Full Length Research Paper

Mobile laser scanning for monitoring Polyethylene City infrastructure networks

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This research discusses a more efficient geospatial monitoring technique for city infrastructure networks. It will concentrate on polyethylene city infrastructure materials, where power, water and communication networks are covered or protected by polyethylene materials. A technical comparison is conducted between current and proposed geospatial monitoring techniques in order to develop an overall performance evaluation. The mobile laser scanning technology achieved the best performance evaluation, where detailed data analysis and collection, mobile laser missions, modeling and interpretation, and system geometrical corrections for location and orientation have also been conducted. Prior to conducting the performance evaluation, the research investigates mobile laser behavior and recognition capabilities with respect to Polyethylene City infrastructure materials. After analyzing the mobile laser pulses behavior, and its correlations with the mission ground speed and exposed scanned surface, it is concluded that the mobile laser pulses response is constant for the Polyethylene City infrastructure materials. The concluded mobile laser pulses constant is utilized to develop a mathematical model for re-planning the mobile laser scanning missions to obtain the best model for monitoring the Polyethylene City infrastructure networks.

Key words: Spatial thinking, smart cities, geographic information system (GIS), city infrastructure development.

INTRODUCTION

Over the past few years, several research and development authorities across the world have started the development and support of intelligent city platforms in terms of monitoring and controlling. The city infrastructure network is one of the primary city subsystems, where the intelligence is very efficient and would significantly improve the overall performance. This research discusses the intelligent city infrastructure monitoring platform in the sense of geospatial monitoring, which highlights the updated geographical location (XYZ) represented in a 3D surface model of the area of interest.

There are several technologies, strategies and methodologies that can be utilized for spatial data collection for surveying and mapping production, including monitoring city infrastructure progress. These technologies include common data collection methodologies using conventional terrestrial surveying techniques, photogrammetry and various types of remote sensing techniques, including laser scanning. Cedillo et al. (2009) conducted a high resolution magnetic survey across a 120 × 120 m area located on an ancient fluvial terrace of the Huерfano River and a global positioning system (GPS) survey over a 2.0 km² extent of the terrace. Guorong et al. (2010) shown that the surveying system is convenient, accurate and feasible to automatically accomplish the whole measurement task. This research provides a technical comparison between most available geospatial monitoring techniques. The goal of conducting this comparison is to validate the performance of the mobile laser scanning technology versus the other geospatial technologies. Li et al. (2010) discuss the need of plan survey in-house, a new close range photogrammetry method was developed by laser reticule system. With the help of the system, two parallel level lines and eight vertical laser lines can be marked on the surface of inner walls.

Laser scanning technology is based on laser scanning of a structured laser line over the surface of an object in order to collect 3D data. Barber et al. (2008) validate the laser scanned point cloud data collected by a ground-
based mobile mapping system. The surface data is captured using a receiver/rangefinder sensor mounted in the laser scanner on top of a vehicle which records accurate dense 3D points in space. The philosophy of geo-referenced dynamic spatial data of the collected point cloud data is based on the integration with the ground position using either GPS or GNSS (global navigation satellite system) technologies observations, or the integrated inertial instrument unit. This system is often referred to as a light detection and ranging (LIDAR) system.

The research analyses the collected mobile laser scanning observations, navigational GPS data, system ground speed, GNSS reference station corrections and IMU observations. These field data sets are not directly related to each other. The preliminary analysis shows that location and time can be used to correlate these data sets, where the analysis will be valuable. Kontogianni et al. (2008) argues the applications of modern geodetic instruments in sports and leisure-related activities. Haifeng (2009) introduces the principle and characters of RTK technique. Worrall and Andrew (2007) develop and assess a legally traceable set of Quality Assurance procedures for using RTK GPS when performing a cadastral survey. The aim of the mobile laser scanning analysis is to identify the best practice methodology of utilizing the new mobile laser scanning technology in city infrastructure monitoring. The research also discusses an extraction mathematical model for identifying the best system ground speed to be conducted during the mobile laser scanning missions for any kind of polyethylene pipelines/cables. Only polyethylene infrastructure materials are considered in this work as to the conducted detailed analysis is for identifying the mobile laser beam intensity constant. Other materials might be subject to different types of studies where the system ground speed is subject to be changed due to material surface reflectivity factors for the mobile laser scanning pulses. Tunstel and Dolan (2009) describe several examples of mobile surveying approaches using local and remote sensing configurations.

