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Smart Crowd Management and Seat Allocation System

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Abstract

Logistics needed to register and control the audience at large event venues are often complex to implement. In this study, an internet-of-things-based crowd management and seat allocation system was designed and implemented. The study is focused on implementing a crowd traffic control system within an event venue. Furthermore, it aims to establish an efficient seating arrangement to ensure that attendees are seated appropriately, utilizing a seat allocation system to prevent unauthorized occupancy of seats. This design exhibits versatile applications, including crowd management at events, conference halls, and airplane booking systems, etc. Previous literature has explored digital and software-based approaches to crowd management and seat allocation. However, this project distinguishes itself by integrating both hardware and software components, presenting a comprehensive system. The successful implementation of the study involved rigorous testing, ensuring the collaborative functionality of all subsystems. The achieved results during the prototype testing and implementation fulfilled the research design objectives. Notably, the final prototype is scalable, allowing future modifications to adapt to diverse physical venues and audiences.

Keywords
Crowd Management, Radio Frequency Identification (RFID), Seat Management, Seat Allocation, and Smart Sensors.

1. Introduction
Since the COVID-19 pandemic, crowd management is of high paramount, not just for the spread of the virus, but for ease, security and control of people attending any events (Ahmed and Memish 2016; Das, Behera, and Paital 2022; Dillette and Ponting 2021). The crowd management and seat allocation system for closed venues can further be used for different applications such as conference hall seating arrangements, aeroplane seating arrangements, stadiums, bus seating arrangements, etc. The maximum number occupying any event can be hard and thus cause an exceeding inflow and outflow of people in the venue (Ferleger 2022; Vouriot, Burridge, Noakes, and Linden 2021; Zhao et al. 2020). Furthermore, it gets very hard for security guards to keep track of the number of people entering and leaving any venue to ensure that the recommended occupancies are not exceeded. Another problem that arises from this is that participants are still being encouraged to practice social distancing while in venues or public places, but mostly not being adhered to (Coroiu, Moran, Campbell, and Geller 2020). On the other hand, a huge number of crowd traffic can be challenging to control. Therefore, organizing large crowd traffic often involves a huge task (Almutairi, Yamin, Halikias, and Abi Sen 2021; Guo et al. 2015).

Crowd management dates back to 1920 when there was no organized structure in response to crowds (Dibley 2023; Kushner 2023). The structure was very standard; security and officials would make a barrier to prevent or let people enter a venue. As years progressed, doors, gates and fences were used as barriers. Managing crowds is very important

because it helps ensure the safety of the people in the venue, staff, and hosts of the event. It also ensures that there is a steady crowd flow and prevents excessively dense crowds (Umair, Cheema, Cheema, Li, and Lu 2021).
This study is further organized as follows: after the introduction is a literature review which details previous work and the significance of the present study. Following is the methodology, experimental setup, analysis of results, and conclusion.

2. Literature Review

Previous work has been done based on crowd-limiting and seat number allocation systems (Shalash and Al Zahrani 2017; Song and Zhou 2013; Vidyasagaran, Devi, Varma, Rajesh, and Charan 2017). Song and Zhou (2013) carried out a software-based system which was aimed at demonstrating the Internet of Things (IoT)-based solution to the crowing problems in public places by using smart seating that can detect and display the seat occupancy status in real-time using the internet or a mobile application. The prototype was simulated using NETSIM simulation and the results showed promising results. Vidyasagaran et al. (2017) create an alarm system warning the participants about the crowd levels at the location of interest. The design made used of a server application connected with the IP cameras at the location to detect the crowd levels while the other one is the mobile application with different user rights that warn the users with the aid of an alarm system about the crowd levels at the venue preventing crowd level dangers. The work in (Shalash and Al Zahrani 2017) made used of a new technique of counting the number of people in a crowd as part of automatic crowd monitoring.

