Introduction and Field Application for Road Safety Inspection using an Automated Road Survey Vehicle

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Abstract: Road safety inspection that uses existing road safety audits involve long inspection times and high costs so this study proposes the features of an automated road survey vehicle, which performs road safety inspection through the application of MMS, and its analysis results. The automated road survey vehicle introduced in this study used algorithms in which genetic algorithms and moving average techniques are applied, thereby analyzing the alignment of the road, and performed sign board identification and extraction of their locations using laser data. Further, it has an automated drawing creation feature of 500m units as well as characteristics for road risk analysis and an assessment system.

With an automated road survey vehicle such as the 'ARASEO', problems in regards to human factors of road use and environmental factors can be determined, and such technology development can increase efficient road safety diagnosis.

Keywords: Road Safety Inspection, Road Survey Vehicle, Mobile Mapping System, Traffic Accident

1. INTRODUCTION

In order to decrease traffic accidents that occur each year, the road management authority performs regular road safety inspections and road safety audits for accident-prone areas. Existing road safety inspections and road safety diagnosis are done by inspectors, in the field and investigating traffic accident related items such as the cause of an accident. However, this method of dispatching an inspector to the scene of an accident to examine the cause of such and accident risk factors requires long investigation times and costs, in addition to a high accident risk to inspectors during the investigation. Therefore, it is required to reduce investigation time and costs; and as a result, an automated road survey vehicle that applies a mobile mapping system (MMS) has been developed and utilized to meet such requirements.

The MMS refers to all types of systems for information acquisition and modeling using a vehicle equipped with sensors such as a Global Positioning System, an Inertial Measurement Unit, a Laser Scanner, and a Charge Coupled Device Camera. When using MMS-applied vehicles for investigation purposes, significant reduction effects can be expected in terms of investigation time, compared to dispatching inspectors to the field. Furthermore, it has advantages such as a collection of a large amount of video screens and storage capability and high accuracy of coordinates using latitude and longitude, which cannot be achieved through human ability.

Therefore, this study presents the features and evaluation results of ARASEO

(Automated Road Analysis and Safety Evaluation Tool), which was developed as the Automated Road Survey Vehicle for the purpose of road traffic safety inspection and diagnosis.

2. AUTOMATED ROAD SURVEY VEHICLE (ARASEO)

2.1 Overview

The automated road safety vehicle introduced in this study is named ARASEO (Automated Road Analysis and Safety Evaluation tOol), and performs road information collection and analysis 'ARASEO', which means "automatically" in Korean. The 'ARASEO' has features of automatic collection and analysis of the alignment of roads and facilities, automatic drawing creation using acquired information, and assessment of potential road risk sections and report creation using the road safety analysis model. In the 'ARASEO', a GPS-INS integration system, DMI, CCD camera, LiDAR road surface camera, and IR camera are installed, and Table 1. shows the data and sensors used for such analysis.

Table 1. Analyzed data and used sensors

Category	Analyzed data		Used sensor
Alignment	Horizontal Alignment	Tangent length Circular Curve Radius and length Transition Curve length	GPS, INS, DMI
	Vertical Alignment	Vertical Tangent and Curve Length Vertical Grade	GPS, INS, DMI
	Cross Sectional Data	Lane and road width Cross slope	GPS, INS, DMI, Camera, Laser Scanner
Road surface	Drainage	Drainage	Laser, Camera
	Friction	Friction	Laser, Camera
Roadside facilities	Road sign	Road sign	Camera, Laser Scanner
	Roadside facilities	Safety barrier, Crash cushion etc.	

2.2 Collection of Information of the Alignment of Roads and Facilities and Analysis Result

Using the GPS-IMU mounted in the 'ARASEO', positioning information (X, Y, Z) and posture information (Roll, Pitch, Heading) of a vehicle is acquired, and using such information, the horizontal alignment, vertical alignment and cross alignment of the road are automatically analyzed. In particular, the 'ARASEO' has a feature of acquiring road geometry structure information using the extracted information of a center line by running the ascending and descending lanes. The analysis methods used were genetic algorithms and moving average technique.

