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*Research Article*

# Smart Intelligent Safety Management System using ICT

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**Abstract:** A traffic accident in a tunnel have occurred continuously all year long for the last five years and the degree of risk for casualties from traffic accidents in a tunnel was higher than that of the casualties from traffic accidents per year. Therefore, the purpose of this study is to design and implement a system that detects the occurrence of abnormality in a vehicle inside a tunnel using a sensor in the tunnel and gives warning to drivers who intend to enter the tunnel from outside in order to prevent the occurrence of an accident inside the tunnel where the degree of risk for casualties is higher. This study also intends to implement a system that uses fire detection sensors in the tunnel to identify the occurrence of a fire inside the tunnel and sends drone to the location where the fire occurred and reports the scene of the fire to 119 in order to prevent the occurrence of a secondary fire inside the tunnel.

**Keywords:** Arduino, GPS, Bluetooth, Drone, Sensor

## 1. Introduction

The issue of traffic accidents due to an increase in the number of vehicles has been raised continuously, and the government and the Korea Expressway Corporation are investing a large amount of money and manpower for IOT (Internet of Things)-based vehicle accident prevention. However, vehicle accidents have not decreased **(Kyung-Gyun Lim, et. al, 2017; Yeo-Dong Yoon, et. al, 2018; Seok-Cheon Park, et. al, 2017; Yo-Hoon Hong, et. al, 2018).** Under such circumstances, the occurrence of an accident inside a tunnel is also brought to the matter because such accidents may lead to a secondary accident due to the accident occurred in the front and the occurrence of a falling object since the tunnel has an enclosed spatial structure unlike normal sections **(Kang Young-Gyun, et. al, 2015; Hojun Son, et. al, 2017; Jonghyeok Lee, et. al, 2018; Dong-Sung Seo, et. al, 2017).** The number of deaths due to a secondary accident, which would never have happened if the information regarding the occurrence of a primary accident was informed in advance, accounts for 14% of the total number of deaths due to traffic accidents **(Sang Hak Lim, 2015; Sang-Yeon Han, 2019).** Therefore, a system for preventing the occurrence of such accidents inside a tunnel is suggested in this study.

In this study, the goal is to prevent the occurrence of a secondary accident by identifying the stoppage of a vehicle inside a tunnel using Arduino sensor and delivering such information to subsequent drivers, and it intends to implement a system that captures the scene of a fire using drone and send the captured image to 119 when such fire occurs.

## 2. Related Works

### 2.1. Bluetooth

Bluetooth collectively refers to short-range wireless communication technologies, standards, and products for implementing two-way short-range communication between information appliances such as a cellphone, PDA, and laptop computer without complicated cables at a low cost. The Bluetooth area is being expanded gradually, and this study intends to use a drive system control module enabling Bluetooth communication based on Arduino which is actively applied in the field of creative and convergent educational activities **(Won-Woong Kim, et. al, 2016; Yoonjung Kim, et. al, 2018; Eun-So Choi, et. al, 2017).**

### 2.2. Arduino

Arduino refers to open source-based boards (products) completed by a single board microcontroller and the related development tools and environment. It provides Integrated Development Environment (IDE) for Arduino as well as software development and executable code uploads **(Thu-Trang Nguyen, et. al, 2016; Jong Kouk Kim, et. al, 2018; Sangbong Park, et. al, 2017).**

### 2.3. Drone

Recently, industries related to drone which refers to unmanned aerial vehicle (UAV) are becoming new industries that will lead the future. Since its development for military purpose in early 20th century, it has mainly performed military duties such as reconnaissance, surveillance, and bombing. Recently, the drone market includes drone as well as an aftermarket such as operation and A/S, and such rapid growth of the drone industry is expected to lead the development of various application fields **(Kang Wang-gu, 2019; Dong-Hwan Gong, et. al, 2018).**

## 3. Smart Intelligent Safety Management System

### 3.1. System Design

This study intends to prevent the occurrence of a secondary accident inside a tunnel by using Arduino board, radar detection module, and object detection sensor that detect the stoppage and abnormality of a vehicle inside the tunnel and by operating the display and barricade placed outside the tunnel based on such module and sensor. In addition, the study suggests a system that extracts information using flame detection sensor and smoke detection sensor for detecting the occurrence of a fire inside a tunnel, uses Bluetooth communication for linkage, captures the scene of an accident with drones using GPS module that can identify the location of a fire, and ultimately, sends the captured image to 119 so the 119 can identify the situation at the scene of the accident. The relevant system design drawing is shown in Figure 1. For the above system design drawing, an accelerator sensor that can identify the acceleration of a vehicle in a tunnel, a radar detection module that can identify the stoppage of a vehicle, a temperature and humidity sensor, a flame detection sensor, and a smoke detections sensor that can detect the occurrence of a fire due to an accident were used. To prevent the occurrence of a secondary accident in a tunnel, the detection of abnormality is displayed at a point 500m away from the tunnel entrance so that drivers who failed to recognize the situation inside the tunnel can reduce the vehicle speed when entering the tunnel.

