

Design and Construction of an Automatic Gate

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Abstract: Automatic gate is one of the most useful things to use in companies, industries, colleges and schools. Automatic gates are important and very useful because it helps save time, reduces the human force applied to the opening and closing of the manual gate which saves energy and also saves gate operators from health hazards caused by exposing themselves to harsh weather conditions in the course of operating the manual gate. The design and construction of the automatic gate sited at the main entrance of Afe Babalola University Ado-Ekiti, Ekiti State, Nigeria was achieved by designing the gate, control unit and the power supply unit. The gate was designed, constructed and mounted, the control unit and power supply unit were also designed and implemented. These various units were incorporated and implemented. The automatic gate was tested for speed and efficiency and from the generated results, it can be said that the gate is 90% efficient. The automatic gate senses an object either human or vehicular within a distance of 0.42m to 0.52m and operates at a speed of 0.186m/s. The automatic gate has helped reduce the stress of opening and closing the gate where buttons are pressed rather than the usual manpower used in operating the gate. This has made life easier and more comfortable. The gate can be further improved by adding a scanning device to perform the searching operation done by the securities thereby making their work easier and more comfortable.

Keywords: Automatic, gate, infrared, manual, sliding

1. INTRODUCTION

Back in the years, gates were being opened using human applied force. These types of gates are known as manually controlled gates. A gate is a point of entry to a space enclosed by walls, or an opening in a fence. Gates may prevent or control entry or exit, or they may be merely decorative [1]. These gates are still appreciated but in terms of sliding manual gates there are a lot of challenges that has come with this gate. A manually sliding gate brings about the application of large human force to be applied in the opening of the gate, it also brings about large amount of friction between the rollers and the metal which the rollers roll upon, it also brings about unwanted noise which is as a result of the rollers which is made of metal and the metal path which it rolls on. Due to this factor, these days there has been advancement in gate creation which is known as an automatic gate.

In the first century AD, Greek mathematician "Heron of Alexandria" invented the first automatic door. He described two different automatic door applications. The first application used heat from a fire lit by the city temple priest. After a few hours, atmospheric pressure built up in a brass vessel causing it to pump water into adjacent containers. This container acted as weights that, through a series of ropes and pulleys, would open the temple's door at about the time people were to arrive for prayer [2].

The first commercial electric gate systems were hydraulic and designed for reliability and ease of use. The cost of the hydraulic system however meant that other companies started producing more affordable electromechanical alternatives. Hydraulic motors are preferred. The theory of an automatic gate is simple, when the open button is pressed, a signal is sent to the main circuit which then allows current to pass through to the gates motor causing the motor to run and the gate opens up. When the gate is fully opened the motor stops operating and waits till its next instruction is being sent. When the close button is pressed, the motor starts operating again but this time in opposite direction to the opening of the gate, thereby causing the gate to close [3].

Automatic gates are used to control access into a secured area or vicinity. Most commonly, automatic gates are used at the entrance to the facility, and are used to control vehicular access on and off the site. For example, a manufacturing plant may use an automatic gate at its main entrance. All vehicles entering and exiting the plant must do so through the automatic gate.

Automatic gates are also used at interior areas within a facility. For example, automatic gates are commonly used within the inside of a parking garage to separate employee parking area form public area of the garage.

The automatic gate has two components which includes: The gate and the gate operator. The gate is the physical object that is moved to block the gate opening, while the gate operator is the machinery that moves the gate in and out of the gate opening. There are various types of automatic gate which includes: Slide gate, Cantilever gate, Swing gate, Vertical lift gate, Vertical pivot lift gate, Bi-Folding gate, Barrier arm gate (Silva Consultants/introduction-to-automatic gates).

Gates are commonly used nowadays at residential area. Today many gate doors are opened by an automated gate operator. Those gates come with many special features. The need for automatic gates has been on the increase in recent times [4].

