*International Journal of Internet, Broadcasting and Communication Vol.14 No.2 162-170 (2022)*
*http://dx.doi.org/10.7236/IJIBC.2022.14.2.162*

IJIBC 22-2-20

# On the Method of Deriving Weather Data to Secure the Reliability of the Variable Focus Function Camera

Min Joong Kim*, Kyoung Lak Choi**, Tong Hyun Kim***, Young Min Kim****†

** Ph. D. Candidate, Department of Systems Engineering, Ajou University, Korea*
*** Senior Engineer, Automotive Engineering Service Team, DNV GL Business Assurance Korea*
**** Ph. D, CEO, CanLab Co., LTD.*
***** Associate professor, Department of Systems Engineering, Ajou University, Korea*
*aquamjkim@ajou.ac.kr, kyoung.lak.choi@dnvgl.com, ken@can-lab.co.kr, pretty0m@ajou.ac.kr*

***Abstract***

*Today, automobiles have become an indispensable element in people's lives, and the distribution of vehicles with various autonomous driving functions is expanding. Sensors such as cameras are used to recognize various situations on the road as an essential element for autonomous driving functions, but camera sensors have disadvantages that are vulnerable to bad weather. In this paper, we present a derivation process that defines external weather environment factors that negatively affect the performance of a camera for an autonomous vehicle. Through the proposed process, it is expected that it will contribute to securing the reliability of the camera and further improving the safety of autonomous vehicles.*

***Keywords:*** *Variable Focus Function Camera, Autonomous Vehicle, SOTIF, External Weather Condition, Safety*

## 1. Introduction
### 1.1 Background

Today, automobiles have become a universal means of transportation, and they are deeply positioned in our lives to the extent that it is inconvenient without them. Furthermore, in recent years, the supply of vehicles with autonomous driving functions such as Adaptive Cruise Control (ACC), Advanced Emergency Breaking (AEB), and Forward Collision Warning (FCW) has increased. The SAE (Society of Automotive Engineers) J3016 standard defines the autonomous driving stage as six stages, from level 0, in which the driver controls the vehicle, to level 5, in which the system controls the vehicle, according to the roles of the driver and system controls the vehicle [1].

In order to realize the autonomous driving function, various cognitive sensors such as radar and lidar as well as camera sensors are used to detect vehicles or obstacles ahead [2]. Weather conditions (fog, rain, snow) obstruct the driver's vision and negatively affect the performance of the sensor, becoming a major factor in causing traffic accidents. Also, in the case of domestic autonomous vehicle camera sensors, data considering

Manuscript Received: April. 5, 2022 / Revised: April. 13, 2022 / Accepted: April. 15, 2022
Corresponding Author: pretty0m@ajou.ac.kr(Young Min Kim)
Tel: +82-31-219-3949, Fax: +82-31-219-2334
Associate professor, Department of Systems Engineering, Ajou University, Korea

the weather environment are very limited. Advanced automotive active safety systems, especially autonomous vehicles, rely heavily on visual data to locate objects so that the vehicle can safely move, but it can be significantly degraded in weather conditions such as rain [3]. Severe weather conditions such as heavy rain, snowy roads, thick fog, etc. can potentially cause unintended changes to sensor data, affecting perception, route planning and vehicle control systems, etc. [4]. Weather that can cause danger while driving due to deterioration of the recognition performance of vehicle sensors such as rain, snow, fog, strong light, and pollution was investigated [5]. Awareness of the external environment is a key challenge for autonomous vehicle technology and is a major factor limiting the availability and performance of systems. In order to increase the availability of the system, various environmental conditions must be considered [6]. Severe weather conditions such as fog, haze, snow, fog and glare cause problems in the visibility of autonomous vehicles and suggest methods to ensure safe and smooth operation in adverse weather scenarios [7].

A study was conducted to suggest a method for securing the safety of autonomous vehicles by combining ISO 21448 (SOTIF) and STAP among various risk analysis techniques [8]. A study was conducted to integrate SOTIF with the RSS model for autonomous vehicles presented by the Mobileye, and a risk scenario in the SOTIF area was defined [9]. By applying ISO 21448 (SOTIF) to a logistics transfer robot, a study was conducted on how to prevent accidents that can be caused by unspecified surrounding environments and perform safe work [10].

