RP-ADAS: Relative Position-Advanced Drive Assistant System based on VANET (GNSS)

Hun-Jung Lim and Tai-Myoung Chung

Abstract—Few decades ago, electronic and sensor technologies are merged into vehicles as the Advanced Driver Assistance System(ADAS). However, sensor-based ADASs have limitations about weather interference and a line-of-sight nature problem. In our project, we investigate a Relative Position based ADAS(RP-ADAS). We divide the RP-ADAS into four main research areas: GNSS, VANET, Security/Privacy, and Application. In this paper, we research the GNSS technologies and determine the most appropriate one. With the performance evaluation, we figure out that the C/A code based GPS technologies are inappropriate for 'which lane-level' application. However, they can be used as a 'which road-level' application.

Keywords—Relative Positioning, VANET, GNSS, ADAS

I. INTRODUCTION

THE vehicle has been used as a human transportation device more than 100 years. Since then, vehicles have been investigated in many ways and become a technology intensive device. Few decades ago, electronic and sensor technologies are merged into vehicles as an Advanced Driver Assistance System(ADAS). ADAS is a system to help the driver in its driving process for safety and convenience with electronic sensors and Human-Machine Interface(HMI). The sensor monitors driving circumstances and detects hazard events instead of human sense of vision, distance, and direction. The warning responds to vehicle actuators or informs humans through human sense of sight, hearing, and touch, to prevent accidents. The examples of ADAS are as follows.

- Lane departure warning (LDW): Warns the driver if he is leaving a defined trajectory within the lane
- Blind spot detection(BSD): The near field collision warning in the blind spot area
- Forward Collision warning(FCW): Detects front obstacles and warns the driver when they are too close
- Adaptive cruise control (ACC): Based on the front vehicle information, regulates own vehicle speed Intelligent speed advice: Informs the driver about speed limits and the recommended speed
- Night Vision: Enhances the perception of the driver in dark light conditions

The examples of sensor technologies for ADAS are as follows

- Radar: A technology that determines distance to an object or surface. The time delay between pulse transmissions gives the range to an object.

- LiDAR(laser radar): A technology similar to Radar to determine the distance, which uses radio waves instead of light.
- Infrared camera: A camera which is sensitive to heat radiation of objects.
- Vision: A vision sensor which collects light on a light sensitive backplate and distinguishes the object by image processing.

However, Sensor-based ADASs have limitations about weather interference and a line-of-sight nature problem. Also, the sensor-based ADAS requires each sensor for every service. In our project, we investigate a relative position based ADAS(RP-ADAS). It does not have a line-of-sight limitation and weather resistance. Also, it uses the same GPS and communication device for multiple ADASs. We divide the RP-ADAS into four main research areas: GNSS, VANET, Security/Privacy, and Application. In this paper, we only focus on GNSS area.

This paper organized as follows. In section 2, we present our Relative position based advanced drive assistant system. In section 3, we research the GNSS technologies and determine the appropriate ones. We also take performance evaluations in section 4. The conclusion shows in section 5.

II. RELATIVE POSITION-ADAS

A. Relative Positioning Technology

The most of VANET services utilizes vehicle's location information. For the reliable service, each vehicle should recognize its own location and others. To recognize own and others location, to the best of our knowledge, the relative positioning technology has been studied in GM since 2006[1]. Furthermore, the idea adapted to CICAS-V and VSC-A projects and still under researched. However, the projects are based on L1/L2 carrier GPS receiver and WAVE based communication device. High-cost L1/L2 receiver and un-widely deployed network infrastructure are main stumbling blocks to vitalize the VANET and RP-ADAS. Therefore, in our project, we consider a customer level (low-cost) GPS receiver and widely deployed networking technologies depending on the stage of VANET implementation.

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TABLE I
STAGE OF VANET IMPLEMENTATION

	Communication environment	Equipment s
Initial Stage	No WAVE based comm.	Cellular + WLAN
Pre-advance stage	Limited WAVE based comm.	Cellular +WAVE
Advanced stage	Fully utilized WAVE comm.	WAVE

Fig.1 and Table II presents the test-bed of VSC-A reference model and our RP-ADAS proposed model.