The detailed analysis of mobile laser scanning pulses behavior with respect to polyethylene city infrastructure networks (cables and pipelines) result in a new planning of the mobile laser missions, which forms a more intelligent city infrastructure geospatial monitoring platform. The new intelligent geospatial platform will develop a new smart city concept. Bernardini and Rushmeier (2002) mentioned that in most situations, a single scan will not produce a complete model of the subject. Curless (2000) argues the variety of technologies for smartly acquiring the shape of a 3D object.

City infrastructure daily development in any city/community is very huge; the large development in city infrastructure networks is reflected in the daily number of new installations, replacements, enforcements, etc. Daily city infrastructure utility updates are subject to maintenance and operation on a frequent basis. The efficiency of the maintenance and operation workflow is strongly related to the geographical location of these city infrastructure networks. Due to the huge daily updates of city infrastructure networks, the ability to collect updated locations using current geospatial monitoring techniques is very difficult.

The utilized dynamic laser scanning surveying equipment and the surveyed area is owned by Limitless LLC, under the Dubai government. Figure 1A shows the system mounted on top of the car. Figure 1B shows the
utilized dynamic laser scanning system units; the system has two main units, the scanner and the IMU unit. The system is supported with a smart georeferenced camera, which it is not investigated in this research. The correlation between the three main components has been well calibrated in the sense of orientation using the IMU, positioning using GPS, and data laser beam pulses emitted from the mobile scanner.

MOBILE MAPPING SYSTEMS

The mobile mapping concept refers to a means of measuring spatial data using mapping technologies and sensors that are mounted on a mobile platform. Schwarz and El-Sheimy (2007) propose a process which was mainly driven by the need of highway infrastructure mapping and transportation corridor inventories. Cameras, along with navigation and positioning sensors, example, GPS, and inertial devices such as IMU, were integrated and mounted on a mobile vehicle for mapping purposes. Kang et al. (2007) discussed an effective mobile mapping system using the vehicle equipped the GPS, IMU, charge-coupled device (CCD) Camera. Objects can be directly measured and mapped from images that have been georeferenced using navigation and positioning sensors. In the early days, the research community had used various terms to characterize this exiting research area, such as kinematic surveying, dynamic mapping and vehicle based mapping. Hug et al. (2004) discussed a study aimed to assess the accuracy, completeness and consistency of high quality terrain information in the coastal zone and derived digital terrain model (DTM) against an independent control dataset and against an airborne LIDAR dataset of the same area.

Schwarz and El-Sheimy (2007) indicate that mapping, which is a well established engineering subject, has become increasingly influential to people’s lives and business processes. Cracknell and Ladson (2007) mentioned that LIDAR is highly sensitive to aerosols and cloud particles and has many applications in atmospheric research and meteorology. It has long been recognized that geospatial data is at the heart of any geospatial application. Consequently, collecting and updating map and image information in a timely and accurate fashion has become more important than ever.

Zhang and Xiao (2003) discuss the latest development and evolution of surveying and mobile mapping technologies that opens new avenues for the acquisition, update, and fast and online processing of data. Ussyshkin (2010) mention that the airborne LIDAR, a more mature technology, which came on the market in mid 90s, the initial uptake in the marketplace was slow, and the newcomers to the LIDAR business had to learn hard way to work with the uncertainties associated with the use of new technology, huge data volumes, new data formats and conservative mentality of the surveying community, where acceptance of the LIDAR-derived end- products had gone through a difficult way.