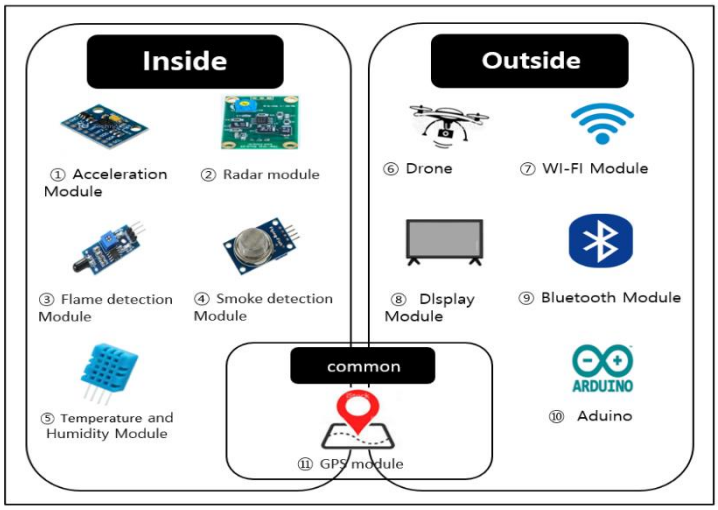


**Figure 1.** System Architecture

In addition, a drone is used to identify the location of a fire, capture the scene of such fire, and send the captured image to 119 in the event of a fire inside a tunnel. Bluetooth module is used for the communication between drone and Arduino module, and the image captured by the drone is sent to 119 through Wi-Fi communication so that 119 can promptly identify the situation at the scene of the fire. As shown in Figure 2, the flow of the relevant systems is divided into ① flow of accident detection and ② flow of drone capture after the fire detection.

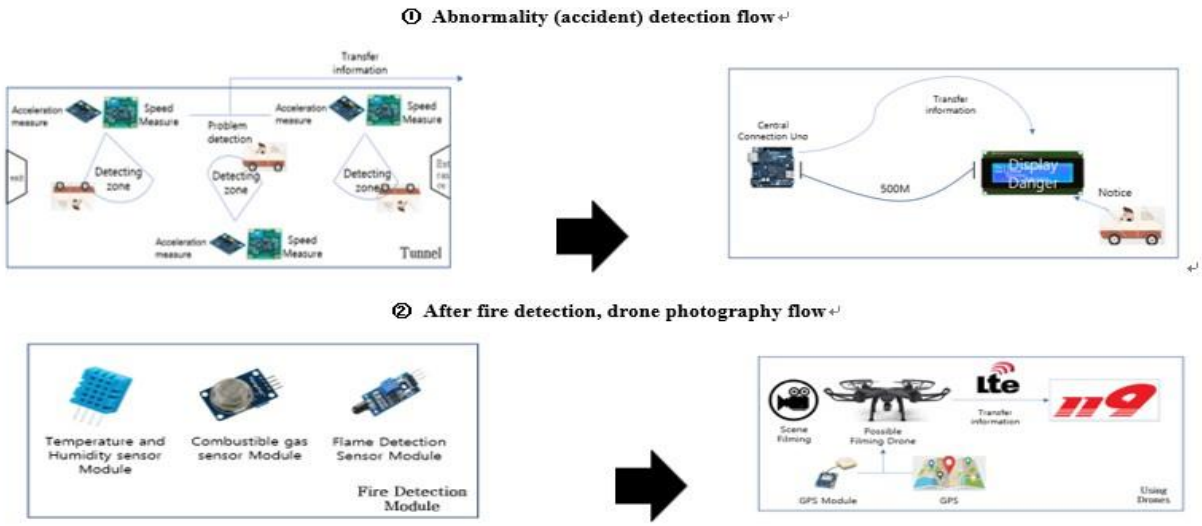


**Figure 2.** System Flow

### 3.2. System Implementation

The system in this study was implemented on Arch Linux ARM AArch64 64bit operating system and Sketch, an Arduino integrated development environment (Arduino IDE) program, was used to implement such system.

