Developing Novel IoT System for Real-time Room Occupancy Monitoring

Matayoshi Shinjiro, Tanaka Daisei, Yun Sena
Department of Mechanical and Electrical System Engineering
Kyoto University of Advanced Science (KUAS)
Kyoto, Japan
2020m062@kuas.ac.jp, 2020m081@kuas.ac.jp, 2020m091@kuas.ac.jp,

I. Problem and Motivation

Coronavirus has changed our lives dramatically over a very short period of time. It forces people to stay apart and keep certain distance from each other. People are encouraged to avoid 3Cs-closed space, crowded place, and close contact. In universities and workplaces, rooms are only allowed to be occupied by up to 50% of their capacities. Nevertheless, there are often many rooms in an organization, making it extremely difficult for people to keep tracking the vacancies of all rooms by themselves. For example, the Kyoto University of Advanced Science (KUAS) holds at least 70 rooms in regular use. As a result, students may have to spend a lot of time searching for available study rooms on campus. Similar problem also exists in workplaces where office workers may have to waste time to look for available meeting rooms.

This study tackles the problems of lack of information about room congestion level by developing a real-time room occupancy monitoring system. The key research question is: What kind of sensor can obtain the most accurate estimation od room occupancy?

II. Related Work and Originality

Several methods for room occupancy estimation have been developed in literature. In [1], the authors proposed a method to estimate the occupancy of buildings based on the detection of CO_2. The drawback of this method is that it requires the implementation of a sensor utility network for CO_2 measurement. PIR (passive infrared sensor) based method for people count was developed in [2-3] and could achieve an accuracy of 95% in people counting. However, these systems were not for personal use; instead, they were mostly used by the administrators of office buildings to adaptively adjust energy consumption (e.g., lighting, air-conditioning).

The AkiKomi system that we will develop differs from existing room occupancy estimation systems in terms of sensing scheme, system architecture and the application scenario. We will thoroughly compare the accuracy and cost-performance of several types of sensors rather than simply relying on RIP. In addition, we will develop a smartphone application that offers intuitive user interface so that everyone—not just trained administrators—will be able to use it. Finally, the AkiKomi system can be used in many scenarios ranging from universities, offices, to restaurants and barbershops.

III. Research Approach

In this study we will develop a novel IoT system called "AkiKomi" to achieve the real-time monitoring of room occupancy. This study consists of four work packages: system architecture design (WP1), sensor comparison and selection (WP2), user interface development and testing (WP3), and whole system implementation and testing (WP4).

A. WP1: Designing System Architecture

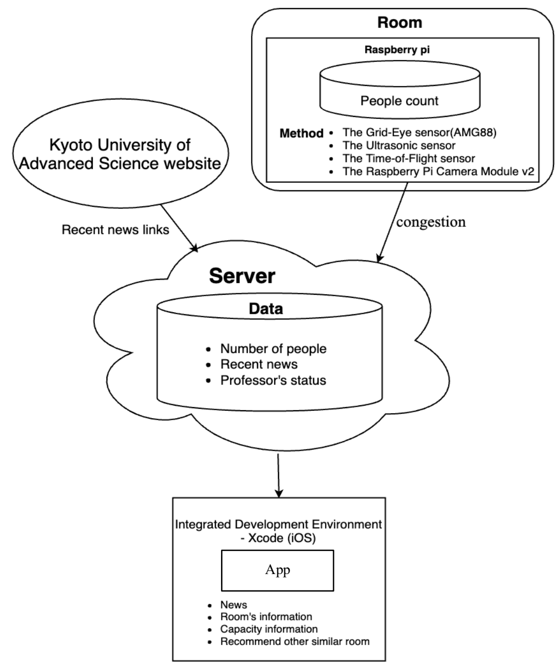

Figure 1. The system architecture of AkiKomi

The system architecture is shown in Fig.1. The AkiKomi system is comprised of sensors, sever and a smartphone. Distributed sensors installed at the entrances of each room, a server, a smartphone application. The app provides visual information of the capacity and congestion level of rooms for users and allows users to interact with the system through the user interface.

