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DEVELOPMNET STRATEGY OF THE ROAD SAFETY SURVEY AND ANALYSIS VEHICLE : ROSSAV

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Abstract : The objective of this research is to develop a strategy to build a mobile system which can be useful for the road safety analysis. Most commonly used data for the road safety analysis are road geometric information. In order to collect and analyze road geometric data, various sensors were tested and installed to collect position data, attitude data, and image data. The development strategies for the RoSSAV are suggested for the various sensors, signal synchronization devices, and the applications of sensor data. Based on the research performed, first, road data acquisition schemes were made; second, required sensors were defined; third, a proto-type analysis vehicle was developed; fourth, a signal synchronization device for the multiple-sensors were designed and developed; fifth, a three dimensional image analysis software was developed.

Key Words : Highway Alignments, GPS, IMU, CCD, Synchronization Devices

1. INTRODUCTION

Existing roads were often designed and constructed based on the minimum design values and thus those were overly simplified drivers' needs. In many cases, the road design criteria do not suggest the desirable range of the design values but suggest the minimum requirements for the road design. Therefore, a completed road design based on the design criteria does not always guarantee the best design in terms of safety and it sometimes contradicts drivers' expectation. As a result, it will increase drivers' psychological burden while they are driving. In order to evaluate the drivers' expectancies in the real world, three dimensional road alignments are needed along the roads. Most analyses of highway alignments are done using the highway drawings(KICT, 2003). However, in many cases, highway drawings are not always available and they are inconvenient to be used for the analysis of a long highway section along the route. For this purpose, it is necessary to develop a road safety information collection and analysis vehicle with various sensors which can collect locational information. The multiple sensors which are used for this project are GPS(Global Positioning System), IMU(Inertial

Measurement Unit), DMI(Distance Measuring Instrument), and CCD cameras.
The objective of this research is to develop a mobile system which can collect road geometric data to evaluate the road safety and analyze road deficient sections along the roads from the collected data. In order to collect road geometric data, various sensors were installed to collect road alignments, road facilities' locational information, and attributes. Using the collected locational information and attributes, road alignment reconstruction algorithms for the horizontal curve sections were developed as a part of the RoSSAV research.

2. DEVELOPMENT OF ROAD SAFETY SURVEY AND ANALYSIS VEHICLE

2.1 Acquisition of Position Data

GPS(Global Positioning System) and IMU(Inertial Measurement Unit) are widely used to obtain the position data and orientation data. Highway alignment information can be obtained with accurate spatial coordinates. GPS has high position velocity accuracy over the long period of time and provides uniform accuracy which is independent of time, but it has low measurement output rates and noisy attitude information. IMU has high position velocity accuracy over the short period of time, accurate attitude information, and no signal outages, but it gives cumulative errors with time. Integration of GPS and IMU provides high position and velocity error, high data rate and navigational output during GPS signal outages.

2.2 Digital Image Acquisition

In order to acquire highway image, two CCD(Charge-Coupled Device) Cameras and frame grabbers were installed in the RoSSAV. The digital image acquisition software was developed and installed in the RoSSAV. Two front view color CCD cameras are used for the front view image acquisition on the top of the vehicle, and two black and white side down-looking CCD cameras are used for the lane making images, installed left and right side on the top of the vehicle. Frame grabbers are used to acquire and save images and to connect with the digital image acquisition software. For the front view cameras, it is known to be better having a wide baseline distance between cameras, and having higher position from the ground to reduce the influence of obstruction. If the measuring distance is relatively long, positional errors are rapidly increased. Therefore, the images taken from the distance within about 35m from the camera to objects are used for the calculation of the three dimensional positions. For the side down-looking cameras which will obtain lane markings, the higher heights from the camera to the ground the wider ground areas.

