Enabling Large-Scale Road Data Acquisition with an Easy-to-Install and Sustainable Setup

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ABSTRACT

In this paper, we propose an easy-to-install and sustainable setup for BigRoad, a system that supports driving and road data acquisition using COTS devices such as smartphones and IMUs. The in-vehicle setup includes energy harvesting modules and a low power motion-based switch to keep the system running for a sufficiently long time without human operations. The device calibration mechanism makes the system independent of vehicle models, steering wheel positions and IMU placements. The system could further leverage infrastructures in the vehicle to design an energy-efficient method for unusual events detection.

Keywords

Self-Driving; In-Vehicle Setup; Unusual Events Detection

1. INTRODUCTION

Automated vehicles offer an unprecedented opportunity to transform the safety, efficiency, and comfort of road travel. While resulting in a number of prototypes with impressive performance, it is widely recognized that ensuring dependability under varied traffic conditions remains a key challenge [1, 2, 3]. Such self-driving vehicles have to operate safely under not just common highway and city traffic situations but also unusual or rare traffic events that might be encountered within billions of miles of driving [4].

Most existing efforts to collect driving data build on a small fleet of highly instrumented vehicles that are continuously operated with test drivers [2, 5, 6]. However, the data collected by such vehicles are restricted by the limited amount of vehicles. As far as we know, Google's fleet has completed about 2 million testing miles [2]. Since many existing efforts to develop automated driving technology are proprietary, the data obtained is usually closely guarded. It is not easy for individuals outside vehicle industry to collect driving inputs such as steering wheel angle and pedal operations. Comma.ai's project OpenPilot [7] reverse engineringed the OBD-II data from two vehicle models of Honda, and uses the collected data to train CNN based Adaptive Cruise Control (ACC) and Lane Keeping Assist System (LKAS). However, this solution can only be deployed in specific vehicle models, which makes it harder to recruit very large numbers of vehicles.

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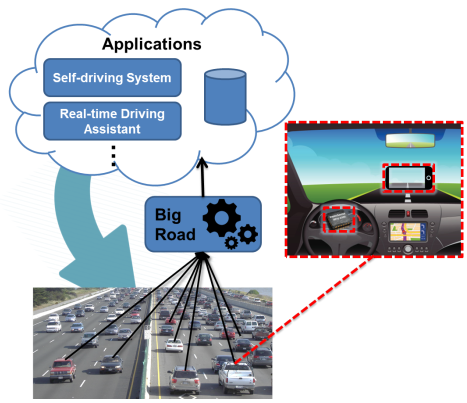

Figure 1: Illustration of BigRoad containing a smartphone and an IMU: scaling road data acquisition.

To address this challenge, we developed BigRoad [4], a system enables large-scale fine-grained driving data acquisition that can support developing dependable automated driving and traffic safety technologies, using very few off-the-shelf sensing devices (i.e., a smartphone and an IMU[1] in a vehicle. As shown in Figure 1, this approach would enable scaling by capturing events from tens of thousands of vehicles rather than only attempting to collect data with a few highly instrumented vehicles or certain vehicle models, as is common practice. However, several technical challenges exist in the BigRoad system. First, a practical setup is required to make it easy to install and keep the system running for a sufficiently long time without human operations. Second, the system needs to identify interesting and unusual events, which is useful to develop dependable self-driving systems. In this paper, we propose several potential techniques to solve these challenges.

