Developing a railway station safety control automation system

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Abstract: For passenger safety management, all railway stations across the Republic of Korea are equipped with CCTVs. However, real-time monitoring is limited due to insufficient professional manpower and CCTV data are used merely for postaccident evidence. Therefore, the purpose of this study is to develop the existing CCTV system into an automated intelligent system for railway station safety management with greater than 90% recognition, thereby reducing the incidence of safety accidents in railway stations and securing the golden hour when accidents do occur. This study introduces technologies for intelligent cognitive, monitoring, and situation notification systems.

Keywords: Camera Calibration, Entry Detection, Congestion Estimation, Multisensor Monitoring

1. INTRODUCTION

Recent accidents, such as a fire at Guro Station in Seoul, South Korea and escalator accidents in other railway stations, along with security issues such as crime in unmanned stations have given rise to the need for improvement in public safety systems and services, including automatic railway station safety management. South Korea's traffic safety rating is low among OECD member nations, and the country bears a high social cost arising from railroad traffic accidents. In addition, safety management in railroad stations has been highly dependent on station personnel, and requires improvement to more efficient management systems to address shortages of manpower and work overloads.

Although the risk of falls and railway intrusion has been reduced in urban railway systems, owing to the mandatory installation of screen doors, it is difficult to replicate this safety measure in high-speed and general railways because of the differing positions of entrance doors by train. Therefore, additional safety measures are needed to prevent such accidents. In addition, escalator and stairway accidents are common, despite various safety measures in place, and approximately 200 unmanned stations nationwide are a blind spot of safety management due to the lack of manpower and budget; both instances require special measures.

In all railway stations across Korea, CCTVs are installed and managed to ensure passenger safety. However, there are limitations to real-time monitoring systems, caused by insufficient professional manpower, and the data obtained from CCTVs are used merely for postaccident evidence. In addition, the resolution of CCTV footage is so low that it is difficult to identify or analyze a situation based on recorded footage.

The Seoul Metro and Railroad Special Judicial Police Force use high-resolution cameras, but lack an intelligent cognitive CCTV system. Thus, accident recognition depends mainly on passenger reports, and CCTV video is reserved for postaccident handling. Although the Railway Traffic Control Center has applied intelligent CCTV-based cognitive systems to vulnerable locations, there is still a limit to their reliability, given their false detection rates. Therefore, it is necessary to prevent accidents and secure the postaccident golden hour by automating safety management through the development of a cognitive system with a high recognition rate and a low false positive rate.

This study aims to develop an automatic intelligent safety management system with a greater than 90% automatic response capability using ICT technology for emergencies such as disasters, platform accidents, track intrusions, trips and falls, and caught-in incidents at large and unmanned stations to provide Koreans with more secure and convenient railway services.

This study investigates some technical elements of intelligent cognitive, monitoring, and notification systems for railroad stations, which comprise an automatic intelligent safety management system.

2. INTELLIGENT COGNITIVE SYSTEM

The intelligent cognitive system aims to develop geometrical analysis and verification methods that can verify the geometrical validity of an abnormal situation detected by image analysis and enhance image detection accuracy using geometric information obtained from cameras. In addition, the development of 3D spatial information analysis is needed to estimate the precise physical location of an accident and automatically calculate the optimal camera combination and viewpoints for the accident situation.

Since most existing image recognition technologies for intelligent monitoring solely depend on pattern analysis of the images themselves, it is difficult to distinguish between people and objects, and these technologies have a high false positive rate based on environmental factors such as weather changes and lighting conditions. However, when geometric information obtained from cameras is utilized, it becomes possible to estimate the physical size and position of an object detected in image pattern recognition, enabling effective segmentation of people and objects and eliminating erroneous detection. To utilize geometric information obtained from cameras, it is necessary to develop a camera calibration technology that can effectively measure the internal and external parameters of the camera (e.g., lens focal length, distortion coefficient, installation height, and direction angle).

