

# Development of atmel microcontroller based automatic sliding door

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## ABSTRACT

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*This research was designed for one door-room installation, primarily to level up the automation design capacity of TUP in developing quality, and significantly affordable automatic sliding doors. It was made of the latest technology in embedded applications such as the Atmel Atmega 328 AVR mini microcontroller, C++ programming language with Arduino 1.5.7 IDE, Passive Infrared (PIR) Sensors, manual override pushbutton switches,*

*limit switches, geared DC motor, high current power supply and its backup, sprocket-pulley system, and manual lock system. It utilized locally available materials, and had gone through extensive testing procedures. The unit was designed for approximately 2 semesters by using the Input-Process-Output (IPO) model, stress tested for at least 50 hours, and evaluated by 20 respondents, 2 faculty members, 3 industry experts, and 15 students. Based on the 5-point criteria evaluation system, the study concluded that the project was very functional ( $\bar{X} = 4.50$ ); highly aesthetic ( $\bar{X} = 4.53$ ); highly workable ( $\bar{X} = 4.63$ ); very durable ( $\bar{X} = 4.50$ ); highly economical ( $\bar{X} = 4.60$ ); highly safe ( $\bar{X} = 4.60$ ), and overall rated as highly acceptable ( $\bar{X} = 4.56$ ).*

### Keywords

Automation, Microcontroller, Sliding Door

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## Introduction

With the proliferation of technology, automatic sliding doors could be seen everywhere – supermarkets, hospitals, hotels, malls, and other places that sport the latest industrial innovation and automation. According to Robert Pearce (2013), there had been growing reasons of people in choosing automatic over manual doors, particularly to highly sophisticated facilities and organizations such as: (1) compliance to regulatory laws on the welfare of disabled and elderly, (2) the ease of access, especially for shopping malls and other public places, (3) improved reliability and maintenance, and (4) provisions for safety. Moreover, a recent study conducted by the American Association of Automatic Door Manufacturers (AAADM, 2007) revealed that above 98% of consumers

preferred automatic doors versus the manual doors. First impressions count and when sophistication and convenience come up on the big picture, people would keep in mind such a positive perception and they tend to return back for more. As for household or office uses, having automatic sliding door could create a high aesthetic value and lasting impression of being technology-viable-social status that could add up to a good reputation (Pearce, 2013). Despite the good benefits and unparalleled virtual appeal of automatic sliding doors, however, the price tag has ever been a concern. Automatic sliding doors have remained very expensive (Anthony, 2013) market prices of automatic sliding doors could cost more than Php. 100,000.00, and for realistic mindset, only affluent families or companies could afford. Nevertheless, this project study was developed to live up the

challenge of introducing an automatic sliding door design that could feature optimized similar features at significantly more affordable cost.

Specifically, this project aimed to (1) develop an automatic sliding door intended for classroom or laboratory room with the following features: (1.1) microcontroller unit that would control the overall operation of the system; (1.2) use of Passive Infrared (PIR) sensors to detect incoming and outgoing people across the door; (1.3) single panel glass-aluminum door that could be opened or closed automatically or manually with back-up power supply and lock system; (2) develop the project by utilizing locally available materials; (3) test and improve the project; and (4) evaluate the projecting terms of functionality, aesthetics, durability, workability, economy, safety, and its overall acceptability.

The study utilized various local and international articles and related literature and studies taken from books to magazines and online references. It employed the Input-Process-Output (IPO) conceptual model, as shown on Figure 1, as basis on the development of the project.

