AIoT Platform of Accident Prevention in Alley Environments

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Abstract— **With the recent advancements in technology, the spread of smartphones has increased rapidly. Consequently, most individuals now carry smartphones and using them while walking has become a common practice. As a result, accidents involving pedestrians who are distracted by their smartphones and fail to notice approaching vehicles have become a significant concern. In this study, we propose an AI-based alleyway accident prevention platform to prevent such accidents. The proposed system integrates AIoT(Artificial Intelligence of Things) functionalities with CCTV(Closed-Circuit TeleVision)s installed in alleyways to detect vehicles and provide real-time notifications of their approach to pedestrian smartphone applications. In this study, YOLOv8(You Only Look Once version 8) was utilized as the AI(Artificial Intelligence) technology for object recognition, with training conducted using both daytime and nighttime data to enhance the model's robustness across different environments. When a vehicle enters the alley and is detected, an LED(Light Emitting Diode) installed on the ground is activated. Subsequently, when an integrated module attached to the bottom of the vehicle detects the LED, it transmits a beacon signal, which is then relayed to the pedestrian smartphone application to issue vehicle approach notifications. The results of the experiment demonstrated that vehicles were detected with an accuracy exceeding 90%, and the functionality of each component was verified. Based on these results, the proposed system is expected to effectively reduce accidents between pedestrians and vehicles.**

Keywords—AI(Artificial Intelligence), Object Detection, YOLOv8(You Only Look Once version 8), CCTV(Closed-Circuit TeleVision), Traffic Accident

I. INTRODUCTION

Recently, as smartphone usage has become more prevalent, the number of accidents involving pedestrians who fail to recognize approaching vehicles has increased. In particular, the risk of collisions between pedestrians and vehicles has risen in confined spaces such as alleys. Consequently, there is a growing need to reorganize the traffic environment in Korea to prioritize pedestrian safety. Accidents frequently occur in narrow spaces like alleys because pedestrians often do not notice vehicles in advance [1]. As a result, research on the correlation between the use of electronic devices while walking and traffic accidents has been ongoing. Notably, the traffic accident rate among pedestrians using smartphones is significantly higher than that of non-users. According to Power Korea Daily (2023), a survey of Seoul citizens aged 15 and older revealed that 69% used smartphones while walking, contributing to an increased traffic accident rate [2]. In fact, 61.7% of pedestrian negligence accidents reported to major domestic insurance companies in Korea occurred while individuals were using mobile phones, with most incidents occurring at crosswalks.

The results of the experiment utilizing a bicycle horn demonstrated that the recognition distance for pedestrians was significantly diminished when using a smartphone compared to when not using one. In a study involving adults aged 20 to 50, the average recognition distance for non-smartphone users was approximately 12.515 meters. However, this distance decreased by up to 80% when participants used a smartphone. Notably, activities such as texting or playing games on a smartphone further impaired the ability to recognize a bicycle horn, thereby increasing the risk of traffic accidents. Table 1 illustrates the correlation between smartphone use and traffic accidents[3].

TABLE I. CHANGES IN PERCEPTION DISTANCE DUE TO SMARTPHONE USES

Age	Not used	Text/Game	Listening to music
20s	15.0 m	10.0 m	6.9 m
30s	15.0 m	8.8 m	7.5 m
40s	12.5 m	7.5 m	5.8 m
50s	12.5 m	2.5 m	2.2 m
Entire	14.4 m	7.5 m	5.5 m

Through the data presented, it is evident that pedestrians exhibit significantly poor situational awareness when using smartphones. While restricting smartphone use while walking could effectively reduce pedestrian traffic accidents, such a measure infringes on personal freedom. Therefore, it is essential to develop a method that directly alerts pedestrians to the approach of nearby vehicles, allowing them to use their smartphones freely while enhancing their safety.

This study aims to enhance road safety and improve traffic flow by establishing a system designed to prevent accidents between vehicles and pedestrians in alleys. To achieve this objective, we developed a real-time vehicle recognition system utilizing YOLOv8 (You Only Look Once Version 8), which provides warning notifications to pedestrians. YOLOv8, the core technology of the proposed system, demonstrates exceptional performance in object recognition and is effective in accident prevention by detecting vehicles and pedestrians in real time. The system leverages existing CCTV(Closed-Circuit TeleVision) cameras and directional beacons to monitor vehicle movement in alleys and promptly alerts pedestrians of approaching vehicles through a smartphone application, thereby reducing the risk of accidents.

