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THE MEASUREMENT COMPARISON OF LANE WIDTH USING SEVERAL SENSORS UNDER THE DIFFERENT SUNLIGHT CONDITIONS

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ABSTRACT

Road lane width is important information not only road management but also autonomous vehicle. Especially, it is normally known that most of autonomous vehicle will use the road lane marking for keeping the travel the road. To measure the lane width, the road lane marking should be detected and then the lane width measured by calculating the interval of two lane markings. The camera and LiDAR are usually used for lane marking detection. However, the performance of each sensor is depend on the sunlight. To compare the performance lane marking recognition, the lane width was selected for performance index. The camera and 3D LiDAR sensors installed on the road survey vehicle and the lane width was measured. The test was conducted on the Korean National Highway and the measurement result from each sensor was compared with the actual lane width. As a result, after the sunrise, the RMSE of camera was 0.19 and the RMSE of 3D LiDAR was 0.34. It was shown that the result from the camera was more favorable compare with the LiDAR. However, before sunrise although the camera could not detect the lane marking, the LiDAR detected the lane marking and measured the lane width as a result of 0.33 RMSE. In conclusion, even though the camera affected by the illumination in terms of recognition objects, the LiDAR is not affected by the illumination.

Keywords: *Road Lane, LiDAR, Camera, Traffic Safety*

I. INTRODUCTION

Various studies and technologies have been developed and proceeded in order to improve the safety of the road domestically and internationally and especially, the development of the technologies to decrease accidents due to human factors among traffic accident triggers is being proceeded. According to the actual analysis of the main causes of the Road Traffic Accidents, it is being reported that over 90% of the traffic accidents are occurring due to human factors. Lane Departure Warning System(LDWS), Smart Parking Assist System(SPAS) and Advanced Driver Assistance Systems(ADAS) as the various methods to reduce accidents due to human factors are being developed and used actually, which focus on supplementing the safe driving of the driver. Recently, being developed from the simple system which helps the safety driving of the driver, the vehicle in which the driver does not manipulate the steering wheel, but which drives mindlessly through the object recognition by the vehicle itself has passed the test driving and is driving actually on the road. For this unmanned vehicle to drive, the recognition of street structure technology for the actual section that the vehicle drives and the positioning technology are required necessarily, through which the street furniture should be recognized on-line which exists on the road. The median barriers, curbs and lanes and so forth which compose the basic elements of the road among the facilities existing in the road are the objects which should be recognized necessarily for safe driving of the unmanned vehicle. Especially, the recognition of the street furniture should be possible under various conditions which reflect the actual driving environment and an accuracy of over a certain level should be guaranteed as well. Especially, in case of the lanes, they are the element which should be recognized necessarily to secure the driving safety of the vehicle and to ensure safe driving by differentiating the vehicle groups and up to now, the lanes are detected and width of the lane is measured using the image recognition or LiDAR.

Thus, this study has selected lanes and widths of the lanes as the object for recognition among the road factors which should be recognized necessarily by the unmanned vehicle and compared the results of the accuracy measured under various conditions. To proceed the research, the National Highway which was relatively recently and thus of which the road condition is favorable was selected and as the equipment to measure and recognize the width of the lane through the actual measurement, the CCD camera and 3D LiDAR were used.