Fig. 1 Test-bed VSC-A and RP-ADAS

TABLE II
TEST-BED VSC-A AND RP-ADAS

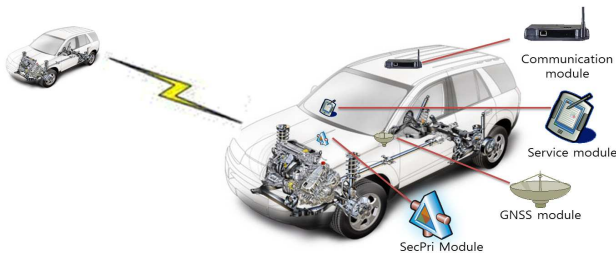|	VSC-A	RP-ADAS
GPS H/W	Standard GPS SBAS GPS RTK-GPS	Standard GPS SBAS GPS NDGPS RTK-GPS
GPS S/W	COTS	RTKlib
GPS Format	NMEA, Raw data	NMEA, Raw Data
GPS-Aid	Dead-Reckoning	None
Communication Device	IEEE 802.11p - DSRC	WLAN, LTE, (WAVE)
Msg. Format	SAE J2735	TCP/IP
Security	ECDSA-VoD	Not Defined Yet

B. Relative Position ADAS

Fig. 2 RP-ADAS modules

The RP-ADAS enabled vehicle has follow modules
1) GNSS module : Identifies own location using code and L1 carrier based GPS receiver
2) Communication Module : Establishes a VANET. Transmits location information and security/privacy relative message
3) SecPri Module : Supports security and privacy services for every transmit messages.
4) Services Module : Supports ADASs based on an In-Vehicle Infotainment(IVI) platform

The follow paragraph describes simple RP-ADAS operation with four modules. FCW, for example, is a key service for ADAS that prevents car crash by relative distance calculation. The former FCW uses a laser sensor by counting the reflected light time that has a line-of-sight limitation. In RP-ADAS, the GNSS module receives its position and transmits the information through the communication module. Every transmitted information is encrypted and privacy preserved by SecPri module. The service module receives the relative position information and calculates the collision possibility. If the possibility excesses the predefined threshold, it warns driver or decreases the vehicle speed.
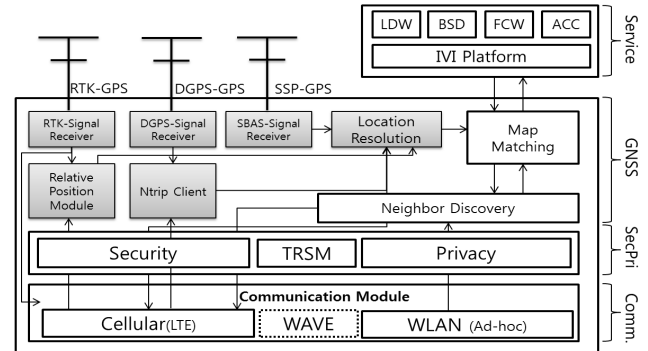

Fig. 3 RP-ADAS modules and Components

Each module has follow components
1) GPS & Signal Receiver: Receives the location signal continuously depending on the network and signal availability
2) Location Resolution: Absolute position is calculated with respect to a global frame based on the GPS signal
3) Map matching: Calculates its own position relate to neighbor vehicles
4) Relative Position: Calculates more precise position base on own RTK-raw data and neighbor's RTK-raw data
5) Ntrip Client : Corrects its own location by DGPS reference station's RTCM message
6) Neighbor Discovery : Identifies the neighbor vehicles upon the radio signal strength
7) Security: Provides security services
8) TRSM(Tamper-Resistant Security Module) : Stores and calculates key materials for security and privacy services
9) Privacy : Provides privacy services
10) Cellular : Receives and transmits the RTK-raw data, DGPS correction data, and service relative messages
11) WLAN : Collects a nearby vehicle's information with WLAN ad-hoc mode
12) WAVE : Replaces or supports Cellular & WLAN functions when the WAVE based network is well established
13) IVI : Manages hardware resources and provides APIs for ADAS software
14) ADAS(LDW, BSD, FCW, ACC) : Provides drive assistance services to drivers

