OBJECT SEGMENTATION IN CULTURAL HERITAGE

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KEY WORDS: Remote sensing, Cultural heritage, Analysis, Close Range, Interpretation, Architectural Heritage, Laser scanning, Segmentation.

ABSTRACTS:

With the introduction of new terrestrial laser scanning technologies it is possible to obtain a "dense DTM" of any cultural heritage object in a very quickly and fast way. The 3D model acquired with laser devices represents a dense point cloud of the object. In the case of very complex 3D models it is not easy to manually directly derive a correct surface reproduction of the object from the model in a simple and correct way.
A valid aid in the modelling of objects is the segmentation technique. This allows on different layers portions of point clouds that have similar geometric ownerships to be organised it.
The following article shows the results of some segmentation techniques applied to the case of architectural survey. The advantages and the disadvantages of every methodology are put in evidence.

1. INTRODUCTION

1.1 Introduction

Recently new instruments have been introduced in the field of surveying that are able to survey portions of land and objects of various shapes and sizes in a quick and cheap manner. These instruments, based on laser technology, are commonly known as laser scanners.
Laser scanners can be considered as highly automated total stations. They are usually made up of a laser that has been optimised for high velocity surveying and of a set of mechanisms that allows the laser radius to be directed in space in a range that varies according to the instrument that is being used.
The laser scanner therefore allows millions of points to be recorded in a short time.
Because of their practicality and versatility, these kinds of instruments are today widely used in the field of archaeological surveying.

1.2 Why segment?

The digital models obtained from laser scanners are nothing more than dense point clouds (DDEM- Dense Digital Elevation Model). These point clouds are often remarkably complex. This occurs above all in the case of archaeological surveying of monuments and historical buildings in which there is a great variability of the structure.
After having acquired any object with the laser technique, the usual aim is that of obtaining the greatest amount of geometric information from the model itself in the easiest and most automatic way.
Research today is often dedicated to this new field and many treatment and management procedures of laser data have been developed.
One of the stages in which it is necessary to do further research is modelling. By modelling we mean passing from a point model, as obtained with the laser sensors, to a surface model. It is in fact possible to automatically extract sections or level curves from the object, carry out numerical analysis or even integrate the model with digital images to create a coloured 3D model or to produce an orthophoto.

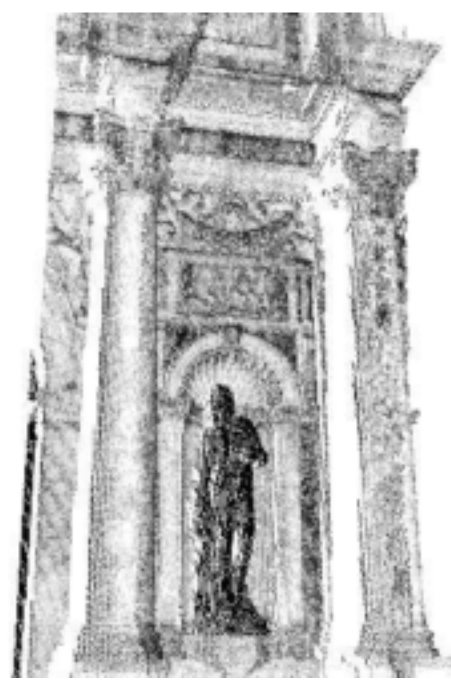

Figure 1 – A DDEM obtained using a RIEGL LMS Z210 laser scanner - Piazza San Marco- Venice – Italy

The solid modelling is easily obtained if the model that has been surveyed with a laser scanner has a simple geometry (for example, a bas-relief or a uniform façade without balconies or high parts protruding), but can become very

complex if the surveyed object has a large number of discontinuities (for example, a historical façade with columns, eaves, statues and niches on the façade, etc.).
In this case the only way to be able to carry out a correct solid modelling of the object is to use segmentation techniques. By segmentation we mean the extraction of geometric information from a set of data and their partitioning into uniform entities. Each of these entities will then be modelled separately. The final form of the model of the object will be generated from the set of the various portions that have been separately modelled.

2. SEGMENTATION TECHNIQUES

2.1 Manual segmentation

As previously shown, in order to carry out a solid modelling starting from a three-dimensional point cloud, it is necessary to segment the object into its simplest portions. Modelling software usually allows this type of operation to be carried out in a completely manual way. The operator chooses and selects a portion of a point cloud on the screen and models this portion of the points to create meshes or nurbs.
On other occasions it is possible to manually segment the objects using graphic management software such as AutoCAD. Therefore the objects are segmented and some portions of the object are placed on different layers.
This type of segmentation which, according to what has been described can be defined as manual requires a remarkable effort by the operator to identify the portions of the points. This is even more the case when the model is dense with information and complex in form.
Today an increasing effort is being made in the field of research into the implementation of automatic segmentation techniques to resolve this problem.

