CONTROLLING DIFFERENTIAL MOTOR USING MICROCONTROLLER

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UNIVERSITI SAINS MALAYSIA
2018

CONTROLLING DIFFERENTIAL MOTOR USING MICROCONTROLLER

by

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Thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Engineering (Electronic Engineering)

JUNE 2018

ACKNOWLEDGEMENTS

Firstly, I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Syed Sahal Nazli Alhady for his invaluable advice, guidance and his enormous patience throughout the development of the project.

Secondly, my special thanks to Ahmad Afiq bin Muhammad Zahir for his helpful comment and support during the process throughout the project. He shared his ideas and provides incessant information on the skills and research technique on this project. Therefore, I sincerely appreciate the feedback and suggestion provided to me so that I have a deeper understanding to the project.

In addition, I would also like to express my gratitude to my loving parent who had helped and always stay by my side, guide, support, and encourage me since I was young until now. They never complain about being tired to feed me. Sometimes I did not perform well on my academic, but they never give up on me. They still cheer me up every day and teach me how to be strong in life. I am really proud to be his son.

Lastly, I would like to thank School of Electrical and Electronic USM Engineering Campus for giving me the chance to undergo final year project successfully. Moreover, the facilities and equipment in the school also play a vital role in helping me to complete the project successfully.

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LIST OF ABBREVIATIONS

CCD	Charge-Coupled Device
CCW	Counter Clockwise
CW	Clockwise
CHR	Chien Hrones Reswick
DC	Direct Current
DIR	Direction of the motor
FPGA	Field Programmable Gate Array
GAs	Genetic Algorithms
IAE	Integral of Absolute Magnitude of the Error
P	Proportional
PI	Proportional Integral
PID	Proportional Integral Derivative
PWM	Pulse Width Modulation
SIMC	Skogestad IMC
ZN	Ziegler-Nichols

PENGENDALIAN MOTOR PEMBEZAAN MENGGUNAKAN MIKROPENGAWAL

ABSTRAK

Dalam sesebuah sistem robotik yang menggunakan motor sebagai penggerak utama, halaju adalah tulang belakang yang mengawal pergerakan robot. Komponen kawalan ini akan memberikan halaju yang stabil kepada sistem dan menyesuaikan halaju pergerakan robot mengikut keadaan-keadaan tertentu. Pengawalan halaju robot menjadi target utama dalam merekabentuk projek kali ini. Pengawalan halaju robot penting kerana ianya adalah aspek utama yang memainkan peranan dalam memacu pergerakan robot mengikut penyelarasan arahan-arahan yang telah diprogramkan ke dalam sistem sesebuah robot. Beberapa proses perlu dilalui bagi mencapai objektif ini, antaranya merekabentuk pengawal kelajuan menggunakan pengawal PID berdasarkan beberapa kaedah-kaedah klasik, menganalisis serta membandingkan prestasi yang diperoleh daripada berlainan kaedah dan memilih satu kaedah klasik yang terbaik serta sesuai digunapakai untuk projek kali ini. Bahagian yang paling rumit dalam merekabentuk pengawal kelajuan adalah untuk menentukan parameter PID yang sesuai dan stabil mengikut ciri-ciri yang dikehendaki. Keputusan akhir dapat dicapai dengan menganalisis keputusan yang diperoleh daripada kaedah-kaedah yang digunapakai. Pengawal halaju berpaksikan pengawal PID berjaya direka serta memberikan kelajuan yang stabil kepada sistem robot pengikut.

CONTROLLING DIFFERENTIAL MOTOR USING MICROCONTROLLER

ABSTRACT

In robotic system that using motor as a prime mover, speed control is one of the crucial element in controlling the robot. The control component will provide a steady velocity to the system and adjust the speed of the robot's movement according to a desirable velocity condition. The main target in this project is to design a speed controlling system for mobile robot. It is a key aspect that plays a role in driving robot movements in accordance with the co-ordinated instructions that are programmed into a robotic system. Some processes need to be pursued in order to achieve this objective, including designing a speed controller using PID controller based on some classical methods, analyzing and comparing performance obtained from different methods and selecting the best classical method and suitable tuning method. The most complex part in designing the speed controller is to determine the appropriate and stable PID parameters according to the desired characteristics. Final results can be achieved by analyzing the results obtained from all the methods used. PID controller for controlling the velocity of brushed DC motor successfully designed.

CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays, the development and research towards mobile robots are increases rapidly. The performance of mobile robots become better from time to time. Nowadays, the usage of robots is not limited to military, hospital and industries only, but it is extending that every level of society seems to need help from robots to carry out work more easily and effectively. Robots that were originally designed for military use, hospitality and industries are now expanding their capabilities to meet the needs of the public. This development clearly shows that the creation of new methods or techniques should be created to enable the rapid development of this technology in parallel with time-shifting.

In the previous years, mobile robots were outlined with vast size, substantial and required a high cost PC framework which should be associated by means of link or remote gadgets. These days, the pattern is to advance with a little portable robot which is diminished in measure, weigh, and cost of the framework by utilizing sensors, various actuators, and the controller are carried on-board the robot (Braunl, 2008). Mobile robots are fabricated in light of a decent connection of both equipment and programming. There is one all the more thing that mobile robot truly needs is a decent route framework, for example, vision camera or sensor. (Chen & Agrawal, 2013).

Based on this project, cart follower is designed to resemble a car to meet the main requirements designed for the use of wheelchair users as a luggage carrying robot. The robot will be able to detect the color code on the back of the wheelchair as a guide to move and provide suitable velocity to the cart. This robot can move forward, backward and also turn left or right but at predetermined turning angle. The velocity of movement of this robot is moved between 5km/h to 10km/h.

Three clasiccal methods Ziegler-Nichols, Skogestad IMC and Chien Hrones Reswick are used to obtain the best PID controller. There are four performance indicators that is being compared which are steady-state error, rise time, settling time and overshoot.

1.2 Problem Statements

Nowadays, there are such a large number of mobile robot that had been produced. The development and the imperative of improvement are vital for each mobile robot. Some mobile robots are planned by utilizing the best possible control system and the others accompanies a basic control system by modifying speed to influence the robot movement (Visioli, 2012).

There are some movement issues that can be found be found on the portable robot which is utilizing a basic control system. In a certain case, forward movement of the robot does not go smooth because the simple system does not provide stable velocity to the system (Pavan Kumar et al., 2010). So, the system provided unstable output velocity. This issue also affects the turning movement of mobile robot.

