Peoples Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

Tissemsilt University

Faculty of Science and Technology

Department of Science and Technology

Final dissertation for obtaining the Master's degree

Sector: Electronics

Specialty: Instrumentation

Presented by: Bensotra Mohamed Amine

Theme

Design and control of a self-balancing robot via Arduino and PID Controller

---

Presented publicly on, 12/06/2023

Before the jury:

Berbera Djilali	President	M.C.B	Tissemsilt-Univ
Marich Mohamed	Examiner	M.C.B	Tissemsilt-Uni
Nail Bachir	Supervisor	M.C.A	Tissemsilt-Univ
Imad Eddine Tibermacine	Co-Supervisor	Doctorate	Sapienza univ of Rome

Academic year: 2022-2023

Dedication

I would like to dedicate to May dears' parents and my family. Moreover, I dedicate to everyone who contributed to this success.

Acknowledgment

I would like from the bottom of my heart to thank God for giving me this favor and also thanks to my Parents for everything and to my friend's and the whole university family, especially the doctor Barbara Djalili and doctor Marich Mohamed.

Abstract

This work is concerned with presenting and studying a self-balancing robot and its design because of its wide uses in many fields. A theoretical study and a physical model containing mathematical equations for the position and angle of an inverted pendulum due to the existence of a common working mechanism between the inverted pendulum and the self-balancing robot. In order to control the movement of the robot and maintain its balance, its movement is processed by the proportional integral differential, which tries to maintain its balance and return the angle to the original position. Therefore, A prototype of the robot has been built. the robot is driven by an Arduino board.

Keywords: self-balancing robot, inverted pendulum, PID controller

Résume

Ce travail porte sur la présentation et l'étude d'un robot auto-équilibré et sa conception en raison de ses larges utilisations dans de nombreux domaines. Une étude théorique et un modèle physique contenant des équations mathématiques pour la position et l'angle d'un pendule inversé en raison de l'existence d'un mécanisme de travail commun entre le pendule inversé et le robot auto-équilibré. Afin de contrôler le mouvement du robot et de maintenir son équilibre, son mouvement est traité par le différentiel intégral proportionnel, qui tente de maintenir son équilibre et de ramener l'angle à la position d'origine. Par conséquent, un prototype du robot a été construit. le robot est piloté par une carte Arduino.

Mots-clés : robot auto-équilibré, pendule inversé, le contrôleur PID

الملخص

يهتم هذا العمل بتقديم ودراسة روبوت ذاتي التوازن وتصميمه لما له من استخدامات واسعة في العديد من المجالات. دراسة نظرية ونموذج فيزيائي يحتوي على معادلات رياضية لموضع وزاوية النواس المقلوب بسبب وجود آلية عمل مشتركة بين النواس المقلوب والروبوت ذاتي التوازن. من أجل التحكم في حركة الروبوت والحفاظ على توازنه ، يتم اضافة التفاضل النسبي المتكامل ، والذي يحاول الحفاظ على توازنه وإعادة الزاوية إلى الموضع الأصلي، تم بناء نموذج أولي للروبوت. يتم تشغيل الروبوت بواسطة لوحة الاردوينو.

الكلمات المفتاحية: روبوت ذاتي التوازن ، النواس مقلوب ، المتحكم PID

.

List of figures

Glossary

TWSBR: Two-Wheel Self-Balancing Robot

PID: Proportional Integral Derivative

WMR: Wheeled Mobile Robots

AMR: Autonomous Mobile Robots

IP: inverted pendulum

General introduction

As the name suggests, the self-balancing robot is an automated vehicle that balances itself without any outside help or support. This project is a rather complex one as it involves using PID Control and involuted programming. Another feature of the self-balancing robot is that it can drive the two wheels independently of each other. In this case, it can turn left, right, or even turn around its own center [1].

These robots have the ability to carry and balance different objects on them without losing their balance. And some other designs can provide wireless communication for remote control. These robots are commercially available as human powered vehicles well known as Segway's PT (the name Segway is derived from the word segue, which means smooth transition. PT is short for Personal Transporter). Another example could be the hover board for entertainment purposes. The idea of the self-balancing robot is related to the inverted pendulum carriage (carriage and pole) which is a classic problem in dynamics and in control theory. While a normal pendulum is stable when suspended downward, an inverted pendulum is inherently unstable and must be balanced actively, precisely, and quickly in order to remain upright. This is the case with the self-balancing robot [2].

Trying to stay stable and recovers its old position when opposed to an external force. Seeking stability while moving between two points is another difficult question and can lead to a loss of consistency and as a result, everything will fall apart. The problem is to ensure a fast and precise response in order to obtain high stability and performance and to reliably find its previous location. The two-wheeled and self-balancing robot belongs to a multivariable, nonlinear, high order, strong coupling, and unstable essential motion control system, and it is a typical device of testing various control theories and control methods; therefore, the research has great theoretical and practical significance. Because it has the advantages of simple structure, stable running, high-energy utilization rate, and strong environmental adaption, it has the broad application prospects whether in the military field or in the civilian field [3].

The objective of this thesis is to design and build a self-balancing two-wheeled robot. First, the mathematic modeling of the robot has been established. Then, type of control are proposed: PID control. A prototype was designed and built based on an Arduino board and a gyroscope for sensing.

After the introduction, this thesis is broadly structured in three chapters:

The first chapter gives a definition and overview to mobile robot and self balancing robot

The second chapter deals with the modeling of inverted pendulum and the two-wheeled self-balancing robot, where the physical model and mathematical equation are established. the robot model and PID controller.

The third chapter proposes to simulation the inverted pendulum and the robot with PID controller. And in the last the realization of a prototype of the robot based on an Arduino board. Finally, the conclusions of this work and the possible extensions were discussed.

Chapter 1

Generalities about robotics

1.1 Introduction

Robotics is the engineering branch that deals with the conception, design, construction, operation, application, and usage of robots. Digging a little deeper, we see that robots are defined as an automatically operated machine that carries out a series of actions independently and does the work usually accomplished by a human.

1.2 Definition of the robot

A robot is a mechatronic device (combining mechanics, electronics and computing) designed to automatically perform tasks that imitate or reproduce, in a specific area, human actions. The design of these systems is the subject of a scientific discipline, a branch of automation called robotics [4].

1.3 Mobile robot

A mobile robot is an automatic machine that is capable of locomotion Mobile robotics is usually considered to be a subfield of robotics and information engineering Mobile robots have the capability to move around in their environment and are not fixed to one physical location. Mobile robots can be "autonomous" (AMR) which means they are capable of navigating an uncontrolled environment without the need for physical or electro-mechanical guidance devices

FIGURE 1.1 MOBILE ROBOT

1.4 Classification of mobile robot

- According to the way of movement, it can be divided in to: wheeled mobile robots, walking mobile robots (single-leg, double-leg and multi-leg), crawler mobile robots, crawling robots, creeping robots and swimming robots and other types.
- According to the working environment, it can be divided in to: indoor mobile robots and outdoor mobile robots.
- According to the control system structure, it can be divided in to functional (horizontal) structural robot, behavioral (vertical) structural robot and hybrid robot.
- According to the functions and uses, it can be divided in to: medical robots, military robots, disabled robots, cleaning robots, etc.

An robot is a comprehensive system that integrates multiple functions such as environmental perception, dynamic decision-making and planning, behavior control and execution. It focuses on multi-disciplinary research results such as sensor technology, information processing, electronic engineering, computer engineering, automation control engineering and artificial intelligence. It represents the highest achievement of mechatronics and is one of the most active fields of scientific and technological development at present.

With the continuous improvement of robot performance, the application range of mobile robots has been greatly expanded, not only in industry, agriculture, medical care, service and other industries, but also in harmful and dangerous occasions such as urban security, national defense and space exploration. Therefore, mobile robot technology has received widespread attention from countries all over the world [5].