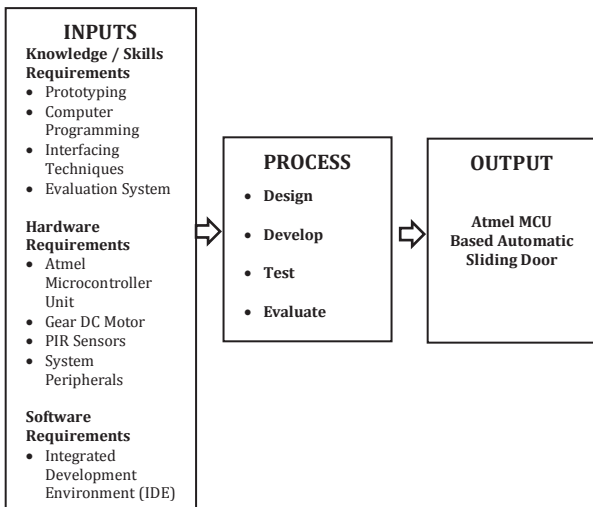


Figure 1. The IPO Conceptual Model

## Methods

Being a developmental research, the project has been designed, as shown on the

Figure 2, with PIR or manual switches as inputs, Atmel MCU as the controller, and the system peripherals, which included relay drivers, and gear DC motor as outputs. Furthermore, the project included an aluminum glass door and other system peripherals such as sprocket-pulley system, chain, and hangers, the overall design of the system as shown on Figure 3.



Figure 2. Block Diagram Design

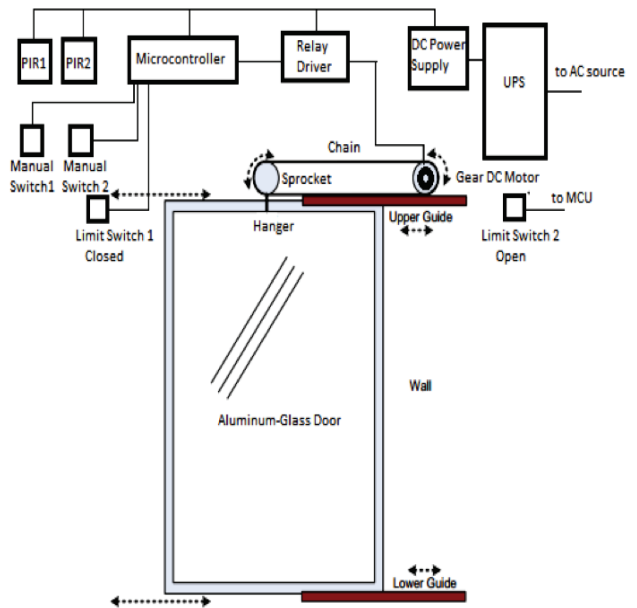


Figure 3. Pictorial Diagram Design

In terms of its operation, the automatic sliding door would start with the scenario when a person would either walk toward or away from the door. If the subject would walk toward the door, the sensor could detect a signal interference or had s/he triggered any of the manual pushbutton switches, this would cause the microcontroller to energize the gear DC motor in forward direction (open door for

approximately 8 seconds; Green LED turned on) until it reached limit switch 2 enough to delay the gear DC motor for approximately 2 seconds. Afterwards, it would shift back to the counter-clock wise direction (door close for approximately 8 seconds; Red LED turned on) until when limit switch 1 would be triggered; the gear DC motor would then full stop. The cycle goes on endlessly.

Contrastingly, if no human temperature has been detected or no manual push button switches activated, the gear DC motor does not energize at all and the status indicators goes off (no lights). To ensure calibration of the system, the automatic sliding door has been programmed to initially reset its input/output ports, thus blinking both the Red and Green LEDs for approximately 30 seconds.

Testing was done in two stages – the pre and final testing. The researcher conducted the pre-testing (designing and prototyping) for approximately 10 months. Quantitative data like the computed and measured values of the circuit component parts were determined using datasheets, user guides, calculator, multi tester, and oscilloscope. Meanwhile, the final testing was done after integrating the different sub-systems, enclosed altogether in the system box for approximately 50 hours of non-stop stress testing with the help of technical experts constructive feedback and suggestions.