Therefore, PID controller is being selected to be used in this project. This type of controller is very effective if applied to control the speed of a system that is subject to the use of DC motors. The speed control based on PID controller will provide a steady and appropriate velocity to the system. Three PID tuning methods will be tests in order to produce the best PID controller for the mobile robot controlling system.

1.3 Objective

The cart follower is a type of mobile robot driven using brushed dc motor to allow it to move forward or stop to avoid obstacle. A stable velocity control should be achieved by a PID controller to be discharged into the microcontroller. Therefore, there is a major objective to be implemented to enable the cart follower control system to be driven by PID control.

- To design the speed controller system by using PID controller.
- To identify the best performance of PID controller for controlling the DC motor.

1.4 Project Scope

To achieve the objective, the parameters for the PID authorization need to be obtained. This is because to ensure that the PID controller to be used is stable and compatible with the DC motor. Testing of parameters obtained can be tested using MATHLAB software to obtain detailed data on PID controller stability based on several important features. This step is to ensure that the PID controller that will be applied by the system is the best available.

Next, the transfer function required by the system needs to be obtained. To get the value of the transfer function, the mathematical model of DC motor need to be derived to get the order of the system. Output velocity of a specific voltage input required in order to approximate the transfer function. So, the DC motors need to be connected to other hardware which are Arduino MEGA 2560, motor driver and encoder for system identification experimental process.

Additionally, Ziegler-Nichols, Skogestad IMC and Chien Hrones Reswick methods will be used. These methods are being used to obtain the PID controller required by the system. For this project, the PID controller is only compared to its performance among the methods used and does not proceed to be embedded into the microcontroller.

1.5 Organization of the Thesis

There are five chapters in this thesis, introduction, literature review, methodology, result and discussion, and conclusion. The quick clarification for each part can be found in this area, which begin with chapter 1 until chapter 5. This section also shows about the outline in this dissertation.

Chapter 1 is about introduction, which depicts about the review of related work, problem statement that express about the issue of utilizing different controllers contrast with PID controller, objective and destinations that need to accomplish in this undertaking, and extent of work which set to be done to accomplish objective and goals.

Chapter 2 contains literature review which gives some fundamental data and result from related research. Those data are identified with system and technique that have been utilizing for applicable innovations. This section will quickly clarify about the consequence of those applicable research. As indicated by those outcomes, the commitment of those system to this extend can be affirmed.

Chapter 3 is about methodology, which depicts the strategy and procedure that have been utilized as a part of this whole undertaking. All ideas about how those methods function and how to lead the trial are found in this part. Equipment and programming segment are likewise clarified in this section.

Chapter 4 explains about results and discussion for the PID controller tuning. All the finished outcomes which is finished by re-enactment and ongoing testing are portrayed in this part. This section is additionally disclosed about how the outcome add to the whole venture.

Chapter 5 is a conclusion segment, which closes all the critical data, and what have been done in this project. What's more, this part likewise gives some ideas for future works to enhance the capacity of utilizing PID controller as a fundamental for closed loop controlling system.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

The significant theories and valuable research accessible which identified with speed control of follower robot are depicted in this section. There are some imperative methods and important research accessible, for example Proportional Integral Derivative (PID) Controller, Velocity Control of DC Motor Based on PID Controller, FPGA Implementation of a PID Controller with DC Motor Application and overview about previous Following Robot that already been developed. Moreover, techniques and hardware use to implement mobile robot can be found in the following robot section. It is important info to create this project in order to make it as well as possible.

2.2 Proportional-Integral-Derivative (PID) Controller

PID Controller Proportional-Integral-Derivative (PID) controllers are widely used in automation systems. They are usually implemented either in hardware using Analog components or in software using computer-based systems. This project outlines several modules necessary for building PID controllers on Field Programmable Gate Arrays (FPGAs).

The corresponding discrete PID equation can be described as equation 2.1.

$$U(z) = K_i T_e \left(\frac{z}{z-1}\right) E(z) - [\, K_P + \frac{K_d(z-1)}{T_e z}\,] y(z) \qquad \textbf{(2.1)}$$

$$where \qquad E(z) = Y_c(z) - Y(z)$$

$Y_c(z)$ = The set point signal

$Y(z)$ = The feedback signals

$E(z)$ = The error signals

$U(z)$ = The control signals

Where K_p, K_i and K_d are respectively the proportional, integral, derivative parameters. The PID controller is shown in Figure 2.1.

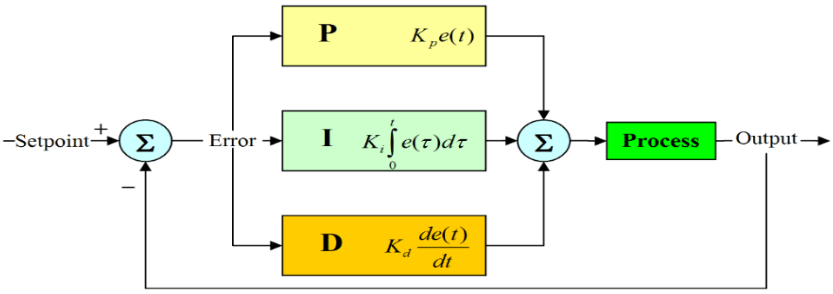

Figure 2.1: A block diagram of PID controller

One of the difficulties for a PID controller is to get the ideal estimations of its proportional, integral, and derivative parameters. Despite the fact that plentiful methodologies have been proposed to naturally tune these parameters (Kiam Heong & Chong, 2005), e.g. Artificial Bee Colony (Elsisi & Soliman, 2015). Instead that, these techniques are infrequently to be used because of their complexity. Therefore, classical PID tuning methods, e.g. Ziegler Nichols rule, are still widely applied in industries due to their robustness and simplicity (Mallesham & Mishra, 2011) (Abdulameer & Sulaiman, 2016).

Among different control methodologies, a proportional-integral-derivative (PID) controller has been broadly proposed to streamline the execution of controlling the speed of the motor. Furthermore, the tuning procedure of PID parameters has not been completely comprehended. This is because in most cases, trial practices and errors have been used.

The closed loop Ziegler Nichols rule is a deliberate tuning approach that has been broadly utilized as a part of businesses to upgrade the parameters of a PID controller. Indeed, Ziegler Nichols rule has been broadly utilized as a benchmark to tune PID parameters in various studies (Korkmaz & Avdogdu, 2012) (Kanojiwa & Meshram, 2012). This could be because of the way that the usage of the closed loop Ziegler Nichols rule does not require the data of a model, and it is probably going to accomplish attractive execution.