1.1 Related Works

Prajapati *et al.* (2014) provided security in an organisation by allowing only the authorised personnel to access the secure area with the use of an RFID tag. This work could be further enhanced by interfacing it with GSM technology [5].

Prajakta *et al.* (2018) designed a mechanical and electrical aspect to achieve the automation of the sliding gate. The proposed method being used was the rack and pinion mechanism for sliding the gate towards forward and reverse direction. The project lacked an insight into high friction that may occur in rack and pinion mechanism and it also lacked sensors to detect the presence of obstacles which could lead to damage of the gate or accident within the gate area [6].

Sighila *et al.* (2016) developed an IOT based RFID gate automation system. The IOT allows the gate to be accessed by the owner anywhere in the world. This gate can be used mainly by large organisations like industries, Military or defence area or Apartments etc. The features of this gate make it a costly thus making them not affordable [7].

Ayodele *et al.*, (2014) designed an automatic gate control using infrared remote with password protection feature. The use of password in the opening of the gate leads to some sort of delay and waste of time [8].

Karthik Krishnamurthi *et al.* (2015) designed a sensor based automatic control of railway gates. The project does indeed close and open gate but it cannot control the crossing of cars and vehicles. The use of load sensors would have been better for this project.

Nathan *et al.* (2015) designed a home Automation system using Arduino. The system could be connected to using phones which have connection to Wi-Fi, Bluetooth etc. A better approach to this system could involve the use of SMS, call alerts [10].

Campbell and Toliyat (2015) designed an automatic swing gate using PIR sensor. The gate designed here with the aid of the PIR sensor was very specific in detecting the presence of a human being before opening. The swing operator used in this gate requires more space for its operation and could prove to be problematic in steep landscapes [11].

2. METHODOLOGY

This section discusses in details the method and processes taken in the design, construction, and implementation of an automatic gate. The components used in the development of the automatic gate can be divided into mechanical and electrical components. The electronic components used in the development of the control circuit of the automatic gate are Electric motor single phase, Arduino UNO, IR sensor, Buzzer, Relay circuit, Magnetic Contactor, Control Switches, Thermal Overload Relay, Circuit Breaker, Indication Lights, Circuit Breakout Switches, Alarm Circuit, Cables. The mechanical components that were being used to carry out the design and construction of an automatic gate includes Metal Framing, Gate Rack, Metal Gear, Rollers, Cantilever Rollers, Counterbalance Post, Last Post, Counter Balance.

The automatic gate can further be said to consist of three major sections which are the design of the power supply system, design of the gate, and design of the control system.

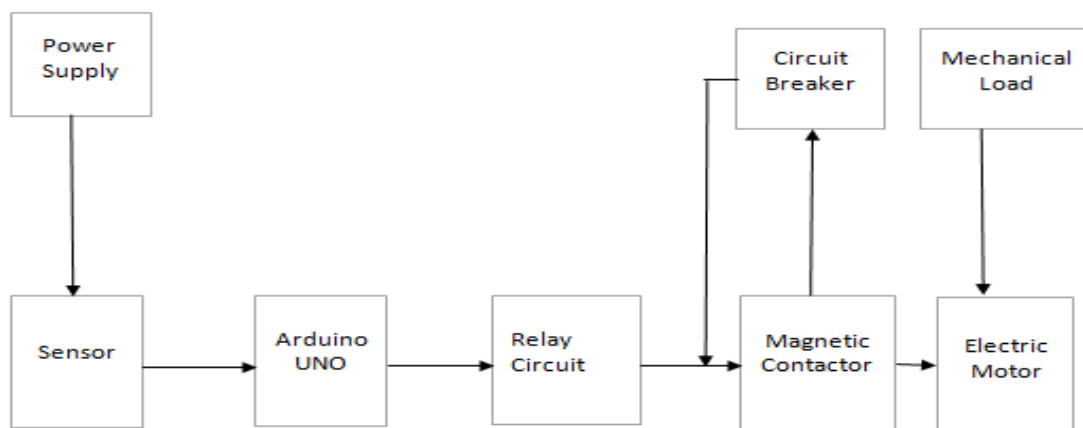


Figure 1: General design concept of an automatic gate.