The qualitative evaluation of the system, as shown on Table 1, adopted the TUP evaluation system for project development based on the Likert’s scale. With 1 as the lowest and 5 as the highest possible response, the average descriptive ratings of the respondents were translated as “not acceptable/poor” ( $\bar{X} = 1.00-1.50$ ); “fairly acceptable/fair” ( $\bar{X} = 1.51 - 2.50$ ); “acceptable/good” ( $\bar{X} = 2.51-3.50$ ); “very acceptable/very good” ( $\bar{X} = 3.51-4.50$ ); and “highly acceptable/excellent” ( $\bar{X} = 4.51-5.00$ ); and assumed percentage error of  $a=0.05$  or confidence level of 95%.

Table 1  
The Likert’s Scale

Numerical Scale	Averaged Response	Descriptive Rating
5	4.51-5.00	Excellent/Highly Acceptable
4	3.51-4.50	Very Good/Very Acceptable
3	2.51-3.50	Good/Acceptable
2	1.51-2.50	Fair/Fairly Acceptable
1	1.00-1.50	Poor/Not Acceptable

$a=0.05$

## Results

Illustrated on Figure 4 was the pre-final project board at the inside section of the system. The left side panel housed the pushbutton switch 1 (SW1), used to manually override the sensor and forced the door to open for approximately 8 seconds. Then the door would close back after 2 seconds delay right after triggering the right limit switch (L2). The upper section, on the other hand, was provisioned for installing the PIR sensor 1, and mechanical system peripherals such as chain, pulley, and sprockets, while the right section housed the main circuit board for the gear DC motor driver, microcontroller unit, UPS, and DC Power Supply. Moreover, the center part was the moving 3 ft. (width) by 7 ft. (height) aluminum glass door that would automatically glide open as long as human temperature could be detected at ideal maximum distance of 7 meters, then close if no human temperature was detected.

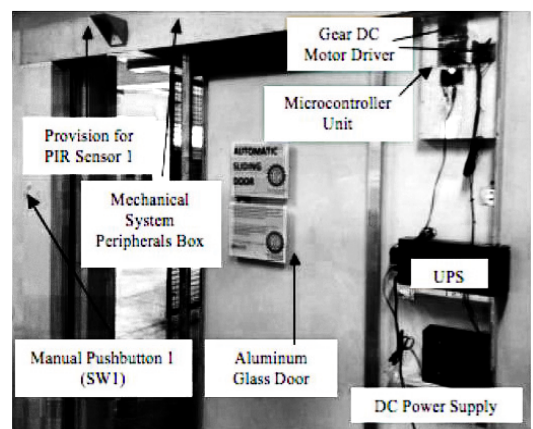


Figure 4. The Project Main Circuit

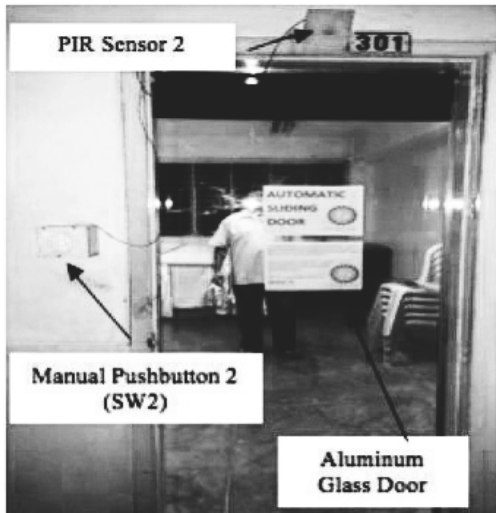


Figure 5. Outside Section of the Project

The outside section of the door, as shown on Figure 5 included the manual pushbutton switch 2 (SW2) installed at the left side, and the PIR 2 at the upper center part of the door. Finally, the final project output at the inside section of the door, as projected on Figure 6, was a simple panel board with visible components such as limit switch 1 (L1), Passive Infrared (PIR1), status LED indicators “red” and “green”, UPS, and DC Power Supply. The box covering was made of quality wood materials painted in light green, which matched the existing wall paint color of the room.

