MITSUI SUMITOMO INSURANCE WELFARE FOUNDATION
RESEARCH GRANT 2013

Next Generation Satellite Navigation for Vehicle Safety Monitoring

Primary Researcher:
Nuksit Noomwongs
Depertment of Mechanical Engineering, Chulalongkorn University

Co-researcher(s):
[1]Sunhapos Chantranuwathana
Depertment of Mechanical Engineering, Chulalongkorn University
[2]Raksit Thitipatanapong, Sunya Klongnaivai
National Electronic & Computer Technology Center

Research summary:

In this project, the novel consumer grade multi-GNSS navigation receivers were investigated with the driving maneuver/behaviour detection algorithm. The automotive filter in navigation receiver combination with multiple satellite navigation system were applied in this study. The results from controlled condition tested track indicated that this novel receiver with simple detection algorithm were satisfy both lateral and longitudinal acceleration detection.
The driver monitoring system developed in this project was evaluated in the real road condition both urban and highway. And the results confirmed that it can be used in real road condition.

Objective

1) To develop the driver monitoring system by using of decimeter level accuracy navigation system to monitor driving behaviour based on lateral motion.
2) To evaluate the developed system in real road situation in Bangkok

Methodologies and Research time schedule

1) Study on decimeter level accuracy navigation system and driver rating technique (M1-M2)
2) Develop a driver monitoring system software, test the system offline. (M3-M4)
3) Prepare for test vehicle by installing measuring devices such as Multi GNSS receiver, Reference Measurement Unit (Inertia Mass Unit Accelerometer - IMU), Drive recorder (VDO camera, GPS, accelerometer), etc. onto the vehicle (M5)
4) Evaluate the test vehicle on proving ground (M5-M6)
5) Compare the data such as lateral acceleration received from measuring devices to data from navigation system (M6)
6) Design for on road experiment such as routes, number of test drivers (M6)
7) Conduct the on road experiment and collect data (M7-M10)
8) Analyse data and wrap up (M11-M12)

- **Precision multi-GNSS Receivers**

Currently, the navigation system technology has been much improved in both availability and accuracy with combination of multiple navigation satellite systems. Normally, this is called Multi-GNSS which combine satellite navigation system including GPS from US, GLONASS from Russia, Beidou from China and QZSS from Japan. With precision less than a meter and high update rate, the GNSS can be a viable alternative for driver behaviour detection.

An advance Multi-GNSS was evaluated in our works (carrier phase, dual frequencies GNSS receivers), the experimental results were divided into (i) cornering and (ii) lane changing, although, the information used was the lateral acceleration but the test results were not accurate. For cornering, the maximum lateral acceleration from SGS (single point solution) deviated just about 2% from the reference IMU while the RTK (real time kinematic solution with reference base) estimated was 5% deviated from the reference IMU. For the lane change, the estimated maximum lateral acceleration from SGS technique was around 19% deviated from the reference IMU while the RTK technique was about 5% deviation from the reference IMU. The different could be explained that the cornering motion can produce more than 10 meter in displacement which is larger than the accuracy with the single solution (SGS, less than 2 meters). On the other hand, the lane change occurred within a few meters of lateral displacements which required RTK solution accuracy (less than 0.2 meters).

The key to successful lane-change maneuver detection with navigation system is the sub-meter accuracy for estimating the lateral acceleration. In addition, the precise point positioning technique (PPP) was applied for vehicle detection without needing a base station correction as the RTK technique (carrier phase, dual frequencies GNSS receivers). The precision level was relatively at the same level as the results from RTK solution in previous study without reference base station. It can be concluded that for detection of lane change maneuver the PPP solution was possible. Furthermore, with PPP the technique, all unsafe driving behaviour could be detected.

However, the test within real road situations were indicated that the satellite signal were affected with road side condition and leaded to fault detection even using PPP navigation technique. The signal integrity function must be included in further investigations. Also, the carrier phase, dual frequencies GNSS receivers system was expensive equipment that cost 2000 USD or more it might not feasible to apply in vehicle system.

