Design and implementation of a prototype active infrared sensor controlled automatic sliding door for mitigation of coronavirus disease 2019 (COVID-19)

A. O. Amole [a*], M. O. Oyediran [b], O. O. Olusanya [c], W. A. Elegbede [d], A. T. Olusesi [e], A. O. Adeleye [f]

ARTICLE INFO

ABSTRACT

The door is an essential part of any structure that provides access and security of lives and properties. The manual operation of a door could be cumbersome and laborious when the traffic volume is high. Also, it has been observed that doors could serve as a medium of spreading the deadly coronavirus disease 2019 (COVID-19) infection. Therefore, a prototype automatic sliding door that plays a crucial role in curbing the spread of this infectious diseases has been designed and implemented in this paper. The design of the prototype sliding door is in two parts namely; the structural part and the automation part. The structural design of the door was achieved using the Microsoft Visio 2016 while the design of the automation system was achieved using express printed circuit board. The implementation of the structural part was achieved using 1 inch particle board while the implementation of the automation system was based on the components like the active infrared sensor, resistors (10 kΩ), capacitor (1000 µF), transistors (TIP41 Q8, BC548 Q7), LED indicators, press button switch, pulley system, drive belt, stepper motor (IP65), and ATMEGA 8 microcontroller. The result of the tests carried out on the door showed that the prototype automatic sliding door was characterized by average opening time, closing time, delay time, and optimal sensing range of 3.10 s, 3.05 s, 5.72 s, and 23.5 cm, respectively. It can therefore be concluded from this work that the prototype automatic sliding door is effective in overriding the manual operation of the door.

1. Introduction

The world lives in a generation where ensuring security and ease of usability continue to be of much higher priority, as a result, the need for more comfortable, efficient, and effective means of entry into restricted areas keep increasing day by day. The door is generally the term used to describe the unit built and installed to restrict and permit access into buildings [1]. Typically, a door can be made of

* **Contact** e-mail: latidassah@gmail.com

a, b, c, d, e Department of Electronic/Electrical and Computer Engineering, Bells University of Technology, Ota, Nigeria; f Eko Electricity Distribution Company, Lagos State, Nigeria

wood, metal, glass, or a combination of materials. The operation of the traditional door could be laborious and lead to easy damage to the door when subjected to high traffic volume. As a consequence of improved development and modernization, the human instinct requests more solace to his life by developing approaches that allow for things to be done effortlessly and saves time. The quest for automation becomes vitals for physically challenged individuals who needed to open doors themselves [2]. The automatic door which is one of the approaches that human instincts imagined to get comfort is a door that opens automatically when approached by someone, rather than needing to be opened manually with a door handle or bar [3]. An automatic door works on the principle of operation of an electro-mechanical device; they can be installed at the entrance of places like room, building, or space, and can perform dual function either for access control or provision of privacy in places like airports, offices, restaurants, and homes [4], [5].

An automatic sliding door is a variant of the automatic door out of many others developed to bring comfort and ease to our daily lives [6]. The sliding door is the general term used to describe a door that exhibited linear motion [7]. However, automatic sliding doors are capable of granting access in and out of an enclosure without anyone performing the role of opening and closing of door. A typical automatic sliding door consists of the sliding door, infrared sensors, the ATMEGA 8 microcontroller, the motor, and the motor drivers' circuit [8]. The operation of an automatic sliding door is triggered by the infrared energy generally emitted by the human body and detected by the infrared sensor from a particular distance [9], [10]. A gear motor is generally responsible for opening and closing of the sliding door automatically and this process is centrally controlled by the microcontroller [11].

Several pieces of literature have reported developments on automatic doors; smart camera was intelligently employed for an automated door control system by Yang et al. [12]. The system operates based on identification of people from its scene, and then predict his intention by tracking his trajectory within the environment before activating the door. The experimental results revealed that the system is advantageous in terms of precision, responsiveness, safety, reliability, and low cost. It is novel to point out that the integration of infrared technology into different designs enhances the smartness of automatic door, hence promote it as trending technology. An access system based on a smart card, which memorizes the user's unique identity code has been with the aid of AT89C52 microcontroller and it has been deployed commercially in wireless doorbell which has been engaged for wireless transmission of user information, the only shortcoming is that it is relatively expensive [13].

Ikpeze et al. [14] proposed the design and development of a low-cost auto gate system considering major issues in home automation systems which include robustness inadequacy, compatibility issues, and acceptability among older and disabled people. Furthermore, Emakpor and Esekhaigbe [15] employed radio frequency identification (RFID) for security door system for controlling of access by an unauthorized person. The essential part of this RFID-based security door RFID unit, liquid crystal display, a microcontroller, synchronous motor, multiplexers, and alarm system; the microcontroller controls synchronous motor operation while alarm circuit rings once intruder is noticed. The experimental results presented revealed that the developed system was able to circumvent the drawback associated with single secret authentication method engage for safeguarding of lives and properties. Also, Okundamiya et al. [16] developed a security door system using RFID technology to provide an efficient monitoring system that secures the entrance to facilities. The system employed a two-factor authentication with a microcontroller to control the hardware while an electromagnetic relay was used to control the opening and closing of the door. The results of the research showed that the system worked properly with the correct tag and is capable of raising an alarm when the system is intruded. However,

the work is limited to pre-programmed tags and using new tags will require programming before it can be used.

In this era of the COVID-19 pandemic, it has been said that doors play a major role in the spread of this deadly disease. Therefore, an automatic sliding door will play a central role in curbing the spread as it allows for hands-free operation of the door thereby maintaining proper hygiene. Consequently, this work designed and implemented an automatic door which is capable of performing this function.

2. COVID–19 and Recent Developments for its Mitigation

The world woke up to the realization of COVID – 19 at the beginning of the year 2020. The COVID –19 is a severe acute respiratory syndrome (SARS) [17] and its transmission is from person to person [18]. It has reported [19] that as of July 7, 2020, over 11.5 million cases and over 530,000 reported deaths have been confirmed COVID – 19 and it is still counting. Consequently, COVID – 19 pandemics has necessitated new methods for combating this virus thereby transforming the nature of both materials and chemical research [20]. Some of the methods that have been developed to combat COVID – 19 are reported in Table 1.