Fig. 4 and Table III present RP-ADAS implementation environments

Fig. 4 Test-bed and screenshot

TABLE III
TEST-BED LISTS

	Features
GPS	SBAS, DGPS, RTK
System	Intel Atom Pineview-M N450, 1.66 GHz
S/W	Ubuntu 11.4 (OS)
	Crypto++ Library 5.6.1 (Crypto module)
	RTKlib (RP Module), BNC (Ntrip Client)
Programing	C, JAVA
Communication	LTE(R8), WLAN(802.11n)

III. GNSS

A global navigation satellite system (GNSS) is a system of satellites that provide autonomous geo-spatial positioning with global coverage. However, the satellite based positioning system has accuracy errors. The errors divide into three categories: system errors, receiver error (ex: Channel Noise), and satellite arrangement error (ex: Dilution Of Precision). In spite of the most error sources are uncontrollable and hard to control, the system errors can be removed by a differential GPS and a RTK. The follow table shows the GPS system errors and its values.

TABLE IV
GNSS SYSTEM ERROR

Error	Values
Satellite Clock Error	0~1.5 n
SV Ephemeris Error	1~5m
Ionosphere refraction	0~30m
Tropospheric refraction	0~30m
Selective Availability	0~30m

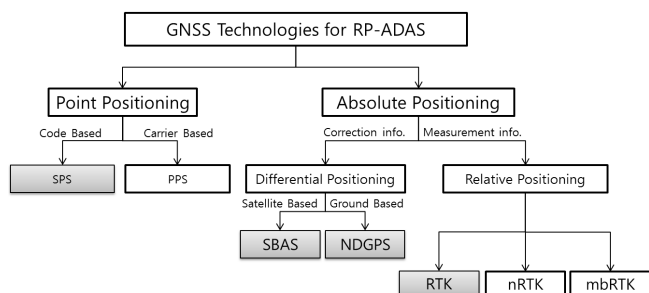We research known GNSS technologies and categorize them.

Fig. 5 GNSS Technology

1) Standard Positioning Service(SPS): The normal civilian positioning accuracy obtained by using the single frequency C/A code. Without any augmentation or correction sources.

2) Precise Positioning Service(PPS): The most accurate dynamic positioning possible with the standard GPS, based on the dual frequency P-code and no SA. PPS was designed primarily for U.S. military. It will be denied to unauthorized users by the use of cryptography.

3) Satellite-based augmentation system (SBAS): A system that supports wide areas or regional augmentation through the use of additional satellite-broadcast messages. Such systems are commonly composed of multiple ground stations, and located at accurately-surveyed points.

Depending on the service area, it can be called as WAAS(USA), EGNOS(European), or MSAS(Japan). In Korea, some areas can receive the MSAS signal.

4) Nationwide Differential Global Positioning System (NDGPS): A ground-based augmentation system that provides GPS accuracy within three feet. Initially developed for the Coast Guard, it was enhanced to cover the entire country. NDGPS is used by highway and road crews as well as by the police, but is available to anyone with an NDGPS receiver. In this paper, we receive correction information through the cellular network using a BNC ntrip client. The base-station should be located within 80km.

5) Real-Time Kinematic(RTK): a process where GPS raw measurement signals are transmitted in real time from a reference receiver from a known location to one or more remote rover receivers. The use of an RTK capable GPS system can compensate for atmospheric delay, orbital errors, and other variables in GPS geometry, increasing positioning accuracy up to less than a centimeter. The limitation of traditional RTK is that some distance-dependent errors will increase in proportion to the length of the baseline between the rover and the reference station(10~20km)[2].