1.5 Autonomous Mobile Robots (AMR)

The Autonomous Mobile Robots (AMR) can be implemented in any place without fixing any feedback system in the working environment and without changing any of the existing setup. The Autonomous Mobile Robots (AMR) is a plug and play solution for any of the suitable use case. The device has its own default navigating system based on the laser and proper feedback system using the Inertial Measurement Unit (IMU) also implemented as a default setup. By using the laser data and the feedback system, the AMR system can find its own optimum path to reach the destination without collision with the obstacles [6].

1.6 Industrial robot

The International Organization officially defines industrial robotics for Standardization (ISO) as being an automatically controlled, multi-application, reprogrammable, versatile, manipulative and programmable system on three or more axes.

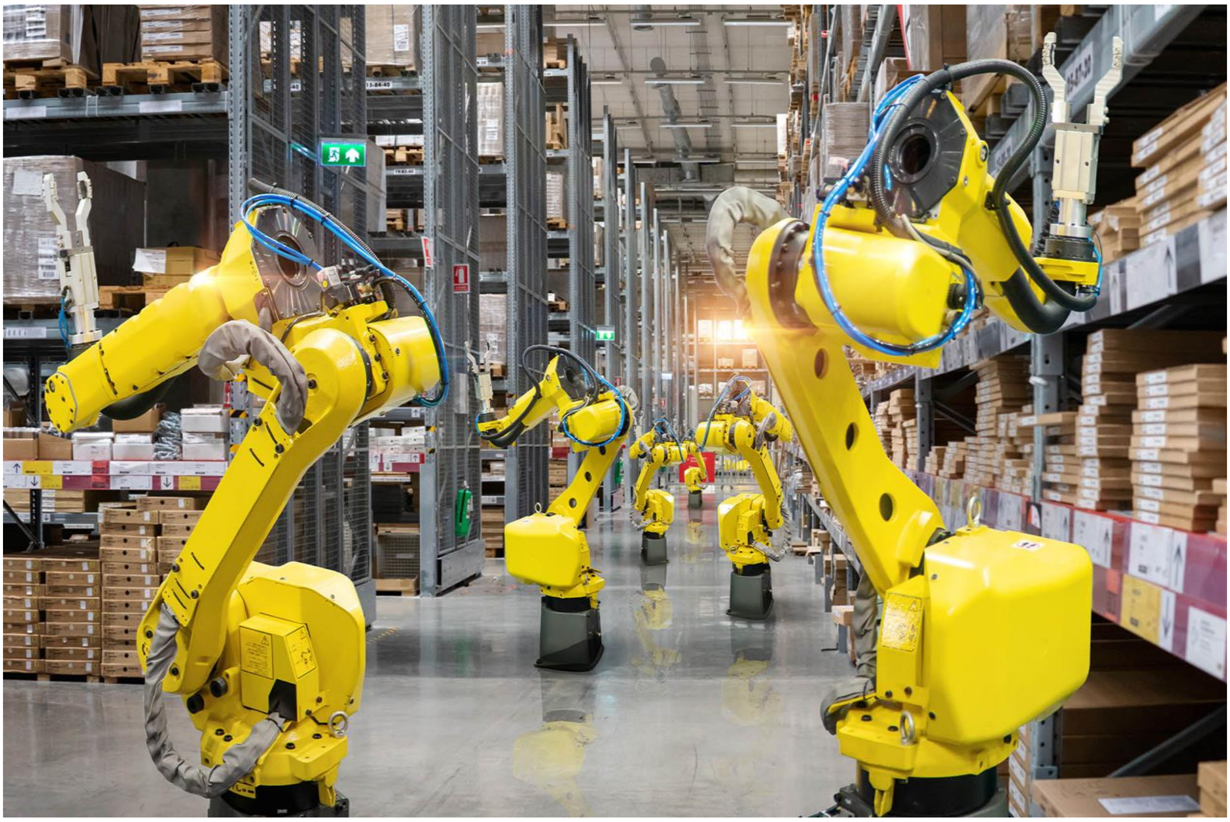

FIGURE 1.2 INDUSTRIAL ROBOT

1.7 Self balancing robot

Self-balancing robots are designed to maintain their balance while moving on uneven surfaces. This is made possible through the use of sensors and a control system that constantly adjust the robot's position to maintain stability. The most common type of self-balancing robot is the two-wheeled robot, which uses a combination of a gyroscope and an accelerometer to balance itself. A **self-balancing robot** is a two-wheeled robot that balances itself so that it prevents itself from falling [7].

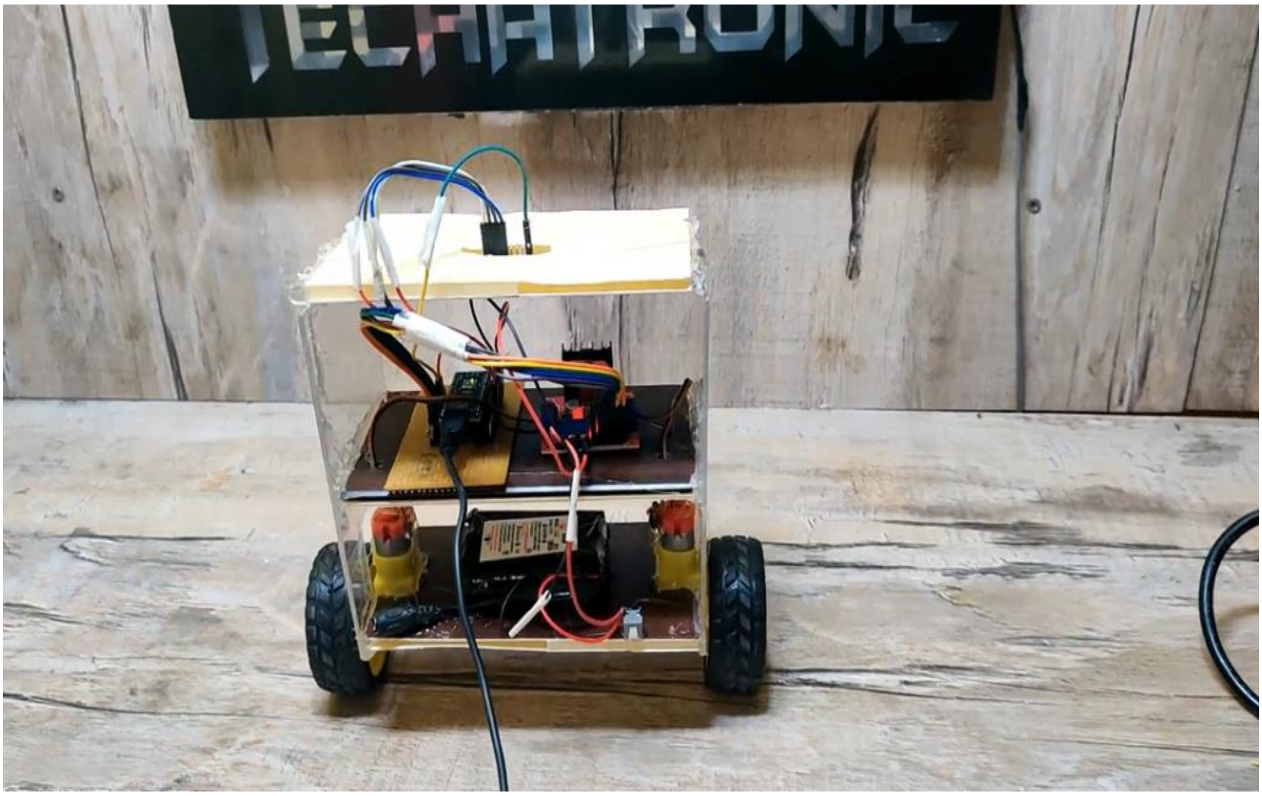

FIGURE 1.3 SELF-BALANCING ROBOT

1.8 Technology behind self-balancing robots

Self-balancing robots are designed to maintain their balance while moving on uneven surfaces. This is made possible through the use of sensors and a control system that constantly adjust the robot's position to maintain stability. The most common type of self-balancing robot is the two-wheeled robot, which uses a combination of a gyroscope and an accelerometer to balance itself [8].