### 1.2 Problem definition

The camera sensor may cause risks such as misrecognition or non-recognition of obstacles due to unintended degradation of performance due to the influence of the external weather environment. In order to improve the reliability of sensor data by reducing the rate of misrecognition and non-recognition due to the weather environment, and to secure the safety of autonomous vehicles, it is necessary to prepare for the risks that may arise from the weather environment. In the case of a Tesla autonomous driving car accident, there is a case where the recognition rate of the camera sensor decreased due to the backlight of the sun.

In order to secure the safety and reliability of autonomous vehicles, it is necessary to derive influence factors from adverse weather conditions such as snow, rain, and fog. In this paper, the process and method of deriving climatic environmental factors affecting safety and reliability are presented.

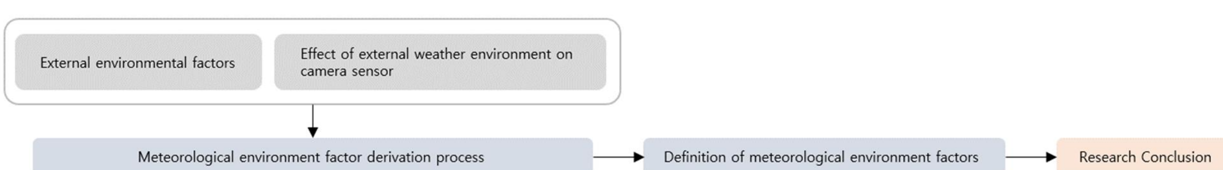


**Figure 1. Scope and Purpose**

### 1.3 Composition of the paper

The composition of this paper is as follows. Clause 2 presents the analysis and derivation process for weather environmental influencing factors. Clause 3 presents detailed procedures and outputs for each step of the process presented in Clause 2. The last Clause 4 gives an overall summary of this paper.

# 2. Weather data influence factor analysis and derivation process establishment

## 2.1 Weather Environment Derivation Process

Figure 2 shows the procedure for defining the weather environment factors that affect the performance of the autonomous vehicle camera presented in this paper. First, domestic/overseas status and previous research papers are investigated, and among them, conditions for the weather environment that affect the performance of vehicle cameras are collected. Based on the collected conditions, the evaluation criteria for the effects of the weather environment are identified. And it defines the elements of the weather environment to be considered in manufacturing and operating the camera.