II. LITERATURE REVIEW

This chapter reviewed the existing studies which focus on recognizing the road information using various sensors.Choi et al. (2012) have studied on the visual Odometer to presume the location of the vehicle driving in the road environment. For the position recognition, the stereo camera to acquire the 3 dimensional information in the front of the vehicle and the single camera to acquire images from the back of the camera were used. An experiment was performed about two long-distance routes acquired under the actual driving environment, and according to its result, over 97% of the matching success rate was showed, which proposed the conclusion that the methodology used in this study can presume correct position. Jang (2005) used the digital video camera and shot and analyzed the road paved in asphalt concrete and extracted the information on the road. He has compared the result with the outcome by way of the measurement of the base point and analyzed them and proposed the average errors of 0.0427m for the X axis, 0.0527m for the Y axis and 0.1539m for the Z axis. Also, the cracking rate, plastic deformation and longitudinal roughness, the road surface evaluation factors were able to be obtained through the processed image, through which the commonality index and maintenance index were calculated and the road evaluation was performed in the object road. Kim andLee (2008) has performed the study of creating 3 dimensional geometric model of the road automatically by using the LiDAR data and numerical map. They have identified the points measured in the road surface through the division and grouping process of the Data Cloud inside the road section and have extracted the linear and surface information of the road. Yun et al. (2006) have proposed the way of measuring the cross slope of the road by using the vehicle for analysis of road safety. They have developed the algorithm which measures the cross slope during driving, using the vehicle which is equipped with the GPS-IMU and laser scanner and compared it with the actual data and verified statistically. MunandSeo (2008) have developed the image analysis model which can measure swiftly using the line scan camera for the facilities of which the installation interval and heights are regularized according to the design(operation) speed and geometric structure among various road safety facilities. They have applied the developed model on the site and proposed the measurement results of the sizes and installation intervals of the facility. Jung et al. (2011) have performed the study of using the vehicle in which GPS-INS is installed and collecting the geometric structure information. They have used the Genetic Algorithm and developed the algorithm to analyze the horizontal alignment and differentiated the direct line, curve and easement curve and so forth. The algorithm was evaluated using the freeway and national highway data and it was analyzed that each showed 90.48% and 88.24% of classification accuracy. Jang et al. (2015) have used the fact that the lanes are brighter than the road and extracted the characteristics of being strong to the illumination using the difference between the lanes and the surface of the road and the width of the lane and by using the extraction result of the characteristics, detected the straight lanes. By using the detected straight line and camera information, candidate curve groups were created in the 3 dimensional road and curve lanes among which the curve lanes were determined. Also, the speed and accuracy were improved using the detection information of the previous frame so that curve lanes can be traced swiftly in continuous frames. Kim et al. (2013) created a few putative factors for tracing through the combination of the characteristics of the Background Subtraction, LK-Optical Flow and community-based histogram, through which they proposed the tracing method which is relatively strong to the objects with change and noise. In other words, they have proposed the method of reliable tracing for external environment also through the verification method of the characteristic points traced by the optical flow which is strong to the change of the color and illumination, verification based on the regional histogram and the mixing method of these tracking. The laser distance sensor was used to propose the method of swift recognizing of the surrounding environment in urban environment made for an unmanned vehicle. Data was collected using the laser sensor and continuous points classification was performed, and detection and removal of the ground, object division and object classification tasks were performed. The conclusion was proposed that the real-time of the surrounding environment recognition algorithm of the unmanned vehicle was secured through the methods proposed in this study. Kim et al. (2013) have proposed the method of recognizing the obstacles real time in the actual road condition using the LiDAR. They have classified the scanned data into the date inside the road and data outside the road and the data inside the road was clustered suing the Euclidean Distance. They also have obtained the location and size of the detected obstacles and calculated the speed and distance. The effectiveness of the algorithm has been verified using the LiDAR installed in the front bumper of the unmanned vehicle and the result of a swift 2ms of performance time has been proposed.

III. OVERVIEW OF ANALYSIS

The GPS-IMU to measure the location information and the image equipment or LiDAR to measure the objects are needed for the recognition of the lane and the measurement of the width of the lane. Information on each sensor used in this study is as follows.

3.1 Sensors

The LiDAR sensor used in this study is the PUCK(16 channels) by Velodyne. The PUCK(16 channels) of Velodyne detects the scope of 360° horizontally and recognizes objects using 16 LiDARs per each 2° at 30° angle vertically. The points cloud can be measured up to 100m maximum. And, This study has selected the Manta-G 125 in order to measure the width of the lane using the images. The CCD(Charge Coupled Device) camera was installed to collect the image of the section driven and the resolutions of the camera installed were 1936 X 1456, 40 FPS(Frame Per Second) and CCD Progressive shape for the shooting. Table 2. has proposed the specification of the video equipment.

3.2 Data Acquisition System

The investigation equipment for road inspection was used as the data acquisition system in this study. The vehicles in which each sensor was installed was used and the data collected through the sensors were synchronized based on the GPS-IMU location. The installation of sensors was showed Figure 1.