The horizontal alignment analysis distinguished straight lines and curved lines using the heading change rate collected in the 'ARASEO' while the vertical alignment analysis distinguished vertical slope and vertical curve using the positioning coordinate Z. Figure.1 shows the analysis algorithm of the horizontal and vertical alignment.

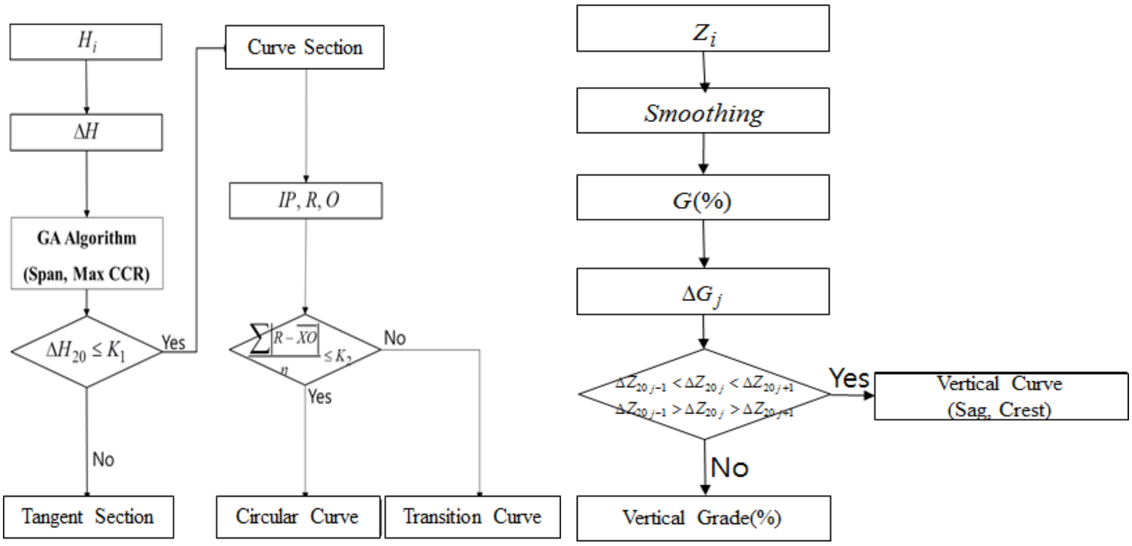

Figure 1. Analysis algorithm of the horizontal(left) and vertical(right) alignment

Table 2. Parameter and description

Parameter		Description
Horizontal alignment	H_i	Heading(˚), i=1,2,3,···,n
	ΔH	Heading change rate of 1m ($H_{i+1} - H_i$), j=1,2,3,···,n
	ΔH	Heading change rate (analysis basic unit), j=1,2,3,···,n
	K_1	Threshold value for assessing straight line or curved line
	IP	Point of intersection
	R	Radius of the curve (m)
	O	Center of the curve
	$\overline{XO}$	Distance between the center of the circle and vertex (m)
	K_2	Threshold value for circular curve or transition curve
Vertical alignment	Z_i	Altitude, i=1,2,3,···,n
	ΔZ_i	Z change rate of 1m ($Z_{i+1} - Z_i$), j=1,2,3,···,n
	G	Vertical slope
	G_{20j}	Vertical slope of the analysis basic unit, j=1,2,3,···,n

Alignment information (horizontal and vertical) of arterial No. 37 was extracted using the alignment analysis algorithm deployed in the 'ARASEO', and is presented in Table 3. The analysis results show that the horizontal alignment was within 10%, and the vertical alignment was less than 0.5 of absolute error so that the analysis data was found to be appropriate for the purpose of road safety inspection.