In current monitoring systems, each staff member monitors 30 or more screens showing varying camera positions and viewpoints; it is therefore difficult to comprehensively identify the scenario when an accident occurs. Furthermore, the viewpoint of the cameras must be manually controlled in case of an accident. Therefore, technology for automatic viewpoint control that can automatically estimate and provide the optimal camera units and viewpoints at the accident point is required. Thus, the technological scope of the intelligent cognitive system is defined in Figure 1 below.

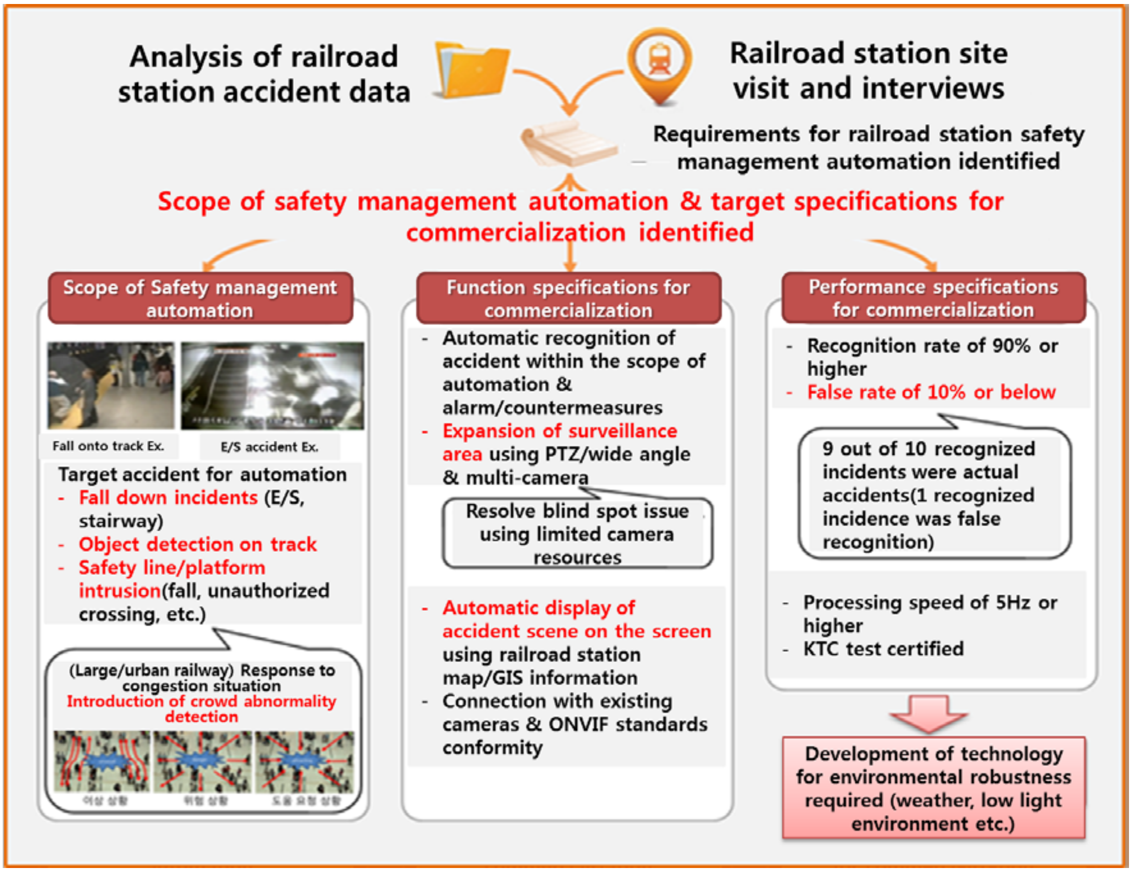

Figure 1. Overview of the automated intelligent cognitive system

2.1. Camera Calibration Technology

Camera calibration technology involves measuring the internal and external parameters of cameras using checkboards and other tools; such technology is essential for effective implementation of all image recognition algorithms. Geometric image analysis is conducted based on camera status and internal parameter information to extract the actual physical position and size of an object detected in an image. Conventional camera calibration techniques require a checkboard to be photographed at various angles (usually 20 images or more), which makes the process very inconvenient and time-consuming. This image acquisition process is either extremely difficult or impossible for environments such as railroad stations in which cameras are already installed.