1.9 How does a self-balancing robot works?

Self-balancing robots use a “closed-loop feedback control” system; this means that real-time data from motion sensors are used to control the motors and quickly compensate for any tilting motion in order to keep the robot upright. Similar self-balancing feedback control systems can be seen in many other applications.

1.10 Applications of self-balancing robots

- Logistics and Transportation

One of the primary applications of self-balancing robots is in the field of logistics and transportation. These robots are designed to transport goods from one location to another, and their ability to navigate through obstacles makes them perfect for use in warehouses and factories. They can move around objects, climb stairs, and even travel through tight spaces without any difficulty.

- Healthcare

Self-balancing robots are also finding use in the field of healthcare. These robots can be programmed to perform tasks such as dispensing medication, monitoring vital signs, and assisting patients with mobility issues. Their ability to navigate through tight spaces and move over uneven surfaces makes them ideal for use in hospitals and care facilities.

- The entertainment industry is also starting to take notice of self-balancing robots. These robots are being used in theme parks and museums to provide visitors with an interactive experience. They can move around and interact with visitors, providing them with information about the exhibits and attractions.

1.11 Future applications of self-balancing robots

In the future, self-balancing robots are expected to find use in many other industries, including construction, agriculture, and even space exploration. Their ability to navigate through obstacles and maintain stability on any terrain makes them ideal for use in challenging environments [9].

1.12 Conclusion

In conclusion, self-balancing robots are a fascinating development in the field of automation. Their ability to maintain balance and navigate through obstacles makes them ideal for use in various industries, from logistics to healthcare and entertainment. As technology continues advance, it is likely that self-balancing robots will become even more prevalent in our daily lives, revolutionizing the way we work and live.

Chapter 2

Modeling and control system

2.1 Introduction

In the chapter, two we give a system physical model and some mathematic equation theatrical study for understand the comportment system.

The two-wheeled, self-balancing robot is a non-linear multi-variable and naturally unstable system. Controlling such a system is a challenge therefore; it attracts attention of many modern control researchers. Control concepts study the inverted pendulum such as system stability and robust control of systems can be verified by experimenting on such systems. Therefore, it serves as a facility for testing and verifying various control techniques. Many techniques for the control of a two-wheel self-balancing robot have been proposed. They include the PID Controller [10].

2.2 System modeling

Two-wheeled self-balancing robot depend upon the principle of operation of inverted pendulum. This concept is a common example found in all control engineering textbooks and a hot topic among the researchers focusing in control area. For the modeling of a self-balancing robot for an object carrying purpose, an inverted pendulum with a cart system can be used. The system is completely unstable without a controller. It can be made stable by moving the cart forward or backward if the pendulum tends to fall in forward or backward direction. This forward or backward force will give an acceleration to the wheels according to the angle between the vertical position of the pendulum and current position of pendulum. The inverted pendulum is an example of highly unstable, on linear dynamic system. Generally, in self-balancing robots controlling depend on the application for which it is used [11].

2.3 Inverted Pendulum

The inverted pendulum on two wheels is widely considered an academic prototype. studied in the field of automation. As its name suggests, it consists of a base mobile (the axle and the two wheels) surmounted by an inverted pendulum in free rotation around a pivot (passive articulation) between the axle and the pendulum rod.

The operating principle of the system is very simple in theory: when the pendulum leans forward, the moving part must catch it by moving forward and vice versa. The difficulty lies in adjusting the reaction intensity of the wheels in order to act in the face of the angle that the pendulum makes with the vertical [12].

2.4 Model Definition

The physical problem of the balancing robot is well described by the widely analysed inverted pendulum. It is commonly modelled as a rigid rod fastened by a frictionless joint to a rigid cart moving in one direction. The simplification that the wheel base can be seen as a cart sliding on a frictionless surface was made. This model definition is inspired by MathWorks tutorial about inverted pendulum [13]. See Figure 2.1 for the simplification steps in this project.

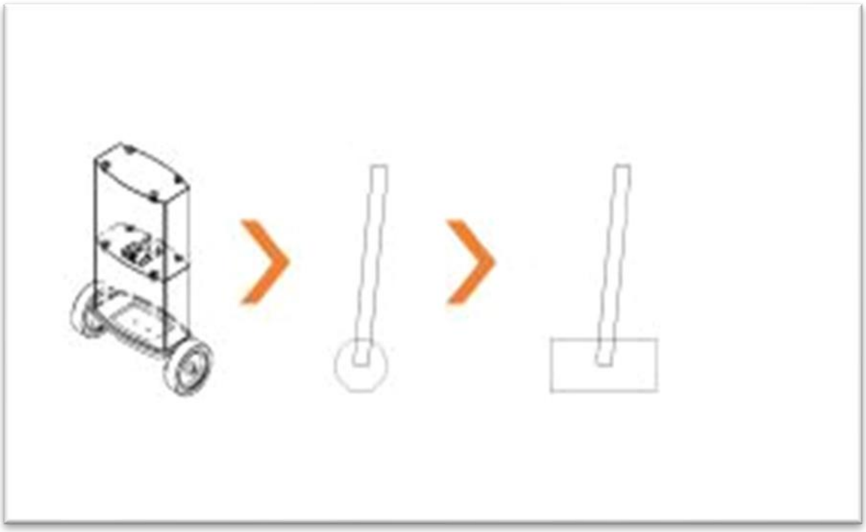

FIGURE 2.1 SIMPLIFICATION STEPS OF THE INVERTED PENDULUM.

An inverted pendulum mounted on a motor-driven cart is shown in Figure 2–2(a). This is a model of the attitude control of a space booster on takeoff. (The objective of the attitude control problem is to keep the space booster in a vertical position.) The inverted pendulum is unstable in that it may fall over any time in any direction unless a suitable control force is applied. Here we consider only a two-dimensional problem in which the pendulum moves only in the plane of the page. The control force u is applied to the cart. Assume that the center of gravity of the pendulum rod is at its geometric center. Obtain a mathematical model for the system.

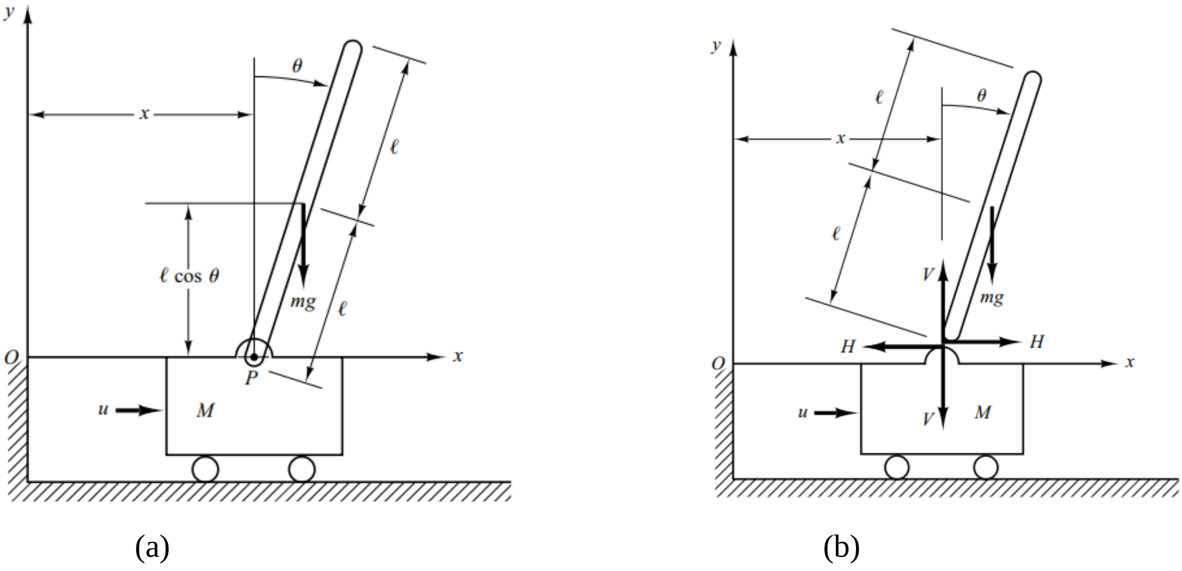

Figure 2.2 (a) Inverted pendulum system; (b) free-body diagram.

