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ABSTRACT
This paper presents an unobtrusive, low cost, light weight and easy to install laser sensor based method for door people counting system. The system employed two paired laser sensors on two doors of one laboratory connected to Intel Edison board. The sensors have the capacity to detect people entering/exiting the doors. The Edison board computes the number of people based on sensing people and directions using the counting algorithm. The application for counting algorithm is developed using python programing language. The system provided fairly accurate counting results under different scenarios with the best scenario 95.3%. The scenarios tested were the sensors placement location on the door (knee (87%) or shoulder (93%) shoulder position using upload option to the cloud the improvement was 8% for changing location alone. Changing rules for uploading data from cloud to local server for the shoulder position has shown a 3% increase in accuracy (93% to 95.38%). The system has many implied applications like controlling room light, Controlling Heating, Ventilation and Air Conditioning (HVAC) and for tracking visitors' statistics in libraries, archival centers, and seat reservation systems.

Author Keywords
Laser Sensors; Smart home; people counting, Edison Board

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Background
The term smart home or intelligent home have been used for more than a decade to imply the integration of technologies and services for home networking for better life [1]. In today's society, emergence of Internet of Things (IoT) concepts as an enabler to connect everything together has made the effort for smart home/room/environment/services simple [1, 2].

The purpose for smart home/room/environment can be convenience of life style, security, healthcare, energy saving and service monitoring particularly Controlling Heating, Ventilating and Air conditioning (HVAC), Lighting and data logging for further analysis of resource utilization patterns by mashing up with other data sources[2].

Sensors play an important role in the development of smart room/environment systems [3, 14]. There are open programmable computing and communication hardware platforms like Arduino, Galileo board, Zigbee, Xbee, Raspberry Pi and Intel Edison board for storing, computing and transmitting data that makes the IoT system development and data transmission easier and cheaper [4,15].

In the broadest sense, it means building interactive physical systems by the use of software and hardware combination that can sense and respond to the analog world is becoming easier and easier on one hand and very crucial on the other hand in human life [5].

People counting is considered as a critical part of smart environment/room [10, 13]. Efficient decision and management of resources would possible if we could appropriately measure the visitors. “If you can’t measure it you can’t manage it” [6]. Door people counting that is important to measure the audience in the room/environment is one technique in certain service room or store to measure the audience.

The early people counting was based on manual fashion where a person sit on the door and tally the number people entering particular service areas like shopping stores, libraries, cinema halls. Manual surveys are tedious and not scalable. This leads to the development of new technologies and techniques for people counting.

Nowadays, technology is advancing to enable automatic people counting using thermal or beam sensors and video cameras [6].

Some of the challenges include the inaccuracies in the case of using either thermal or beam sensors for mere fact that they fail to separately count two or more people entering or exiting the door at the same time or the effect of temperature spikes in the case of thermal sensors. In case of the video camera based people counting, it is expensive, some of the applications are proprietary and needs on site server. Therefore, research efforts to come up with low cost and more accurate door people counting system is underway.

This research is one of this efforts that tries to prototype the door people counting based on laser sensors and Edison board.

RLATED WORKS

People counting systems are very crucial in developing intelligent services or control routine activities in the home/environment. Automatic people counting systems are also important in various application areas, where the activities of people is need to be analyzed, track the service load on a certain day, hour and minutes . Decision and actions that, managers of different resources/services needs visitors’ statistics [6, 13]. Some of the systems developed so far are working based on occupancy detection principle in form presence of people is represented by 0 or else based on voltage level of heat emitting from human source as in Suk Lee et..al [7] not actual counting. The disadvantage of the occupancy detection is it depends on the motion of people. That mean if someone is sitting inside the room it is considers as no presence since it works by the principle of motion in the sensing area as existence and no motion in the sensing area as nonexistence for example smart floor [7]. Some of the counting systems developed so far are camera based which is limited to field of view, invade the privacy of users and are very expensive, proprietary, hard to install and needs expensive onsite server as it is best example in for this Easyliving [8, 12]. Some systems need devices with infrared transceiver or RFID to be handled by the human subjects to be detected best example for this Active Bat [11] but in this research, we aimed to prototype the new and low cost system that is capable of sensing human passage and its direction without people are required carrying or attaching any devices to their body and the system will provide the actual number of people, not only occupancy detection.

