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Automated road markings extraction from mobile laser scanning data

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ABSTRACT

Road markings are used to provide guidance and instruction to road users for safe and comfortable driving. Enabling rapid, cost-effective and comprehensive approaches to the maintenance of route networks can be greatly improved with detailed information about location, dimension and condition of road markings. Mobile Laser Scanning (MLS) systems provide new opportunities in terms of collecting and processing this information. Laser scanning systems enable multiple attributes of the illuminated target to be recorded including intensity data. The recorded intensity data can be used to distinguish the road markings from other road surface elements due to their higher retro-reflective property. In this paper, we present an automated algorithm for extracting road markings from MLS data. We describe a robust and automated way of applying a range dependent thresholding function to the intensity values to extract road markings. We make novel use of binary morphological operations and generic knowledge of the dimensions of road markings to complete their shapes and remove other road surface elements introduced through the use of thresholding. We present a detailed analysis of the most applicable values required for the input parameters involved in our algorithm. We tested our algorithm on different road sections consisting of multiple distinct types of road markings. The successful extraction of these road markings demonstrates the effectiveness of our algorithm.

1. Introduction

Road user safety may be affected by existence and condition of safety interventions along the route corridor. A well designed and maintained route corridor assists in driver safety as well as in the efficient use of overall network in terms of route navigation (ETSC, 1997). Road markings play an important role in reducing accident frequency and severity as they provide guidance and instruction to the road users for safe and comfortable driving. They are intended to direct traffic by indicating the direction of travel, warn road users about specific obstacles or hazards and define the territorial limit for traffic flows (Gatti et al., 2007). Road markings are retro-reflective surfaces having an ability to reflect most of the incident light back to its originating source. These markings retain their visibility criteria in day and night. Road markings may deteriorate due to intensive use or suffer from reduced visibility due to many factors such as occlusions that arise from vegetation growth. Road markings are required to be located, measured, classified and recorded in a timely, cost effective manner in order to schedule maintenance and ensure maximum safety conditions for road users (Kumar, 2012).

Various safety schemes and standards such as the Road Safety Audit (RSA), Road Safety Inspection (RSI) and Network Safety Management (NSM) are implemented to qualitatively estimate potential road safety issues along the route corridor. The aim of these road safety assessment methodologies is to identify the elements of the road that may present a safety concern and explore the various opportunities to eliminate identified safety concerns (ETSC, 1997). The information collected through these surveys is sometimes incomplete and insufficient for qualitative estimation of potential road safety issues. It can also be time consuming and expensive to conduct these inspections on a large scale. A recent research call highlighted the requirement for common evaluation tools and implementation strategies in carrying out these inspections and assessing risk along route corridors (Pecharda et al., 2009). One research project European Road Safety Inspection (EuRSI) demonstrated that terrestrial Mobile Mapping Systems (MMS) could be used to collect physical route corridor information for rapid safety analysis (McCarthy and McElhinney, 2010).

Mobile mapping refers to a methodology of collecting geospatial data using mapping and navigation sensors that are mounted rigidly onboard a mobile platform (Schwarz and El-sheimy, 2007; Barber et al., 2008). Multi sensor integrated mapping technology has enabled rapid and cost effective acquisition of georeferenced information about road network environments (Li and Chapman,

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2008). Their initial development was primarily driven by advances in digital cameras and navigation technologies. Later, laser scanning systems were integrated with MMSs which facilitated more accurate and dense collection of 3D point cloud data. The applicability of mobile laser scanning (MLS) systems continues to prove their worth in route corridor mapping due to their rapid, continuous and cost effective 3D data acquisition capability. MLS systems usually record the intensity data which can be used to distinguish road markings that produce high reflectivity due to their retro-reflective property. Knowledge of the location, dimension and condition of road markings can be useful for road safety, route network maintenance and driver assistance systems. In Kumar et al. (2013), we presented an automated algorithm for extracting road edges from MLS data. The automated road edge extraction algorithm is applied to estimate road boundaries from LiDAR data. The output road boundaries are then used to identify the LiDAR points that belong to the road surface. Knowledge of the road surface area facilitates a more efficient and accurate extraction of road markings. In this paper, we will present an automated algorithm for extracting road markings from MLS data. The algorithm is based on applying a range dependent thresholding function to the intensity values to extract road markings from MLS data. In Section 2, we review various approaches developed for extracting road markings from LiDAR data. In Section 3, we present a stepwise description of our automated road marking extraction algorithm. In Section 4, we present our analysis to find the most applicable values of input parameters required to automate the road marking extraction algorithm. In Section 5, we test our algorithm on various road sections, demonstrating the successful extraction of different types of road markings. We discuss the results following validation of the road marking extraction process in Section 6. Finally, we conclude the paper in Section 7.