6) Network RTK(nRTK): To overcome the single RTK distance limitation. A nRTK server collects the raw observations from a number of reference stations, and sends corrections to a rover positioning terminal after carrying out an integrated processing. The rover then combines these corrections with its local carrier phase observations, to obtain a high accuracy real time positioning solution. The separation between the NRTK reference stations can be extended to 100km[3]. However, it lacks availability of Cell Coverage for all country and computational overhead for every vehicle.

7) Moving Base RTK(mbRTK): mbRTK differs from conventional RTK positioning, where the reference station remains stationary at a known location, while the rover moves, by allowing both the reference and rover receivers to be moving whilst calculating a centimeter accurate 3D vector between them. In its simplest form, the Moving Base RTK solution provides an absolute position accurate to the autonomous GPS level (approximately 20m). However, the enhanced Moving Base RTK is allowed for either shore or satellite broadcast DGPS, or shore based RTK corrections to be included in the solution.

TABLE V
CONSIDERATIONS FOR RP-ADAS GNSS MODULE

	Accessibility (Satellite)	Standard alone	S/W Independency	Scalability	Price	Accuracy[4]
SSP	O	O	O	O	Low	428.9cm
PPS	X	O	△	O	High	135.7cm
SBAS	△	O	O	O	Low	109.2cm
NDGPS	O	X	△	O	Low	126.0cm
RTK	O	X	X	△	Mid(L1), High(L1/L2)	13.1cm
nRTK	O	X	X	X	Mid(L1), High(L1/L2)	-
mbRTK	O	△	X	O	Mid(L1), High(L1/L2)	-

We also determine considerations for the RP-ADAS's GNSS module

1) Accessibility: A special purpose satellite supports anthologized groups or special areas
2) Standard alone: For the location accuracy, a rover requires a reference station's correction information
3) S/W independency : Some GNSS technologies requires not only the signal analyzer but also the extra functioned software
4) Scalability: For the RP-ADAS, the GNSS should support unlimited number of receivers
5) Price: For the wide implementation, the module price must be reasonable.
6) Accuracy: For the "which-lane(less than 1~1.5m)" and "which-road(less than 5m)" level services requirements[5].

We analyze seven GNSS technologies in Fig.5 based on the six considerations in table 5. According to our analysis, the SSP satisfies all the considerations for the "which-road" level accuracy. The PPS has limited accessibility for military and authorized groups. It is not appropriate to general users. The SBAS also supports limited areas such as Europe, USA, Canada, Japan, and some Asian countries. The NDGPS requires infrastructure communication devices for correction information. Therefore, it depends on the network availability (not standard-alone). The RTK also requires a communication device and 10km baseline between the rover and the reference station(low scalability). It is not appropriate to the vehicle movement pattern. The nRTK overcomes the RTK scalability problem(10km baseline limitation) by the virtual reference station. However, the nRTK is based on a server calculation. It is not appropriate on a large number of vehicles. The mbRTK uses the neighbor vehicle as the reference station. Therefore, it is free from to baseline limitation and server overhead. We select the SSP, SBAS, NDGPS, mbRTK as the RP-ADAS GNSS technologies. We take performance evaluations for the SSP, SBAS, and DNGPS. As the mbRTK requires additional studies about s/w requirements, we will consider it in our future work.

IV. PERFORMANCE EVALUATION

For the GPS receiver performance evaluation, we measure the accuracy and the precision.

1) Accuracy: The degree of closeness of measurements of a quantity to that quantity's actual (true) value.
2) Precision: The degree to which repeated measurements under unchanged conditions show the same results.

For the relative positioning system, we also re-define the relative position measurement based on the precision.

3) Relative Position: The degree of value differences of two receivers in the same circumstances: Receiver, Time and Position.

A. Evaluation Scenario

1) Accuracy

To measure the accuracy, we use a geographically known position 'A'. We locate the GPS receivers and compare the measured data with the known position.

Fig. 6 Position A (Lat : 37 °17'42.76'', Lon : 126 °58'39.76'')

2) Precision

To measure the precision, we use an average value of each GPS receiver. First, we calculate the average value. Second we compare the average value and the received value for difference. Third, we sum up all the differences. The measurement took in position 'B'.