### 3.3. System Implementation Results

The system implementation result suggested in this study is as shown in Figures 3, 4, 5, and 6. Figure 3 shows the result of the x, y, and z coordinates displayed using the accelerator sensor which measures the rapid change in the acceleration of a vehicle inside the tunnel. Figure 4 shows the speed measurement result for an example to measure the speed of a moving object with a frequency change using a radar detection sensor. The goal is to find a location where the relevant value becomes 0.

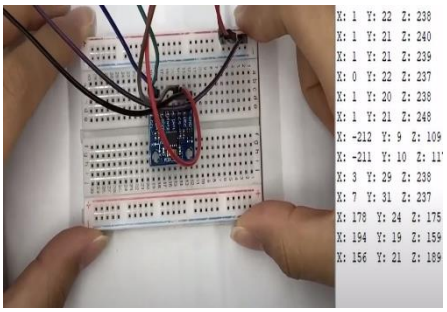


**Figure 3.** System Implementation Results 1

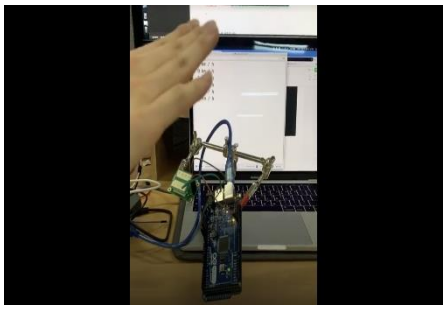

**Figure 4.** System Implementation Results 2

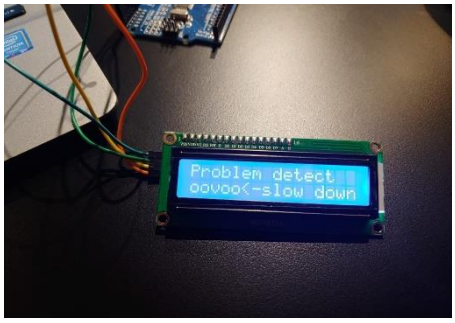


**Figure 5.** System Implementation Results 3

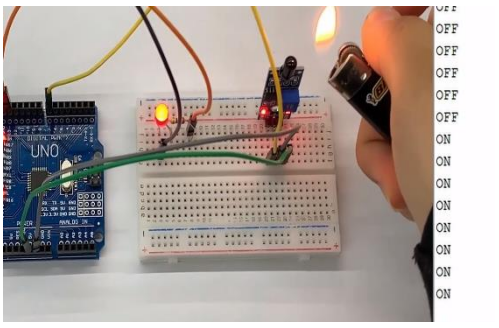


**Figure 6.** System Implementation Results 4

In Figure 5, when abnormality inside a tunnel is detected using Arduino LCD 16x2 4-pin, the detection of such abnormality is notified to drivers who intend to enter the tunnel on a position which is 500M away from the tunnel

entrance. Figure 6 shows the analog or digital signal output result displayed when the flame detection sensor detects a flame through the infrared LED at the time of a fire

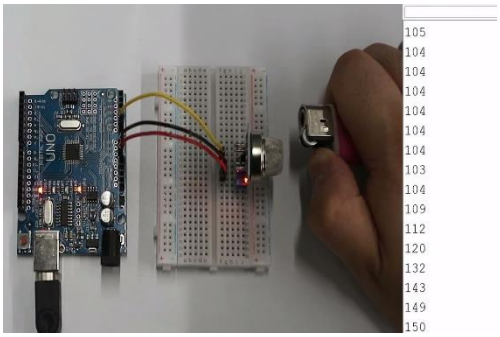


**Figure 7.** System Implementation Results 5

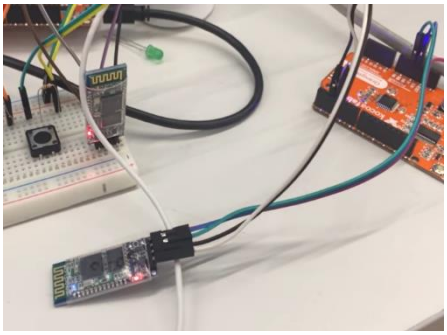

**Figure 8.** System Implementation Results 6

Figure 7 shows the resistance output result of the MQ-2 gas sensor module, and the components in the air are analyzed using the resistance value of the heater inside the gas center. It is used for the purpose of detecting the occurrence of a fire together with the flame detection sensor shown in Figure 5. Figure 8 shows the output result of wireless communication between Arduino through two Bluetooth modules (HC-06). Lighting on the Bluetooth module indicates that the communication is in progress. Figure 9 shows Arduino Wi-Fi ESP-8266 module (ESP-01) operation result. It shows that the use of wireless Internet is available within the signal range without LAN cable connection.