Some of the challenges of the laser sensor based people counting systems are counting more than one people crossing the sensing line together at the same time as one, direction sensing is also a problem and object indiscrimination from the human as laser source for counting. The challenge in this research is to come up with best combination of hardware and algorithm to obtain better system for automatic door people counting. For this purpose, we propose a laser low cost laser sensor with Edison board with new algorithm.

MOTIVATION

The motivation behand this research paper is prototyping low cost, lightweight, unobtrusive, and easily installed and provide actual counting instead of only detection with acceptable accuracy using laser sensors, Edison board combined with efficient computing algorithm for counting and data transmission. In addition, it is aimed at the determination of the best scenario for position of the laser sensors on the door and means of data acquisition for higher accuracy so that the resulting data would be mashed up with other data and be analyzed for the purpose efficient decision making and resource utilization.

METHODS

The system is basically consisted of paired light-weight laser sensors attached on the door frames of the lab selected for the experiment and connected to the Edison board. The counting algorithm is programmed and the application is residing on the Edison board. The code is written in a way it uploads the counting data in Google sheet or the personal portal server based on the scenarios for every entry or exit of the people into the room in a real time basis. The framework of the system is as presented in figure 1, Where laser sensors were attached on the two doors’ frames of the lab were connected the the Edison board through cables and the Edison board is programmed for the counting algorithm, data is transmitted to the server wirelessly as shown in figure 2. The role of the sensor is to sense people through laser, which emanates from people passing the sensing line and the direction signal.

The sensors send signals to the Edison board. The number of people can be accessed from server anywhere at any time on a PC, tablet or smart phone from the cloud

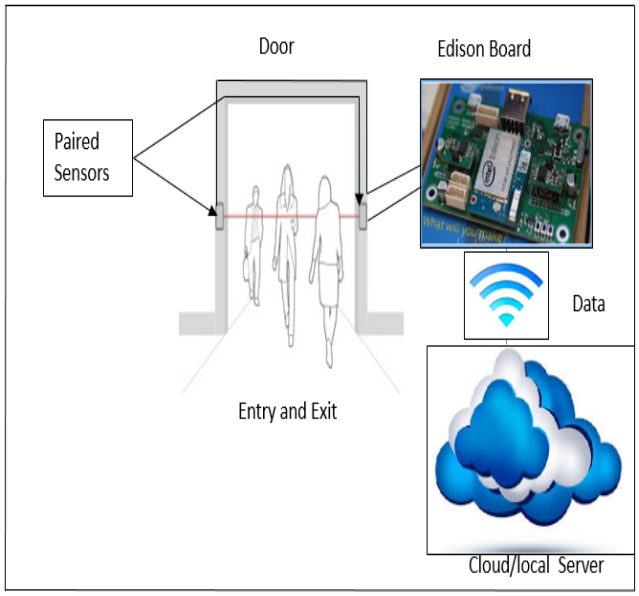


Figure 1: Conceptual Framework of the Counting System

or the local server to which the data is uploaded, if the administrator shared it users.

For evaluation of the accuracy of the sensors we made a careful observation of the number of people in the laboratory and the data from the sensor count at particular time. The average accuracy was calculated as the summation of the of the absolute value of the difference between the manual count and the sensor count dived by the number of times the observation was made

The physical configuration of the system is as depicted in figure 2.

The paired laser sensors were connected to the Edison board through cables and the two boards are also connected through a cable as illustrated in the figure 2 above.

Edison board wirelessly connected to the server and the excel sheet data accessed from the server. Close observation of people behavior during the experiment for handling unique cases and what factors determine counting accuracy.