Two domains of crowd size estimation were combined for the technique of which one is to approximate crowd size and the other one is counting the exact number of people in the crowd. These used the image features to approximate the crowd size and the other classifies the images into suitable classes and combining the two determines the number of people in the crowd. The study is a mathematical model-based and optimization-based study where the data of the crowd is analyzed based on classes and characteristics of models used to monitor and control future crowds. However, these works done on crowd management were software and theory based thus failed to give a prototype that shows how well the system ensures that the crowd traffic is controlled, the limited number of occupancies is not reached and that participants are sitting in a good sitting arrangement. Even though a low-cost IoT-based crowd management system for public transport showed promising results with the software prototype in achieving the objective of managing crowds, there was no work done on an automatic hardware device/system that ensures that the crowd is being managed and the smart seating ensures a good sitting arrangement. Furthermore, the work on the mobile-based crowd management system was aimed to control crowds based on the decision made by the participants after receiving the warning of the crowd levels at the specific location. There was no work done on managing the crowds if the participants decide to go to the location.

Therefore, this study aims to design and build an automatic crowd control system that allocates seat numbers to the crowd occupying event venues. The final prototype has an automated door opening control, counting participants when entering the venue and self-disallowing participants to enter when maximum number of seats is reached and vice versa. It also gives an update of the total number of occupants and communicates this to the event organizers, allocates seat numbers to each person in the venue, makes sure that each person is occupying the seat number allocated to them, warns a person when the person tries to occupy the wrong seat, and counts down when a person is leaving the venue.

With the world transitioning into machine learning and artificial intelligence, data from any source is very important. The sensors in the gates or access points of the different venues can be used to collect a massive amount of data. With this data, business in the event hosting industry can use it when trying to fund their target markets. Furthermore, machine learning and decision learning using deep learning can be used to refine and improve the seat allocation feature of the system (Khan et al. 2020). With the improved and refined system, for different events and venues, families, couples, groups of people from same sex, industry, age group and etc can be allocated seat together depending on the type and purpose of event. A good example will be a cinema or a sports field, it will be good for the system to automatically assign families, couples, and friend with seat numbers next to each other.

3. Methods

The crowd management and seat number allocation system are aimed to limit the number of crowds in an indoor venue and ensure that there is a proper sitting arrangement and that they practice social distancing. The following primary components will be used to achieve the objective of the study: Microcontroller (central control unit), Sensors (input devices), Display (output device), Alarm (output device) and an Automatic door (output device). The three different designs involved input from the sensors and three different outputs: the automatic door, the number seat matching sensors, and the buzzer. The three alternative designs differ based on the user input devices used. The user input devices, which are sensors, are any control system's main components. The three inputs that will be investigated are the fingerprint reader and the RFID reader and tags. The different designs should achieve the processes of the different subsystems as shown in Figure 1.

The first design uses Radio Frequency Identification (RFID) sensors and tags as shown in Figure 2a. The entrance and exit RFID sensors will be programmed to accept everyone's tags when entering the venue (Mitchell, Rashid, Dawood, and AlKhalidi 2013). These will then send a signal to the controller for the automatic door to open and for the counter to count up or down depending on whether the person is entering or leaving the venue. However, if the maximum number of occupancies is reached when entering the door remains closed to prevent anyone from entering to limit the crowd. RFID sensors 1 and 2 will be programmed to accept only a specific tag based on the seat number allocated to the tag/access card to ensure an organised sitting arrangement and social distancing. If the tag does not match the number allocated, the alarm system will go off to signal the occupant that they got the seat number wrong. This will further alert the organizer to know who's occupying wrong seat.

The second design uses fingerprint readers (shown in Figure 2b). The fingerprint readers suggested according to research for this study were the optical types. This is because they are commonly used and readily available. The entrance fingerprint readers will be for the counter system and fingerprint data capturing. Every person attending the event in the venue needs to register their fingerprint ID, which is captured using the entrance fingerprint reader. Using the aid of a serial monitor, the fingerprint is captured and given an ID as that of a serial number, which is stored in the serial server library of the microcontroller.

