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Design and Fabrication of an Intelligent Self Closing and Opening Door

Jimoh Endurance[a]*, Sufianu A. Aliu[b]

[ab]Department of Mechanical Engineering, University of Benin, Benin City, Nigeria

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ABSTRACT

This project demonstrates an intelligent self-opening and closing door system that is dependent on human motion close to the door. The door achieves this functionality with the help of a PIR sensor. Every live body emits some infrared energy, this energy is sensed by the PIR sensor from a good distance and uses this signal to process the opening and closing of the door. The use of an automatic door can be made to solve most of the challenges associated with manually operated doors. These challenges necessitate the design and fabrication of a door system that is capable of opening and closing on its own. The door was designed and built with locally sourced materials. The self-opening and closing sliding door was tested after fabrication and the system was validated to have performed as expected. The design values for the design parameters were compared to the actual values measured from the system while it was running. The percentage deviation of actual values from design values for design parameters such as door opening time, door delay time, door maximum velocity, door minimum velocity, and total time taken for the door to complete one operating cycle are 7.69%, 3.15%, 3.53%, 14.89%, and 6.51%, respectively. The comparison revealed that the discrepancies between the actual and design values were insignificant. Thus, the design and fabrication of an intelligent door system was successfully executed.

1. Introduction

In today's work schedules, the flow of people, commodities, and services must be quick and efficient. Doors are positioned between these schedules, and they play a significant part in creating a pleasant work atmosphere. Any impediment to effective mobility is damaging to the organization's or industry's efficiency and must be addressed. The traditional manual door may be an impediment to efficient mobility [1]. It has become more difficult for persons with impairments to utilize doors without assistance. Because traditional doors can be difficult to use for people in wheelchairs and other physically challenged people, automated doors are really useful. [2].

The aim of this project is to design an intelligent self-opening and closing door and fabricate the door with locally sourced materials to display its functionality and performance. The system was designed to receives signal from a PIR sensor aided by programmable logic circuit (PLC) as an interface for controlling the mechanical movements of the door through electronic systems.

The design of an intelligent door system varies, some slide open while others consist of panels which fold when people enter or exit and others swing in or out like conventional doors. The doors are equipped with various motion sensor which can detect people when they approach, and the sensitivity of the sensor can be adjusted as needed. For people in wheelchairs and other disabled individuals, automatic doors are an immense boon, since conventional doors can be very hard to work with. It may be impossible to open a conventional door while seated in a wheelchair or navigating with crutches, for example, and for people with disabilities in their hands and arms, conventional doors can present a real obstacle [3].

These doors are made up of electro-mechanical components which interact with one another and work together to perform a certain job. Intelligent doors employ smart locks. A smart lock is an electromechanical lock that is configured to lock and unlock a door when an authorized device sends an instruction. This door is also sensitive to doorway impediments. This is done to keep the door from closing on someone or something that happens to be in the way of the entryway. This safety feature enhances the automated door's security [4].

2.0 Materials and Methods

This section involves both the design process and design factors. It consists of material selection, system component design, fabrication processes and door operation.

2.1 Design Considerations

The absence of friction between the machine and the humans is critical to the success of a design. That is, the designer has succeeded if the use of the equipment makes humans safer, more comfortable, more efficient, or just happier [5]. Dependability, corrosion resistance, cheap cost, ease of operation, high efficiency, maintainability, and locally accessible materials are among the design concerns for this work.
The system's functional needs include the capacity to offer an airtight environment, safe ways of entry, heat resistance, and privacy. The operational criteria also include the door always opening when a person or persons approach, closing at a specified period, being noise free throughout operation, and working properly under any atmospheric situation.

2.2 Materials

Materials for each component were selected with regards to the various requirements. The components and the materials selected are:

- **i.** **Chain drive:** A chain drive is a type of mechanical drive system that transfers mechanical power or motion from one shaft to another. A chain is made up of links that are joined together using pin joints. [6]. Alloy steel was used as the material for the roller chain and sprockets. On the basis of wear resistance and strength, alloy steel was chosen as the material for both the chain and the sprockets.
- **ii.** **Roller bearings**: A bearing is a machine element that supports another moving machine element. It permits relative mobility between the contact surfaces of the members while bearing the load [7]. The rollers used are made of cast nylon. Cast nylon was chosen due of its characteristics, which include low rolling resistance, minimal or no noise generation when in operation, and the capacity to absorb stress and vibration.
- **iii.** **Door panel:** Glass door panels were chosen because they are an excellent insulator, are resistant to most chemicals, are light in weight, have an appealing and welcoming look, and have a high compressive strength (1000N/mm2).

iv. **Door frame and the structure:** The structure houses the door frame as well as other system components' supports. Medium carbon steel was chosen for the structure and frame because it is ductile, has excellent mechanical strength and wear resistance, is inexpensive and quickly welded.

v. **Track:** The track serves as the bearing's runway. Steel is used to make the track. Steel was chosen for its strength, ductility, corrosion resistance, and durability.

vi. **Floor guides**: The floor guides keep the glass door from swinging open while it is in use. Steel was used for the floor guides because of its longevity, corrosion resistance, and great strength.

vii. **Electric motor:** The electric motor generates rotating motion, which is communicated to the glass door through the chain drive. The electric motor is a bidirectional electric motor that can revolve both clockwise and counterclockwise. The motor's spin opens or closes the door in response to the microcontroller's signal.

viii. **Microcontroller:** The microcontroller is the system's central controlling unit. It is in charge of the spinning of the electric motor. This is accomplished by the sensor signal received by the controller.

ix. **PIR sensors:** The PIR sensor detects heat energy emitted by a person approaching the entrance and sends a signal to the controller. The sensor detects this heat energy only when the individual is inside the sensor's range. The range of the sensor may be modified to match the needs of the system.

