Finding anomalies in high-density LiDAR point clouds

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Modern three-dimensional (3D) terrestrial scanning systems such as the TITAN system make it possible to acquire precise, geo-referenced datasets over areas spanning many square kilometers. These systems consist of several vehicle-mounted lasers for acquiring point data, a high-precision GPS unit for providing geo-reference data, and an inertial measurement unit (IMU) for tracking vehicle motion. Two liabilities of this type of approach are that the navigational accuracy degrades when the GPS signal is lost, and moving objects can cause data artifacts. These induce particular anomalies in the acquired data that must be eventually corrected, often by hand, during the post-processing stage. The goal of this paper is to show that by exploiting the configuration of the LiDAR sensors, such anomalies can often be detected automatically from the dataset. In particular, we demonstrate that under an appropriate tessellation, iterative closest point (ICP) algorithms can be used to reliably localize anomalies and provide an estimate of their magnitude.

Les systèmes de balayage terrestre modernes à trois dimensions (3D) comme le système TITAN nous permettent d'acquérir des jeux de données géoréférencées précis pour des régions s'étendant sur plusieurs kilomètres carrés. Ces systèmes sont composés de nombreux lasers montés sur véhicule pour obtenir les données sur les points, d'une unité GPS de grande précision pour fournir les données géoréférencées et d'une unité de mesure par inertie (UMI) pour suivre le mouvement du véhicule. Deux points faibles de ce genre d'approche sont que l'exactitude de la navigation se dégrade lorsqu'on perd le signal du GPS et que les objets en mouvement peuvent causer des artéfacts aux données. Ceci produit des anomalies particulières des données obtenues qui doivent éventuellement être corrigées, souvent manuellement, au cours de l'étape du post-traitement. Le but du présent article est de démontrer qu'en exploitant la configuration des capteurs Lidar, ces anomalies peuvent souvent être détectées automatiquement dans le jeu de données. Plus particulièrement, nous démontrons qu'à partir d'une tessellation adéquate, il est possible d'utiliser les algorithmes itératifs du point le plus près (ICP) pour localiser les anomalies de manière fiableet fournir une estimation de leur magnitude.

1. Introduction

Mobile, ground-based LiDAR systems such as the TITAN system, developed by Terrapoint Canada Inc. [*Ambercore Inc.* 2009], or StreetMapper, developed by 3D Laser Mapping and IGI mbH [*StreetMapper* 2008], help satisfy the ever-increasing need for the acquisition of the dense 3D data needed to create accurate models of man-made structures, natural environments and terrain features. These systems are capable of acquiring large volumes of data very quickly; for example, TITAN can record up to 20 000 data points per second, resulting in the rapid collection of high-density, multi-million point datasets. TITAN (Figure 1) and StreetMapper each use several laser profilers mounted to scan on different sides of a moving vehicle. The LiDAR data are combined with the position and orientation data of the vehicle to create a full 3D view of an environment as the vehicle moves through it. These systems require a very accurate estimate of the vehicle's position and orientation at each instant, so a Global Positioning System (GPS) and an Inertial Measurement Unit (IMU) are used in parallel to track the vehicle's motion.

While working on the design of an "Optical IMU" [*Hefford et al.* 2009], that is, a third system to work in concert with the GPS and IMU to further improve the position estimates, we developed a new approach for automatically detecting two types of anomalies in large, high-density point clouds.

The first type of anomaly occurs when navigational accuracy is degraded. When the GPS receiver