Congestion Monitoring System Using Infrared Sensor

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***Abstract*—Social-distancing is one of the measurements to prevent and reduce COVID-19 infection risk. An easy and effective way to keep a distance in a confined space is to limit the number of people in that area at a time. In this paper, we develop a congestion monitoring system using an existing motion sensor to indicate the occupation in the recreation area where a number of students will get together during break time. For the first phase, an infrared sensor, HC-SR501, and Raspberry Pis have been manipulated to collect motion data in order to generate graph visualization together with a heat map of the density of congestion. In the next phase, video images will also be used to identify the occupancy for higher accuracy.**

Keywords—congestion, occupation, monitor, sensor, IOT

I. Introduction

The pandemic of the Coronavirus (COVID-19) has changed our way of living as no one expected. Stereotypes and practices that people in society are ordinarily familiar with and have been able to anticipate have been changed in a new way under an unfamiliar standard that is different from the past. The concept of "new normal" led to a new lifestyle adjustment to keep oneself safe from infection, along with efforts to maintain and restore economic potential. Various inventions, innovations, and novel management have been introduced to society regarding food, costume, hygiene, education, communication, etc. Social distancing, which is staying away from anyone, is also one example of the new normal concept.

As several vaccinations are given to the public widely, living outside the home becomes more relaxed. Students are able to go to school, while workers can also go to their offices. However, social distancing, one of the measurements to prevent and reduce infection risk, still needs to be continued. An easy and effective way to keep a distance in a confined space is to limit the number of people in that area at a time.

In these past few years, efforts have been made to eliminate place congestion, primarily by limiting the number of people in that location at any given time. There are various methods even requiring special hardware, using a mobile phone, or obtaining data from any sources, according to the limitation of the users and budgets. In Japan, a simple and easy way to monitor the number of people in an area without investing in hardware is to look at the number of people from GPS on their mobile phones. However, there were some limitations to collecting the congestion degree of micro areas, such as in buildings, and it is challenging to manage the congestion degree data in each room in the building.

In this paper, we propose the first phase of developing a micro area's congestion monitoring system using IoT to prevent crowded gathering areas in the faculty. The first and current experiment can identify congestion density even though the second phase is planned for more accuracy.

The remainder of the paper is organized as follows. The related works are described in Section 2. Section 3 describes the methodology and experiment. The results and discussion, as well as the conclusion and future works, are in Sections 4 and 5, respectively.

II. Related Works

Congestion status has attracted both research and business interest, especially in the Pandemic COVID-19 era. The concept has been applied in various fields, including traffic congestion, human congestion, and human tracking. There are also many solutions to measure the congestion according to the degree of population density and the degree of utilization of the area, as well as the differences in used equipment and the way to collect data. The followings are some prominent solutions available in the market.

A. Congestion degree measurement by sensor data

1) Congestion degree measurement using the camera sensor

One of the congestion degree measurement methods using sensor data is congestion degree measurement using camera image processing by moving object measurement. This system uses the background subtraction method to detect moving objects. The congestion index is quantified on the program, and the user can grasp the congestion status from the output result. The noteworthy of this method is that it detects moving objects for each frame and continuously measures the degree of congestion. This makes it possible to measure the degree of congestion considering the situation before each measurement stage [1].

2) Congestion degree measurement using a line scanner

A line scanner is used as a congestion measurement method, especially for the particular situation of the railway. This system acquires image data using a line scanner for a railway vehicle stopped at the platform. The passenger's head coordinates are extracted from the image as feature data. The passenger's position in the vehicle is estimated based on the obtained feature data, and the estimation result is visualized [2].

In this system, the final output images are divided into vertical columns, and the images are heat-mapped according to the features obtained within the division range. This makes it difficult to estimate the depth in two dimensions. In the image, it is also possible to measure the degree of congestion by taking into account the number of passengers from the vehicle window on the shooting side to the vehicle window on the opposite side.