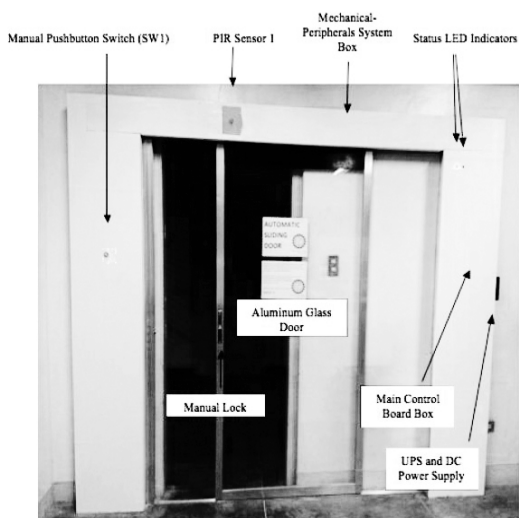


Figure 6. Inside Section of the Project

The Atmega 328 AVR mini microcontroller manufactured by Atmel Corporation, as presented on Figure 7, was chosen as the brain of the entire system widely due to its compact size, affordable price, availability, and compatibility to wide range of freeware programs and technical supports worldwide. The microcontroller was designed to read inputs from Passive Infrared (PIR) sensors 1 and 2, manual switches (SW) 1 and 2, and limit switches (L) 1 and 2. With 32-pin configuration at flat-surface mount packaging, specifically, pin 23 would control limit switch 1 (L1), pin 24 for limit switch 2 (L2), pin 25 for Passive Infrared 1 (PIR1), pin 26 for Passive Infrared 2 (PIR2), pin 27 for manual switch 1 (SW1), and pin 28 for manual switch 2 (SW2). Pins 9 and 10 were connected to the 16 MHz crystal clock generator, which would give digital pulses as life to the entire circuitry.

Nonetheless, output status indicators red LED1 (close door), and green LED2 (open door) were interfaced to pins 15 and 16 of the AT328 microcontroller while pins 17 and 18 were connected to the inputs of the ULN2803/4 line driver IC to the relay driver circuit of the gear DC motor.

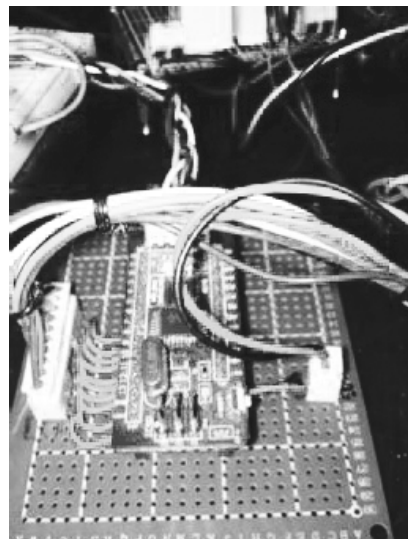


Figure 7. Atmel Atmega 328 AVR Mini Microcontroller Circuit

As illustrated on Figure 8, the input sensing devices were the Passive Infrared (PIR) Sensors, manufactured by Murata

Corporation. The researcher opted to use this PIR sensor due to its accuracy, reliability, size, and price. It would be one of the smallest and ultra-thin sensors in the market to date with high sensitivity and superior electromagnetic noise resistance characteristics.

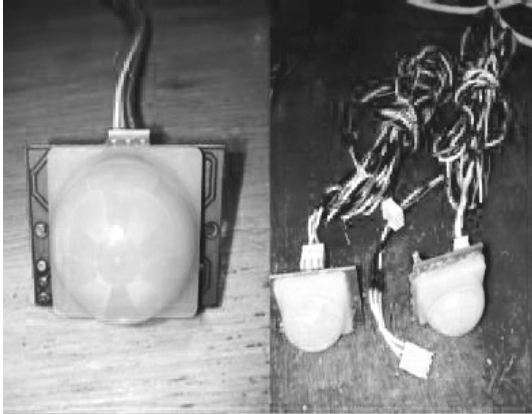


Figure 8. Murata Passive Infrared (PIR) Sensors

Ideally, the PIR would detect human temperature as much as 7.7 to 10 meters maximum in horizontal area while 1 to 10 meters for vertical area. PIR1 was installed outside the door, with PIR2 mounted inside, for whichever any of the two had detected human temperature, it would send logic 0 signal to the microcontroller. Eventually, it would shift the output – gear DC motor to the right (door open) until it could reach limit switch 2 (L2) then be delayed for 2 seconds, and finally would shift back to the left (door close) or would totally stop when the limit switch 1 (L1) were triggered on that end.