x. **Limit switches:** Limit switches are used to identify the presence of an object or to track the movement of an object automatically. It aids in indicating when the door's movement limit has been achieved.

xi. **Relays:** A relay is an electromechanical device that employs an electromagnet to move a pair of moveable contacts from open to closed. The benefit of relay is that it requires very little electricity to run the relay coil. It may be used to control motors, heaters, and lights, among other things.

xii. **Batteries:** When there is a power outage or breakdown of the national grid, the battery stores DC electrical energy that may be utilized to power the system. There are two of them. The batteries have a voltage rating of 6 volts each. Both batteries are wired in series to provide a voltage of 12 volts.

xiii. **Timer:** The timer regulates the amount of time the door remains open before closing.

xiv. **Switch:** The switch is a manually controlled device that controls the electricity supply. This is accomplished by either opening or closing a circuit.

xv. **Light-Emitting Diode (LED):** LEDs are semiconductor light sources that emit light when electricity is passed through them. It can be used to show whether or not a circuit is closed.

2.3 Design of the System Components

The design of the system components consists of the door panel, door frame, rollers and the drive system.

2.3.1 The Door Panel

The door panel is a moveable component of the system that moves aside to allow people to utilize the door. The door's measurements are as follows:

Height of the door panel (H) = 2000 mm

Width of the door panel (b) = 840 mm

Thickness of the door panel (t) = 12 mm

Mass density of the door panel material which is glass (ρ) = 2500 kg/ m^2

The mass of the door can be obtained from the equation (1) [8];

Mass of the door panel $(Mg) = p \times H \times b \times t$ (1)

Mass of the door panel (Mg) =2500 × 2 × 0.84 × 0.012=50.4kg

Weight of the door panel (Wg) = (Mg) × g = 50.4×9.81= 494.424 N (2)

2.3.2 The Door Frame

The material of the frame is medium carbon steel and its dimensions are given as Rectangular hollow section of (40×20×3) mm3.

Mass per unit length = 2.36 kg/m. [9]

Total length of the steel material (L) = 2H + 2b (3)

= 2×2000 + 2×840 = 5680 mm = 5.68 m

Total mass of the frame (Mf) = 2.36 × 5.68 = 13.4 kg

Weight of the frame (Wf) = Mf × g = 13.4 × 9.81= 131.5 N (4)

Total weight of the door (W) = Wg + Wf = 494.424 × 131.5 = 625.925 N (5)

2.3.3 Force Analysis for the Door

The force analysis of this work is done as in [10]

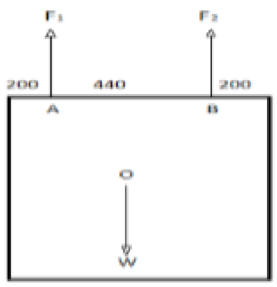

Figure 1 Free body diagram of the door

where W is the weight of the door,

F1 and F2 are the forces acting on the two hinge joints.

$\sum Fy = 0$

$F1 + F2 - W = 0$

$W = F1 + F2$ (6)

Taking moment about point A

$\sum MA = 0$

$F2 \times 440 = W \times 220$

$F2 = \frac{220W}{440}$

$F2$= 220 ×626 440 = 313 N

Assuming that the mass of the door is evenly distributed.

Then, $F1 = F2$= 313 N

2.3.4 Selection of Roller from Manufacturer's Catalogue

Dongguan Kentie Bearing Co. catalogs and technical brochures were used for the roller selection. The process of roller selection was done following [6]. The radial load (Fr) = 313 N, axial load (Fa) = 0, bore diameter (d) 10 mm (assumed), speed (N) = 229.18 rpm, rated life of the bearing (L10h) = 60000 hours while the race-rotational factor (υ) = 1.2. The bearing is subjected to only radial load

Dynamic load (P) = υ × Fr = 1.2 × 313 = 375.6 N (7)

The rating life of the bearing (L10) = 60 ×N × $L10h$ 106 =. 825.059 million revolutions (8)

Dynamic load capacity (C) = P(L10)1/3 = 375.6(825.059)1/3 = 3522.79 (9)

From manufacturer's catalogue, for bore diameter of 10 mm; bearing number 6000 is suitable for this application. Bearing number 6000 has the specifications:

Bore diameter (d) = 10 mm

Outer diameter (D) = 26 mm

Axial width of the bearing (B) = 8 mm

2.3.5 Force Analysis for the Rollers

Force analysis for the rollers is done in the manner of [11].

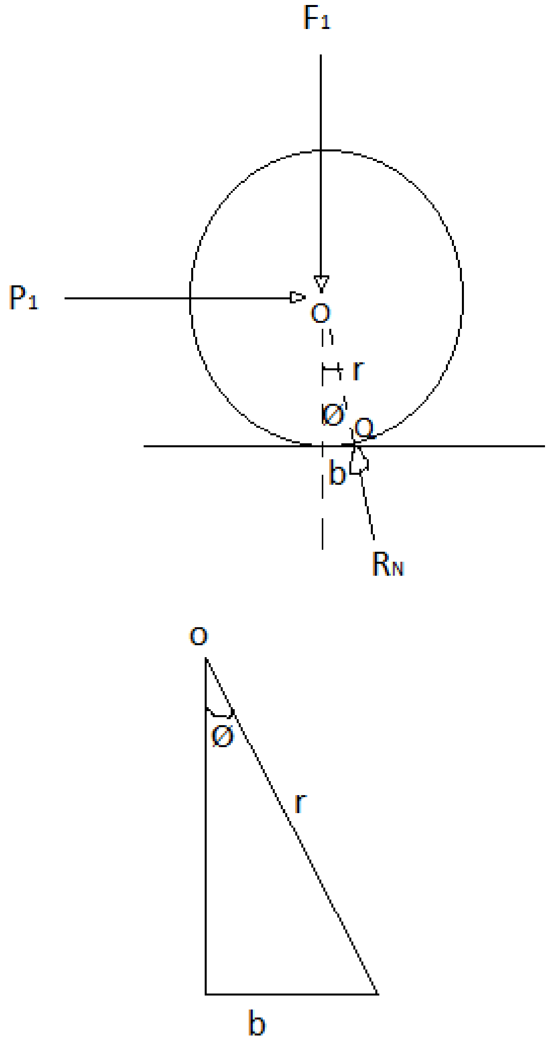

Figure 2 Free body diagram of the roller

Where F1 is the force or load on the roller,

P1 is the force required to overcome rolling resistance, RN is the normal reaction.