Table 1 Recent developments for mitigation of COVID – 19

Solutions	Techniques	Advantages	Limitations
Automated detection of COVID-19 [21]	▪ X-rays ▪ Bayesnet classifier ▪ Multi-convolutional neural network ▪ Correlation-based Feature Selection	▪ High accuracy, 97.44%	▪ No preprocessing of data ▪ No segmentation was performed ▪ Multi-class scenario not explored
Automatic classification system for COVID-19 [22]	▪ X-ray ▪ Texture descriptors ▪ Computed Tomography (CT) ▪ Multi-convolutional neural network	▪ High accuracy, ▪ F1-Score of 81%	▪ No preprocessing of data, ▪ No segmentation was performed ▪ Failed to provide definite COVID – 19 diagnosis
Automatic image analysis tool [23]	▪ CT ▪ Deep convolutional neural network	▪ Time-efficient development, ▪ Human-level performance, ▪ 0.97 Dice coefficient	▪ Small dataset was used ▪ No classification was done
Patient flow management system [24]	▪ Carbapenemase-producing Enter-obacterales (CPE)	▪ Enabled real-time oversight	▪ No quantitative evaluation was performed
Screening model [25]	▪ CT ▪ Bayesian function, and deep learning techniques	▪ High accuracy rate, 86.7%	▪ Segmentation and classification accuracy of the model could be improved
Smart door [26]	▪ Internet of things ▪ Biometric	▪ Seamless authentication	▪ The system does not support contactless authentication, ▪ No quantitative testing was reported
COVid SAmple Collection Kiosk (COVSACK) [27]	▪ Computational Fluid Dynamics simulations ▪ Disinfectant spray nozzle, long cuff gloves	▪ Faster rate testing ▪ Drastic reduction in use of personal protection equipment (PPE)	▪ No quantitative testing was reported
COVID Predictive tool [28] Automatic materials testing device [29]	▪ Ordinary least squares ▪ Traveling history and contacts ▪ Gas chromatograph (GC) ▪ reactant partial pressures	▪ High prediction, 88% ▪ Low cost ▪ High-throughput	▪ No comparative study was reported ▪ Lacks multiple detector
COVID-19 Paraplegic wheelchair [30]	▪ SolidWorks ▪ Anthropometry parameters	▪ Ergonomically safe with vibration dose value (VDV) ranges between 0.01 m/s^2 and 1.35 m/s^2 ▪ Reduced production cost	▪ Automation is lacking
COVID-19 Patients Detection Strategy (CPDS) [31]	▪ Enhanced k-nearest neighbor (kNN) Classifier ▪ CT ▪ Genetic Algorithm ▪ Gray Level Co-occurrence Matrix (GLCM)	▪ Maximum accuracy rate, 96%	▪ No preprocessing of data ▪ No segmentation was performed

Table 1 Recent developments for mitigation of COVID – 19 (Continuation)

Solutions	Techniques	Advantages	Limitations
Automatic COVID-19 Detection system [32]	▪ X-ray ▪ CNN ▪ kNN ▪ Support Vector Machine (SVM) ▪ Decision tree	▪ Cheap ▪ Fast and reliable intelligence tool ▪ Accuracy of 98.97%	▪ No data preprocessing ▪ No segmentation was performed ▪ Multi-class scenario was not explored
Smart home healthcare support system [33]	▪ Hyperspace analogue to context (HAC) ▪ Android based mobile application ▪ Physiological health parameters	▪ Improved comfortability	▪ No statistical evaluation of the system was done
Novel COVID – 19 diagnostic framework [34]	▪ X-ray ▪ Faster regions – CNN	▪ Accuracy of 97.36% ▪ 97.65% Sensitivity, specificity 95.48% ▪ F1-score of 98.46%	▪ No data preprocessing ▪ No segmentation was performed ▪ Multi-class scenario was not explored

Table 1 shows that much has been done in the area of software solutions for automatic detection, screening, and prediction systems based on methods like multi-convolutional neural network (CNN), CNN, k-nearest neighbor (kNN), Enhanced kNN, support vector machine (SVM), and Bayesian classifier. It can also be inferred from the table that x-ray and computed tomography (CT) are the two most widely adopted imaging modalities used for developing these solutions. Most of these solutions did not take into cognizance the importance of image preprocessing and segmentation, which are crucial steps that can improve the performance of these solutions. Some of these works also failed to examine multi-class scenarios, which in most cases depict the field experience by the end-users. The table also revealed that little has been done in the area of finished products where the smart door, wheelchair, and COVSACK were reported as a means for mitigating COVID – 19. The existing works in this category are not fully automated as some of them did not support the hands-free operation. As an instance, the paraplegic wheelchair reported is not automated. Therefore, a voice-controlled paraplegic wheelchair might serve a better purpose. Also, the door reported in this section only addresses the security aspect of the door but not the hands-free opening and closing of the door. As a result, it can be said that more is needed to put this deadly disease under control. Hence, an automatic sliding door is proposed, designed, and implemented in this work.

3. Design Approach of the Prototype Sliding Door

This section discussed the detailed design methods and analysis employed to implement an automatic sliding door system. The structural design showing the dimension of the prototype door is shown in Fig. 1 while the block diagram in Fig. 2 presents the interconnection of the components of the automatic sliding door designed and implemented in this work. The implemented automatic door system consists of two sections namely; the monitoring section which consists of two passive infrared sensors and the control section which consists of the microcontroller ATMEGA 8, the motor drivers' circuit, and the motor.

3.1. Structural Design of the Prototype Door

The drawing of the wooden work of the entire prototype door is shown in Fig. 1. The whole structure is 70 cm by 28 cm mounted on a wooden base of length 70 cm and width of 10 cm. The prototype door being considered in this work is made of hardwood of width 32 cm and height 23 cm.

3.2. Design of the Automation System

The block diagram of the designed automatic sliding door is presented in Fig. 2. The block diagram is subdivided into five major sections (microcontroller, driver circuit for motor, motor, sensing, and power supply).
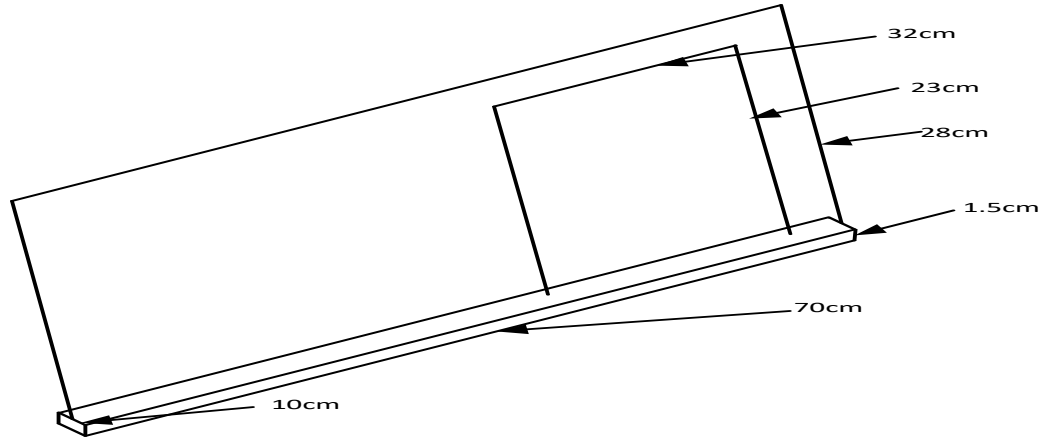