Initial parameters of P, PI, and PID controllers for each speed using the classical Ziegler Nichols formulae as that tabulated in Table 2.1.

Table 2.1: The formulae used to estimate the values of K_p, K_i and K_d for P, PI and PID controllers using Ku and Pu.

Controller	**Proportional gain, K_p**	**Integral gain, K_i**	**Derivative gain, K_d**
P	$K_U \div 2$	0	0
PI	$K_U \div 2.2$	$1.2K_P \div P_U$	0
PID	$K_U \div 1.7$	$2K_P \div P_U$	$K_P P_U \div 8$

2.3 Velocity Control of DC Motor Based on PID Controller

The DC motor is a necessary component for every mobile robot. The velocity control is one of the most important part in order to provide a stable velocity to the system. According to the previous research, there are a lot of techniques which are used to control velocity of DC motor. However, PID controller is most common choice as a main controller for velocity control of DC motor. This section is described about velocity control of DC motor by using optimization techniques based on PID controller.

PID controller is well known as a control which is used to control speed and position of DC motor framework. In this research, genetic algorithms (GAs) are used to optimize the PID gains for speed controller of a DC motor. Genetic Algorithms are a stochastic general pursue procedure that simulate the strategy of standard change (Pavan Kumar et al., 2010). Moreover, PID controller is utilized due to its simple control structure is very simple and less expensive (Visioli, 2012).

According to the execution of generic algorithms, the best tuning of PID controller parameters can be obtained. During the execution records, the ideal PID controller analyse the extension values by using GAs. The Integral of Absolute Magnitude of the error (IAE) is settled to provide a best PID controller. The proposed method was demonstrated with a second request physical plant as DC motor, where the PID turning parameters calculations were driven for the most part.

2.4 FPGA Implementation of a PID Controller with DC Motor Application

(Paul Leisher Christopher Meyers, 2002) The top-level system block diagram illustrates the Digital PID Controller and DC Motor System in a closed loop configuration. The Motor Shaft Velocity will be feedback and confirmed with the Speed Command Signal to drive the system by means of an error signal. This is shown in Figure 2.2.

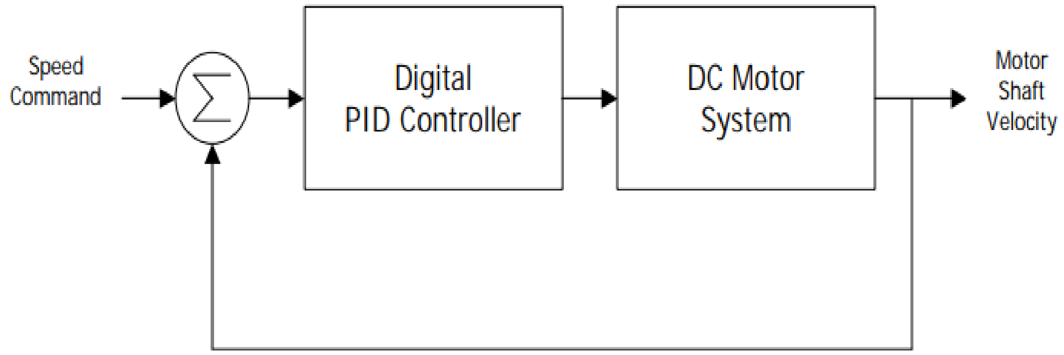

Figure 2.2: Top-Level Block Diagram

The FPGA, or Field Programmable Gate Array, will be performing a number of tasks in the system. These tasks include processing the Speed Command Input, outputting a DC voltage level drive signal for the DC Motor (this DC voltage level may require further amplification depending on the specifications of the D/A converter included on the FPGA development board), processing the DC Motor RPM encoder's frequency, providing the comparator to compare the Speed Command Input to the Motor Shaft Velocity signal (thus producing an error signal), and the actual implementation of the Digital PID Controller. All of these tasks will be programmed for the FPGA in VHDL. The DC Motor system will be controlled with a DC voltage level. This DC voltage level will be produced on the outputs of the FPGA development board.

The purpose of the proportional gain in the digital PID controller is to provide high loop gain in the system. This high loop gain is crucial to the operation of a closed loop system. Ideally, the system output should follow the system input. For this ideal case, the loop gain would be infinity. However, the proportional gain cannot be made arbitrarily large. The higher the proportional gain, the larger the working numbers in the software will become. At some point, the hardware will not be able to handle such large numbers, and software overflow will occur. This is the first issue which will be addressed in the detailed design of the project, that is, a reasonable balance between the desire for high loop gain and the importance of using smaller numbers will be found. The purpose of the integrator in the digital PID controller will be to software will depend largely upon how the system will need to track different changes in speed. This system is primarily concerned with tracking step up or step-down inputs, so only one integrator will be required. The purpose of the differentiator in the digital PID controller will be to increase system speed by increasing the bandwidth. The functionality of the PID controller on the system is shown in a root-locus sketch below in Figure 2.3.

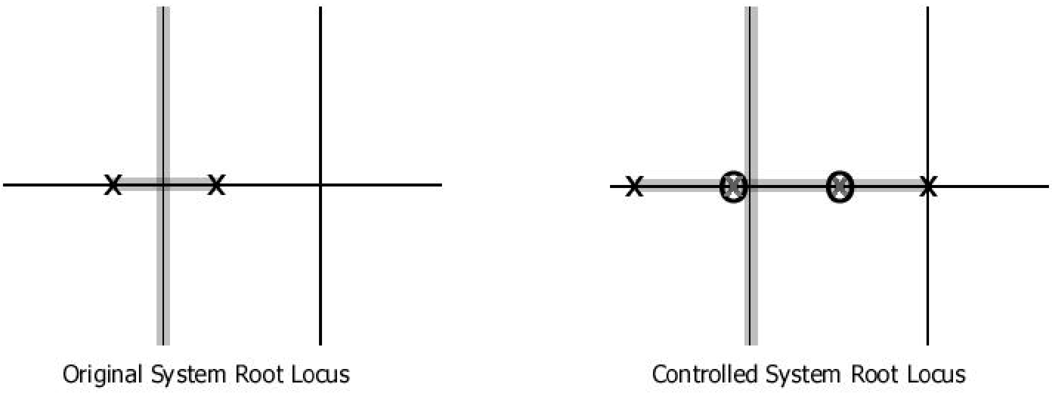

Figure 2.3: Impact of PID Controller on DC Motor Systems

This project will follow a strict outline of design procedures. The first step will be system simulation. This will be done in MATHLAB – Simulink. The simulations will be crucial to developing appropriate PID constants for desired system specifications. Although this project will not result in a practical system for direct implementation in industry, a few specifications have been laid down for "academic" purposes. These specifications are listed below:

1. Steady State Error = 0% for command inputs
2. Percent Overshoot = 5%
3. Phase Margin > 50º

The second step will be to develop the software for the FPGA, this includes debugging. The software will be developed based off the design obtained through simulation. Once the software has been designed, it will be implemented on the FPGA, and the system will be operational for testing. From this point on, the goal will be to both improve system performance by "tweaking" the software or by changing the PID parameters, and also to add features to the project by exploring other possibilities. One possibility will be to change the DC Motor System block to input a PWM signal rather than a DC level. Another possibility will be to attempt to add feed-forward control to improve system performance.