$\sum \mathrm{Fy} = 0$

$$\mathrm{RN} \times \cos(\emptyset) - \mathrm{F1} = 0 \quad (10)$$

$\mathrm{F1} = \mathrm{RN} \times \cos(\emptyset)$

$\sum \mathrm{Fx} = 0$

$$P1 - RN \times sin(\emptyset) = 0 \quad (11)$$

$\mathrm{P1} = \mathrm{RN} \times \sin(\emptyset)$

$\frac{\mathrm{P1}}{\mathrm{F1}} = \frac{\mathrm{RN} \times \sin(\emptyset)}{\mathrm{RN} \times \cos(\emptyset)}$

$\frac{P1}{F1}$ = tan∅ The value of ∅ is small since the area of contact of the roller with the track is small. Thus,

$\tan\emptyset \cong \sin\emptyset$

$$\sin\emptyset = \frac{b}{r} \quad (12)$$

From Equation (12)

$\frac{P1}{F1} = \frac{b}{r}$

$P1 = F1 \times = \frac{b}{r}$

The radius of the bearing (r) = $\frac{D}{2}$ = 13 mm

The distance (b) is called the coefficient of rolling friction.

The value of b for cast nylon roller on steel track is 0.027 inches (0.6858 mm) [12].

∴ $P1$= 16.512 N

The total force required to overcome rolling resistance on both rollers $(P) = 2\,P1$

P = 33.024 N

The force (P) is the force required to sustain its motion.

The value or magnitude of the kinetic frictional force, that acts when there is motion, is usually less than the maximum magnitude of the static frictional force that must be overcome to start motion [13].

The force (Fa) required to start or initiate its motion is generally 2 to 2.5 times the force (P) required to sustain its motion [12].

$Fa = 2P$ = 66.048 N

2.3.6 The Drive System (Chain Drive)

The chain and sprocket were selected from RENOLD Superior Chain Technology catalog [14].

i. Selection of chain

The process of chain selection was done using [6].

$$\text{Maximum velocity of the sliding door } (V) = \frac{S}{t} \quad (13)$$

Where S is the distance covered at maximum velocity, t is the time taken.

Taking $S = 740$ mm and $t = 4.5$ seconds

Then, $V = 0.164$ m/s

The maximum velocity of the door is 0.164m/s.

The minimum velocity of the door at the extreme positions (fully closed and opening positions) is ($\boldsymbol{Vmin}$) = $\frac{S2}{t2}$

where $S2$ is the distance covered by the door with the minimum velocity, $t2$ is the time taken. $S2$ = 100 mm (assumed), $t2$ = 2.5 seconds (assumed)

Minimum velocity of the door ($\boldsymbol{Vmin}$) = 0.04 m/s

The total time taken for the door to get to its fully opened or closed position is the sum of the time taken during maximum velocity and minimum velocity.

Total time = 4.5 + 2.5 = 7 seconds

The power required to accelerate the door = $Fa \times V = 10.83$ W

Transmission efficiency (ηT) = $\frac{Pout}{Pin}$

$$Pin = \frac{Pout}{\eta T} \quad (14)$$

Where Pin is the power input into the drive system from the motor. $Pout$ is the power output from the drive system to accelerate the door. The efficiency of a well lubricated chain drive is of the range 96% to 98% [6].

Using an efficiency of 97% (assumed) and $Pout$ = 10.83 W

From Equation (14),

Pin = 11.165 W

The input power (Pin) is the power to be transmitted by the chain drive or the transmitted power (TP). Rating power (RP) = $\frac{TP \times Ks}{K1 \times k2}$ (15)

Transmitted power (TP) = 11.165 W

Using a pinion (driving sprocket) with 15 teeth (assumed). For electric motor as the input power and smooth driven load, the Service factor (ks) is 1.0. For chain with single strand, the Multiple strand factor (k1) is 1.0. For pinion with 15 teeth, the Tooth correction factor (k2) is 0.85 [6].

Rating power (RP) = 13.135 W

According to [6], the maximum tension in the chain drive is given s;

Chain tension $(Pc) = \frac{\mathrm{RP}}{\mathrm{V}}$ (16)

Chain tension (Pc) = 80.09 N

The driving sprocket (pinion) rotate at the same speed with the spindle of the motor.

That is, pinion speed $(Np) = 229.18$ rpm. The closest higher speed is 300 rpm [6]. At pinion speed of 300 rpm, the most suited chain drive is 06B.