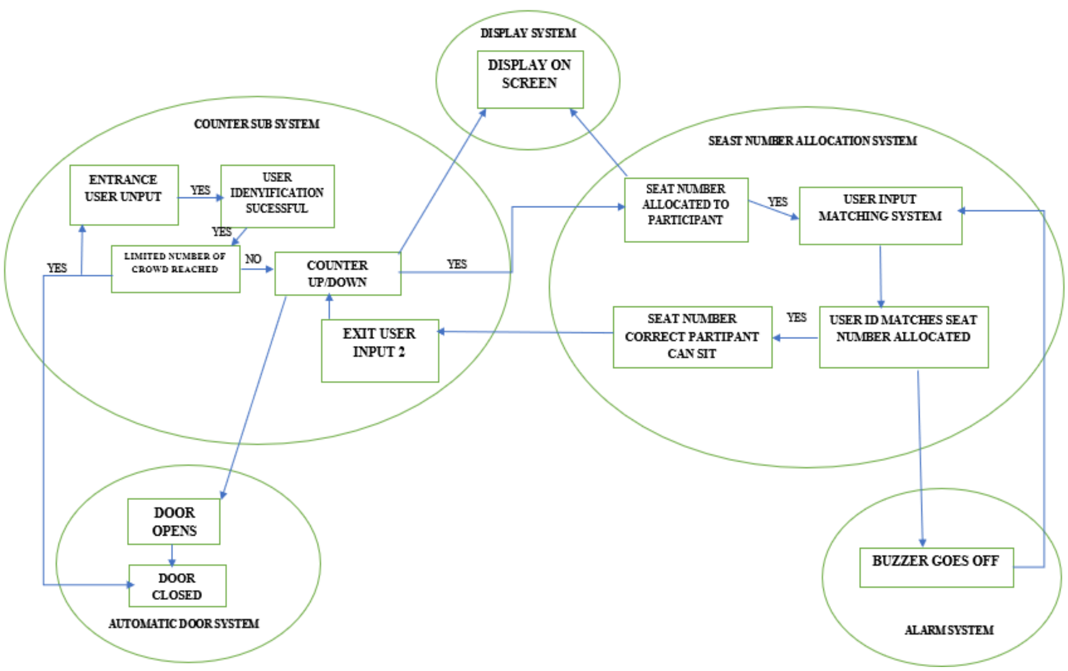


Figure 1. Subsystem working collaboratively together.

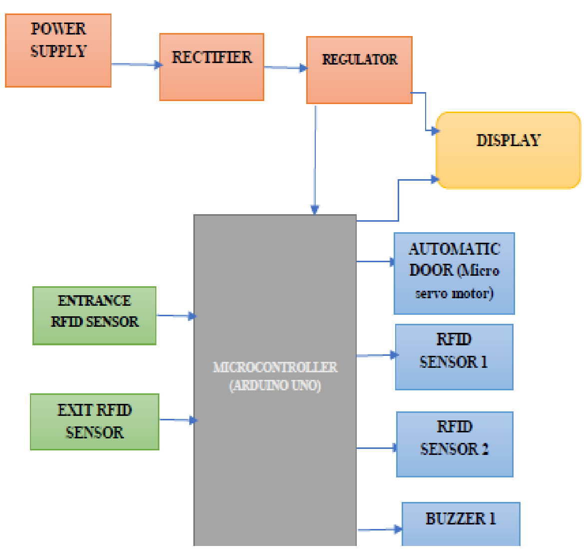


Figure 2a. Tag design using RFID sensor.

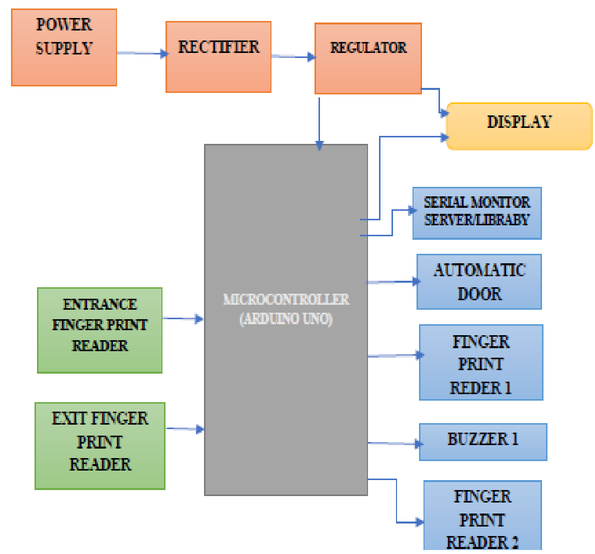


Figure 2b. Tag design using fingerprint sensor.

