Design and Implementation of Image Electronic Fence with 5G technology for Smart Farms

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***Abstract*--The 5G era brings the rapid development of the *Internet of Things (IoT)*. New technologies, such as image recognition, have promoted the traditional agriculture to a new milestone. Through advanced research and development of image recognition, it can intelligently monitor the growth of crops and effectively reduce agricultural damages, while avoiding crops being stolen and reducing the manpower of farms. In this paper, we design and implement an *image electronic fence* based on the technology of image recognition and sensor fusion with 5G technology for smart farms. By applying cameras and beacon tags, our system can identify whether the incoming/leaving people are authorized or not at the entry and exit of farms. In addition, with the high speed and low latency of 5G technology, the video data of cameras can be transmitted in a flash and fused with the beacon detection. In this way, the incoming/leaving people can be identified efficiently so as to avoid the farms being damaged. Based on field trials, we validate that the identification accuracy of our system approaches 90% in average.**

***Index terms*--5G, Internet of Things (IoT), image electronic fences, sensor fusion.**

I. INTRODUCTION

The 5G era is coming and makes *Internet of Things (IoT)* come true. One of the fascinating applications of *IoT* is environment monitoring. Based on IoT networks, each device can collect the real-time environmental information from sensors. However, only sensing information may not provide the precise and straightforward monitoring results, especially for the farm safety. Currently, if the farm administrator wants to know the information of daily personnel access to avoid farm damages, such as the unauthorized people stealing or destroying crops, the most common way is to apply the camera capturing. However, traditional monitoring system needs a lot of manpower to inspect the monitoring videos to find the suspicious events that are very ineffective and inefficient. In addition, it is difficult to recognize whether the incoming/leaving person is authorized or not when inspecting the videos once the damages happen.

For this reason, we develop an *image electronic fence* for smart farms with image recognition, personnel analysis and intelligent fusion technique to highly and precisely identify the incoming/leaving people automatically. Specifically, this system mainly bases on the sensing information, including the wireless signals of BLE beacons, which are carried by the authorized people and detected at the entry and exit areas of the farm, and utilizes the analysis results of image recognition to identify the incoming/leaving people. As shown in Fig. 1, the sensing devices and environmental cameras are deployed in the smart farm. The sensing devices, including the beacon receivers, are used for recognizing the authorized/non-authorized people and deployed at the entry and exit. The cameras are responsible for recording the events of people entering and leaving to achieve real-time access monitoring. In addition, these cameras are connected with the 5G wireless interfaces to achieve high speed and low latency transmission. Once the event occurs, the system will identify whether it is normal or abnormal immediately and notify the administrator via 5G communication instantly.

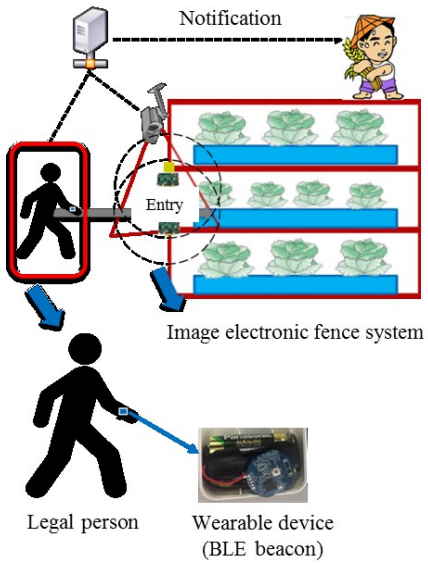

Fig. 1. Image electronic fence system.

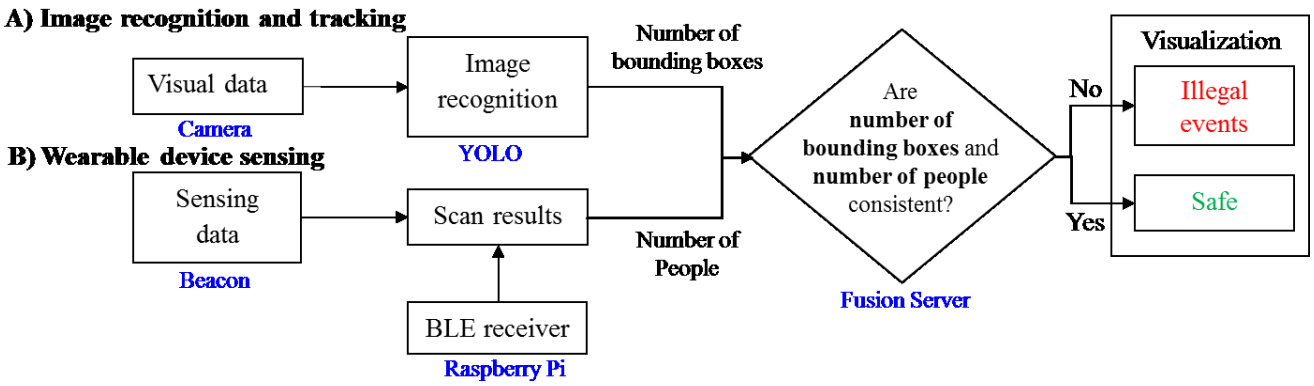

Fig. 2. System architecture.