Chain number 06B has a speed of 300 rpm and power rating of 0.61 kW

Chain number 06B has the dimensions and breaking load:

Pitch $(p) = 9.525$ mm

Roller diameter $(d1) = 6.35$ mm

Width $(b1) = 5.72$ mm

Breaking load $(WB) = 8900$ N

Number of links in the chain $(Ln) = 2(\frac{a}{p}) + (\frac{\mathrm{Z1+Z2}}{2}) + (\frac{\mathrm{Z2-Z1}}{2\pi})2 \times (\frac{a}{p})$ (17)

where Pitch $(p) = 9.525$ mm,

number of teeth of the driving sprocket (pinion) (Z1) = 15 teeth and number of teeth of the driven sprocket (Z2) = 15 teeth Using a center distance (a) of 1550 mm. (assumed)

Number of links in the chain $(Ln) = 340.46$

Since the number of links must be even, then number of links in the chain (Ln) = 340 Actual center distance (a) between the driving sprocket and the driven sprocket is given as

a = $\frac{p}{4}\{[Ln - (\frac{Z_1+Z_2}{2})] + \sqrt{([Ln - (\frac{Z_1+Z_2}{2})]2 - 8[\frac{Z_2-Z_1}{2\pi}]2)}\}$ (18)

$a = 1547.8$ mm

length of the chain $(L) = Ln \times p = 3238.5\ mm$ (19)

ii. Selection of sprocket

The driving sprocket and driven sprocket have the same dimensions.

Pitch circle diameter $(D) = p\ sin\ 180\ Z$ (21)

Pitch circle diameter $(D) = 45.81\ mm$

Top diameter (Da):

$$(Da)max = D + 1.25p - d1 = 51.366mm \quad (22)$$

$$(Da)min = D + p(1 - \frac{1.6}{Z1}) - d1 = 47.969mm \quad (23)$$

∴ Top diameter $(Da) = \frac{(Da)max + (Da)min}{2} = 49.67mm$

Roller seating radius (ri) $= 0.505(\mathrm{d1}) + 0.069(\sqrt[3]{\mathrm{d1}})$ (24)

ri $= 3.33$ mmRoot

diameter $(Df) = D - 2ri$ (25)

Df $= 39.15$ mm

Tooth width $(bf) = 0.93(b1)$ (26)

bf = 5.3 mm

iii. Selection of electric motor

Power rating of the motor

The angular velocity of the motor (ω) can be obtained from Equation (27)

$$V = \omega \times r \quad (27)$$

where V is the maximum velocity of the chain, r is the pitch circular radius of the sprocket

$\omega = 7.1616\ rad/\mathrm{s}$
The speed (N) required can be obtained from Equation (28).

$$\omega = \frac{2\pi N}{60} \quad (28)$$

N = 68.39 rpm

The motor power required is the power to be transmitted by chain drive or the input power (Pin) into the drive system as obtained from Equation (14).

Thus, the power rating of motor $(Pm)\ is\ 11.165\ W$.

The torque (T) required can be obtained from Equation (29)

$$Pm = T \times \omega \quad (29)$$

$T = Pm\ \omega$

$T = 1.56\ Nm$

2.4 Duration of Operation of the Door with Battery

When there is a power loss from the main power source, an alternate source of electric power supply must be provided through the use of batteries to ensure the uninterrupted operation of the sliding door (whose exploded view is illustrated in Figure 3). As a backup for the system, a pair of two batteries with voltage ratings of 6v and battery capacities of 5Ah each was chosen. This section's analysis and formulae followed the format of [15]. These batteries are wired in series.

Total output voltage $(V) = V1 + V2$ (30)

where $V1 = V2 = 6$ volts

The duration (Time, t) of operation of the sliding door using battery as alternative source of power supply is calculated.

Power $(P) = IV$ (31)

where V is the voltage to be supplied by the battery (12V), P is the power required by the system $(15W)$, I is the current.

$I = 1.25A$

Battery capacity $(C) = It$ (32)

where battery capacity $(C) = 5Ah$

$t = \frac{C}{I}$

Current $(I) = 1.25A$

$\therefore t = \frac{5}{1.25}$

t = 4h

The duration of operation of the door with battery is 4 hours

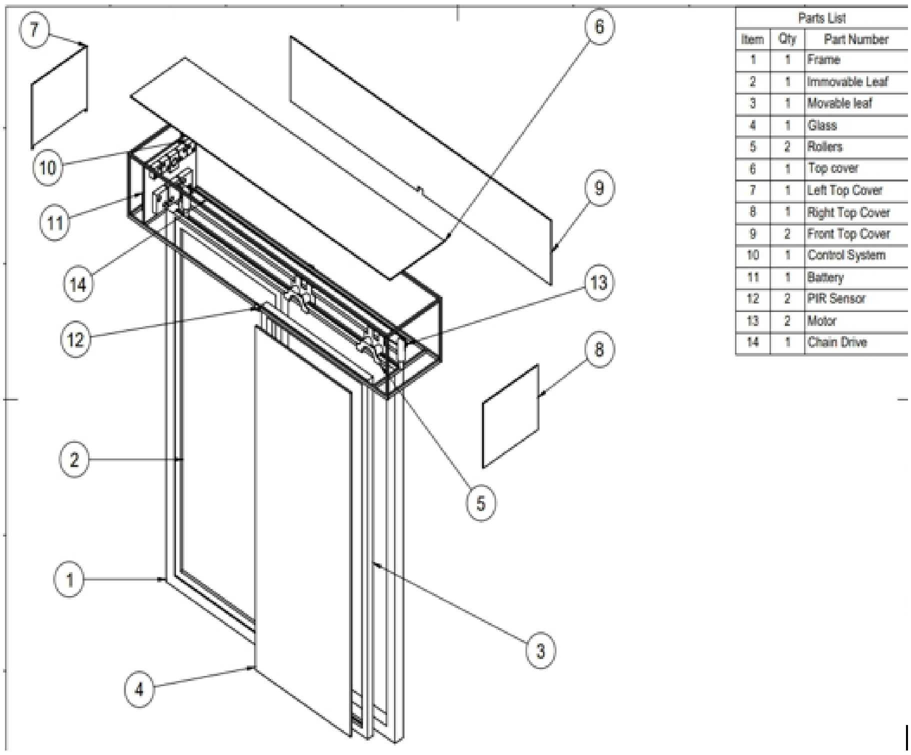

Figure 3 Exploded view of the self-opening and closing door

3.0 Fabrication Process

This section involves the fabrication processes of the intelligent door system

i. The structure: The first step in the fabrication involves the cutting of the medium carbon steel square hollow pipe into their respective length