2.2 Automatic segmentation

The problem of segmentation can be found in many scientific applications.
As far as laser technology is concerned, there are many researchers who at present are working on comparisons of segmentations. These are usually carried out on laser data derived from aerial platforms. Some very interesting results have already been obtained.
The case of aerial scanning differs however from that of ground laser scanning. The laser data from aerial platforms are distributed in planimetry while the most obvious discontinuities can be found at heights.
In the case of ground laser scanning, the data are widely and differently positioned in space and the complexity of these dispersions depends above all on the complexity of the surveyed object.
Although the field of aerial laser scanning is rather different from the field of ground laser scanning (close range), some of the segmentation algorithms and techniques that were developed for segmentation of DDEMs obtained from aerial platforms can easily be applied or adapted for ground surveying.

2.3 Segmentation through the identification of the main plains of the object

In order to be able to model the point clouds acquired with ground type laser scanners it is first of all necessary to divide the 3D model into its main plains. In the case of a building, the main plains can be represented by the individual facades or, as is the case for more complex buildings, by portions of these facades.
In order to be able to segment the object according to its main plains, the authors have developed specific software which functions as follows:

- A point that belongs to the scansion. This point can be imposed by the key board or by the operator, or can even be extracted by chance.
- A search radius around an initial point is established and all the points that fall into to this area are considered. The set of these points is used to determine a mean plain that passes through the points. This plain is calculated using the least square estimation.
- If the parameters of the estimation that derive from the calculation of the mean plain that passes through the chosen points are considered to be sufficiently correct (this decision is up to the operator), or in other words if the maximum rejects obtained by the estimation are lower than a previously imposed value, it can be considered that one of the main plains has been identified. After having identified one of the main plains, all the points of the scansion that are at a closer distance from the plain, according to a previously established reference, can be considered as belonging to the plain. It is the operator who decides the maximum distance between the points and the plain for the aggregation.

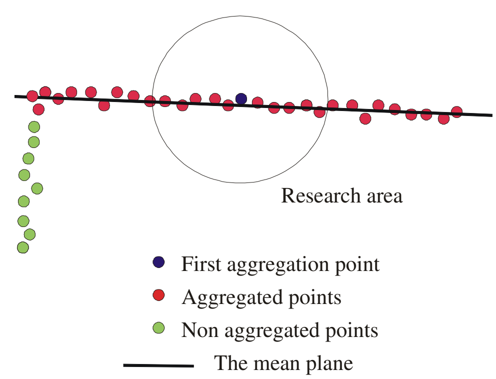

Figure 2 - An example of a plain considered valid, as seen from above.

- In the case in which the parameters of the estimation of the plain are not considered valid, that is, when the number of rejects is too high, they are considered as not belonging to a plain that can be considered as being a main plain.
- The aggregation operation is continued. Another point to which a layer has not yet been assigned is extracted and the operation is repeated.

All the procedures that have been described are repeated until all the points of the scansion have been assigned a layer or until a maximum number of plains, as imposed by the operator, have been found.
The described procedure is nothing else but a first very rough segmentation, but it allows one to easily separate, for example, two facades of the same building that are oriented in a different way.

The software that was developed for this kind of segmentation was prepared in Visual Basic 6 environment.
The choice of the parameters that are necessary for the search for the aggregation points is left to the operator. The choice of these parameters is of fundamental importance for a correct identification of the plains and it greatly depends on the density of the point cloud and on the size and complexity of the model.

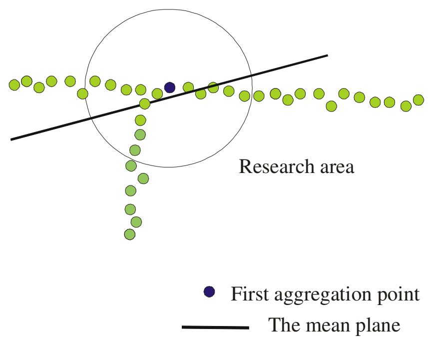

Figure 3 - An example of a plain considered not to be valid as seen from above.

It is possible to obtain aggregations that are completely different from each other by varying these parameters.
The software that has been developed by the authors helps remove the necessity of making a chance choice of the starting point.
The operator can a priori choose from which point to start the aggregation procedure.