To address such issues, this study simplifies and automates the camera calibration process, shown in Figure 2, to serve as a source technology for 3D spatial analysis that can simultaneously estimate camera lens calibration and 3D status information (height, direction, etc.) from a single image.

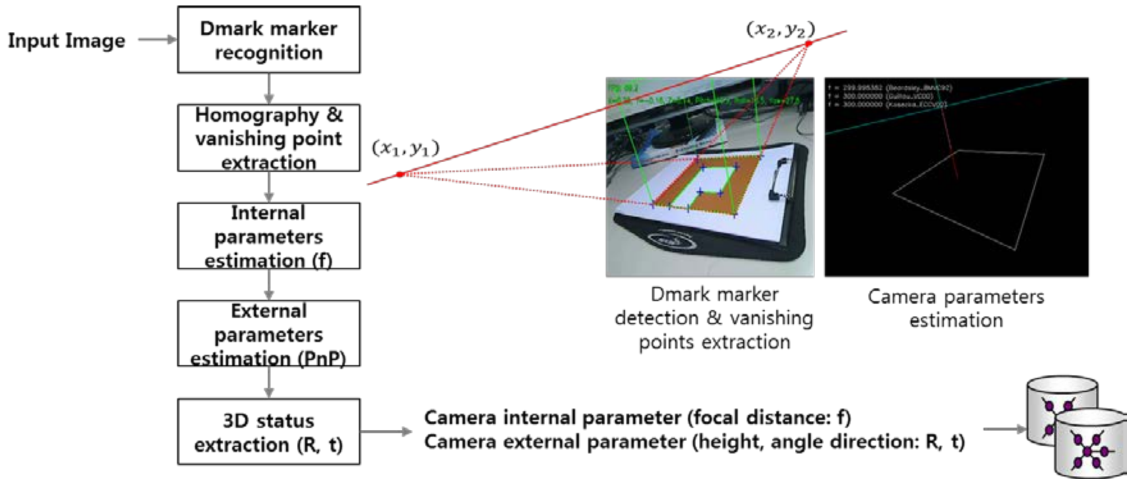

Figure 2. 3D-spatial-information-based camera calibration

2.2. Entry Detection Technology for Restricted and Important Areas

Object detection is an fundamental technology that detects changes in images and detects objects that are not part of the input image background through learning. This study uses object detection for track intrusion and crowd density estimation.

Technology detecting entry into restricted and important areas identifies passengers jumping or falling from a platform onto a track using object detection. In the past, only pixel information was acquired to perform this task and the false recognition rate was high. Through the acquisition of 3D information with general cameras, however, false recognition rates of 0% have been achieved by accurately estimating the position and height of an object in meters, as shown in Figure 3. Different image recognition processes and scenarios are graded for instances such as approaching a safety line, being on the safety line, passing the safety line, falling onto the track, and track accidents.

