doi: 10.14355/ijrsa.2015.05.004

Urban Objects Extraction from 3D Laser Point Clouds Acquired by a Static Laser Scanner and a Mobile Mapping System

Mohammed Bendaanane*, Kaoutar Eddahmani, Imane Sebari

Department of Photogrammetry and Cartography, School of Geomatic Sciences and Surveying Engineering, Hassan II Institute of Agronomy and Veterinary Sciences – Madinat Al Irfane 6202, Rabat, Morocco

*mohammed.bend@gmail.com; eddahmani22@gmail.com; imane.sebari@gmail.com

Abstract

Terrestrial laser scanning (TLS) whether in static scanning or mobile scanning, as in the case of a mobile mapping system (MMS), generates a large amount of 3D data. These data can be used for a variety of purposes. The aim of this research study is to experiment terrestrial laser scanning, in both static and mobile mode, for the extraction of urban objects of an urban street survey. Particularly, this research aims to develop a comparative study, of the two methods, according to the conventional method (tachometry measurement). We have established a methodology in order to extract objects form 3D data collected by a static laser scanner and a mobile mapping system. The proposed methodology has been tested on two urban street sections of 300 meters length. Finally, we fixed a comparative analysis between the two laser scanning methods, within the following comparison levels: qualitative level (precision and completeness criteria), time level (operative time for acquisition and processing) and financial level (direct costs). The results show the efficiency of the mobile mapping approach especially for data acquisition. To establish an urban survey, the direct cost is 71% cheaper using a mobile mapping system and 50% cheaper using a static laser scanner, than using the conventional method.

Keywords

Terrestrial Laser Scanner; Mobile Mapping System; Point Cloud; Object Extraction; Urban Survey

Introduction

The uses of terrestrial laser scanning technologies, in both static and mobile mode, have encountered significant grow during the past few years. Such technologies bring customers 3D point clouds that has been used for many purposes especially for accurate 3D mapping of urban structures like road details, building facades or urban furniture. Objects extraction from 3D terrestrial laser point clouds in urban environments has been a research topic in recent years. Numerous model driven approaches have been developed and applied as 'objects recognition processes'. On the first hand there are edge based approaches (Gross and Thoennessen, 2006; Wani and Arabnia, 2003) devoted to detection of boundary points from point cloud, and then fit them to lines. And on the other hand there are surface based approaches. These methods use local surface properties as a similarity measure, and merge together the points which are spatially close and have similar surface properties. Surfaces can be either planar surface (Dold and Brenner, 2004, Schuster, 2004), or curved surfaces such as cylinder, sphere and cone (Rabbani, 2006). Other approaches are focusing on objects nature; for instance vertical objects. In this sense, Lehtomäki and al. (2010) proposed a pole-like objects detection in road environments; Liberge and al. (2010) suggested model for the extraction of vertical posts in dense urban areas. Such model driven approaches are generally automatic and rely on a deep competencies in point cloud processing and programming. Furthermore, they are very specific and cannot be generalized to other objects like sidewalk edges, etc.

In this paper, we examine the possibility to extract a wide range of objects from 3D terrestrial data acquired by a static scanner and a mobile mapping system via the deployment of existing point clouds processing solutions. We experiment these laser scanning technologies in order to establish an accurate urban survey (scale 1:200). So far, it is evident that urban surveys are exclusively established with conventional approaches (tachometry measurements). We are trying to answer the following questions: could laser scanning approaches be an effective alternative to establish an urban survey via objects extraction? In comparison with the conventional approach, what is the most effective method? To answer these questions, we first aim to develop a simple methodology applicable to static and mobile mapping point clouds for the extraction of urban objects (trees, poles, buildings, break lines, etc.) which form an urban survey. Then, we particularly develop a comparative analysis between the two laser scanning methods considering criteria of precision, operative time and direct costs. This comparison takes in consideration, as a reference, an existing survey executed by the conventional method.

Our methodology is demonstrated on two urban street sections, each one is 300 meters in length. We performed a data acquisition using a laser scanner and a mobile mapping system. We proceeded to point cloud processing and objects extraction using appropriate solutions. Once all the objects of our urban scenes were extracted, we developed a comparison analysis to define the most cost-effective method that responds to the requirements of an urban survey.