2.5 Following Robot

In this area, the field of mobile robot that is identified with following robot will be depicted. A following robot can be said as a robot that figure out how to do the assignment of following (Noridayu, 2014). For the most part, this robot performs following assignment based on data got from the tracking device.

2.5.1 Line or path following

The Line Follower robot is a mobile machine that can recognize and take after the line drawn on the floor. For the most part, the way is predefined and can be either noticeable like a dark line on a white surface with a high differentiated shading or it can be undetectable like an attractive recorded. Unquestionably, this sort of Robot should detect the line with its Infrared Ray (IR) sensors that introduced under the robot. From that point forward, the information is transmitted to the processor by particular change transports. Consequently, the processor will choose the best possible recognizes and afterward it sends them to the driver and accordingly the way will be trailed by the line supporter robot.

This sort of robot can be utilized for military purposes, conveyance administrations, transportation frameworks, dazzle assistive applications. On the other hand, there are numerous yearly line adherent robot's rivalries composed by colleges or enterprises far and wide. They more often than not approach mechanical groups for building a little robot with particular measurements and weight as indicated by the opposition rules. As a matter of fact, the line supporter robots are an enduring most loved of the little robot manufacturer yet unquestionably the dubious part is to make the line devotee quick and smooth in its reaction.

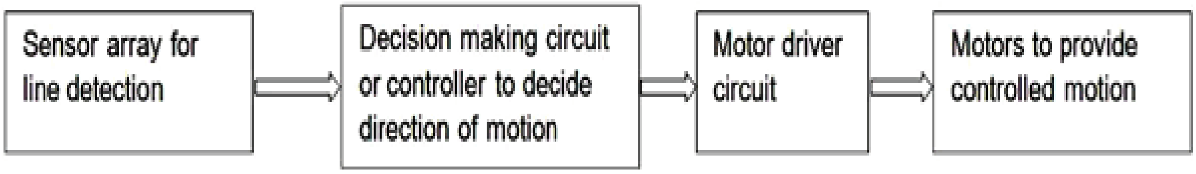

Figure 2.4: Line follower robot block diagram

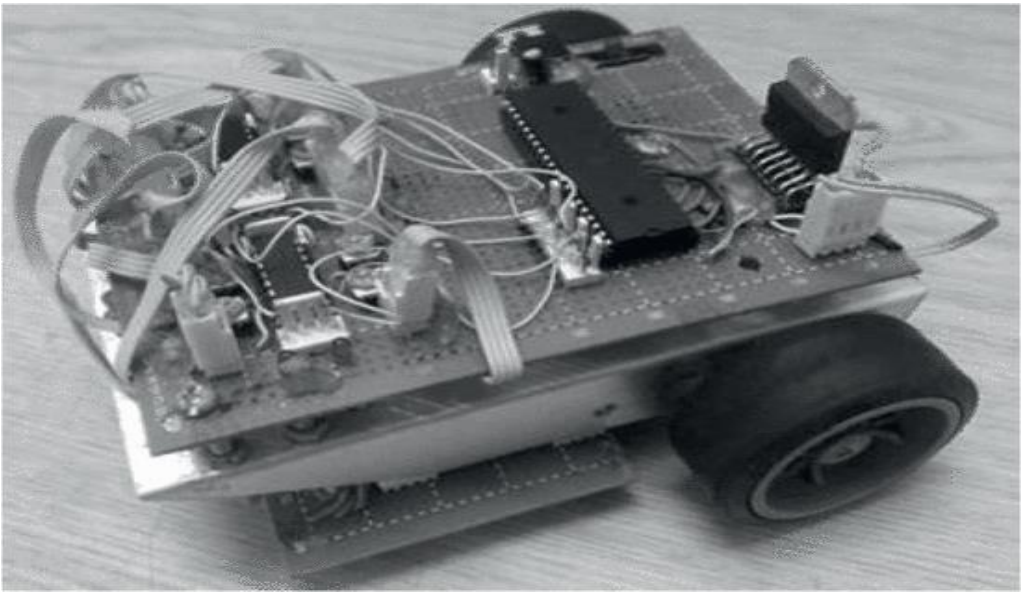

Figure 2.5: Line follower robot model (M. Mehdi Sanaatiyan & Mehran Pakdaman, 2009).

2.5.2 Sound following robot

A sound signal following control of a mobile robot with the estimation of the sound source area has been actualized in this examination utilizing an amplifier cluster. The geometry of the amplifier exhibit and the voyaging time distinction of the sound signal contingent upon the separation gives the two-dimensional directions of the sound signal. To identify a similar transmission snapshot of the sound signal, cross-connection among the got sound signal has been used. To take after the main sound signal definitely and rapidly, the single ebb and flow exploring has been arranged from the portable robot to the sound source, which is outstanding amongst other directions for the differential driving mobile robots. The genuine trials with two mobile robots are executed: one robot is pushing ahead producing the sound signal and the other robot is following the main robot by perceiving the sound signal. This calculation can be pertinent for platooning of the portable robots executing observation and safeguarding tasks (Jong-Ho Han, Uk-In Lee & Jang-Myung Lee, 2014).