2.4 Segmentation using region growing and analysis of the main components

One of the models that were developed for the segmentation of the laser point clouds from aerial platforms is the region growing technique and analysis of the main components.
This method considers the problem of grouping sets together of single entities that have certain properties defined by the partitions in the n-dimensional space of the objects. The algorithms of this method look for the solution using clustering techniques that originate from image analysis techniques. The function principle is based on the hypothesis of the knowledge of certain geometric properties, called describers, whose particulars one wishes to study to identify the partitions in a space. The solution of this problem can be obtained through a simple implementation: the aggregation of the point entity under study or region growing. The space of the describers is defined through the local analysis of the main components, which allow the local geometric properties of the object to be defined in an intrinsic reference system.
The connection algorithm of the growing region begins the aggregation starting from a chance seed, which can be any entity which has not yet been aggregated; this point entity p1 is memorised in a 0 level of a tree structure. Each point is identified by an indicator, which refers to the data base. Starting from this chance seed, the algorithm searches for the nearest points in an a priori defined neighbourhood in the space that unites the spaces of the object with the describers. The neighbourhoods, that is, the entities contained in such neighbourhoods, are aggregated and memorised in level 1 of the structure, as a new branch of the tree. The algorithm continues the aggregation starting from the entity contained in the last level, and so on until the terminal branches of the structure are obtained. The terminal branches are determined by the occurrence of at least one or two events. The first is when there are no other non aggregated entities in a neighbourhood; the second, when the branch contains a particular. The algorithm finishes the aggregation of an object when all the branches of the tree have reached a terminal point; it then starts another object starting from a new chance seed.
The analysis of the main components (PCA) can be used to study the structure of a set of data. The PCA searches a vector base for a (sub) space that:

- maximises the variance of the distributions
- minimises the correlations (which is equivalent)

The local properties of the objects in the three-dimensional case or in the more generic multi-dimensional case can be described using some describers such as:

- inertia moments and tensors
- curvature
- static moments

The software used for the elaboration utilises two different types of algorithms that combine region growing techniques with an analysis of the main components (Roggero, 2002).

3. EXAMPLES OF SEGMENTATION

3.1 Identification of the main plains of the object

The data relative to the façade of a building were treated to validate the efficiency and actual correct functioning of the proposed method.

Figure 4 - Segmentation of a building façade. Test area of the Politecnico di Torino – Department of Georesources and Land.

The segmentation work was carried out on a part of the building which contains the Department of Georesources and Land of the Politecnico di Torino. The survey was performed using a RIEGL LNS-Z420 laser scanner. Apart from the façade, the laser scanner also surveyed some internal parts of the building and part of the external pavimentation.
It was hoped to obtain the main plains of the object using the developed software: the façade, the external pavimentation and then the remaining parts.
The result was positive. Only a few minutes were necessary to carry out the whole operation.
From the figure it is possible to see how the objects belonging to different plains were in fact grouped together in different layers. These are visualised in the image by assigning different colours to them. The model can be exported into AutoCAD environment, assigning a different layer to each entity.

3.2 Region growing and Analysis of the main components

A scansion of the "loggetta" of Sansovina was used for the evaluation of the segmentation capacity of the region growing model and for the analysis of the main components; this --- can be found on the lower part of the bell tower in Piazza San Marco in Venice.
He survey was carried out using a RIEGL LMS-Z420 laser scanner.

Figure 5 - the "loggetta" of Sansovina – Venice - Italy

This is an interesting archaeological example as the object has a series of complex structures, including columns, some internal niches inside which there are statues and bas-reliefs.
Two different types of elaborations were carried out.
The software that was used for the elaboration combines region growing techniques with an analysis of the main components (Roggero, 2002). Some describers were defined for the segmentation (inertia moments and tensors, curvature and static moments).
Limits were imposed on the curvature in order to be able to correctly carry out the aggregation.
A first elaboration of the data was carried out using not very rigid constraints on the aggregation. This means that during the segmentation procedure the most evident discontinuities were evaluated while the small discontinuities were not considered.
The results of this first elaboration are shown in figure 6
The segmentation algorithm identified 14 main portions of point clouds (the columns, the statue, portions of walls etc.).
The software that was used for the elaboration organised the results in an AutoCAD file according to the different layers that were identified.

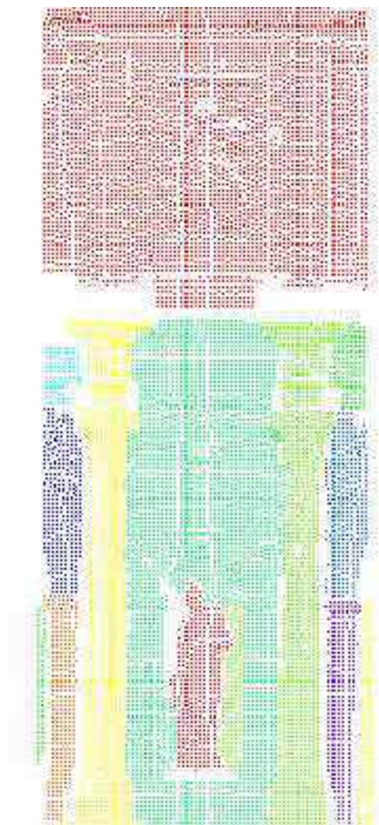

Figure 6 - Segmentation of - the "loggetta" of Sansovina. – Venice – Italy

The elaboration was then repeated using more rigid research parameters.
Using this more rigid aggregation method means looking for the less obvious discontinuity models. This type of elaboration allows the point cloud to be chosen in smaller and more homogeneous portions.
This time it was possible to distinguish not only the columns but also the capitals on different layers.
The presence of many layers on one hand can lead to an increase in the time that is necessary for the solid modelling, while on the other it can lead to a better sub-division of the model and therefore to a more complete model.

