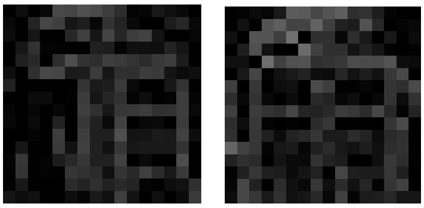

Fig 6 Images of edges from the training set

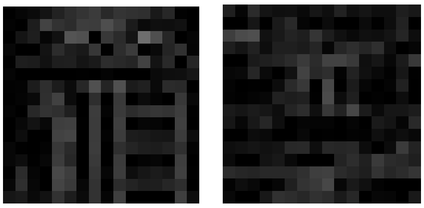

Fig 7 recognized window unknown window

This system enables to consider, in the future, the creation of a library of architectural components, which could be augmented by training.

4. MODELING OF ARCHITECTURAL KNOWLEDGE

The elaboration of an architectural model consists in the structuration of a set of geometrical entities which can represent the relation between the architectural work and the information it bears. The building is described as a set of elementary components, organized by a set of topological relations corresponding to a translation, in geometrical terms, of the architect’s vocabulary.

An architectural representation must be adapted to an aim. This aim determines the choice of the method, the procedures, and the tools to use. This brings to light the notion of “aim of representation”. The step of realisation of an image actually uses the information organized in the model of an architectural work. This model can be considered as a kind of information database from which are extracted the contents of the representation. An architectural model must contain, since the measurement step, the structure of the representation we want to get.

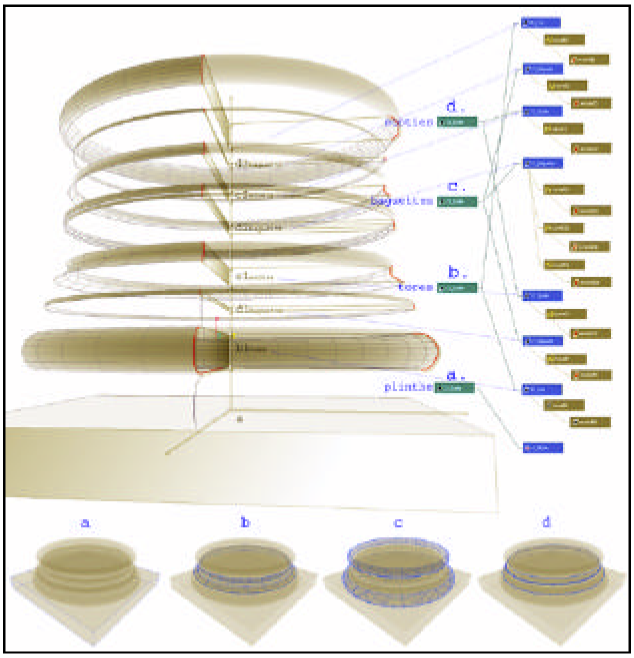

Fig 8. Parametric model of the base of a Corinthian column.

The first step is the description of the building. It requires the knowledge of a *vocabulary* which can express the elements which make it up and their hierarchical organization. The *grammar* describes the relation between the components. These topics are current in the architectural domain, since the first treatises (Vitruve), since appeared the necessity of capitalizing knowledge of the art of building, the necessity to give support to knowledge.

Architectural knowledge is a support to the modeling process. With the help of treatises on architecture, we can deduce the modeling functions which are well adapted to set a certain number of architectural primitives. We thus model a knowledge which enables to describe architecture with architects’ language.