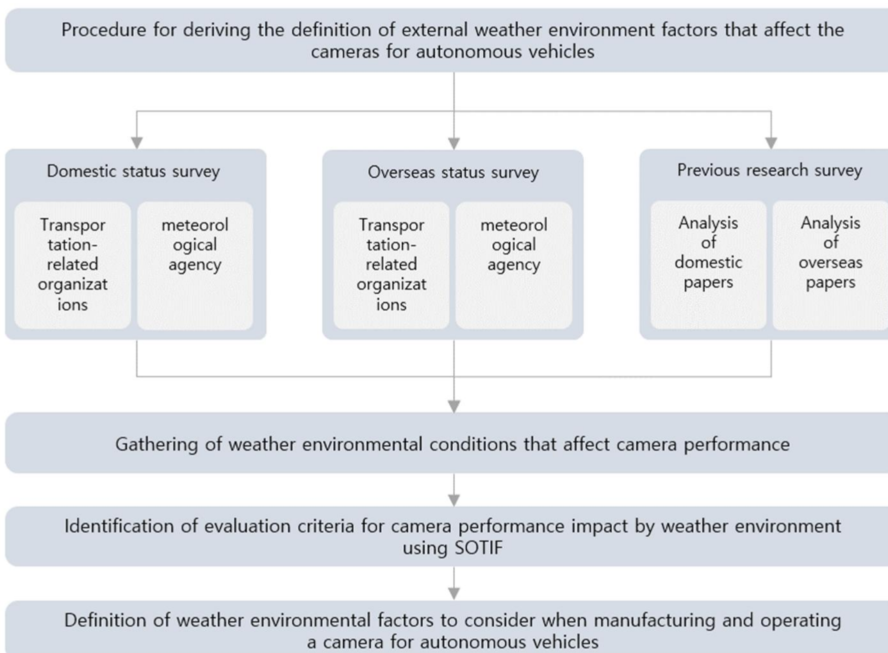


**Figure 2. Weather Environment Derivation Process**

## 2.2 External environmental condition

External environmental conditions include static factors caused by non-moving objects and dynamic factors caused by moving objects, and weather environmental factors caused by natural phenomena exist. Static factors include traffic conditions such as traffic lights, signs, and broken vehicles, buildings, street trees, road structures, and falling objects. Dynamic factors include vehicles, pedestrians, motorcycles, bicycles, and wild animals. Weather environmental factors include rain, snow, and fog.

**Table 1. External environmental factors**

| Category | Type | Subtype |
|---|---|---|
| static | traffic conditions | traffic lights |
| | | traffic signs |
| | | broken vehicles |

| | | |
|---|---|---|
| | buildings | |
| | street trees | |
| | falling objects | |
| dynamic | vehicles | |
| | pedestrians | |
| | motorcycles | |
| | bicycles | |
| | wild animals | |
| weather | rain | |
| | snow | |
| | fog | |

### 2.3 Effect of external weather environment on camera sensor

Weather environments such as rain, snow, fog, etc. and backlight by the sun cause a decrease in the performance of the camera sensor that recognizes an object, which causes the sensor to reduce the recognition rate of objects and lanes and cause non-recognition or misrecognition. Table 2 shows the causes of the external environment and the effect on the camera sensor.

**Table 2. Effect on camera sensor by external environment**

| External Environment | Cause | Impact on the camera sensor |
|---|---|---|
| right source | backlight | Obstacles not recognized or misrecognized due to photo saturation of the image sensor |
| | low light | Non-recognition of an object due to insufficient light intensity of the image sensor |
| | illumination difference | The image is distorted due to the difference in illuminance between the dark and bright areas, resulting in unrecognized or misrecognized objects |
| weather environment | rain | Non-recognition or misrecognition of an object or lane due to image distortion caused by water drops due to rain or the operation of the wiper |
| | snow | Non-recognition or misrecognition of objects or lanes due to image distortion caused by snow droplets or wiper operation |
| | fog | The performance limit of the sensor occurs due to the limited visibility due to the visibility restriction caused by fog, which causes misrecognition or non-recognition of objects and lanes. |
| particulate matter | pollution | Due to contamination by dust, micro-materials, etc. the sensor performance is limited due to the limitation of the visible range, resulting in unawareness or misrecognition of obstacles and lanes. |

## 3. Weather environment derivation procedure and output

The contents of the step-by-step procedure for deriving weather environment factors that affect the performance of the autonomous vehicle camera and the output derived by the results of each step are as follows.

### 3.1 Survey of Domestic Status and Preliminary Research

Factors and conditions that negatively affect the performance of cameras for autonomous vehicles are derived through the current situation in Korea and various previous research papers. As shown in Table 3, the Korea Meteorological Administration differs in the expression of rain depending on the amount of precipitation per hour, and the intensity of fog is classified as shown in Table 4.

**Table 3. External environmental factors**

| expression | light rain | rain | strong rain | heavy rain |
|---|---|---|---|---|
| precipitation per hour | ~ 3 mm | 3~15 mm | 15~30 mm | 30 mm ~ |

**Table 4. External environmental factors**

| intensity 0 (weakness) | intensity 1 (middle) | intensity 2 (strong) |
|---|---|---|
| 0.5 ~ 1.0 km | 0.2 ~ 0.5 km | ~ 0.2 km |

According to the Korea Expressway Corporation, when the visibility is less than 100m due to heavy rain or fog, it is suggested that the speed limit be reduced by 50% or more, and sufficient time and space should be secured for the vehicle to stop safely. In particular, it is suggested that in the case of sudden heavy rains, such as localized heavy rains, that it is difficult to distinguish ahead, it is recommended to avoid the rain for a while in a safe place such as a rest area or a resting place for drowsiness.

