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Study of Driver Assistant Services using Ubiquitous Smartphone

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ABSTRACT
Smartphones are increasingly becoming popular. All Smartphones have rich set of sensors, which can be used to provide driver assistant services. Services such as road traffic information and road condition to provide such services, there is need of sensors such as GPS, Gyroscope, Accelerometer. Now day's smartphones are coming with this sensor. Smartphone camera sensor, one of the most powerful and neglected Sensor can be used to analyses traffic scene. In this paper we have provided surveys on different approaches to provide collaborative driver assistant service and analyze road surface disruption.

General Terms
Green Light Optimal Speed Advisor (GLOSA), determining Road surface disruption, Sensor data classification.

Keywords
Mobile sensor, pervasive computing, Intelligent transportation system.

1. INTRODUCTION
Smartphones contains rich set of sensors which can be useful to provide different services to user. Driver assistant services such as Road traffic information, signal information, road surface disruption and more information traffic situation present ahead in driver's path. Today's smartphones contains GPS, Gyroscope and accelerometer sensors which can be used to provide these driver assistant services. The camera sensor is the most important but underutilized while driving. Generally driver mount his smartphone on vehicles windshield to get road advice from GPS at the same time smartphones camera is focusing on road. This camera can grab the content rich information from the scene, information such as traffic information, traffic signal status, parking availability, Bus timings, Taxi service and speed advisories. Human can perceive this information very easily but it is difficult to implement this into smartphone because of its resource constrained environment. Smartphone vision is also blocked most of the time because of its placement in pocket or on table person can use this camera sensor by mounting it on the windshield of the vehicle to grab the content rich information from the scene. Another important part of the survey is to bump detection on road. This part has great significance. Poor roads result into west of fuel, increase in traffic and hazardous result might be accidents. Smartphone's accelerometer sensor assumes 3-axis with respect to itself. That can be used to detect and analyze the bumps and potholes on the road.

In this paper we have done survey on different methods to provide advisories to driver. To provide these services we need to overcome several challenges. [1]Listed some of the challenges to provide driver assistant services.

- Commodity cameras: Smartphone's camera provides lower quality images than any high end camera. The image quality as well as resolution is lower. To apply any computer vision algorithms, system requires large amount of memory resource. Smartphone doesn't provide large amount of memory as compare to desktop environment.
- Limited Processing Power: Pattern recognition task and detection algorithms require processing power. Signal detection involves processing of total image, and algorithm should check multiple frames of video capture by the same camera sensor. Algorithm should output the result in real time.
- False detection: Since camera is detecting red/green round objects chances of misdetection is very high. Also red light at the back of the car may get detected as red traffic signal. [1] Uses these timings of traffic signals and feed support vector machine. Small change in timing may result large change the output and result into wrong prediction. Same way in pothole detection at high speed a very small bump can show large deviation in accelerometer pattern.
- Need for collaboration: Every smartphones view angle is different. To get more detailed and accurate information all smartphone's information must be collaborate. Different vehicles may show different numbers of potholes on same road, so to give better prediction collaboration is needed.

2. MOTIVATION
Poor condition of roads, cross train tracks, manhole covers, stroam drains and potholes are the some of the examples of road surface disruptions [2]. These elements and traffic signal alter the flow of vehicular communication system results into frustration of driver. In developed countries there is large development in surveillance system to monitor and management of roads and terrestrial pathways, along with systems there are system monitors the elements which altering the mobility of transportation system. Likewise, there are sensor nodes which can identify or even predict the effect of environment on road. In developing countries administration for this system is challenging. Technology used is also minimal which can result into road surface disruption to chaotic level, because this repairing of this system may take weeks or even months.

The [1], [6] provided collaborative sensing platform based on windshield mounted cameras, Also Signal Guru service is introduced which gives Green Light Optimal Speed Advisory(GLOSA) and predict timings of the next traffic signal. For pothole detection Nericell system uses accelerometer, GPS, microphone and GSM radio which are available in Smartphone.