Figure 4. The structure of the intelligent door

ii. Door Track construction and the attachment of the Rollers: This involves the cutting and welding of the door track steel material to the structure. Also, the rollers were attached to the door hangers using bolts and nuts. There were two sets of rollers used, which are the main rollers and the supporting rollers. The main rollers are the rollers at the front of the structure which carries the weight of the door. While the supporting rollers are the rollers at the back of the structure which prevent the door from jumping when in operation

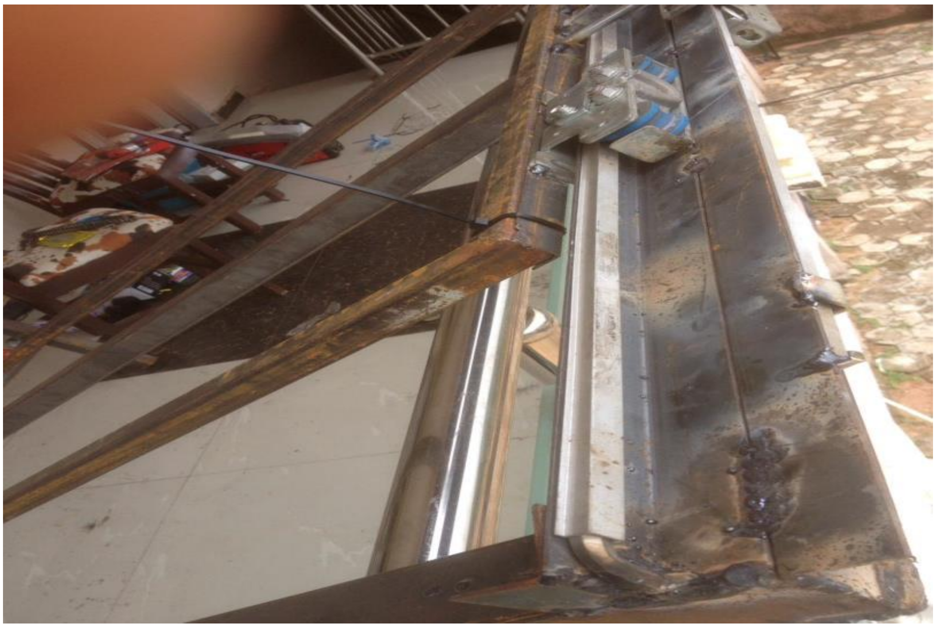

Figure 4. The door track on the frame

Figure 6. The main rollers of the sliding door

Figure 7. The supportive rollers of the sliding door

Figure 8. A pictorial view of both the main rollers and the supportive rollers

iii. Motor and Chain drive installation: This process involves welding of the motor hanger to the structure of the sliding door and fastening of the motor to the hanger using bolts and nuts. Then, the driving sprocket (which is the pinion) was attached to the shaft of the motor

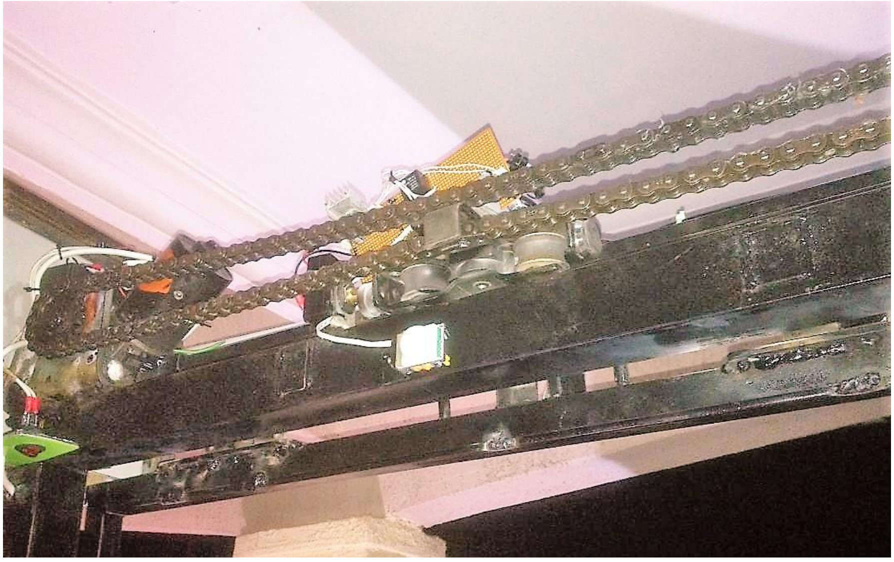

Figure 9. A pictorial view of the installed sprockets, chain, and motor

iv. The installation of the limit switches and the PIR sensors: This was done by attaching the PIR sensors and the limit switches to the structure of the sliding door at their respective positions. One of the PIR sensors was attached at the top of the entrance of the door, while the other PIR sensor was placed at the opposite side of the entrance

