OPTICAL IMAGES AND TERRESTIAL LASER SCANNING CO-REGISTRATION BY THE USE OF FEATURE BASED METHODOLOGY

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ABSTRACT

This paper focuses on the use of control linear features extraction from a terrestrial laser scanning (TLS) surface to produce a good datum definition for a close range photogrammetric model. The difficulty of identifying conjugate points between both datasets is overcome by the derivation of automatic features extraction. Hence, the extracted features from the terrestrial measurements represent a good candidate for co-registration. Field work is performed to validate the proposed methods. It combines a TLS acquisition on different city buildings, while a complete dataset of close range images of the same area is measured. Some additional geodetic survey control is added to the overall data to perform global registration.

Those experiments are based on planar patches automatic recognition derived from segmentation techniques. Planar segmentation is the extraction of planes from a point cloud. Assuming that linear features are at the intersection of those planes, we are able to generate a solid photogrammetric datum. After identifying selected control points from the images dataset, a bundle adjustment is performed. The corresponding linear features are extracted manually from the photogrammetric dataset. The next consistent step is to calculate the similarity transformation between the TLS and the photogrammetric model using the lines previously identified.

Results illustrate the good behavior of the proposed methodology in this particular type of study. This object based method is particularly interesting for the co-registration of photogrammetric images and points clouds coming from terrestrial LIDAR. Further studies should be conducted on the estimation of the normal distances between the lines and on the automation of these methods to produce 3D textured models.

INTRODUCTION

The traditional mapping industry is equipped with tools increasingly diverse, whose recent developments have enriched the production both in terms of quality and data's availability. Various fields, such as architectural mapping of web based 3d information provider, rely more and more on three dimensions enhanced modelisation.

Photogrammetry process of overlapping images is a well established acquisition technique. Surface reconstruction and high redundancy is achieved by observing multiple images, enhancing the reliability of high positional information distributed on the object. The other advantage is the high semantic description of the imaged scene, since they are usually easily recognized and identified. The significant drawback of photogrammetry, especially in the terrestrial domain, is the matching problem. Dealing for example with large scale urban areas will considerably affect the process of automatic matching procedures because of radiometric distortions or large depth between the acquisition images. These types of measurements require manual identification of conjugate points to be performed and thus drastically increase the overall processing time and the reliability of the data.

On the other hand, the performance of laser scanners has been greatly improved in recent years and the results obtained are now more accurate and completed reduced time. Terrestrial LIDAR (Light Detection and Ranging) systems proved to be reliable and offered to collect large volume of data over objects or surface. The dense point clouds dataset involve precise surface reconstruction techniques to enhance the precision of single point data. Given the amount of data generated by such processes, it is necessary to find methods to automate many tasks, i.e. to deal with large amount of "unclassified" data. One disadvantage of LIDAR data is the lack of redundancy and the absence of semantic information. Therefore intensity images proved to be difficult to interpret and not straightforward to use for automatic classification. Also from a geometrical point of view, despite the large number of points acquired, object space break lines can not be directly measured

Hence, integrating the two methods would be extremely valuable, as photogrammetry could be completely augmented with the complementarity, given by the dense data coming from terrestrial LIDAR, and reciprocally. (Baltsavias, 1999) Such a combined integration can be achieved with respect to a good derivation of surface reconstruction. A variety of applications in the industry, in the architectural domain or in cultural heritage feeds the growing need of strong co-registration process, efficient and reliable enough to take the advantages of both techniques (Vosselman, 2004).

This paper introduces one approach for the co-registration of terrestrial LIDAR data and photogrammetric surfaces relative to a common reference frame. Rather than using a point based method to identify common features, a linear featured based approaches is achieved through derivation of these particular object based elements. The following paragraph emphasizes the derivation of linear features derived from the terrestrial LIDAR data with a segmentation method and plan intersection. The second section outlines the mathematical model relative to featured based photogrammetry. The third section develops the suggested methodology and the concept of the proposed approach. Finally, our results and experimental pattern with architectural dataset are presented.

METHODOLOGY

Combining multiple datasets to achieve better accuracy and enhance the possibility of using relevant information as a result of data fusion leads to some issues that have to be considered.