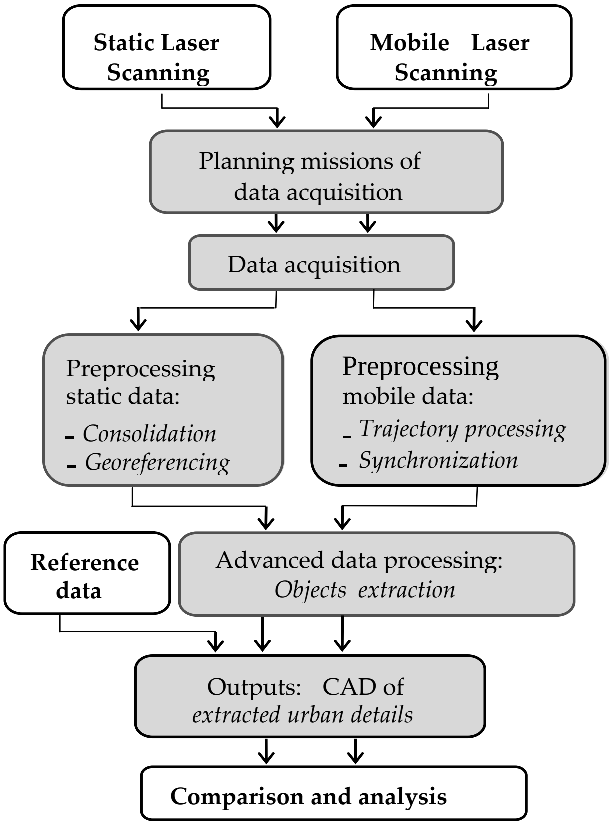

FIGURE 1. GLOBAL SCHEME OF ADOPTED PROCEDURE

Methodology and Materials

Before dealing with the core problem of objects extraction, we had to think about a general procedure to acquire and process terrestrial 3D data. The figure 1 shows the global scheme of our procedure which elucidates the general canvas of our work. It includes steps that we conducted starting by data acquisition, data processing then objects extraction, and finally dressing the comparison analysis.

Reference data consists of urban surveys (scale 1:200) covering street sections of interest. These surveys were established using tachometry measurements (total station) and concerned all urban details existing like building, pole objects, sidewalks, trees, etc. We used CAD file of these surveys. In the next two paragraphs, we'll be introducing all the instruments, hardware and software we deployed in our research.

Materials and Software

Besides the software package delivered with the RoadScanner3 system, we relied on other IT solutions. All these computer software can be split into three groups:

- (A) *Planning software* : it includes applications used to plan, estimate and manage our missions of data acquisition (in both static and mobile scanning);

- (B) *Preprocessing software*: this group gathers software we employed in order to preprocess data, prepare and generate point clouds;
- (C) *Advanced processing software*: it regroups IT solutions we used extract objects and handle point clouds.

Regarding our purposes, the main utilization of each one is explained on the table below (Table 1).

TABLE 1. SOFTWARE AND APPLICATIONS

A	TopoPLA- NNER	Web-based application we used to plan and estimate our static scanning mission.
	TopoMISSION	Web-based application we used to plan and estimate our mobile scanning mission.
B	SCENE	Faro's point cloud processing software. We used it to consolidate and generate our point cloud.
	AutoCAD	Geo-referencing point cloud of static scan
	POSPac MMS	Applanix software for GNSS/Inertial processing data: used it to obtain navigation position and orientations of RoadScanner3 vehicle.
	RoadScanner3 software package	This package includes 4 software (POS LV, RoadScanner, RSPostProcess & RoadSIT): used to process the MMS raw data and generate final point clouds.
C	TopoDOT	Advanced software processing used to extract objects from point clouds. It runs within the CAD plateforme of Bentley Microstation V8i.
	Siteco Plug-in	AutoCAD plug-in used to extract objects from point clouds collected by RoadScanner3.

Data Acquisition

We performed two missions of data acquisition located in two urban street sections in the city of Casablanca (Morocco). These two urban scenes have the same characteristics: double lanes, a median strip with some bushes and sidewalks with trees.

Static Laser Scanning

As for static laser scanning, it was performed within a 300 meters length of a section along Mohammed Zerktouni Avenue in Casablanca. We have chosen this section because, a recent urban survey covering this area, established with the conventional approach (tachometry measurement), is available. It was helpful for us as we were intending to compare conventional urban survey with urban survey resulting from objects extraction out of laser scans. Our static scan was performed using one single laser scanner. A team of three operators was involved. This mission took 3 hours with 18 stations, 5 minutes per station (3 minutes point cloud acquisition and 2 minutes images acquisition). The remaining time was absorbed while positioning marks (spheres) and looking for appropriate spots to place the scanner. The practical rang of Faro Focus 3D scanner during daylight is up to 15-20 meters. We had to take this in consideration for placing marks and the laser scanner stations. We have used three spheres (marks) on three known points. It was crucial for us in order to proceed point cloud geo-referencing.

Mobile Laser Scanning

Concerning mobile laser scanning, although the system "RoadScanner3" is designed to hold up to three laser scanners, we used only one. We performed a 300 meters length scan of a section along Socrate Avenue in Casablanca. This section was chosen due to its similarity with the section where we have already performed the static scan. A team of two operators was involved and the mission mobile scanning took 45 minutes which includes:

- Mounting the system on the vehicle and connecting all its components;
- Initialization and finalization of the mission;
- Scan of the section.

In parallel with data acquisition, we were performing a static GPS survey of a known points near our section of interest. The raw GPS data collected is crucial for preprocessing vehicle trajectory and obtaining reliable navigation solution (position and orientations). The RoadScanner3 navigation system (POS LV) operates in DGPS mode and phase observation.