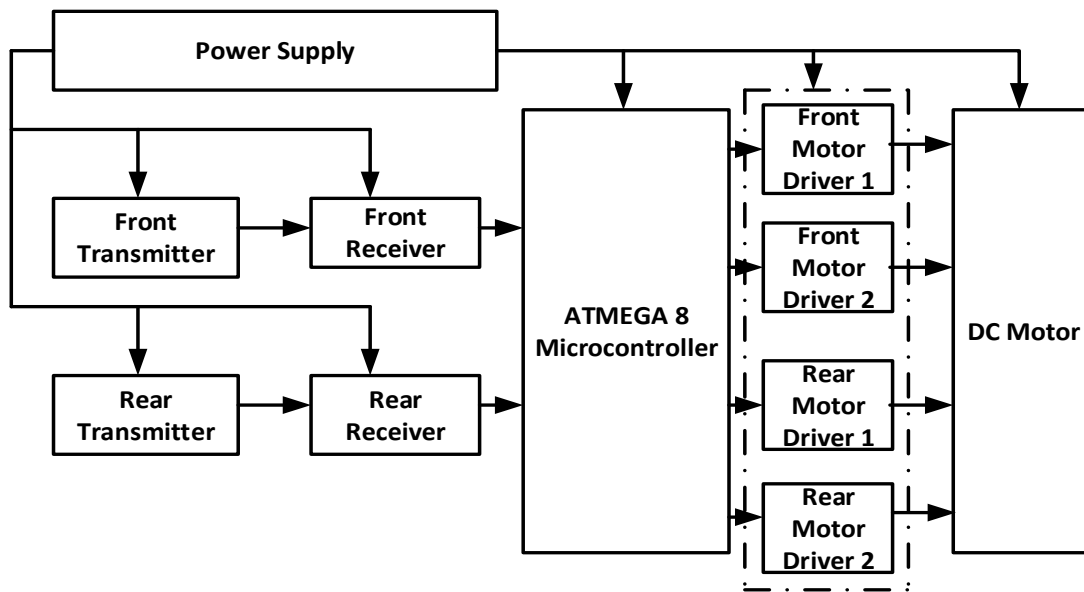**Fig. 1** Structural drawing of the prototype door

Fig. 2 Block diagram of an automatic sliding door system

3.2.1 Microcontroller section: The ATMEGA8 microcontroller forms the brain of this work, it acts as the control center for all the major components in the system designed. Fig. 3 shows the circuit diagram as well as connection of microcontroller section to the reset. This section acts as instruction hub to all the sub-circuits connected to it while all the sensors monitoring the environmental parameters report to the microcontroller via a written set of programming codes written in Assembly language to activate it sensing operation, measure and give the value in analog data to the microcontroller, which converts it to the digital signal, a format recognized by the ATMEGA circuit. The digitized parameters of all the various sensors are closely monitored and cheeked against the predefined threshold values. The state of the system reported via monitoring and checking helps in making informed decision as to when corrective actions are to be taken, once the need be, activators are activated to perform a controlled operation.
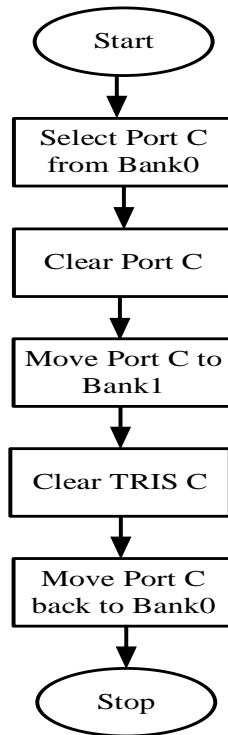
Fig. 3 Flow chart for configuration of microcontroller ports as output port

From the diagram shown in Fig. 4, Pin 1 is the reset pin. The reset logic is used to place a device status bit into a known state and its design is such that system cost is reduced while increasing system reliability. While master clear (MCLR) voltage is less than +4V, the microcontroller is held at reset point, when the voltage rises beyond +4V, the program begins. Diode IN4148, D4 helps discharge the capacitor quickly when power is down; Resistor, R33 is chosen as 10kΩ to limits the current flowing into MCLR from capacitor, C3 in the event of MCLR pin breakdown. The microcontroller pins are input pins by default except for Reset, Oscillators, positive (+ve) and negative (–ve) pins. Hence, the flow chart in Fig. 3 is used to set some pins to output pins to signals generated from them.

Fig. 4 Circuit diagram showing the microcontroller section connection to the reset

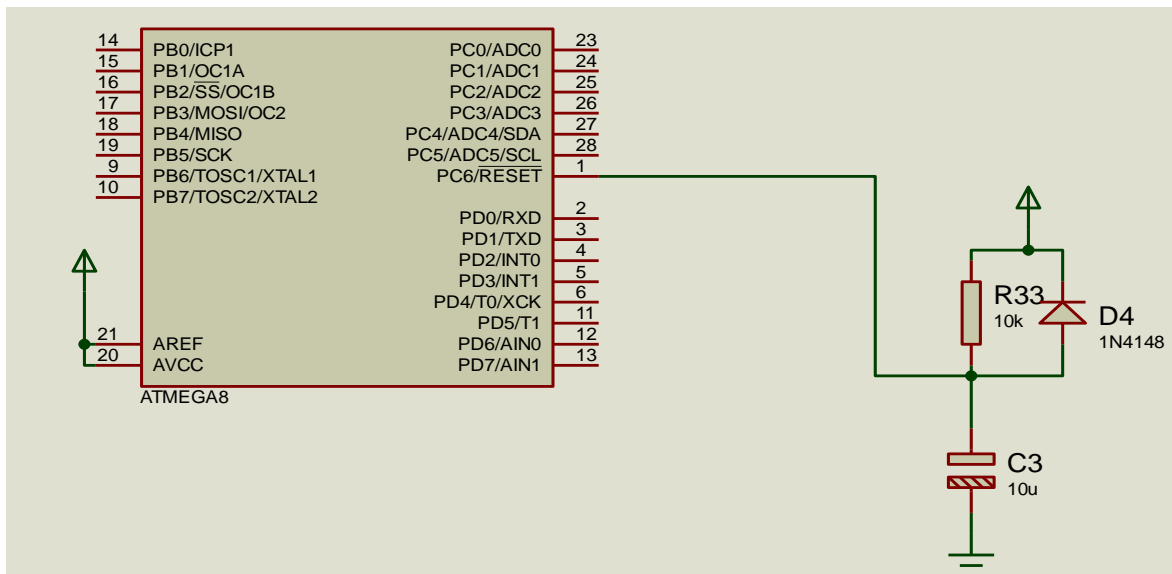*3.2.2 The Motor Driver:* Motor drivers are motor interfacing circuits used to run a motor, it is easy to interface these drive circuits with the motor known fully that the selection of the circuit primarily depends on type of motor being used. The motor's activities are controlled by the microcontroller via the driver circuit. The motor used rated voltage of 12V while the microcontroller is rated 5.5V; hence, buffers and transistors were introduced to amplifier the signal from the microcontroller. A transistor-based driver circuit is shown in Fig. 5. The transistor BC548, Q7 was used as a current buffer for the signal from the microcontroller and passed it to the power transistor TIP41, Q8 via the base resistor R13 47R, which protect the base of the power transistor from overvoltage. TIP41, Q8 acts as a switch that changes the state of the DC motor via a protection diode IN4007 D2, the DC motor was externally powered by the protection diode connected in parallel with the power transistor TIP 41. The motor was operated depending on the input voltage V_{CC} to the base of the transistor which must be about +5V for the motor to rotate. This V_{CC} can be determined using Eq. (1);

