MICROSCOPIC TRAFFIC DATA WITH REAL-TIME KINEMATIC GLOBAL POSITIONING SYSTEM*

Prakash RANJITKAR**, Haruka SUZUKI***, Takashi NAKATSUJI****

1. Introduction

With increased interest in microscopic traffic simulation tools, several car-following and lane changing models have been developed in the last few decades[1), 2) 3)]. These models are essential components to simulate longitudinal and lateral movement of vehicles in a multi-lane road facility. The microscopic approach is generally preferred for its preciseness in dealing with real driving behavior at individual driver's level. This emphasizes the need for prercise and high resolution data to calibrate and validate these models. It is difficult to acquire the desired level of precision and resolution using video camera or conventional equipments such as distance meter, speedometer, accelerometer etc. Besides, they are cumbersome due to synchronization problems and data processing afterwards. In this sense Real-Time Kinematic (RTK) GPS, an advanced surveying tool is ideal for traffic data collection, where the position and speed of a vehicle can be measured precisely at desired resolution by a receiver mounted on it.

Previously, we performed several car-following experiments in a test track using RTK GPS and investigated different aspects of driving behaviors under car-following situations[4), 5) 6) 7)]. In this attempt, we have conducted car-following and lane changing experiments together under three different driving conditions including a test track, urban arterial road and expressway. In the first two, we have used conventional RTK GPS technique (the one with your own base station), while for the third one we used Virtual Reference Station (VRS) technique, a network based RTK GPS. This study has two objectives. First, evaluate the data acquisition techniques for car-following and lane changing experiments. Second, investigate car-following and lane changing behavior of drivers under different driving conditions. This paper deals with only the first part.

2. Global Positioning System

GPS is a well known surveying tool that provides users with accuracy level ranging from millimeters to several meters depending on the equipments and techniques used. A GPS receiver located on ground computes its global coordinates in terms of longitude, latitude and altitude based on its distances from at least four satellites by triangulation method. The accuracy of GPS can be improved substantially by removing common mode errors, the major source of errors, which are same for all receivers in a local area though they can not be observed with a single receiver unless its position is already known. In differential GPS (DGPS) technique, a receiver is installed at a known location called 'base station' to measure these errors and broadcast the correction signals to all other receivers called 'rover' with in some distance range as shown in **Fig.1**. The number of rover receiver is not limited.

The real-time kinematic GPS is the most precise DGPS technique with millimeter level accuracy in position measurement. A typical radio link required for RTK is in the UHF, VHF or spread spectrum radio band. The RTK GPS receivers trace P-code signals from the satellites. With carrier-phase tracking technique, it can precisely measure the position as well as speed of the rover. This technique requires installation of your own base station. Its effectiveness is limited within a certain range from the base station (up to 10 kilometers). This technique is termed here as conventional RTK GPS. Gurusinghe et al.[4)] have confirmed its accuracy against the measurements taken by mechanical equipments.

The reliability and range of RTK GPS can be extended further through a set of permanent reference stations. The typical example of this technique is the virtual reference station (VRS). The VRS concept involves some permanently running GPS reference stations located up to 80 km apart. They feed GPS data to a central processing computer via communication network. The central processing computer processes these data to model spatial error and generates appropriate corrections. From users' view point, the rover receiver sends its approximate position via mobile phone to the central processing facility and receives correction signals for that approximate position so is called virtual reference station. This technique has two advantages; first the range of its effectiveness is much wider provided that the rovers are with in the network and second it doesn't require user's own reference station as in the case of conventional RTK GPS. The critical disadvantage is that it requires a two-way communication that limits the robustness of the system and increases its cost.

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3. Car-Following and Lane Changing Experiments

We have performed several experiments under three different driving conditions: arterial road section, expressway section and a test track located nearby Sapporo city. Four drivers/passenger cars participated in these experiments. The details of drivers and vehicles characteristics are presented in **Table 1**. This includes vehicles' manufacture, model, capacity and dimensions, while for drivers' their age and driving experience.