Define the angle of the rod from the vertical line as θ. Define also the (*x*, *y*) coordinates of the center of gravity of the pendulum rod as (x_G, y_G). Then

$$x_g = x + l\sin\theta \tag{2.1}$$

$$y_g = l\cos\theta \tag{2.2}$$

To derive the equation of motion for system .consider the free body diagram shown in figure(2.2) the rotation motion of the pendulem rod about its center of gravity can be described by

$$I\ddot{\theta} = Vl\sin\theta - Hl\cos\theta \tag{2.3}$$

Where I is the moment of inertia of the rod about its center of gravity.the horizontal motion of center gravity of pendulum rod is give by

$$m\frac{d^2(x+l\sin\theta)}{dt^2} = H \tag{2.4}$$

The vertical motion of center of gravity of pendulem rod is

$$m\frac{d^2(lcos\theta)}{dt^2} = V - mg \tag{2.5}$$

The horozontal motion of cart is described by

$$M\frac{d^2x}{dt^2} = u - H \tag{2.6}$$

Since we must keep the inverted pendulum vertical,we can assume that θ(t) and $\dot{\theta}$(t) are small quantities sush that sinθ=θ,cosθ=1 and θ$\dot{\theta}$=0,then ,equation (2.3) trough (2.5) can be linearized equation are

$$I\ddot{\theta} = Vl\theta - Hl \tag{2.7}$$

$$m(\ddot{x} + l\ddot{\theta}) = H \tag{2.8 }$$

$$0 = V - mg \tag{2.9}$$

Form equation(2.6)and (2.8) obtain

$$(M + m)\ddot{x} + ml\ddot{\theta} = u \tag{2.10}$$

Form equation(2.7)and (2.8) and (2.9) we have

$$I\ddot{\theta} = mgl\theta - Hl$$

$$= mgl\theta - l(m\ddot{x} + ml\ddot{\theta}) \tag{2.11}$$

Or

$$(I + ml^2)\ddot{\theta} + ml\ddot{x} = mgl\theta \tag{2.12}$$

Equation (2.10) and (2.11) describe the motion of the inverted pendulum on the cart system thes constitute a mathematical model of the system.

Consider the inverted-pendulum system shown in Figure 3-6. Since in this system the mass is concentrated at the top of the rod. The center of gravity is the center of the pendulum ball. For thiscase, the moment of inertia of the pendulum about its center of gravity is small, and we assume I = 0 in Equation (2-11). Then the mathematical model for this system becomes as follows:

$$(M + m)\ddot{x} + ml\ddot{\theta} = u \qquad (2.13)$$

$$ml^2\ddot{0} + ml\ddot{x} = mgl\theta \qquad (2.14)$$

Equations (2-13) and (2-14) can be modified to

$$Ml\ddot{\theta} = (M + m)g\theta - u \qquad (2.15)$$

$$M\ddot{x} = u - mg\theta \qquad (2.16)$$

Equation (2-15) was obtained by eliminating x from Equations (2-12) and (2-13). Equation (2-16) was obtained by eliminating $\ddot{\theta}$ from Equations (2-12) and (2-13). From Equation (2-14) we obtain the plant transfer function to be

$$\frac{\theta(s)}{-U(s)} = \frac{1}{Mls^2-(M+m)g} \qquad (2.17)$$

$$= \frac{1}{Ml(s+\sqrt{\frac{M+m}{Ml}}g\ )(s-\sqrt{\frac{M+m}{Ml}}\ g\ )} \qquad (2.18)$$

The inverted-pendulum plant has one pole on the negative real axis an another on the positive real axis, the plant is open-loop unstable Define state variables X1. X2, X3. and X4 by

$$x_1 = \theta \qquad (2.19)$$

$$x_2 = \dot{\theta} \qquad (2.20)$$

$$x_3 = x \qquad (2.21)$$

$$x_4 = \dot{x} \qquad (2.22)$$

‘Note that angle θ indicates the rotation of the pendulum rod about point P. and x is the location of the cart.

(Notice that both θ and x are easily measurable quantities.) Then, from the definition of the state variables and Equations (2-14) and (2-15), we obtain

$$\dot{x_1} = x_2 \tag{2.23}$$

$$\dot{x_2} = \frac{M+m}{Ml} g x_1 - \frac{1}{Ml}u \tag{2.24}$$

$$\dot{x_3} = x_4 \tag{2.25}$$

$$\dot{x_4} = -\frac{m}{M} g x_1 + \frac{1}{M}u \tag{2.26}$$

terms of vector-matrix equations, we have

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \\ \dot{x_4} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ \frac{M+m}{Ml} g & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ -\frac{mg}{M} & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 0 \\ -\frac{1}{Ml} \\ 0 \\ \frac{1}{M} \end{bmatrix} u \tag{2.27}$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} \tag{2.28}$$

Equations (2.27) and (2-27) give a state-space representation of the inverted-pendulum system.

(Note that state-space representation ofthe system is not unique.

2.5 Method to determinist

To fulfil the purpose the following method will be used:

•Derive dynamical equations based on theory of the inverted pendulum

•Form transfer functions for the angle deviation θ *and* position x

• Find a controller that can control these two conditions in this case we use the PID controller

• Set up requirements for the demonstrator

•Chosen error sources will be investigated.

2.6 PID Controller Design

The PID controller is considered as one of the most popular control schemes. That is the simplicity in implementation. Because that, they are applied to a wide range of applications.

The PID controller can be expressed in Eq. (2.29)

$$U(t) = Kp.e(t) + Ki \int e(t)\, dt + Kd.\frac{d}{dt}e(t) \qquad (2.30)$$

Proportional (P) control This component adjusts the output of the process based on the current error between the setpoints and the process variable (PV). The larger the error, the larger the correction applied.

Integral (I) control This component adjusts the output based on the accumulated error over time. It helps eliminate steady-state error and can improve the stability of the control system. **Derivative (D) control** This component adjusts the output based on the rate of change of the error. It helps to dampen oscillations and improve the stability of the control system but is often omitted because PI control is sufficient. The derivative term can amplify measurement noise (random fluctuations) and cause excessive output changes. Filters are important to get a better estimate of the process variable rate of change.