Table 3. Analysis result of arterial No. 37

Horizontal alignment				Vertical alignment			
Section	Drawing	Result	Error rate	Section	Drawing	Result	Absolute value difference
Curve1	440	440.4	0.09	Slope1	0.59	0.55	0.04
Curve2	680	678.7	0.19	Slope2	1.32	1.30	0.02
Curve3	530	530.4	0.08	Slope3	1.62	1.80	0.18
Curve4	420	422.3	0.55	Slope4	2.18	2.25	0.07
Curve5	420	423.2	0.76	Slope5	3.14	3.18	0.02
Curve6	420	441.4	5.10	Slope6	3.96	4.01	0.05
Curve7	1005	992.0	1.29	Slope7	1.60	1.65	0.05
-	-	-	-	Slope8	2.20	2.26	0.06

In order to minimize the damage of traffic accidents in addition to the prevention of traffic accidents, safety facilities are installed on roads. Typical safety facilities, such as guard rails, median barriers, and chevron signs can be found, and also other traffic safety signs are available to provide information for drivers. All facilities are to be installed at a place according to the installation and management instructions such as the ‘Road safety facility installation and management instructions’ to maximize the effect of traffic accident prevention. If such facilities are not installed at the recommended places or improper management such as damage occurs, the proper function of the facility cannot be achieved.

Accordingly, the ‘ARASEO’ acquires facility information using lasers and cameras. The alignment information and chevron signs installation location were acquired when driving the vehicle. These results were then analyzed and the information acquired is displayed using the matched road video thereby supporting an inspector to determine risk factors.

Video data collected by the vehicle regarding road signs are normalized, and through the collection process of video coordinates and video numbers, more than a 90% identification rate of road signs are able be obtained in fine weather conditions. This study used an intensity specialized laser to measure the locations of the road signs. Table 4. shows the identification results according to the facility measurement points and distribution of the cluster. RMSE, which is a difference of measurement values obtained from the facility laser and total stations, was 0.227m, and the average value of the difference of the measurement value was 1.51m.

Table 4. The identification results

Measurement point No.	Identification result	Distribution of cluster	Measurement point No.	Identification result	Distribution of cluster
1	1.38	0.44	9	1.62	1.25
2	1.84	0.57	12	1.52	0.15
5	2.06	0.22	13	1.52	0.97
6	1.41	0.27	...	...	...
8	1.26	0.11			

2.3 Automatic Drawing Creation Feature

Drawings can be created using the information of alignment and facilities collected by the 'ARASEO'. The entire set of drawings and drawings of 500m increments and horizontal drawings of 20m distances can be obtained, which are as shown in Figure 2. Furthermore, road facilities for road safety inspection such as chevron signs, median barriers, guard rails and road safety signage can also be indicated.

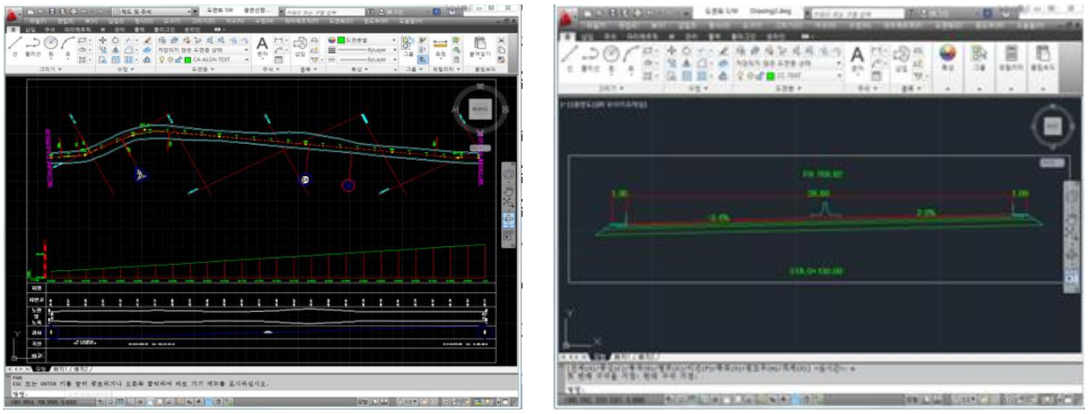

Figure 2. The entire set of drawings

2.4 Road Risk Analysis and Assessment System

Generally, causes of traffic accidents can be classified into road environment factors, human factors and vehicle factors, and using the 'ARASEO', safety inspections regarding road environmental factors can also be done. In particular, risk factors are divided into speed, cross-section element configuration, alignment, sight distance, pavement and drainage, and signboards and other associated facilities to review the suitability of each item. Table 5. shows the groups of safety inspection items detected in the 'ARASEO', as well as diagnosis items and risk factors.

