

# PID CONTROLLED LINE FOLLOWER ROBOT DESIGN ON INDOOR 3D NETWORKS

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## Abstract

Robots are commonly used and developed for different purposes in various areas such as research, educational, commercial, and industrial fields, also in emergency situations and space missions in today's modern world. Robots are the machines that increasingly gain the importance with each passing day by the development of micro-electronics and micro-mechanics industry. To define a machine as a robot, it needs to have the sensors to check its environment; the mechanisms to evaluate the information received from these sensors and to transfer to the processing units.

In this study, an intelligent controlled line follower robot was developed. Proportional-integral-derivative (PID) method was used for controlling. According to the information from the sensors, the method applied to the engines as Pulse Width Modulation (PWM). Online Fez Panda II embedded system board was used as the control element. This board has a 2-bit ARM 7 (Acorn RISC Machine) processor and it is suitable to .Net Micro Framework Technology. The system software was written with C# programming language in Visual Studio 2010 platform.

The robot was tested on 3D indoor network, and has potential to be used for evacuation process on extraordinary situations in buildings. Another usage areas of this robot are factories and production lines. 3D network analyses and navigation applications could also be performed using the lines on the ground of this kind of environment.

**Keywords:** *PID controlled; robot design; 3D Network; indoor; line follower*

## 1. Introduction

The need for the human labor force has declined in many areas with today's technology. Things that were supposed to be done by human beings are done by smart devices. These devices are reducing

the cost and have become functional in quality controlling and production. Robots are everywhere in industry and daily life and the need for thinking devices is always increasing. The tracking robot created within the scope of this project tracks a white line on a black platform.

Line tracking robots are one of those difficult ones. Their coordinates are variable since they are not fixed to a surface and even a slight deviation can lead to faulty processing of data and therefore to a wrong decision

Lines are important issues but they are seen as a problem in real world. Controlling algorithms can be used in order to solve the problem, track at a high speed and arrive at the correct target.

PID (Proportional-Integral-Derivative) controlling is widely used in modern industry and can be applied into linear and non-linear systems, and is the most well known and widely used controlling method. It is a controlling device that combines superiority of three basic controlling impacts. In the integral effect, possible permanent case error is zeroed and in the derivative effect consistency and response speed increase. According to this, PID controlling method is an active and widely preferred controlling practice that resides zero permanent case error, that enables the system to respond consistently and fast and that combines the cons of P and PI control [1].

In this study, a tracking was carried out using PID controller, which is widely used in the industry. The line in the middle of the path was tracked by eight sensors. Six sensors control the lines on the side of the path. Among these six sensors, three of them control the lines on the right while the other three control the ones on the left.

## 2. Material

In this study, a FEZ Panda II development card with ARM processor, QTR-8 optical sensors, L298N motor driver integration as well as current regulator was used.

### A. Development Card

ARM processors are widely used in robotics, automation and consumer electronics and contribute to the development of these areas. In this study, a Fez Panda II framework supported development card with an ARM 7 processor was used as controlling element. The development card produced by GHI works at 72 Mhz and contains an LPC2387 microcontroller. 32-bit ARM 7 micro controller has a memory of 512 Kb. Moreover, programs can easily be installed into this controlling element using Visual Studio 2010 with C# language. That the processor enables access to its own recorders makes it possible to write comprehensive code [2]. Fez Panda II development card can be seen in figure 1 and input pins of the card can be seen in figure 2.

Microsoft developed .Net Framework under the name of Smart Personal Object Technology (SPOT). Microsoft's .Net Framework provides more options and designs for engineers and programmers who deal with embedded systems as well as C# and Visual Studio. Contrary to Windows CE (Compact Edition) and other embedded systems, .Net Micro Framework can be used in ARM7, ARM9 and Blackfin processors with lower power consumption and lower cost. Micro Framework requires only a couple of KByte Ram and Flash/Rom memory. .Net Micro Framework presents C# language for programming. Due to the fact that C# language is an easy-to-learn language and it is based on C, it is preferred by programmers more and more. .Net Micro Framework, which is a suitable architecture for embedded systems, is used extensively. Companies designing embedded system development cards has accelerated developing cards compatible with Micro Framework.