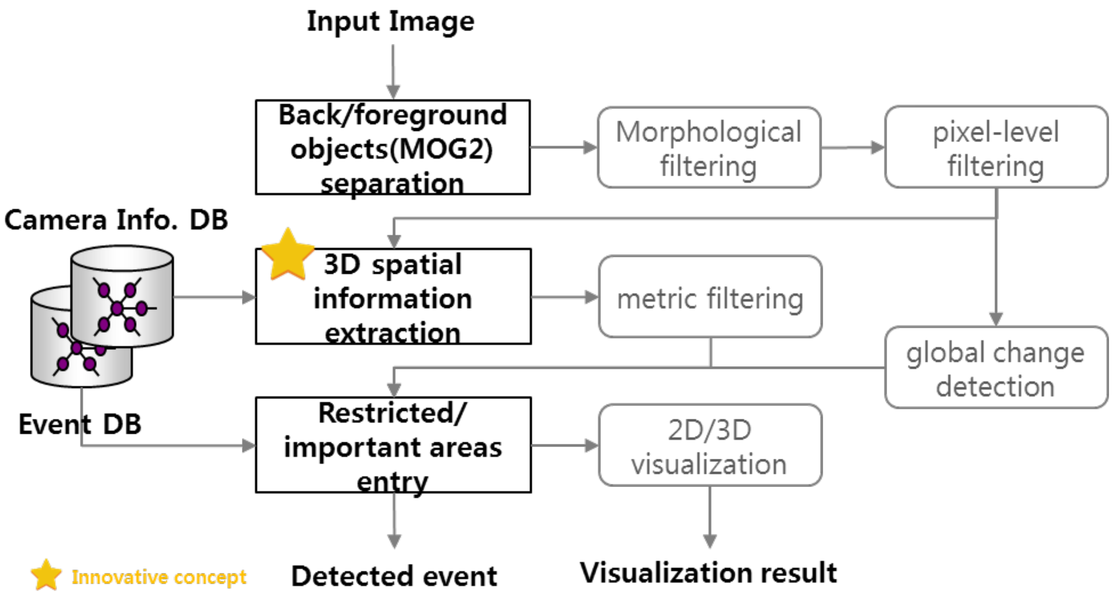

Figure 3. 3D-spatial-information-based technology for detecting restricted and important area entry

2.3 Crowd Congestion Estimation

To estimate crowd congestion levels, this study applies an intelligent image recognition technology that can judge the risk or abnormality of a situation by analyzing the crowd congestion level, changes in congestion, crowd movement flow, and pattern recognition. Through crowd analysis and recognition technology, it is possible to detect abnormal crowd movement that may occur due to sudden changes in congestion level, a platform fall, a fainting passenger, fighting, and other situations within railroad stations. In addition, real-time crowd congestion information and crowd movement flow analysis, which are necessary for effective evacuation in the event of an emergency, is provided.

Existing image recognition technologies have mostly relied on analyzing individual behavior. In the event of an accident, such as a platform fall or a fainting passenger, camera views are often obscured by the gathering crowd and it is difficult or impossible for existing crowd analysis technologies to effectively discern the situation.

To solve this issue, this study develops an algorithm for crowd congestion, as shown in Figure 4, and classifies abnormal crowd behaviors into evacuation, circumvention, and congestion situations. In addition, using geometric information such as camera status and internal parameters, the concept of pedestrian personal space is introduced based on crowd movement flow to estimate density while factoring in physical and psychological factors. To estimate density, the minimum occupation space is set as the shoulder width of the pedestrian and the change in the size of an individual’s psychological space is applied based on the pedestrians’ movement speed. Then, the density of the corresponding area is estimated by combining pedestrian counting technology, to which personal psychological space was applied, and position estimation technology, which involves geometric analysis. In addition, object overlap is addressed by 3D probabilistic human template generation and projection through 3D-spatial-information-based crowd density and congestion estimation, matching technology, and a density estimation technology that considers crowd distribution and movement speed.