(1) Front View CCD Cameras

Two front view CCD cameras were installed on the top of vehicle. The baseline distance between two cameras was 1.8m and installation height from the ground was 2.14m. The right camera was installed to view the front and the left camera was rotated 3 degree to the right side. The output images which were taken 35m ahead from the left and right cameras perfectly duplicated. If the images from the RoSSAV which were taken in the outermost lane on the four-lane highway in both directions, then the three dimensional position can be analyzed from the images of highway and roadside facilities. Because the images from the RoSSAV can be taken every 10 m, the similar coverage areas can be duplicated resulting in the higher reliability in data collection.

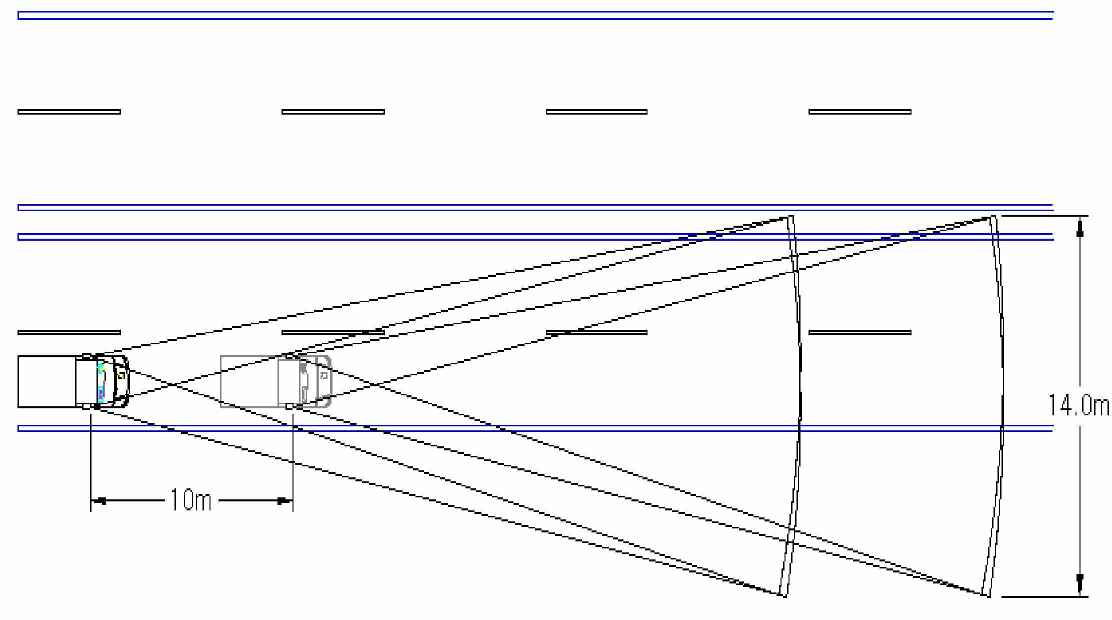

Figure 1. Ground Coverage Area from the Front view Cameras

The height appears differently depending on the observing distance. The observing distance is defined as a distance from camera to the ground point which meets the extended line of the center of camera angle. As shown in Figure 2, if the observing distance is 35m, the height of 5.283m can be covered at the 35m observing distance, and if the observing distance is 50m, the height of 5.925m can be useful height of the covered area based on the 35m observing distance. Testing observing distance based on the height of the measuring objects is required because the covered height according to the observing distance. Figure 3 shows the measurable height according to the observing distance.