For reliability, costs, and efficiency, the first design, the RFID design, was best suitable to build the prototype. This is because once the ID of the RFID tags is stored in the server/libraries of the microcontroller, they can be reused by any person. There will be no need to enter and erase the ID like the fingerprint ID because another person can re-use the same tag once a seat is available. Fingerprint IDs can be used for exclusive private venues where each guest is known personally, and their seats are always reserved for them. But for this study, the objective is to design a system that accommodates everyone which is both public and private venues. The major components of this design are Arduino Uno R3 – Microcontroller, 5X MFRC522 RFID Module + IC Card – User input, LCD module with an I2C interface - 16x2 or Monitor – Display, 4X SG90 Micro Servo Motor 180 degrees – Automatic door, 5 V DC power supply, and LF 13C Buzzer.

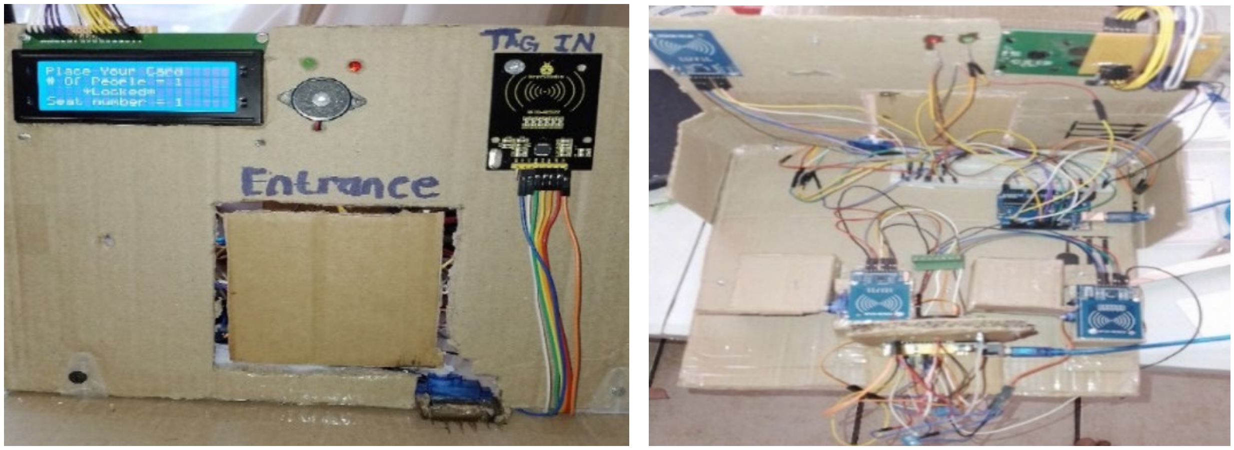
4. Experimental overview

The crowd management and seat allocation system have two phases. The first phase of the study includes the implementation and experimentation of the crowd management system. The second phase will be the implementation and experiment of the seat allocation system. The two systems will then be put together to work collaboratively to perform the objective of the crowd management and seat allocation system and experimented too. A strategy was used to test the designed prototype to make sure that it fits into the global objective. This includes running different experiments on the two systems and the entire system when the two are put together. The experiments are broken down into functional and performance experiments.

4.1 Tag crowd managements

Add numerical results here. Make sure to describe all tables and add inferences (10 font) The crowd management system is expected to work and fulfil the following objectives: When the RFID tag with a registered ID is placed on the RFID reader, a beeping sound and the green LED are triggered and go on for 3 seconds which means that access is granted. The LDC will display a count-up, access granted and the status of the venue in terms of occupancy every time access is granted. This tests if the display subsystem and the counter subsystem work. When access is granted the servo motor rotates 90 degrees to open the door for 5 seconds and then closes to ensure that only one person enters within those 5 seconds. This tests if the automatic door subsystem works. The counter is set up for a maximum of 3 people and it tests if the counter subsystem works.