In addition, the Korea Road Traffic Authority has developed the B-Sang system that integrates and provides information on bus drivers to prevent accidents in emergency situations such as traffic accidents in fog zones. B-Sang System refers to a system that provides emergency situation information collected through observation information of bus drivers. This system is expected to prevent accidents in advance by inducing careful driving such as decelerating when sudden situations such as fog occur because the driver can recognize the traffic and road conditions on the road on which he is driving in advance.

### 3.2 Survey on Overseas Status and Preliminary Research

Table 4 shows an example of the classification of external environmental conditions presented by the National Highway Traffic Safety Administration (NHTSA). External environmental conditions are classified into weather, light sources, fine materials, and road conditions, and weather is subdivided into rain, temperature, wind, and snow. In addition, it is suggested that the speed should be reduced by 3~13% in light rain or snow, 3~16% in heavy rain and 5~40% in heavy snow [11].

**Table 5. Example of Hierarchical Levels in the External Environment Condition**

| External Environment Condition | Type | Intensity |
|---|---|---|
| Weather | Rain | Light |
| | | Moderate |
| | | Heavy |
| | Temperature | |
| | Wind | |
| | Snow | |

| | | |
|---|---|---|
| Particulate Matter | | |
| Roadway Condition | | |
| Illumination | | |

Visibility distance of 1 km or less is defined as fog, 200 m or less is defined as dense fog, and 40 m or less is defined as high-density fog [12].

**Table 6. International fog definition and classification**

| Visibility range | Description |
|---|---|
| ~ 40 m | Dense fog |
| 40 ~ 200 m | Thick fog |
| 200 ~ 1000 m | Fog |

### 3.3 Gathering weather environmental conditions

Among various external environmental factors, the weather environment has a great influence on vehicle driving. Among the items in Table 4, rain, snow, fog, etc. related to the weather, and the backlight due to the low altitude sun in Table 2 or low illumination in places such as shade or tunnel greatly affects cameras for autonomous vehicles, causing safety and reliability problems. Therefore, factors and conditions related to the weather environment such as rain, snow, fog, backlight, etc. are collected as factors affecting the performance of the camera.

### 3.4 Identification of weather assessment criteria that affect camera performance

ISO 21448 (SOTIF) can be used to identify and define evaluation criteria for each weather environment that affect the aggregated camera performance. As shown in Figure 3, SOTIF is divided into a total of four areas: safe situations (Area 1), dangerous situations (Area 2), scenarios (Area 3), and scenarios (Area 4).