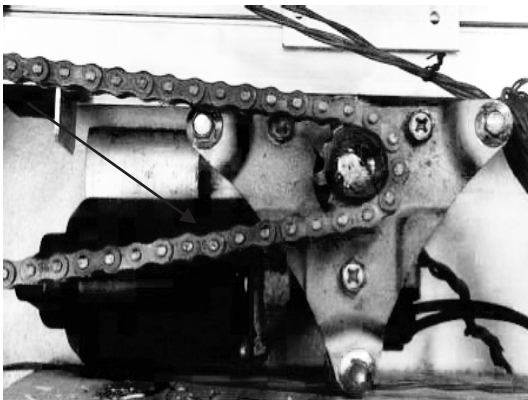


Figure 9. Toyota Gear DC Motor – 12V 6A

The main controlled output of the circuit was the 12V 6A gear DC motor manufactured by Toyota Corporation, as presented on Figure 9, used as wiper motor to its sedan cars. The researcher opted to use this, instead of other motor types such as AC motors, brushless/brushed DC motors, or servomotors due to its price, reliability, brand quality, and torque. The gear DC motor was programmed to move forward or shift right to open the door if any of the PIR1, PIR2, SW1, and SW2 switches were triggered, and would reverse or shift left to close the door if no detection/triggered caused by any of those inputs. The closing and opening of the door as simulated was approximately 8 seconds.

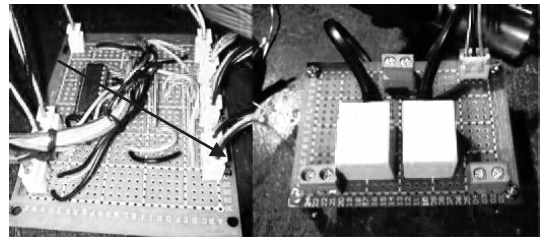


Figure 10. Dual ULN2803 Relay Driver Circuit

The ULN2803 line driver (Darlington pair amplifier) integrated circuit and the dual relay driver circuit, as highlighted on Figure 10, played an important role on the project, aimed at increasing the logic output current of the microcontroller, which was almost 25mA to approximately 4-6A, enough to drive the gear DC motor as the output of the circuit.

For emergency consideration or as manual over ride to the sensor circuits, the researcher opted to include manual pushbutton switches – SW1 at the left of the door inside while SW2 at the left of the door outside, as exhibited on Figure 11. They were programmed such that any of them was triggered; the gear DC motor would shift to the right to open the door and had been set as emergency push button switches.



Figure 11. Manual Pushbutton Switches

Meanwhile, limit switches were also essentially used in the project, as illustrated on Figure 12. The researcher decided to use those with rollers to ensure smooth glide while in operation. These limit switches were grounded so that once activated, it would send logic 0 to the microcontroller, then control to the output for a certain set of conditions.



Figure 12. Sprocket-Pulley System and Limit Switches (L1 and L2)

While the door would be opening (on shift right direction), L2 was programmed such that once triggered, the gear DC motor would stop; then would shift to the left after 2 seconds delay. If L1 were triggered, in this case, the gear DC motor would stop fully until another sensor or manual push button activation would happen. The system peripherals of the project included the DC converter power supply at 12V 6A full wave rating manufactured by Dai Star, as shown on Figure 13. The rating was perfectly compatible to the power supply requirement of the gear DC motor.