2.7 Control Process

The basic idea behind a PID controller is to read a sensor, then compute the desired actuator output by calculating proportional, integral, and derivative responses and summing those three components to compute the output. Before we start to define the parameters of a PID controller, we shall see what a closed loop system is and some of the terminologies associated with it, [14] and the result could be a Block diagram model as shown in Figure (2.3)

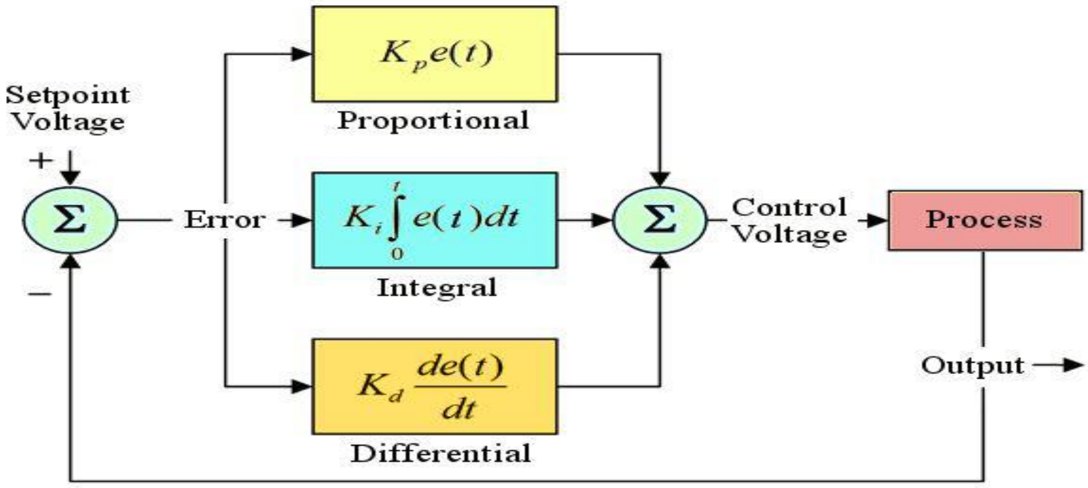

Figure 2.3 PID Controller Block Diagram

2.8 Working PID

As the name suggest is going to give a precise idea about the structure and working of the PID controller. However going into details, let us get an introduction about PID controllers. PID controllers are found in a wide range of applications for industrial process control.

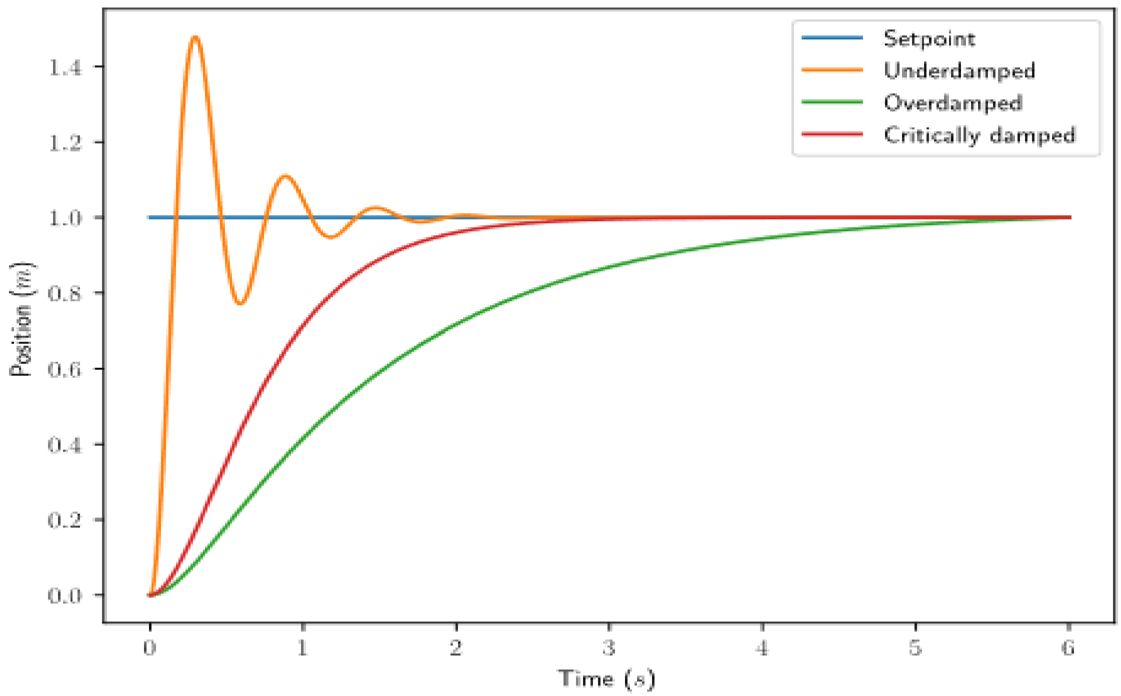

FIGURE 2.4 PID CONTROLLER RESPONSE TYPE

2.9 Conclusion

Modeling is very important in the study of the movement of robots, especially in the field of research and development of robots. In this chapter, we focused on the compute of the model and the dynamic model of a two-wheeled self-balancing robot, and we tested the validity of the modeling by mathematical equation. Modeling is the study of the movement of mechanical systems without taking into account the forces that affect the movement, and dynamic modeling is the system. Study of the movement of the mechanical system, taking into account the forces affecting the movement. In the next chapter, we will propose a control system based on PID.

Chapter 3

Simulation and prototype

3.1 introduction

This project is designed for attempting on developing an autonomous self-balancing robot. In this work, the two-wheel robotic system consists of a microcontroller (Arduino), Dc motor, and sensor. The Arduino is used to read the sensor data and gives the order of the motor based on the control algorithm to remained the system is stable at different impediment [15].

Therefore, in this chapter, we do the simulation of invented pendulum and self-balancing robot in matlab after that assembled the robot.

3.2Inverted pendulum simulation

We make a montage like figure (3.1) we put a same scope for measure angle and position.

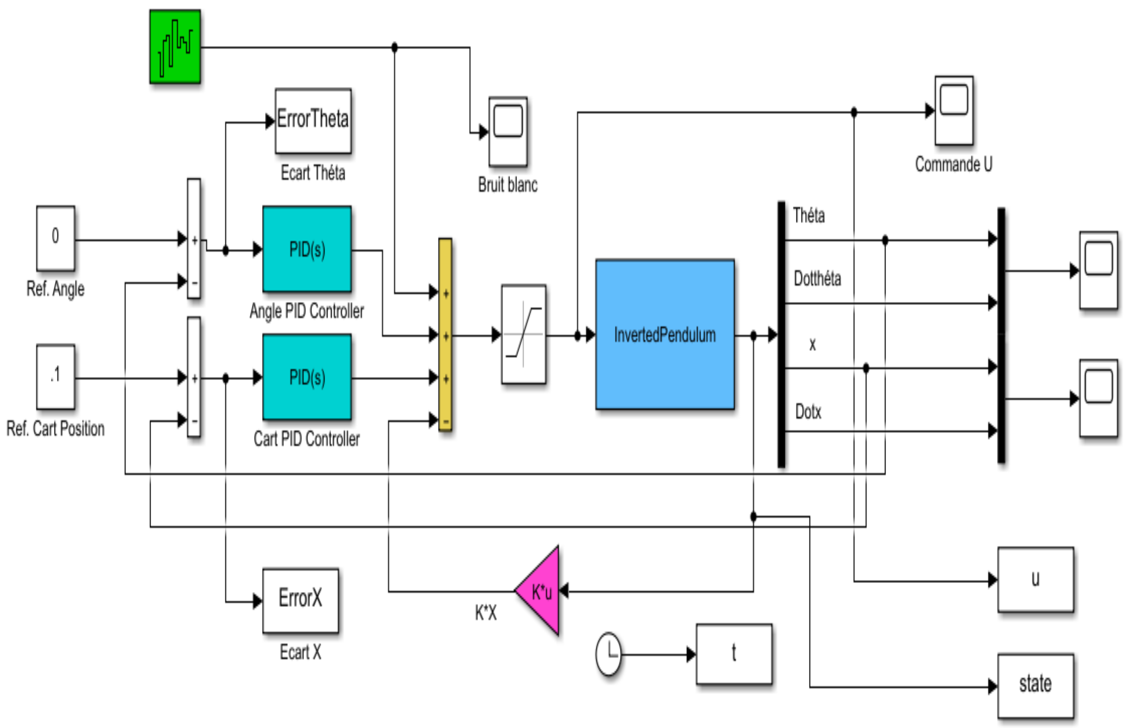

Figure 3.1 Angle PID, Cart PID Control of Inverted Pendulum System with Disturbance Input.

.

Figure (3.2) in red represent variation of speed angle in 10 seconds and the bleu represent the variation of angle before settling stable.