Fig. 7 Position B(Lat : 37 °17'30.59'', Lon : 126 °58'41.14'')

3) Relative Position

To measure the relative position, we use the two same GPS receivers. We also execute the evaluation in the same position at the same time. Then we compare two GPS receivers' values for difference. The measurement took in position 'B'.

Fig. 8 Position B(Lat : 37 °17'30.59'', Lon : 126 °58'41.14")

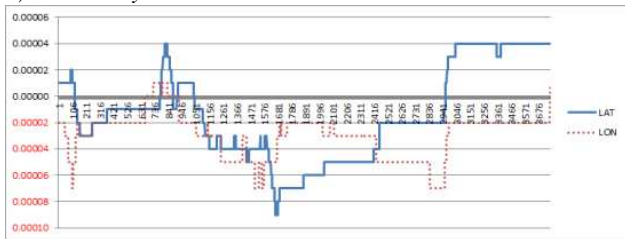*B. Evaluation Result*

1) Accuracy

Fig. 9 Accuracy of SSP receiver

The SSP's accuracy rate of lat. is 0.6% and lon is 0.4%. The max aberration of lat. is 9m and lon. is 7m. The average aberration of lat. is 1m and lon. is 3m.
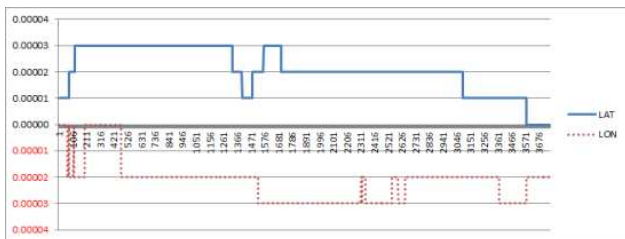
Fig. 10 Accuracy of SBAS receiver

The SBAS's accuracy rate of lat. is 4.7% and lon is 9.2%. The max aberration of lat. is 3m and lon. is 3m. The average aberration of lat. is 2m and lon. is 2m.

Fig. 11 Accuracy of DGPS receiver

The DGPS's accuracy rate of lat. is 0.0% and lon is 0.0%. The max aberration of lat. is 11m and lon. is 13m. The average aberration of lat. is 6m and lon. is 8m.

2) Precision

The SSP's total changes of lat. is 6224m and lon. is 5779m. The average change of lat. is 2m and lon. is 2m.
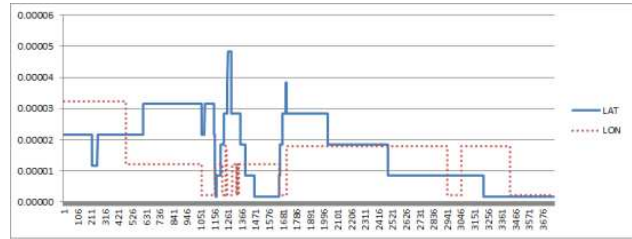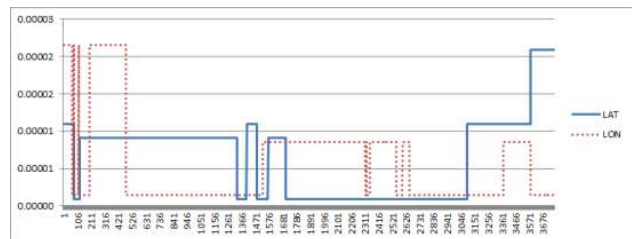

Fig. 12 Precision of SSP receiver

Fig. 13 Precision of SBAS receiver

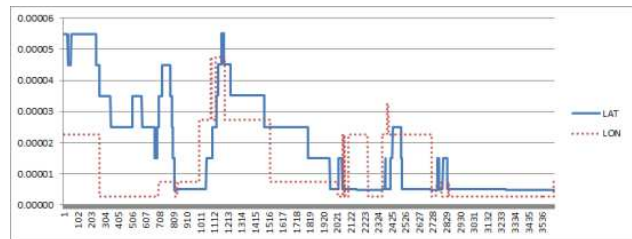The SBAS's total changes of lat. is 2445m and lon. is 2146m. The average change of lat. is 1m and lon. is 1m.