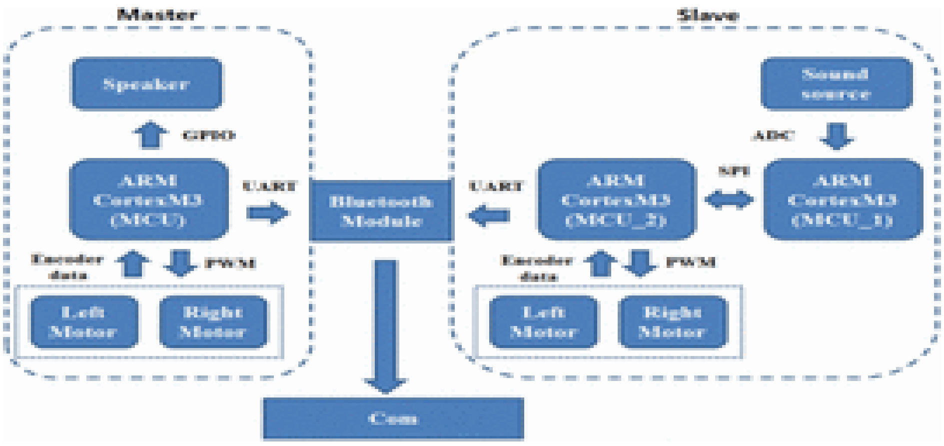

Figure 2.6: Sound following robot block diagram

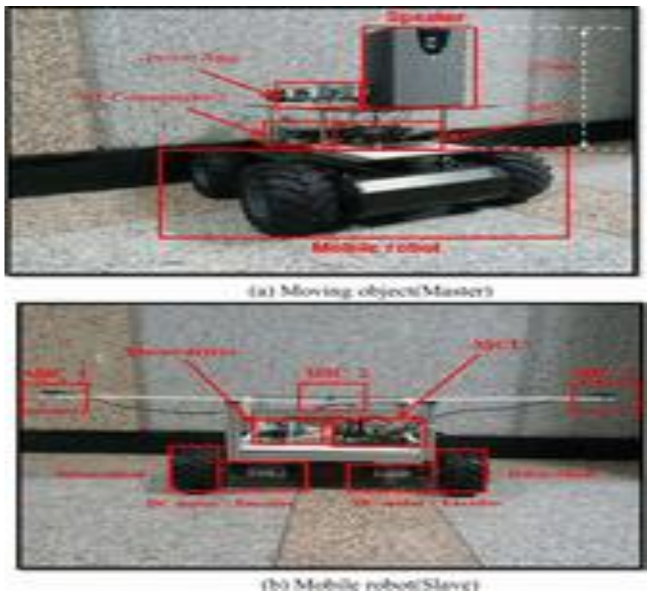

Figure 2.7: sound following robot model (Jong-Ho Han, Uk-In Lee & Jang-Myung Lee, 2014).

2.5.3 Human following robot using infrared camera

Human following robots have been explored and grown effectively these decades because of its copious applications in day by day life and assembling. A human-following robot requires a few methods, for example, human's objective discovery, robot control calculation and snags evasion. Different methodologies of following robots have been proposed, for example, utilizing ultrasonic sensors, voice acknowledgment sensors, laser run sensors, charge-coupled gadget (CCD) camera et cetera. These advances distinguish the relative position between a mobile robot and a human. In this paper, analyst exhibit another approach in recognizing position of a portable robot utilizing an infrared camera which is the fundamental system in human following robot. In this investigation, a Wii camera, which catches four gatherings of IR-LEDs introduced on the robot, is joined on a human. A straightforward application actualized continuously utilizing a PI controller demonstrates a few favourable circumstances of the proposed technique (Quoc Khanh Dang & Young Soo Suh, 2011).

2.6 Summary

This literature review section is a fundamental essential part before beginning this project. This part gave the important explores which every one of the methods can be clarified with the last outcome. There are four fundamental areas in this part, for example, case Proportional Integral Derivative (PID) Controller, Velocity Control of DC Motor Based on PID Controller, FPGA Implementation of a PID Controller with DC Motor Application and overview about past Following Robot that as of now been produced. Additionally, this part is contributed a considerable measure to this extend. The table 2.2 show the research summarization.

Table 2.2: Research summarization

No.	Research Title	Researcher	Research Summarization
1.	Assisting versus repelling force-feedback for learning of a line following task in a wheelchair	Chen,X. & Agrawal	• Repelling force versus an assisting force for learning of a line following task in a wheelchair through a force-feedback joystick. • Implementation of assisting force based on "assist-as-needed" paradigm and repelling force field.
2.	ABC Based Design of PID controller for Two Area Load Frequency Control with Nonlinearities	Elsisi, M., Soliman, Aboelela & Mansour	• An application of the Artificial Bee Colony (ABC) to optimize the parameters of Proportional-Integral-Derivative controller (PID) of nonlinear Load Frequency Controller (LFC) for a power system. • The performance of the technique has been evaluated with the performance of the conventional Ziegler Nichols (ZN), Genetic Algorithm (GA) and Bacterial Foraging Optimization Algorithm (BFOA).
3.	Sound signal following control of a mobile robot with the estimation of the sound source location by a microphone array	Jong-Ho Han, Uk-In Lee & Jang-Myung Lee	• The detection of the same transmission moment of the sound signal cross-correlation. • The algorithm can be applicable for platooning of the mobile robots executing surveillance and recuing operations.

4.	Ziegler- nichols based controller parameters tuning for load frequency control in a microgrid	Mallesham, G., Mishra, S. & Jha	• The load frequency control of a small scale microgrid consisting power generating sources and energy storage elements. • Uses systematic approach to obtain frequency bias parameter and tuning the PID parameters by using Integral Square Time Error evaluation criterion (ITSE) and Ziegler Nichols.

CHAPTER 3

DESIGN METHODOLOGY

3.1 Introduction

The idea and plan for velocity control of cart follower will be discussed in this part. Components to consider on accomplishing the objective and targets in this project included the detail data about the cart follower development, the system identification of brushed DC motor, the development of PID control system. The process flow of the general framework is shown in Figure 3.1.