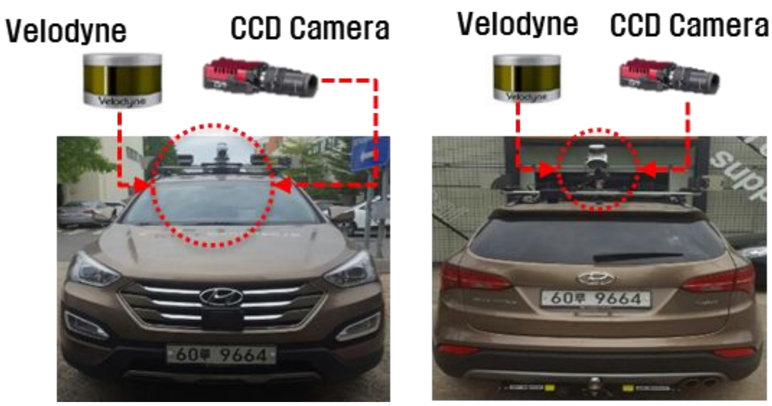

Figure 1. The installation of Sensors

3.3 Summary of the experiment

Result measured in the National Highway No.37 sector was proposed for the comparison of the widths of lanes. The detection was made for 1.6km road and the driving speed was 80km/h on the average. The object section used for the analysis of the width of the lane was a section which was constructed 15 years ago and is relatively good condition and the width of the lane of the object section was measured through actual measurement. As the representative time for the comparison between night and day, the measurement was made before and after the sunrise based on the sunrise time (5:12AM).

IV. METHODOLOGY FOR ANALYSIS

This study has used the LiDAR and the image equipment in order to recognize the lane for an unmanned vehicle to drive and measure the width of the lane to drive along and this chapter proposed the process for the measurement of the width of the lane.

4.1 Detection of width of the lane using the LiDAR

The 3 dimensional LiDAR used in this study can measure the 3 dimensional coordinate values(x, y, z) from the sensor to the point and intensity reflected in the object. The lanes were recognized through the intensity measured by the LiDAR and reflected and for the detection of the width of the lane, the plane coordinates were extracted among

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the 3 dimensional coordinates and reflected into the X-Y axis coordinates and the threshold that the lanes are detected were deducted. The ROI was configured to improve the accuracy and detection of the lane and was set to be 5m in the rear and 5m in the right and left from the center of the LiDAR installed in the vehicle. Also, the 180° needed in the rear was set to be FOV(Field of View) and the data acquisition cycle was set to be 10Hz. The scope of intensity acquired in the Velodyne was 0 ~ 255, the average intensity of the road paved in asphalt was under 20 and the intensity about the lane was under 60. As the result of the analysis result through the pilot test performed in this study, the case that intensity was detected to be over 45 was used as the threshold about the detection of the width of the lane. The intensity of over the threshold was detected through the Velodyne and the lane was detected and the right and left side from the center axis of the vehicle was searched and the width of the lane was calculated.

4.2 Detection of the width of the lane using the image

The camera installed in the front of the vehicle was used in the measurement of the width of the lane which uses the image. Calibration has been performed for correct measurement of the width of the lane and as in the figure 2, focus boards were installed in 2m intervals for the calibration and the image was acquired and the actually measured distance information was matched to the pixel coordinates of the image.