Table 5. The groups of safety inspection items

Main category	Sub-main category	Diagnosis items	Risk factors
Speed	Speed	Inspection of suitability of speed limit for each curved section	Unsuitable speed limit on curved sections
		Inspection of suitability of exit speed	Unsuitable exit speed on ramps
		Inspection of consistent speed limit applied	Inconsistent speed limit
Cross-section element configuration	Road lane	Inspection of suitability of lane width according to class and road classification	Unsuitable lane width
	Median barrier	Inspection of suitability of median barrier	No median barrier
Alignment	Horizontal alignment	Inspection of suitability of continuity and consistence of alignment	Inconsistent road alignment
		Inspection of suitability of horizontal alignment of ramps	Unsuitable horizontal alignment in ramps
		Inspection of suitability of transition curve length	Unsuitable length of transition curve
		Inspection of suitability of horizontal curved section considering safe driving speed	Unsuitable super-elevation
		Inspection of providing sufficient width for horizontal curved sections considering vehicles characteristics	Unsuitable width for horizontal curved section
	Vertical alignment	Inspection of suitability of vertical alignment for ramps	Unsuitable vertical alignment on ramps
		Inspection of suitability of vertical slope	Unsuitable vertical slope
		Inspection of suitability of vertical curve length	Unsuitable vertical curve length
	Cross alignment	Inspection of harmony of combination of horizontal and vertical alignments	Imbalance between horizontal and vertical alignments
Sight distance	Sight distance	Inspection of sufficient sight distance inside curves	Unsuitable sight distance inside curves
		Inspection of suitability of stopping sight distance and overtaking sight distance	Unsuitable stopping sight distance
Pavement and drainage	Pavement	Inspection of sufficient friction coefficient due to worn pavement surface	Unsuitable road surface friction
		Inspection of flatness of paved road surface	Unsuitable vertical flatness
		Inspection for cracks or damage in pavement	Unsuitable holes holding water
	Drainage	Inspection of suitability of drainage by slope	Unsuitable road surface drainage by slope
Signs and other affiliated facilities	Signs	Inspection of more than two different signs at one place	Too many signs
	Traffic obstacles	Inspection of whether a facility is provided to prevent damage and clash against obstacles on the road	Installation of crash barrier on the roadside
	Sight induced facility	Inspection of suitability of installation location and criteria for chevron sign boards	Unsuitable location of chevron sign board

In the ‘ARASEO’, risk factors, which are highly related to the occurrence of traffic accidents, are displayed by the hazard profile as an accumulated manner as shown in Figure 3. In particular, risk levels are shown on the satellite road map according to actual drive trajectory by using different colors, thereby providing a view function for each risk factor. Also, it can interoperate with the accident data management system to provide a feature of risk level analysis indication by utilizing accident data collected, thereby providing an analysis for the actual cause of a traffic accident and effectively improve measures.

Figure 3. Road safety analysis software

3. CONCLUSIONS

In order to decrease traffic accidents that occur each year, the road management authority performs regular road safety inspections and road safety audits for accident-prone areas. However, the existing examination method for road safety inspection requires much time and high costs. Therefore, this study presents the features and analysis results of an automatic safety inspection vehicle, which performs MMS-applied road safety inspection.

The ‘ARASEO’ can analyze the road alignment for horizontal alignment within a +/-10% error, and for vertical alignment within an absolute error of 0.5, as well as providing an over 90% sign board identification rate in fine weather conditions with a 1.51m location accuracy error., It also has features an automatic drawing creation function of 500m units and a road risk analysis and assessment system.

By utilizing such automatic safety inspection vehicles such as the ‘ARASEO’, investigation and analysis times can decrease effectively, and are also able to identify problems and improvement measures thereby expecting a reduction effect of the occurrence of traffic accidents. Furthermore, the drawing technology implemented in the ‘ARASEO’ can also be used in areas where road information is required.

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