$$V_{CB} = I_C R_C - V_{CC} \tag{1}$$

where; V_{CC} is the collector voltage, I_C is the collector current, and R_C is the collector resistance. TIP 41 transistors have a maximum collector current rating of 10A.
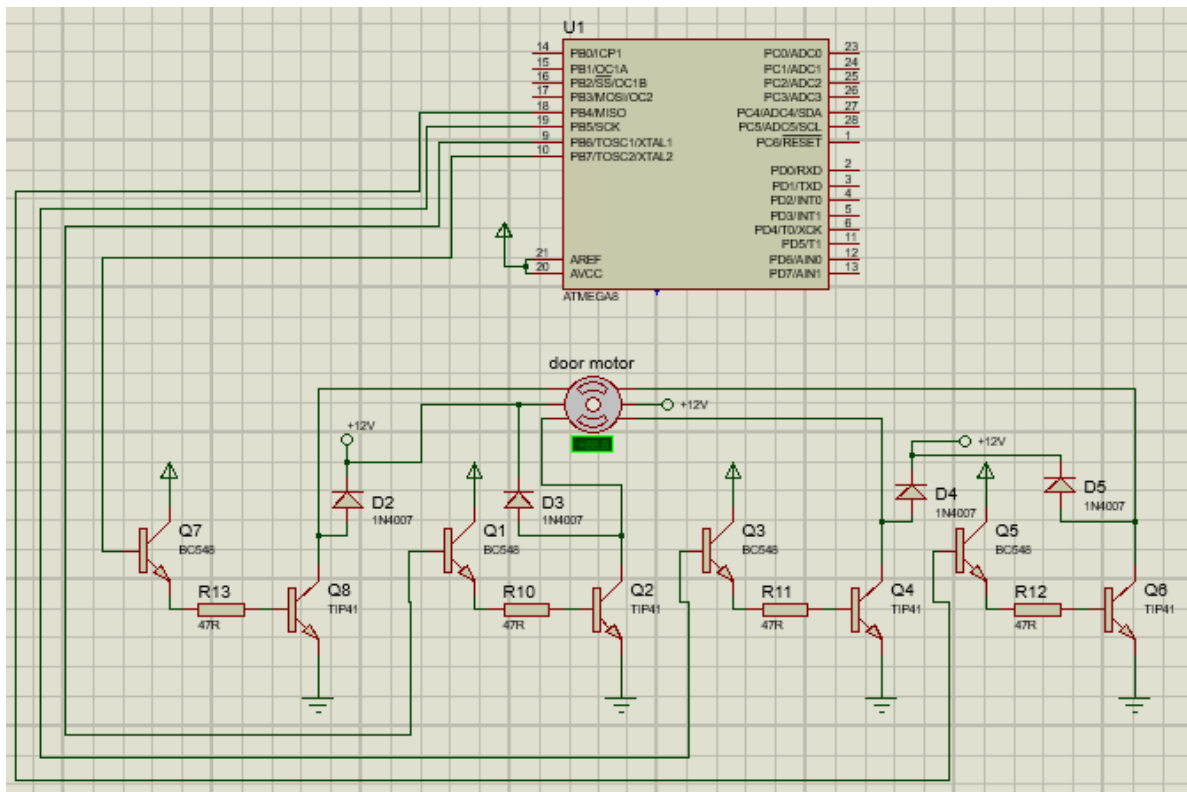
Fig. 5 Circuit diagram showing the transistor based driver circuit

3.2.3 Sensing Section: An infrared sensor belongs to the family of electronic device with ability to detect pre-registered ambient features of its immediate surroundings, and this achieved by either emitting or detecting infrared radiation. Also, Infrared sensors has the capability to measure the heat being emitted by an object and detecting motion. Each infrared sensor is in pairs namely; transmitter and receiver. Two active IR sensors were used in this work, the first pair of infrared sensors (transmitter and receiver) is placed to sense the incoming individuals while the second pair was used to sense the outgoing individuals. As shown in Fig. 6, the first pair of the infrared sensor is connected to pins 14 and 15 of the microcontroller while the second pair was connected to pins 23 and 24 of the microcontroller.

When powered, the transmitter of these sensors continuously emits a signal which when obstructed, the reflected signal is received by the receiver that in turn sends the signal to the microcontroller to power the motor. The infrared sensor must be placed in phase with each other to ensure for maximum sensing.

3.2.4 The Stepper Motor: Stepper motors have been widely used for precise position and speed control by supplying a definite number of pulses which turns the shaft through a definite angle. The stepper motor responds in discrete step increments to proper electrical pulses sequence while the stator poles determine its direction of the rotation. The stator poles are determined by the current sent through the wire coils. Change in the polarity of the current through the wire coil induces results in reverse motion of the motor through its spindle. According to [35] a stepper phases *a* and *b* can be electrically modeled as in equations (2) and (3):

$$L_a \frac{di_a(t)}{dt} = -R_a i_a(t) - e_a(t) + u_a(t) \tag{2}$$

$$L_b \frac{di_b(t)}{dt} = -R_b i_b(t) - e_b(t) + u_b(t) \tag{3}$$

where; $e_a(t) = K_m \omega_m sin(p\theta_m)$ and $e_b(t) = K_m \omega_m cos(p\theta_m)$, R_a, and R_b are phase resistance, L_a and L_b are phase inductances, $u_a(t)$ and $u_b(t)$ are terminal voltages (V), $e_a(t)$ and $e_b(t)$ are back emf (V), $i_a(t)$ and $i_b(t)$ are phase currents (A), , K_m is the motor constant and p is the number pole, ω_m is the rotor angular speed (rad/s), and θ_m is the rotor angular position (rad).

The motor used in this paper is responsible for opening and closing of the sliding door through its torque. The motor is activated when the microcontroller receives signal from the sensor, the microcontroller then send command to the motor driver circuit which powered the motor with $12V_{dc}$. The connection of the motor to the microcontroller via pin 10 is shown in Fig. 7 where the stepper motor was used and interfaced with the microcontroller through the driver circuit.
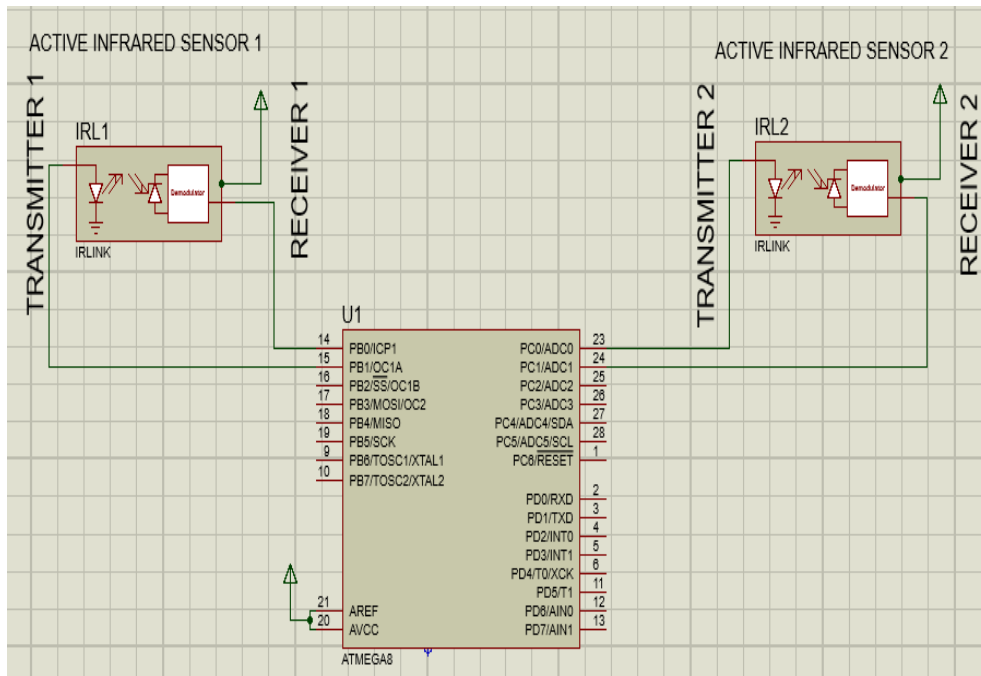