Figure 13. 12V 6A DaiStar Power Supply

Moreover, to ensure the safety and convenience of users/visitors even without electricity, the researcher had included an Interruptible Power Supply (UPS) with 500VA rating manufactured by Intex Corporation. He opted to choose this brand due to its durability, price, and size. The UPS, as illustrated on Figure 14, could back up the power need of the system for approximately test condition of 15 to 30 minutes, hence, quite reasonable enough to set the system on default off or on whenever needed.



Figure 14. Intex Mission 500VA Uninterruptible Power Supply (UPS)

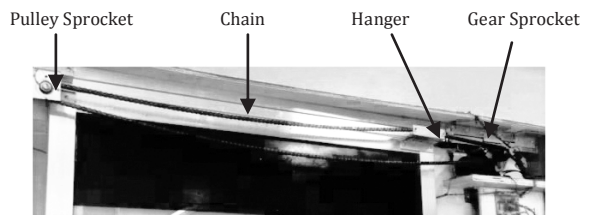


Figure 15. Mechanical System Peripherals

The door would not automatically move without the mechanical capability of the

pulley sprocket, chain, hanger, and the gear sprocket, which were installed at the upper part of the project. The researcher had chosen these instead of belt-pulley system due to their reliability, availability, and price.

This project was evaluated by twenty (20) respondents composed of 2 faculty members, 3 industry experts, and 15 students of the Technological University of the Philippines, by answering a survey questionnaire, which qualitatively assessed the functionality, aesthetics, workability, durability, economy and safety of the project. Initially, the researcher demonstrated the operation of the project to the evaluators, and discussed its advantages and limitations. Later, the evaluators had their own turns in testing the system and rated the questionnaire based on various technical criteria discussed further below.

Table 2  
Overall Acceptability Evaluation Result

1. Functionality	Mean	Descriptive Rating
1.1. Ease of Operation	4.4	Very Good/ Very Functional
1.2. Provision for Comfort and Convenience	4.6	Excellent/ Highly Functional
1.3. User Interface	4.5	Very Good/ Very Functional
<b>Functionality Mean</b>	<b>4.5</b>	<b>Very Good/ Very Functional</b>
2. Aesthetics	Mean	Descriptive Rating
2.1. Color Appeal	4.7	Excellent/ Highly Aesthetic
2.2. Attractiveness of Design	4.5	Very Good/ Very Aesthetic
2.3. Appropriateness of Size	4.4	Very Good/ Very Aesthetic
<b>Aesthetics Mean</b>	<b>4.53</b>	<b>Highly Aesthetic</b>
3. Workability	Mean	Descriptive Rating
3.1. Availability of Materials	4.6	Excellent/ Highly Workable
3.2. Availability of Technical Expertise	4.7	Excellent/ Highly Workable
3.3. Availability of Tools and Machines	4.6	Excellent/ Highly Workable
<b>Workability Mean</b>	<b>4.63</b>	<b>Excellent/ Highly Workable</b>
4. Durability	Mean	Descriptive Rating

4.1. Quality of Materials	4.5	Very Good/Very Durable
4.2. Quality of Workmanship	4.4	Very Good/Very Durable
4.3. Endurance to Stress Test	4.6	Excellent/Highly Durable
<b>Durability Mean</b>	<b>4.5</b>	<b>Very Good/Very Durable</b>
5. Economy	Mean	Descriptive Rating
5.1. Materials Needed	4.7	Excellent/ Highly Economical
5.2. Time/Labor Spent	4.5	Very Good/Very Economical
5.3. Machines Required	4.6	Excellent/ Highly Economical
<b>Economy Mean</b>	<b>4.6</b>	<b>Excellent/Highly Economical</b>
6. Safety	Mean	Descriptive Rating
6.1. Absence of Toxic/ Hazardous Materials	4.7	Excellent/ Highly Safe
6.2. Absence of Sharp Edges	4.6	Excellent/ Highly Safe
6.3. Provision for Protection Needed	4.5	Very Good/Very Safe
<b>Safety Mean</b>	<b>4.6</b>	<b>Excellent/Highly Safe</b>
<b>Overall Acceptability of the Project</b>	<b>4.56</b>	<b>Highly Acceptable</b>

