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A smartphone based technique to monitor driving behavior using DTW and crowdsensing

Gurdit Singh *, Divya Bansal, Sanjeev Sofat

Department of CSE, PEC University of Technology, Chandigarh, India

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ABSTRACT

Safety issues while driving in smart cities are considered to be top-notch priority in contrast to traveling. Today's fast paced society, often leads to accidents. In order to reduce the road accidents, one key area of research is monitoring the driving behavior of drivers. Understanding the driver behavior is an essential component in Intelligent Driver Assistance Systems. One of potential cause of traffic fatalities is aggressive driving behavior. However, drivers are not fully aware of their aggressive actions. So, in order to increase awareness and to promote driver safety, a novel system has been proposed. In this work, we focus on DTW based event detection technique, which have not been researched in motion sensors based time series data to a great extent. Our motivation is to improve the classification accuracy to detect sudden braking and aggressive driving behaviors using sensory data collected from smartphone. A very significant feature of DTW is to be able to automatically cope with time deformations and different speeds associated with time-dependent data which makes it suitable for our chosen application where data might get affected due to factors such as: high variability in road and vehicle conditions, heterogeneous smartphone sensors, etc. Our technique is novel as it uses fusion of sensors to enhance detection accuracy. The experimental results show that proposed algorithm outperforms the existing machine learning and threshold-based techniques with 100% detection rate of braking events and 97% & 86.67% detection rate of normal left & right turns and aggressive left & right turns respectively.

1. Introduction

Transportation from one place to another following the shortest possible route and time has always been the necessity [1]. Therefore, the safety issues during traveling are often ignored [2]. This leads to accidents due to aggressive driving behaviors such as sudden lane change, overtaking and sudden braking. It has been researched that by monitoring the driver's driving behavior, the probability of dangerous or aggressive driving can be reduced [3]. There are some commercial products [4–6] available which can be mounted in-vehicle, and are equipped with various sensors like GPS, camera, accelerometer and so on and used for purposes such as tracking the taxi [7,8] routes and detecting driving behavior.

In ITS [9], the information related to the sensors is collected and sent to the central server for analysis. The information is further analyzed to find certain parameters like collisions, braking, congestion or traffic on the road and so on. Condition of vehicles and condition of roads are some of the other additional factors which can affect the driving behavior. Accidents due to road conditions have also been reported in the recent past [10,11]. Hence, aggressive driving behavior can be distinguished

* Corresponding author.
E-mail addresses: gurditsinghpec@gmail.com (G. Singh), divya@pec.edu.in (D. Bansal), sanjeevsofat@pec.ac.in (S. Sofat).

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from normal driving events, which occur while driving. Thus, it becomes imperative to detect these harsh events while driving and classify the aggressive behavior of a driver.

Nowadays high-end cars already have these sensors and warning systems in-built in a vehicle to assess the driving behavior [12]. In low end vehicles, driving monitoring systems can be embedded in-vehicle to record the driving behavior. These systems are usually not removable and hence cannot be used in other vehicles. In this paper, we investigate the use of smartphones as an alternative solution to embedded driving monitoring systems, as smartphones are easily available with all drivers. Smartphones are equipped with various multi-sensors on-board, through which data can be recorded. The recorded data can be analyzed to detect the driving behavior of the driver and can be classified them into aggressive and non-aggressive driving behaviors.

There are certain applications which can be installed on the smartphones to enable the use of in-built sensors such as accelerometer, gyroscope, magnetometer, GPS and so on [13]. The data from these sensors can be used to detect the human activity performed [14,15]. Accelerometer sensor is widely used for longitudinal and lateral movements while GPS provides the location of the phone in terms of latitude and longitude. In the recent past, many researchers had used smartphone as a data collection tool for analyzing the driving behavior and road conditions [16,17] [18,19]. The smartphone can be mounted at a fixed position inside the vehicle to detect the driving events such as sudden acceleration, harsh braking, sudden left, right turns and so on. In this paper, we only focus on detecting braking events and lateral maneuvers experienced by the vehicle using accelerometer, gyroscope, GPS and gravity sensor of the smartphone using DTW (Dynamic Time Warping) algorithm.

Dynamic Time Warping (DTW) is an algorithm for comparing two given (time-dependent) sequences which may vary in speed, which has historically been applied to temporal sequences of video, audio, and graphics data, indeed any data which can be turned into a linear sequence can be analyzed with DTW. DTW has been used in well known application like automatic speech recognition, to cope with different speaking speeds [20]. Other applications include speaker recognition and on-line signature recognition [21,22]. DTW computes similarities between two sequences of time series data and returns a distance value. The lower this value, the better the match, and a distance of zero means the sequences are identical. In order to classify an unknown time series sequence, it is compared with a number of different known template sequences. The above two steps give a value representing the similarity between one sample dataset and one template (training) dataset. Then these steps are compared for all of the sample/template data pairs. The pair that has the smallest "path sum value" indicates the detected event.

DTW has also been used in finding similarities in human walking patterns that is doing gait analysis [23], if one person was walking faster than the other, or if there were accelerations and decelerations during the course of an observation, DTW still able to detect similarity between the patterns.

1.1. The problem

This paper focuses on the problem of analyzing driving behavior by detecting braking events and lateral maneuvers using efficient and low cost techniques. In recent past, the detection of driving behavior was done by detecting the events like sudden right turn, sudden left turn, sudden accelerate, sudden brake, U-turn and sudden U-turn etc. Many researchers have proposed different techniques for the detecting these events but most of them are based on fixed threshold values and machine learning techniques. The threshold values are dependent on type and condition of the vehicle, sensitivity of the sensor, and cannot accurately distinguish between an event and non-event caused by other factors thereby reducing accuracies when the same threshold values are used in different conditions. On the other hand, machine learning based techniques require intensive and continuous training to detect the events and hence do not work efficiently for such like applications. Our proposed technique does not use any specific equipment other than smartphones of the commuters to determine the reckless driving behavior.

1.2. Our contribution

The main contribution of this paper is as follows:

1. Accelerometer, gyroscope, gravity sensor and GPS based sensory data has been collected by commuting on the roads of Chandigarh city. The data has been analyzed and patterns of events such as braking and lateral maneuvers have been extracted by conducting an empirical study.
2. DTW technique has been used to match patterns and find the similarity between different patterns. Instead of using fixed threshold based values, DTW method has been used to overcome the limitations of existing techniques (further explained in Appendix).
3. Filters has been applied on the raw accelerometer data to eliminate various noises such as vibrations of car and gravity component which got added in the accelerometer readings.
4. Fusion of sensors like gyroscope and gravity sensor has been done to acquire angular velocity w.r.t. direction.
5. A technique has been proposed to detect and identify the driving behavior event using sensory abilities of the smartphones. This information can be useful for school authorities and to commuters especially for senior citizens, patients and expecting women.