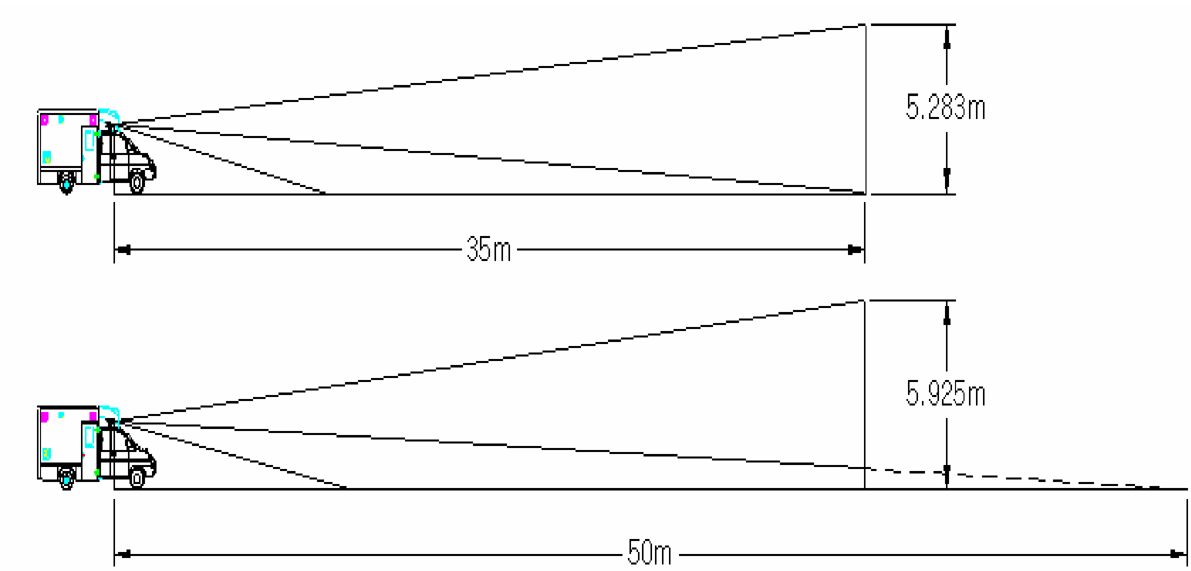

Figure 2. Measurable Height According to Observing Distance

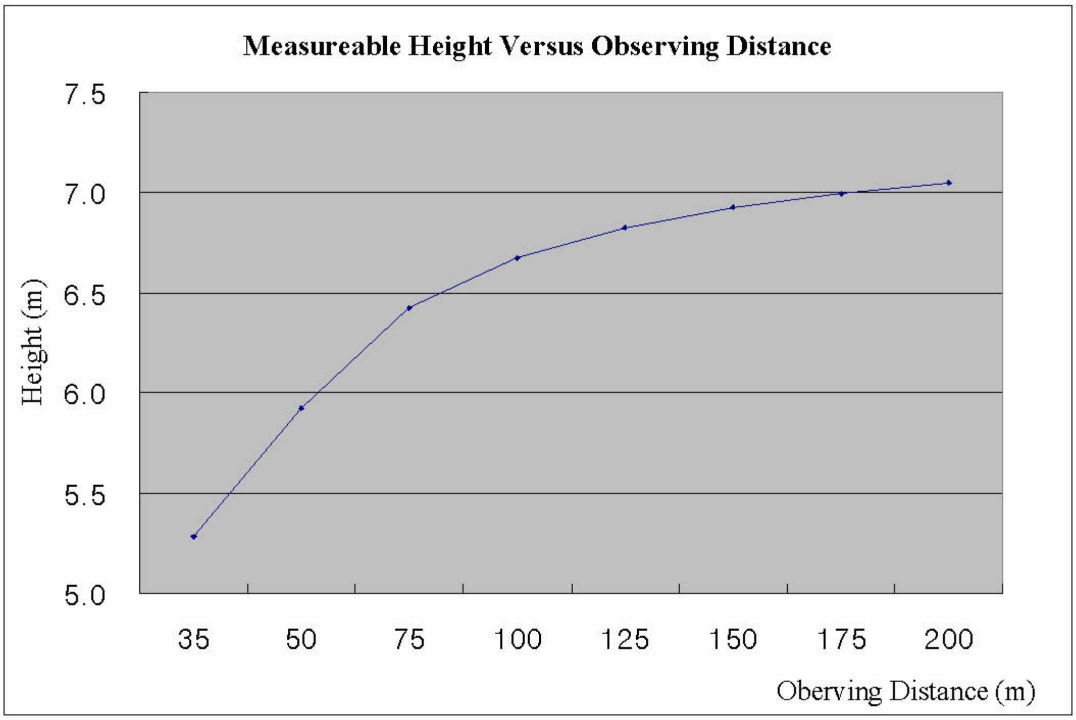

Figure 3. Measurable Height Versus Observing Distance

(2) Side Down-looking CCD Camera

In this study, the reason for using two side down-looking cameras are to obtain the highway lane making images, to measure the width of lane, and to check the vehicle driving trajectory. The side down-looking camera is different with the front view camera in terms of the fact that the distance from camera to ground point is known. Two side down-looking cameras were installed on the left and right side top of the RoSSAV.

To increase the ground cover areas the height of the camera position should be higher. However, by considering the stability of camera support, it should not be too high. The width of highway lanes is normally 3.0 to 3.5m. The camera should be installed to be tilted to take the images which include vehicle and