In addition, the system analyzes beacon and CCTV data using object recognition technology powered by AI(Artificial Intelligence) to detect potential collisions between vehicles and pedestrians at an early stage. This enables pedestrians to anticipate the approach of vehicles and respond safely. The performance evaluation of the system revealed that the

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YOLOv8 model achieved high accuracy and demonstrated stable recognition performance both during the day and at night.

The proposed system is expected to achieve two significant outcomes. First, regarding traffic safety, it assists drivers in recognizing the potential for collisions with pedestrians in alleys, thereby promoting safer driving practices. Second, in terms of manpower efficiency, the system enables real-time monitoring and notifications to prevent traffic accidents in alleys, eliminating the need for existing human surveillance personnel.

The paper is structured as follows. Section 2 describes the system configuration of the proposed system, Section 3 explains the implementation of proposed system, and Section 4 discusses the experiments and results. Finally, Section 5 presents the conclusions of this paper and outlines future research directions.

II. System Configuration

This section explains the configuration of the proposed system. First, the overall structure of the system is illustrated in Fig. 1.

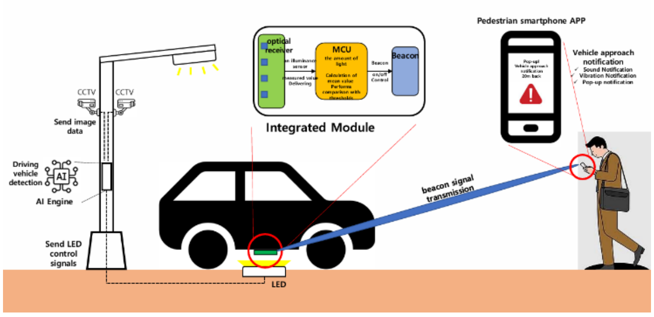

Fig. 1. Overall structure of the proposed system.

As depicted in the figure, the proposed system can be broadly categorized into three main components. The first component is the object detection unit, which utilizes CCTV and an AI engine to monitor the alley in real-time, identify approaching vehicles, and process the relevant data. The second component is the integration module, which detects the LED(Light Emitting Diode) lights installed on the road using a photoresistor located beneath the vehicle. This module also manages the beacon signals corresponding to each vehicle. The third component is the pedestrian smartphone application, which receives the beacon signals and provides visual and auditory alerts regarding the approach of vehicles. This function enhances pedestrian safety by alerting them to oncoming traffic. Each component is described in detail in the subsequent subsections.

A. *Object detection unit*

This subsection explains the configuration of the object detection unit. The unit relies on image data captured by CCTV cameras. By utilizing the YOLOv8 model, the object detection system achieves exceptional performance, characterized by rapid object detection speeds and high accuracy. OpenCV (Open Source Computer Vision) is applied to define the ROI(Region of Interest), an algorithm that crops and restricts the camera's focus to a specific area. This is implemented through code that sets the ROI and crops the image based on specified coordinates. In this platform, the

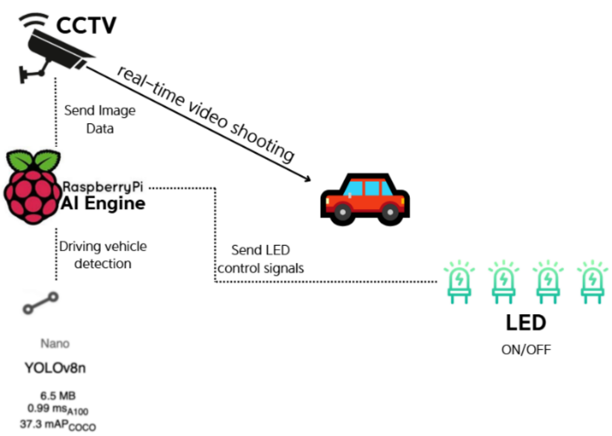

Fig. 2. System configuration of object detection unit.

area is constrained to a width of 300 to 600 pixels and a height of 300 to 700 pixels, allowing for the targeted detection of moving vehicles. Consequently, vehicles are detected using YOLOv8 in conjunction with OpenCV. When a vehicle is detected by YOLOv8, the LED lights installed on the floor of the alley are activated according to the GPIO settings.

