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Analyzing Driver Behavior using Smartphone Sensors: A Survey

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Abstract

In today's life, everyone is in hurry to reach their destination as quickly as possible. So people intentionally or unintentionally take harsh driving events such as sudden acceleration, sudden turns or sudden brakes which further lead them to accidents or even loss of their lives. And it is a common belief that if a person behavior is being monitored, it would be relatively safer. To monitor driver behavior various sensors are being used either deployed inside the car, roadside or inbuilt in Smartphone. This paper provides a survey of various methods for analyzing driver behavior appeared in literature survey. This paper also provide some research directions which various researchers can explore.

Keywords: Smartphone, accelerometer, gyroscope, sensors, braking, turns, threshold, machine learning

Introduction

India is the world's largest democratic country. In the last 50 years, India's automobile population has grown 170 times while the road infrastructure has expanded only nine times. The country's vehicle population is over 5.5 crore and growing at a rate of 5 lakh/per year [1]. Travelling in India by roads is considered dangerous as the traffic is chaotic, people drive fast, recklessly without obeying the traffic rules, cross speed limits and overtake others without signaling, drive dangerously, honk horns often. So with the advancement of transport system in past few years, driving in developing countries is becoming dangerous and difficult, so there is a need to monitor driver behavior and it is a common belief that driver behavior is relatively safer when it is being monitored [14][15] or feedback of their events is given or records of their aggressive driving events are recorded for their safety or insurance benefit.

In the literature various methods are being used to monitor driver behavior using both dedicated sensors deployed inside car, roadside or smartphone inbuilt sensors. Smartphone based approach for detecting driver behavior is considered good as smartphone is less expensive than specialized traffic monitoring infrastructure and also considering the fact that many people already own it.

This paper is organized as follows, section 1 describes brief overview of Smartphone sensors currently being used in analyzing driver behavior, section 2 discusses survey of driver behavior detection techniques, section 3 contains challenges and research gaps and section 4 provides the conclusion.

I. Smart Phone Sensors

This section describes the brief description of various types of sensors present in Smartphone which are currently being used in analyzing driver behavior.

a. **Accelerometer** An accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static (z axis), like the constant force of gravity pulling at your feet, or they could be dynamic (x, y axis) caused by moving or vibrating the accelerometer [2]. An accelerometer is a sensor which measures the tilting motion and orientation of a mobile phone. Instead, the accelerometer sees the acceleration associated with the phenomenon of weight experienced by any test mass at rest in the frame of reference of the accelerometer device. For example, an accelerometer on the surface of the earth will be at rest so measures an acceleration force of g= 9.81 m/s2 straight upwards, because of its weight. By contrast, accelerometers in free fall or at rest in outer space will measure zero [3]. We can also say accelerometer measure g-force acceleration. Its unit is m/s2.

b. **Gyroscope** Gyroscope detects the current orientation of the device, or changes in the orientation of the device. Orientation can be computed from the angular rate that is detected by the gyroscope. It basically works on the principle of angular momentum [4]. It is expressed in rad/s on 3 axis.

c. **Magnetometer** Magnetometers are measurement instruments used for two general purposes-to measure the magnetization of a magnetic material like a ferromagnet, or to measure the magnetic strength and the direction of the magnetic field at a point in space [5]. It senses orientation relative to the Earth's magnetic field using the Hall Effect.

d. **Global Positioning System (GPS)** GPS is a satellite based Navigation tracking [16], often with a map showing where you have been. It give us the value of longitude and latitude which determines the point of location on earth.

e. **Camera** Camera is a device used to capture images. In smartphone, camera can be both used to capture images and video chat. In detecting various human behavior camera plays a vital role as it captures the live image of a human.

f. **Microphone** Microphone is a device used to detect the sound. The various patterns of sound are collected for research purpose and trained. e.g, from the frequency of sound, it can be determined whether sound pattern is of horn or indicator.

II. METHODS FOR DETECTING DRIVER BEHAVIOR

Various researchers have tried to monitor driver behavior using both dedicated sensors deployed inside car, roadside and smartphone inbuilt sensors.

In [6] P. Singh et al. developed an android based application, This application collects data from accelerometers, GPS and also record sounds with the help of microphone, and then data is combined and analyzed to detect rash driving patterns. The various pattern such as speed breaker, lane-change left/right, left/right turn, sudden breaking, sudden acceleration were analyzed and verified using ‘Ground Truth’. Correlation of audio and accelerometer data is done to find new patterns. For Example: if a lane change is not accompanied with indicator sound, then this mean rash driving event. The limitation of this work is that machine learning techniques are not used to classify driving patterns.

In [7], Fazeen et al. have proposed a innovative application using a mobile smartphone that are integrated inside an automobile to evaluate driver style. They have used the three-axis accelerometer of an Android-based smartphone to record and analyze various driver behaviors and external road conditions that could potentially be hazardous to the health of the driver. They have utilized x-axis and y-axis accelerometer data to measure the driver’s direct control of the vehicle as they steer, accelerate, and apply the brakes. Safe acceleration or deceleration never reach a g-force of more than±0.3 g, and sudden acceleration or deceleration approach ±0.5 g. With this comparison, it is easy to quantify the difference between safe and sudden acceleration or deceleration. Safe right/left-lane produce an average g-force of less than ±0.1 g and unsafe or sudden right/left lane produce a g-force well over±0.5 g. It was observed that the average time to complete a safe lane change was 75% longer than a sudden lane change. Phone placement locations in a vehicle was also observed and the loc. 1, the center console, gave the best relative data with low engine feedback. The drawback of this work is that the best results of prediction driving behavior were found, when phone was placed on a center dashboard, but in car the phone placement is not necessarily at center dashboard, it‘s location can be anywhere, so there should be mechanism for virtually re-orienting the accelerometer.