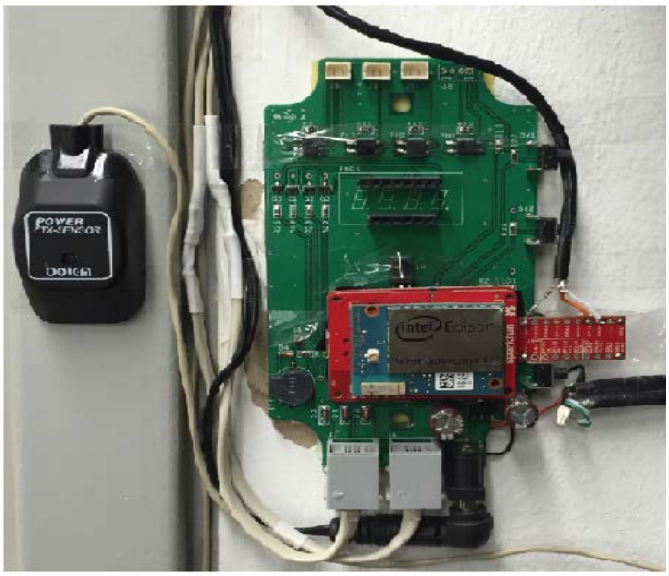


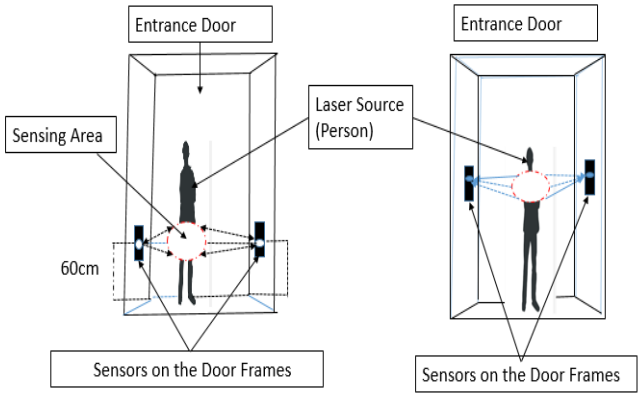
Figure 2: Physical Configuration of the boards to which the paired sensors are connected

EXPERIMENTS AND RESULTS

In the experiment, there are three scenarios, which were tested. These are:

1. Placing the paired laser sensors at Knee position and uploading the data to the google sheet (Cloud).

In this experiment, low accuracy of counting was obtained relative to the second and third scenarios, which is attributed to the counting of the two legs of one person going slowly as two and counting two people coming in or out at the same time as one, as observed. The accuracy was 86.5% on average for the observed number of times. In addition, the sound from the Edison board when people cross the counting line was annoying to the people when observed during the experiment. The scenario for this position illustrated in figure 3, scenario #1.



Scenario #1 Scenario #2

Figure 3: Paired laser Sensors at knee and shoulder positions

The calculation of the evaluation was done by taking the average of the accuracy measures of the observation at t_1, t_2, t3 … t_n , where time t_n is the time at which the actual people in the lab is observed or counted and compared with the sensors count. The actual count is the actual number of people at time t_n and the sensor count is the number obtained from the sensor data at time t_n.

2. Placing the paired of sensors at shoulder position and uploading the data to the google sheet.

In this scenario, we achieved, a better performance of the accuracy (93%) on average for the number of times it is observed. The difference is due to the change in location of placing the sensors on the door that lead to the discrimination of objects people may have at hand as it was strictly observed and tested. The difference in accuracy was 8% due to well performance of the sensor counting at shoulder location.

3. Placing the paired of sensors at shoulder position and uploading the data to the personal portal (local server) than in to the cloud. In this scenario we could find better accuracy than the previous two scenarios because of the changed rule from uploading data to the cloud to local server, which to some extent reduced the problem of interruption of data uploading of free google API. This in turn led to the fast update time. In the other way round, it means that the speed of real time updating the data is become fastest than previous scenarios from 1 minute in the case of cloud to nearly 30 seconds in the case of local server. The accuracy of the third scenario was 95.38% for the observed number of times. This is a 3% increase than in the second scenario and 11% increase than the first scenario i.e when changing the sensor location from knee to shoulder and change in data uploading rule combined compared to knee position and uploading to the cloud.