Fig. 2 shows the schematic layout of the portion of arterial road, test track and expressway. For arterial, a reference (base) station was set at sidewalk near the middle of 2 km long road section having U-turns on each end and an unsignalized intersection. The traffic volume in this portion was low on that day making it easier for the experiments. First we conducted experiments using conventional RTK and in next round, we used conventional RTK, VRS and SR sensor together for each car to compare their preciseness. For test track, only conventional RTK GPS was used. The reference station was set along sidewalk near the middle of the test track lifted with a crane mounted vehicle for better performance. In the case of expressway conventional RTK can not be used due to its range limitation so we used VRS. A portion of Hidaka expressway was chosen for these experiments where the lane configuration changes intermittently from single to double lane and vise versa, useful to catch lane changing behavior.

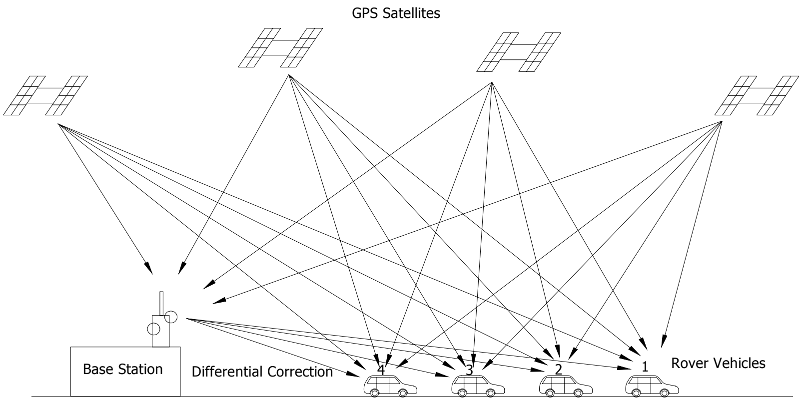


Fig. 1 Sketch showing typical DGPS arrangements

Table 1 Driver's / vehicle's characteristics

V.N.	Manufacturer	Model	CC	Dimension			Driver's Age	Driving Experience
				L	W	H		
1	Nissan	Cedric	3000	4.75	1.75	1.35	60	40+
2	Nissan	Bluebird	2000	4.50	1.70	1.35	50	25+
3	Toyota	Premio	1800	4.50	1.70	1.45	22	4+
4	Toyota	Corolla	1500	4.10	1.70	1.35	23	5+