When the 4th person tags in an alarm go off to warn the officials that the maximum number of occupancies has been reached, the alarm will go off until that specific person tags out. This ensures that the threshold is kept below the maximum number of occupancy. This will test if the alarm subsystem and the counter system work collaboratively together. No access is granted when any random RFID tag is placed on the RFID reader. This tests if the counter system works as, it's the one triggering all the other subsystems. This whole process will fulfil the objective of the crowd management system with the aid of RFID technology. Both the implementation and the experimental diagrams are shown in Figures 3 and 4. Participants are to scan their RFID tag before going in.



(a) (b)

Figure 3. Experimental setup of the Crowd management system (a) frontend view (b) backend view

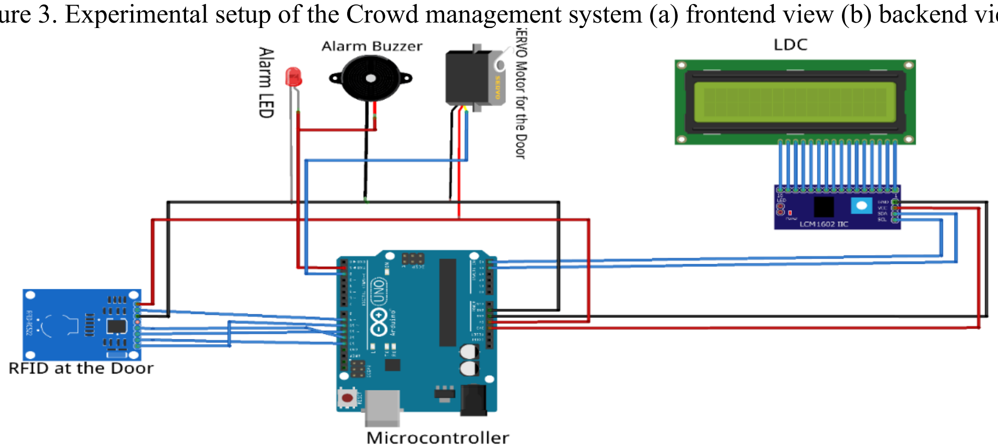


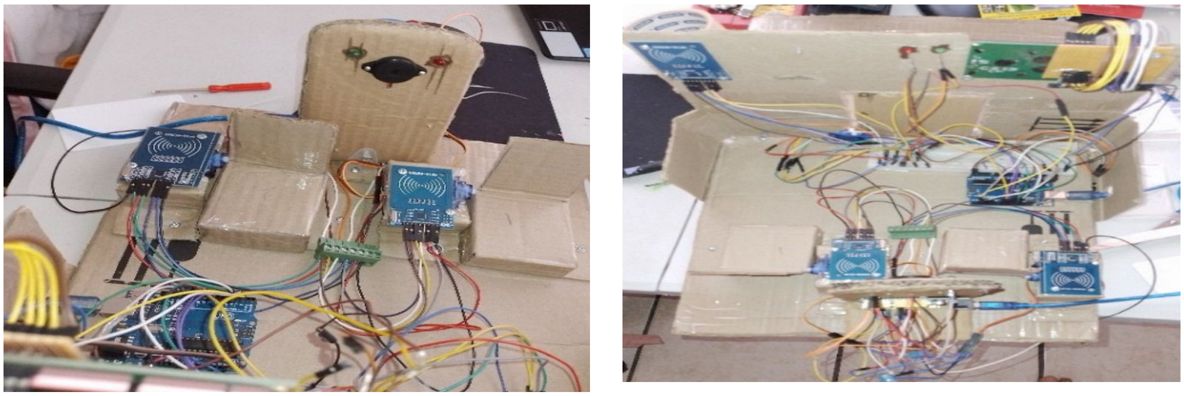
Figure 4. Experimental setup of the crowd management system

4.2 Pin connection

The RFID reader was connected to analogue pins 9-13 and 5 V and the ground pin of the Arduino Uno. With the I2C interface connected to the LCD, the SCL and SDA of the I2C were connected to pin A5 apinsA4 of the Arduino respectively. The input of the servo motor was connected to pin 3 of the Arduino and the LEDs were connected to pins 4 and 5 of the Arduino respectively. Furthermore, the buzzer was connected to pin 2 of the output of the Arduino UNO. All the components were connected to the ground and the 5 V pin of the Arduino Uno for the power supply. The whole system was powered by the USB type A/ B cable (for Arduino Uno) which was connected to the computer. The C code was loaded on the Arduino Uno, which enabled the components to work collaboratively to achieve the objective of the crowd management system. Details of this is shown in Figure 4.