2.1 Design of the Power Supply Unit

The power supply system supplies current to the whole system. It sends current across the IR sensor, motor, switch, and circuit breaker. The transformer produces 110V – 240V. The power supply design consists of a transformer, rectifier, voltage regulator (7812 and 7805 IC), capacitor, resistor. The transformer uses a 230/12/5V which operates like every other transformer. The rectifier is a bridge rectifier which consists of four diodes connected in a square shape.

From the circuit above, when the switch S1 is turned on, it takes 230/12/5V AC which is stepped down to 12v and 5v by the transformer. The full wave rectifier converts the 12v and 5v AC into a pulsating DC and the capacitors C1 acts as a filter, it removes repulse and eliminate the AC component of the waveform and produces nearly constant DC voltage output. The IC LM7812 and LM7805 are used to regulate the voltage to produce 12v and 5v respectively. LM7805 can deliver up to 1.5A of current (with heat sink).

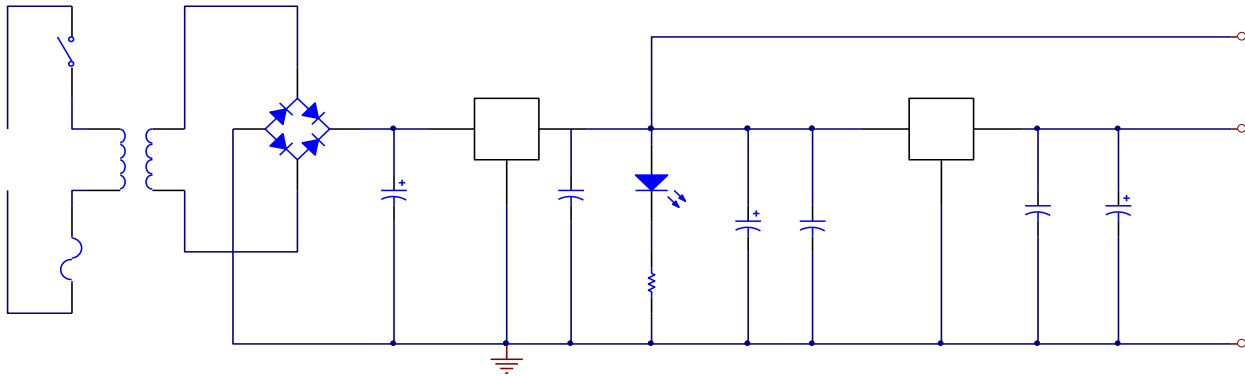


Figure 2: Power supply circuit

2.2 Design of the Gate

The design of the gate included the use of metal, welding machine, rollers, gear, rack. The metal was being used to design the gate into the preferred shape. The metal was of length 5.358m each. The gate being created was of length 7.8m. With the length of each metal being 5.358m, an additional length of 2.442m was added to 5.358m to give us the desired length of 7.8m. The height of the gate was 1m. The various length were welded together to give a rectangular gate of 7.8m in length and 1m in height and 645kg in weight. The rectangular gate was further segmented with a measurement of 95.25m in order to make it more firm.

The gate rack has a total length of 100.5cm, the screwing point of the rack has a distance of 45cm. The rack was placed at a distance of 10cm from the bottom of the gate. It has a forward space of 130cm from the starting point of the gate and a backward space of 68.1cm from the back of the gate. The forward and backward space is an indication of where the gate rack starts and where it stops.

2.2.1 Construction of the gate: Measurement of the gate was taken and the metal was cut accordingly using a cutting machine and then welded together with the aid of a welding machine. Two poles were mounted with a depth of 55cm on which the rollers were mounted.