B. Congestion degree measurement by personnel wearing equipment

One of the measurement methods using personnel wearing equipment is to measure the degree of congestion with the microphone mounted on the smartphone and the accelerometer. This system collects the low frequencies contained in the ambient sound with the microphone of the smartphone. In addition, the walking cycle of the subject is measured by an acceleration sensor. By comparing the measured walking cycle with the normal walking cycle and analyzing it together with the surrounding low frequencies that change depending on the degree of congestion, each user's mobile terminal can be used. The congestion status is judged in real-time. By sharing these data on the cloud server, it is possible to perform participatory sensing of congestion information. This method does not use GPS but uses indirect sensors such as a microphone and an accelerometer. This makes it possible to collect the degree of congestion according to the situation in which each person is staying. Also, it can be obtained from multiple terminals. By integrating the data, more accurate data measurement is possible in that area [3].

In addition to these, there are also researches related to the analysis and visualization of specific site densities, including counting people using an infrared and a camera [4],[5], or counting system for smart buildings using Raspberry Pi [6]. A consideration on using these solutions, including devices, largely depends on their usage and accuracy together with the implementation costs.

III. Methodology and Experiment

The proposed Occupancy Monitoring System is a simple design with a small amount of cost, which can be adopted to use in schools, offices, and homes. In this section, the devices used and the methodology for Occupancy Monitoring System creation will be presented.

A. Main Devices

1) HC-SR501 Passive Infrared Motion Sensor

The HC-SR501 is based on infrared technology, with an automatic control module widely used in various auto-sensing electrical equipment. It is a kind of passive motion sensor module that uses pyroelectric principles to detect infrared radiation. This infrared radiation is caused by heat radiation from living things. When an organism passes in front of this sensor, it can detect infrared radiation and send it to the amplifier circuit to get enough intensity to send a "HIGH signal" out. At the end of every "HIGH signal," the module will stop working without any detection for 3 seconds which is the minor second of HC-SR501 time delay.

2) Raspberry Pi

The Raspberry Pi (Ras-Berry-Pie) is a small computer board that is similar in size to a credit card. It is a high-performance and affordable computer with its own specific operating system. The Raspberry Pi board is designed to have CPU, GPU, and RAM inside the same chip. And there is a GPIO (General Purpose Input/Output) connection point that can be used with other electronic devices, including a mouse, keyboard, and monitor as well. Moreover, it can connect to a wired network or wireless to make it a full Internet of Things (IoT) device that can be applied to connect to sensors in order to collect data as needed [7],[8].

B. Congestion Monitoring System

The objective of developing this Congestion Monitoring System is to measure the congestion or density of some small areas like classrooms, school clubs, or recreation areas in schools or offices to avoid crowded occupancy in this COVID-19 pandemic. The system is composed of an infrared sensor and Raspberry Pi2b.

The rationale for using the Raspberry Pi is that the Raspberry Pi currently occupies a large share of the microcomputers on the market. There are significant advantages in the availability and low cost. The Raspberry Pi is easy to use and efficient in connecting to sensor devices in comparison to other microcomputers such as Arduino, which has more complicated processing when using new sensor data analysis. In addition, Raspberry Pi can work well with machine learning modules.

Fig. 1 shows the system configuration of the proposed Congestion Monitoring System. The system consists of an infrared sensor for measuring the degree of congestion and the sensor control unit, database, as well as Web server unit using Raspberry Pi 2b, which is one of the microcomputers.