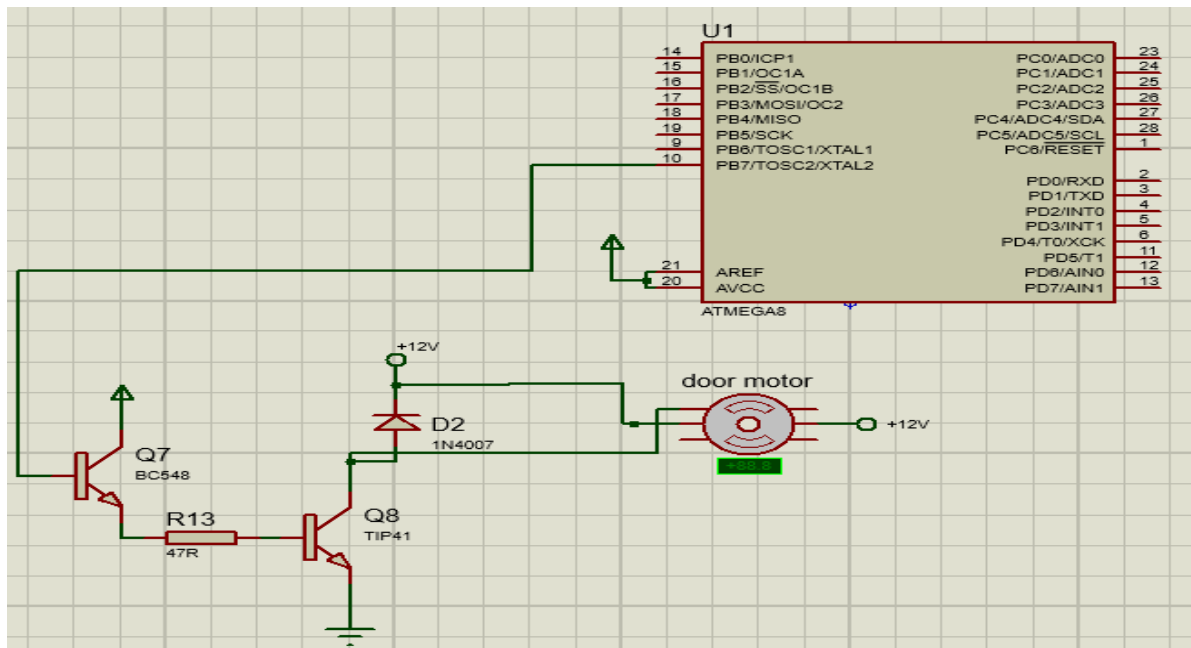**Fig. 6** Infrared sensors connection

Fig. 7 Circuit diagram showing the motor connection to the microcontroller

3.2.5 Power Supply: A variable power supply with auto-selector is used since different voltage levels are required to power components such as DC motor, Microcontroller and Infrared Sensors. For instance, the DC motor requires +12V power supply, the microcontroller requires about +5V power supply while infrared requires +5V. Emitter of the transistor is placed to ground; the ground is switched to the motor via the transistor's Q8 TIP 41 emitter as shown in Fig. 8. Normal V_{cc} given to the circuit is 12 Volt. Here the main point to note is that, check the DC motor being used.
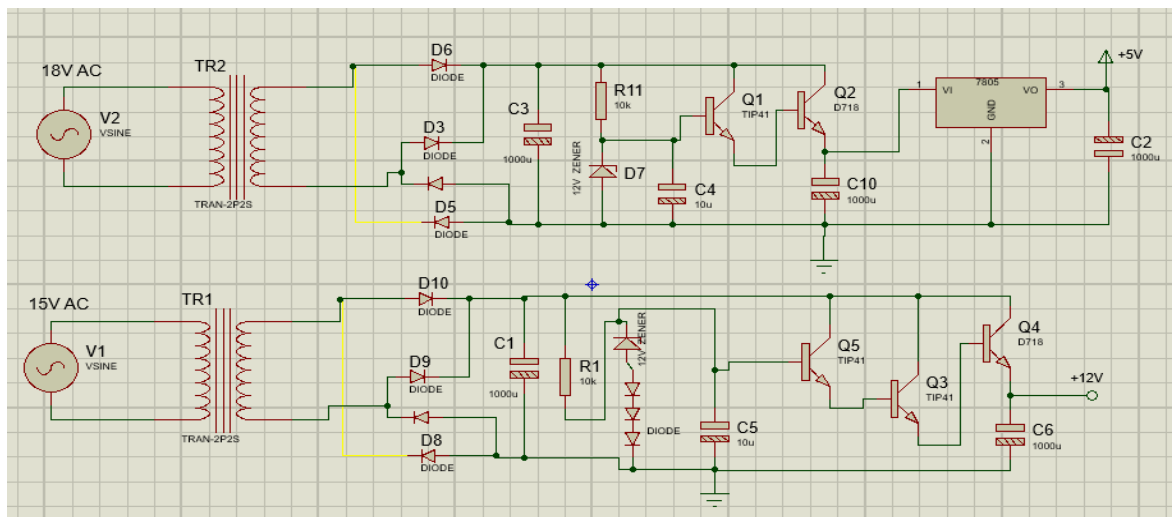
Fig. 8 Circuit diagram of the power supply for the automatic sliding door system

It is imperative to know that in the course of choosing the transistor and the DC motor; the current rating must be noted. Always the current rating of the DC motor must be smaller than that of the transistor being used. To generate this, an AC transformer having an input voltage of, 220V was used, only the 220V input terminal was used to give an output of 12V AC, these two AC outputs were rectified using diodes. To generate +5V DC, 12V AC output were rectified using four diodes (full rectification), diodes D3, D5 and D6 were used for this, the output was then filtered by 1000μF, C3 capacitor to give

216.6064V DC. This output was fed into 12V Zener diode, D7 to give a 12V DC output, which was further filtered by 10μF, C4 capacitor. A base resistor of 10kΩ, R11 resistor was connected to transistor TIP 41 Q1, which serves as a buffer for the signal transmitted to it. A higher powered transistor D718, Q2 was used as a switch to switch 12V DC to the input pin of the voltage regulator. The output voltage was first filtered by 1000μF, C10 capacitor. The voltage regulator output finally gave +5V DC, and the final output was finally filtered before being used to power different sub-circuits. The +12V supply was thus generated by this equation:

$$V_{DC} = \frac{2(V_{AC} - voltage\ drop\ accross\ a\ diode)}{\pi} \tag{4}$$

where; V_{DC} is the direct current voltage, which is equal to the expected output voltage, V_{AC} is the alternating current from the transformer, being 220V. The voltage drop across a diode is 0.6V. Hence,

$$V_{DC} = \frac{2(220 - 0.6*4\ (4\ diodes))}{3.142}$$

$$V_{DC} = 138.51\ V \tag{5}$$

The value of V_{DC}, given in Eq. (5) was fed into the Zener diode D7, to give an output of +12V realized voltage value before the capacitor connection to ground which was to filter out ripples from the DC output, the value was further fed into the voltage regulator 7805 to give a final output voltage of +5V, the output is further filtered by the 1000μF capacitor to give a smooth voltage output. The connection of the power supply is shown in the complete circuit diagram in Fig. 9.