Data Preprocessing

Static Laser Scanning

Preprocessing of static scan data consists in importing data and consolidation of successive point clouds to have final point cloud of the section (figure 2).

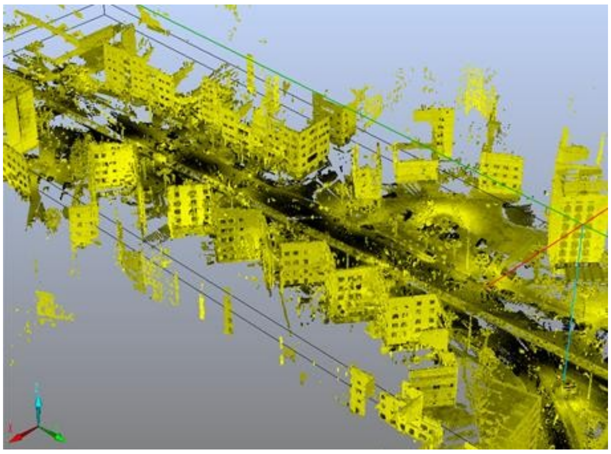

FIGURE 2. 3D VIEW OF FINAL POINT CLOUD RESULTING FROM STATIC SCANS

The readjustment of successive point clouds (consolidation) was fixed with satisfying results. One sphere observed in two point clouds has a mean distance of one millimeter. The maximum gap between two point clouds is equal to 1.04 centimeters. The final point cloud was geo-referenced using three known points where three spheres were placed during data acquisition. In order to conserve values of reflectivity, we exported the point cloud to E57 format. Reflectivity values are important and will be exploited in advanced processing for objects extraction.

Mobile Laser Scanning

Data acquired with the mobile mapping system can be divided into two groups: (1) Data relative to vehicle trajectory collected by POS LV navigation system (IMU data and GPS raw data); (2) Data collected by sensors (laser scanners and Ladybug imagery system). First, we handled trajectory to obtain a refined navigation solution of the vehicle. Then, we synchronized data collected by sensors. Therefore, we managed to generate geo-referenced point clouds and video images.

1) Trajectory Data

The processing of trajectory data consists in combining IMU data, GPS raw data of POS LV integrated receivers, and also GPS raw data collected via static survey, in order to obtain a refined navigation solution. The trajectory is processed using an algorithm incorporated with POSPac software. This algorithm of data fusion relys on kalman filter in order to obtain a reliable vehicle trajectory (Farrell and Barth, 1999). Trajectory is processed in two senses: forward and backward. The mean of these two determinations is adopted. In our case, planimetric position (North, East) was calculated with RMSE of 1 to 2 centimeters. Height RMSE was 2 centimeters. Once we finish trajectory treatments and we verify that the RMSEs are tolerable, we export two files (events) called: event1 and event2. “event1” covers the time when the Ladybug images were taken and “event2” covers the time when the laser scanners collected point clouds. It is very important to mention that these events are crucial. They are used to synchronize sensors data: they are the link between trajectory data and sensors data.

2) Sensors Data

The processing of sensors data consists of synchronization, which means to attribute a time and a position to each point cloud profile acquired and to each image taken with Ladybug imagery system. Most of this processing is executed with RSPostProcess and RoadSIT solutions.

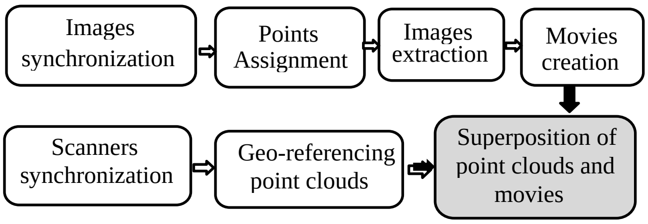

FIGURE 3. STEPS OF DATA SYNCHRONIZATION

The scheme above (figure 3) shows the steps we followed in order to synchronize sensors data. They consist of first images and scanners synchronization: by linking each data to a certain time. It is the time of acquisition. Concerning Ladybug images, we execute a “points assignment” step; it makes the link between each image and its real position during data acquisition. Concerning point clouds, we execute a “geo-referencing” step which attributes to each point cloud its real position during data acquisition. At this stage, every image and every point cloud profile has a spatial reference (a well-defined position). Time is the joining aspect for synchronization. Therefore, we can assemble collected data.

Once these steps are executed, we can extract georeferenced images and gather them in order to produce movies: which are videos allowing to look over all the scanned section. Those videos can be overlaid with point clouds (figure 4). We have used these videos in order to extract objects.