They also identify currently advanced technologies that support mobile mapping systems, including GPS and inertial navigation systems (INS), high resolution imaging sensors, multispectral and hyper spectral sensors, portable computers, and highly intelligent processing / automation algorithms. The definition and history of the mobile mapping system (MMS) is reviewed and briefly outlined. Advancements in low-cost, micro-GPS technologies has catalyzed the progress of MMS. Some new advancement of the current MMS has recently been developed and integrated to demonstrate current progress and expected future trends of development. Chun and Chun (2005) discuss the efficiency of the three dimensional laser ranger scanning which has the characteristics of high speed, high efficiency and real time operation, etc. however, the limitation on the memory and computation in computer has been recognized for its large volume of data and the detailed data depiction.

Multi-platform and multi-sensor integrated mapping technology has clearly established a trend towards fast geospatial data acquisition. Schwarz and El-Sheimy (2007) discuss some sensors that can be mounted on a variety of platforms, such as satellites, aircraft, helicopters, terrestrial vehicles, water based vessels and even people. The increasing use of internet and wireless communication networks, and the recent advances in sensor networks further enable us to transfer and process data in a more efficient manner. As a result, mapping has become mobile and dynamic.

Kim et al. (2006) provide an effective base for the management of information on construction and repair of highways and auxiliary facilities. The photograph data is collected with a MMS composed of the CCD cameras, GPS, and INS. Xue et al. (2008) mentioned that a surface mathematic model need to be established when these data to be used. Xue and Hong (2008) also highlight the basic principle of laser scanning technology and its definition of the coordinate system for 3D data cloud used in laser.

The research also provides a methodology for management of data collected on a pilot section of a highway. The prototype of the highway facility management system can improve cognitive power, and enables the extraction of qualitative information on the attributes and the positions of the interested objects.

TECHNICAL COMPARISON BETWEEN THE GEOSPATIAL MONITORING TECHNOLOGIES

A technical comparison is conducted between six common geospatial monitoring technologies in order to evaluate efficiency factor for each geospatial monitoring technology. The technical comparison methodology is designed to identify most of the functionalities and capabilities adopted in each technology (Figure 2). The
average coverage capacity, extracted objects, data format, mission type, average obtained accuracy, average system initialization, average post processing time, system operational complexity and data extraction complexity are the investigated functionalities, where each function has an efficiency factor. Each surveying technology is subjected to mission data collection and extraction, where some of surveying technologies are not applicable with all the efficiency factors. Taking into consideration that some of criterions cannot be precisely measured, such as measuring system complexity, these criterions will be estimated accordingly.

The overall efficiency factors evaluation is concluded by gathering and averaging the nine efficiency factors for each surveying technology. Figure 3 shows the overall efficiency factors for the six surveying technologies. The highest efficiency factor is achieved using dynamic laser scanning, where the efficiency factor is equal 7.6. The lowest overall efficiency factor achieved is using the total station technique, where the efficiency factor is equal 4.8. GNSS VRS, static laser scanning, aerial photogrammetry efficiency factors provide good overall efficiency factors.

ANALYTICAL ANALYSIS FRAMEWORK

The analytical analysis developed to interpret mobile laser scanning behavior with respect to polyethylene city...
infrastructure networks, in order to identify accordingly the mobile laser response model constant and to develop. The extraction mathematical model will be the base for mobile laser scanning mission planning. Prior conducting the mobile laser mission, a site investigation using measuring tape is needed to measure the exposed portion of the pipeline / cable. The exposed portion of the feature pipeline / cable (exposed perimeter) will be the only input for the mathematical model, where the laser response and material constant are known. The calculated values will be used to determine suitable mobile laser scanning mission speed.