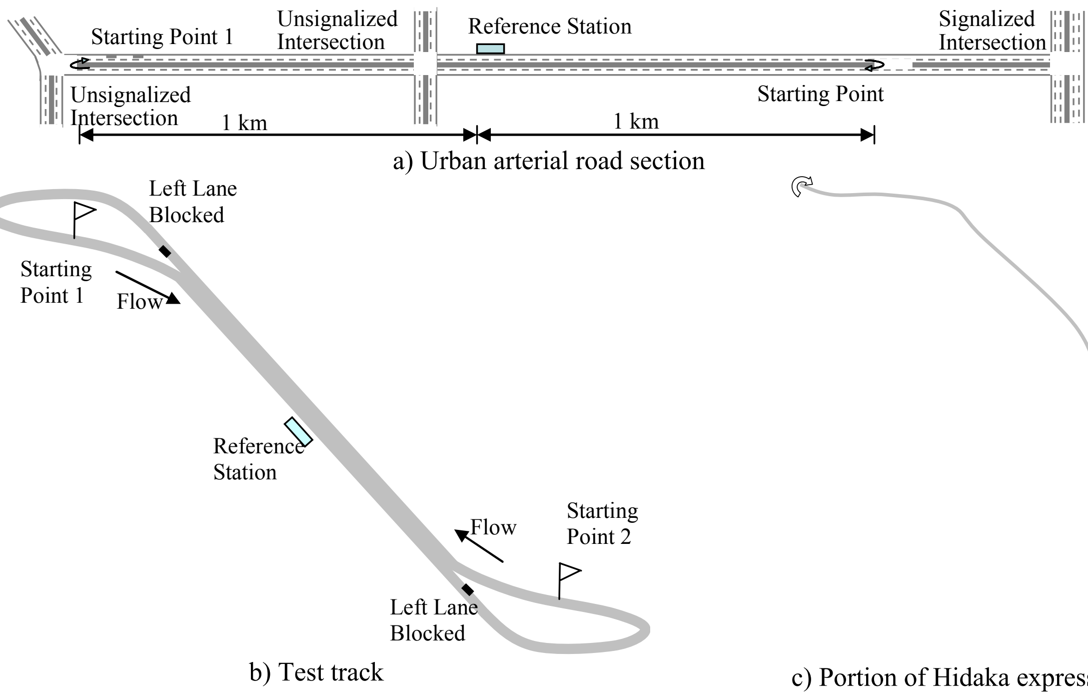
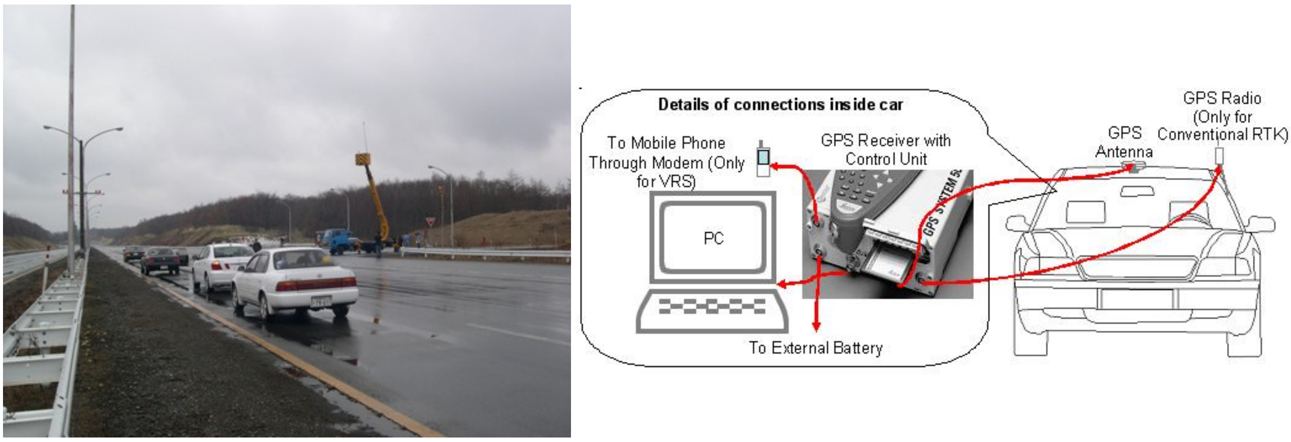


Fig. 2 Schematic layout of experiment location

Fig. 3 shows the details of equipments installed in the rover cars. Each car was fitted with a set of GPS receiver, personal computer, GPS antenna and external battery. For conventional RTK a GPS radio was used to receive correction signals while for VRS a mobile phone and modem were used instead. For the experiments using both conventional RTK and VRS together, each car was equipped with two sets of these equipments in addition to a SR sensor.

