Developing a Portable Data Acquisition System to Study Road User Behavior

Small Project Proposal

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Abstract

Data on driver behavior under various circumstances is essential both for understanding traffic and for quantifying traffic safety. Traditional approaches of data collection (such as using driving simulators and video-graphic method) possess various drawbacks. Therefore, innovative ways of data collection need to be explored to gather continuous data of vehicle interactions with the driving environment. Recent advances in technology make instrumented vehicles (IV) affordable and. In such an experimental setup, a portable data acquisition system (PDAQS) is equipped with various sensors, including LiDAR, to capture driver behavior when driving the vehicle as naturally as possible. A PDAQS helps to observe instantaneous vehicle information and driver behavior accurately for longer road sections and durations. Also, such a PDAQS can be used as a probe unit to capture the drivers' driving behavior around the IV. The data that can be obtained accurately at high frequency include changes in headways and speeds and interactions among various road users on the road. Based on preliminary research findings, a PADQS can also capture high-quality data of non-motorized road user behaviors. It is proposed to develop a PDAQS setup and to conduct studies related to understanding road user interactions. Since the installation is portable, the same structure can be moved across different vehicles and locations (such as urban, rural, and different states.) to capture driving and environment data for various conditions. The tasks include developing the hardware, developing software programs to extract useful data, and carrying out a project to study motorists' behavior in extreme weather. The PDAQS will facilitate collecting valuable data that will help address both safety and mobility issues more efficiently in regions, such as rural regions within the Pacific Northwest, where a greater understanding of driver behavior lack.

Research type (applied research vs advanced research): Applied and advanced research

Introduction

Capturing detailed road user behavior is critical in planning and designing a safe transportation infrastructure. Traditionally, transportation researchers use data from sensors such as loop detectors, video detectors, Bluetooth sensors, and radar sensors to gather and analyze macroscopic traffic data. Probe vehicles are also used to capture macroscopic data on traffic streams such as speed, flow, and density. For microscopic data, researchers rely mainly on video data and speed guns. With the improvements in image processing, video data can be used for various applications, including capturing properties of the stream and individual vehicles. However, its inability to measure distances effectively is a significant drawback for different transportation application that requires micro-level vehicle-by-vehicle trajectories. At the same time, since video cameras are stationary, one can only observe the traffic within its vicinity.

One way to address these limitations by using a portable data acquisition system (PDAQS), assembled on a vehicle. Unlike roadside sensors, such a system provides flexibility in data collection because it can be moved as required. With the fast development of sensor technologies, most of the drawbacks of video data can be addressed to an extent with the use of portable sensor units. Sensors such as Light Detection and Ranging (LiDAR) can obtain high-resolution traffic data in real-time. LiDAR sensors can scan 360° three-dimensional surrounding objects and collect coordinates of each object in its scanned range at a high frequency with accuracy sufficient for CAV applications. Since LiDAR collects data at a high rate (typically in the range of 10 to 20 Hz), the coordinates can be processed to extract trajectory and estimate speeds of vehicles and other objects.

Objectives

The main objective of this proposal is to develop a portable data acquisition system (PDAQS) that can capture trajectories of various road users with high accuracy.

Details of Proposed Sensors

The PDAQS include various sensors. Although there are several sensors available, a few of them are selected based on prior experience and intended application. The critical sensors include LiDAR, video cameras, an OBD sensor, and a GPS unit. Some other sensors may be added to the list if required. Each of these sensors is briefly discussed in this section.