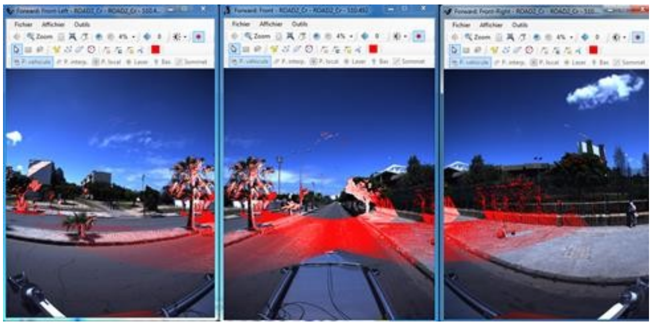

FIGURE 4. VIDEO IMAGES OVERLAY WITH POINT CLOUD VISUALIZED IN ROADSIT SOFTWARE

Objects Extraction

Objects extraction can be automatic, semi-automatic or manual. In our case, objects extraction was done semi-automatically using appropriate solution. We opted for extraction by classifying objects in three categories (figure 5): isolated details (trees, streetlight, etc.), characteristic lines (sidewalk edges, crosswalks, etc.) and building limits.

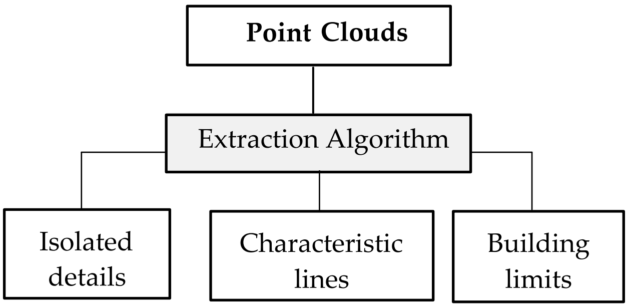

FIGURE 5. OBJECTS CLASSIFICATION FOR EXTRACTION

In the next two paragraphs, we will be presenting extraction procedure. The first paragraph focuses on point cloud of static mode using TopoDOT solution and the second paragraph sheds light on point cloud of mobile mode using AutoCAD plug-in available with RoadScanner3 software package.

Extraction from Static Scan using TopoDOT

1) Isolated details

Via TopoDOT tools, we can view horizontal and vertical sections centered on any isolated object. Once done, we can localize accurately the point on the ground of the considered object. In one single section, we can include many objects, for instance, the case of aligned trees or streetlights.

In TopoDOT, isolated details extraction relies on vertical and horizontal section. We exploited appropriate tools in order to extract trees, palm trees and streetlights. We have previously set up a cell library in Microstation V8i, so we just had to insert cells at the right point for each detail extracted. For example, if we consider extracting a palm tree (figure 6). Via the horizontal view, we managed to center a circle on the tree trunk right at the ground level. The vertical view allowed to fit a line along the tree starting from the bottom at ground level to the top. The cell symbol is inserted at the circle center on the horizontal section. Thus, the object is extracted accurately and its symbol is placed precisely. Furthermore, as a description we can add other information to the symbol like diameter and height of the object (figure 7). Same thing goes for extracting other isolated details, for example an advertising panel (figure 8). We should mention it, the sections add a valuable asset for object identification and extraction. Which makes it easier to exploit every single data in the point cloud.