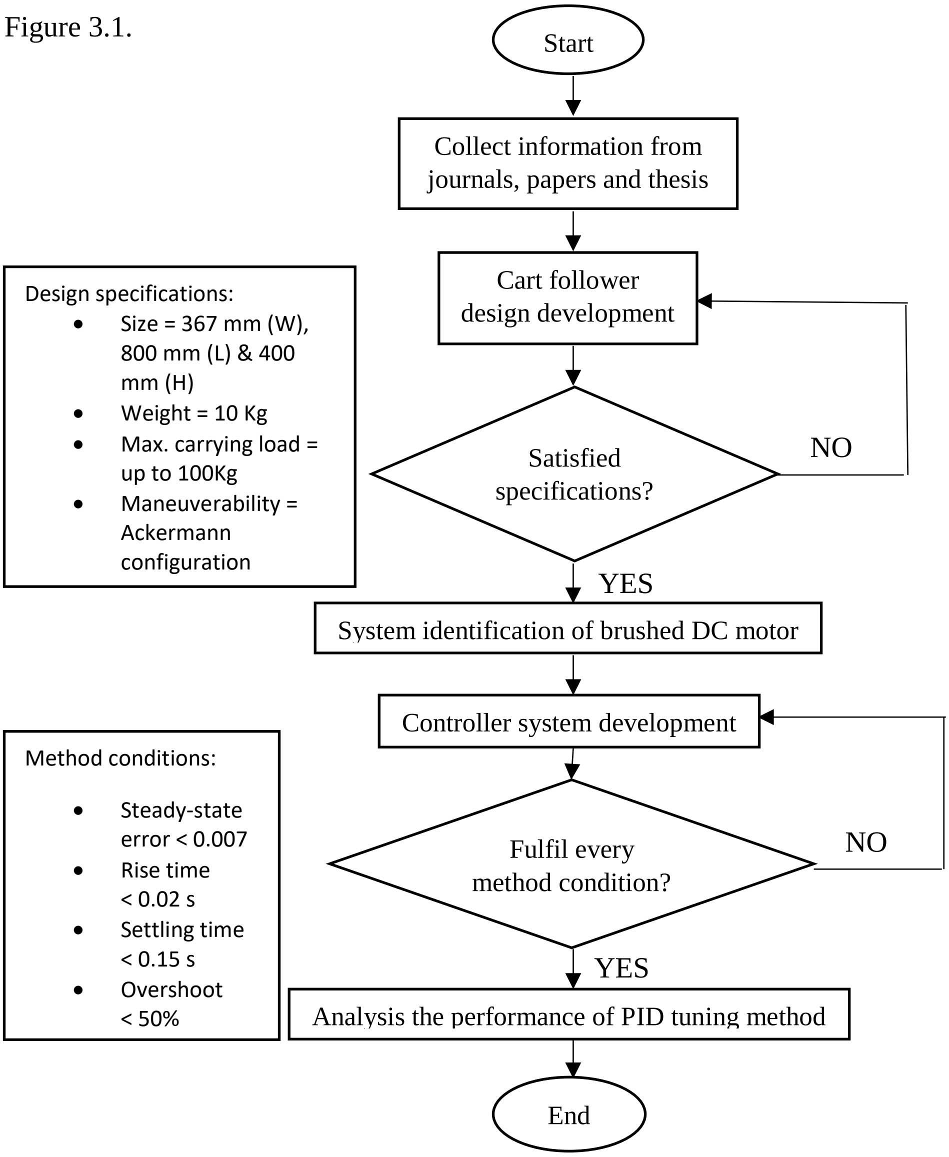

Figure 3.1: Overall designing process flowchart

In this project, data collection from various sources plays an important role. This is because data obtained need to be analyzed to design cart follower with the best system. The system that will be applied in this cart follower must meet all the requirements and follow the correct theories to enable this project to be successful.

In addition, cart follower design is also one of the most important part. Based on this designed cart follower, all of the system that will be used will be applied. Therefore, this cart should be designed to meet all the features required by the system to be used.

Next, the transfer function required by the system needs to be obtained through system design identification. To get the value of the transfer function, the mathematical model of DC motor need to be derived to get the order of the system. Output velocity of a specific voltage input required in order to approximate the transfer function. So, the DC motors need to be connected to other hardware which are Arduino MEGA 2560, motor driver and encoder for system identification experimental process.

In the controller system development section, the speed controller used will be described carefully. The choice of suitable parameters of K_p, K_i and K_d is very important to enable this control system to control the velocity of the motor with a stable velocity. This selected speed control system will affect the overall control of the cart follower drive system. In this part 3 PID tuning methods will be used which are Ziegler-Nichols tuning rule, Skogestad IMC rule and Chien Hrones Roswick autotuning.

To ensure that the PID controller system designed with the best parameters, the analysis of the performances for each of the methods used will be done. The best parameters provided by the tuning methods will be used for the system. Four step response characteristics will be analysed in this part which are steady-state error, rise time, settling time and overshoot.

3.2 Cart Follower Development

This section then will be distributed into two subsections which is the conceptual design of the cart and movement of the cart.

3.2.1 Cart Follower Design

The cart follower is designed with 367mm width, 800mm length, and 400mm height. The distance between front and back wheel is 680mm. The side view, top view and front view of cart follower can be found as shown in Figure 3.2.

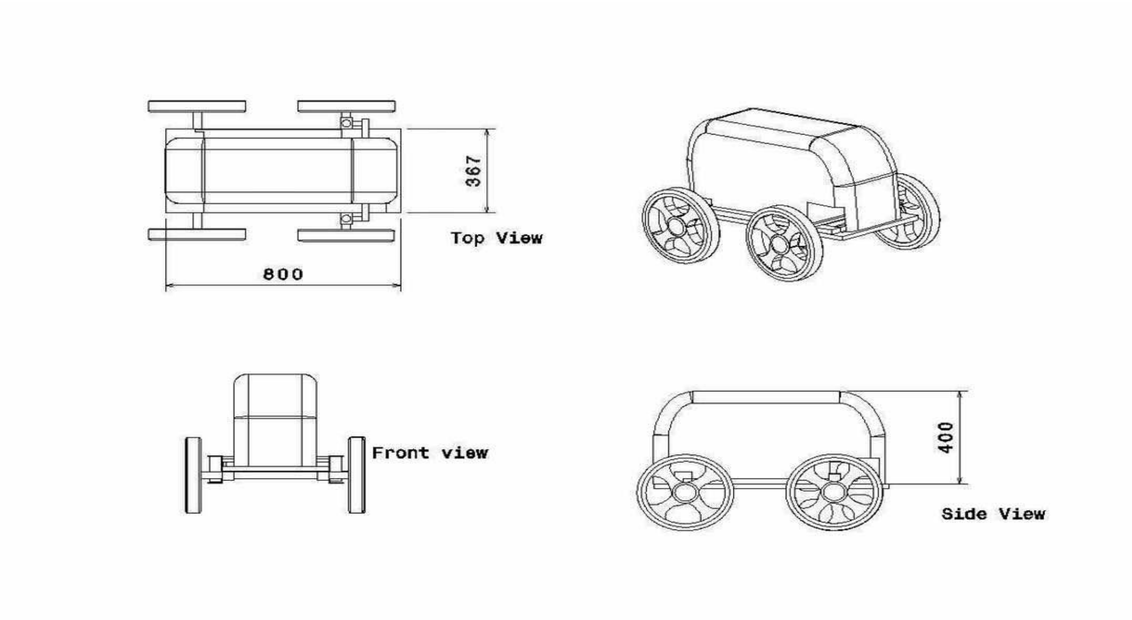

Figure 3.2: Cart follower design

The cart follower weight is within 10kg and is capable of carrying up to 100kg load. Based on the weight and size of this cart follower, it is able to move at around 3km / h to 5km / h. There is a rod that renders both of these cart follower's front wheels. This rod is intended to ensure the movement of the front tire is parallel. This part of the rod is connected to a servo motor that will control its movement.

