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Development of Nighttime Visibility Assessment System for road using a Low Light Camera

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Abstract : *Although the numbers of traffic accidents and fatalities in Korea have been decreased constantly, traffic accidents during night time have not been decreased. Thus, it is necessary to conduct comprehensive studies that can investigate, analyze, and assess the visibility environment of drivers in order to ensure safety in roads during nighttime. The purpose of this study is to develop the technology of acquiring and analyzing the nighttime driving environment in roads from driver's viewpoints. For this purpose, this study suggests a nighttime visibility assessment system that can quantify suitability. To do this, this study defined driver's visibility and selected effectiveness scale thereby developing an assessment model that reflected driver's level of recognition. The suggested system is developed consisting of two parts: the investigation device using a low light cameraequipped with investigation program and the web-based assessment program utilizing the document database. In the future, verification on the system will be conducted under various drivers' visual environments and pilot field application will be planned to improve accuracy of assessment on nighttime road visibility based on the system.*

Keywords: *road, visibility, safety, assessment, nighttime, low light camera*

I. INTRODUCTION

1.1. Background and Objective of Study

Although the numbers of traffic accidents and fatalities have been decreased continuously, nighttime traffic accidents have not been diminished yet. The total number of traffic accidents as of 2015 in South Korea was 232,035 cases, which were composed of 55.6% (129,049 cases) of daytime traffic accidents and 46.6% (102,986 cases) of nighttime accidents [6]. The nighttime traffic accidents are proportionally lower in terms of the ratio and the number of events than those of the daytime traffic accidents. However, the annual road fatality rate, which represents the number of the dead in 100 accident, of the nighttime traffic accidents is 1.32 times higher than that of the daytime accidents (1.75 for daytime and 2.30 for nighttime). The above analysis results imply that a risk of traffic accident that is felt by drivers reaches about 3 times of the daytime driving considering 30% of nighttime traffic volume.

Existing assessments on nighttime road visibility have been done at sections where lighting is installed in accordance with the road lighting standards [4]. However, the lighting standards cannot reflect the characteristics of road and traffic as well as drivers. They also have limitations that cannot investigate and measure all sections due to too much time taken since a fixed measurement mode is employed. In recent years, although a video luminance meter developed for the purpose of defective pixel detection in LCD panel has been employed to some extent, it can only provide luminance value in the shot image but no standards that assess visibility are available. A video luminance meter is also relatively expensive, which is not employed easily to assess visibility of nighttime roads. Moreover, road safety diagnosis performed in South Korea assesses visibility of nighttime roads by subjective judgment of experts, which cannot perform quantitative assessment based on objective indexes. Although a technical trend around the world in relation to nighttime road visibility searches for performance evaluation and improvement measures on individual facilities with regard to pavement markings, lightings, and delineator, most of them are focused on improvements on materials only. The visibility assessment on individual facilities sets a mean visibility value of all sections as a representative value by installing equipment at the assessment target sections. Thus, this type of assessment is highly disadvantageous in terms of reliability, investigation time, human resource, and equipment at specific road sections. Accordingly, it is necessary to have comprehensive research related to effective investigation, analysis, and assessment on a level of recognition and perception on road conditions by drivers in order to ensure safety of nighttime roads where various conditions are mixed.

The purpose of this study is to develop the technology of acquiring and analyzing the nighttime driving environment in roads from driver's viewpoints. For this purpose, this study suggests a nighttime visibility assessment system that can quantify suitability (ex: excess, suitable, and insufficient). This suggested system can investigate and assess visibility in nighttime roads continuously where drivers, road, and traffic characteristics are reflected.

1.2. Determination of development principle

Currently video luminance meter (Hi-Land Korea) and portable brightness and luminance device (Kangwon University) which are designed to collect and analyze the luminance value based on roadway lighting as well as to evaluate the luminance value according to roadway lighting criteria [5].However, the portable brightness and luminance devicecannot collect precise data according to observation conditions and the video luminance meter may collect data conveniently but data such as a distance to the driver in the analysis target area are not accurate thereby having an issue of reliability of analysis and taking a considerable time to analyze data [3].