Regarding this, the system configuration of the object detection unit is illustrated in Fig. 2. As depicted in the figure, the CCTV first captures the alleyway and transmits the image data to the Raspberry Pi. The YOLOv8 model, installed on the Raspberry Pi, detects the approaching vehicle and regulates the power of the connected LED. This functionality is subsequently utilized to control the integrated module mounted on the underside of the vehicle.

B. *Integration module*

The integrated module measures the light signal emitted by the LED installed on the alley floor and controls the On/Off power of the beacon module. To complement for measurement errors from the sensors, multiple photoresistors are employed. Each photoresistor utilizes the ATmega328 as its MCU (Micro Controller Unit), and the measured lux values are averaged by excluding the maximum and minimum readings. The microcontroller communicates with peripheral devices through its pins. It functions as a type of computer and features a pin layout structure, as illustrated in Fig. 3 [4].

Afterward, if the average value exceeds the threshold, it is determined that the LED is on, and the beacon is activated. The threshold was established by analyzing the photoresistors

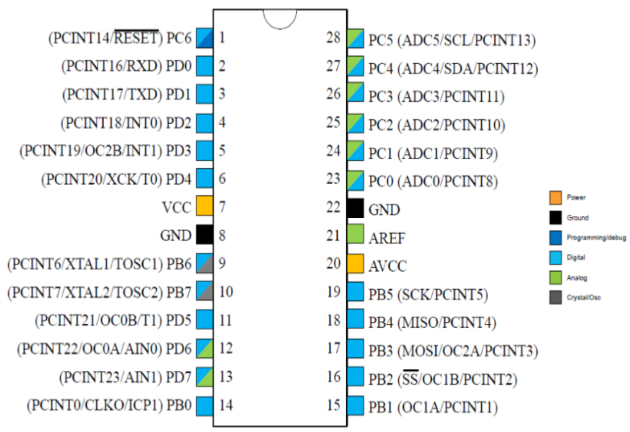

Fig. 3. Pinout structure of ATmega328.

Fig. 4. Appearance of directional antenna.

measurements during the daytime when sunlight is present, taking into account the lighting conditions beneath the vehicle. Various tests confirmed that a lux value below 900 was detected, while the lux value measured by the LED averaged around 1000 lux. Consequently, a threshold value of 950 lux was set. Additionally, to accommodate situations where the vehicle is parked in an alley, the engine is turned off, and then restarted, a function was implemented to retain the current on/off status of the beacon in the EEPROM(Electrically Erasable Programmable Read-Only Memory), a non-volatile memory component within the ATmega328. The EEPROM features a straightforward structure, with memory addresses and input/output operations managed in byte units. Furthermore, an external antenna was incorporated to transmit the beacon signal toward the vehicle without interfering with nearby facilities that do not utilize the platform. The antenna is directional, and as shown in Fig. 4, its radiation angle is confined to 120° with linearity, achieved through the use of a metal reflector to direct the signal toward the vehicle [5].

C. Smartphone APP

The RSSI (Received Signal Strength Indicator) value received from the integrated module to the pedestrian APP(Application) serves as a numerical representation of the strength of the radio waves received by the receiver. This value is expressed as a negative number, with the closer proximity to 0 dBm indicating stronger signal strength. Typically, a value near -100 dBm is regarded as negligible, as it signifies very weak signal strength, leading to unstable data transmission and reception. The RSSI range measured in the implemented APP spans from -10 dBm to -100 dBm at distances of 150 meters or more. This indicates that the data transmission and reception environment remains stable within a distance of 150 meters. The RSSI is represented in (1), while the distance between the transmitter and receiver can be calculated using (2).

$$RSSI = -10n\log(d) + a \quad [dBm] \tag{1}$$

$$d = 10^{\frac{a-RSSI}{10n}} \tag{2}$$

where, a represents the Tx power of the beacon, and n is the path loss index. In addition, the RSSI value becomes unstable due to noise in the external environment. To solve this problem, the implemented APP uses the Kalman Filter, which estimates the joint distribution of the current state variables based on the measurements performed in the past, to build a stable communication environment [6].