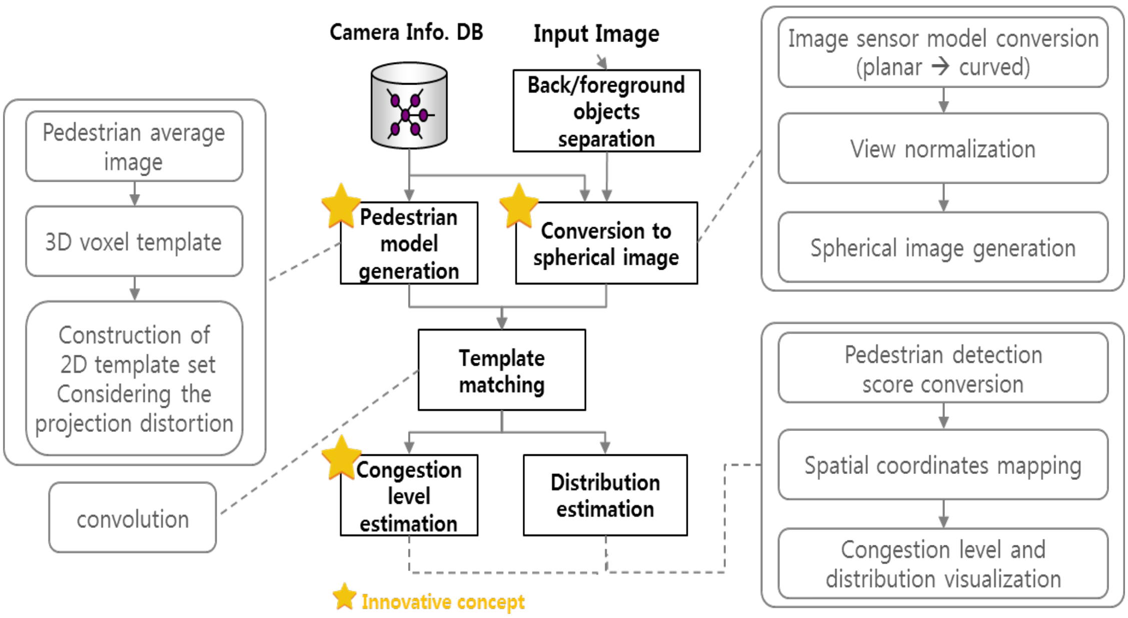

Figure 4. Crowd congestion estimation technology

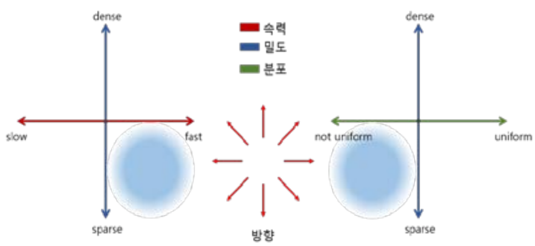

Figure 5. Abnormal crowd behavior modelling in evacuation scenario

Figure 6. Congestion level estimation through 3D spatial information and modelling

3. MONITORING AND SITUATION NOTIFICATION SYSTEM

The monitoring and situation notification system propagates information processed by the intelligent cognitive system to the control room, station personnel, and train operators. It is comprised of an automated multisensor monitoring system and situation response/notification system; big data warehouse system; platform, escalator, pedestrian accident, crime prevention, disaster prevention, and other unexpected situation monitoring; and fire and terrorist attack evacuation aid system. As shown in Figure 7, this study aims to develop a multisensor monitoring prototype linked to image analysis software, design a situation notification module, and develop fire detection software.