2.2.2 Construction and mounting of gate rollers: After the poles have been mounted, rollers were created with the use of plates, metal rollers, washers and metals. The metal on which the rollers were inputted was created with the use of metals which are L-shaped. Two L-shapes are joined together with a metal. The L-shape is called the angle bolt, which consists of a washer, rollers and two plates. The arrangement of components on the angle bolt is in the form of a metal plate followed by a washer, the rollers which were greased to enable ease movement, then a washer and a metal plate. All these were locked to the angle bolt with the aid of bolt and nut. Four of these were made as shown in figure 3.



Figure 3: Four rollers

These rollers were then placed on the poles that were being mounted. After successful mounting of the rollers, the gate was tested and it was able to move freely through the rollers.

2.2.3 Construction of motor frame and casting: Upon successfully achieving a smooth movement of the gate with the rollers, the rack was added to the gate which was 10cm from the bottom of the gate. The frame for the motor was created with a height of 30.6cm, length of 40.4cm, breath of 40cm and then casting was done.

The sitting bottom of the motor was created and put into the casting region. The essence of the casting is to increase the height of the motor from the ground in order for the rack to be able to roll on the gear of the motor. When the cast dried, the motor was placed on it, with the gate in position and the rack attached to it as shown in figure 4. Caution was taken to ensure that the rack was properly balanced on the motor to avoid displacement during operation.



Figure 4: Rollers, gate, rack and motor in position.

2.3 Design of Control System

This is the system that controls the forward and backward movement of the gate. This section mainly discusses the sensor used in the connection of the motor which enables the movement of the gate.

2.3.1 Configuration and installation of electric motor

The electric motor used is DES-HF20 as seen in figure 5. This gate opener is made with 24V DC motor that is able to open and shut a gate up to at least 4meters wide weighing up to 1000kg. It also comes with manual keys which can be used to switch the motor from automatic operation to manual operation in the case of power failure. There is an immediate stop and reverse mode of operation. The electric motor consists of a control board which has the following features; totally integrated electrical mechanical system, control board interface for optional impact-proof infrared photocells, alarm lamp interface, automatic delayed closing, adjustable resistance sensitivity, gate will auto-stop and reopen when an obstacle is encountered, wireless remote control or wired remote control are optional.



Figure 5: Integrated board of the motor.

With the rack attached to the gate and well balanced on the motor gear, the gate was rolled to ensure that the rack was properly bolted and balanced. A limit lever was then installed to control the forward and backward movement of the gate. It was placed at the beginning of the rack in order to stop the gate during reverse operation and at the end of the rack for closing operation when the limiting lever comes in contact with the bezel. The motor consists of a clutch, when in open position it allows for manual pushing of the gate and while in close position allows for automatic control of the gate.

2.3.2 Programming the Arduino and connecting the relay circuit: Upon successful installation of the limit levers the Arduino UNO was connected and programmed with the relay circuit as shown in figure 6. Arduino UNO is a micro controller which consists of digital and analog pins, he codes for the Arduino is written in the Arduino IDE.