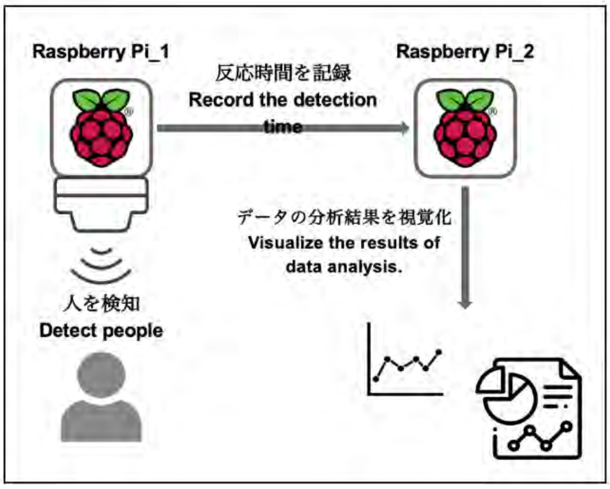

Fig. 1. Congestion Monitoring System

C. Methodology

According to the sensor data analysis method, the system will analyze the data obtained from the sensor and illustrate it visually and automatically. Users can understand the illustration of congestion which is dynamic processing without page transition and any special knowledge of users.

1) Pre-processing of sensor data

For preprocessing the data obtained by the infrared sensor, the recorded number of sensor reactions is accumulated every 15 minutes as one unit. The number of sensor reactions for each unit obtained will be analyzed for visualization. As for the motion data collection, three-second sleep time is provided to prevent the same person from reacting after the reaction signal. A number of reactions during the given time then is able to indicate the occupation of multiple persons in the area.

2) Visualizing sensor data

As the first provision of data visualization, the sensor data is graphed. In the process up to the output, the user selects the sensor for which the graph output is desired according to date and time. A line graph that meets the specified conditions is dynamically illustrated in which the output graph's start time and end time can be set freely, so the data transition in the time zone to be analyzed is described. And from the graph, the user can intuitively confirm the transition and peak of the congestion degree in the selected area, date, and time.

3) Statistic summarization and primary analytical output

The maximum number of reactions of the sensor under the output condition is selected by the user, as well as the average value of the number of reactions and the total value throughout the day. The number of reactions of the top (75% or more) and the lower (25% or less) under the selected condition will be recorded, while the congestion time under the specified conditions is calculated as an output.

As for the calculation of the congestion time, if the number of reactions of the top 75% or more mentioned above is recorded continuously for 30 minutes from the start time of the previous phase to the end time of the later phase in the continuous-time is defined as the congestion time. In addition, the analysis using the data recorded immediately before the selected condition is also the output at the same time. By this, the comparison of the analysis contents and the degree of congestion under the specified condition are different. It is possible to analyze the standing position compared to the data.

4) Congestion degree visualization in the area map

We provide a congestion degree heat map based on the recorded data in the area where the sensor is installed. In this analysis, a map of the area where the infrared sensor is installed in advance. Alternatively, by importing a floor map and setting the position coordinates of the installed sensor, an analysis of how much the infrared sensor responded in each time zone is provided in the form of color change. The analysis results can be obtained while imagining the actual space with a map so that more spatial consideration can be obtained regarding the analysis contents. However, the required time can be selected, so it is possible to confirm continuous changes in the degree of congestion. Fig. 2. displays the overview workflow of the system.

D. Experiment

The experiment was conducted in the recreation area before and during break time. The HC-SR501 PIR motion Sensor had been placed in the recreation area. Fig. 3a. shows the environment of the area before the break time with a few people coming in and out. While Fig. 3b. is during the break time.