two lane markings. For this study, the position of camera are installed with 2.7m height and 12° 52´ 11´´ tilted outside of the vehicle. The coverage area is 1.6m by 1.3m. If the images taken from the side down-looking cameras for every 1m, there will be duplication for the consecutive images about 60cm. Figure 4 shows the duplicated areas. The duplicated areas are important to tracking the continuity of lane marking in cases of the alignments with the radius of curve is small or lane markings are missing.

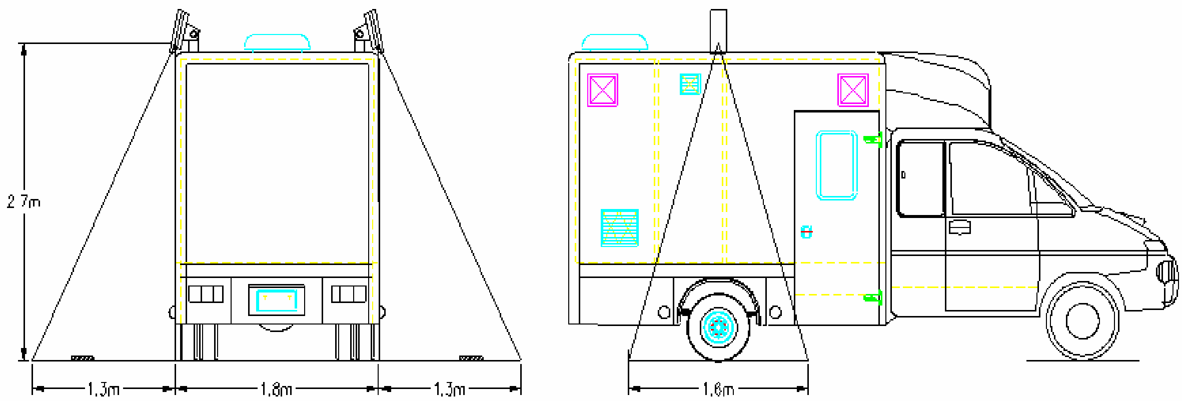

Figure 4. Ground Covered Areas by Installing Down-looking Cameras

2.3 Synchronization of Multiple Sensors for the Integration of Information

Individual sensors have their own signals with the different time interval and the information acquisition times for each individual sensor are not identical. Therefore the synchronization process is needed to integrate the information based on time(Yoon et al, 2003).