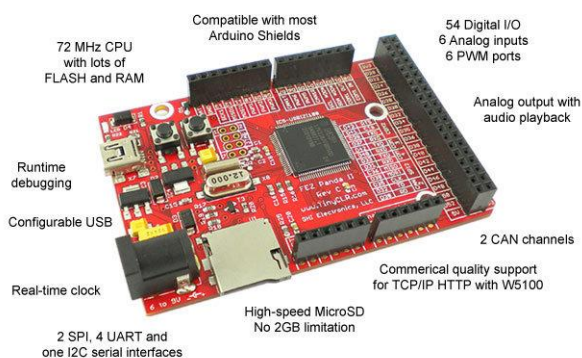


Fig. 1. Fez Panda development card[2]

### B. Sensing Unit

In this study, QTR-8A length sensing sensor was used as the sensing unit. This sensor card designed for line tracking robots has 8 IR LED/Phototransistor pair located in 1cm difference. Since it works consistently, it is preferred for robots.

Each sensor on the card provides a different resistance. A pull-up resistance is connected to each sensor. The voltage changes depending on the reflection of the floor and the distance between the objects. The voltage increases while the reflection increases. QTR-8A Sensor Card can be used in proximity and object sensing sensor apart from line tracking robots. Below is the presentation of support, earth and outputs of QTR-8A sensor.

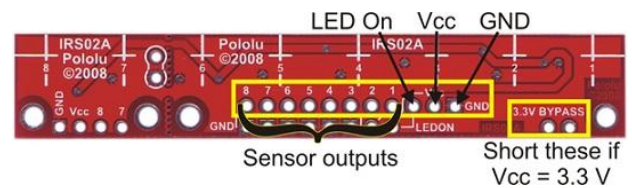


Fig. 2. QTR-8A sensor[3]

### C. Motor Driver

In the study, L298N was used as the motor driver integration. L298 is motor driver integration. It is resistant to high voltages when compared to L293. While L293 can only resist up to 0.5 amperes, L298 can resist up to 2 amperes. Therefore, it is preferred in the circuits. There are 2 H bridges in L298. H Bridge is a useful method to use the DC motor in both directions. It is done by keying method of 4 transistors. It is named after the shape that it looks in the shape of letter H.

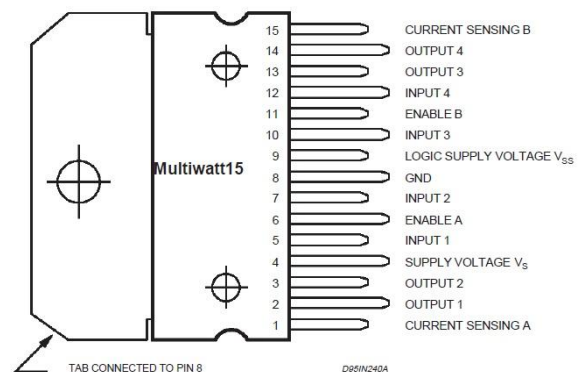


Fig. 3. L298N pin structure.

### D. Voltage Regulator

The basic element used in current regulator is LM7805. LM7805 can lower the 12V input to 5V with 1A. The electrolytic buffer capacitors parallel connected to the input (Vin) and output (5V) of the voltage regulator filter the electrical noise at the entry and output. The mini capacitor parallel connected to the output filters the output voltage and provides with a smooth and filtered 5V.

### E. Decision Making System

What the line-tracking robot needs to control is to find the direction of the line [4]. How the robot should be directed depending on the sensing of black and White surface is explained here.

The decision making process is realized by the assessment of sensor's conditions. Probable conditions of the sensors are as below:

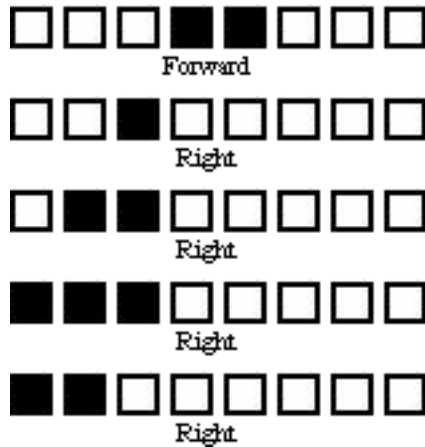


Fig. 4. Location of the Right Sensors

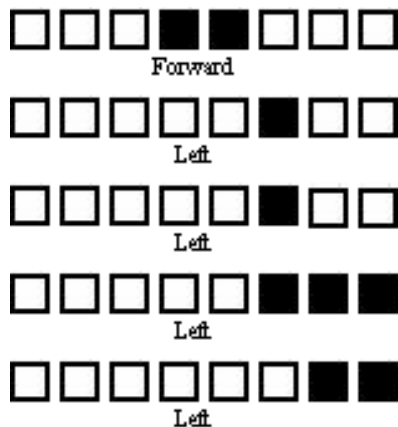


Fig. 5. Location of the Left Sensors

### F. Movement System

The most preferred driving system in line tracking robot projects is the differential driving system. In this system, there are motors on the right and the left of the robot independent from each other and wheels connected to them. Generally, an engine and a wheel on both sides are used for cost effectiveness. In such usages, for a better movement and turn of the robot, a roll-on wheel is used either in the front or at the rear depending on the wheels. Various locations of the wheels and the motors can be seen as follows[5]:

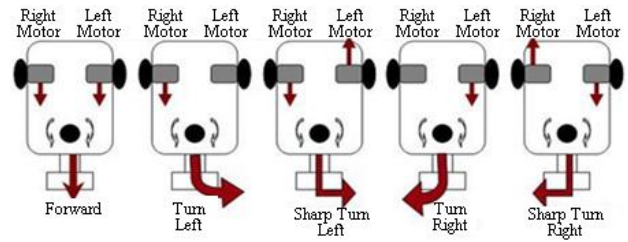


Fig. 6. Differential Driving System

## 3. Method

### A. PID Controlling

PID is an acronym for Proportional Integral Derivative. These terms explain the three basic mathematical functions applied to the error. The main task of the PID controller is to minimize the error whatever the condition is. It gets an input, calculates the targeted behavior derivation [6].

PID is a widely used control method. It is practiced in the 75% of the industrial practices. Although there is a wide range of application areas, there is no standard explanation for PID applications. According to Karl Astrom, the PID algorithm is as follows[6]:

$$U(t) = K \left[ e(t) + \frac{1}{T_i} \int_0^t e(T) d(t) + T_d + \frac{de(t)}{d(t)} \right] \quad (1)$$

$$e(t) = r(t) - y(t) \quad (2)$$

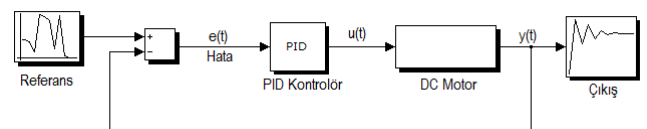


Fig. 7. Inside of a PID block

### B. Modelling PID Control in Matlab Simulink Environment

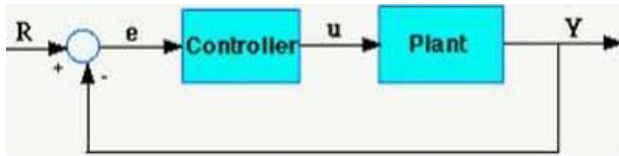


Fig. 8. Feedback system

Plans provides the system to control and the Controller provides stimulus for Plant as the controller. It is designed to control the system behavior.

If we need to study how the PID controller with a closed loop system in Fig.8, variable shows the tracking error (e), namely the difference between input value (R) and real output value (Y). This error (e) send the signal to the PID Controller and the controller computes the derivation and integral of this error.

$$U = K_p e + K_r \int_0^t e dt + K_d \frac{de}{dt} \quad (3)$$

(u) signal is sent to the system being controlled and new output (y) is obtained. This (y) output signal is sent back to the sensor and new error signal (e) is found. The controller applies the same procedures to the new error signal and this process goes on. Below is the PID output signal.

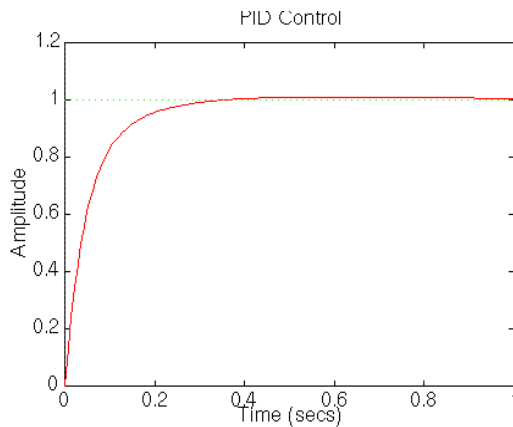


Fig. 9. PID output signal

## 4. Method

### A. General Structure of the Robot

QTR-8A sensor is used so that the robot can sense the line on the path. The sensor makes color sensing by looking at if the ray it sent is reflected or not. The output of the sensor is read by the digital input of the