A typical lane changing situation is shown in **Fig. 4**, where a subject vehicle (SV) is approaching a slow moving lead vehicle (LV) ahead. The SV driver will try to move to adjacent lane change to increase his speed provided that it is safe to do so. For this the driver has to make sure that his gap with adjacent lead vehicle (ALV) and adjacent following vehicle (AFV) in the adjacent lane is safe enough to go for lane changing maneuver. The lane changing process can be categorized into two types: mandatory lane change (MLC) and discretionary lane change (DLC). A driver is under MLC condition when he needs to change lane due to lane block, lane drop or some other traffic regulations. It's DLC if the driver desires to change lane to improve his driving condition. A typical situation is to overtake slow moving vehicle ahead as explained earlier. We have tested four different scenarios in test track with and without AFV for DLC and MLC conditions as shown in **Fig. 5**. For urban arterial only DLC conditions were tested. Five different speed combinations were tested that includes leader 20/follower 40, leader 20/follower 60, leader 40/follower 60, leader 40/follower 80 and leader 60/follower 80 km/h. For expressway experiments, no instructions were given to drivers either about lane changing scenario or speed. They were free to drive at desired speed and change lane as they wish.



a) Vehicle queued in test track b) Details inside each car

Fig.3 Cars equipped with RTK GPS receivers

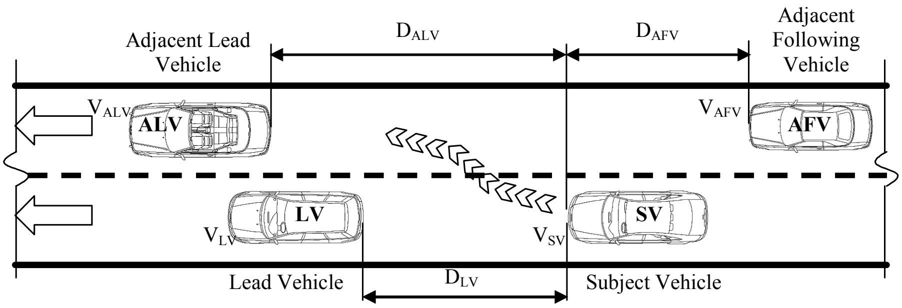
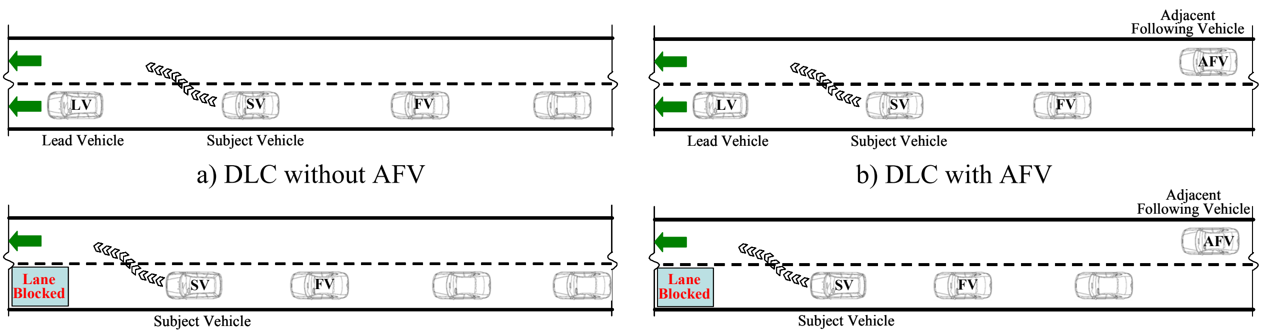