Traditional procedures for the registration of two dataset involve the determination of tie points which are used for the computation of the transformation parameters. These parameters permit to establish a strong mathematical relation between the images and the TLS data. Unfortunately, manual extraction of tie points over a three dimensional point clouds is almost impossible, because the corresponding point in the image are hard to find, incoherent or even inexistent. This point based approach has its limits which exclude many applications combining both principles.

TERRESTRIAL LASER SCANNING

Alternatively, terrestrial laser data are usually rich of features or primitives. By using appropriate classification and segmentation techniques, it is easier to extract features from different resolution and different type of dataset, which is not usually the case with isolated points. As an example, the human environment is much outfitted with linear features, e.g. road, building, or objects… Adding to this point is the fact that linear features can be precisely derived by the use of source features and their intersection, typically plane intersection. A straight line obtained by intersecting two best fitting plane is far more precise that a line derived by extraction of several point along this line This is especially true with terrestrial LIDAR data, where in most cases, points are not determined on the edge, but most likely on both sides.

In our research, linear features are selected as the primary primitives available for the registration process. Based on the nature of the surfaces being surveyed, mainly coming from building's facades, we have collected planar patches to achieve, on purpose, plane intersection and linear features extraction. Due to the large number of points present in the model, a full segmentation of the data was not achievable. The algorithm was helped by pre-selecting good candidates for automatic plane fitting and automatic line extraction. Finally, after removal of blunders and non planar features, we were able to intersect planes and determine linear features that would latter be measured from the photogrammetric dataset as well.

CLOSE RANGE PHOTOGRAMMETRY

As for classical terrestrial photogrammetric project, we were trying to maximize the overlap while minimizing the total number of images on the overall facades. We were able to reduce the usable images to nine for the final measurements.

Prior studies developing the use of linear features in photogrammetric dataset (Habib, et al, 2003) focus on the strength, from a photogrammetric point of view, of the representation of a line based on the identification of two points from the image along the line, as it represents well the line in the object space. This appealing representation of image space lines, allows the use of intermediate point even in distorted images. This approach is very valuable if we consider the large amount of distortion we could face while using low cost metric camera for architectural mapping.

The issue of methodologies involving linear features in photogrammetry and their extraction is discussed in the following paragraph.

MATHEMATICAL MODEL

This approach starts with the fixation of seven coordinates of three well distributed points in the photogrammetric bundle adjustment procedure. For extracting the lines in the images material and use them in the adjustment, one has to measure the “beginning” and the “end” of relevant tie lines. Then, each intermediate point along this line is measured in every image where it appears, giving this way a constraint of co planarity. As developed by (Habib et al, 2004), the constraint state that the vector from the perspective center to any intermediate point is included in the plane formed by the perspective center and the two extreme point defining the line in the object space. A pair of two conjugate line portions will produce an estimation of two parameters. See figure 1.

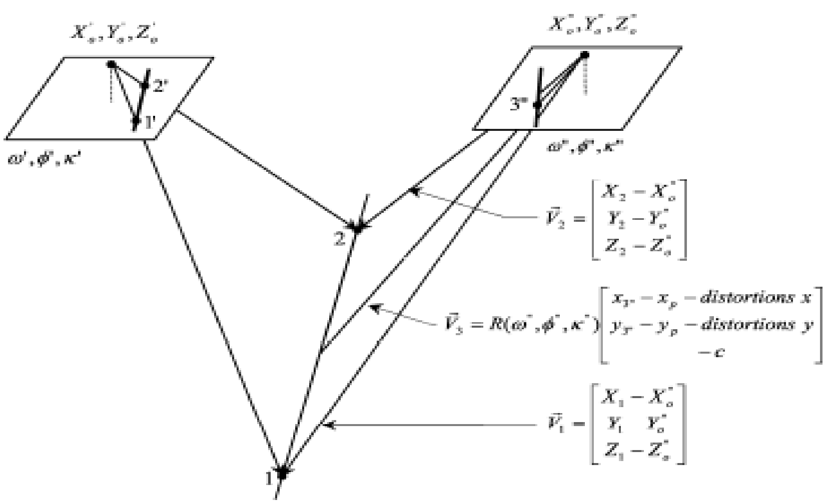

Figure 1. Perspective transformation between image and object space straight lines and the co planarity constraint for intermediate points along the line. Courtesy of (Habib et al, 2004)