development card. Below is the block diagram of line tracking

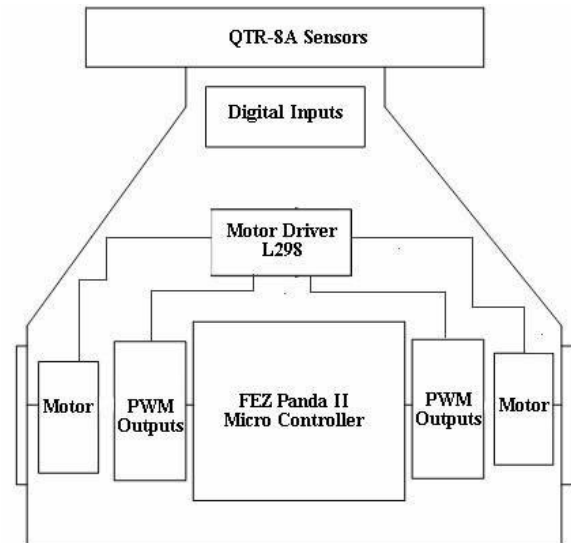


Fig. 10. Block Diagram of Line Tracking

As seen on the block diagram of line tracking, the information coming out from the sensors' output is evaluated in Fez Panda II micro controller according to the location information and is transferred to PWM outputs of the micro controller as speed information. The output of the micro controller forwards this information of L298N motor driver and leads to the movement of the robot.

### B. System Software

In the algorithm, developed in order that the line tracker can complete the path shortly and that it does not deviate from the line, sensors are read depending on the time. According to the information, PID value is produced. The PID value, on the other hand, constitutes the PWM value to be loaded to the engine. The PWM value reduces depending on the bending of the lines at the turning points on the runway. Thus, the tumbling at sharp curves is prevented. Below is the developed software flow chart for the line tracking robot [7].

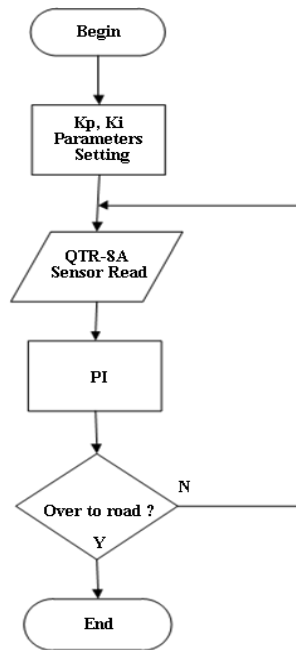


Fig. 11. PID flow chart

The robot was tested on 3D indoor network, and has potential to be used for evacuation process on extraordinary situations in buildings. Another usage areas of this robot are factories and production lines. 3D network analyses and navigation applications could also be performed using the lines on the ground of this kind of environment.

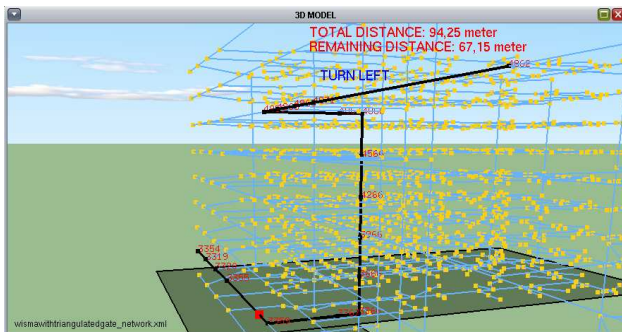


Figure 1. Routing simulation process for an evacuation robot in 3D environment

## 5. Conclusions

Robots need signs distinguishable from the place and sensors sensing these signs in order to go from one point to another via a path. In this project, a two-wheeled robot was produced; color difference technique was used as a sign so that the robot can proceed from one place to another by using a white band on black surface.

In the PID algorithm,  $K_p$  and  $K_i$  parameters were found by trial and error. During the trials done on a

circular runway the  $K_p$  and  $K_i$  parameters were tried till the best value was obtained.

This study can be converted into a prototype of a vehicle for load carrying tasks in the industry. Load carrying tasks can be achieved by robots by having a white band on black surface so that the robots can follow to go from one place to another. Due to the various specifications of Fez PANDA II development card, the robot can be moved according to an image file that can be loaded on a Micro SD card as a map. Moreover, the line tracking can also be achieved by using cameras rather than sensors.

In the project, a line tracking robot was produced. In the future studies, it is aimed to develop the current study by using different algorithms for line tracking, by imaging the path on an LCD panel located on the robot and by drawing the path using a Micro SD card.

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