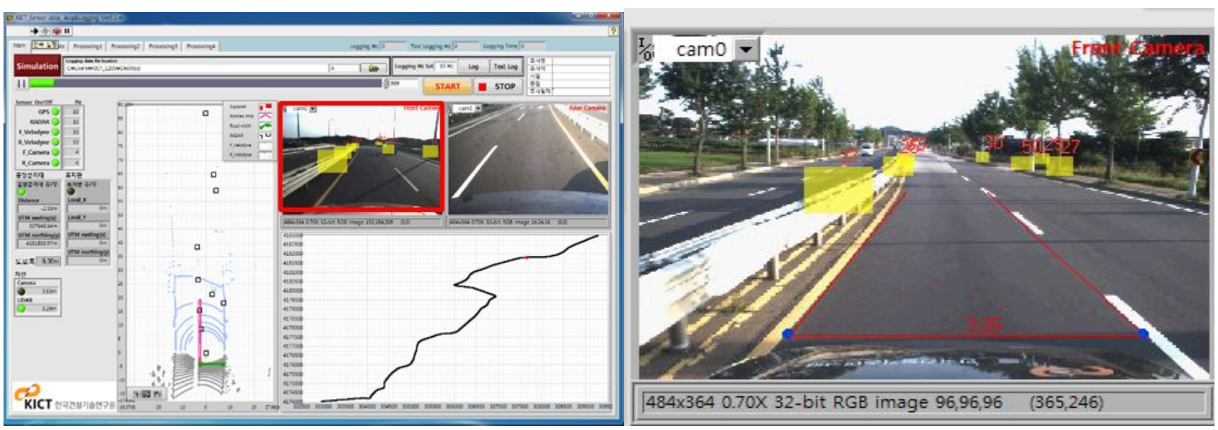

Figure 2. Display for Acquisition of Lane width

V. ANLYSIS RESULT

Measurement result of the width of the lane through the measurement, image and LiDAR of the section of the National Highway No. 37 for the comparison of the width of the lane and the compared errors were proposed. In the result of the measurement before the sunrise, in case of having used the image, the width of the lane was not measured and in case of having used the LiDAR, the minimum width of the lane was 2.4m, maximum width of the lane was 3.79m and the average width of the lane was 3.23. After the sunrise, in case that the LiDAR was used, the minimum width of the lane was 2.61m, maximum width of the lane 3.79m and the average width of the lane was 3.34m. The RMSE of the measurement result of the width of the lane using the LiDAR before sunrise was 0.33, RMSE of the measurement result of the width of the lane using the image after the sunrise was 0.19 and the RMSE of the measurement result of the width of the lane using the LiDAR was 0.34. According to the analysis result, a difference about image recognition result existed for during the day. The Result was shown on table 1.

Table 1. The Result of Lane Width Measurement and Absolute Error

The result		Before the sunrise		After the sunrise	
		Image	LiDAR	Image	LiDAR
Result of Measurement	Minimum(m)	None	2.40	2.61	2.40
	Maximum(m)	None	3.79	3.79	3.79

	Average(m)	None	3.23	3.34	3.21
Result of absolute error	Minimum absolute error(m)	None	0.00	0.00	0.00
	Maximumabsolute error(m)	None	1.29	0.78	1.10
	Averageabsolute error(m)	None	0.07	0.04	0.09
	RMSE(m)	None	0.33	0.19	0.34

VI. CONCLUSION AND FUTHER STUDY

This study has selected lanes and widths of the lanes as the object for recognition among the road factors which should be recognized necessarily by the unmanned vehicle and compared the results of the accuracy measured under various conditions. According to the analysis result, the after the sunrise, the averages of the widths of the lane using the image or LiDAR were 3.34m and 3.21m and the RMSE was 0.19 and 0.34 and thus it was shown that the measurement of width of the lane using the image was more favourable in the phase of the accuracy. However, before the sunrise, the width of the lane was not detected in the image and in the case of the measurement of the width of the lane using the LiDAR, the average was 3.23m and the RMSE was 0.33 and thus the limitation of the measurement of the width of the lane using the image was proposed.

The following study is needed for the development of this study. First, collection of a large amount of data is needed for various sections. More objective results should be approached by expanding the analysis scope and object section. Second, Improvement of the comparison, verification and recognition method of various sensors is needed. Accuracy of measurement should be able to enhance through this. Third, most of car manufacture companies want to use camera when detect the object the road facilities and objects to minimize the cost. However, the camera has its limitation for detection the object under the low illumination condition. To make up for the limitation of camera, the new concept of road facilities such as self-illuminated road facility should be developed. Lastly, a study is needed in which technology which recognizes other road facilities other than the width of the lane which was the object of this study can be developed and analyzed.

It is expected that the result of this study can become a basic study which can help the unmanned vehicle to recognize the street furniture and drive

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