4.3 Seat allocation

The seat allocation works closely together with the crowd management system. When access is granted upon tagging an RFID tag that has been registered on the system, a seat number should be allocated to that RFID tag. This tests if the seat allocation system is working. With the seat number allocated, when the same RFID tag is tagged on the RFID reader on the correct seat, the seat opens to let the person seat using a servo motor. This will test if the automatic seat subsystem works. If the tag is tagged on the wrong seat, a buzzing sound will be emitted by the buzzer to signal the person that they are trying to occupy the wrong seat or that that seat has already been allocated to someone. The seat will not open to let him/her sit. This tests the alarm system and the automatic seat subsystem working collaboratively together. Upon leaving the venue, a person must tag out the RFID reader at the exit door. This triggers the system to count down and allow another person in if the maximum number of occupancies was reached. This will test if the counter system works. Details on the implementation is shown in Figure 5a and 5b. These diagrams also showcase the seats, and the alarm systems to detect if occupant is at the correct seat allocated. The functional performances of the subsystems that make up the seat allocation system ensure that the different subsystems.



(a) (a)

Figure 5. Experimental setup of the seat allocation system, (a) backend, (b) frontend

The seat allocation system is expected to fulfil the following objectives. To allocate seat numbers to each person in the venue. Then make sure that each person is occupying the seat number allocated to them, and then warn a person when they try to occupy the wrong seat. And finally counts down when a person is leaving the venue.

4.4 Pin connection

The schematic diagram of the seat allocation is shown in Figure 6. The connection is as follows; the 6 RFID readers will be connected to the Arduino UNO on pins 5-13 and the power pins of the Arduino UNO. The input of the servo motors will be connected to pins 3 1-4 of the Arduino. With the I2C interface connected to the LCD, the SCL and SDA of the I2C were connected to pins A5 and A4 of the Arduino respectively. The buzzer will be connected to pin 0 of the output of the Arduino Uno. All the components were connected to the ground and the 5 V pin of the Arduino Uno for the power supply. The whole system was powered from the USB type A/ B cable (for Arduino Uno) which was connected to the computer.

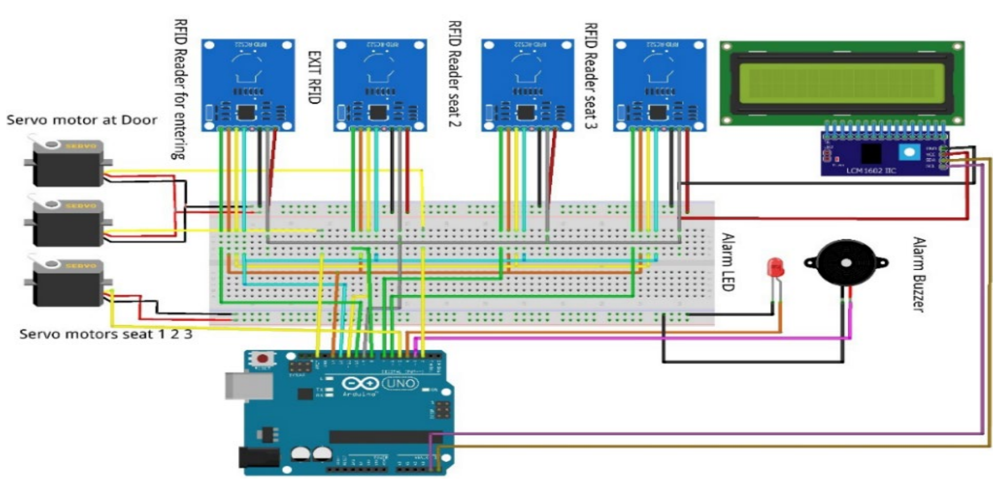


Figure 6. Experimental setup of the seat allocation system

5. Results

5.1 Crowd management system

When the RFID tag with a registered ID is placed on the RFID reader as shown in Figure 7a, a beeping sound and the green LED are triggered and go on for 3 seconds, meaning that access is granted. The LDC will display a count, access granted and the status of the venue in terms of occupancy every time access is granted. This shows that the display subsystem and the counter subsystem work. As shown in Figure 7b, immediately the participant enters and the door closes, the counter on the displays shows that there is one person inside.