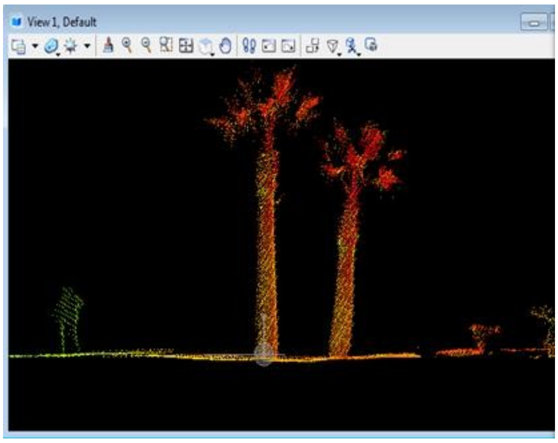

FIGURE 6. VERTICAL SECTION CROSSING TWO PALM TREES IN TOPODOT

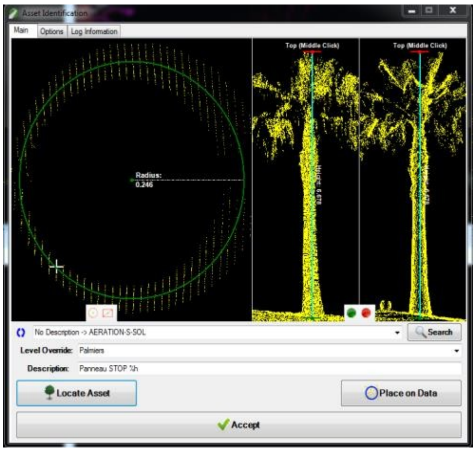

FIGURE 7. PALM TREE EXTRACTION IN TOPODOT USING HORIZONTAL AND VERTICAL SECTIONS

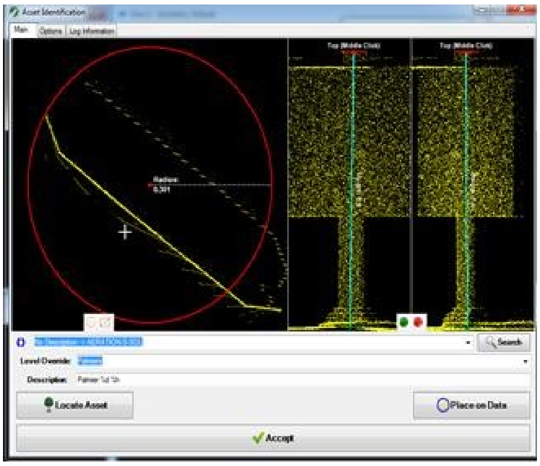

FIGURE 8. AN ADVERTISING PANEL EXTRACTION EXAMPLE USING TOPODOT

2) Characteristic Lines

TopoDOT software integrates smart pick algorithms with advanced tools like break line extraction. We used these tools in order to extract characteristic lines and draw correctly on the point cloud. If we consider extracting sidewalk edges, first we need to detect automatically an approximate line to the sidewalk edges. Then, based on this line we can extract the edges. The approximate line is used as a guide along the sidewalk in order to facilitate the extraction of edges. We can add as many edges as we want depending on the point cloud quality. In our work, we managed to extract three edges. We placed three point on the cross section: Row line, top of the curb and back of the curb (figure 9). Through successive cross section with user defined step, we extracted break-lines along the sidewalk. Lines are simultaneously drawn in the attached CAD file (.dgn).

3) ***Building limits***

Concerning the extraction of building limits, the technique is the same as break-lines extraction. But in the case of construction, we need to pay more attention to horizontal section. A good section of the building façade helps to extract limits correctly. We place only one point on the transversal cross section, then we start drawing the limit (figure 10).

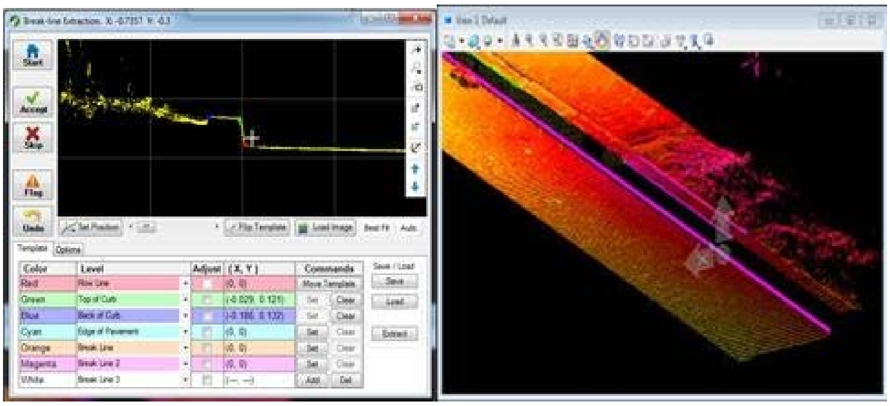

FIGURE 9. BREAK LINE EXTRACTION IN TOPODOT: CROSS SECTION VIEW (LEFT) AND ISOMETRIC VIEW (RIGHT)

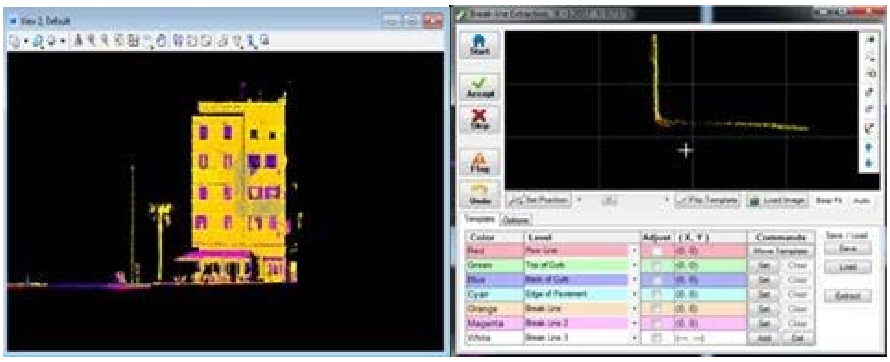

FIGURE 10. BUILDING LIMITS EXTRACTION, HORIZONTAL SECTION ON THE LEFT AND TRANSVERSAL CROSS SECTION ON THE RIGHT

The horizontal sections allow to extract other information such as doors. We can also recognize the number of floors. These information are very helpful for any survey where we have to localize constructions limits, mention the number of floors and to localize the doors and garages, etc. At this stage, we managed to extract all the details. We swept the scanned scene and identified all isolated details, break-lines and building limits existing in the 300 meters; while calculating time needed for extraction procedure. This will help us to evaluate the method when we'll be dressing the comparison study.

Extraction from Mobile Scan Using AutoCAD Plug-in

First, we exported the mobile laser scanning point could and processed it in TopoDOT in order to extract objects. Just like for static mode, we performed the extraction in three phases: (1) Isolated details, (2) Characteristic lines and (3) Building limits. Then, we used AutoCAD plug-in to extract the same objects since it is available with 'RoadScanner3' software package. A comparison between the two solutions will be discussed later. We present in the next sections the adopted procedure to extract objects using AutoCAD plug-in.