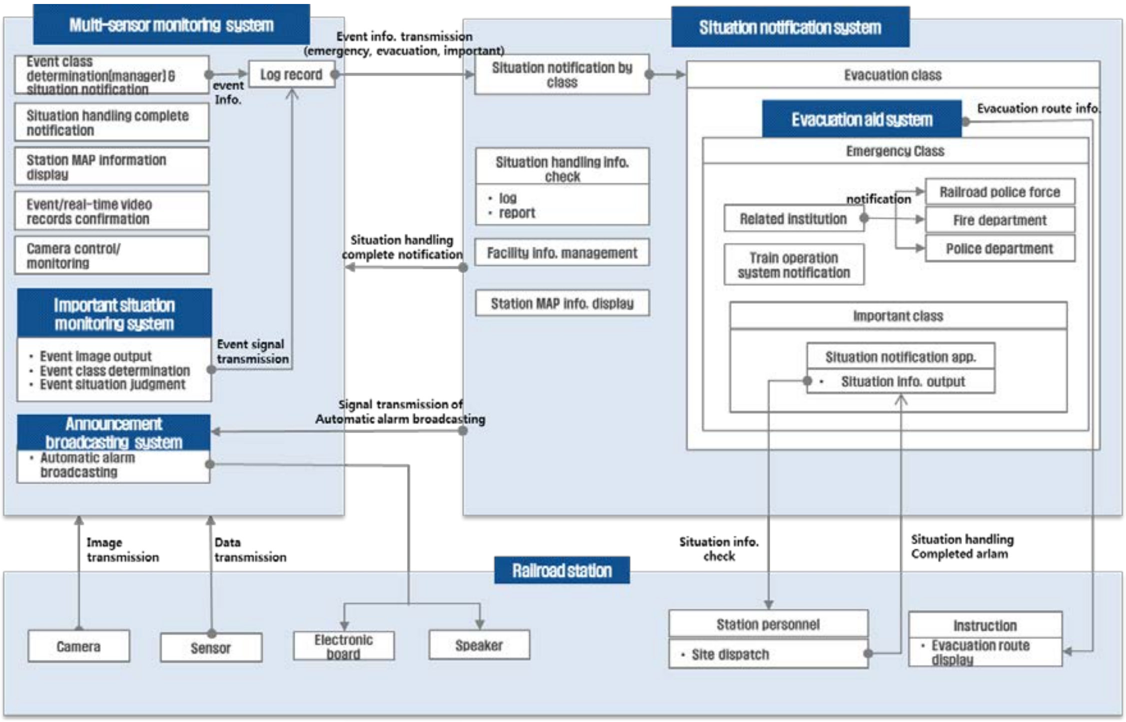

Figure 7. Diagram of a multisensor monitoring and situation notification system

3.1. Multisensor Monitoring System

As shown in Figures 8 and 9, the multisensor monitoring system is designed to support integrated management, monitoring, and decision-making for railway station safety. CCTV camera control, monitoring, event confirmation, video record view, and transmission to the situation notification and response system are designed as core architecture. With this design, our aim is to establish a railway station that allows preemptive safety management using a multisensor monitoring system capable of real-time monitoring, situation confirmation, video recording, and sensor connection.