Figure 7a. First person entering

Figure 7b. Display and counter system updating the number of people in the venue.

When the second participants use their RFID tag, an access is granted, and the servo motor will rotate 90 degrees to open the door for 5 seconds and then closes to ensure that only one person enters within those 5 seconds. This proves that the automatic door subsystem works. When the 4th person tags in, an alarm goes off to warn the officials that the maximum number of occupancies has been reached, the alarm will go off until that specific person tags out. This ensures that the threshold is kept below the maximum number. This shows that the alarm subsystem and the counter system work collectively together. When any random RFID tag is placed on the RFID reader, it recorded no access is granted as shown in Figure 8. This tests if the counter system works because it's the relay that feeds the alarms and other subsystems.

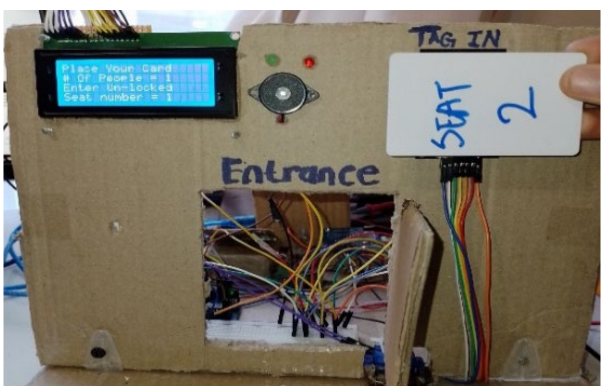


Figure 8a. Servo motor rotating +90 degrees to open the door when the RFID tag was tagged on the reader

Figure 8b. Maximum reached after the 3rd tag and alarm going off with red LED, no entry for the 5th tag

5.2 Seat allocation system

The seat allocation works collaboratively together with the crowd management system. In an instant when an access is granted upon using an RFID tag that has been registered on the system, a seat number should be allocated to that RFID tag. This tests if the seat allocation system is working. If the tag sensors are used on the wrong seat, as shown in Figure 9a, a vibrating sound will signal that the user is trying to occupy the wrong seat or that that seat has already been allocated to someone else. Besides, the seat will not open to let such person to sit. This test shows that the alarm system and the automatic seat subsystem effectively works together.

With the seat number allocated, when the same RFID tag is utilized on the correct seat as shown in Figure 9b, the seat, using a servo motor, opens to let the person sit. This test shows that the automatic seat subsystem works. Upon leaving the venue, a person must tag out on the RFID reader at the exit door. This triggers the system to count down and allow another person in if the maximum number of guests is not reached. The success in these procedures shows that the counters work as proposed.

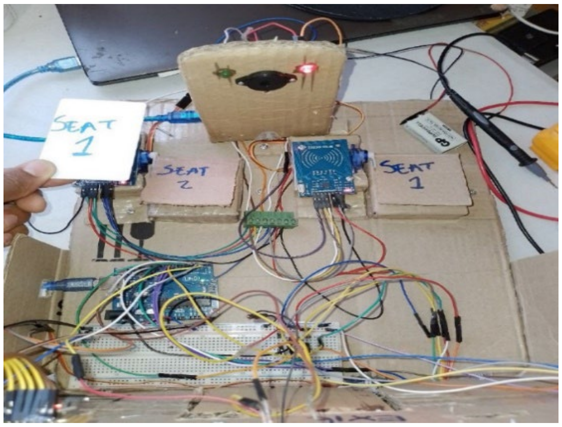


Figure 9a. Seat number 2 allocated to the second person entering the venue.