For the power source for this cart follower, 12v lead acid battery has been selected. This power source is selected based on the assessment of the power source required by this cart follower system to work. This battery will power all hardware parts found in this cart follower. The power source for motor driver and microcontroller may go through an additional circuit as this board works only if the power supply is supplied between the minimum power supply and maximum power supply.

3.2.2 Cart Follower Movement

The cart follower movements section is divided into three subsections namely the forward and backward movements, the turning movements and the movement to avoid obstacles. In each subsection will be explained further every movement that will be done by cart follower.

3.2.2.1 Forward and backward movements

Moving forward and reverse is the main characteristic of the cart that need to be consider. This segment will center around bearing of the cart in moving forward or reverse. The cart will be at stationary position unless if the sensors identifies the coordinating example with the predefined design, at that point the cart will moved forward. Two manila cards being utilized. One is green and another is yellow. They were mounted at the back of the wheelchair with same level of the camera edge. The determined wheeled motor is set at the back of the cart wheels. It will incite the cart. The engine is associated with the Cytron motor driver MD30B to controls the motor's heading. The best distance has been set so cart follower can maintain the distance between the wheelchair as it allows it to avoid any collision.

3.2.2.2 Turning movements

For the movement of the cart follower, the servo motor has been used as a motor which will work if the cart follower is in the turning motion. Movements made by this servo motor will move both sides of the cart follower front tires because a single rod has connected both these tires so the turning movement of these two tires is parallel. So, when the cart follower detects there is a barrier that prevents its path, the system will direct the cart follower either to continue, turn left or right or backward first before turning. The servo motor used is shown in the figure 3.3 below.

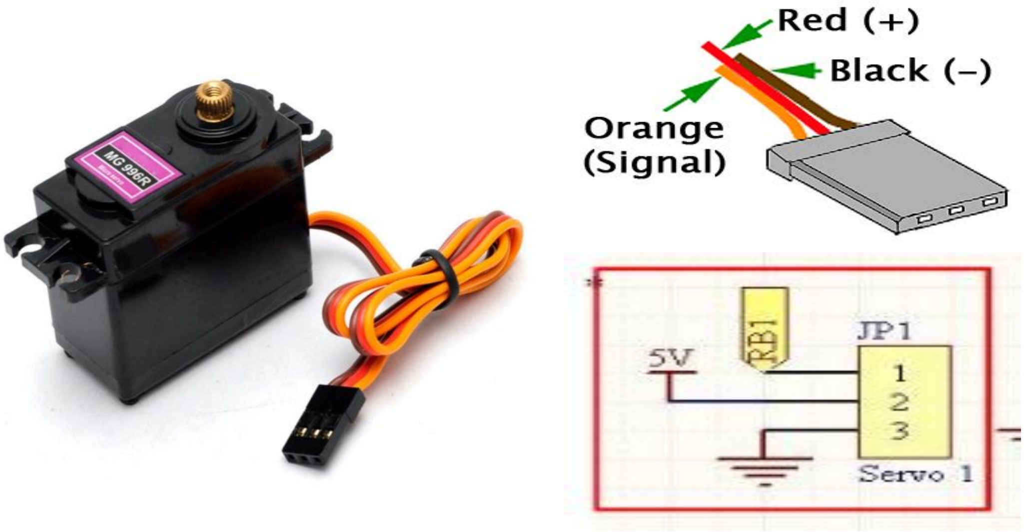

Figure 3.3: Servo motor (metal gear)

3.2.2.3 Obstacle avoidance

In designing this cart follower, obstacle avoidance is one of the important features to consider. This is because when a cart follower performs his job according to the wheelchair the probability of going through obstacles is high. So, this cart follower needs to be designed with features passing through obstacles. Therefore, ultrasonic sensors have been installed on this cart follower to enable them to be aware of the obstacles ahead of it. When these sensors find that there is a barrier blocking, it will tell the system to move forward or turn or back or stop. So, cart follower can avoid breaking obstacles or possibly breaking the wheelchair itself. If there is no obstacle that interferes with this cart follower, it will follow the path that the wheelchair user passes.

3.3 System identification of brushed DC motor

The plant identity is one of the main thing that is needed to be specified before proceeding with the control system development. It can be simulated by using Arduino hardware package in MATLAB. In order to get the angular velocity, the encoder need to be used. By using MATLAB, the System identification Toolbox will help the users to determine the plant transfer function and characteristics. In our case, bump test need to be done where the constant voltage need to be supply until the motor velocity reach equilibrium. Through this process, the transfer function based on time domain data will be collected by System Identification Toolbox (MATLAB).

The mathematical model need to be derived in order to estimate the order of the system. Refer Figure 3.4 for the circuit of armature DC motor and equation 3.1 and 3.2 for electrical and mechanical equation produced based on the circuit.

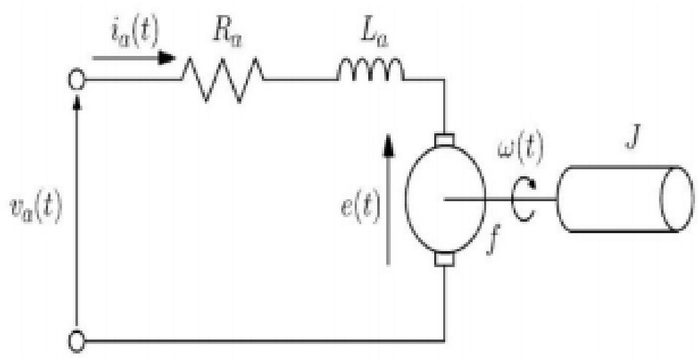

Figure 3.4: Circuit of brushed DC motor.

$$R_a i_a + L_a i_a' + K_m \theta' = v_a(t) \tag{3.1}$$

$$K_m i_a = J\theta'' + B\theta' \tag{3.2}$$

R_a = armature resistance	i_a = inductance
L_a = current	K_m = motor constant
θ' = shaft rotational velocity	J = rotational inertia
B = viscous friction constant	$v_a(t)$ = applied voltage

In order to get the transfer function of the DC motor, the equation 3.1 and 3.2 need to be transform into frequency domain by using Laplace Transform. The final general transform function of DC motor can be described as equation 3.3.

$$\frac{w(s)}{v(s)} = \frac{K_m}{L_a J s^2 + (BL_a + R_a)s + K_m^2} \quad \textbf{(3.3)}$$

Based on the equation 3.3, the system is in second order system with no zeros and two poles.