Therefore we are able to estimate the seven parameter of the 3D similarity between the photogrammetric dataset and the terrestrial measurements using the conjugate lines attributes. (Habib et al, 2004) explained this method in details and developed fully the equations that were used as constraints for this approach. Note that only the scale parameter cannot be straightforwardly recovered if not having the two non coplanar lines. Hence, the overall process is based on the assumptions that at least two non coplanar lines could be used for the estimation of the seven parameters.

EXPERIMENTAL RESULTS

The LIDAR measurements were captured over an architectural candidate, representing well the type of object needed to map facades, a university building depicted on figure 1. For that purpose, we used the Trimble Terrestrial Laser Scanner (TLS) GS200. The strategy was to acquire three dataset from three points of view of the same facade. Focusing on one side of the building, the experiment aimed at verifying the proposed method, combining terrestrial laser scanning and close range images. The TLS dataset were measured with three scans, at a ground sampling distance around 2 cm and two measured point averaged per each point derived. The distance of acquisition ranged roughly from 50 meters to 90 meters.

Figure 2. “CCIT” building, University of Calgary, Canada.

Registration steps were conducted with an Iterative Closest Point (ICP) algorithm. Since ICP requires good approximate values, manual detection of tie points were introduced to initiate the registration process between the three different point clouds. Despite the abundant literature on planar segmentation for the use of the primary registration of each measurement, these methods were not implemented within the frame of this study.

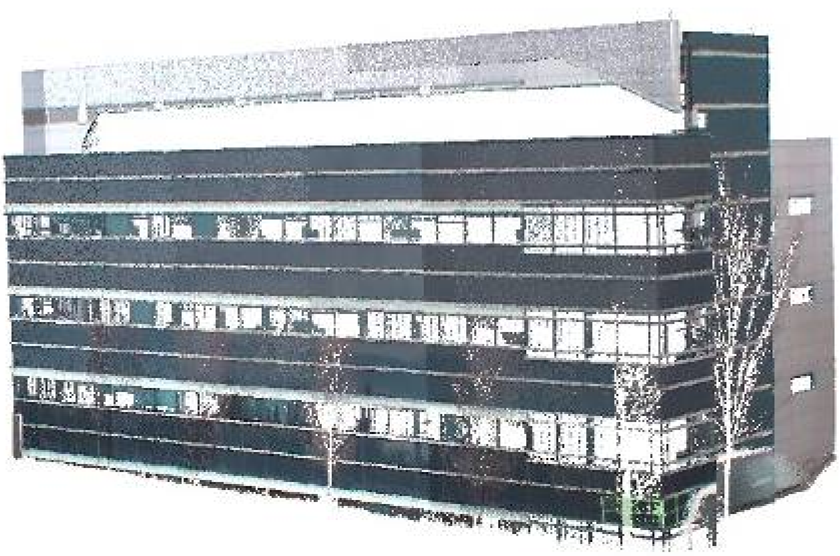

Figure 3. Registration of the three TLS dataset.

However, many “holes” were observed on the laser scanning data because of the reflective material superimposed on the building facades and especially over the windows that were transparent for the wavelength of the scanner. Thus no returned echoes were observed from these portions of the building. Internal reflections, e.g. reflections from inside the rooms, were removed after a first filtering step, because they were badly affecting the segmentation algorithm. To determine the features, each subset of points belonging to one planar patch was considered for computation within a best fitting plane. In order to facilitate the automatic detection of point belong to a plane, extraction of the planes and the lines by our algorithm, these subsets were chosen manually for our experiments.

For the photogrammetric dataset, eight convergent images were acquired with a Canon EOS Digital Rebel XT camera. These 3456 by 2304 pixels images were taken with a 35mm fixed focal length. Before the metric panoramic image can be made, the accuracy of the internal orientation of the camera must be considered. Hence, we performed a geometrical calibration of the camera. An outdoor calibration test bench was used and improved for the realization of the calibration process. The existing workbench includes several targets that were previously surveyed with local total stations. They are utilized as fixed ground control point.