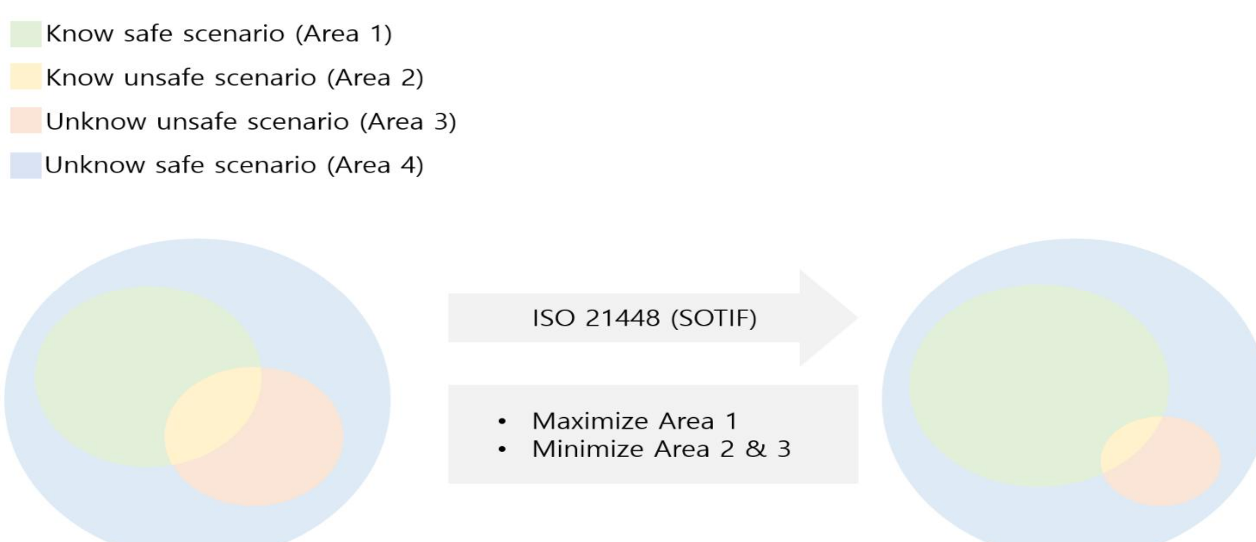


**Figure 3. SOTIF Goals**

As shown in Figure 4, the evaluation criteria for the weather environment, such as rain, snow, fog, backlight, etc., are identified as predictable parts and unpredictable accidental factors in consideration of SOTIF Area 2 and Area 3. For example, information such as hourly precipitation can be obtained from an organization such as the Korea Meteorological Administration that provides weather information and can be predicted, but there is a limit to prediction in the case of sudden localized heavy rain.

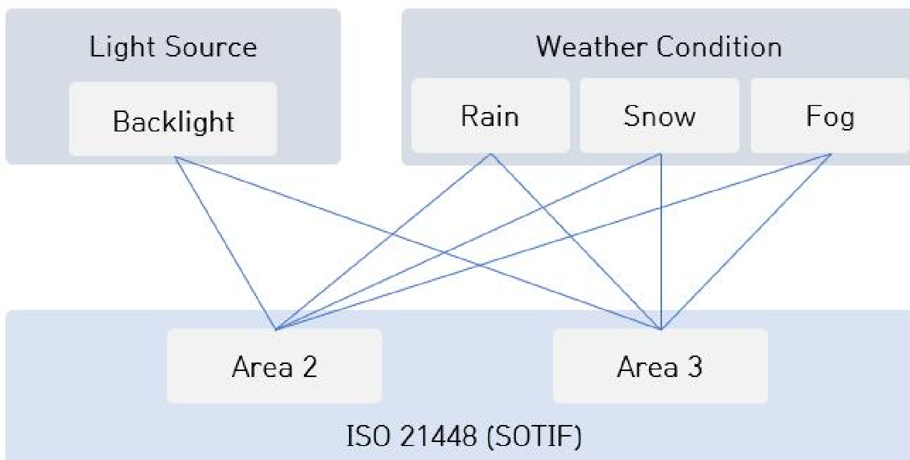


**Figure 4. The result of performing an evaluation with a combination of possible events**

### 3.5 Definition of weather environment factors to be considered when manufacturing and operating cameras for autonomous vehicles

Table 7 presents factors to be considered in manufacturing or actually operating a camera for an autonomous vehicle using SOTIF based on the definition of the evaluation criteria for the weather environment defined above.

**Table 7. Factors to consider when manufacturing and operating cameras for autonomous vehicles**

| ISO 21448 (SOTIF) | External Weather Condition | Description |
|---|---|---|
| Area 2 | Rain | Forecast rain |
| | Snow | Forecast snow |
| | Fog | Predictable regular fog in a specific area (waterside area) |
| | Backlight | Backlit by sunrise and sunset |
| Area 3 | Rain | Local heavy rain |
| | Snow | |
| | Fog | Fog caused by climate change |
| | Backlight | Backlight due to driving altitude change |

The effects of weather factors such as rain, snow, and fog presented need to be considered from the concept stage of camera development. By obtaining pre-image data on weather factors such as rain, snow, and fog that negatively affect the performance of camera sensors, and using real-time driving data to correct images through

SW image processing using AI technology, it can overcome factors that negatively affect camera sensor performance.

## 4. Conclusion

Recently, as the spread of vehicles equipped with autonomous driving functions has expanded, the role of sensors such as cameras for recognition has greatly increased. Therefore, in this paper, the process of deriving weather data is presented as a method to secure the reliability of the camera sensor.