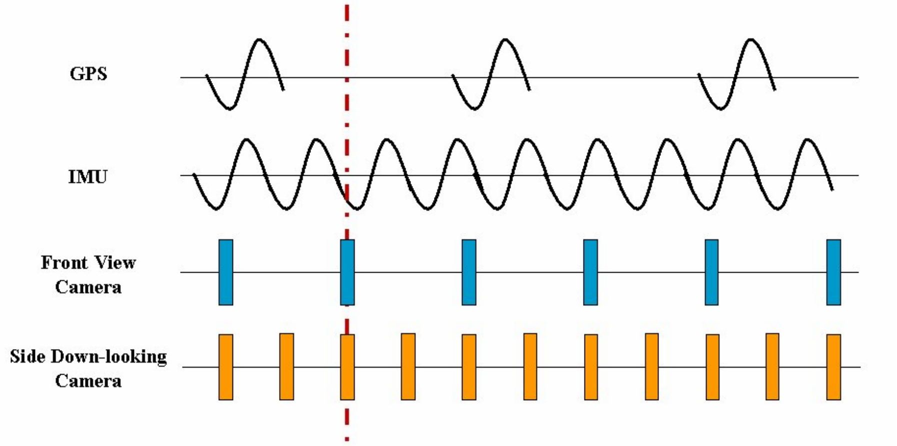

Figure 5. Different Information Acquisition Time for Each Sensor

In this study, an external synchronization device was developed to integrate information and synchronize the signals from the CCD camera, GPS receiver, IMU, and DMI. From the external synchronization device, constant signals will be sent to CCD camera and computers to get synchronized. In the development of external synchronization device, GPS time in 1 PPS(Pulse/Sec) signals from the GPS receiver was divided into 1/1000 second. By providing 1/1000 second time information to each sensor, the signal acquisition time can be interpreted. It was developed that time division can be reset when 1 PPS signal come into the device. Also the external synchronization device can record the number of rotations from the DMI and generate and send signal to the two front view CCD cameras and two side down-looking cameras through trigger signal. Figure 6 shows the signal synchronization device for the integration of data.

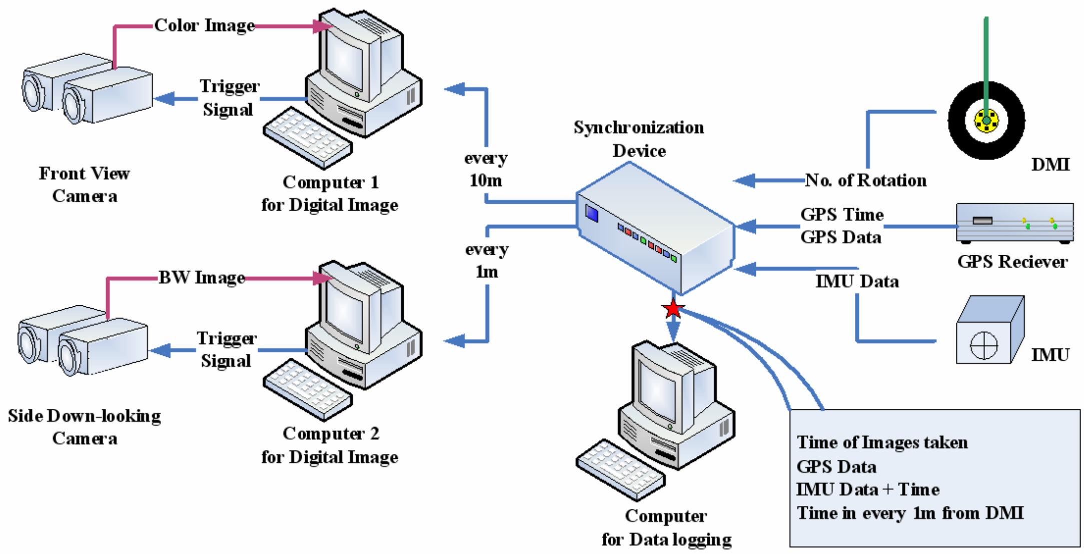

Figure 6. Signal Synchronization Device for the Integration of Data

2.4 Application Software for the Digital Photogrammetry

Digital image acquisition Software can be used for the analysis of highway alignments, roadside facility management. The three dimensional positions of highway facilities can be determined through the digital photogrammetry. Figure 7 shows the developed procedure of three dimensional position analysis(Jeong et al, 2004).