In [8] Chigurupa et al. developed a android application which uses data from accelerometer sensor, GPS sensor and video recording is done with the help of camera to give rating to the driver. The feedback can be used to aware the driver and improve performance. The range of acceleration or deceleration values are given for the safe driving. Whenever the accelerometer values exceed the safe limits it would be considered as an event. X-axis, direction-front and rear, driving pattern-Accelerating / Braking, Safe g value =-3 to +3. Y axis, direction-Left/right, driving pattern-Turning / Swerves / Lane Change, Safe g value =-3 to +3. Z-axis, direction-Up/down, driving pattern-Bumps / Road Anomalies, Safe g value =-8 to-11. The limitation of this work is that entire system is not fully automatic, so there is the need of administrator to analyze the videos.

In [9] Johnson et al. proposed a approach for predicting driving style. They categorized driving style into normal, aggressive and very aggressive. They collect data from various sensors (accelerometer, gyroscope, magnetometer, GPS, video) and fused related data into a single classifier based on Dynamic Time Warping (DTW) algorithm. Their system is known as MIROAD: A Mobile-Sensor-Platform for Intelligent Recognition Of Aggressive Driving, The system can provide audible feedback if a driver's style becomes aggressive as well as the information leading up to an aggressive event. They used iPhone 4, and detected events like right turns, left turns, u-turns, aggressive right, left, u-turns, aggressive acceleration, braking etc. The drawback of this work is that only aggressive events are detected, standard lane changes (non-aggressive) are not currently being detected, because natural lane change movements do not exert enough force or rotation on the accelerometer to distinguish.

In [10] Dai et al. have proposed a highly efficient system for detection and alert of dangerous vehicle maneuvers (weaving, drifting, swerving, turning with a wide radius, accelerating or decelerating suddenly, braking erratically, driving with tires on center on lane marker, driving without headlights at night) basically related to drunk driving. They implemented the detection system on Android G1 phone. They used accelerometer and orientation sensor. Detection of drunk driving patterns is done through windowing and variation thresholding, Their solution shows 0% false negative rate and 0.49% false positive rate for abnormal curvilinear or lane changing movements and 0% false negative and 2.39% false positive rate for speed control problems. Their system shows tolerable energy consumption, as we know our smartphone works on battery. The limitation of this work is that the set of drunk driving patterns were limited and difficult to distinguish from normal driving patterns such as weaving and lane changing have the similar pattern.

In [11] Zhang et al. proposed a Pattern recognition approach to characterize drivers based on their skill level. Skill level was defined as low, medium, or expert level, or a simple 1-to-10 scale. Using a high-end vehicle simulator, they compare driver behavior such as steering control, lane changes, and traffic levels with an expert driver to help with category resolution. The input values they have taken is DFT coefficient of steering wheel angle and accelerator. They used machine learning and the learning algorithms which includes multilayer perception artificial neural networks (MLP-ANNs), decision tree, and support vector machines (SVMs). The SVM with polynomial kernel shows better performance than both the MLP-ANN and the decision tree.

In [12] Sathyanarayana et al. proposed a Driver Behavior Analysis and Route Recognition by Hidden Markov Models in two different approaches. The first (bottom-to-top) approach takes isolated maneuver recognition with model concatenation to construct a generic route, whereas the second (top-to-bottom). approach models the entire route as a 'phrase' and refines the HMM to discover maneuvers. Only left turn (LT), right turn (RT) and lane change maneuvers are considered.

In [13] Gazali monitored erratic Driving Behavior caused by Vehicle Overtaking using Off the-shelf Technologies. Orientation sensor is used to detect the movement of the vehicle in the left, right and the forward directions. GPS is used for obtaining the location of the vehicle and its speed as it moves and forward this information to application server to obtain real time information of this location. They proposed a technique that identify any overtaking patterns and distinguish them from other patterns through the use of Neural Networks. They present a map matching technique for how to match and confirm these overtaking patterns on an actual road network. The drawback of this work is that the system is fully dependent on GPS sensor, but GPS can't be available everywhere under every condition.

III. Challenges:

Although various researchers have contributed in monitoring driver behavior but there are still some research directions which various researchers can explore.

1. **Environmental Factor-**Environmental factors such as rain, wind need to be taken into account while predicting driver behavior.
2. **Crowd sourcing-**The data from multiple vehicles should be obtained to determine under what conditions driver drives rashly. For example driver apply brakes frequently due to congestion or its own habit.
3. **Road Conditions-**Road conditions must also be considered for accurately determining driving style.
4. **Machine Learning Technique-**Machine learning algorithm should be used to determine driving events instead of simply defining the range or threshold value.
5. **Anonymization-**As most of research papers use GPS sensor for predicting the driver style. But by determining the location, ones privacy is breached. So there must be some technique to anonymize these values.
6. **Sensor fusion**-Data from multiple sensors should be used rather than using a single sensor to detect driver behavior as it will increase the efficiency of the system. As by using accelerometer, magnetometer and gyroscope in conjunction we can get more accurate reading of device orientation.
7. **Virtual Reorientation**-As the phone can be at any location inside the car, so there must be some mechanism to virtually reorient the device to align the device axis along with vehicle axis.

IV. Conclusion

Driver Behavior monitoring has evolved tremendously in recent years. Driver safety can be enhanced by monitoring driver behavior, recording their aggressive driving events and giving feedback of recorded events. Monitoring driver behavior using inbuilt sensors of smartphone has been evolving as a new trend because of less cost and considering the fact that many people already own it. This paper surveys various methods of detecting driver behavior. It also presents the challenges faced by researchers in detecting and predicting driver behavior.

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