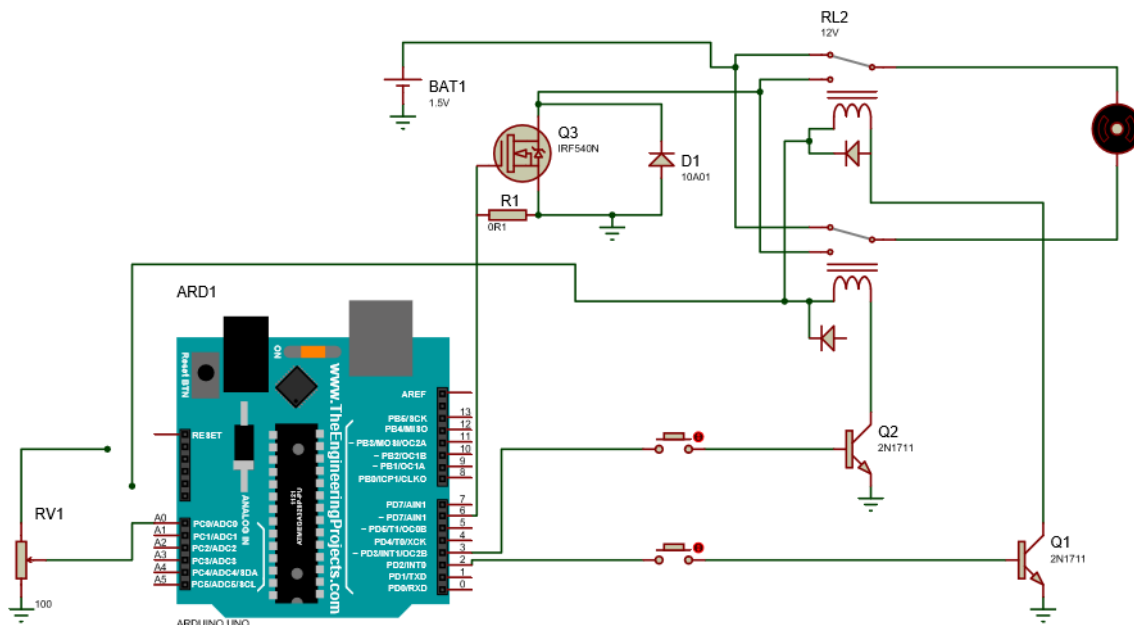


Figure 6: Arduino UNO and relay circuit.

In the above circuit, the transistors are being used because the digital pins of the Arduino cannot supply the amount of current needed to turn on a normal 5V relay as a 12V relay is being used. The V_{in} pin of Arduino cannot supply enough current for both relays, hence, a transistor is being used to conduct the current from the V_{in} pin to the relay. MOSFET (Metal Oxide Semi-Conductor Field Effect Transistor) is used to control the speed of the motor. The MOSFET is switched on and

off at high frequency voltage and since the motor is connected in series with the drain of the MOSFET, the PWM (Pulse Width Modulation) value of voltage determines the speed of the motor.

2.3.3 Configuration of Infrared Transmitter Module

The infrared transmitter has the ability to transmit infrared beam but can only travel in a rectilinear manner or line of sight, which is received by the infrared receiver at another end. Infrared transmitter and receiver are used in many situations to control things remotely. It can be seen in some home appliances such as TV and remote control. The circuit in figure 7 shows the transmitter module of the infrared.