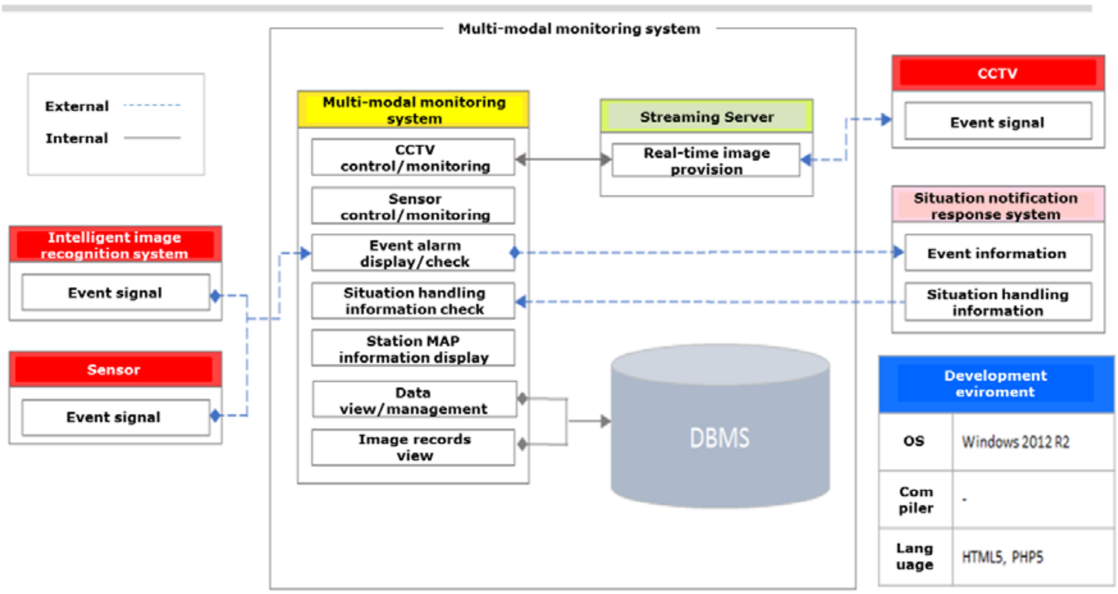

Figure 8. S/W diagram of multisensor monitoring system

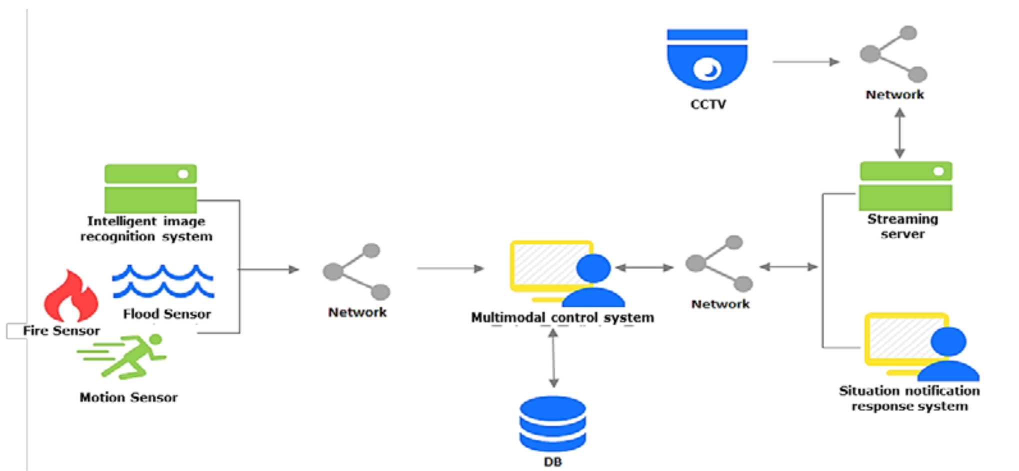

Figure 9. Physical configuration diagram of multisensor monitoring system

3.2. Image-based Fire Detection Software

Fire detection software allows the detection of and prompt response to fires that occur in railroad stations and optimizes the operation personnel and costs required to handle situations, such as fires, in real time. In addition, the fire detection software can prevent secondary accidents and minimize damage.

Fire detection software is image-based software that mainly consists of detection algorithms for smoke and flames. As shown in Figures 10 and 11, in these detection algorithms, smoke or flame candidates are extracted using color modeling and detected using patch-based periodic analysis. The resulting algorithm has a high detection rate and low false detection rate, as shown in Table 1. However, research on this algorithm is ongoing, to reduce the false detection rate.