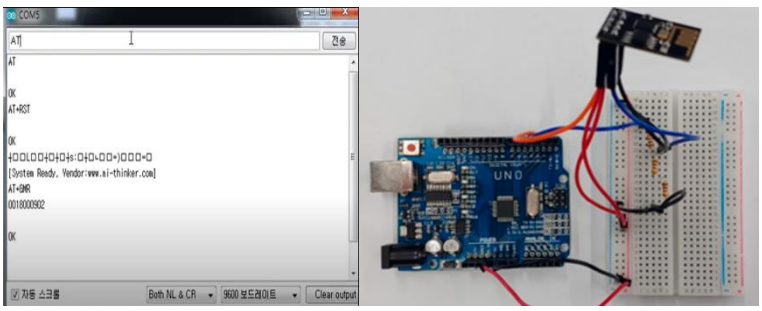


**Figure 9.** System Implementation Results 7

## 4. Performance Evaluation

The performance evaluation for the prevention of an accident and a secondary accident in a tunnel using Arduino sensor modules is as shown in Figures 10, 11, and 12. In Figure 10, it was first confirmed whether the acceleration sensor module could identify the rapid change in the acceleration of the model vehicle and whether the radar sensor module could detect a model vehicle accident by the vehicle speed maintained at 0. If so, it was confirmed whether the display module showed the detection of abnormality inside the tunnel accurately. The result is shown in Figure 11.

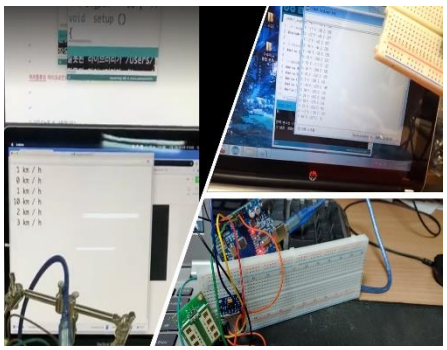

**Figure 10.** Performance Evaluation 1

| | Accident Dection | Required Time |
|---|---|---|
| SCENE 1 | O | 3 |
| SCENE 2 | O | 3 |
| SCENE 3 | O | 4 |
| SCENE 4 | O | 5 |
| … | … | … |
| … | … | … |
| … | … | … |
| SCENE 18 | O | 3 |
| SCENE 19 | O | 4 |
| SCENE 20 | O | 3 |

**Figure 11.** Performance Evaluation 2

In Figure 11, it was checked whether the system could detect each accident case, and if so, how long (seconds) it took to detect an accident. This process was expressed in a graph shown in Figure 12. Based on Figure 12, the model vehicle accident detection rate was 75%, false detection rate was 25%, and the required time for detection was approximately 3.8235 seconds on average. The cases with an error include the case of a model vehicle accident that occurred without a change in the acceleration of the vehicle, and the sensor was unable to detect such accident when this type of accident occurs. Figure 13 shows the result on whether a drone moves to the location of an accident using latitude and longitude values from the location information received from Arduino GPS module and hovers. When the correct GPS values were entered, there was no problem for the drone to hover on the location, but there was a difficulty in extracting accurate GPS values in a sealed indoor area such as a tunnel.

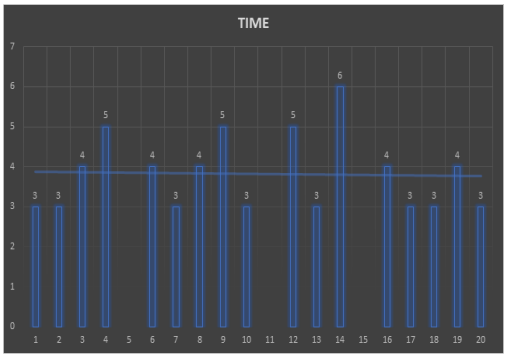


**Figure 12.** Performance Evaluation 3

**Figure 13.** Performance Evaluation 4

## 5. Conclusion

In this study, a system for reducing an accident or a secondary accident occurring in a tunnel by identifying the situation inside the tunnel in advance through Arduino board, sensor, and GPS module was suggested. In addition, the system was designed using drone, Bluetooth communication module, and Wi-Fi communication module to send the drone to the scene of a fire, capture the scene of the fire, and send the captured image to 119 so that 119 can identify the situation at the scene of the accident before they arrive when the fire occurs due to an accident inside the tunnel.

It is still impossible to avoid false detection rate and the time required for detection which are common issues of the secondary tunnel accident prevention systems that have been implemented so far. However, further studies intend to supplement the system through continuous development with the goal of reducing false detection rate and the time required for detection.

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