Automatic Road Inventory Using LiDAR Technology: A Review

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ABSTRACT*:** ***Road inventory is very important to manage the transport effectively. The method of road inventory involves an identification of items that can be located either on the road or in proximity to the road. Types include signage to the lane, road markings, guardrails and more. Much information about such objects, such as their location, condition or size, can be registered. In general, there are two sources of the information needed for the inventory to be collected. The first source is a compilation of camera-caught photos. The second source is data which a LiDAR captures. Mobile LiDAR technology is actually one of the attractive subjects for remote sensing and laser scanning applications. LiDAR allows for a rapid collection of huge volumes of highly dense, irregularly distributed, precise geo-referenced data, in the form of 3D point clouds. It technology has gained popularity in identifying roads and artifacts on the road-scene. In this article, information which can be obtained from camera images and LiDAR measurements was compared. The analogy is based on three examples: street signals, road markings and general items in the form of a pole. In addition, a process based on our algorithm has been defined which detects traffic signs in the LiDAR measurement and transforms the results into a common format used in geographic information systems. Our method has been tested in an urban area on a roughly two-kilometer long road. The study then provides a more in-depth overview of existing LiDAR studies on the inventory of road information, including the identification and retrieval of road surfaces and demonstration of LiDAR technology's great potential in road information inventories.

***KEYWORDS*:** ***Camera, Traffic Signs, Data Captured, Graphic Information System, LIDAR Technology, Road Sign, Road Markings, Road Inventory*.**

INTRODUCTION

Vegetation inventory, roads, or e.g. buildings is a common process which provides the basis for any effective management. A digital inventory record is usually stored in a series of various map layers in a geographic information system. Such map layers define the position / shape of inventory items and their properties (e.g. state or accurate description). This method generally involves a considerable amount of manual work (field measurements), post-processing data etc. It is therefore time-consuming, and costly. It has therefore concentrated on approaches which can improve the efficiency of inventories. In this article the attention was on the inventory of roads in particular. Especially the traffic signs, road markings [1] and trees around roads are items that are taken into account. There are many other items (e.g. milestones or guardrails) that can definitely expand this package. Methods of object detection were compared based on RGB data obtained from specific cameras and methods of object detection based on LiDAR measurements in relation to those objects described. This describes in detail the identification of two simple objects: traffic signals and road markings. Hence, this article focuses on researchers and developers who are considering the possibility of implementing an automated or semi-automatic inventory system. The purpose of this article is to provide an overview of technologies that are commonly used, to illustrate their limitations and, in particular, to clarify potentials of LiDAR-based methods that are not explained as thoroughly as traditional RGB image-based detection methods.

MOBILE LiDAR TECHNOLOGY

As the Global Navigation Satellite System (GNSS) technologies, LiDAR technologies have become well-established survey techniques for acquiring geospatial knowledge. Closely followed by airborne LiDAR, terrestrial LiDAR (i.e. the laser scanner is mounted on a tripod), and increasingly evolving mobile LiDAR technologies. Thanks to the following advantages, the mobile LiDAR technology [2] is being used at an increasing rate for transport-related applications. One of the key advantages of mobile LiDAR is its greater protection over other conventional survey methods because mobile LiDAR carries out road survey inside a vehicle with traffic flow, avoiding traffic visibility and environmental hazards for surveyors. In addition, handheld LiDAR reliably conduct road surveys at traffic speeds, day and night, with fewer surveyors. Additionally, mobile LiDAR gathers a very wide range of data sets at different accuracies, ranging from geographic information system (GIS) to survey grade. As a result, an increasing number of transportation agencies around the world have considered mobile LiDAR for road inventory and have provided corresponding guidelines for applications related to transport. To thoroughly demonstrate the usefulness of mobile LiDAR for road surveys, this review [3] will explain

(1) Their device setup.

(2) Geo-referencing.

(3) Error analysis.

(4) Validation of geometric precision.