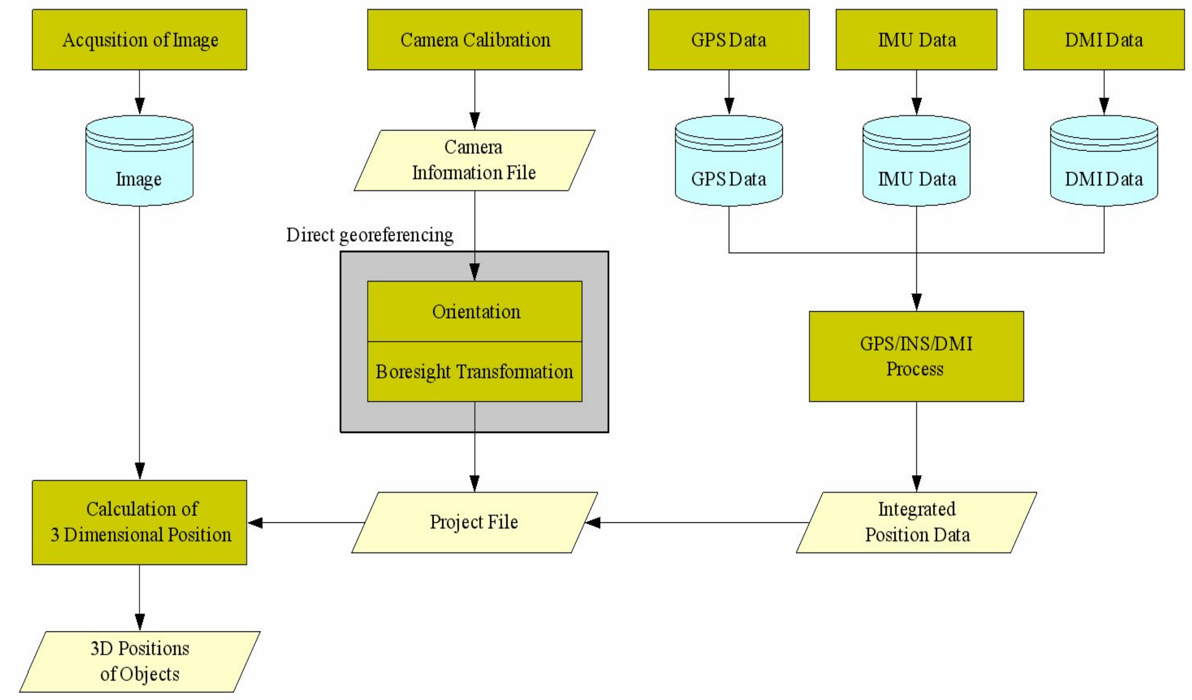

Figure 7. Three Dimensional Position Analysis Process

In Figure 7, the camera information file includes orientation information through the camera calibration process such as effective pixels, number of cells, and so on. The project file includes the information about time of image taken, route number, beginning position, and vehicle position and attitude information when images taken. All other information which is needed for three dimensional position analysis will be added to the project file. During the camera calibration, camera focal length, locations of principal points, and camera lens correction coefficients are calculated. This process is to check the characteristics of the camera used, and therefore if there is no significant change in camera position, this is performed only once before camera is used. Image data, GPS data, IMU data, and DMI data will be saved in the computer with the precise time information. The process of direct geo-referencing is composed of orientation module and Boresight transformation module. Before the three dimensional position analysis, name of image and integrated GPS/IMU data are matched and recorded in the project file. In the three dimensional position analysis, the three dimensional position of object is calculated. Figure 8 shows the front view image software which is used for the three dimensional position analysis.