II. SYSTEM DESIGN

Specifically, we design the image electronic fence for smart farms by integrating image recognition and sensing fusion for personnel identification. We use the beacon events to identity the incoming/leaving people as legal or illegal ones. This system contains three components: (i) image recognition and tracking; (ii) wearable device sensing; (iii) image and sensing fusion, as shown in Fig. 2.

A. Image recognition and tracking

We use YOLO2 (you only look once) [1] technology to analyze image and identify human. In addition, the object detector and tracking mechanism are also applied to efficiently trace the bounding box of human in the images.

B. Wearable device sensing

We implement the Bluetooth receiver by Raspberry Pi to identify the incoming/leaving people legal or not. Such receivers can continuously scan the number of legal beacons in the environment to precisely evaluate the number of incoming/leaving people, as shown in Fig. 3.

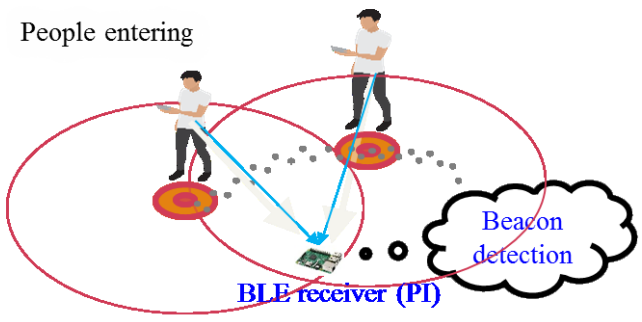

Fig. 3. Real-time scanning the environment.

C. Image and sensing fusion

With the high speed and low latency of 5G technology, it can send the image and sensing information rapidly to the fusion server. By the proposed intelligent fusion algorithm, it can pair the number of people recognized by the images with the number of legal persons identified by the BLE receiver to judge and assess the legal or illegal results.

III. SYSTEM IMPLEMENTATION AND PERFORMANCE EVALUAIONS

This system has been implemented. Fig. 4 shows the hardware of the system, including: (i) **Bluetooth receiver**: implemented based on Raspberry Pi (model B), which is deployed at the entry and exit of the farm to continuously scan the incoming/leaving person with legal identification or not; (ii) **BLE beacon**: carried by the authorized person to identify as the legal event for safety when people enter or leave the farm; (iii) **surveillance camera**: deployed on the top of fences to continuously capture the entering/leaving events and responsible to transmit captured videos to the fusion server via 5G interfaces; (iv) **fusion server**: responsible to pair the image identification and sensing information to judge the results and notify the farm administrator.

Fig. 4. Hardware components.

This system is deployed at the experimental farms in National Chung Hsing University (NCHU), Taichung city.

Each authorized farmer carries one beacon tag as the legal identification. When a person detected in the captured video, the system will inspect whether this is a corresponding legal identification or not. Fig. 5 shows two examples of the fusion results, which are one legal event and one illegal event as follows.

A. Case 1: Legal event

There are two persons entering the farm and each with a legal identification (beacon). The system judges this event as "Safe", shown on the upper-right corner of the screen in Fig. 5(a).

B. Case 2: Illegal event

When an illegal person (without identification) tries to enter the farm, the system detects this abnormal event and shows a "illegal event" on the upper-right of the screen in Fig. 5(b). Meanwhile, the system will notify this abnormal event instantly to the farm administrator by 5G network.

(a) Legal event.

(b) Illegal event.

Fig. 5 Two cases of identification results.

The performance evaluation results are shown in Fig. 6, where there are 7 different cases to verify: one person with identification in case 1; two persons with identification in case 2; three persons with identification in case 3; one person without identification in case 4; two persons without identification in case 5; three persons without identification in case 6; one person with identification while the other person without in case 7. Note that the cases 1~3 are legal while the other cases are illegal. In average, the identification accuracy of our system approaches 90% in average .

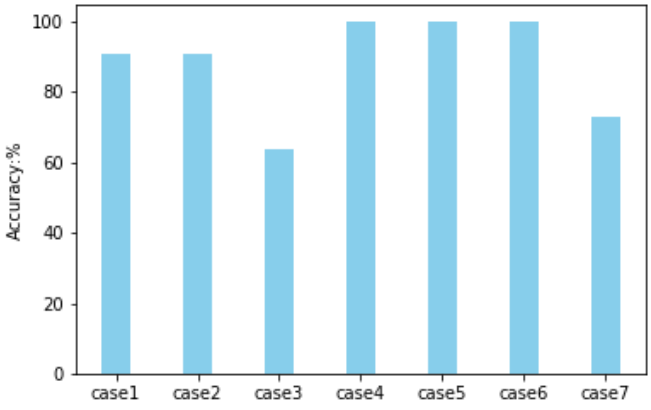

Fig. 6. Evaluation results of 7 cases.

IV. CONCLUSIONS

In this paper, we proposed and implemented an image electronic fence for smart farms by fusing image recognition with sensing information to intelligently identify the legal or illegal people. Thus, the incoming/leaving people can be identified efficiently and thus avoid the farms being damaged. Based on the field trials, we have validated that our system are practical and sufficient to ensure the safety for farms.

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