In this paper, the process and methods for deriving climatic environmental factors such as snow, rain, and fog that affect the safety and reliability of autonomous vehicles are presented. Conduct research on domestic/foreign conditions and previous research papers for transportation-related organizations and meteorological-related organizations. Various factors that negatively affect the camera sensor are collected through current status investigations and previous thesis research, and weather conditions are collected among the collected factors. Using ISO 21448 (SOTIF), we identify the weather environment that affects camera performance, and based on the identified factors, we present essential factors to consider in the production and operation of cameras for autonomous vehicles.

It is expected that the reliability of the camera sensor will be secured through the proposed weather factors and procedures, and furthermore, it is expected to contribute to securing the safety of autonomous vehicles that meet the SOTIF standards.

## Acknowledgement

This work was supported by a grant from R&D program of the Korea Evaluation Institute of Industrial Technology (20014470)

## References

[1] J. Shuttleworth, "SAE Standard News: J3016 Automated-Driving Graphic Update," 2019.

[2] R. O. Chavez-Garcia, J. Burlet, T. D. Vu, and O. Aycard, "Frontal object perception using radar and mono-vision," 2012 IEEE Intelligent Vehicles Symposium, pp. 159-164, 2012.
DOI: https://doi.org/10.1109/IVS.2012.6232307

[3] M. Hnewa, and H. Radha, "Object detection under rainy conditions for autonomous vehicles: a review of state-of-the-art and emerging techniques," IEEE Signal Processing Magazine, 38(1), pp.53-67, 2020.
DOI: https://doi.org/10.1109/msp.2020.2984801

[4] N. Goberville, M. El-Yabroudi, M. Omwanas, Rojas, J., R. Meyer, Z. Asher, and I. Abdel-Qader, "Analysis of LiDAR and camera data in real world weather conditions for autonomous vehicle operations," SAE Int. J. Advanc. Curr. Prac. Mobil, 2, pp. 2428-2434, 2020.
DOI: https://doi.org/10.4271/2020-01-0093

[5] Y. Zhang, A. Carballo, H. Yang, and K. Takeda, "Autonomous Driving in Adverse Weather Conditions: A Survey," arXiv preprint arXiv:2112.08936, 2021
DOI: https://doi.org/10.48550/arXiv.2112.08936

[6] R. Heinzler, P. Schindler, J. Seekircher, W. Ritter, and W. Stork, "Weather influence and classification with automotive lidar sensors," In 2019 IEEE intelligent vehicles symposium (IV), pp. 1527-1534, 2019
DOI: https://doi.org/10.1109/ivs.2019.8814205

[7] A. Mehra, M. Mandal, P. Narang, and V. Chamola, "Reviewnet: A fast and resource optimized network for enabling safe autonomous driving in hazy weather conditions," IEEE Transactions on Intelligent Transportation Systems,

22(7), pp. 4256-4266, 2020
DOI: https://doi.org/10.1109/tits.2020.3013099

[8] M. J. Kim, K. L. Choi, J. U. Kim, T. H. Kim, and Y. M. Kim, "On the Ensuring Safety and Reliability through the Application of ISO/PAS 21448 Analysis and STPA Methodology to Autonomous Vehicle," International Journal of Internet, Broadcasting and Communication, 13(3), pp. 169-177, 2021
DOI: https://doi.org/10.7236/IJIBC.2021.13.3.169

[9] M. J. Kim, T. H. Kim, and Y. M. Kim, "On the Integrated process of RSS model and ISO/DIS 21448 (SOTIF) for securing autonomous vehicle safety," Journal of the Korean Society of Systems Engineering, 17(2), pp. 129-138, 2021
DOI: https://doi.org/10.14248/JKOSSE.2021.17.2.129

[10] K. L. Choi, M. J. Kim, and Y. M. Kim, "On safety improvement through process establishment for SOTIF application of autonomous driving logistics robot," International journal of internet, broadcasting and communication, 14(1), pp. 209-218, 2022
DOI: https://doi.org/10.7236/IJIBC.2022.14.1.209

[11] E. Thorn, S. C. Kimmel, M. Chaka, and B. A. Hamilton, “A framework for automated driving system testable cases and scenarios,” United State. Department of Transportation. National Highway Traffic Safety Administration, 2018

[12] A. H. Perry, L. J. & Symons, "Highway meteorology," CRC Press., 1991