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Automated parking surveys from a LIDAR equipped vehicle

Douglas A. Thornton [a,b], Keith Redmill [b], Benjamin Coifman [b,c,*]

[a] Battelle Memorial Institute, 505 King Avenue, Columbus, OH 43201, USA
[b] Electrical and Computer Engineering, The Ohio State University, 2015 Neil Ave., Columbus, OH 43210, USA
[c] Civil, Environmental and Geodetic Engineering, The Ohio State University, 2070 Neil Ave., Columbus, OH 43210, USA

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ABSTRACT

Parking surveys provide quantitative data describing the spatial and temporal utilization of parking spaces within an area of interest. These surveys are important tools for parking supply management and infrastructure planning. Parking studies have typically been performed by tabulating observations by hand, limiting temporal resolution due to high labor cost. This paper investigates the possibility of automating the data gathering and information extraction in a proof of concept study using a two-dimensional scanning Light Detection and Ranging (LIDAR) sensor mounted on a vehicle, though the work is compatible with other ranging sensors, e.g., stereo vision. This study examines parallel parking in the opposing direction of travel. The ranging measurements are processed to estimate the location of the curb and the presence of objects in the road. Occlusion and location reasoning are then applied to determine which of the objects are vehicles, and whether a given vehicle is parked or is in the traffic-stream. The occupancy of the parking area, vehicle size, and vehicle-to-vehicle gaps are then measured. The algorithm was applied to an area with unmarked, on-street parking near a large university campus. Vehicle counts from 29 trips over 4 years were compared against concurrent ground truth with favorable results. The approach can also be applied to monitor parking in the direction of travel, eliminating the possibility of occlusions and simplifying the processing.

1. Introduction

A review of 11 international cities estimated that cruising for open parking spaces accounts for 30% of the total vehicular volume, causing significant congestion in central business districts and elsewhere (Shoup, 2006). Parking surfaces account for up to 40% of a typical city's land area, dramatically affecting efficient land usage (Childs, 1999). Parking consumes a considerable amount of resources while contributing to the environmental costs of passenger vehicle use. Meanwhile the topic of parking "has received comparatively little study upon which to ground our development of policies for the future," and, "[w]e do not understand nearly enough about how individuals respond to parking policy interventions nor how these responses interact with local circumstances" (Marsden, 2006). De Cerreño (2004) found that "many cities lack basic information about their parking resources." A primary contributor underlying the scarcity of knowledge about parking, and on-street parking in particular, is the effort required to obtain the requisite data through traditional, labor-intensive parking surveys.

Parking surveys, such as those applied in Deakin et al. (2004), Guo et al. (2013), and Marshall et al. (2008), are used for obtaining quantitative data to describe the usage of parking surfaces over temporal and spatial regions of interest. These surveys provide valuable information, revealing the parking needs, habits, and trends of motorists. Using this knowledge,

* Corresponding author at: Civil, Environmental and Geodetic Engineering, The Ohio State University, 2070 Neil Ave., Hitchcock Hall 470, Columbus, OH 43210, USA. Tel.: +1 614 292 4282.

E-mail addresses: thorntond@battelle.org (D.A. Thornton), redmill@ece.osu.edu (K. Redmill), coifman.1@osu.edu (B. Coifman).

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planners can adjust current parking policies and shape future parking infrastructure to better match demand or encourage alternative transportation modes. Researchers can develop better models to set more effective guidelines (a need demonstrated by Marsden (2006)), forecast future demands, and predict individual responses to policy changes. Over-utilized areas can be addressed to properly price parking and reduce occupancy as proposed by Vickrey (1954) and analyzed in practice in by Pierce and Shoup (2013). These methods increase public satisfaction and reduce the environmental costs of drivers searching for parking spots. Further, if the data are collected and disseminated in real time, travelers looking for parking could utilize the information (e.g., Mathur et al., 2010).