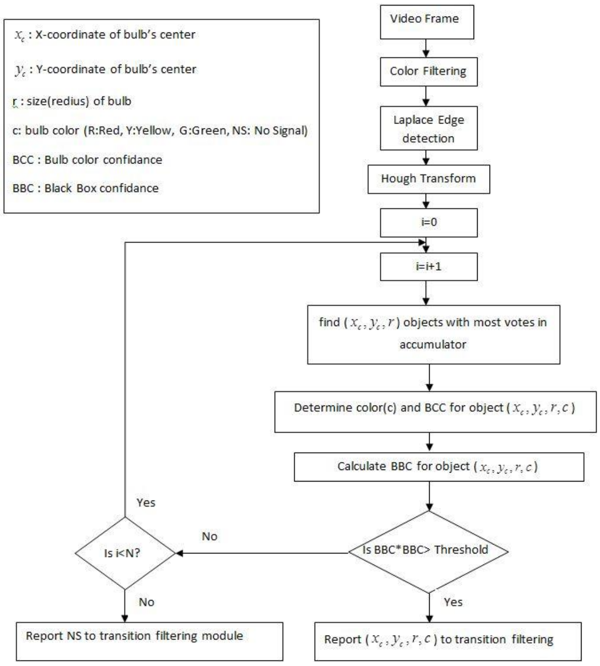

Fig. 1: Traffic Signal Detection Algorithm

To find the orientation of the smartphone Nericell uses GPS and accelerometer. Nericell uses threshold based approach to detect road traffic condition. [2] Uses accelerometer patterns to find road surface disruption (RSD). This data can be delivered to central system periodically to give advice to another Smartphone. To collect, process, deliver and visualize data from sensor of smartphone [7]CarTel system is proposed.

3. GREEN LIGHT OPTIMAL SPEED ADVISOR

The main purpose of Green light optimal speed advisor (GLOSA) is to advise drivers the optimal speed to drive vehicle. GLOSA algorithm will advise the driver such that driver don't have to wait on red signal. The vehicle can pass through the intersection before traffic signal turns red. This system offers several benefits such as

- Decreased fuel consumption
- Smoothed traffic flow
- Decreased environmental impact

To predict the upcoming traffic signal timing GLOSA system needs four piece of information

- Remaining amount of time to traffic signal turns green
- Upcoming intersection location
- Vehicles current location
- Queue length

To collect these information [1] uses camera sensor of smartphone. [6] Uses the signal guru application to determine the remaining time of traffic signal. Intersection location and vehicles current location can be determined by the maps and GPS service present in that smartphone. [8] Introduces Predictive cruise control concept. Signal broadcasts its remaining timing to vehicle so that each vehicle finds its optimal velocity and pas through intersection without halt on red light, main objective is to find optimal velocity of vehicle. To find near optimal solution with reasonable amount of computations [8] handles problems with two levels; 1) a set of logical rules that calculates reference velocity for timely arrival at green lights combined with 2) a model predictive controller that tracks the target velocity. The solution will be suboptimal but can be implemented in real time

3.1 Reference Velocity Evaluation

Reference velocity v_{target} can be determined by the distance of vehicle from intersection. The simple idea would be set v_{target} to the maximum allowed speed. The main purpose is to avoid waiting at red light. If vehicle cannot make that speed then it has to wait for next signal, then system have to set the minimum allowed speed. Algorithm can get the approximate distance to the next traffic light by maps. This distance can be denoted as d_i the subscript i denoted as the light number in the vehicle path. That means d_1 denotes the distance from first upcoming traffic light and d_2 from second and so on. Traffic light timing settings can be acquired from city transportation authority. In case they are not available system can use the past transitions to calculate the future transition of the traffic signal. [2] Has given prediction schemes which are used to predict the length of the phase by collecting the past traffic signal transitions history, and feeding it to SVM [3]. traffic lights timing can denoted as g_{ij} or r_{ij} where g_{ij} is the j^{th} green of i^{th} traffic light and r_{ij} is the j^{th} red of i^{th} traffic light. For example, traffic light number 1 can represent the timings as

$$[g_{11}, r_{11}, g_{12}, r_{12}, g_{13}, \dots] = [60,70,120,190, \dots] \qquad (1)$$

The above implies that g_{12} will turn green after 120 seconds. This way vehicle which equipped with the prediction algorithm can use remaining time and distance to calculate the speed to cross the intersection. The targeted speed should be in feasible limit $[v_{min}, v_{max}]$ whereas v_{min} is rode's minimum speed limit and v_{max} is the road's maximum limit speed. Vehicle can pass through the first traffic light only if $[d_1/r_{11}, d_1/g_{11}]$ is in v_{min} and v_{max} limit. That means the speed is only feasible only if the intersection with the interval $[v_{min}, v_{max}]$ is feasible. This can be written mathematically as

$$\left[\frac{d_1}{r_{1i}}, \frac{d_1}{g_{1i}}\right] \bigcap [v_{min}, v_{max}] \qquad (2)$$

If the first interval is not next interval is checked this process is repeated till the feasible interval.