In this study, the code phase, low cost, multi-GNSS receivers were evaluated with maneuver detection algorithm within close vehicle testing facility. Then evaluation of driver behavior algorithm in urban and highway condition was carried out.

○ Driver maneuver detection and monitoring algorithm

For the vehicle unsafe behavior, three types of maneuver interested in this work are braking, turning and lane-changing. In case of rapid acceleration, normally it does not exceed our safety threshold. Therefore, these can be categorized using two physical parameters: lateral acceleration and longitudinal deceleration. The simplified lateral acceleration detection algorithm was developed in this project and employed to the driver maneuver monitoring algorithm. Dangerous level of both types of accelerations were listed when their magnitude are greater than 0.25g as the uncomforted level indicated from passenger refers to our experiences. Finally, the maneuvers detected from this algorithm were taken into an account with timestamp for verification as illustrated in Figure 1

Experiments and Results

○ Experiment in closed test track

The experiment were conducted in department of land transport test facility in Pathum-Thani, it has 2 km per round and approximately 850 meters in length which can simulate high speed lane-change and high speed turning (R30) as shown in Figure 2

For equipment, the consumer grade receiver also evaluated was U-blox M8N Multi-GNSS which also received GPS, GLONASS, and QZSS. Three type of GNSS satellites were compared which GPS, GPS+GLONASS+QZSS [GNSS(GLO)] and GPS+BDS+QZSS [GNSS(BDS)]. The receiver ran on 5-Hz update rate and filter was set to automotive application and the output were manipulated. The result might not good as sub-meter accuracy in true position but in this applications accuracy in velocity is more important.

Racelogic VDO VBOX Pro was used to record the VDO footage and 10-Hz of GPS acquisition for analysis. The test was performed using a utility vehicle. Sample of results are shown in Figure 3.