In order to overcome the limitation, measurement devices should be mobile while measuring data and convenient in terms of operation. They also should reflect what drivers are actually felt in assessment. By doing this, investigation human resource and time can be saved and safety of nighttime driving can be ensured through user-oriented scientific determination standards.Thus, this study set its direction to technological development to facilitate mobility, simplicity, intuition, and reflect visual sight of drivers and road environments. It also aimed to implement a technology that can investigate road environment continuously with less expensive than commercially available products.

II. DEVELOPMENT OF THE NIGHTTIME VISIBILITY ASSESSMENT METHOD FOR ROAD

2.1 Definition of driver's visibility at nighttime

According to the Study on improvement of road markingvisibility to reduce traffic accidents,visibility is defined as a level of recognition of certain object clearly at a certain distance by a driver[8].Wikipedia defines the visibility as "In meteorology, visibility is a measure of the distance at which an object or light can be clearly discerned [10]. It is reported within surface weather observations and METAR code either in meters or statute miles, depending upon the country. Visibility affects all forms of traffic: roads, sailing and aviation. Meteorological visibility refers to transparency of air: in dark, meteorological visibility is still the same as in daylight for the same air". In the color glossary, visibility is defined as a property of easy identification about existence or shape of target object from a remote distance, which is different from a sense of attention [7]. The larger the brightness difference, the better the visibility.

The dictionary meaning of visibility is only defined conceptually and other related studies defined visibility as a level of clearly recognizing an object from a certain distance. This indicates that defining visibility, which is a certain characteristic, is difficult and can be done only by using conceptual words. In general, the definition of visibility can be done by using a condition of certain distance and a thing as an object. Thus, visibility can be defined by clarifying the meaning of them.

Accordingly, this study defined nighttime road visibility as follows: minimum stopping sight distance (MSSD) was set as a concept of certain distance and road surface and road safety facility that functions linear guidance were set as things. The visibility in the road surface was defined as a level of brightness in the road surface to the stopping distance and the visibility of linear guidance was defined as a level of brightness of lanes up to the stopping distance at least and surrounding road safety facility (delineator, Chevron alignment sign)

2.2 Index utilized in the assessment

Y-value that represents brightness in the chromaticity coordinates was selected as an index. Luminance values in dark nighttime and bright daytime are distributed at a considerably large range but the Y-value can be collected easily through image pictures and can be converted easily by general conversion equations [2]. In addition, a simple value is more advantageous to assessment since a level of recognition felt by drivers is more important than precise data value in terms of visibility [1].Y-value represents brightness, which can be obtained after measuring RGB followed by converting it to YUV. Its conversion equation is as follows:

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ -0.14713 & -2.8886 & 0.436 \\ 0.615 & -0.15499 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

2.3 Study on nighttime road visibility criteria through analysis on a level of recognition felt by drivers

In order to derive a relationship between visibility and a level of recognition on the front by drivers with various levels of driving skills, indoor experiments were conducted with aged drivers and non-aged drivers. The samples used in the experiment were constructed by selecting non-illumination section where background light was minimal that can affect the front view of the driver. A level of recognition with regard to visibility of nighttime road was assessed using investigated image data in three road sections in four facilities (139 road surfaces, 135 lanes, 75 delineator, and 73 chevron alignment signs were constructed and utilized). In addition, a level of recognition related to nighttime road visibility of drivers can be evaluated differently depending on