The output velocity of a specific input is needed in order to approximate the transfer function in MATLAB. So, the DC motor need to be connected to the other hardware to get this value. The connection of DC motor is as shown in Figure 3.5.

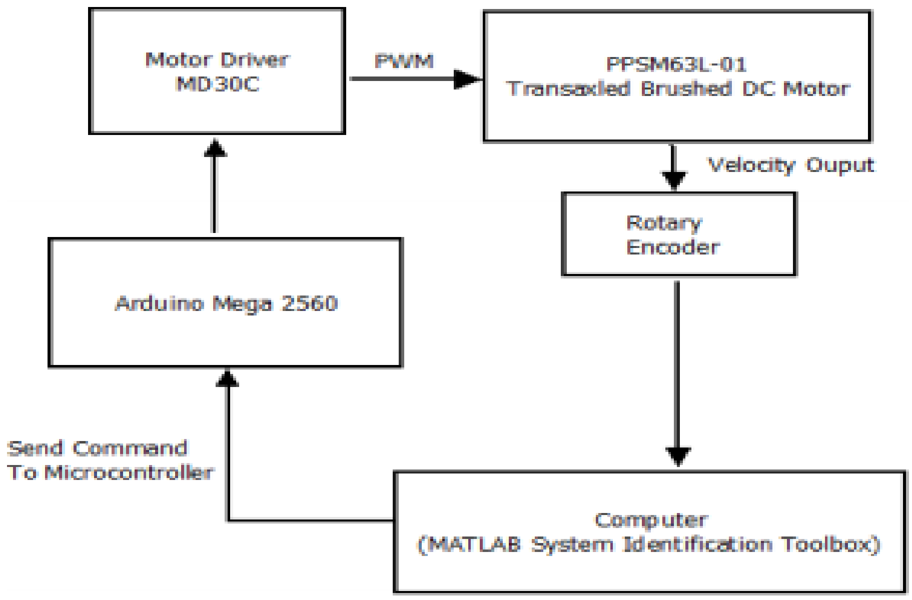

Figure 3.5: Experimental process for data collection

Based on Figure 3.5, DC motor is connected with encoder to measure the Revolution Per Minute (RPM). The Revolution Per Minute (RPM) value is needed in order to get the linear velocity of the system. The equation for linear velocity is as equation 3.4.

$$velocity = \left(\frac{2\pi}{60}\right) \times \ RPM \ \times r \qquad \textbf{(3.4)}$$

r = radius of the wheel

Based on the System Identification Toolbox, the transfer function of the system could be generated directly by using Graphic User Interface (GUI). The number of zeros and poles are the only parameters needed. The toolbox will generate the graph of model output, transient response, frequency response and zero and poles.

3.4 Control system development

A specific control system design is very important for every robotic field, especially in cart follower design. A specific control system method helps the cart to improve the accuracy of movement. In this project, the main purpose is to control speed of the controller by using PID control. The PID controller should generate a stable velocity to the system used and meet all the features described in the theory of control. This control system should use the parameters of K_P, K_I, and K_D that are appropriate to the intended goal.

3.4.1 PID architecture

There are two sorts of system; open loop and close loop system. An open loop system is otherwise called an uncontrolled system and close loop system is known as a controlled system. In open loop system, the produced output is not controlled because this system does not have feedback to the input of the system and in a close loop system, the produced output is controlled with the assistance of controller and this system requires at least one feedback connection. An open loop system is exceptionally straightforward however not helpful in modern control applications since this system is uncontrolled. Close loop system is more complex but helpful for real industrial application because this system provides stable output at desired value. PID controller is one of the example that referred to the close loop system. Figure block diagram for PID controller shown in figure 3.6.

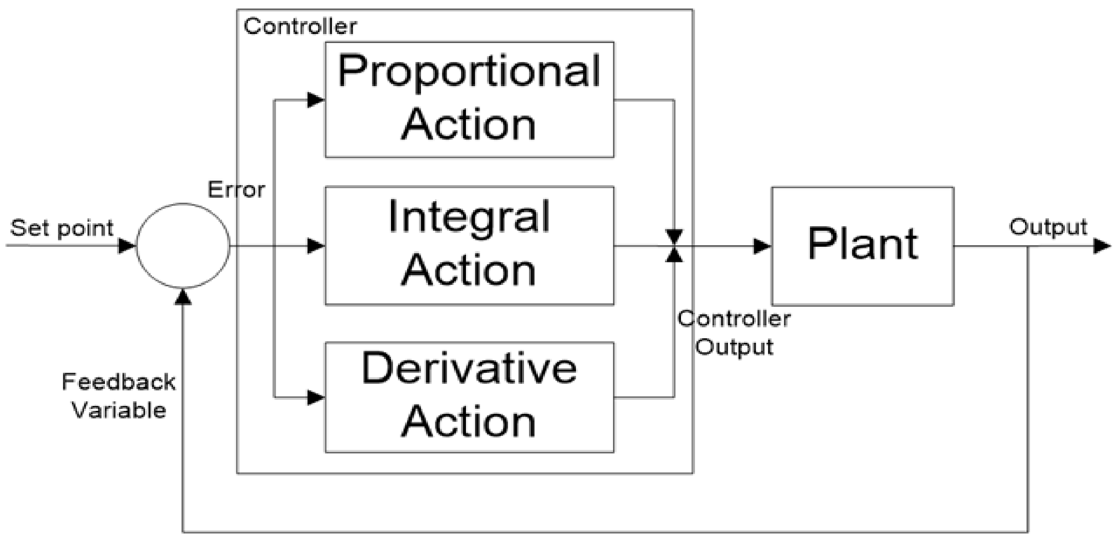

Figure 3.6: PID controller block diagram