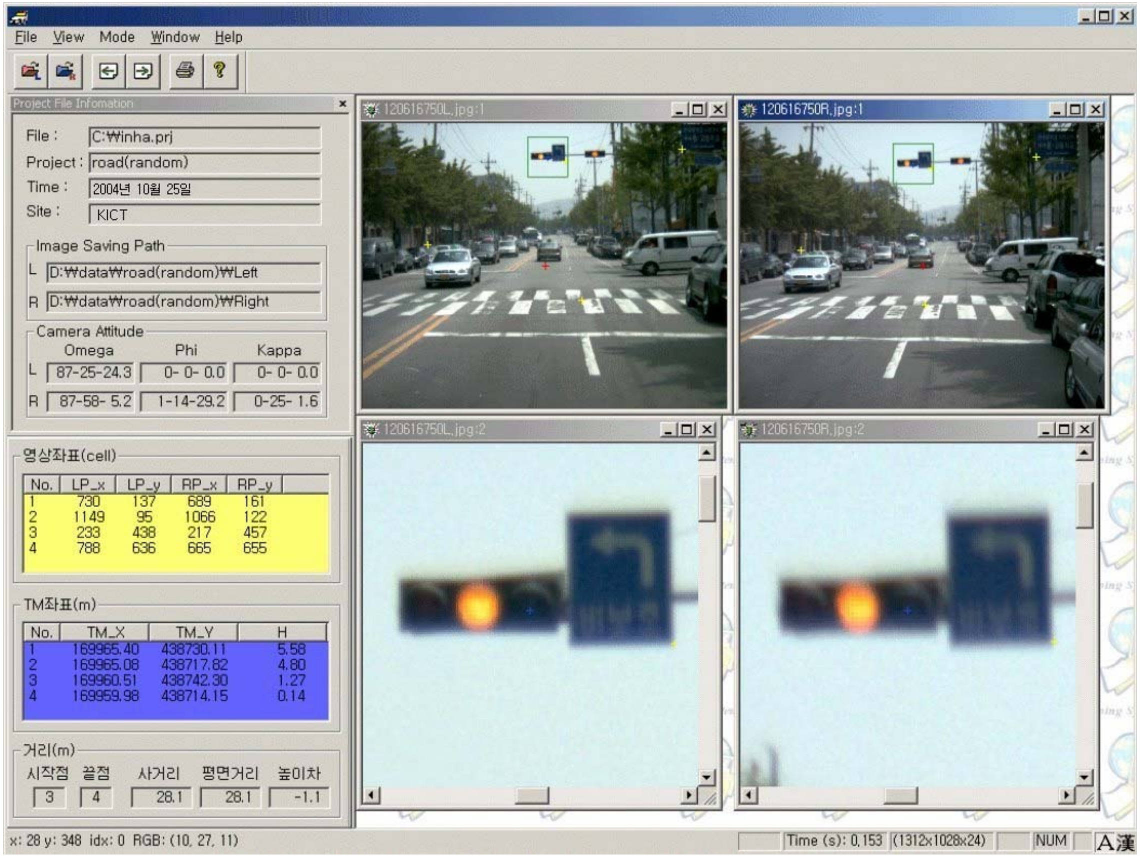

Figure 8. Front View Image Software

From the side down-looking cameras, the center of lane markings is determined. The image thinning process is needed to extract centerline from the lane marking images taken for every 1m and the coordinates are transformed from the position and attitude of camera when the image is taken. Highway centerlines are reconstructed through connecting the coordinates and applying the interpolation techniques. Figure 9 shows the ground cover areas. Since the side down-looking cameras are tilted toward outside of vehicle, the ground cover areas are 1.6m at the inner direction and 1.8m at the outer direction.