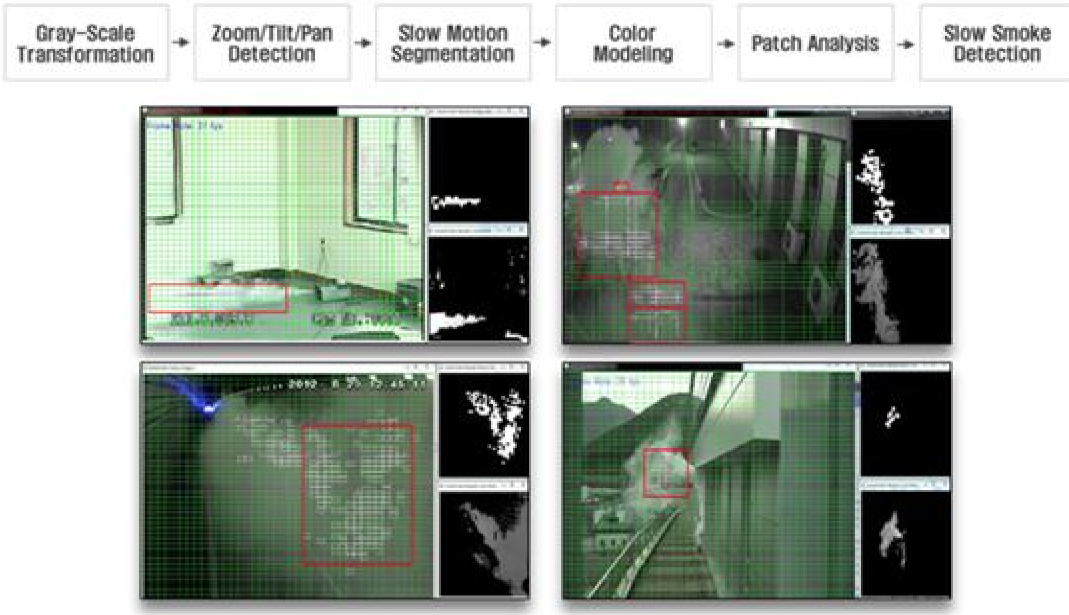

Figure 11. Block diagram and performance test of the smoke detection algorithm

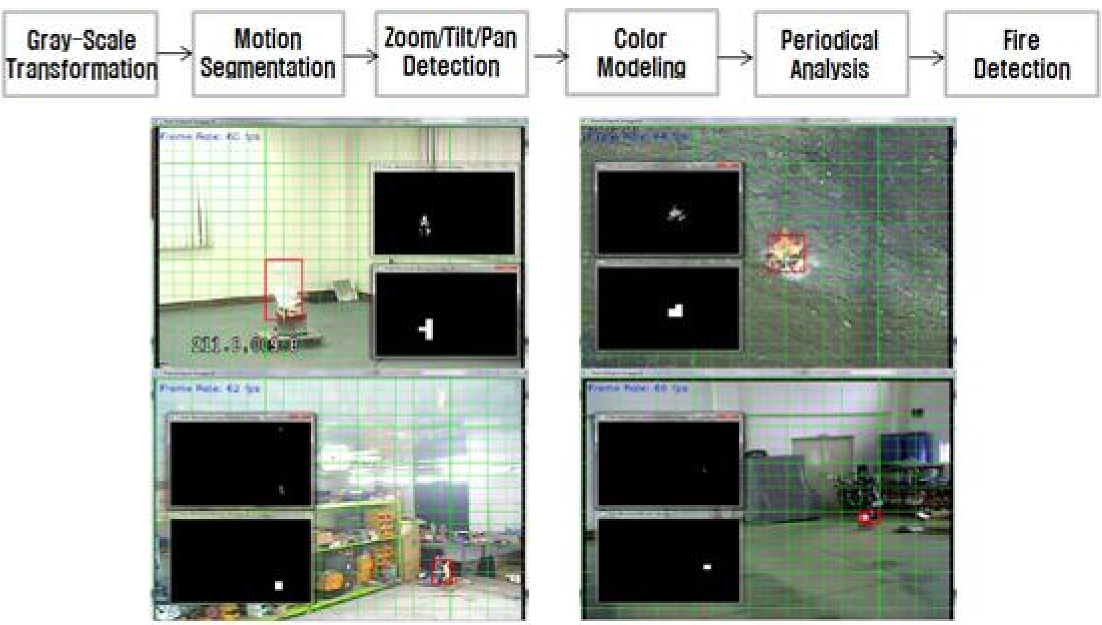

Figure 12. Block diagram and performance test of the flame detection algorithm

Table 1. Smoke and flame detection algorithm test results

Category	Smoke	Flame
Detection rate	93.75% (75/80)	96% (48/50)
False detection rate	5% (4/80)	8% (4/50)

4. CONCLUSION

Safety management automation technology can be applied not only in railroad stations, but also in public facilities such as subways, airports, and bus terminals. Such technology is planned to be subject to further development, to link existing facilities for more practical use. Through automatic safety management systems in railroad stations, integrated facility and service management becomes possible, which accordingly allows early detection of and prompt response to unexpected or dangerous situations in the railroad station. This will ultimately contribute to accident prevention and reduction. By reducing passenger-related accidents, especially for citizens with disabilities or who experience difficulties using public transportation, the welfare of the people, and their understanding of accidents and disasters, will be improved. In addition, operation personnel and costs will be optimized for unexpected or dangerous situations, such as fires and casualties. The cost of safety management automation can also be reduced through connection with and utilization of existing facilities.

5. FUTURE WORKS

A testbed selection study is required to apply railroad station safety management automation to the field. Through on-site surveys, data on the risks, uncertainties, and congestion in the station will be collected; safety management related to operational facilities will be investigated; and inspection of safety facilities, such as the scale of station, facility status by floor, station type, and elevator facilities will be conducted. A vulnerable station (determined by factoring in the number of users, the frequency of accidents, the risk level of the platform and the escalator, etc.) is the most ideal testbed. Therefore, the station to be used as the testbed must be selected efficiently by considering safety and cost.

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