individual's physical and emotional characteristics. Thus, it is limited for existing analysis methods to evaluate a level of recognition by considering individual's subjective and diverse characteristics. Accordingly, this study employed a fuzzy set theory, which has been known to be effective to evaluate a level of recognition of users in order to analyze a subjective level of recognition by driver. Based on this, a relationship between level of recognition of driver and nighttime road visibility was derived through regression analysis (ordered logit model). A fuzzy set is suitable to explain ambiguous existence or concept where an element can be both of true and false or in the middle of true and false in contrast with dichotomous logic (true or false) used in existing set theory.A Likert scale (five point scale) was used to measure driver's response to nighttime road recognition as an index of a level of recognition on brightness and how much facilities were helpful to road driving through the experiment. Considering that a driver has no difficulty in driving operation if a certain level of brightness is ensured, the experiment was divided into two: a level of recognition according to a level of brightness and satisfaction on environment for driving.The experiment results were analyzed through the ordered logit model. A level of recognition by a driver was set as a dependent variable, and Y-value of facilities (road surface, lanes, delineator, and chevron alignment signs) that affected a level of recognition of driver was set as an independent variable. Based on the analysis result, impact of each road facility was analyzed according to geometric structure and facility installation characteristics to develop two models (Equation 2, 3).

$$Y_{tangentsegment} = -5.17135 + 0.04720X_{roadsurface} + 0.03509\,X_{lanes} + 0.01066X_{delineator} \quad (2)$$

$$Y_{curvedsegment} = -0.011 + 0.022X_{roadsurface} + 0.015X_{lanes} + 0.007\,X_{chevronalignmentsigns} \quad (3)$$

where, *Y*: Level of recognition by a driver

X: Y-value of road facilities

III. DEVELOPMENT OF NIGHTTIME ASSESSMENT VISIBILITY SYSTEM FOR ROAD

3.1 System architecture design

The assessment system of nighttime road visibility was designed. It has two components: nighttime road visibility data acquisition program based on low light camera and web-based assessment program of nighttime road visibility including data analysis and management function (Fig. 1).

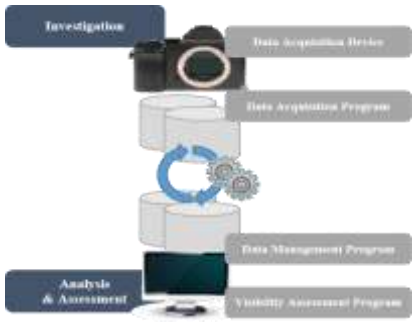

Fig. 1. System architecture

3.2. Data Acquisition Device Development

The developed acquisitiondevice of nighttime road visibility data was developed using low light camera that can acquire high-quality images even at low light and integrated technology of GPS and IMU. Moreover, it mounted a simple brushless gimbal controller based on motion sensor so that it was developed not to be affected by the behavior of the investigation vehicle and enable stable data acquisition and analysis (Fig. 2).

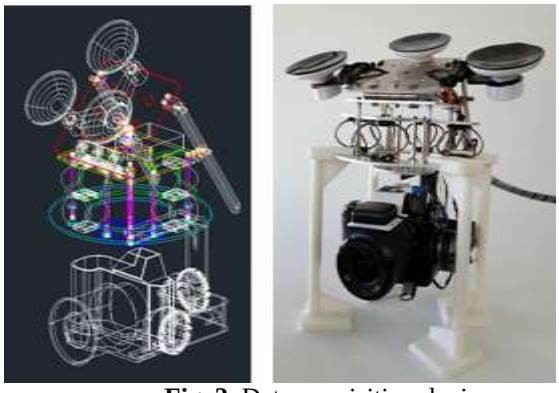

Fig. 2. Data acquisition device

3.3. Data Acquisition Program Development

The developed acquisition program of nighttime road visibility data was developed by including tracking function for target area extraction in addition to Y-value acquisition based on image data. Furthermore, environment information storage function such as image data saving index and location information, data acquisition device setup function including data collection interval and camera setup function, and calibration function of acquisition device were implemented.Fig. 3 shows the data acquisition program view of the RGB mode, which was developed that Y-value can be collected through tracking of target objects. Fig. 4 shows theview of calibration module developed to calibrate target area and attribute information of the acquisition device.