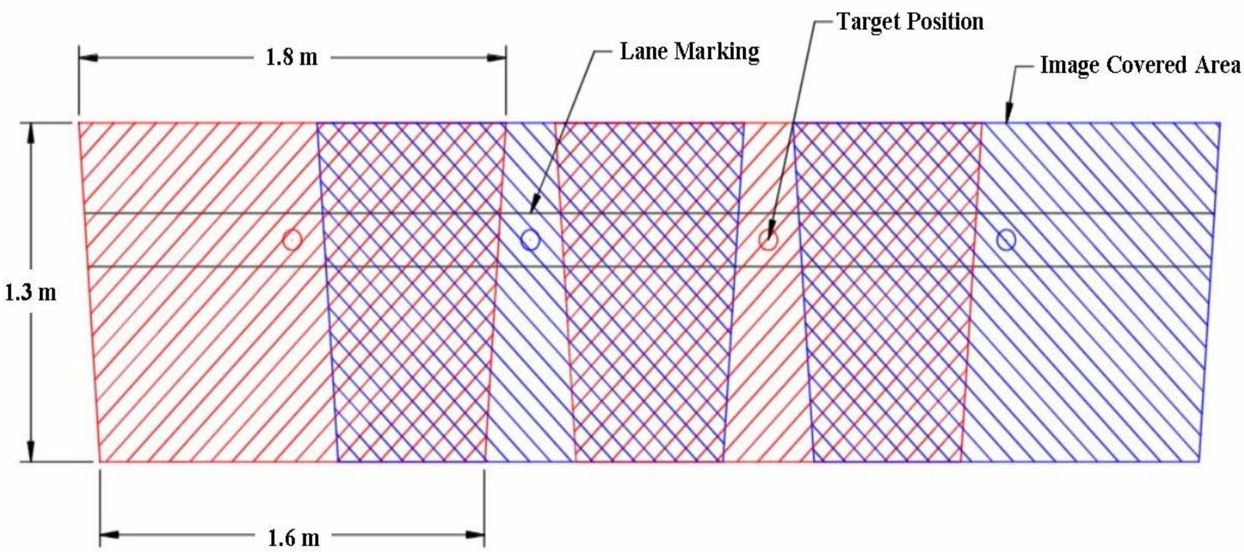

Figure 9. Ground Cover Areas from the Side Down-looking Camera

The images from the side down-looking cameras can be processed in highly automated manner because the extraction of centerline, determination of center points, and transformation of coordinates are relatively simple.

2.5 Highway Design Element from the Acquired Data

The types of data from the GPS, IMU, DMI, and CCD cameras which will be used for road geometric and safety analyses are summarized in Table 1.

Table 1. Design Elements, Required Sensors, and Data Types

Design Elements		Sensors	Data Type
Highway Alignments	Highway Alignment	GPS/IMU, Side down-looking Cameras	Position(x, y, z)
	Location and Specifications of Roadside Facilities	Front view Cameras Laser Scanner	Position(x,y,z) Specification(height)
Cross Section	Superelevation	GPS/IMU, Laser Scanner	Superelevation(%)
	Width of Highway Lane	Side Down-looking Camera	Width of Lane(m)
	Shoulder Width	Front view Cameras	Shoulder width(m)
	Length and Heights of Median Barriers	Front view Cameras, Laser Scanner	Position(x,y,z) Specification(height)
Horizontal Alignment	Length of Tangent Section	GPS/IMU	Position(x, y, z)
	Design Parameters	GPS/IMU	Position(x, y, z)
	Length of Circular Curve	GPS/IMU	Position(x, y, z)
	Length of Transition Curve	GPS/IMU	Position(x, y, z)
Vertical Alignment	Vertical Grade	GPS/IMU	Position(x, y, z)
	Length of Vertical Curve	GPS/IMU	Position(x, y, z)

Figure 10. Road Safety Survey and Analysis Vehicle

3. CONCLUSION

In this study, the data acquisition scheme and the development strategies for the RoSSAV are suggested such as acquisition of position data, image data, signal synchronization devices, and application of sensor data. The detailed algorithms for the analysis of highway alignments using position and attitude data, and highway safety analysis application software will be developed by operating and testing the RoSSAV.

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