B. WPI2: Comparing Sensor Performance

As illustrated in Fig.1. small sensors will be installed at the entrance of a room to estimate how many people are currently inside the room. Several types of sensors can achieve the purpose, such as ultrasonic sensor, time of flight (TOF) sensor, infrared camera. The key research focus of this project is the selection of sensors. We will compare the accuracy of the following sensors in counting people:

1) Grid-Eye sensor (AMG88) is a sensor that offers digital output for thermal presence, direction and temperature values.

2) Ultrasonic sensor (HC-SR04) is a sensor that can provide 2cm – 400 cm non-contact measurement function, the ranging accuracy can reach to 3mm, the modules includes ultrasonic transmitters, receiver and control circuit.

3) *Time-of-Flight sensor (VL53L0X)* is a sensor that integrates a leading-edge SPAD array (Single Photon Avalanche Diodes) and embeds ST's second generation Flight Sense patented technology. The VL53L0X's 940 nm VCSEL emitter (Vertical Cavity Surface-Emitting Laser), is totally invisible to the human eye, coupled with internal physical infrared filters, it enables longer ranging distance, higher immunity to ambient light, and better robustness to cover glass optical crosstalk.

4) *Raspberry Pi Camera Module v2* is a camera which has a Sony IMX219 8-megapixel sensor. The Camera Module can be used to take high-definition video, as well as stills photographs.

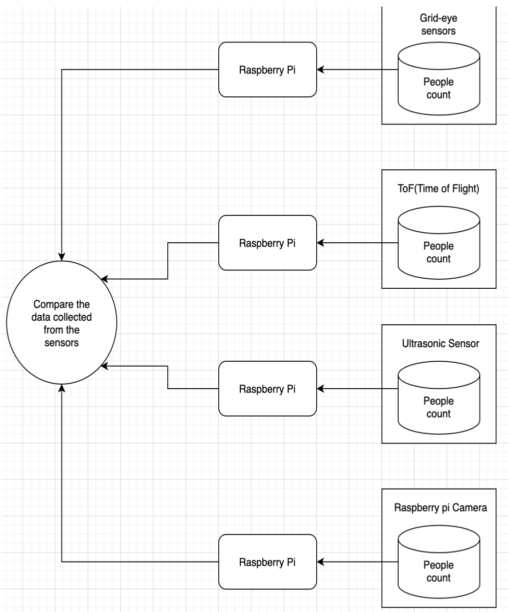

Figure 3. Comparing sensors method

The sensors that will be set up on the door in the same room. In order to construct a solid foundation to compare the passerby count numbers data collected from the sensors. Constant environment and controlled environment are used to have a fair comparation. Furthermore, similar microcomputers are used to have equal processing unit. Data collected from each sensor will be send to a server where the data will be compared and evaluate. Thus, knowing which sensors have the highest accuracy.

C. WP3: Developing Mobile Application

We will develop a smartphone application that users can check room vacancy in real-time. The app will consist of a front-end and a back-end. On the front-end, users will be able to get real-time information of the congestion level or vacancy rate of rooms. Based on this information, users will have a chance to decide where to go. A database will be implemented at the backend to store historical information of the crowded level of rooms. The historical data can be used in the next step to develop algorithms for room vacancy prediction. The problems at the current stage are the data consumption and data migration from the server to the application. It consumes a big data so reducing the amount of data need to be done.

Figure 2 Two screenshots of the user interface of the AkiKomi app. When a user taps the room button, the occupancy of the room will show up on the user interface.

D. WP4: Implementing and Testing the Whole System Usability study with 12 users.

Participants who will test the system usability are the key to improving this system even further. The method of recruiting participants will be through poster, online survey, and university website. The test users will be mainly university students, students will be given a task to insert the congestion level using the app that will be provided. If the students are able to understand and do the task effortlessly, this can conclude that the app interface and system are working seamlessly. The score of the students will be evaluate through the star from one to five. One is bad and Five will be perfect.

IV. Expected Results and Contribution

The contribution of implementing the AkiKomi can have multiple beneficials. One of the examples is being able to grasp the real time information of one place congestion level. The users are able to know in advance of the congestion level of the desired location and can avoid further congestion. Due to the current Coronavirus (Covid-19) pandemic. More and more people are needed to distance themselves from one to another. Through this benefit, the current society that are changed by the pandemic can be improve and lowering the risk of going to crowded places.

References

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