LiDAR has a wide range of applications; one use is in controlling traffic and, in particular, enforcing speed limits. Current devices are designed to automate the entire process of detecting speed, identifying a vehicle, identifying a driver and recording evidence. Radar has broad signal beam separation, so that an individual vehicle cannot be targeted, requiring considerable operator skill, training and certification to visually estimate speed in order to locate an offender in a stream of traffic, and offenders may use the protection offended by some other vehicle.

Radar will register the speed of any object in its field, for example a tree swaying or an airplane passes overhead. LiDAR has a narrow beam, and it easily targets an individual car, removing the need for visual calculation, and at the same time some models will capture a picture of the license plate as capturing the infringement of speed. Speed estimate takes less than half a second, resulting in offending vehicles having little notice even when using an avoidance system in combination with the short, focused spotlight. LiDAR can detect' too close' (tailgating) infringements by measuring the distance between vehicles. The speed of a car can't be measured in the shadow of another vehicle.

METHODOLOGY

This section compares details that can be gathered on three chosen examples from RGB images (from the visible part of the spectrum) and LiDAR measurements (so-called point clouds): road [4] signs, road markings, and general pole-like artifacts.

Road Signs:

The procurement method of automated road signs involves two steps: detection [5] of the location of the sign and identification of the form of sign (e.g. "Roundabout" or "Main road"). You can do those two steps separately. In fact, even the identification of the sign location provides a significant speed-up of the inventory process. This provides exact location of the sign (possibly even its condition), and the operator must choose only the specific type of sign. First group of methods for reconnaissance of road signs using RGB images from raising cameras. Generally speaking these methods are very simple. Sign location identification typically is based on the shape or color of the sign. Both these approaches are used to identify the so called region of interest (ROI) in the source image. This ROI provides part of a picture likely to contain a warning. A signal recognition algorithm is then applied to this region in order to obtain an exact type of symbol. There are three common approaches: match template (calculation of pixel correspondence between a given image and a template), methods based on descriptors and neural networks. The second group of methods, not as popular as RGB-based methods, only use point clouds from LiDAR [6]. Each point in the point cloud represents a reflection from the surface of an object. Other properties (angle of reflection, its intensity etc.) are calculated among this three-dimensional position given by the reflection point. Thanks to the properties of the point clouds, these methods are commonly used for detecting sign locations in three dimensional spaces. Virtually all methods that use point clouds to identify road signs use the sign reflexivity as a key feature for detection. A Point Cloud holds color information only when paired RGB images provide it. Therefore the most important difference is that the form of sign can only be derived from RGB data or from a point cloud combined with such RGB data. Nevertheless, even from the point cloud the color degradation that is determined from color pixel values in the case of RGB data can be measured by analyzing the reflection intensities of a point. By addressing color details, accurate information [7] on the sign location, shape (including its possible bumpiness), direction and the sign base position can also be obtained. Evaluation of the sign damage can be done by fitting the calculated points to an arbitrary plane. The direction of the sign can be determined simply as usual of the sign points given to a plane. The position of the sign base is given by the location of points at the bottom of the sign pole. That is protected by this method. Some of these properties (e.g. position or direction) can also be approximated partially from RGB images; however, the precision is typically incomparable with point clouds. Such methods are based on perspective measurements not as precise as the exact position provided by a reflection of the laser beam, not even considering the distortion of the lens or the calibration problems. Therefore, the identification of shape changes, distance, pole base and location is considerably more difficult from RGB images; however, a significant advantage of point clouds over RGB images is their ability to work even under bad weather conditions. Detection of road signs from RGB data requires a relatively good weather conditions and a sufficient amount of light to locate the high probability signs. That restriction does not extend to point clouds, however. The data collection can be done even in bad weather (see Fig 1).