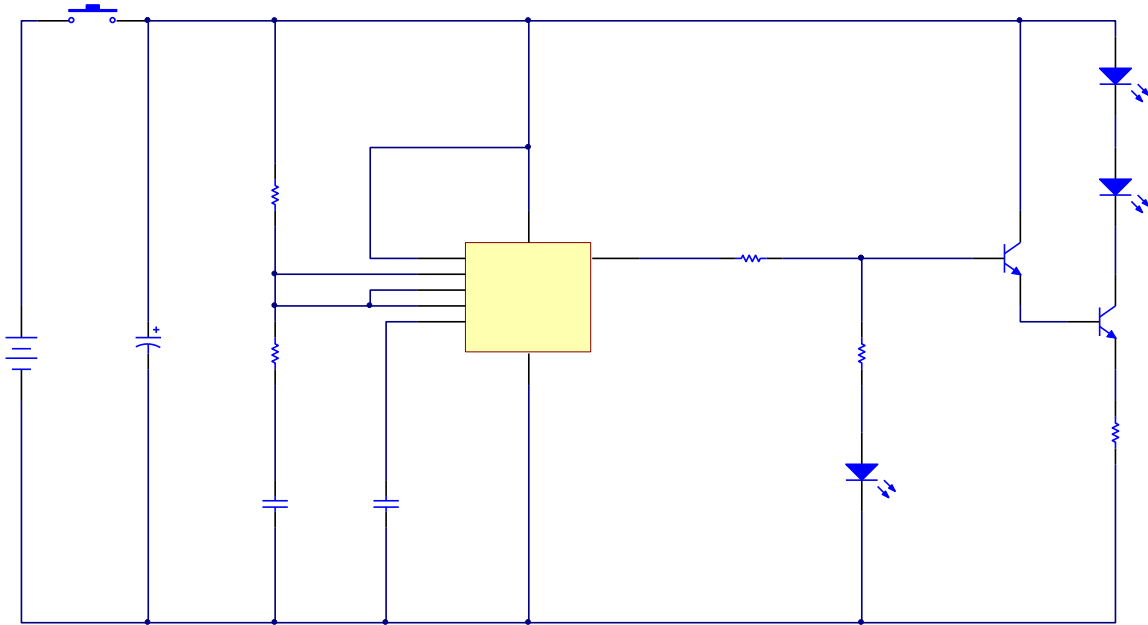


Figure 7: Circuit diagram of infrared transmitter [12]

2.3.4 Configuration of receiver circuit: The receiver circuit receives the signal coming from the transmitter circuit. This reception or non-reception of this signal is what determines the opening or closing of the gate. The receiver circuit is being shown in figure 8.

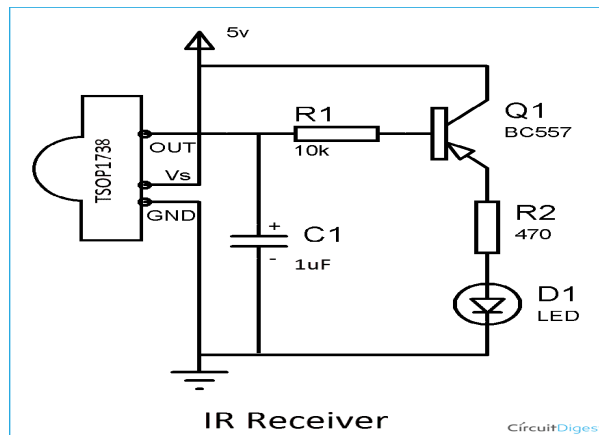


Figure 8: Receiver circuit of the IR sensor [13].



Figure 9: Installed and fully functional automatic gate

3. RESULTS AND DISCUSSION

This section contains the results and discussion obtained from testing the fully installed automatic gate in figure 9. The closeness of human to the gate that prompts the opening of the gate, was evaluated to ascertain the efficiency of the gate.

Distance of gate in open state: 465cm

Time taken for gate to close: 25 seconds

$$\text{The speed of the gate} = \frac{\text{Distance}}{\text{Time}} \tag{1}$$

Using equation (1), the speed of the gate is 0.186m/s

$$\text{The rotational speed of the motor, } \omega = \frac{\text{Value in rpm} \times 2\pi}{60} \tag{2}$$

From equation (2), $\omega = 146.6 \text{ rad/s}$

The radius of the motor gear, $r = \frac{50}{1000} = 0.05\text{m}$

When motor is at full speed, the speed of the motor V is,

$$V = r\omega \tag{3}$$

$$V = 7.33\text{ms}^{-1}$$

The time for the gate to fully open which is to travel a distance $D = 0.465\text{m}$ at constant speed of $V = 7.33\text{ms}^{-1}$ and the force from the motor are gotten using equation (4) and (5) respectively;

$$D = vt \tag{4}$$

$$t = 0.068\text{s}$$

$$F = \frac{T}{r}$$

where, T = Torque, F = Force, r = Radius

$$F = 600\text{N}$$

3.1 Human Response Evaluation Result

After the gate was fully installed as seen in figure 9, evaluation was carried out to know the efficiency of the gate. The proximity of humans/vehicle to the gate was evaluated. The gate is designed to detect obstacles using its sensor when the gate is performing the close operation in order to avoid accident. Table 1 shows the response of the gate as it detects human motion.

Table 1: Response of gate to human motion

Human Count	Opening/ closing time (Seconds)	Distance of Humans from gate (cm)
1	25	42
2	25	44
3	25	43
4	25	50
5	25	47
6	25	42
7	25	52

From the data in table 1, a graph of human count against distance of human from was plotted in figure 10.

