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Accuracy verification of the Lynx Mobile Mapper system

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ABSTRACT

LiDAR technology is one of the most effective and reliable means of data collection. Given the increasing use of LiDAR data for close range metrology applications such as deformation monitoring and infrastructure inspection, it becomes necessary to test the relative accuracy, boresight calibration of both LiDAR sensors and performance of navigation solution (or absolute accuracy) of any mobile laser scanning system employed for this purpose. Therefore, the paper's primary contribution is a set of tests for the characterization and evaluation of any mobile laser scanning system based on two LiDAR sensors. We present experimental results of the Lynx Mobile Mapper system from Optech Inc. Employing a low-cost calibration standard, we demonstrated sub-cm accuracy of targets at distances up to 10 m. Also, we introduce boresighting results derived from the Lynx system. Moreover, the global system's accuracy is tested with a series of rigorous experiments operated at a maximum scan frequency of 200 Hz, pulse repetition frequency of 500 kHz per sensor and a 360° scanning field of view. Assuring good GPS conditions, we proved a good global performance of the system, which makes it suitable for very accurate applications.

1. Introduction

There are several methods and tools existing in the current market that can be used to collect 3D spatial data for mapping and surveying purposes. These methods include photogrammetry [1,2], different types of laser scanning and the traditional surveying techniques. Nevertheless, mobile LiDAR technology has been highlighted in recent years because of its revolutionary key benefits compared to these other technologies.

Terrestrial laser scanning, for example, continues to prove its worth in applications such as architectural applications [3], cultural-heritage recording [4,5] and ground survey tasks [6,7]. However, registration of overlapping scans requires the identification of common points in each scan, which currently limits its efficient use over wide areas.

As a consequence, mobile laser scanning systems (MLS) have become popular and are increasingly used in providing as-built and modeling data in civil and environmental applications, including road-surveying [8], architecture, 3D city modeling or archeological studies.

These systems show a great potential for acquiring detailed point cloud data thanks to the combination of one or more LiDAR devices with an inertial measurement unit (IMU) and differential GPS that are mounted on the car [9].

The resulting detailed 3D model can be very useful for engineers to extract, measure and analyze all the required data in the office, avoiding surveyors to return to the site for additional measurements. Using mobile laser scanner systems will dramatically improve safety and efficiency over traditional survey methods.

However, to take full advantage of using laser scanners, they must be used in appropriate applications. Like any other instrument, the LiDAR sensor of any MLS system has its own set of limitations and its performance varies with distance, object reflectivity, and angle of incidence to the reflective surface. The technical specifications of laser scanners as stated by individual manufacturers are typically difficult to reproduce in real-life applications.

This paper introduces a new low-cost artifact that makes possible to evaluate the accuracy and other related aspects for MLS systems. Some other studies on this topic have been published previously [10–12]. A verification artifact with calibration spheres is commonly used in metrology if the same magnitudes are to be measured for different types of case studies. Matlab software was also used to provide the geometric information of spheres (the *X*-, *Y*-, and *Z*-coordinates and the diameter) for this purpose. In the following sections, the steps for the realization of this study are discussed. Finally, a discussion of the results and some conclusions are provided.

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Fig. 1. (a) Lynx LiDAR sensor and camera. (b) Applanix GPS antenna deployed on the vehicle and (c) Lynx control unit.

Table 1
Manufacturer specifications for the Lynx Mobile Mapper.

Number of lidar sensors	1–2
Camera support	Up to 4 × 5 Mpx cameras
Maximum range	200 m, 20%
Range precision	8 mm, 1σ
Absolute accuracy	± 5 cm (1σ)[a]
Laser measurement rate	75–500 kHz programmable
Measurement per laser pulse	Up to 4 simultaneous
Scan frequency	80–200 Hz programmable
Scanner field of view	360° without obscurations
Laser classification	IEC/CDRH class 1 eye-safe

[a] To meet its stated accuracy, the Lynx must receive GPS data of sufficient quality.

Fig. 2. The Lynx Mobile Mapper system used to collect the test datasets.

2. Material

2.1. System description

The mobile laser scanning system selected for this study was the Lynx Mobile Mapper, released at the end of 2007 by Optech Inc. [13]. The Lynx is based on two LiDAR sensors, typically named A and B (Fig. 1a) to collect survey-grade LiDAR data at 500,000 measurements per second with a 360° FOV (each scanner). An overview of the specifications for the Lynx system is given in Table 1. The Lynx also incorporates the POS LV 520 produced by Applanix, which integrates an IMU with a 2-antenna heading measurement system (GAMS), providing absolute accuracies (RMS) of 0.015° in heading, 0.005° in roll and pitch, 0.02 m in *X*, *Y* positions and 0.05 m in *Z* position (Fig. 1b). All those values are determined by differential GPS post-processing after data collection using GPS base station data.

Optech provides up to four 5 Mpx digital cameras. Each camera (Fig. 1a) is boresighted to its LiDAR sensor and produces georeferenced images. The Lynx control rack is located inside the vehicle. The control unit (Fig. 1c) controls the LiDAR data which is fused with GNSS/INS data from Applanix's POS LV 520 system, Distance Measuring Instrument (DMI) information as well as imaging cameras.

A three-dimensional point cloud can be generated and used to provide detailed positions and dimensions of the area over which the vehicle has driven. Fig. 2 shows the actual system used in the study.

In addition, the Lynx Mobile Mapper system's performance is determined by its resolution. The Lynx's spatial resolution is selectable in terms of both horizontal and vertical axes. The horizontal resolution is set by the scan frequency of both LiDAR heads, that varies from 80 to 200 Hz while the vertical resolution is defined by the pulse repetition rate (PRR), ranging from 75 to 500 kHz. Moreover, both resolutions are influenced by the driving speed, which is also responsible for the space between two consecutive road cross sections.

2.2. Calibration standard

The calibration standard comprises mostly of five 100 mm diameter spheres equidistantly assembled on an aluminum block and seven cubes of different dimensions, with edges measuring 100, 80, 60, 40, 30, 20 and 10 mm [14,15]. This artifact (Fig. 3) is manufactured by an accurate CNC (Computer Numerical Control) machine while the assembly between the delrin spheres and the aluminum block is performed using screws and epoxy glue. Spheres are often used instead of 2D targets because they look the same from each direction and provide well defined reference points: fitted sphere centers. Moreover, they transfer better traceability from more accuracy technologies as coordinate measuring machines with touch probes.

The coordinate measuring machines (CMM) are mechatronics instrumentation composed of three orthogonal axes (*X*, *Y* and *Z*) in a typical three dimensional coordinate system. The CMM reads the input from the touch probe directly by the operator handling or automatically using a software routine. These systems can typically achieve a precision of 10 μm for lengths around 1 m if they are accompanied with a strict measurement procedure (controlled environmental conditions, sufficient number of data, well trained technicians, etc.). They are specially indicated for quality control of low tolerances in manufactured parts and for dimensional measurements of an object. Although this calibration artifact consists of cubes and spheres, only spheres were indicated to study the metrological parameters in this work. In this sense, distance between centers of the spheres allows determining accuracy and boresight calibration parameters of both LiDAR sensors.