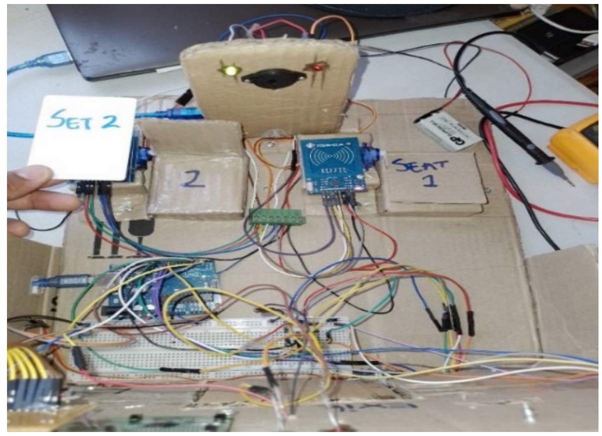


Figure 9b. The wrong tag on the wrong chair, seat 2 was assigned to tag number 2.

From the displayed figures, it has shown that the system was able to counts when a person is entering the venue, open the door automatically for a person to enter when the maximum number of occupancies is not reached and when the maximum number of occupancies is reached, the doors will remain closed, and no one will be allowed to enter. Signal the people that the maximum has been reached and the signal only off when the extra person has tagged out, to keep the threshold below the maximum number. Allocate seat numbers to each person in the venue. Make sure that each person is occupying the correct seat number allocated and warn when wrong seat is occupied.

6 Conclusion

The prototype built demonstrated and accomplished the objective of the study. The crowd management system ensured a steady crowd traffic flow. The system has a counter which operates at 16 MHz and can count to 6555535. This number shows that the system can accommodate venues of different sizes, small, medium, and large. The number of the counter was displayed on the LDC. The RFID reader triggered the counter when tagged with a readable RFID tag. The counter triggered the servo motor to rotate 90 degrees to open the door, as well as the alarm system and LED. The mechanism of the crowd management system can be manipulated to suit the venue's specifications. This specification includes the number of people the venue can accommodate and the components to be used as input and output devices. In real-life situations, the RFID reader and the servo motor can be replaced by other components such as fingerprint readers or IR sensors (for the RFID reader) and the solid-state relay module, which controls the motor which operates the sliding door. The seat allocation system ensures that there is a good sitting arrangement and that everyone is sitting in their designated seats. There is a room for improvement in this study.

For future work, a module can be added to send a notification to the people wishing to occupy the venues after tagging in. The system can also be improved for private venues, so that people can book their desired seats remotely and just occupy them upon arrival instead of waiting for the system to allocate a seat number to them upon arrival at venue. For these improvements, the counter system can be enhanced with a monitoring system that updates all users about the venue's status after every desired time. The monitoring system will use IoT technology to connect between the venue and the user. Furthermore, with the internet of things technology, users can book their seats remotely, using a mobile application or a website directly connected to the smart crowd and seat allocation system. Upon booking, the users can choose their desired seats or allow the system to choose their seats. A typical RFID reader can hold up to 128 bits of data, equal to 3.4x10^40 bytes, enabling it to hold more than 2^128 addresses. For scalability, this design is suitable for small, medium, and larger venues with a high attendance.

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Biography

Oluwafemi Emmanuel Oni is a postdoctoral researcher in the Electrical and Electronic Engineering Science department at the University of Johannesburg, South Africa. He received his BSc (Honours) Degree in Electrical and Electronic Engineering from Ekiti State University, Ado Ekiti, Nigeria, in 2013 and his MSc and PhD in 2017 and 2021 respectively. He was a system and maintenance engineer at Egbin Power Thermal Plant, Lagos, Nigeria, in 2012 and at Omotosho Power Plant, Ore, Nigeria, in 2013/2014. He is currently a postdoctoral research fellow at the University of Johannesburg. His research includes power systems stability analysis using High Voltage Direct Current transmission scheme, integration of renewable energy into the grid using a multi-terminal HVDC scheme, and smart grid systems using FACTs. Dr. Oni's award and honours include MTN Foundation, ETISALAT, and Ekiti state scholarships.

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