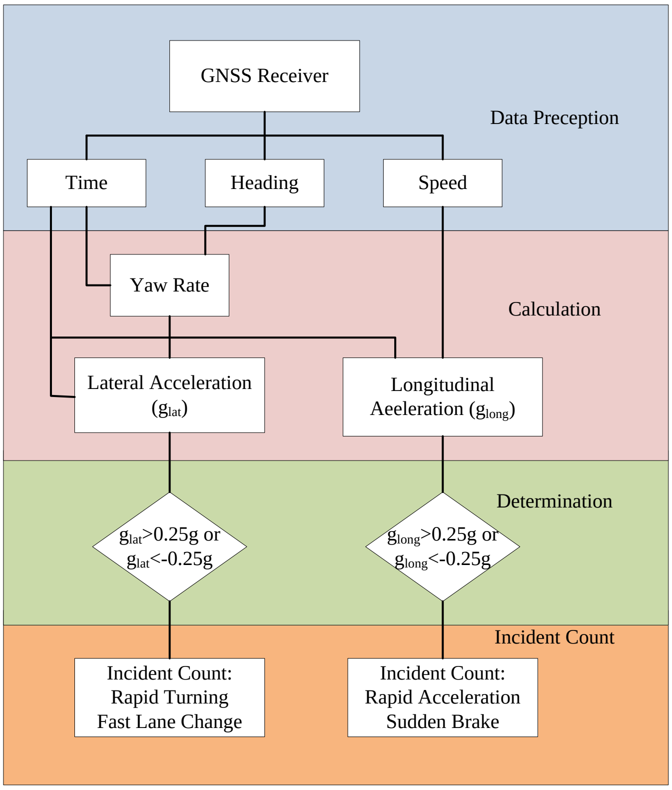


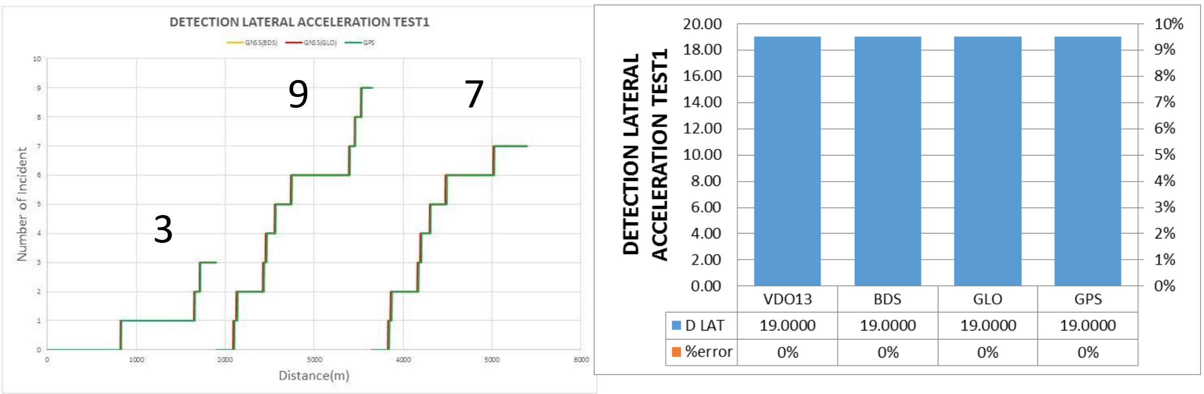
Figure 1 Driver maneuver monitoring algorithm

Figure 2 Department of land transport test track

For both lateral and longitudinal acceleration, this consumer grade receiver have proofed that it could applied for advance vehicle monitoring system. In tested track, the multiple satellite navigation system ([GPS+Glonass+QZSS] and [GPS+BDS+QZSS]) have no different from dedicated GPS system. However, in real road condition, the multi-GNSS should be advantage

- **Evaluation of Algorithm in Urban and Highway condition**

To test our developed driver maneuver monitoring system, several road tests were carried out. In this report, the results from two test conditions which are, (i) urban road test condition from Rama III Road Bangkok to Bangpu, Samuthprakarn and (ii) highway road test condition from Nakornratchaseema to Saraburi route, are illustrated in table 1. The results from our monitoring system were checked with Vdo back up, and there is no error found. And the results confirmed that this driver monitoring system can be used in real road condition.



(a) (b)

Figure 3 Driver#1 Lateral Detection, number of incidents(a), compare among three satellite system and VDO(b)

Table 1. Driver maneuver detection results from (i) Bangpu, Samuthprakarn to Rama III Road Bangkok route and (ii) from Nakornratchasima to Saraburi route

Acceleration level	Detection of excessive acceleration per 10 km distance (times)	
	Samuthprakarn to Bangkok route (~30 km)	Nakornratchasima to Saraburi route (~30km)
Lateral Acceleration > 0.25g	1.22	0.33
Longitudinal Acceleration > 0.25g	2.14	0

Next step of works

More road test should be done to collect data to use as a database to set up the criteria for driver rating system based on our developed driver monitoring system.

Means of Official Announcement of Research Results

1. N. Noomwongs, R. Thitipatanapong, S. Chantranuwathana, P. Wuttimanop, P. Boonprom and S. Klognaivai," Vehicle Safety Monitoring System with Next Generation Satellite Navigation: Part 1 Lateral Acceleration Estimation", SAE Technical Paper, pp. 2015-01-0123, 2015.

2. N. Noomwongs, R. Thitipatanapong, S. Chantranuwathana, P. Wuttimanop, P. Boonprom and S. Klognaivai," Vehicle Safety Monitoring System with Next Generation Satellite Navigation: Part 2 Excessive Acceleration Detection", SAE Technical Paper, pp. 2015-01-0124, 2015.

3. N. Noomwongs, R. Thitipatanapong, S. Chantranuwathana and S. Klognaivai, "Driver Behavior Detection Based on Multi-GNSS Precise Point Positioning Technology," Applied Mechanics and Materials, vol. 619, pp. 327-331, 2014. DOI: 10.4028/www.scientific.net/AMM.619.327