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Advances in Microscopic Traffic Data Collection: A Comparative Study of GPS Techniques

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1. INTRODUCTION

The microscopic approach of traffic analysis deals with the interaction between individual vehicle/driver and their surrounding environment that include adjacent vehicles, infrastructure and control systems. It is largely preferred for its preciseness in dealing with the vehicular dynamics at the individual driver's level. With rapid increase in the processing capabilities of computer processors, it is now possible to acquire network level representation without compromising on the indigenous vehicular dynamics. A great deal of investigations have been carried out in the past on the development of car-following and lane changing models to simulate the longitudinal and lateral movements of vehicles respectively (Chandler et al. (1958), Gipps et al. (1982, 1986), Hidas (2005)). Some of the car following models have been calibrated and validated as well (Chandler et al (1958), Ranjitkar et al. (2003, 2004, 2005)) while only a few literatures deal with the calibration and validation of the lane changing models.

The disaggregate vehicular movement data is of particular importance for such calibration and validation as emphasized in the next generation simulation (NGSIM) program launched by FHWA. The microscopic data collection technique has taken several folds since the first car following experiments conducted on a test track using vehicles connected with rope to measure space headway (Chandler et al (1958)). Kometani and Sasaki (1959) captured car-following data in a film. Since then several researchers used the video technique to collect car-following and lane changing data using video camera placed at some location e.g. tall buildings or some time using helicopter to capture traffic movements on a certain road section. This technique has range limitation and might not be that accurate. As with the increase in the field of view the frame size of vehicle decreases that increases the potential distance measurement error.

There has been increasing use of GPS techniques for the microscopic traffic flow data collection in recent years (Hatipkarasulu et al. (2000), Jiang and Li (2001), Gurusinghe et al. (2002)). A range of GPS techniques are available with the accuracy from a few centimeters to several meters and resolution from 1 to 0.1 second depending on the techniques and equipments used. The position and speed of a moving vehicle can be measured by a receiver mounted on it. As it works on global time basis, there is no synchronization problem as in the case using conventional equipments e.g. distance meter and speedometer. This paper reports a comparative study of GPS techniques applicable for microscopic traffic flow data collection.

2. DATA COLLECTION

Early this year in April, we conducted car following and lane changing experiments on an arterial road section located in Ishiakari area, a northern part of Sapporo city. We used simultaneously three different GPS techniques to measure the position as well as speed of two passenger cars participated in the experiment that include a single GPS combined with safety record (SR) sensor, real time kinematic (RTK) GPS and virtual reference station (VRS) techniques.

The SR sensor consists of accelerometer and gyroscope synchronized with a GPS device in each car to measure position, speed, angular velocity and acceleration of the vehicle. The position is measured at 1 second interval while speed and acceleration are measured at 0.1 second interval. The accuracy in position is that of a single GPS technique. RTK GPS is a precise D-GPS technique with the accuracy of ± 2 cm in position and ± 0.2 km/h in speed measurements. However its effectiveness is limited with in a certain range, typically a few kilometers from the reference station. A network RTK concept is being devised to improve the range and reliability of the RTK GPS technique. Virtual reference station (VRS) is a typical implementation of network RTK concept. It works through a network of permanently installed reference stations. So far around 1,300 permanent reference stations have been installed all over Japan as shown in Fig. 1. It is in operation since 2003. The central processing unit models the errors based on the data received from the network of permanent reference stations for the approximate position of the moving vehicle send by mobile phone. The rover receives the respective correction signals using mobile phone via the service provider. Virtually this system is available all over Japan.

Fig. 1 Network of permanent reference stations installed all over Japan

Table 1 presents the characteristics of vehicles and drivers participated in the experiment that include information on manufacturer, model, capacity and dimensions of vehicles and age and driving experience of the drivers. Both of the drivers were experienced one with more than 25 years of driving experience. Fig. 2a illustrated the schematic layout of the arterial road section. A reference station was set up along the sidewalk approximately at the middle of 2 km long test section with U-turns on the each ends. As seen in the figure an unsignalized intersection crosses the road section on the left side of the reference station though the traffic volume on that day was significantly low. Fig. 2b shows equipments fitted in each car that include two GPS receivers together with a PC card and a battery for each, two GPS antennas, two personal computer, a GPS radio to receive correction signal for RTK GPS and a mobile phone to receive correction signal for VRS technique. Besides these, each car was equipped with a single GPS receiver combined with SR sensor. The single GPS combined with SR sensor outputs position and speed data every 1 second while the RTK GPS and VRS techniques output the same every 0.1 second.