To explain this more specifically, the Kalman Filter operates in two stages: state prediction and state update, and the reliability of the measurement values is gradually increased by repeating this process. In the state prediction stage, the current state is predicted based on the previous state, and in the state update stage, the predicted value is corrected based on the actual measurement value. By repeating this process, the variability of the RSSI signal is reduced, and more accurate values can be estimated. The process of filtering the RSSI value with the Kalman Filter to alleviate the variability due to external noise is implemented in Kotlin code.

The UI (User Interface) of the implemented pedestrian APP is visualized so that pedestrians can respond immediately. When a vehicle approaches, the current RSSI value is displayed in dBm units, and vibration and sound notifications are provided according to the RSSI value. In addition, background operation was added to the APP, so that even if the APP is terminated, the presence or absence of a vehicle can be confirmed through a pop-up notification. This is a way to directly notify pedestrians of approaching vehicles while preserving their privacy as much as possible.

III. Traning of Object Detection Model

In this paper, we employ an object recognition model designed to identify a moving vehicle using Roboflow [7]. The model specifically recognizes a single class, to detect vehicles in CCTV footage. Labeling was conducted using Roboflow, while OpenCV was utilized for pre-processing to differentiate between driving vehicles and those that are parked or stopped, particularly in environments such as alleys. This approach allows us to categorize the recognition process into two sections: driving and parked vehicles. For the purpose of enhancing model performance, we labeled vehicle data across various environments and analyzed the comparative ratios of these data sets.

To learn YOLOv8, vehicles of the corresponding classes were first collected and labeled, as showed in Fig. 5. Among the collected data, usable samples were classified, resulting in 699 labeled daytime images and 230 labeled nighttime

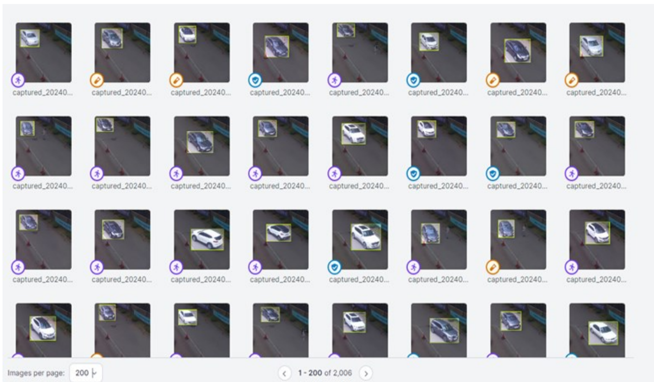

Fig. 5. Labeling process about CAR class.

Fig. 6. Labeling process about CAR class.

images, for a total of 926 car images. As shown in Fig. 6, the dataset was divided into 793 training samples, 102 validation samples, and 34 test samples. The learning process was conducted with the number of epochs set to 200, patience set to 32, and the image size configured to 416x416 pixels.

IV. Experimental Results

A This section presents the test results of the previously implemented platform. First, the results of detecting a moving vehicle through cropping in the object detection section are showed in Fig. 7. It was confirmed that the detection of a moving vehicle occurred in real-time, both during the day and at night, and included variables such as vehicle type and color. The vehicle recognition test was conducted over two months, encompassing both daytime and nighttime conditions while considering various factors. The moving vehicle was recognized in real-time without any errors.

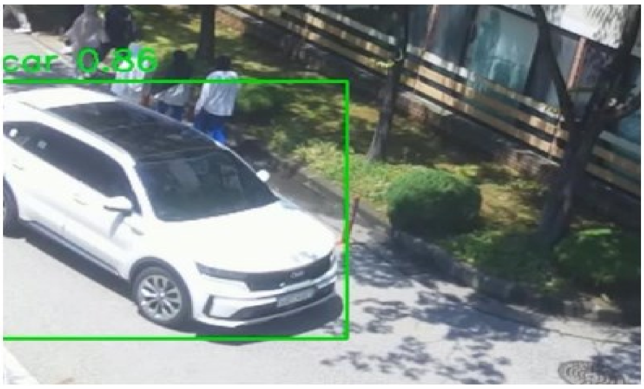

Fig. 7. Driving vehicle detection results.