The adopted analytical analysis methodology has been divided into several aspects. The main aspect is to analyze the IMU observation, which is mainly related to interpretation of the mobile laser beam pulses intensity at each point of time. The time series is considered as the primary link to correlate the mobile laser pulses, locations (latitudes and longitudes) and system ground speed. These three coefficients are recorded with respect to time. The locations will define the exact latitudes and longitudes of the investigated polyethylene pipeline; where the time interval will be identified accordingly. The identified time interval will be used to identify the system ground speed, and accordingly, the laser response at each point of time and system ground speed are coordinated. The expected correlation between the system ground speed and the mobile laser response is to determine the highest mobile laser response constant for scanning the polyethylene city infrastructure networks. Taking into consideration that the pipeline’s exposed perimeter and material is known, a mathematical model to extract the best speed practice for any exposed polyethylene city infrastructure feature will be developed.

The mobile laser system sends and receives 200 pulses per second in positive and negative directions; where the system records the frame ground speed every 0.02 s. Accordingly, there is a gap between the recorded mobile laser pulses (recorded every 0.005 s) and the frame ground speed (recorded every 0.02 s). The mobile laser pulses have been resembled from 0.005 to 0.02 s in order to compare the frame ground speed with the mobile laser pulses response at the same point of time. The positivity (+) and negativity (-) of the received mobile laser beam pulses only represent the laser beam direction, and hence, all negative values have been
transferred to absolute values prior to conducting the analytical analysis.

Prior to synchronizing the mobile laser pulse response with the system ground speed, the time series needs to be identified in very high accuracy level. Accurate time series identification is significantly related to the accuracy of identifying the polyethylene locations. The location accuracy is mainly related to the geometrical correction for field mission locations (XYZ) and the IMU orientation angles (roll, pitch, and heading). The geometrical correction of the IMU orientation angles is also related to the geometrical correction of the system reference frame. The system reference frame and GPS observations will be geometrically corrected using the input correction combined from the GNSS reference station. The geometrical correction of the reference frame, GPS observations and IMU orientation angles are conducted using least square adjustment embedded in the POSPac Mobile Mapping Suite V 5.2.

The mission reference frame, GPS observations and IMU observations analysis have been conducted initially for the complete mission. The reason of analyzing the complete mobile lasers scanning mission is to filter out and delete anomalies and all unwanted records from the collected observations. Normally, the laser pulses field observations include unwanted observations due to the high sensitivity of the system, and hence, very small objects such as dust or objects around the desired features will be captured. The overview mission data analysis is important to fine tune the collected observed mobile laser beam pulses with respect to mission speed units. Figure 4 presents the schematic workflow for the

Figure 4. Analytical analysis framework.
conducted research analytical analysis.

**DISCUSSION AND CONCLUSION**

The research conclusion with respect to polyethylene city infrastructure network monitoring and frequent update utilizing the new mobile laser scanning methodology is very efficient. The research is proving the ability of the developed methodology utilizing the mobile laser scanning technology in frequent geospatially monitoring of the Polyethylene City infrastructure networks. The achieved results and conclusions are providing a very encouraged platform for city infrastructure monitoring. On the other hand, the achieved results in the sense of geospatial monitoring of polyethylene city infrastructure network has a primary effect in the new trend of the smart city architecture development.

The practicality of implementing the developed mathematical extraction model in re-planning the mobile laser scanning missions in order to monitor the polyethylene city infrastructure networks is referring to the ability of monitoring and controlling other the city components in a more intelligent way. The research conclusions importance is emanated from the importance of monitored features, where the city infrastructure is forming the large sector of the city components.

The achieved geospatial monitoring presented in this research is extremely important not only to update the huge daily progress update for the Polyethylene City infrastructure networks, but also when the controlling stage take place using the communication protocols and technologies. The intelligent control is strongly related to the accuracy, completeness and updated information, where the research is providing an excellent platform to update the polyethylene city infrastructure information's accurately on daily basis.

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