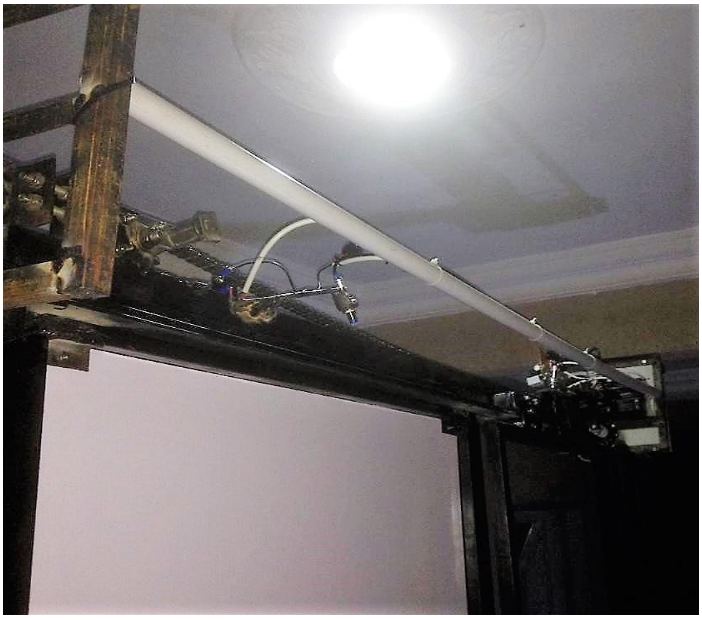

Figure 10. A pictorial view of the installed limit switches

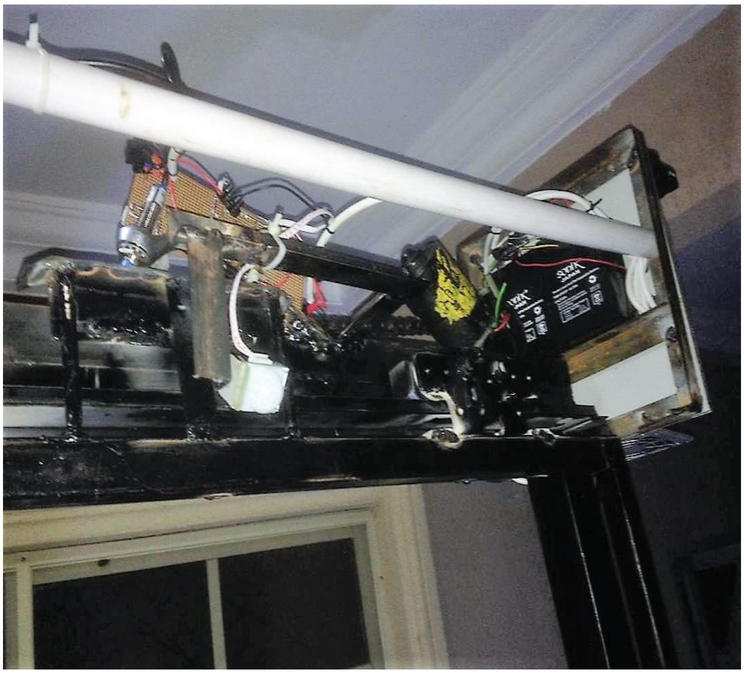

Figure 11. A pictorial view of the installed PIR sensor and the batteries

v. Battery installation: Some of our components are electronics components, such as the PIR sensors, limit switches and the electric motor, which need a (DC) voltage source. This DC voltage is supplied by a set of two batteries with each of them capable of supplying 6volts. The batteries are connected in series to supply a total voltage of 12volts

vi. The installation of the Relays, the Timer and the Power supply circuit: This process involves the attachment of the power supply circuit, the timer and the relays to a board that has been fastened to the structure of the sliding door.

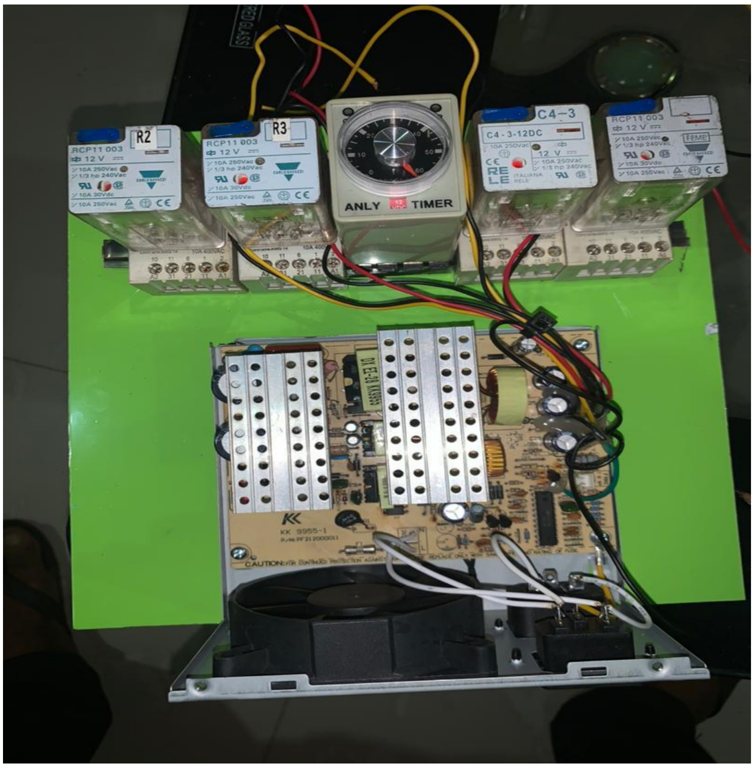

Figure 12. A pictorial view of the installed relays, timer and the power supply circuit.

vii. Electrical connections: This involves the connections between the relays, the timer and the power supply circuit. Also, the PIR sensors and the limit switches were connected to the relays and the power supply circuit.