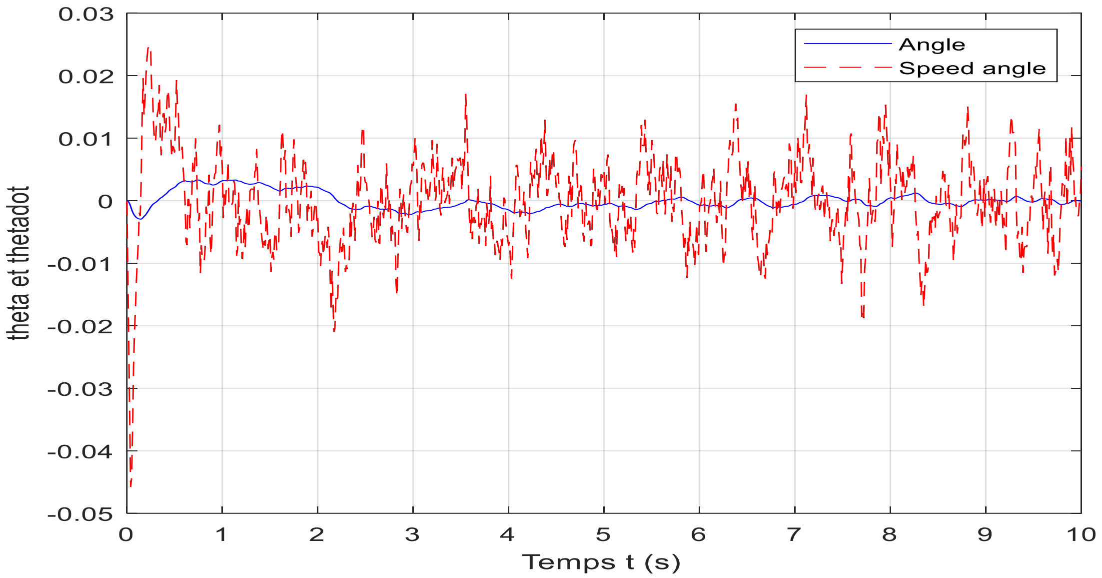

Figure 3.2 Angle θ and the speed angle $\dot{\theta}$ of inverted pendulum.

Figure 3.3 represent the input signal u of the inverted pendulum, after use PID and collect with reference signal and external influence signal, so commanded u is higher frequency that cause the inverted pendulum move right and left quickly.

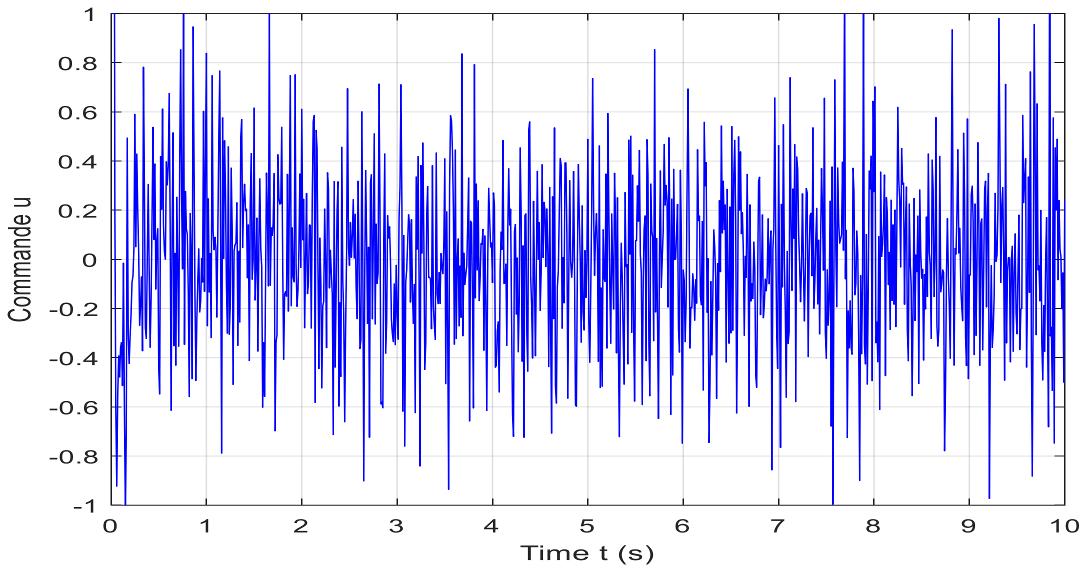

Figure 3.3 Signal of Commande u

The cart of pendulum move rapidly increasing and then becoming bouncy in one direction like figure 3.4.

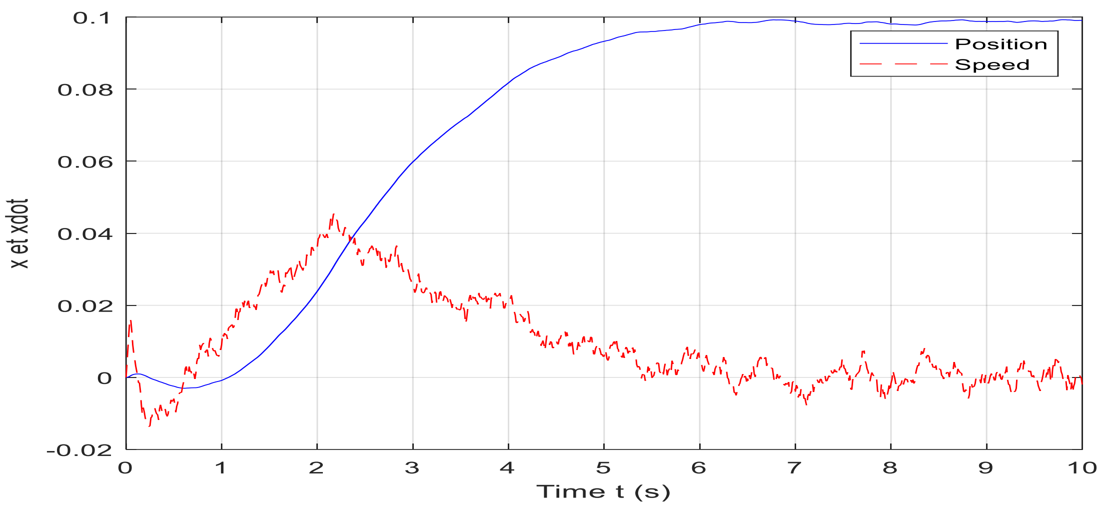

FIGURE 3.4 POSITION x AND THE SPEED $\dot{x}$ OF CART.

The error in the angle of movement is the difference between the current value and the original. value it is large at the beginning and away from the angle of origin, this is due to the large movement of the vehicle at the beginning of the movement, and after a few seconds, the error becomes less until it is non-existent. The robot trying to keep the tilt angle to zero (vertical) and at the same time following its desired position, as we ca see in the following Figure 3.5.

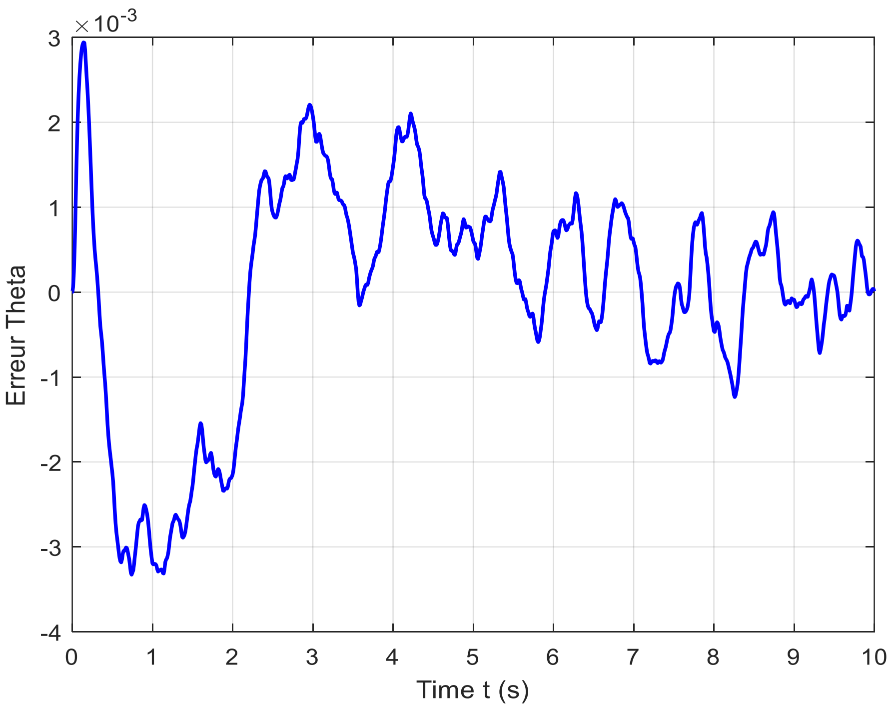

FIGURE 3.5 ERROR OF ANGLE.