On-street parking does not lend itself to easy assessment due to the vast spatial and temporal regions of interest. The conventional methodology for performing a parking survey of on-street parking is to either walk or drive through the area of interest, manually tallying the number of parked vehicles. This method is labor intensive, and typically only provides coarse measures, such as percent occupancy in a given area. Data collection costs increase greatly with the temporal resolution required. According to the Institute of Transportation Engineers (2011), estimating peak parking accumulation for some land uses, "may require spot counts at specified intervals such as every one-quarter, one-half, one, or two-hour intervals throughout the day or portions of the day in order to assure accurate data." Furthermore, "[t]he parking survey should also be sensitive to the fact that land uses may exhibit different parking trends from day to day." Conventional parking studies are poorly suited to these needs due to the significant labor requirement.

Finer detailed information can be provided by more sophisticated survey techniques such as recording license plate numbers to track turnover and parked duration per vehicle (Gray et al., 2008; Federal Highway Administration, 2007). Several cities are starting to deploy sensors to monitor individual metered parking spots (e.g., as discussed in Pierce and Shoup (2013)). Another method employs stationary cameras observing the parking area (Alessandrelli et al., 2012; Chen et al., 2010;). Such detail comes at increased cost, limiting these studies to high-impact areas.

This paper investigates using a Light Detection and Ranging (LIDAR) sensor mounted on a vehicle in a proof of concept study to automate the conventional parking survey data collection for parallel parking areas along arterial streets. LIDAR uses laser-based ranging to measure the distance from the sensor to nearby objects, providing a precise *point cloud* of the surrounding environment at high frequency. LIDAR is seeing rapid adoption within the transportation field in areas such as the creation of accurate digital maps and the automation of bridge and pavement inspection (Olsen, 2013). The proposed algorithm uses the point cloud to find and spatially locate vehicles parked on-street. Once the vehicles are found, we also measure their height and length. While unmarked on-street parking is studied herein, the methodology could be extended to marked on-street parking or off-street parking such as parking garages, similar to the method presented in Wanayuth et al. (2012).

This automated vehicle presence detection promises to greatly reduce the labor of parking surveys by eliminating the human in the loop to count vehicles while simultaneously providing measures that were formerly cost prohibitive, and potentially do so in real time. By using vehicle height and length measures, turnover can be tracked anonymously, providing for the estimation of the majority of parking characteristics as defined by Lautso (1981), e.g., momentary accumulation, average accumulation, and intensity of arrivals and departures; greatly aiding in the development of parking models. With measures such as these available the various costs of the parking search problem can be reduced, e.g., as in Kokolaki et al. (2011). Techniques for programmatically determining open parking spots can be employed (e.g., Coric and Gruteser, 2013), allowing practitioners to inventory the available parking resources.

For our system the host vehicle carrying the LIDAR sensor could be a transit bus or another municipal vehicle performing ordinary duties on defined or undefined routes, further reducing the data collection costs by eliminating the need for a dedicated driver or vehicle. The cost of a sensing system could be well below $10,000 per unit, whereas instrumenting a limited access facility using traditional fixed sensors costs approximately $60,000 (Rodier and Shaheen, 2010), while the cost to conduct a conventional on-street parking survey is dictated by the man–hours necessary to observe and reduce the data.

This research develops an algorithm using real world data from an area with unmarked, on-street parking near a large university campus. This study uses an instrumented probe vehicle to examine parallel parking in the opposing direction of travel. The LIDAR returns were processed to estimate the location of the curb, find the presence of objects in the road (i.e., on the near side of the curb) and to discern which of these objects are parked vehicles. The occupancy of the parking area, individual vehicle sizes, and vehicle-to-vehicle gaps are then measured. Note that the basic approach developed herein should be compatible with many other parking configurations, e.g., surface lots, and many other ranging sensors, e.g., stereo vision (Ohashi et al., 1997), radar (Schmid et al., 2011), or emerging Around View Monitor (AVM) systems, (Suhr and Jung, in press).

The remainder of the paper is organized as follows. First, the background of the proof of concept study is given, followed by a description of the location of the study. Next, a three-stage process for taking the raw data and converting it to meaningful measures of parking is introduced. Then, results from 29 tours through the study corridor are presented. Finally, the paper closes with conclusions and a discussion of future work.

2. Proof of concept study

2.1. Overview

This work develops an automated process to measure on-street parking utilization using a host vehicle's position via GPS, and ranging sensors to monitor the nearby vehicles. While ultimately it is envisioned that the ranging sensors could be