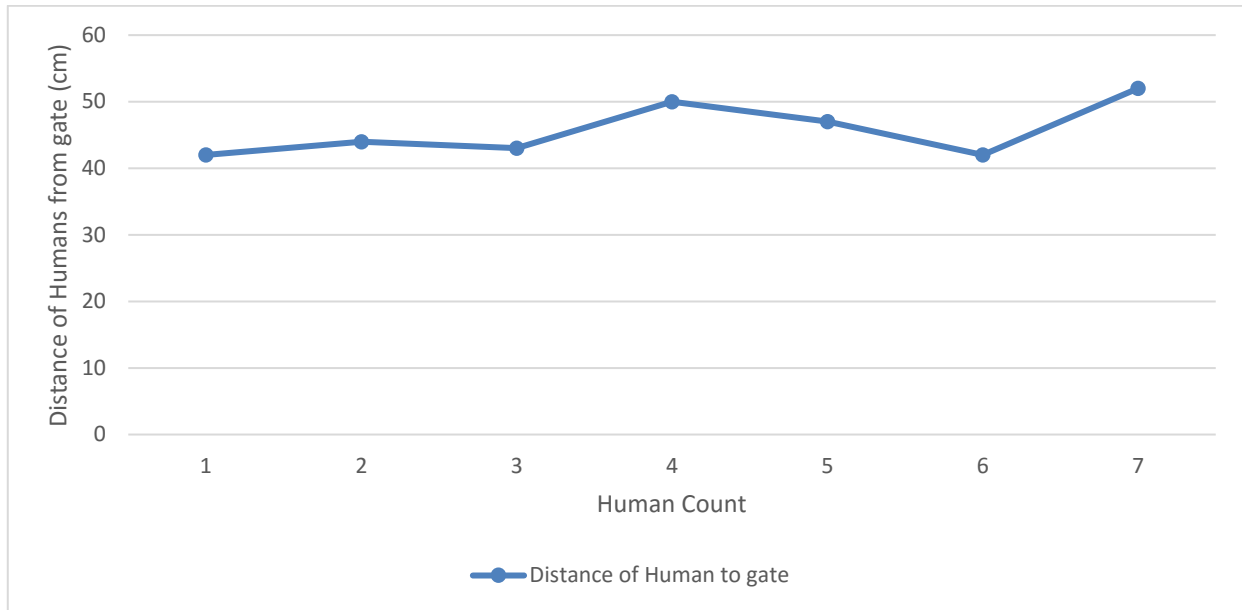


Figure 10: Graph of human count against distance of human from gate in cm

3.2 Discussion

The automatic gate was successfully completed with the gate capable of detecting the presence of approaching human beings and vehicles aided by the installation of two active infrared sensors (transmitter and receiver sensors) when coming from within the university compound. The speed at which the gate opens or closes is a function of the weight of the gate (645kg) which is relatively high for the capacity of the motor.

The distance between these sensors is 6m, the distance between the sensor and the gate is 0.42m and the distance between the pillar and the gate is 0.52m. From the test carried out it was observed that before the sensor senses the presence of the human/vehicle, the human/vehicle must be within the within the range of 0.42m to 0.52m from the gate.

From the graph in Figure 10, it can be seen that human 1 to 7 were detected within the stated range.

4. CONCLUSION

The objectives of this work has been successfully achieved with an efficiency of 90% in both harsh and fair weather conditions. The automatic gate can successfully sense and detect vehicles and humans within a range of 0.42m to 0.52m and also perform the required operation.

5. RECOMMENDATIONS

The project has shown a full demonstration of the opening and close operation of the gate, but there are advancements and recommendations that can be done in order to make the system more efficient. The recommendations include:

- A bigger motor would be preferable for faster movement of the gate.
- A rubber roller would have been better used than a metal roller to decrease friction.
- An increase in the sensor being used can improve the performance of the gate.

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