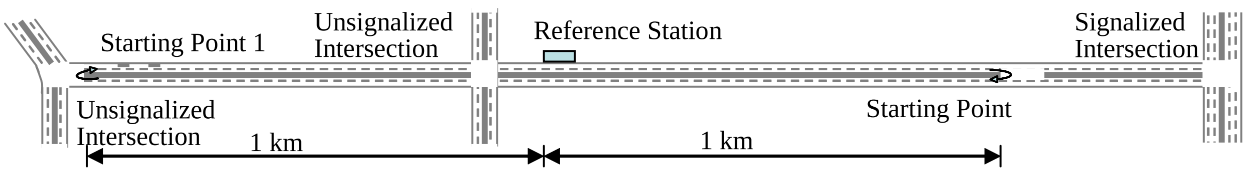
3. DATA ANALYSIS

Both of the RTK GPS and VRS techniques outputs the quality of GPS signals in numbers 1, 2 and 4 representing the status of GPS signals to be single, differential and RTK GPS respectively. The GPS status at 4 i.e. RTK GPS represents the highest level of accuracy typically a few centimeters while the GPS status at 2 i.e. differential GPS represents the accuracy with in a meter. The GPS status at 1-single GPS represents no correction signals are available and so the error in position measurement may go up to a few meters.

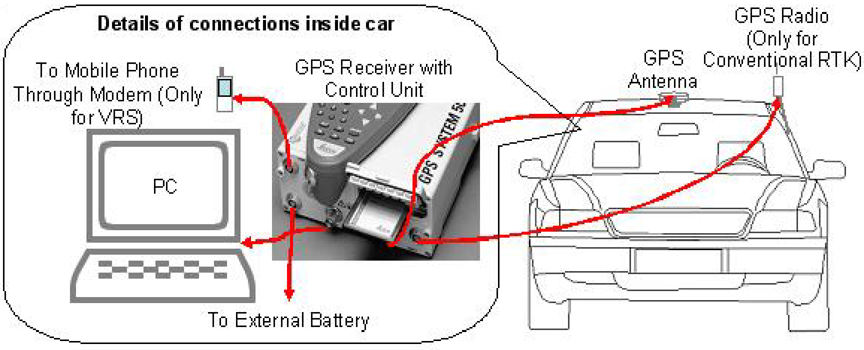
Figure 3a presents the frequency distribution of the GPS status. It remained at RTK GPS status for the most of time for both of RTK GPS and VRS techniques. There were no cases of drop to single GPS status or discontinuity throughout the experiments. Fig. 3b presents the time series of the GPS status showing some occasional drops to differential GPS from the RTK status. Fig. 3c and 3d present the discrepancies in space headway and speed measurements by RTK GPS and single GPS combined with SR sensor. The error varies from + 5 m to – 8 m in the former case while in the latter case though most of the time they fluctuates around zero there are many peaks that goes up to ± 6 kph. Fig. 3e and 3f present the discrepancies in space headway and speed measurements by RTK GPS and VRS techniques. In the former case, most of the time it fluctuates around zero while there are some peaks going as high as 0.9 m. If we superimpose this figure with fig. 3b, these peaks are just located at the points where the GPS status has dropped to the differential GPS. That means they represent the accuracy at differential GPS status. For RTK GPS status, the value is estimated less than ± 4 cm. In the latter case, the discrepancies in speed measurements fluctuate around ± 0.4 kph for the most of the time.

Table 1 Driver's / vehicle's characteristics

V.N.	Manufacturer	Model	CC	Dimension L	Dimension W	Dimension H	Driver's Age	Driving Experience
1	Nissan	Cedric	3000	4.75	1.75	1.35	60	40+
2	Nissan	Bluebird	2000	4.50	1.70	1.35	50	25+