1) Isolated Details

Isolated details are extracted directly by pointing the lowest point in the point cloud and inserting cell from existing cells library (figure 11). So that, we make sure that we are on the ground level. We can also extract three points from the considered detail and draw a circle to localize the center then insert according cell.

2) Characteristic Lines

Characteristic lines extraction is also simply executed by drawing directly on the point cloud. We point the lowest point. For instance, if we consider extracting sidewalk edges, the distinction between those edges is easier by using the images (figure 12). We can keep extraction scrolling through the video images.

FIGURE 11. EXTRACTING A PALM TREE USING ROADSCANNER3 AUTOCAD PLUG-IN

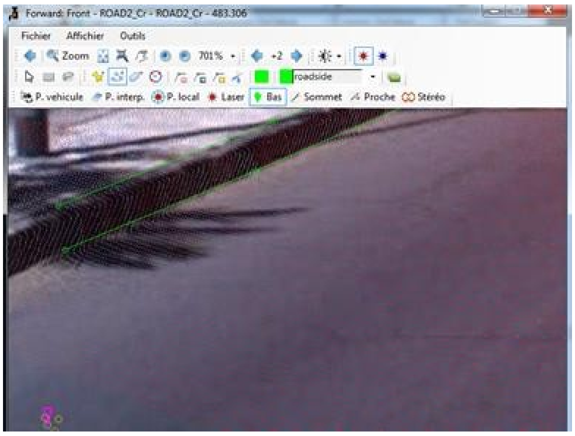

FIGURE 12. SIDEWALK EDGES EXTRACTION

3) Building Limits

In this plug-in, somehow like TopoDOT, building limits are extracted using transversal sections. Once we realize a section, we exploit the colors visualization to reach the ground and then the construction limit on the ground. At that point, we can start extraction by selecting the lowest point. In the next paragraph, we will be discussing closely the comparison between these methods in reference to the conventional approach.

Comparison and Analysis

Based on a criteria grid we have fixed, we analyzed and compared each method, conventional method, static laser scanning and mobile laser scanning, taking in consideration three comparison levels: qualitative level, time level and financial level. Our grid has been applied to the extracted details by the three methods in the 300 meters urban scene. All our estimations were based on the experience of the company ETAFAT (Moroccan surveying company where our research was conducted) in this kind of surveys.

Operative Time Comparison

The comparison of operative time is split in two groups. The first group considers time needed for data acquisition and the second one focuses on time needed for data processing and objects extraction.

The 300 meters urban survey takes 18 hours for data acquisition by conventional approach, equivalent to three business days (6 hours per day). It takes 25.5 hours to process data and deliver a CAD file of the surveyed section. We conclude that the conventional approach requires 43.5 hours. Concerning static laser scanning, it is necessary to count 5 minutes preparation needed to set up laser scanner station and place marks (spheres) appropriately. As in our case, we performed 18 stations, which makes it 90 minutes only for preparation. Furthermore, Faro laser scanner (Focus 3D) needs 5 minutes for acquisition; with 18 stations, it makes 90 minutes for acquisition. So, the static approach takes 3 hours for data acquisition. We calculated the time needed for consolidation, geo-referencing, and objects extraction, it is estimated to 17 hours (1 hour for preprocessing and 16 hours for objects extraction). We conclude that the static approach requires 20 hours.

Regarding the mobile approach, each data acquisition mission begins with a 5 minutes initialization: the vehicle stay steady, and a 5 minutes finalization. Plus, the 300 meters survey took us 5 minutes. So, using the RoadScanner3 MMS we needed just 15 minutes for data acquisition. As for the data processing phase, the time needed for preprocessing is estimated to 1.5 hours; and for objects extraction it is the same as the static mode: 16 hours. We conclude that the mobile approach requires 17.75 hours.

TABLE 2. TIME NEEDED FOR DATA ACQUISITION AND PROCESSING (IN HOURS)

	Conventional approach	Static Laser Scanning	Mobile Laser Scanning
Acquisition	18	3	0.25
Preprocessing	1.5	1	1.5
Advanced processing	24	16	16
Total	**43.5**	**20**	**17.75**

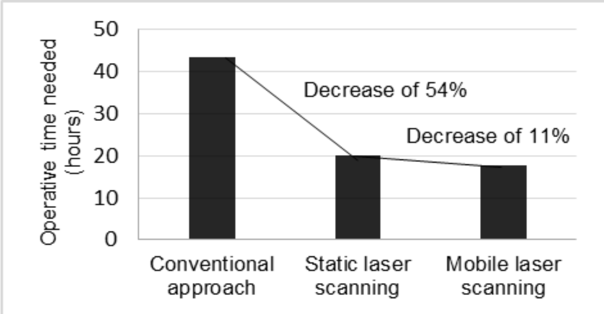

FIGURE 13. OPERATIVE TIME NEEDED FOR EACH METHOD TO ESTABLISH AN URBAN SURVEY FOR A SECTION OF 300 METERS LENGTH (SCALE 1:200)

The operative time comparison reveals that laser scanning technologies can reduce to more than half (54% for static mode and 65% for mobile mode) the time needed to extract urban details and establish the desired survey plan (figure 13). We also note that the mobile mapping system reduces significantly time needed for data acquisition. If we imagine performing acquisition in a larger zone, the difference would be more noticeable, with static approach we will need more stations to acquire data, and by then more hours; whereas fewer will be needed using the mobile mapping system.