3.3. Operation Mechanism

The complete circuit diagram consists of two infrared sensors which are placed on top of the sliding door, the first infrared sensor whose transmitter and receiver must be placed in phase with each other to achieve the highest sensitivity, this first sensor is responsible for sensing presence of incoming persons to the automatic door while the second infrared was used to sense presence of outgoing persons from the automatic door. The opening and closing of the prototype automatic sliding door is controlled by the microcontroller, which sends control signal to the motor through the motor driver circuit. The operational flow chart of the prototype automatic sliding door is presented in Fig. 10, which shows that whenever the system is powered on, it first checks the status of the door. If the door opened, it automatically instructs the door to close and if closed, the infrared sensor starts scanning for the presence of an incoming person. If the presence of an incoming person could not be detected by the sensor, the incoming person readjusts his position to fall within the sensor range for the sensor to detect the incoming person. Upon the detection of an incoming person by the infrared sensor, the microcontroller triggers the driver circuit to drive the motor which opens the door. After the door has opened, a delay of averagely 5.72 s is observed while the system checks over again if the person has passed or not, if the person has passed the door is activated to close but if not the delay process continues till the person pass and the door is closed.
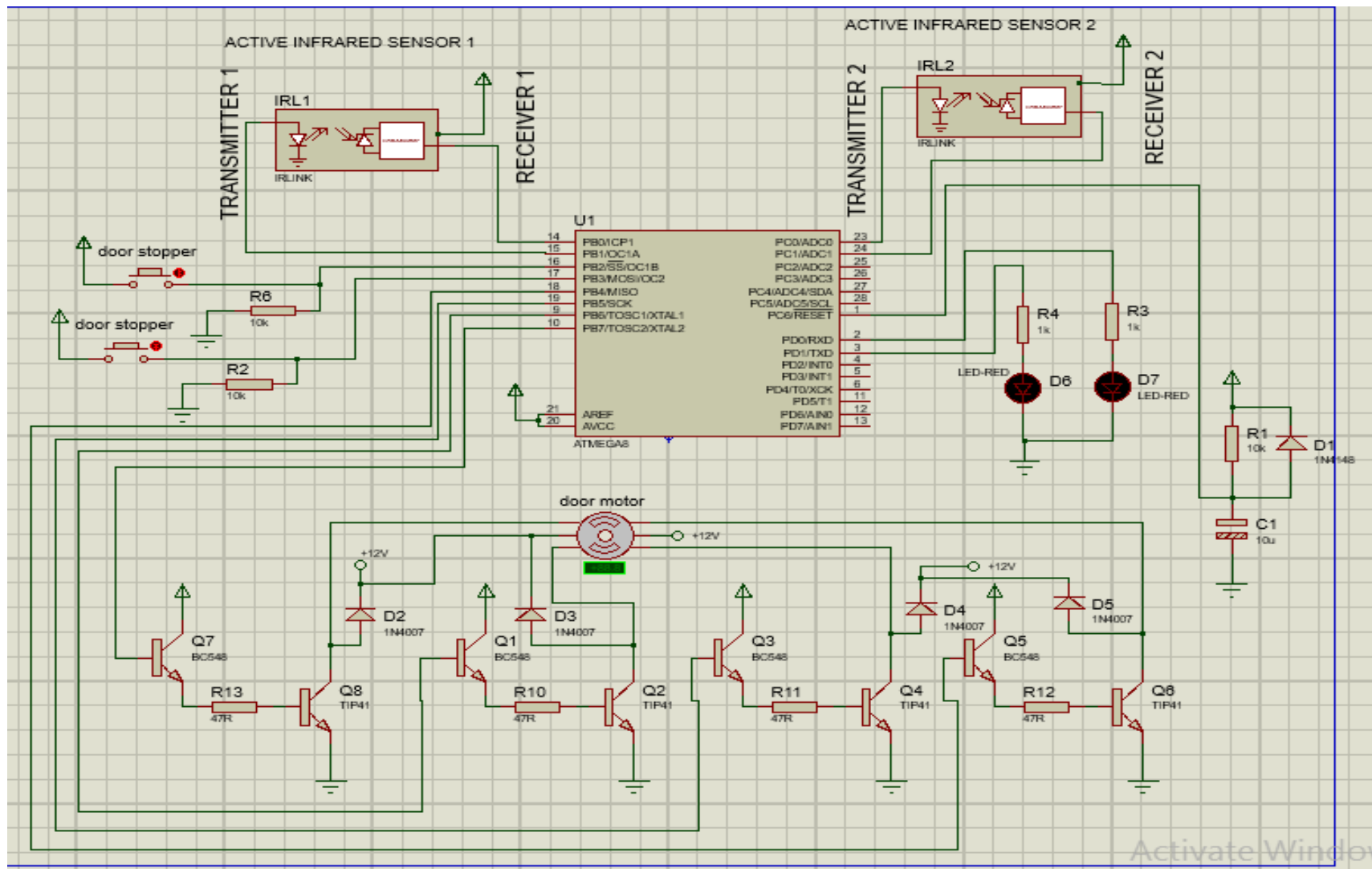
Fig. 9 Complete circuit diagram of the automatic sliding door system
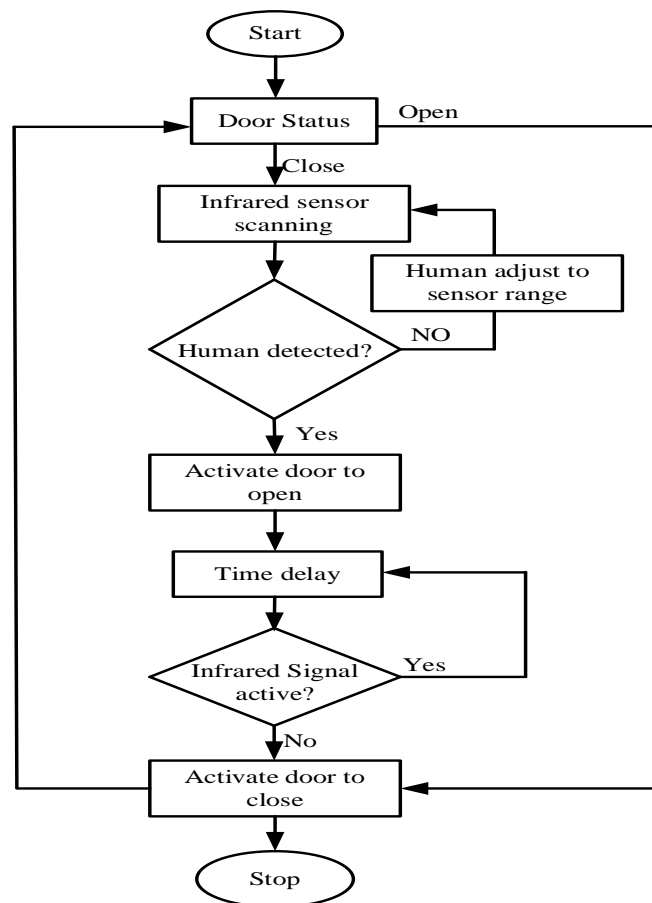
Fig. 10 Operational flow chart

4. Results and Discussion

This section presents and discusses the results obtained from the implementation and the testing of this work.