Additional targets, for enhancing the global geometry and constraining the photogrammetric process, were added to complement the tie points dataset. The calibration was successful and we were able to measure the needed parameters for the radial lens distortions. Table 2 contains the properties of the calibrated camera.

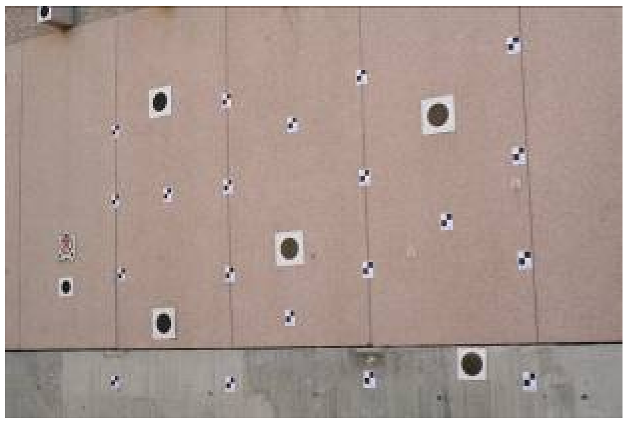

Figure 4. Calibration bench.

Table 1. Results of the EOS calibration

x_p	-5.861e-002	σx_p	9.052e-002
y_p	2.886e-002	σy_p	8.892e-002
c	3.533e+001	σc	6.344e-002
K_1	-7.300 e-005	σK_1	1.760e-005
K_2	1.272e-008	σK_2	1.121e-007
P_1	-2.299e-005	σP_1	2.825e-005
P_2	-1.096e-005	σP_2	2.703e-005
A_1	1.788e-005	σA_1	1.219e-004
A_2	1.233e-004	σA_2	2.771e-004

The datum for the model has been chosen through arbitrarily fixing seven coordinate of three well distributed tie points. Handheld GPS was used to fix the approximate camera position and orientation in the object space coordinates. Later measurement of ground survey points contribute to the absolute orientation of the combined model.

DISCUSSION OF EXPERIMENTAL RESULTS

Final computation for the co-registration of the terrestrial laser data over the photogrammetric were derived and were able to estimates the transformation parameters and how accurate they were. The results could still be improved, especially if we consider the importance of the segmentation part. This validated the principles chosen in this paper of using the linear features as primary primitives for the registration. For a typical building

like our subject, the building face is designed so as there is not that much plane intersecting. Hence, the global geometry cannot be fully exploited since many of our lines are coplanar, because belonging to one face of the building. The corner edge used in this study, are not sufficient to do constraint a good automatic registration process. Reference points will be added by complementary ground surveys.
As observed in this study, the point density was not playing a key role on influencing the overall accuracy. Since the proposed approach use local plans to intersect, there were enough points included in the plane fitting equation to achieve a correct accuracy. The total distribution and the geometry of these planes relatively of each over were more of concern.

CONCLUSION AND FUTURE WORKS

The purpose of this study was to demonstrate the use of appropriate complementarity between two surveying techniques. Experimental results from the highly semantic information of photogrammetric images, combined with the large amount of points, directly measured in space with a terrestrial laser scanner, proves how valuable this hybridization is. This experiment demonstrated the capabilities of the proposed co registration method. Linear features are prominent, especially in human being environment which are rich in terms of geometry. Based on this assumption, our work emphasizes on the complementarity of both photogrammetric and laser scanning techniques.

In future work, more automation should be achieved for the terrestrial LIDAR segmentation. The segmentation, and before that, the registration, should use extensively the availability of previously described linear features as constraints.

Another research direction should assess the contribution of curvatures detection on the detection of edge and better constrained segmentation.

Overall, the main objectives of future studies should be to test possibilities of co-registrating aerial and terrestrial LIDAR data, aerial and close range images, through the use of feature detection. The growing need for virtual city modelisation enlightens the need of combined techniques for producing 3D textured models.

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