This is considered the promising accuracy that can be achieved by this very low cost combination hardware and best algorithm for counting the number of people in a room. This finding will have very important implications for many application areas like automatic light control, managing room temperature, seat reservation, user/visitor statistics in the service areas like libraries, archival centers, museums etc…

Finally, the means to make the sensor counting unobtrusive was by avoiding the sound of the sensor when people cross the sensing line by disconnecting the audio circuit from of the Edison board that made the system silent and unobtrusive. The distraction that happened to people and the consequent dissatisfaction is decreased when counted by the sensor as obtained through observation before and after the sound is eliminated.

This result indicates that, in this research the combination of hardware (laser sensors and Edison Board) and newly developed counting algorithm provided a promising counting accuracy with low cost, unobtrusive, lightweight and easily installable. The improved accuracy is attributed to tuning the algorithm rules for counting for example the way data is uploaded and the best way for direction detection combined with finding the optimal location for placing the sensor on the for discriminating objects from humans.

The summary of the three scenarios are presented in table 1 bellow.

Table 1: summary of scenarios and Accuracies

Sensor Location	Data Upload Rule	Accuracy (%)
Knee	Cloud	86.5
Shoulder	Cloud	93
shoulder	Local Server	95.38

DESIGN IMPLICATIONS

Even though this research is a prototype on a single laboratory room having two doors, it has a lot of implication for designing service products for many application areas.

It is possible to use the data for automating the switching on/off the light in a room. This means possible to design a system that automatically switch on the light when the first person is in (when the count is set 1) and switch off when the last person leaves the room. It has also a potential to study the electricity consumption patterns/behavior of the people by mashing up the people counting data and the electricity consumption patterns in the particular room.

It is possible to develop a system that can regulate the room lighting system based on the number of people using. Usually room temperature raises as the number of people raises which can also be studied by mashing up room temperature with people counting data keeping other constant in the case of HVAC.

It has also the implication for seat reservation systems. It is known that certain room can accommodate only a certain number of people and the room should say “I am full” based on the sensor count. User statistics sensitive services like libraries, archival centers, museums and the like can make use this cheap technology to estimate their user statistics and mange and allocate necessary resources for the efficiency of their services.

LIMITATIONS AND FUTURE WORKS

One of the limitation of this research is that there was no automatic way for adjusting sensor counting error. It was handled in manual option for the prototyping purpose. Searching for automatic way of doing it will be important future work. Currently the sensors and Edison board are open for physical interference by humans intentionally or unintentionally that would affect its accuracy and it needs more protected system from human intentional interference for better accuracy. This paper is limited to prototyping the door people counting system on a single laboratory our graduate school and its evaluation for accuracy under careful observation but in the future, using the data for the purpose of developing service based on prototyping result will have paramount importance. For example like analyzing the pattern between electricity consumption and the number of people in the room by mashing it up with electricity consumption data, room temperature versus the number people in the lab. System that can automatically switching on the light when first person enters the room and switching it off when the last person leave the room could be the future work and the like. Moreover, the findings are not supported by the statistical test, it is just descriptive report of the experiments.

CONCLUSIONS

In this paper, different related works were reviewed to see the technologies existing so far and to clear show the research gap for which this research is necessitated. It has been uncovered that the existing technologies so far: some of them just do detection not counting, some of them are visual counting based on camera which is privacy invading or limited to the angle of view. Some of the technologies are very expensive to implement for the average people. In addition there have been some challenges to implement the low cost sensors for people counting like direction sensing, counting two people as one coming in out at the same time and adjusting the errors. This research used a novel approach to combine laser sensors, Intel Edison board and networking principle with a new and efficient algorithm for counting people and transferring data to the server. We could find also the best scenario for placing the sensor with promising accuracy of counting. The finding can be a base for designing applications based on this finding automatic switching of lights in a room, the data can be used for other managerial decision making as a result of the analysis that would be obtained from the data for efficient resource management.

It has been found that making the system unobtrusive by avoiding the sensing sound make it comfortable the people who are being counted. This prove that people being counted are not to be distracted by the sound because they are even not aware of being counted as confirmed through observation compared to when the sound was not off.

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