a) Schematic layout of the road section



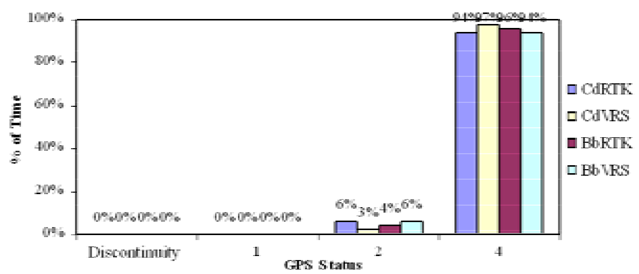
b) Equipments fitted in each car

Fig. 2 Experimental arrangements

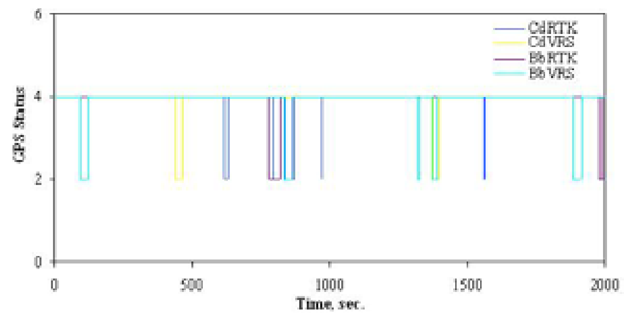
4. CONCLUSION

This paper has reported a comparative study of three different GPS techniques implemented for microscopic traffic flow data collection. It includes a single GPS combined with SR sensor, RTK GPS and VRS techniques. Each has their own merits and demerits in terms of cost effectiveness and accuracy in measurements. A single GPS combined with SR sensor is a cost effective solution though its accuracy features are not that attractive. The RTK GPS is a very precise GPS technique with the accuracy of ± 2 cm in position and ± 0.2 kph in speed measurements. However, it is effective only with in a certain range typically 2 to 3 kilometers from the reference station beyond which the accuracy drops significantly. This technique requires the users to install their own reference station. It is several times expensive than the single GPS technique. This type of GPS technique is applicable for test track type of experiments. The recently introduced VRS technique is the most advanced GPS technique developed so far. Virtually it works throughout the network using mobile phone to send approximate position and receive the correction signals. However at the moment it is expensive than the conventional RTK GPS technique as the cost includes mobile phone service charge and provider's charge for the correction signals. It is applicable in the cases where high level of precision in required over large network. The two-way link required for this technique restricts the number of the users that can be provided with this service at a time.

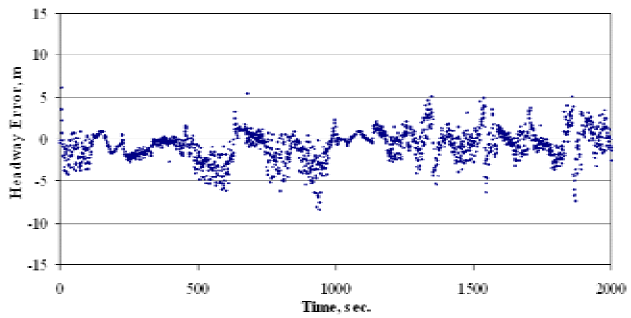
The discrepancies in the space headway measurements by RTK GPS and single GPS varies from -5 m to +8 m while the same for speed measurements fluctuates significantly. The discrepancies in the space headway measurements by RTK GPS and VRS varies with in the range of ± 4 cm and the same for speed measurements varies with in the range of ± 0.4 km/h. Some disturbances were observed near the intersections that cause drop in the GPS status to differential level of accuracy otherwise most of the time these figures are maintained.



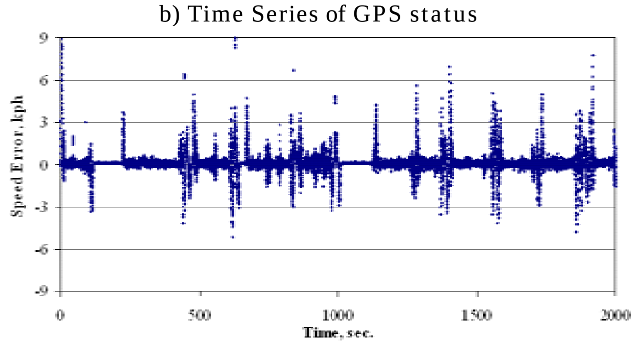
a) GPS status



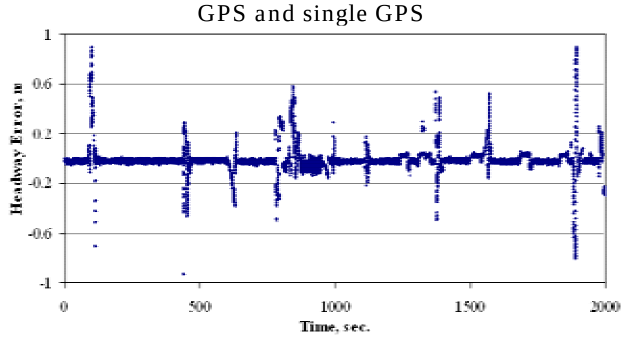
b) Time Series of GPS status



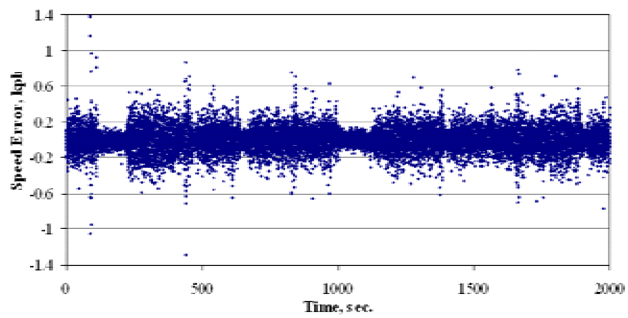
c) Discrepancies in space headway measurements by RTK GPS and single GPS



d) Discrepancies in space headway measurements by RTK GPS and single GPS



e) Discrepancies in space headway measurements by RTK GPS and VRS techniques



f) Discrepancies in speed measurements by RTK GPS and VRS techniques

Fig.2 Results of data analysis

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