2. Literature review

MLS systems enable the acquisition of an accurately georeferenced set of dense LiDAR point cloud data. Because of the fundamental structure and intrinsic properties of LiDAR data, it enables more efficient and accurate road feature extraction approaches to be explored. Apart from facilitating the collection of 3D positional information, laser scanning systems record a number of attributes including intensity, pulse width, range and multiple echo which can be used for reliable and precise extraction of different spatial objects. The pulse width from the laser scanning system refers to a recorded time difference between half maximum amplitudes of the pulse (Kumar, 2012). The pulse width attribute can be used to classify terrain objects as its values vary with the surface roughness (Lin and Mills, 2010). The methods developed for segmenting LiDAR data are mostly based on the identification of planar or smooth surfaces and the classification of point cloud data based on its attributes (Vosselman, 2009). In a related area, several methods have been developed over the past decade for extracting urban building features from LiDAR data (Hammoudi et al., 2009; Rutzinger et al., 2009; Kabolizade et al., 2010; Haala and Kada, 2010). Other approaches have been based on extracting road and its environment from LiDAR data. Clode et al. (2004) and Hu et al. (2004) segmented Airborne Laser Scanning (ALS) data into road and non-road based on elevation and intensity attributes, while Samadzadegan et al. (2009) used first echo, last echo, range and intensity attributes to classify the ALS points into road objects. Mumtaz and Mooney (2009) used ALS elevation and intensity attributes to extract spatial information about buildings, trees, roads, poles and wires in the route corridor environment. Lam et al. (2010) extracted roads through fitting a plane to 3D terrestrial mobile point cloud data and then used the extracted information to distinguish lamp posts, power line posts and power lines by employing context based constraints. Pu et al. (2011) segmented MLS data into traffic signs, poles, barriers, trees and building walls based on spatial characteristics of point cloud segments like size, shape, orientation and topological relationships. Similarly, Zhou and Vosselman (2012) used elevation attribute, while McElhinney et al. (2010) and Kumar et al. (2013) employed elevation, intensity and pulse width attributes to extract road edges in multiple route corridor environment from MLS data.

LiDAR data provides an intensity attribute which depends upon the range, incidence angle of the laser beam and surface characteristics. The intensity values are required to be normalised with respect to these factors prior to the threshold implementation or the use of a range dependent threshold approach is recommended for segmentation or feature extraction (Vosselman, 2009). Most of the approaches used for normalising their values are based on using models and data driven methods (Pfeifer et al., 2008; Jutzi and Gross, 2009; Oh, 2010) while other approaches are based on using external reference targets of known reflectivity behaviour (Kaasalainen et al., 2009; Vain et al., 2009). The intensity attribute can be used to distinguish road markings from the road surface. Precise extraction of road markings from LiDAR data has drawn limited attention from the research community. Jaakkola et al. (2008) estimated road markings by first performing a radiometric correction of the LiDAR intensity data using a second order curve fitting function. Finally, road markings were estimated by applying a threshold and morphological filtering methods. Toth et al. (2007, 2008) used road markings as ground control for assessing the positioning quality of ALS data. The search window for finding the road markings in the LiDAR data was reduced by making use of the Global Positioning System (GPS) survey data collected over the pavement. The road markings were extracted by thresholding the LiDAR intensity values. Later, extracted road markings were compared with the GPS survey data to assess the quality of the LiDAR points. Vosselman (2009) described the use of a range dependent thresholding for extracting road markings from MLS data. The thresholded road marking points were grouped using connected component analysis and then full outlinings of the road markings were obtained by fitting predefined shapes to the grouped segments. Chen et al. (2009) developed a method for extracting lane markings from the MLS data. The road surface was detected by discarding the non-road points based on the standard deviation values of LiDAR elevation attribute and then candidate lane marking points were localised by applying a threshold to the intensity values of road surface points. The lane markings were clustered by applying the Hough transform to 2D binary image generated from candidate points and were further refined using trajectory and geometry check constraints. Smadja et al. (2010) developed an algorithm for extracting roads from MLS data based on the detection of slope break points coupled with the RANdom SAmple Consensus (RANSAC) algorithm. The estimated road information was used to extract road markings by applying a threshold approach to the LiDAR intensity data. Butler (2011) developed an automated approach to extract road markings from MLS system. The road marking points were extracted by thresholding the LiDAR intensity attribute and then output points were filtered based on their neighbourhood within a specified threshold distance. The road marking points were clustered and convex hulls were fitted to them. Yang et al. (2012) described an automated approach for extracting road markings from MLS data. In their approach, 2D image was generated from LiDAR point cloud data and then road markings were filtered by applying threshold to the LiDAR intensity and elevation values. Finally, the outlines of road markings were extracted based on priori knowledge of the shapes and arrangement of the road markings.

The majority of methods developed for extracting road markings are based on applying a threshold to the LiDAR intensity values. The development of a robust threshold approach will provide a