Comparison of Completenss and Precision

Data quality is crucial to achieve a good objects extraction. If the point clouds contain less data it will be harder to recognize objects precisely. In this paragraph, we will be evaluating and measuring quality of data acquired with static and mobile mode. This evaluation approach is based on the approach proposed by Yoo (2011). Our comparison considers two criteria: completeness and precision.

To evaluate completeness, we considered two different zones: the first one is a pavement zone and the second one is a building. On an area of 1 m2, we noticed a difference between the two point clouds (static and mobile) in terms of point cloud density on the pavement. Average density on pavement is 7.8% less important in static mode in comparison with mobile mode. In mobile mode, acquisition is continuous and point cloud is homogenous however in static mode, where occlusion phenomenon is more significant in urban area, point cloud is not quiet regular with some empty and less dense places. Average density decrease affects objects extraction directly. Same deduction has been shown for buildings.

Precision criterion is composed with accuracy and precision. To calculate this criterion, we use the following formula:

$$\gamma^2 = \delta^2 + \sigma^2 \quad ; \tag{1}$$

Where

γ : Precision criterion (RMS error)
δ : precision (standard deviation)
σ : accuracy (biais)

In our case, we considered samples of points for each category of extracted objects (isolated details, characteristic lines and building limits). Our samples were formed randomly. For each category, we considered points and their peers on the urban survey (conventional method). So far, this is how we calculated accuracy and precision for each category: (1) Accuracy measured by calculating the mean of all obtained differences; (2) Precision was measured by calculating standard deviation of obtained differences. We calculated the precision criterion for each detail category of objects extracted using TopoDOT and AutoCAD Plug-in. The results are shown on the following table (table 3).

Processing the two point clouds on the same software (TopoDOT) reveals better precision values for static mode in comparison with mobile mode. Moreover, processing mobile mode point cloud in AutoCAD plug-in shows approximately the same precision values as its processing in TopoDOT. Nevertheless, the RoadScanner3 AutoCAD plug-in remains less advanced than TopoDOT. The details extraction is approximate in comparison with TopoDOT. Plug-in tools does not allow an accurate objects extraction while with TopoDOT tools; the cross sections make the extraction more accurate.

TABLE 3. CALCULATED PRECISION CRITERION OF EXTRACTED DETAILS (IN CENTIMETERS)

		Isolated Details	Character istic lines	Building limits
Mobile mode TopoDOT	X, Y	±4	±3	±5
	Z	±5	±2	±4
Static mode TopoDOT	X, Y	±3	±2	±3
	Z	±3	±3	±1
Mobile mode AutoCAD Plug-in	X, Y	±4	±3	±4
	Z	±5	±4	±7

Comparison of Direct Costs

We evaluated direct costs (in US. Dollar) generated by each method for the establishment of a survey of a 300 meters length boulevard section. We considered human and material resources deployed. Results are shown on the following table (table 4).

Concerning acquisition phase, the comparison shows that direct cost generated by static laser scanning is 60% less important than the one engendered by the conventional approach. Furthermore, we also observe that the cost is 96% less important with mobile laser scanning approach in comparison with the conventional approach. For the processing phase, the two laser scanning methods have approximately the same direct cost, which is quiet obvious since the points clouds undergo the same processing for objects extraction. Finally, we conclude that the static laser scanning approach is 50% cheaper that the conventional approach; while the mobile laser scanning method is 71% cheaper.

TABLE 4. DIRECT COST GENERATED BY EACH METHOD CONSIDERING 300 METERS LENGTH OF AN URBAN BOULEVARD SECTION (US. DOLLAR)

	Conventional Approach	Static laser Scanning	Mobile laser scanning
Acquisition	207	75	6
Processing	124	92	87
Total	**331**	**167**	**93**

Normalization of Results

In order to elucidate properly the comparison results, we proceeded to a normalization taking in consideration each criterion of the three comparison levels. A certain score was affected to each criterion. For precision criterion, the scores respect the following grid (If $\gamma \leq \pm 1$ cm then score is 0.8), (If ± 1 cm $< \gamma \leq \pm 2$ cm then score is 0.5), (If ± 2 cm $< \gamma \leq \pm 3$ cm then score is 0.4) and (If ± 3 cm $\leq \gamma$ then score is 0.3). Regarding other criteria, we calculated normalized scores using the following formula:

$$N_i = \frac{C_i - C_{max,i}}{C_{min,i} - C_{max,i}} \quad ; \tag{2}$$

Where

N_i : Normalized score for criterion i

C_i : Value of criterion i for considered method

$C_{min,i}$: Minimum value of criterion i

$C_{max,i}$: Maximum value of criterion i

Laser scanning methods, both in static and mobile mode, offer interesting advantages especially for criteria of operative time and direct costs (Table 5). However, mobile laser scanning is more efficient regarding time and cost needed for data acquisition.