The bounding box that appears when a vehicle is recognized is displayed in green and indicates the vehicle recognition rate in real-time as a numerical value. This image can be seen in Fig. 7.

After identifying the approaching vehicle, the LED on the roadway activates, and the integrated module responds as the vehicle passes over it. Testing and analysis of the illuminance levels beneath the vehicle in various environments, both during the day and at night, confirmed that the optimal threshold value is 950 lux. Based on this value, the threshold for the integrated module was established, and the recognition rate was found to be high across different environments.

The BLE antenna of the integrated system transmits a signal at an angle of 120° in the direction of the approaching vehicle, prompting a response from the pedestrian APP carried by the pedestrian. The notification process is illustrated in Fig. 8, which varies based on the distance from the vehicle. Testing of the RSSI value in an external environment confirmed that the pedestrian APP functions effectively at distances of up to 150 meters. In Fig. 8, the vehicle's distance is indicated, and a visual notification is provided. The notification includes a pop-up window, vibration alerts, and notification sounds, all of which can be promptly verified in a real-world external environment.

Therefore, in the implemented pedestrian app, it was confirmed that even when pedestrians merely held their smartphones in environments with poor visibility, such as alleyways, the distance from the vehicle and notifications were accurately communicated to them.

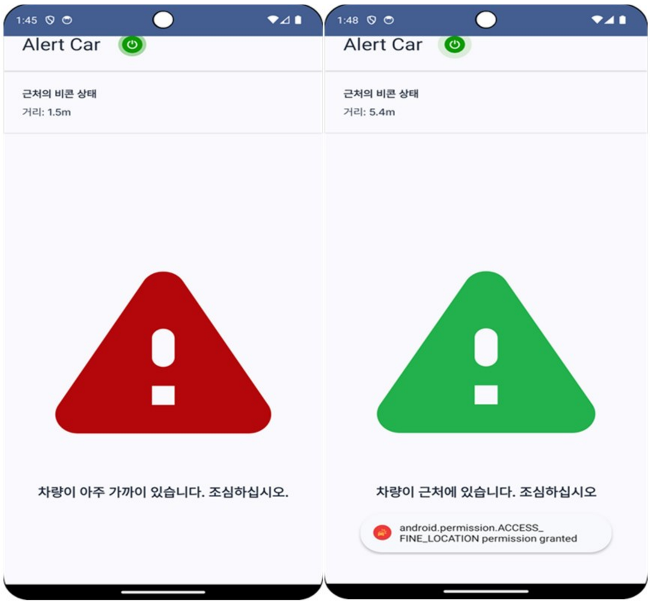

Fig. 8. Smartphone APP UI of pedestrian.

V. Conclusion

This paper aims to prevent traffic accidents by directly informing pedestrians of the approach of vehicles in alleys. The system introduced in this paper is an AI-based YOLOv8 and beacon-based alley vehicle approach notification platform. By effectively integrating YOLOv8-based vehicle object detection with a CCTV system, we have designed and developed an advanced system to prevent traffic accidents in alleys and blind spots. The YOLOv8 model provides accurate vehicle object detection and real-time performance, and its integration with the CCTV system is proven. These results not only have great potential for upgrading existing CCTV systems and ensuring traffic safety, but also seem to be an important system for enhancing pedestrian safety. In addition, the system can exchange information between vehicles and pedestrians within 30m by utilizing beacons and apps to promote effective communication between pedestrians and vehicles, and prevent accidents in alleys and blind spots. In addition, we aim to contribute to solving social problems in addition to the proposed technology based on intelligent CCTV.

In the future, we plan to add data sets and train models to improve the accuracy of the YOLOv8 model, and we plan to compare the performance improvement by changing the existing LED to an IR sensor method. Through this, we expect to achieve the expected effect of relieving the anxiety caused by the lack of visibility in pedestrian alleys.

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