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Review

Review of mobile mapping and surveying technologies

I. Puente *, H. González-Jorge, J. Martínez-Sánchez, P. Arias

Close Range Remote Sensing and Photogrammetry Group, Department of Natural Resources and Environmental Engineering, School of Mining Engineering, University of Vigo, 36310 Vigo, Spain

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ABSTRACT

Mobile surveying is currently one of the most popular topics in the LiDAR industry. The collection of highly precise point cloud data is provided by laser scanning systems on moving platforms with an integrated navigation solution. The potential of LiDAR based mobile surveying technology is now well proven. This article introduces an analysis on the current performance of some outstanding mobile terrestrial laser scanning systems. In this work, an overview of the positioning, scanning and imaging devices integrated into these systems is also presented. As part of this study, a systematic comparison of the navigation and LiDAR specifications provided by the manufacturers is provided. Our review suggests that mobile laser scanning systems can mainly be divided into two categories (mapping and surveying) depending on their final purpose, accuracy, range and resolution requirements. A refined integrated analysis based on hardware components could be expected to cause further improvements on these results.

Contents

* Corresponding author. Tel.: +34 986 813 499; fax: +34 986 811 924.
E-mail addresses: ipuente@uvigo.es (I. Puente), higiniog@uvigo.es (H. González-Jorge), joaquin.martinez@uvigo.es (J. Martínez-Sánchez), parias@uvigo.es (P. Arias).

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1. Introduction

The development of mobile mapping systems (MMSs) began in the late 1980s and early 1990s, when the first usable land-based MMS was developed by the Centre for Mapping at Ohio State University. Their system, called GPS-Van™, integrated a code-only Global Navigation Satellite System (GNSS) receiver, two digital CCD cameras, two color video cameras and several dead-reckoning sensors (two gyroscopes and a distance measurement unit on each of the front wheels), all of which were mounted on a van [1,2].

The aforementioned description provides an approximate idea of the design of a MMS. A mobile mapping system consists mainly of three components: mapping sensors, a positioning and navigation unit for spatial referencing, and a time referencing unit. These systems capture 2D or 3D geometric environmental information using an imaging sensor that is attached to a moving platform, which may be a land vehicle, a vessel or an aircraft. Mobile mapping systems can be characterized by the imaging unit in use. The GIM™, GPSVision, VISAT™, KiSS™ and GI-EYE™ systems are some existing examples of MMS based on photogrammetry [3,4]. Mobile mapping systems that use LiDAR technology as their main imaging unit (called mobile laser scanning systems) are the most recently developed type. Light Detection and Ranging (LiDAR) technology, which is based on laser range-finding measurements of the distance between the sensor and the targeted object, provides a significant increase in the number of data points of exceptional accuracy over traditional data capture methods.

Mobile LiDAR term is widely used for laser scanners that are deployed on any mobile platform, such as vans, trains [5], boats [6], snow mobile sledges [7] or even 4×4 all-terrain vehicles [8]. Due to the scope of this paper, only land-based mobile laser scanning systems (MLSs) are considered.

Land-based mobile laser scanners share many features with airborne laser scanners (ALSs), especially among those features introduced by the fundamentals of laser distance measurement and scanning. Moreover, data processing workflows are very similar (or nearly identical) in both cases. On the other hand, these systems clearly differ in terms of typical project size and obtainable accuracy and resolution, among other factors. ALS systems almost exclusively use the pulse time of flight measurement principle for ranging [9–14], and they have been widely used for the generation of bare-earth digital elevation models, the estimation of forest inventory attributes, and even operational forest management [15]. Compared with ALS, locating the scanner on a mobile ground platform provides some distinct advantages for the capture of discrete objects from multiple angles. In this paper, a state-of-the-art review of land-based mobile laser scanning systems is presented. Some reviews on this topic have been published previously [16–21].

Because of the increasing need for 3D geoinformation and the current interest in the field of mobile mapping, the parameters of laser scanners and navigation are rapidly varying as a result of technological developments; consequently, this review will soon be outdated. However, this study, which is the result of a time-consuming research that required the help of numerous people from relevant firms, not only presents a complete survey of existing commercial systems but also provides a comparison of navigation and scanning solutions between them. The work contained here is important for researchers who are considering the development of their own system, the improvement of an existing one or the purchase of a system that is available in the market today. The contents of this work include a description of the technologies involved in mobile laser systems, a review of the different present-day systems available in the market, and a discussion of their technical characteristics and limitations.

2. MLS technology

Professionals in Civil Engineering and Construction [22,23], Environment [24], Mining [25], Petroleum [26], Pipeline and Plant Design [27] are the typical end-users of LiDAR data. Mobile LiDAR technology provides accurate, three-dimensional images enabling designers to experience and work directly with real-world conditions by viewing and manipulating rich point clouds in computer-aided design software. The laser scanner is able to record millions of 3D points. These X, Y, Z measurements can be imported into specific CAD design software and displayed on a computer monitor as "point clouds", which have photographic qualities portrayed in one-color, grayscale, false-color or even true color. The files with the point clouds can be viewed, navigated, measured and analyzed as 3D models. Mobile LiDAR technology presents some benefits [28]: high speed data capture (time and cost reduction), remote acquisition and measurement (increases survey efficiency and safety), high point density data ensures a complete topographic survey, abundance of data captured in laser scanning reduces the effect of questionable data in the result, imagery and 3D visualization provide added confidence that mapped objects correspond to actual existing conditions.

Any mobile LiDAR system integrates several subsystems: digital frame cameras, a laser scanner, an Inertial Measurement Unit (IMU) in combination with a Global Navigation Satellite System (GNSS), and a control unit that operates all of these components, synchronizes measurement acquisition and records the collected data [29–33].

The description of the technology will be organized into three main parts. The first describes the positioning (or geo-referencing) components of mobile LiDAR systems, which are the principal building blocks for the construction of such systems. The second considers the laser ranging and scanning devices. Imaging devices will be briefly discussed for each particular MLS system. Finally, calibration and boresighting will be explained.

2.1. Positioning and navigation components

Direct geo-referencing is the determination of time-variable position and orientation parameters for a mobile LiDAR system. Three types of technologies are able to