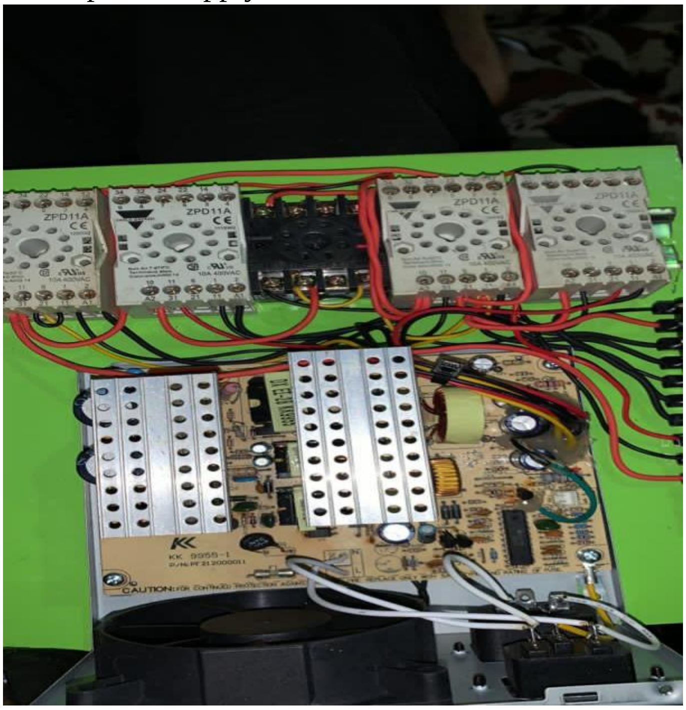

Figure 13. Further connection of the relays, timer and the power supply circuit

viii. Electrical motor connection: The motor was connected to the voltage source (batteries) and to the relays. Then, the batteries were connected to the power supply circuit.

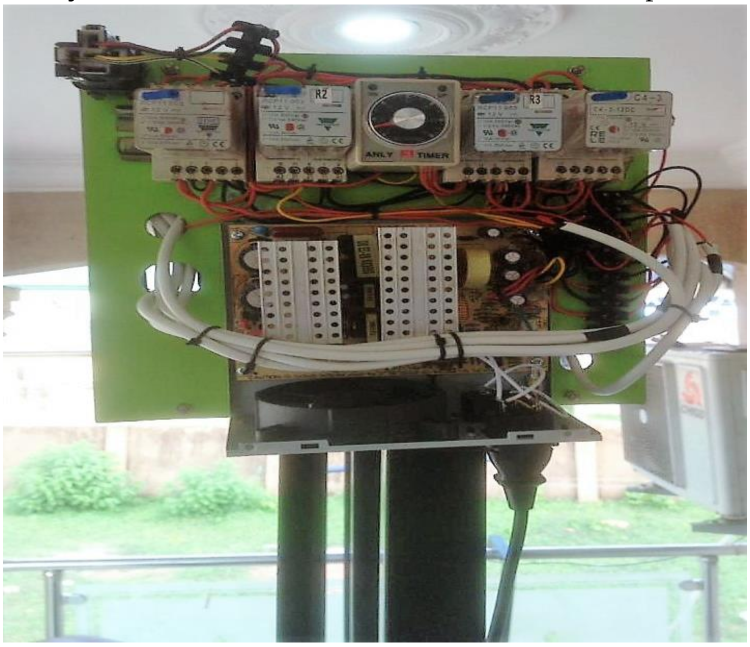

Figure 14. Further connections between the sensors, the relays, the motor and the power supply circuit

ix. Casing Construction: This involves the covering of the upper part of the structure that contains the sensitive components of the automatic door with a casing. This was done by cutting the casing material (plywood) into rectangular shapes that will cover the upper part of the structure

Figure 15 A pictorial view of the intelligent door with the casing

x. Glass Attachment: Finally, the glass door was carefully attached to the frame using screws.

Figure 16 A pictorial view of the intelligent door with the glass sliding door

3.1. Operation of Sliding Door

The sliding door is an automatic door system that detects movement when a person approaches the entrance. A passive infrared sensor (PIR Sensor) installed at the top of the door frame detects the motion of the person. The PIR sensor, microcontroller, motor driver, and relay are all connected to the power supply circuit, which converts AC to DC. The relay is linked to the door motor, which is linked to the limit switches. The microcontroller is linked to the limit switches. The PIR sensor detects motion inside the sensor's range of view by detecting thermal energy generated by the person. The sensor's signal is relayed to the microcontroller, which subsequently starts the motor rotating. The rotating motion of the motor is conveyed to the door through the chain drive (a roller chain and two sprockets of the same dimensions). The door slides open as a result of the transmitted motion. The door remains open for a predefined length of time (4 seconds), known as the delay-time, to allow the individual to completely pass through it before closing or shutting. This delay time can be adjusted.

The sliding door begins with a high velocity and gradually comes to rest at a lower velocity. Limit switches were used to do this. For this technique, two sets of limit switches are employed. The first set consists of two contact sensors mounted at either end of the track. The other pair consists of two proximity sensors positioned between the two contact sensors. The proximity sensors are set 100mm apart from each of the contact sensors. When the door approaches the proximity sensor, the sensor transmits a signal to the microcontroller, which lowers the door's velocity to a lower velocity through a series of relays. When it reaches the touch sensor, the door gently comes to a halt. The touch sensor delivers a signal to the microcontroller, which uses a relay to reduce the velocity of the door to zero. For 4 seconds (the delay period), the door remains motionless in the fully open position to allow the person to pass through the entrance path. The timer may be used to change the delay time. The timer then sends a signal to the microcontroller, which causes the door's velocity to vary from zero to maximum velocity through the relay. When the door reaches the second proximity sensor at the opposite end of the track, its maximum velocity decreases. On reaching the second contact sensor, the door gradually comes to rest in the completely closed position at a lesser velocity. When the PIR sensor senses the motion of a person approaching the entrance, the entire procedure is repeated.