Fig. 3. View of data acquisition program (RGB Mode)

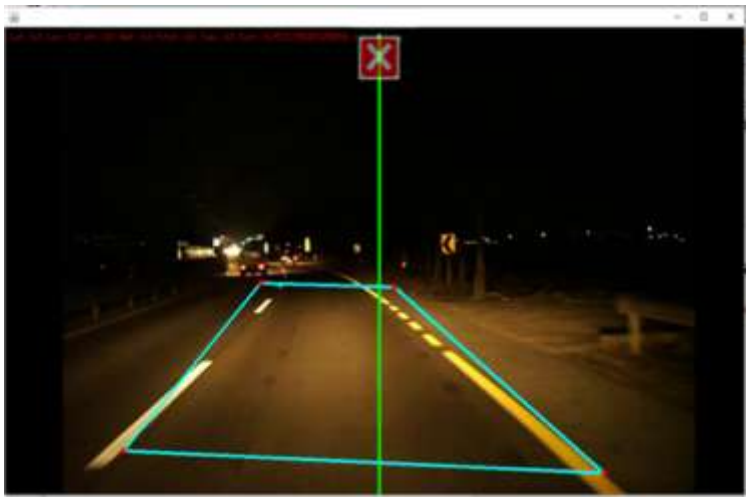

Fig. 4. Calibration module view

3.4. Development of Data Management &Visibility Assessment Program

The web-based nighttime road visibility assessment program was developed to manage and assess investigated data using the data acquisition program systematically (Fig. 5). In the left side of the screen, a database query function was provided. If the queried data item is selected, the investigated location is displayed in the map in the right side screen as well as providing image and related information. A function that can modify image-processed results obtained in real-time in the data acquisition program was developed. The modification function was developed to re-calculate Y-value in the target region if the target region is re-adjusted.

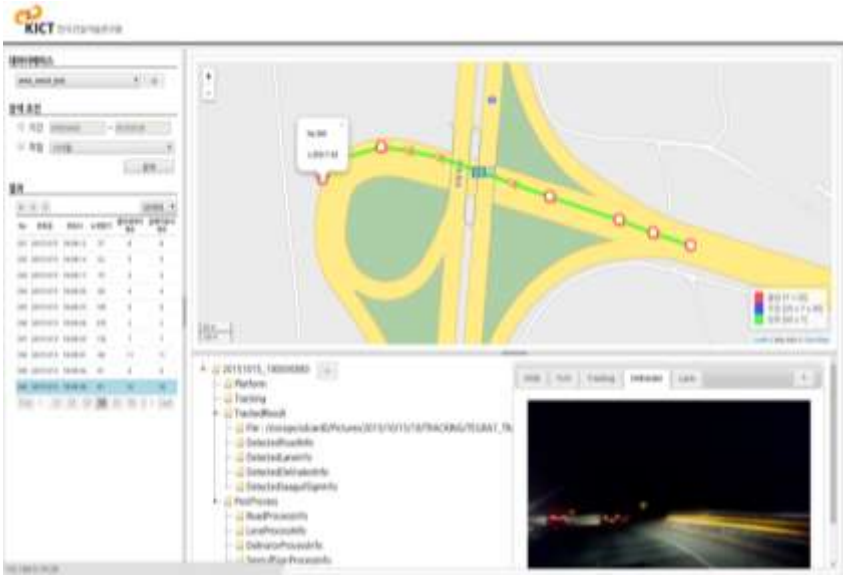

Fig. 5. Main View of Web-based Data Management & Visibility Assessment Program

IV. CONCLUSION

This study defined driver's visibility and selected effectiveness scale thereby developing an assessment model that reflected driver's level of recognition. It also developed asystem that assessed nighttime road visibility. The system was developed to be suitable for various driver visual environments. The system was composed of data acquisitionprogramand web-based data assessment program. All data in the system were developed to be collected and managed based on spatial information thereby enabling spatial expression and analysis on assessment data. The system can be interlinked with various road-related information thereby helping various analyses in the future.In the future, verification on the system will be conducted under various drivers' visual environments and pilot field application will be planned to improve accuracy of assessment on nighttime road visibility based on the system.

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