Fig. 14 Precision of DGPS receiver

The DGPS's total changes of lat. is 6803m and lon. is 4373m. The average change of lat. is 2m and lon. is 1m.
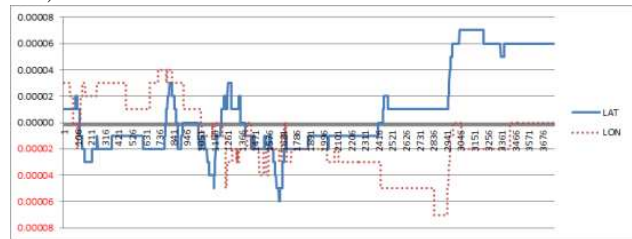
3) Relative Position

Fig. 15 Relative Position of SSP receiver

The SSP's concordance rate of lat. is 6.1% and lon. is 14.6%. The max gap of lat. is 7m and lon. is 4m. The average gap of lat. is 2m and lon. is 2m.

Fig. 16 Relative Position of SBAS receiver

The SBAS's concordance rate of lat. is 0.0% and lon. is 0.5%. The max gap of lat. is 7m and lon. is 5m. The average gap of lat. is 3m and lon. is 3m.
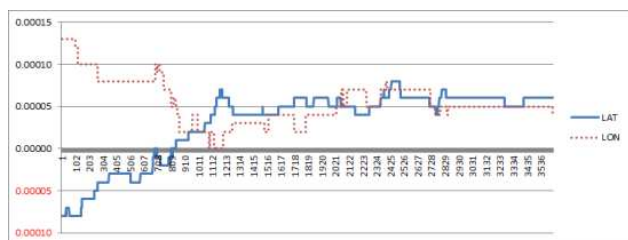

Fig. 17 Relative Position of DGPS receiver

The DGPS's concordance rate of lat. is 1.1% and lon. is 1.9%. The max gap of lat. is 8m and lon. is 13m. The average gap of lat. is 5m and lon. is 6m.

C. Evaluation Result

1) Accuracy: We don't use an absolute positioning of two vehicles. Therefore, the accuracy is not a critical factor but a reference factor to determining the GNSS technologies for RP-ADAS. The SSP and NDGPS show the lowest accuracy rate. Relatively, the SBAS has the higher accuracy rate(7%). The average aberration of the SSP and SBAS is the same as 2m. The DGPS has the 7m average aberration. However, we should pay attention to the stable DGPS values after 1819 second.

2) Precision: The precision is required for the reliable and stable positioning. The SBAS shows the lowest values of changes and average changes. The SSP and the DGPS have the same changes and averages that are three times higher than the SBAS.

3) Relative Position: This is the most important factor for RP-ADAS. We define three requirements: the high concordance rate of relative position value, the stable gap of relative position value, and less than 1m of relative position gap. The SSP has the highest concordance rate among the GPS receivers, but it is not reasonable for RP-ADAS. The average gap of the SSP is 2m that is 1/3 of others. The SBAS has the stable gaps. However, for the relative positioning system, it should be less than 1m.

V. CONCLUSION

In this paper, we design the RP-ADAS and the research areas are divided into four. For the first step, we investigate the GNSS technologies for RP-ADAS. We categorize them and define six

requirements. We choose four GNSS technologies among them and take performance evaluation: SSP, SBAS, NDPGS, and mbRTK. As a result, the SBAS shows a reliable measurement. Also, we figure out that the C/A code base GPS technologies are inappropriate for 'which lane-level' application. However, they can be used as a 'which road-level' application. For the future work, we will investigate a relationship between reference distance and measurements of the DGPS. Despite the correction information, the DGPS shows the unusual result compared to that of the SBAS.

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