4.1. Hardware Implementation of the Prototype of Sliding Door

The pictorial representations of the proposed Prototype active infrared sensor controlled automatic sliding door are shown in Figs. 11 to 15.

Fig. 11 Infrared sensor connection to the microcontroller

Fig. 12 Power supply section for the automatic sliding door

Fig. 13 Diagram showing the motor /switching speed section implemented

Fig. 14 Diagram showing the transformer connection to the power supply panel

Fig. 15 Prototype automated sliding door

4.2. Testing

4.2.1 Component testing: In this section, all the components used were tested to ascertain their functionality before assemblage on the board. The major test carried out on these components was continuity testing done with the use of multi-meter like transistors. The test made on transistors was used to test each terminal of a transistor. Polarity testing was also performed on some components like diodes, capacitors and transistors. Fig. 11 shows the connection of the infrared sensors to the microcontroller while the power supply with an output voltage of +4.3V shown in Fig. 12 used to power the microcontroller (16F628), the microcontroller in turn generated the required frequency 38 kHz for the infrared sensors.

4.2.2 System response testing: The results of the response and proximity tests carried out on the prototype automatic sliding door implemented in this work are presented in this section. The prototype automatic sliding door designed and implemented in this work is presented in Figure 15 while the results of the basic tests were presented in Tables 2 – 4.

Table 2 Response test results of the sliding door for incoming and outgoing human

Trial	Human status	Door Opening	Opening Time (seconds)	Door Closing	Closing Time (seconds)	Failure	Delay Time (seconds)
1	Incoming/Outgoing	Yes	3.11	Yes	3.06	Nil	5.50
2	Incoming/Outgoing	Yes	3.10	Yes	3.05	Nil	5.50
3	Incoming/Outgoing	Yes	3.09	Yes	3.04	Nil	5.60
4	Incoming/Outgoing	Yes	3.10	Yes	3.06	Nil	6.00
5	Incoming/Outgoing	Yes	3.11	Yes	3.05	Nil	6.00

Table 3 Response test results of the sliding door for stationary human

Trial	Human status	Door Opening	Delay Time (seconds)
1	Stationary	Yes	Indeterminate
2	Stationary	Yes	Indeterminate
3	Stationary	Yes	Indeterminate
4	Stationary	Yes	Indeterminate
5	Stationary	Yes	Indeterminate

Table 4 Proximity measurement of distance from the sensors

Trials	Distance from the Sensor	Remark
1	27.5cm	Door remains Close
2	25.5cm	Door remains Close
3	23.5cm	Door Open
4	21.5cm	Door Open
5	19.5cm	Door Open
6	17.5cm	Door Open
7	15.5cm	Door Open

The automatic sliding door response test is presented in Table 2 for scenarios where a human being was entering and leaving a facility through the automatic sliding door, the average opening time was found to be 3.10s while the average closing time of the door was reported to be 3.05s. A comparison of the average opening time and closing time shows that the average opening time is more than the average closing time by 0.05s which may be due to inertia. The average delay time which is the time the door remains open when it is in operation before it closes is found to be 5.72s. It was found that the door remains closed as long as the body is within the sensor proximity. Table 3 presents the result of a scenario where a human being approached the door and remained stationed with the proximity of the sensor, the result presented (Table 3) shows that the delay time is indeterminate which implied that the door remained open for as long as the human being remained within the sensors' range.

The proximity test result of the automatic sliding door is presented in Table 4 where seven trials were made. The distance between the base and the sensor is approximately 28cm and it is graduated at an interval of 2.5cm as reported in Table 3. Based on this table, it was observed that the door responded to the person coming in when the distance to the sensor is about 23.5cm which suggests the range of the sensor to be around this value.

5. Conclusion

This work has successfully carried out the design and implementation of a prototype active infrared sensor controlled automatic sliding door that can be scaled up to field use for different applications to avoid the spread of COVID – 19 in places like hospitals, hotels, and event centers. The design was carried out in two stages namely; the structural stage and the automation stage. The detailed design of the structural aspect of the prototype automatic sliding door was achieved in Microsoft Visio environment and hard particle board cut into sizes was used to implement the design. The Express PCB, which is available free online was employed to design the different circuit of the automation aspect of the door while various components like infrared sensor was used for detecting the presence of an incoming/outgoing person.

The LED indicators was engaged to show the status of the system, press button switch was used for stopping the door, stepper motor provides the required torque to drive the door, and ATMEGA microcontroller acts as the brainbox for the entire system designed. In addition, the integrity of the prototype automatic sliding door was investigated via basic tests such as component test and system test. The result of the tests carried out on the door showed that the prototype automatic sliding door is characterized by the average opening time of 3.10s, the closing time of 3.05s, delay time of 5.72s, and optimal sensing range of the automatic sliding door was found to be around 23.5cm. It is therefore concluded that this prototype automatic sliding door is effective in overriding the manual operation of the door which aids the transmission of the deadly COVID – 19. This technology can be very useful and deployable both in residential and industrial buildings. Future work will tend to focus on integrating biometric systems like facial and iris as a means of authentication as the present work is devoid of security checks.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

ORCID

A. O. Amole 🆔 https://orcid.org/0000-0002-0275-8670

M. O. Oyediran 🆔 https://orcid.org/0000-0001-6756-1476

O. O. Olusanya 🆔 https://orcid.org/0000-0001-6893-0472

W. A. Elegbede 🆔 https://orcid.org/0000-0001-6498-8319

A. T. Olusesi 🆔 https://orcid.org/0000-0002-1978-9027

References

[1] Model Building Bye-Laws, Ministry of Urban Development, Government of India, 2016.

[2] A. Z. Alkar, and U. Buhur, "An Internet based wireless home automation system for multifunctional devices," *IEEE Consumer Electronics*, vol. 51, no. 4, pp. 1169-1174, 2005.

[3] A. M. Zungeru, J. G. Kolo, and I. Olumide, "A simple and reliable touch sensitive security system," *Int. J. Network Security Applications*, vol. 4, no. 5, pp. 149-165, 2012.

[4] I. Potamitis, K. Georgila, N. Fakotakis, and G. Kokkinakis, "An integrated system for smart-home control of appliances based on remote speech interaction," EUROSPEECH 2003, 8th European Conference on Speech Communication and Technology, Geneva, Switzerland, Sept. 1-4, 2003, pp. 2197-2200.

[5] D. I. G. Chomo, D. S. Yawas, and Z. S. Johnson, "Development of an automatic door system," *American J. Eng. Res.*, vol. 7, no. 5, pp. 168-173, 2018.

[6] M. Oladunmoye, A. A. Oluwatomi, and O. Obakin, "Design and construction of an automatic sliding door using infrared sensor," *Comput. Inform. Sys, Dev. Informatics Allied Res. J.*, vol. 5, no. 4, pp. 168-173, 2014.