As gleaned on Table 2, the overall acceptability evaluation of the project proved that the system was very functional ( $\bar{X} = 4.50$ ), highly aesthetic ( $\bar{X} = 4.53$ ), highly workable ( $\bar{X} = 4.63$ ), very durable ( $\bar{X} = 4.50$ ), highly economical ( $\bar{X} = 4.60$ ), and which all meant that the project was highly acceptable ( $\bar{X} = 4.56$ ), as evaluated and perceived by the evaluators themselves.

## Discussions

After ten months of thorough design, development, testing, and evaluation, the project had been successfully completed in May 2013 by diligently following the objectives of the study.

The project had been fabricated and finally installed at one door of Room 421 of the College of Industrial Technology building at TUP Manila. The system had been developed with an Atmel Atmega 328 AVR mini microcontroller, C++ programming language with Arduino 1.5.7 IDE, Passive

Infrared (PIR) Sensors, manual override pushbutton switches, limit switches, geared DC motor, high current power supply and its backup, sprocket-pulley system, and manual lock system. It utilized locally available materials, and had gone through extensive testing procedures.

The system had been stress tested for at least 50 hours to ensure its durability and reliability, and evaluated by 20 respondents, which consisted of 2 faculty members, 3 industry experts, and 15 students. The study concluded that the project was very functional ( $\bar{X} = 4.50$ ); highly aesthetic ( $\bar{X} = 4.53$ ); highly workable ( $\bar{X} = 4.63$ ); very durable ( $\bar{X} = 4.50$ ); highly economical ( $\bar{X} = 4.60$ ); highly safe ( $\bar{X} = 4.60$ ), and overall rated as highly acceptable ( $\bar{X} = 4.56$ ) based on the 5-point criteria evaluation system.

## Conclusion and Recommendations

In reference to the results of the study, the following conclusions were derived:

1. The use of microcontroller, Passive Infrared (PIR) sensors, gear DC motors, and other system peripherals were very good choices in designing the automatic sliding door.
2. The use of local materials on the development of the project significantly helped in fabricating a very affordable output.
3. The project was evaluated as very functional, highly aesthetic, highly workable, very durable, highly economical, highly safe, and overall highly acceptable.

Moreover, to maximize the features and potentials of this project, the following recommendations were proposed:

1. Add tags such as "Emergency Push Button" on each pushbutton switch, which could be used to manually override the detection of the Passive Infrared (PIR)

sensors. Once activated, these buttons could forcibly open the sliding door.

2. The PIR sensors were designed to certain sensitivity levels, hence, if it would not be necessary to automatize the sliding door, unplug the terminals labeled as PIR1 and PIR2 at the microcontroller unit module.
3. Since the maximum power backup of the UPS runs approximately 30 minutes only, use higher capacity UPS, if longer power back is required.
4. In case of mechanical stuck up, open the safety screws on the upper part box of the sliding door, which houses the mechanical system peripherals. Unscrew the 2 threads of the chain installed on the hanger; then remove the chain from the sprocket of the gear DC motor and the pulley. Make sure that the DC power supply would be OFF before doing any troubleshooting on the circuit main control box.
5. To increase the speed of the automatic sliding door, use a gear DC motor with higher revolutions per minute (RPM) rating or install a hanger roller on the upper part of the door.
6. To minimize the friction and noise of the sliding door while moving, use extra rollers on the upper side of the door or add extra rubber lining on both ends if needed.
7. Paste an approximately 8 inches-sticker lining and place it right at the middle section of the glass door such as "AUTOMATIC SLIDING DOOR" marking for notification purposes.
8. To minimize the sensitivity of the PIR, tilt it to approximately 20-30 degrees angular position.
9. The project would be open for any developmental research to further improve its capabilities and features.



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