1) **LiDAR:** LiDAR: Since the purpose of the instrumentation is to capture the driving environment, the most important sensor is LiDAR. LiDAR has increasingly been used in CAV applications. The sensor emits laser beams and measures the time it takes for the reflected laser beams to be detected by the sensor. This information is used to compute distances to objects. The main advantage of the LiDAR sensor is that it generates a 360¬∞ field of view and reports the location of objects within its range. UltraPuck, a commercially available LiDAR from a market leading manufacturer Velodyne, will be procured. This sensor generates a 3-D picture of the surrounding environment using 32 laser beams mounted in a compact housing. It provides relative positions of the objects with respect to the LiDAR. The range of this LiDAR sensor in the horizontal plane is 200 meters, and the vertical field of view is 40 degrees. The frequency of data collection of is 5 to 20 Hz.
2) **Video cameras:** Video cameras: Although LiDAR captures the surroundings using point clouds, the shape of point clouds of the object may vary depending on the relative location of those from the LiDAR and the angle they make with the LiDAR. This could pose severe challenges in efficient detection. Video cameras can help avoid some of these challenges. Also, as some other studies showed, a fusion technique using the video and LiDAR images may help efficiently detect objects.
3) **GPS:** Since LiDAR and video cameras capture data from the surroundings, the data are all relative to the LiDAR. The exact location of the instrumented vehicle must be determined to estimate actual positions of objects captured. A GPS unit can help to achieve the location information of the vehicle carrying the LiDAR. GPS coordinates can also be used to estimate the speed of the instrumented vehicle, which is vital in determining the speed of other vehicles within the visibility of the instrumented vehicle.
4) **OBD sensors:** Onboard diagnostics (OBD) sensors capture various vehicle properties. In this case, they are used to extract the speed of the instrumented vehicle. It is important to note that the speed of various objects estimated using LiDAR data shows the relative speed to the instrumented vehicle. Therefore, to calculate the actual speeds of the objects, the speed of the instrumented vehicle needs to be accurately determined. GPS can also be used to determine speeds. However, as the location data provided by the GPS have associated errors, the estimates of speeds could amplify these errors. Besides, bad weather conditions, dense surroundings, and forested areas can limit the use of GPS further because, in such conditions, satellites fail to provide accurate location information.

In addition, a data synchronizer, a laptop computer, and a power source (battery) is also required.

Proposed Methodology

The development of PDAQS involves two steps: setting up the hardware and developing software programs to extract useful data.

As the first step, the sensors need to be put together to develop the hardware setup of the PDAQS. Since the installation will be used on the field to collect data, these sensors need to be fixed to a frame, which can be attached to the roof of a passenger vehicle. Figure 1 shows one such setup. Figure 1b shows how the two major sensors, the LiDAR, and video cameras, are attached to the frame. The other sensors, such as GPS and OBD sensors may not require any particular setup as they can be placed inside the vehicle. All these sensors need the power to operate. A battery and power distributor will be used to serve this purpose. Finally, a laptop computer and (or a data integrator) will be used to collect all the data on the same timestamp for efficient post-processing. This step will be completed prior to the start of the project the funding for this project will be used for the second step, that is discussed as follows.