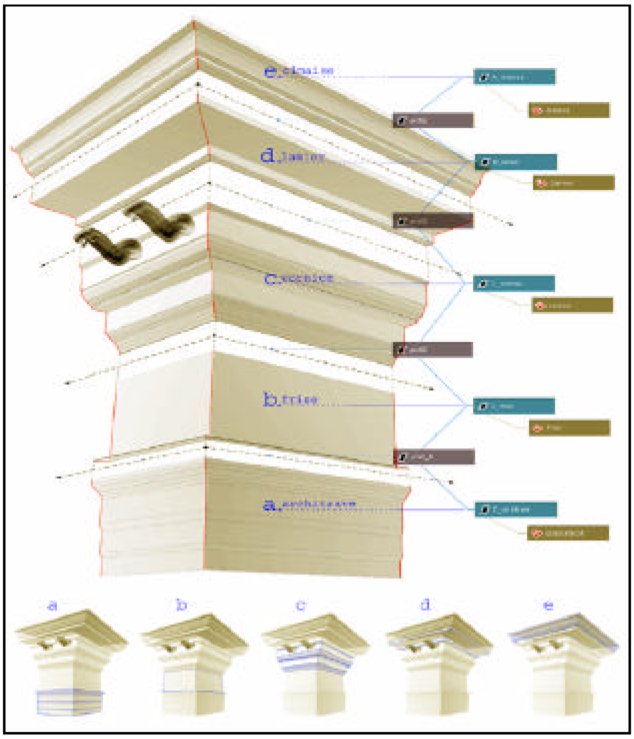

Fig 9. Parametric model of an entablature

Practically, the vocabulary is digitally modeled by a set of parametric 3D curves. The grammar is modeled by a set of constraints. This has been experimented with the MEL language (from Maya, Alias Wavefront). With such a set of parametric components, only a few points are necessary to model an entire building. These points can be obtained from the scanning of relevant profiles (see previous section). However, dense point clouds are still necessary to model unique structures such as sculptures or bas-reliefs.

Furthermore, extracting texture consistently with the structure of the building, gives an abacus of materials. Future prospects are thus open for databases and above all for the possibility to use several sources (images from different period for example). If the structure of description we used since the measurement step remains the same, the entire process can become a system of production of graphic information attached to the 3D model. 3D model thus becomes a useful tool for access to heritage information.

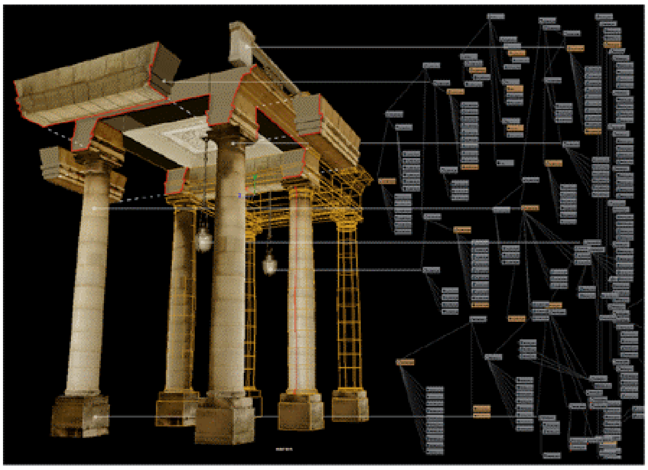

Fig 10. A module of the colonnade with its describing structure.

5. CONCLUSION

We described the first result of a program aiming to couple image analysis and laser scanning, in order to model an architectural work more quickly and more easily. Two approaches were considered:

- driving the scan by image analysis to accurately get 3D points relevant for modeling;
- the creation of a library of architectural components to make modeling easier. There again image gives useful information for positioning the components in the point cloud.

Furthermore, the use of architectural knowledge in the modelisation makes from the 3D model a well organized database of heritage information.

References shall enable a librarian to supply the quoted paper/book to the reader. References should be cited in the text, thus (Smith, 1987b; Moons, 1997), and listed in alphabetical order in the reference section, leaving a blank line between references (this is done automatically when using the provided Word template file). The following arrangements should be used:

6. REFERENCES

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Fig 11. Result of the modeling showing the point cloud, the textured and the wireframe model.

Fig 12.Result of the modeling showing the textured and the wireframe model.