[7] R. De Luca, "Sliding doors," *Brazilian J. Physics Educ.*, vol. 30, no. 3, 2008.

[8] S. Sadi, "Prototype system control car garage based microcontroller ATMEGA 8535," *Comp. Eng. Intelli. Sys.*, vol. 6, no. 4, pp. 91-107, 2015.

[9] G. Conte, and D. Scaradozzi, "Viewing home automation systems as multiple agents systems", RoboCUP2003, Padova, Italy, 2003.

[10] B. Kiran, L. Amarteja, S. Madarshareef, and J. Bindhusekhar, "Motion based automatic garage door opener," *Int. J. Eng. Trends Applica.*, vol. 5, no. 2, pp. 324-336, 2018.

[11] S. Gibilisco, *Electronics Portable Handbook*, New York: McGraw-Hill, 1999.

[12] J. Yang, C. Lai, H. Sheu, and J. Chen, "An intelligent automated door control system based on a smart camera," *Sensors*, vol. 13, pp. 5923-5936, 2013.

[13] S. Corazza, L. Mündermann, E. Gambaretto, G. Ferrigno, and T. P. Andriacchi, "Markerless motion capture through visual hull, articulated ICP and subject specific model generation," *Int. J. Comp. Vision*, vol. 87, no. 1-2, pp. 156–169, 2009.

[14] O. F. Ikpeze, E. C. Uwaezuoke, B. Samiat, K. M. Kareem, "Design and construction of an automatic gate," *ABUAD J. Eng. Res. Dev.*, vol. 2, no. 2, pp. 123-131, 2019.

[15] S. Emakpor and E. Esekhaigbe, "Development of an RFID-based security door system," *J. Electri. Control Telecomm. Res.*, vol. 1, pp. 9-16, 2020.

[16] M. S. Okundamiya, and S. Emakpor, "Design and control strategy of a security door system using radio frequency signal," 2017 IEEE 3rd Int. Conference on Electro-Technology for National Development, Owerri, Nigeria, pp. 406–412.

[17] Z. Ceylan, "Estimation of COVID-19 prevalence in Italy, Spain, and France," *Science Total Environment*, vol. 729, no. 138817. 2020, doi: 10.1016/j.scitotenv.2020.138817

[18] A. Narin, C. Kaya, Z. Pamuk, "Automatic detection of coronavirus disease (COVID-19) using x-ray images and deep convolutional neural networks," preprint at https://arxiv.org/ftp/arxiv/papers/2003/2003.10849.pdf

[19] A. Chern, & S. H. Selesnick, "Dissemination of information during public health crises : early COVID-19 data from the laryngoscope," *Laryngoscope*, vol. 130, pp. 2508-2515, 2020, doi: 10.1002/lary.29147

[20] T. Degnan, "How will the COVID-19 pandemic affect the catalysis community?" *Focus Catal.*, vol. 2020, no. 5, pp. 1, doi: 10.1016/j.focat. 2020.04.001

[21] A. Bejoy, and M. S Nair. "Computer-aided detection of covid-19 from x-ray images using multi-cnn and bayesnet classifier." *Biocybernetics Biomedical Eng.,* vol. 40, no. 4, pp. 1436–1445, 2020.

[22] R. M. Pereira, D. Bertolini, L. O. Teixeira, C. N. Silla, and Y. M. G. Costa, "COVID-19 identification in chest x-ray images on flat and hierarchical classification scenarios," *Comp. Methods Programs Biomedicine*, vol. 194, no. 105532, 2020.

[23] C. Anastasopoulos, T. Weikert, S. Yang, A. Abdulkadir, L. Schmuelling, C. Buehler, F. Paciolla, et al., "Development and clinical implementation of tailored image analysis tools for covid-19 in the midst of the pandemic: the synergetic effect of an open, clinically embedded software development platform and machine learning," *European J. Radiology*, vol. 131, no. 109233, 2020, doi: 10.1016/j.ejrad.2020.109233

[24] M. Foley, I. O'Neill, B. O'Neill, H. Humphreys, K. Burns, E. de Barra, and F. Fitzpatrick, "From bench to bedside – development of an integrated covid-19 patient flow management system," *J. Hospital Infect.,* vol. 106, no. 1, pp. 211-213, 2020.

[25] X. Xu, X. Jiang, C. Ma, P. Du, X. Li, S. Lv, L. Yu, et al. "A deep learning system to screen novel coronavirus disease 2019 pneumonia," *Engineering*, (in press), doi: 10.1016/j.eng.2020.04.010

[26] C. O. Akanbi, I. K. Ogundoyin, J. O. Akintola, and K. Ameenah, "A prototype model of an iot-based door system using double-access fingerprint technique", *Nigerian J. Technological Dev*., vol. 17, no. 2, pp. 142-149, 2020.

[27] J. R. Joshi, "COVSACK: an innovative portable isolated and safe covid-19 sample collection kiosk with automatic disinfection," *Trans. Indian National Acad. Eng.*, vol. 5, no. 2, pp. 269-275, 2020.

[28] R. O. Ogundokun, A. F. Lukman, G. B. M. Kibria, J. B. Awotunde, and B. B. Aladeitan, "Predictive modeling of covid-19 confirmed cases in Nigeria," *Infectious Disease Modeling*, vol. 5, pp. 543-548, 2020.

[29] G. Kumar, H. Bossert, D. McDonald, A. Chatzidimitriou, M. A. Ardagh, Y. Pang, et al., "Catalysis-in-a-box: robotic screening of catalytic materials in the time of covid-19 and beyond," *Matter*, vol. 3, no. 3, pp. 805-823.

[30] M. K. Adeyeri, S. P. Ayodeji, and A. O. Orisawayi, "Development of a dual - purpose wheelchair for covid-19 paraplegic patients using nigerian anthropometry data," *Scientific African,* vol. 9, 2020, doi: 10.1016/j.sciaf.2020.e00547

[31] W. M. Shaban, A. H. Rabie, A. I. Saleh, and M. A. Abo-Elsoud, "A new covid-19 patients detection strategy (cpds) based on hybrid feature selection and enhanced knn classifier," *Knowledge-Based Systems*, vol. 205, no. 106270, doi: doi: 10.1016/j.knosys.2020.106270

[32] M. Nour, Z. Cömert, and K. Polat, "A novel medical diagnosis model for covid-19 infection detection based on deep features and bayesian optimization," *Appl. Soft Comput.*, (in press), doi: 10.1016/j.asoc.2020.106580

[33] O. Taiwo, and A. E. Ezugwu, "Smart healthcare support for remote patient monitoring during covid-19 quarantine," *Informatics Medicine Unlocked*, vol. 20, no. 100428, 2020, doi: 10.1016/j.imu.2020.100428. 2020

[34] K. H. Shibly, S. K. Dey, M. T-U. Islam, and M. M. Rahman. "COVID faster R–CNN: a novel framework to diagnose novel coronavirus disease (covid-19) in x-ray images," *Informatics Medicine Unlocked*, vol. 20, no. 100405, 2020, doi: 10.1016/j.imu.2020.100405

[35] A. M. Karadeniz, M. Alkayyali, and P. T. Szemes, "Modeling and simulation of stepper motor for position control using labview," *Recent Innov. Mechatron.*, vol. 5, no. 1, pp. 1-5, 2018.