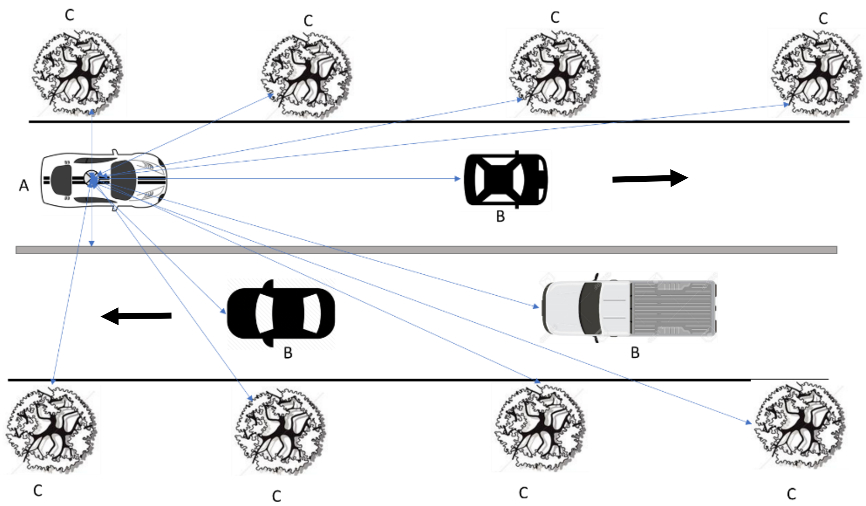
1a. Instrumented vehicle

1b. LiDAR and video camera set-up

Figure 1. An example of hardware set-up of the PDAQS

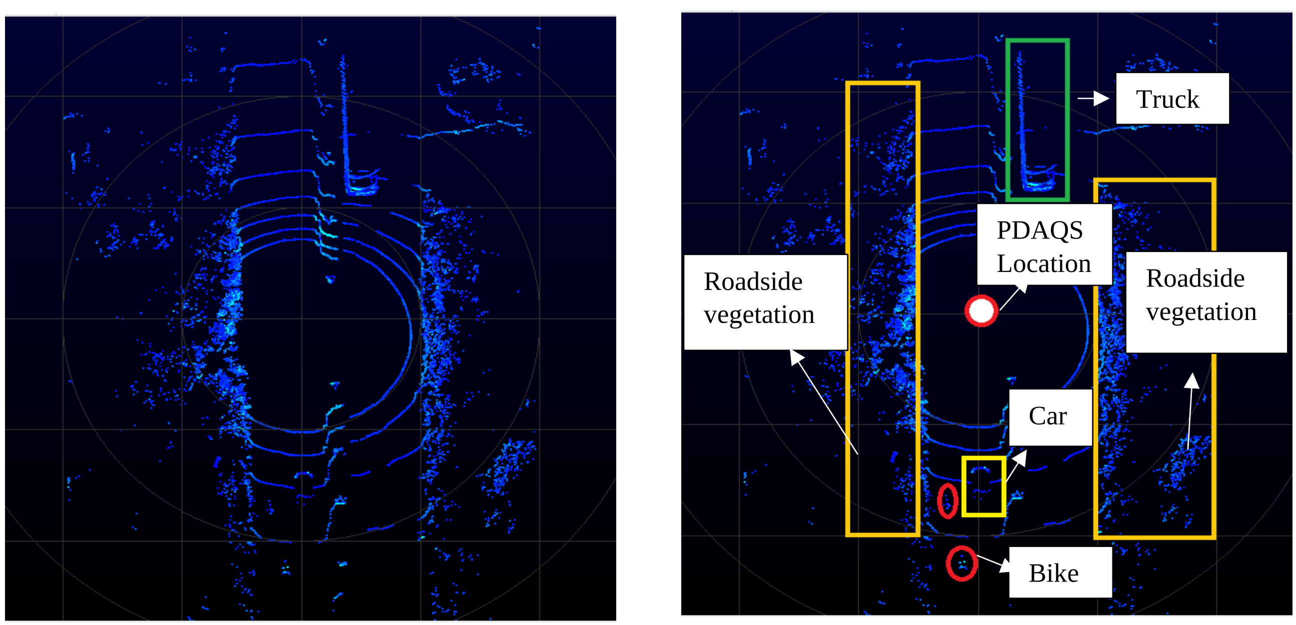
The second step in developing software programs to extract useful data. Figure 2 shows an illustrative diagram of an instrumented vehicle equipped with a PDAQS on a divided road, capturing data on objects such as other vehicles, roadside infrastructure, vegetation, and the median. For illustration purposes, this figure shows the objects' detection in front of the instrumented vehicle, although the instruments can capture objects 360° around the vehicle. As it shows, the relative coordinates of the other objects detected by the instrumented vehicle can be extracted using the sensors. Using the relative position coordinates, the trajectory of these objects can be traced. The relative speeds of the object to the instrumented vehicle can be estimated once the path is traced. It is worth mentioning that not all the objects detected by the instrumented vehicle may be of equal significance for transportation application. Figure 3 shows the point clouds as captured by LiDAR. While the details and locations of the roadside vegetation, roadside infrastructure, and other static objects may be necessary for transportation applications, these data could be collected in advance and used. This would mean that the accurate extraction of useful data related to dynamic objects, such as various users of the roads, including pedestrians, is more critical for the PDAQS. The extraction of these valuable data is a challenging process. This can be divided into two steps: object detection and object tracking. Each of these is discussed as follows.

Object detection: The next step is to detect objects from the filtered data. Since the shape of the point cloud is a function of the distance of it from the LiDAR, it is a challenging task. One way to carry out this process is by using some of the clustering algorithms.



A: Instrumented vehicle with PAQS, B: Other vehicles, C: Roadside vegetation (or pedestrians).

Figure 2. Schematic diagram of a divided road with vehicles and roadside vegetation



a. 3-D LiDAR image for a time frame

b. Different objects near the IV in the scan

Figure 3. A sample LiDAR scan image

Object tracking: One major issue with the LiDAR data is that, unlike GPS data, the point clouds do not have any unique identity. This means that even after detecting objects across various time frames, one cannot track them across various frames. While there are a few options available to track objects, the most appropriate process needs to be identified.

The PIs will identify the most efficient methods to detect and track objects. This will be one of the major outcomes of the project. Once software programs are available to detect and track objects, the PDAQS can be used to study the complex behavior of road users, which were not possible with the traditional data.

End Product

The primary end product will be an efficient PDAQS system capable of collecting detailed vehicle trajectories.