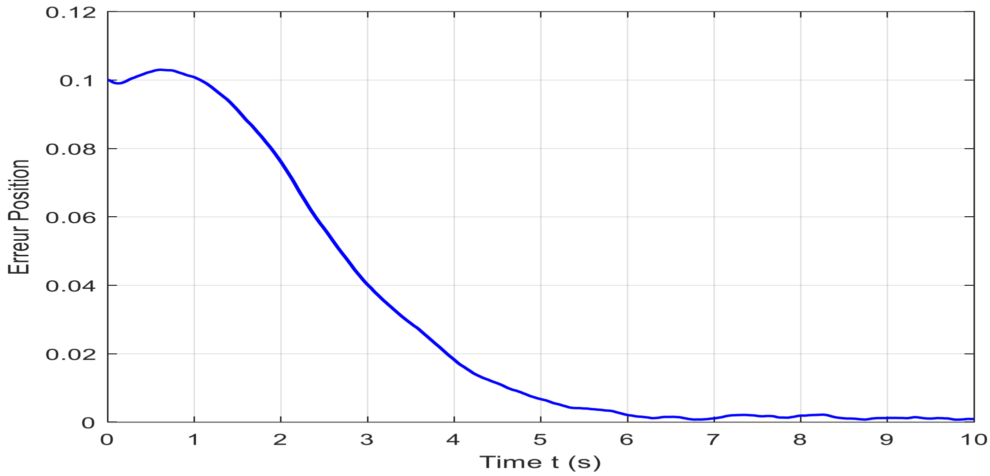

Figure 3.6 Error position.

The error in the position is the result of the difference in the movement of the robot that is trying to balance and the partial position, i.e. the distance between it and the position of balance figure 3.6

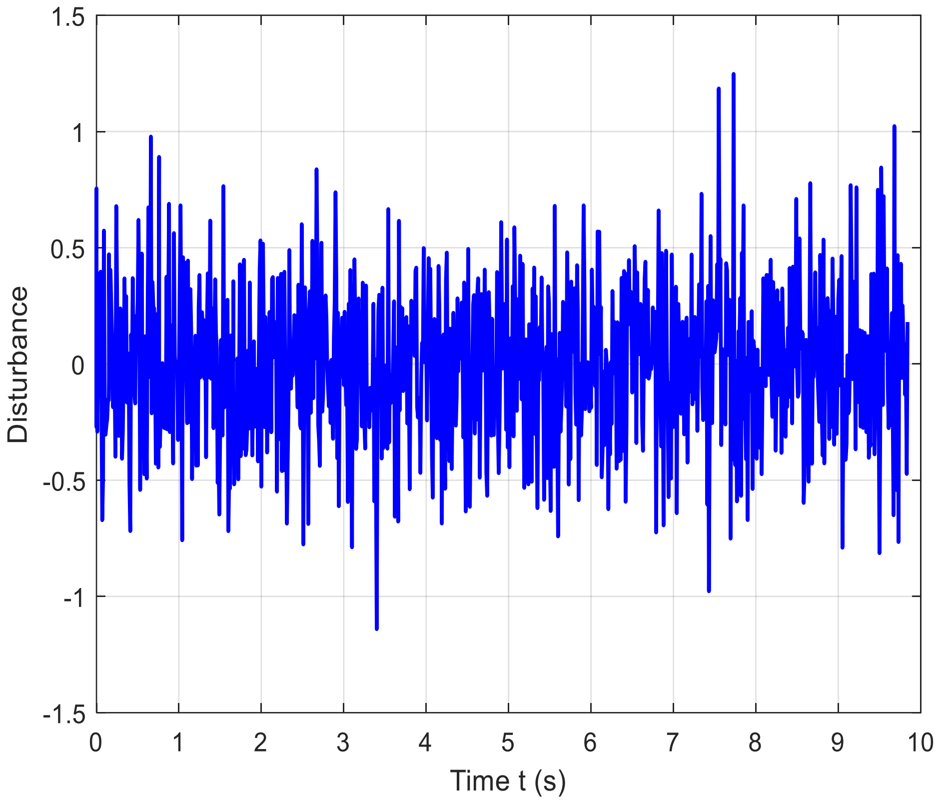

FIGURE 3.7 DISTURBANCE SIGNAL.

3.3 The component

3.3.1 Arduino Uno

Is a micro controller board based on the AT mega328P (data sheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the Micro controller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. can tinker with Uno without worrying too much about doing something wrong, worst-case scenario you can replace the chip for a few dollars and start over again.

FIGURE 3.8-ARDUINO UNO BOARD.

3.3.2 DC motor and pair wheel

A DC motor is any of a class of rotary electrical motors that converts direct current (DC) electrical energy into mechanical energy. The most common types rely on the forces produced by induced magnetic fields due to flowing current in the coil. Nearly all types of DC motors

Figure 3.9 Dc Motor and Pair Wheel.

have some internal mechanism, either Electromechanical or electronic, to periodically change the direction of current in part of the motor.

3.3.3Gyroscope sensor mpu6050

Gyroscope sensor is a device also known as angular rate sensor or angular velocity sensors, are devices that sense angular velocity Angular velocity. In simple terms, angular velocity is the change in rotational angle per unit of time. Angular velocity is generally expressed in deg/s (degrees per second).that can maintain the orientation and angular velocity of an object. These are more advanced than accelerometers.

These can measure the tilt and lateral orientation of the object whereas accelerometer can only measure the linear motion. Gyroscope sensors are also called as Angular Rate Sensor or

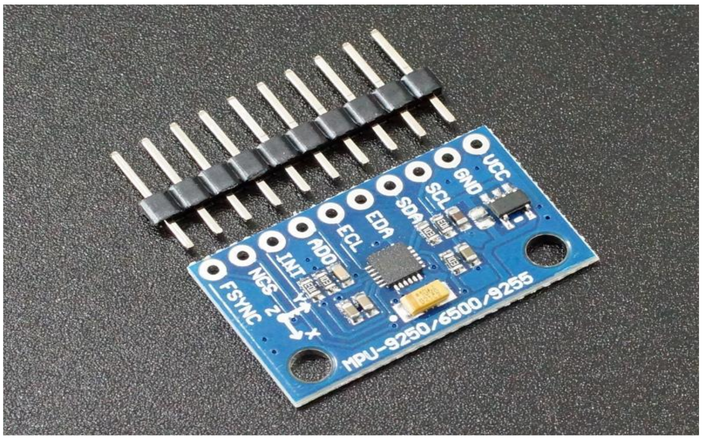

Figure 3.10 MPU-9250 3-Axis Accéléromètre, Gyroscope Magnétomètre Sensor Module

Angular Velocity Sensors. Humans install these sensors in the applications where the orientation of the object is difficult to sense. Measured in degrees per second, angular velocity is the change in the rotational angle of the object per unit of time. The MPU-9250 combines a 3-axis accelerometer, a 3-axis gyroscope and a 3-axis Magnetometer with an on-board Digital Motion Processor (DMP) all packaged in a high-performance small module.