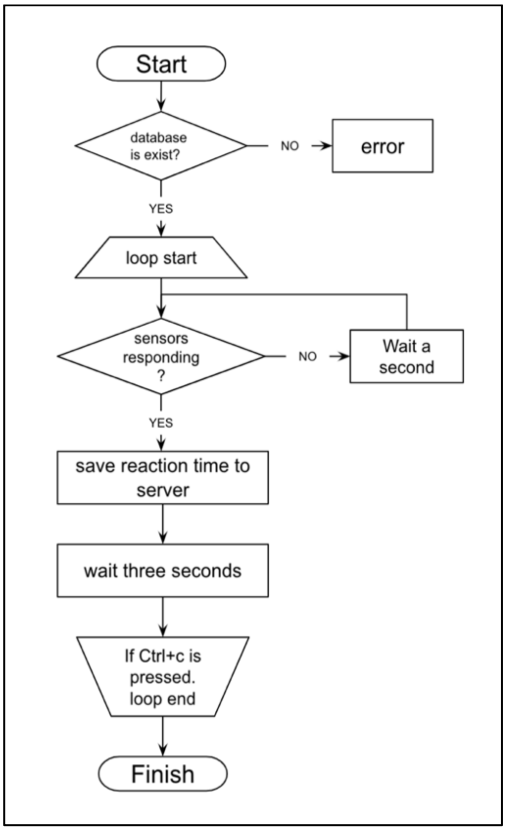

Fig. 2. System manipulation flow

Fig. 3a. Target area before the breaktime

Fig. 3b. Target area during the breaktime

Fig. 4a. Graph visualization from sensor data of the recreation before breaktime

Fig. 4b. Graph visualization from sensor data of the recreation during breaktime

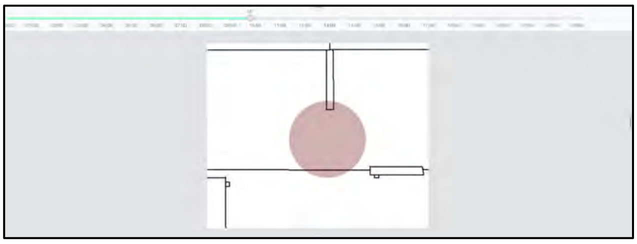

Fig. 5a. Heat map generation of low congestion before breaktime

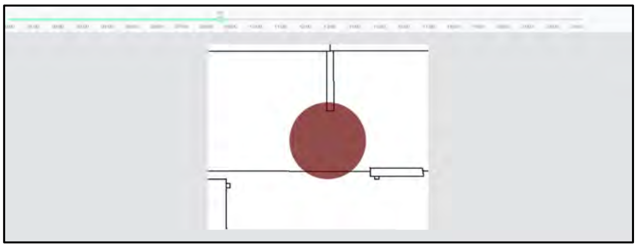

Fig. 5b. Heat map generation of high congestion during breaktime

IV. Results and Discussion

Regarding the result obtained from the experiment, the graph data analysis is shown in Fig. 4a. and 4b. illustrates the congestion before and during break time, which can also be represented as the heat map shown in Fig. 5a. and 5b. respectively.

The data recorded on November 19, 2021, with an assigned sensor is graphed. The graph is created every 15 minutes. The X-axis shows the recording time, and the Y-axis indicates the number of reactions of people who passed the sensor. However, three-second sleep time is provided to prevent the same person from reacting after the reaction signal. A number of reactions during the given time then is able to indicate the occupation of multiple persons in the area.

For heat map generation, which is illustrated in Fig. 4a. and 4b., the generation can be selected by timeslot from the slide bar. The intensity of the color displayed indicates the density of the area. The weak intensity of the red color indicates the low congestion, as shown in Fig. 4a, while the high intensity in Fig. 4b. indicates high congestion.

V. Conclusion and Future Work

The purpose of this paper is to describe the current state of the development of a congestion monitoring system using an existing sensor that aims to analyze the occupation of the recreation area during this pandemic of COVID 19. The experiment has been conducted to measure the degree of congestion in a micro area by constructing a simple system. The implementation of a system that can be easily used without external content has been completed. The result analyzed from sensor data can be visualized as the degree of occupation. Even though the condition of motion had been set, it still cannot confirm whether the density found in the area from the number of signals that appeared cannot completely identify the number of people in the area. The actual movement-image from the video will be used for the second phase of development and experiment to improve the accuracy of congestion identification. In addition, there are two other issues that need to be adjusted for our future works. The first issue is to config a more freely heat map illustration. In this state, the heat map is created by setting the position coordinates of the sensor in advance on the program. It would be easy to use if users could freely customize heat map analysis by voluntarily selecting the sensor position on the browser. The second issue is related to databases and web servers. For this current state, Raspberry Pi is used as a database and Web server, but communication lag occurs when connecting from multiple devices due to insufficient processing capacity. We plan to divide the roles of these servers into various Raspberry Pis.

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