2. SENSING DRIVING AND ROAD DATA

In our previous work, we proposed BigRoad [4], a system leverages various sensing technology in smartphones and IMUs to provide fine-grained measurements and experimental ground truth in the context of real driving. The infor-

[1]Inertial measurement unit (IMU) contains accelerometers, gyroscopes and magnetometers.

mation generated by BigRoad is two-fold: 1) Internal Driver Input including *Steering Wheel Angle Estimation* and *Driving Speed and Acceleration Estimation* fuse GPS location and calibrated sensing measurements from inertial sensors to derive steering wheel angles, vehicle speeds, and accelerations. 2) External Perception including *Road Condition Estimation* and *Time-stamped Video Capture* utilize video camera and inertial sensors to capture critical information in driving environment (i.e., traffics, road conditions, etc.). We evaluate the accuracy of collected data using over 140 real-driving trips in a 3-month time period. The results show that the system can generate steering wheel angle with 0.69°median error, driving speed with 0.65km/h deviation, and determine binary road conditions with 95% accuracy. We further develop train an automatic steering angle predictor to demonstrate that data from such light-weight sensors can be used without significant performance degradation.

3. EASY-TO-INSTALL AND SUSTAINABLE SETUP

In order to achieve large-scale driving and road data collection, the BigRoad system needs an easy-to-install and sustainable setup. In particular, the system should be compatible with most vehicle models, have little installation overhead, and be able to run in the vehicle for a long time without human operations. Towards this goal, we proposed a *Device Calibration* module in the previous work [4] to make the system disregard vehicle models, steering wheel positions and IMU placements. In the future, we plan to further include energy harvesting modules and wake-up units to the BigRoad system using COTS mobile devices.

Energy Harvesting in Vehicle. Different from the smartphone that can be charged with a wire connected to the power supply of the vehicle, the IMU is mounted on the rotating part of the steering wheel, which makes it extremely hard to charge with a traditional wire connection. In the future, we plan to design a setup in the vehicle to harvest energy from the surrounding power source, such as solar light, RF signal or vehicle vibration [8]. This module will provide the whole setup with longer lifetime while decreasing the maintenance needs.

Low Power Motion-based Switch. We plan to attach a motion-based switch to the IMU device to manage its duty cycle. According to a study done by the Harvard Health Watch [9], an average American spends 101 minutes per day driving, which is only a small proportion of the whole day. If the IMU runs only when driving, the energy consumption will decrease significantly. Compared to a commercial tire pressure monitoring sensor, which uses an accelerometer to trigger the IMU, we plan to use cheap and nano-power (as little as 50 nA) tilt sensors [10] to switch the IMU on and off. With a timer, the IMU can enter sleep mode when steering motion is not detected for a while, and wake up when motion is detected. The threshold of this sensor can be adjusted by the capacitors connected to the tilt sensor. This task could be used to periodically stop sensor reading and radio transmitting, and significantly reduce the energy consumption of the IMU without any human operations.

4. UNUSUAL EVENTS DETECTION

Unusual events stand for those dangerous cases (e.g., objects on the roadway, pedestrians crossing a highway, a deer standing next to the road, etc.) which are hard to handle by the current self-driving vehicles. Compared to the common situations, such an unusual event is extremely rare, but can provide significant feedback for self-driving algorithm development. Detecting unusual events not only provides the collected data another layer of information, but also largely reduces the bandwidth needs of our system by selectively uploading useful data. Towards this goal, we further propose an unusual events detection method leverage the BigRoad setup to efficiently identify potential interesting and unusual events. As we know, the dangerous events on the road usually involve hard braking or sudden steering. Thus, we could first change the threshold of the tilt sensor to wake the IMU up only when large motion is detected, which can cut down the energy consumption on collecting data when driving straight with constant speed. Second, the smartphone analyzes the fine-grained road data with driving behavior models (e.g., hard braking detection, sudden steering detection) or image processing techniques (e.g., object detection), and uploads the data to the cloud only when interesting events are detected.

5. CONCLUSION

In this paper, we discuss several technical approaches to improve our BigRoad system. An easy-to-install and sustainable setup is designed to make the system compatible with different vehicles and keep the system running for a sufficiently long time without human operations. We further discuss the need for an unusual events detection method that takes advantage of the setup to collect interesting and useful driving events while cutting down the energy consumption and bandwidth requirements of our system.

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