3.2 Traffic Signal Detection

One more approach to get the remaining timing of the traffic signal is by detecting the light changing intervals. Vehicle driver mounts its smartphone on windshield to get path suggestions from GPS camera of that device is focusing on the road that can be used to detect the traffic light intervals. [9] [6] Uses color segmentation approach to detect traffic lights. Fig 1 shows detailed description of traffic light detection.

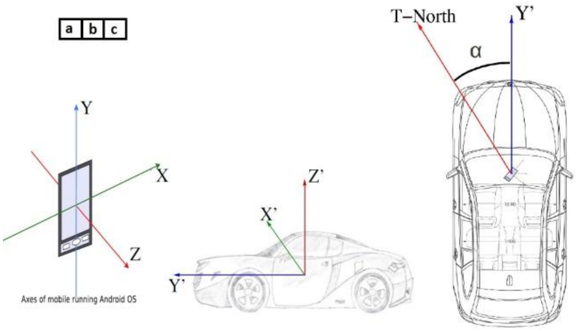

Fig2: Accelerometer Orientation

The first step contains the color filtration process. Traffic signal are bright and generally in red, green and yellow color. This step filters the color and set the pixels to background which doesn't belong to the red/green/yellow color. Now present part of video frame is in red/green/yellow color.

Second step includes qualification which examines and qualifies the signals based on the shapes detected in that video frame. This can be achieved by edge detection algorithm. To detect the circles in the video frame Hough transform can be used. This transform uses voting mechanism to decide which pattern best matches to the traffic signal bulb.

Next part examines the Bulb color confidence (BCC) of the candidate frame. This can be done by percentage of pixels fall into particular color. Black box confidence reports on how many pixels are black and neighbor of traffic signal bulb which confirms the traffic signal light. Last step contains the product of BCC * BBC which gives the detection confidence.

4. ROAD CONDITION MONITORING

Smartphone's assumes axis of the accelerometer as shown in figure 2(a). Y axis is along longer edge when the phone is held in portrait mode; X axis is along smaller edge in same mode and Z axis is perpendicular to the plane of the front face of the screen. For the magnetometer X and Y axis are same, Z axis is inverted and points towards the center of the earth. Vehicle axes are assumed as shown in figure 2(b). The direction in which vehicle moves is assumed as Y axis, the direction towards the right hand of the vehicle is X axis and the Z axis is pointing vertically upwards from the center of gravity. Let's assume that Smartphone's accelerometer axes are (X, Y, Z) i.e. reference axis and vehicles axes are (X', Y' Z') i.e. target axes.

4.1 Determining Accelerometer Orientation

Smartphone can be in any arbitrary orientation. There is need to find the readings along the Y' axis and Z' axes of the vehicle to detect the breaking event and pothole/Bump on road surface. Even if Smartphone is kept ideal in any rotation it accelerometer shows non-zero readings, which gives illusion of movement but actually it is not. These non-zero readings are recorded because of the gravity which is acting vertically downwards. Same way when device is accelerating in some orientation gravity affects the readings; it is important to find out that, by how much factor gravity affecting the axes and subtract those vales from the accelerometer readings.

Accelerometer is disoriented if reference coordinates are not aligned with target coordinates. For example if Z is aligned with X' episodes of sharp acceleration values will be taken as potholes. Thus before taking readings virtually reorienting the Smartphone is important. This can be done by the rotation matrix. A column vector can be transformed to new coordinate system by just multiplying the rotation matrix

$$V' = R(\theta) \times V \tag{3}$$

In similar way rotation matrix corresponding to the rotations of the reference coordinate system at an angle (ϕ, ψ, θ) around axes (Y, Z, X), can be formed by multiplying the rotation matrix corresponding each rotation. Now vector of reference coordinate system can be represented in target co-coordinate system as

$$V' = R(\emptyset)R(\varphi)R(\theta) \times V \tag{4}$$

[10]Use the two methods for virtual reorientation. Virtual reorientation can be done in two steps, consider phone's axes as reference axes and vehicles axes as target axes. Total orientation can be done in two steps. First, transform the Smartphone's accelerometer coordinates to geometric coordinates, in second step transform geometric coordinates to vehicle's coordinates system.