Fig.4 A typical lane changing situation



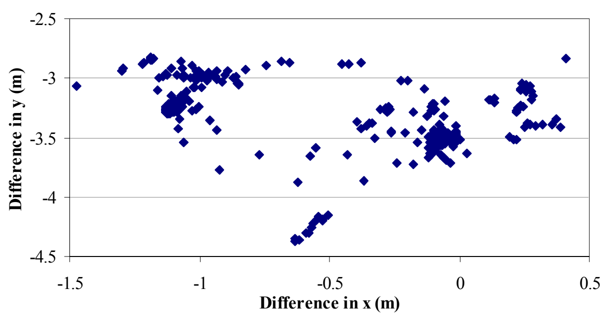
a) DLC without AFV b) DLC with AFV

c) MLC without AFV d) MLC with AFV

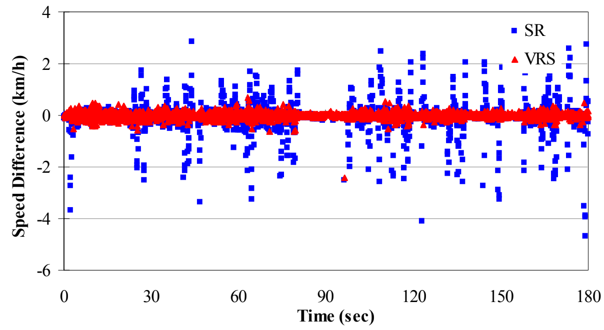
Fig.5 Lane changing scenarios tested in experiments

4. Conventional RTK versus VRS and SR Sensor

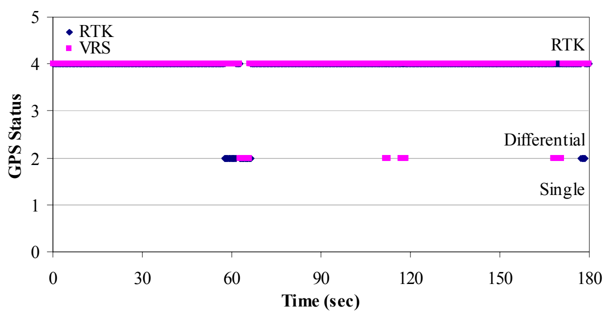
The time, position and speed data extracted from GPS receivers are processed further to compute car-following and lane changing variables such as space headway, acceleration, relative speed, lateral position of the vehicles etc. At this stage, we have analyzed only the data from the experiments using conventional RTK, VRS and SR sensor together in urban arterial road condition. The results are presented in **Fig. 6**. For position measurements, the first Fig. 6a shows the difference in position measurements by conventional RTK and VRS technique in local coordinate system. The actual gap between these receivers measured during experiment was only 0.75 m. Here the difference along X axis varies with in 0.5 to -1.5 m and that for Y axis varies from -2.5 to -4.5 m. There might be some discrepancy in these measurements as they were measured with different receivers and different techniques though such discrepancies are yet to be verified. Besides others, the disturbances from heavy trucks might have disturbed on receiving the correction signals. For speed measurements, Fig. 6b shows difference in speed measured by VRS and the one using SR sensor with respect to the conventional RTK. The discrepancy in the former case is quite low with a few exceptions. While for SR sensor the discrepancy is relatively high that varies from 3 to -4 km/h. The third Fig. 6c shows the status of GPS signal where 4 indicates high quality RTK GPS status, 2 for differential GPS and 1 for single GPS status. The signal quality remained in RTK GPS status for the most of time with a few exceptions probably due to the disturbance caused by heavy trucks some times. The fourth Fig. 6d shows the number of visible satellites with conventional RTK, VRS and SR sensor. The number exceeds the critical number 4 for all cases.



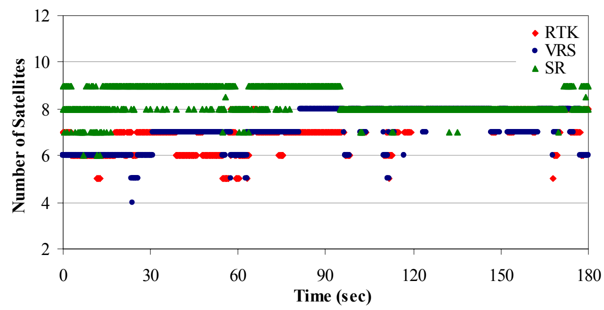
a) Difference in position measurements by VRS-RTK



b) Speed difference RTK-VRS



c) GPS status



d) Number of visible satellites

Fig.6 Comparison of GPS techniques

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