4.0 Results and Discussion

A person's movement might be sensed as far away as 410cm from the entrance. The time it took for the door to completely open was recorded (Table 1). A time average of 6.50 seconds was obtained.

Table 1: Door Opening Time

S/N	Door Opening Time, $\boldsymbol{to}$ (seconds)
1	6.50
2	6.80
3	6.35
4	6.70
5	6.40
6	6.55
7	6.30
8	6.40

The closing time of the door was also measured (Table 2). The average of the recorded values was 6.27 seconds

Table 2: Door Closing Time

S/N	Door Closing Time, $\boldsymbol{tc}$ (seconds)
1	6.41
2	6.13
3	6.30
4	6.40
5	6.25
6	6.35
7	6.20
8	6.15

The duration spent in the resting state of the door before it begins its reverse motion or movement was also measured (Table 3). The average delay time was calculated to be 4.13 seconds.

Table 3: Delay Time

S/N	Delay Time, $\boldsymbol{td}$ (seconds)
1	4.03
2	4.30
3	6.23

4	6.05
5	4.15
6	4.10
7	4.20
8	4.00

The actual maximum velocity achieved by measuring the time required for the sliding door to cross the distance was 0.170m/s. The minimum velocity was also computed using the results of the door testing. The lowest velocity measured was 0.47m/s. The time required for the door to complete its operating cycle, which includes door opening, delay, and shutting, was determined to be 16.90seconds. Some of the main design parameters' desired or design values were compared to their actual values. The real values were derived from the testing results. Table 4 compares the values of design parameters to the actual values.

Table 4 Deviation of the actual from design values of some design parameters

S/N	Design Parameters	Design Value	Actual Value	Deviation	Percentage Deviation
1	Door opening time	7.00 s	6.50 s	0.5 s	7.69 %
2	Delay time	4.00 s	4.13 s	0.13 s	3.15 %
3	Maximum velocity	0.164 m/s	0.170 m/s	0.006 m/s	3.53 %
4	Minimum velocity	0.04 m/s	0.047 m/s	0.007 m/s	14.89 %
5	Total time	18.00 s	16.90 s	1.1 s	6.51 %

Table 4 shows that the variances of the actual values from the design or target values are minor. The deviations are considered insignificant.

5.0. Conclusion

The goal of this project, which is to design and build an intelligent self-opening and shutting door, was realized by careful evaluation of the project objectives.

The door was designed to alleviate the challenges experienced by physically challenged people when attempting to use manually operated doors, and it can also lessen the possibility of cross-contamination in locations such as labs, hospitals, and so on. There would also be no need to pay somebody to open doors for customers at commercial establishments. The movement of people and products is also made easier. It was tested once the construction of the intelligent self-opening and shutting sliding door was completed. The system worked as expected. The design values of the design parameters were compared to the actual values measured by the system while it was running. The percentage variation of actual values from design values for design parameters such as door opening time, door delay time, door maximum velocity, door minimum velocity, and total time taken for the door to complete one operating cycle are 7.69%, 3.15%, 3.53%, 14.89%, and 6.51%, respectively. The comparison revealed that the discrepancies between the actual and design values were insignificant. As a result, the self-opening and closing door mechanism was working well.

References

[1] Chomo, D. I. G., Yawas D. S. and Johnson Z. S. (2018) "Development of Automatic Door System" American Journal of Engineering Research (AJER), Vol 7, no 5, 168-173.

[2] Zungeru A. M., Maidawa K. D., Ambafi J. G. and Omokhafe J. T (2012). "Design and Implementation of a low cost Digital Bus Passenger Counter" Innovative Systems Design and Engineering, www.iiste.org accessed 07/01/2021

[3] Oladumoye M., Oluwatobi A. A. and Obakin O. (2014). "Design and Construction of an Automatic Sliding Door using Infrared Sensor". Computing, Information System, Development Informatics and Allied Research Journal. Vol 5, no 4. www.cisdijournal.net. accessed 07/01/2021

[4] Webster, J. G. (1999). Wiley Encyclopedia of Electrical and Electronics Engineering. (vol 4). New York: John Wiley & Sons, Inc

[5] Dreyfuss, H. (1955) Designing for people. New York, NY: Allworth Press.

[6] Bhandari. V.B. (2009). Design of Machine Elements. Third edition New Delhi: Tata Mc Graw Hill Education.

[7] Khurmi, R.S. & Gupta, J.K. (2006). A Textbook of Machine Design. Multicoloured Edition. Ram Nagar, New Delhi-110055: Eurasia Publishing House Ltd., 7361

[8] Khurmi, R. S. (2006) "Strength of Materials: Mechanics of Soilds". (1st edition), Chand (S.) & Co Ltd, India.

[9] https://www.ssabwebsitecdn.azureedge.net. (10/01/2021).

[10] Hibbeler R.C. (2010). Engineering Mechanics (Statics). Twelfth edition. ISBN-10: 0-13-607791-9.

[11] Beer F. P., Johnson E. R, Mazurek D. F. and Eisenberg E. R. (2010). Vector Mechanics for Engineers (Statics). Ninth edition. ISBN 978-0-07-352923-3

[12] Lippert, D and Spektor, J. (2007). Rolling Resistance and Industrial Wheels. Hamilton White Paper, No. 11

[13] Halliday, D and Resnick, R, (2007), Fundamentals of Physics, Tenth Edition, ISBN: 978-1-118-23072-5.

[14] RENOLD Superior Chain Technology. www.renoldcom. accessed (17/01/2021).

[15] Theraja, B. L and Theraja, A. K., A Textbook of Electrical Technology. S. Chand, 22nd Edition, Vol. 2, 2005.