.

3.3.4L298N Motor Driver Module

The L298N is a dual-channel H-Bridge motor driver capable of driving two DC motors and one stepper motor. Means it can individually drive up to two DC motor for any applications like 2WD robots, Small drill machine, solenoid valve, DC lock etc. An L298N motor driver module consists of an L298N motor driver chip(IC). Which is an integrated monolithic circuit in a 15-

lead Multi watt package. It is a high voltage, a high current dual full-bridge driver designed to accept standard TTL logic levels.

FIGURE 3.11 L298N MOTOR DRIVER MODULE.

Be used to connect peripheral sensing resistors. Another input power supply can be installed to enable the logic to work at low voltage. The L298 chip is an integrated chip in a multi-watt in-line package with 15 leads. It contains a 4-channel logic drive circuit, which is a dedicated driver for two-phase and four-phase motors.

To make the input signal independent or disable the device, two enable inputs are provided. The emitter tubes of the transistors under each point bridge are connected together, and the corresponding response external terminals can be used to control the connection of the external sense resistor. An additional power input is provided to make the logic work at a lower voltage.

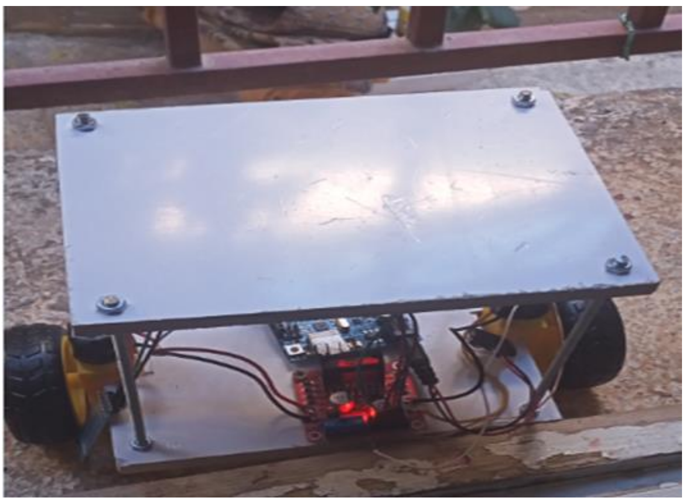

FIGURE 3.12 PROTOTYPE OF SELF-BALANCING ROBOT.

3.4 How does it function?

The 3-axis gyroscope of MPU6050 measures angular rate (rotational velocity) along the three axes. For our self-balancing robot, the angular velocity along the x-axis alone is sufficient to measure the rate of fall of the robot. The data is then fed back to the Arduino board to calculate the command needed using a PID controller, to drive the DC motors.

3.5Conclusion

Prototype of the two-wheeled self-balancing robot was designed and built based on an Arduino board for control and a gyroscope sensor for perception. The prototype has been tested to show its ability to stabilize autonomously. The system model in which controls of two subsystems: self balance (preventing system from falling down when it moves forward or backward) and yaw rotation (steering angle regulation when it turns left or right) are considered.

General conclusion

Modelling based on the inverted pendulum shows that the system is unstable without a controller. The system is a self-balancing robot. It is implemented using PID Controller, which is a Proportional Integral Derivative Controller. We balance the robot by driving its wheels in the direction of its fall. In doing that, we are trying to keep the center of gravity of the robot above the pivot point. To drive the wheels in the direction of its fall, we should know where the robot is falling and the speed at which it is falling.

Recently a lot of work has been done in the self-balancing of objects. The concept of self-balancing started with the balancing of **inverted pendulum**. This concept extended to design of aircrafts as well. In this project, we have designed a small model of self-balancing robot using the **PID (Proportional, Integral, and Derivative)** Algorithm. Since then, this method is the new face of the industrial process control systems. This report reviews the methods involved in self-balancing of objects.

- **Refrences**

[1] Azar, A. T., Ammar, H. H., Barakat, M. H., Saleh, M. A., & Abdelwahed, M. A. (2019). Self-balancing robot modeling and control using two degree of freedom PID controller. In *Proceedings of the International Conference on Advanced Intelligent Systems and Informatics 2018 4* (pp. 64-76). Springer International Publishing.

[2] Sun, C., Lu, T., & Yuan, K. (2013, June). Balance control of two-wheeled self-balancing robot based on linear quadratic regulator and neural network. In *2013 Fourth International Conference on Intelligent Control and Information Processing (ICICIP)* (pp. 862-867). IEEE.

[3] Phan, H. N., & Nguyen, C. X. (2017). Building embedded quasi-time-optimal controller for two-wheeled self-balancing robot. In *MATEC Web of Conferences* (Vol. 132, p. 02005). EDP Sciences.v

[4] Nehmzow, U. (2012). *Mobile robotics: a practical introduction*. Springer Science & Business Media.

[5] Zhang, H. Y., Lin, W. M., & Chen, A. X. (2018). Path planning for the mobile robot: A review. *Symmetry*, *10*(10), 450.

[6] An, W., & Li, Y. (2013, December). Simulation and control of a two-wheeled self-balancing robot. In *2013 IEEE International Conference on Robotics and Biomimetics (ROBIO)* (pp. 456-461). IEEE.

[7] Juang, H. S., & Lum, K. Y. (2013, June). Design and control of a two-wheel self-balancing robot using the arduino microcontroller board. In *2013 10th IEEE International Conference on Control and Automation (ICCA)* (pp. 634-639). IEEE.

[8] Wu, J., & Zhang, W. (2011, August). Design of fuzzy logic controller for two-wheeled self-balancing robot. In *Proceedings of 2011 6th international forum on strategic technology* (Vol. 2, pp. 1266-1270). IEEE.

[9] Duan, M., Liu, D., Chen, X., Liu, R., Tan, Y., & Liang, L. (2020). Self-balancing federated learning with global imbalanced data in mobile systems. *IEEE Transactions on Parallel and Distributed Systems*, *32*(1), 59-71.

[10] Wasif, A., Raza, D., Rasheed, W., Farooq, Z., & Ali, S. Q. (2013, September). Design and implementation of a two wheel self balancing robot with a two level adaptive control. In *Eighth International Conference on Digital Information Management (ICDIM 2013)* (pp. 187-193). IEEE.

[11] An, W., & Li, Y. (2013, December). Simulation and control of a two-wheeled self-balancing robot. In *2013 IEEE International Conference on Robotics and Biomimetics (ROBIO)* (pp. 456-461). IEEE

[12] S. Marteau J. Lottin. Le pendule inversé : un système hybride? In CETSIS'2005, Nancy,

France, 2005

[13] Raheem, F. A., Midhat, B. F., & Mohammed, H. S. (2018). PID and fuzzy logic controller design for balancing robot stabilization. *Iraqi Journal of Computers, Communications, Control and Systems Engineering*, *18*(1), 1-10.

[14] Johnson, M. A., & Moradi, M. H. (2005). *PID control*. London, UK: Springer-Verlag London Limited.

[15] Ahmed, E. Q., Aljazaery, I. A., Al-zubidi, A. F., & ALRikabi, H. T. S. (2021). Design and implementation control system for a self-balancing robot based on internet of things by using Arduino microcontroller. *Periodicals of Engineering and Natural Sciences*, *9*(3), 409-417.

[16] Jin, D. 2015. *Development of a Stable Control System for a Segway*. AvailableAt: http://www.raysforexcellence.se/wp-content/uploads/2013/01/Dennis-Jin-Development-Of-a-stable-control-system-for-a-segway.pdf. [Accessed 02 May 2015]

[17] An, W., & Li, Y. (2013, December). Simulation and control of a two-wheeled self-balancing robot. In *2013 IEEE International Conference on Robotics and Biomimetics (ROBIO)* (pp. 456-461). IEEE.