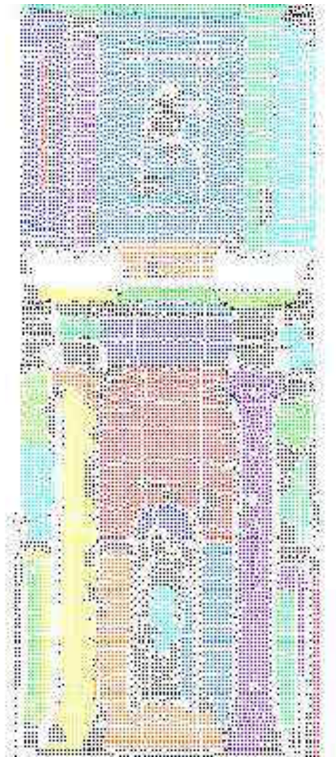

Figure 7 - Segmentation of - the “loggetta” of Sansovina. – Venice – Italy

4. SOLID MODELLING

4.1 Modelling of the segmented point cloud

After having finished the segmentation stages of the objects, it is possible to go on to their modelling.
This kind of elaboration should be carried out manually portion by portion. Many software packages are available on the market that offer good performances to
model a point cloud.
A specific modelling program was used to prepare the surface model that is called Cirrus AC and it is made by Menci software. This programme, which works in AutoCAD, is able to build surfaces by choosing point cloud portions. These surfaces are created using the algorithm for the creation of the meshes.
The thus segmented model was imported into an AutoCAD graphic environment and a different layer was assigned to each of the portions of the object obtained by the segmentation. The modelling of the various aggregations was obtained by isolating each portion of the point cloud step by step.
In this way the modelling was particularly simple and quick. It was in fact possible to model each part of the model one at a time.
The result of the modelling can be seen in figure 8.

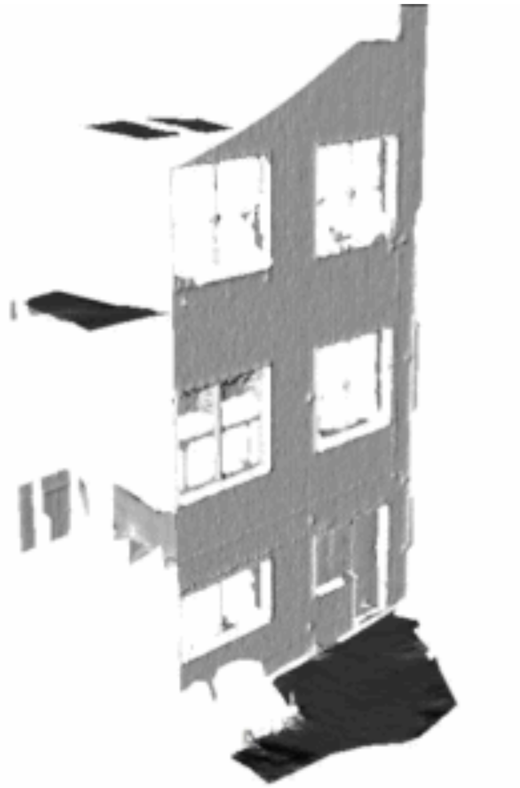

Figure 8 - solid model of the external walls of the building

It is possible to automatically export sections or level curves from the thus obtained solid model.
Another possibility that is offered by modern 3D model instruments is the possibility of projecting a digital image on a 3D model thus obtaining a coloured 3D model of the object and then the orthophoto.

5. FUTURE DEVELOPMENTS

5.1 Future Developments

This article has been written to show some of the first results of the segmentation that was performed on archaeological objects surveyed using laser instruments. Particularly simple instruments have so far been developed by the authors for segmenting and models that are available on the market were used. This first approach seems necessary to understand how to proceed in the research field to segment archaeological surveys.
In the near future it is intended to optimise the segmentation techniques, paying particular attention to ground type laser scanning.
This is an application environment where there is still a lot to learn because of the recent introduction of sensors that allow point clouds to be surveyed.

Figure 9 - solid model of the bell tower in Piazza San Marco in Venice.

Figure 10 - solid model of the bell tower in Piazza San Marco in Venice - top views.

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7. Acknowledgements

The research has been part of the activity financed by the PRIN 2002, national responsible Prof. Carlo Monti – DIIAR – Politecnico of Milan