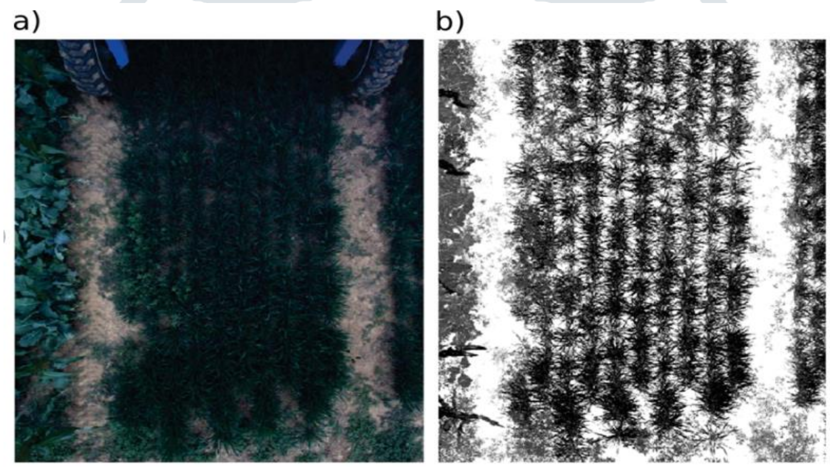

Fig.1: Comparison of an RGB Image (A) And LiDAR Intensity Image (B), Both of Which Were Acquired Over the Same Rice Map

The weeds and shadowing in the RGB picture present a clear challenge for the automated extraction of the fr actional cover, while the use of an active sensor, such as the LiDAR red laser, creates a high contrast betwee n soil and plants and can even distinguish between species based on the strength or pattern of reflectance.

ROAD MARKINGS

Road markings detection is widely used for autonomous car driving or as a driver assistance service. Hence, most of the approaches use data obtained from common RGB camera to detect road markings. The use of RGB cameras is substantially cheaper in comparison to LiDAR [7]. The common approaches for detection from RGB images are usually based on analysis of the pixels right in front of the car path. The camera image is threshold in this case, potential road marking pixels are extracted and on the appropriate region with these pixels is applied perspective correction to bird's perspective. It then senses pixels with right perspective that reflects the markings. All strategies generally rely heavily on the sign property. The dashed line, for example, always has parameters [8] provided by the defined government decree (length, distance between single lines). Likewise, a full-line is established. Among the sides, there are many different types of marks that the zebra crossings can be identified, and the most frequently seen are different arrows. Road marking detection based on point clouds is also often performed in real time, when the car is on the road. Typically the first step is to identify ground points (defined by their position) and then filter those ground points which represent potential markings according to their reflexivity. The methods for identifying specific types of road markings (dashed line, arrow etc.) are very close to the identification of RGB images and also rely heavily on the marking properties. Hence, in this case, both groups of approaches work with a set of points which represents a road marking. In the case of RGB images these points are selected color pixels and are represented by filtered 3D [9]points in the case of point cloud. All sources of data can be used to detect marker shape and type. The benefit of RGB images once again is the possibility to detect the color of the road. The point clouds, on the contrary, have considerably more accurate marking location [10]. Table 1 portrays the RGB and LiDAR road marking identification.

Table.1: Road markings identification comparison of precise information that can be obtained from RGB images with information provided by point cloud

RGB Images	Point Clouds
Color of the marking	Shape of marking
Shape of the marking	Position of the marking
Type of marking	Type of marking

POLE-SHAPED OBJECT

Several objects can be described as polar-shaped. This group includes electricity poles, public lights set along the road; in some cases even trees (especially tree trunks). Detection of these phenomena is basing on point clouds in most situations. The basic idea of pole-like object recognition is to identify points which are distributed as a ring in the horizontal direction. A method is proposed which classifies objects in three categories: utility poles, lamp posts and traffic signs. The cloud is divided into horizontal cross-sections, first. Typically, the color of the object is just details that can be derived from RGB images. Nonetheless, first the object itself needs to be identified to detect the object color. Popular RGB images are therefore typically not appropriate for detecting or recognizing pole-shaped objects, and should be used primarily in a pair with point clouds. By comparison, LiDAR data can be used to collect most of the required information. A location of the object is the most commonly used knowledge. It can either be the centroid position, or the trunk base position. However even information such as height of the pole and trunk diameter can be easily extracted from the point cloud that represents the object.