We can't judge about the accuracy of the conventional approach as soon as we have fixed it as a reference for our comparison. All what we can assess is that objects extraction from point clouds avoids mistakes of oblivion that may occur in site while performing a survey with total station. Laser scanning methods bring the considered scene to computer, so there is likely less chances to forget or oversight some detail. The normalization shows that the most cost-effective method is mobile laser scanning. Yet each approach has its positive and negative sides.

TABLE 5. NORMALIZED SCORES FOR EACH METHOD

Criterion		Conventional Approach	Static laser scanning	Mobile laser scanning
Precision	X,Y	0.8	0.4	0.3
	Z	0.8	0.5	0.3
Time level		0	0.91	1
Financial level		0	0.53	1
Global score		**0.4**	**0.58**	**0.65**

Conclusions

We presented a methodology to acquire process and extract objects from 3D laser point clouds collected by static and mobile laser scanning. Our objective was to evaluate the potential of laser scanning technologies in the extraction of details of an urban survey (1:200). This methodology relies on the deployment of advanced solutions for point clouds processing. We looked closely at details extraction algorithms via TopoDOT solution specifically, but also via AutoCAD plug-in delivered with software package of RoadScanner3, mobile mapping system.

Our research included an important part which is the comparison of the two laser scanning methods in reference to conventional approach. We considered three comparison levels: Qualitative level (precision criterion), Time level (operative time) and financial level (direct cost). The results of this comparison were normalized to shed-light properly on the most costeffective method. This normalization shows that mobile laser scanning has a very interesting score (0.65 out of 1) in comparison with static laser scanning (0.58 of 1); also the mobile approach was estimated to be 71% cheaper than using the conventional method.

A perspective of this work is to develop a methodology to integrate the images taken by the imaging system in the process of objects extraction and to evaluate the potential of the cooperation between images and point clouds to extract urban objects.

ACKNOWLEDGMENT

The authors would like to thank Mr. Ben Addou Idrissi Kamal, ETAFAT's Chief Executive Officer, for making the company's mobile mapping system, laser scanners and other resources available for our work. Thanks are also addressed to Mr. Adouane Najib, Head of Laser Scanning Department at ETAFAT for his help, and Madame Jennifer Triana, Processing Software Manager at Certainty 3D for making TopoDOT trial license available for our work.

REFERENCES

[1] Dold, C., Brenner, C., 2004. Automatic Matching of Terrestrial Scan Data as a Basis for the Generation of Detailed 3D City Models. International Archives of Photogrammetry and Remote Sensing, 35 (Part B3), pp. 1091-1096.

[2] Farrel, J., Barth, M., 1999. The Global Positioning System and Inertial Navigation. McGraw-Hill, New York.

[3] Gross, H., Thoennessen, U., 2006. Extraction of Lines from Laser Point Clouds. In: Förstner, W., Steffen, R. (Eds)

Symposium of ISPRS Commission III: Photogrammetric Computer Vision PCV06. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 36 (Part 3), pp. 86-91.

[4] Lehtomäki, M., Jaakkola, A., Hyyppä, J., Kukko, A., Kaartinen, H., 2010. Detection of Vertical Pole-Like Objects in a Road Environment Using Vehicle-Based Laser Scanning Data. Remote Sensing, 2 (3), pp. 641-664.

[5] Liberge, S., Soheilian, B., Chehata N., Paparoditis, N., 2010. Extraction of vertical posts in 3D laser point clouds acquired in dense urban areas by a Mobile Mapping. In: Paparoditis, N., Pierrot-Deseilligny, M., Mallet, C., Tournaire, O., (Eds.), Proc. IAPRS, 38 (Part 3B), Saint Mandé, France, 1-3 September, pp 126-130.

[6] Rabanni, T., 2006. Automatic reconstruction of Industrial Installations using point clouds and images. PhD thesis. NCG Nederlandse Commissie voor Geodesie Netherlands Geodetic Commission, 154 p.

[7] SitecoInformatica, 2014, Road-Scanner Mobile Mapping System, http://www.sitecoinf.it/index.php/en/solutions/roadscanner-mms. (Accessed 12 January 2014).

[8] Schuster, H.F., 2004, Segmentation of Lidar Data Using The Tensor Voting Framework, XXth ISPRS Congress, 12-23 July 2004 Istanbul, Turkey, pp1073.

[9] Wani, M. A. and Arabnia, H. R., 2003, Parallel edge region based segmentation algorithm targeted at reconfigurable multiring network. Journal of Supercomputing 25(1), 43–62.

[10] YOO, H-J, 2011. Analysis and design of mobile laser scanners dedicated to 3D mapping of urban environments. Ph. D thesis. Ecole Nationale Supérieure des Mines de Paris. 127 p.