4.2 Bump Detection

Bump arises due to different reasons, when vehicle passes through bump significant vertical jerk can be found in accelerometer reading. Algorithm can store measurement of Z' to identify the next bump. But at different speeds same bump may show different level of spikes [3]. [3] Uses two different thresholds to detect bumps, at high speeds such as (>25kmph), Z'-peak can be used and at slower speed (<25kmph) Z'-sus can be used. However, the characteristics of accelerometer changes over environment and configuration. In other words, vehicle, Smartphone device affects the sensor data. Due to variable characteristics threshold based is not suitable for all types of environment. [10] Uses the 1 second window frame as single data point, accelerometer sensor in Smartphone gives 50 samples per second. Six features are used in [10] mean and standard deviations in three coordinate axes, $(\mu_X, \mu_Y, \mu_Z, \sigma_X, \sigma_Y, \sigma_Z)$ over the window. These features are then input to machine learning algorithm.

Two machine learning techniques can be used to classify these features. First is K-means clustering algorithm, this unsupervised learning technique take numbers of clusters and features as input. Since there is need to classify the data into two classes i.e. Bumpy/smooth number of clusters can be inputted as 2, and features gathered from accelerometer. Second algorithm can be used is Support vector machine classifier, this is supervised learning method so person need to feed it correctly labeled accelerometer data, after SVM gets trained Smartphone can input the new data to SVM predict algorithm to identify its class. To get output from SVM person need to make effort to manually label every data points.

4.3 Vehicle Breaking Detection

A high incident of breaking can be happen because of poor quality of roads or heavy traffic on the road. GPS can detect the breaking event based on the GPS coordinates, but that incurs high energy cost, also on very heavy traffic vehicle moves very slowly, because of GPS error of 3-6 m it may not detect breaking correctly. So Instead of using GPS based method accelerometer can be used to identify the breaking events.

Breaking causes surge in Y' axis reading since Y' is pointing towards direction of motion of vehicle. Surge is significant even if break is applied at low speed. Presence of significant amount of surge in Y' denotes either heavy traffic road or heavy number of obstacles on road. Number of breaking events in short number of times will denote heavy traffic road, and number of breaking events occurred in same geographical area will denote the presence of obstacle on that geographical location. There is difference between breaking event accelerometer reading and bumpy road accelerometer reading. Braking event is more sudden than that of the bumpy road event. The six features used in bump detection may not enough to classify the breaking event [10]. So, extra features are introduced in [10] to identify the braking event. Difference metric or is defined

$$\delta_x = max_{a_i \epsilon window \ a_i} - min_{a_i \epsilon window \ a_i} \quad (5)$$

Where, a_i is acceleration at i^{th} instance, in similar manner algorithm can calculate for Y' and Z' axes. Now, nine features are collected$(\mu_X, \mu_Y, \mu_Z, \sigma_X, \sigma_Y, \sigma_Z, \delta_x, \delta_y, \delta_z)$, since the Y' is direction of motion so breaking is best observed in Y' direction. Next step is to input this features to machine learning algorithms. First to K-means clustering algorithm after this step manual labeling stage followed by training of support vector machine learning stage.

5. SUMMARY

As road traffic increasing day by day, maintaining it in effective way is very important and challenging to researchers. Smartphone are becoming popular very fast and penetrating into common people's life, utilizing the sensors present into the Smartphone is good and efficient idea. The data generated by one user or Smartphone can be send to central server, that data can be used to advice another user. This data can contain lots of information like intensity of traffic at a junction, nature of a particular road (Bumpy/Smooth) and optimal speed of drive to save fuel as well as time. All this information can be generated in energy efficient manner with the use of inbuilt, low energy consuming components. Also applying the machine learning techniques allows system to adapt according to vehicle and road environment.

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