TRAFFIC SIGN DETECTION IMPLEMENTATION

This part of the article explains our process of identification and localization of road signs from point clouds. The whole method of detecting and localizing the road sign is outlined in Fig. 2. The first aspect of the identification of signals is Filtering reflexivity. The road signs are made with special material which is extremely reflexive. For this purpose, the input cloud can be filtered to get only points with a strong reflexive value. The reflexive value depends on the scanner being used and has to be calculated by experiment. The signs in the clouds being measured have a strength scale of 4000 and greater. The strength filtering produces a new cloud which needs to be segmented further. This cloud also includes signs and many other items, such as road parts, vehicle registration plates and more.

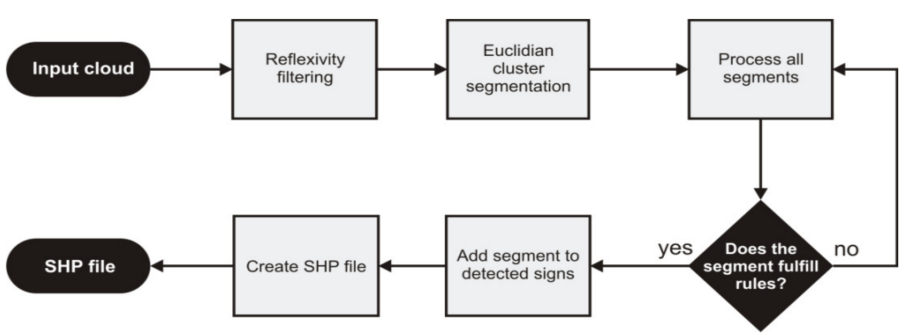

Fig.2: Process of Road Sign Detection and Localization

Segmentation is the second part of the process. Euclidian cluster extraction1 implemented at Point Cloud Library has been used. This segmentation is based on the distance between two points in Euclidia. If the gap is below the threshold, the points are considered to be part of a single segment. The threshold can be set to any value, and depends on the scanner's resolution. The half-meter gap criterion was used. The next step is processing of the pieces. The problem with automatic identification of road signs lies in identifying the rules which each section that contains a sign must fulfill. Three rules have been established to our method:

- The section should have at least 70 points and a maximum of 150 000. This rule is determined by the sensor resolution and is used to screen out very small or large objects.
- The centroid section shall be at least 1.5 m above level. This law does away with temporary signs.
- A total distance of 0.4 m between the lowest and highest point of the line. This value was chosen by national decree according to the range of sign sizes issued. This rule excludes small segments that are normally on facades to be constructed.

If a section complies with all those rules, it will be marked as a road sign. It has stored two features for each recognized symbol. The first one is the position of the sign centroid and the second one is a position of the sign pole base. Those points are finally stored as a common map layer in an ESRI Shape format. Therefore they can be stored digitally in any system of geographical knowledge.

CONCLUSIONS

The approach suggested works properly for single signals. Of the 86 signs it correctly identified 80 signs. That provides a success rate of 93%. Also the percentages of false hit and false miss are very small (both only around 8 percent) and most of them can't be removed just using point clouds. Nevertheless, our system can't distinguish between the individual signs in case of multiple signs on one pole. This ensures that our system is ideal for semi-automatic detection where potential indications are indicated and these specific issues are fixed by the operator. It is necessary to mention that there are situations where the number of failures could be much higher. Many traffic signs are so heavily blurred that they cannot be seen from either the RGB images or the point clouds. These are usually barely visible even by a human observer in such situations.

A LiDAR-based mapping method is employed in this analysis to collect the inventory of roads in an urban environment. The major works include preprocessing data and extracting functionality. The two major steps in the preprocessing of data are co-registration and 3D similarity transformation. Extraction of the feature consists of collection of road points, elimination of road marks, and calculation of artifacts. The automated filtering allows correct collection of ground points. In addition, the digitized road marks may be incorporated for further processing with another GIS sheet.

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