IMPLEMENTING PID CONTROLLER FOR A MOBILE PLATFORM

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Abstract: This paper presents the steps taken to develop and tune a PID controller for a mobile platform built in the Department of Industrial Machinery & Equipment, of the Engineering Faculty of Sibiu. In a first phase, a brief description of the mobile robot is presented, followed by a description of the various principles underlying the tunning of a PID controller for a mobile platforms. At the end the paper contains several principles describing how to implement the PID controller onto the mobile robot.
Keywords: mobile robot, PID controller

1. INTRODUCTION

With the advent of the mid twentieth century computers start a new industrial revolution. The key element is the image of robots and computers. This appearance leads to a rapid development of computers and robots [1], [2].

The fascination for new of people is known from ancient times. At first humans had a distrust in these new technological breakthroughs. Now the robot is becoming more known and more appreciated for high performance and advantages it presents. Means of modern transportation, electronics and appliances and everything begins to mark the style of life will become automatic, robotic and autonomous [1], [2].

The next step in the new industrial revolution will be using robots in all the areas.

Robots will reach the ability to mimic any human action. Already there are many areas where robots have replaced humans. The more complex robots today are those used by NASA in space exploration. Humanoid robots designed by NASA for future space missions will be the most highly trained astronauts and will be deployed in areas that pose a particular risk to astronauts in the flesh.

2. MODELING OF THE MOBILE ROBOT

Mobile robots is a rising research topic. Originally used in defense department's projects from the army, and then in the industry as a autonomous guided vehicles, mobile robots are newer highlight of mankind XXI century.

To define a robot vehicle, we must first make a reference to one of the basic definitions of a robot, "a mechanical device that can be programmed to perform certain tasks that are given them by automatic control." [3].

An intelligent mobile robot is supposed to be a type of autonomous mobile vehicle that is able to independently plan its own route and navigate through obstacles to reach its specified destination. There is no human input or intervention. Applications range among civilians (automatic cars), industrial (cooperative mobile robots in factories), military (unmanned vehicles to destroy enemy target) and fun (soccer player robots) usages [4].

The proposed control system is shown in Figure. 1. The control system consists of a PID controller, the kinematic model of mobile robot, a reference trajectory generator and two encoders which provides odometric information. In this section the kinematic model of mobile robot with differential drive and convergence conditions of overall control structures are described. Design of PID controller will be presented in the next subsection.

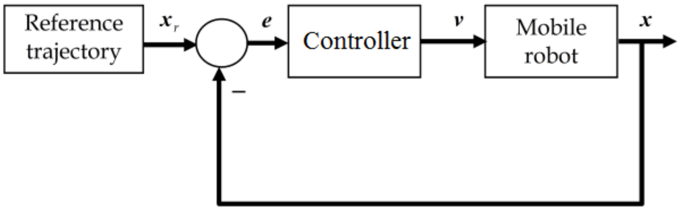

Fig. 1. Mobile robot motion control system.

Modeling of the mobile robots and especially the dynamic model of mobile robots have received a great deal of research in recent years. A significant amount of research has been published in many aspects related to mobile robots. Most of the research is devoted to design and develop some control techniques for robot obstacle avoidance and path planning are from the most important problems in mobile robots, especially in unknown environment. Methods such as obstacle avoidance are inspired from the nature, and have been developed by fuzzy logic to train an intelligent robot in unknown environment [5].

The mobile robot considered here is shown in Figure 2.

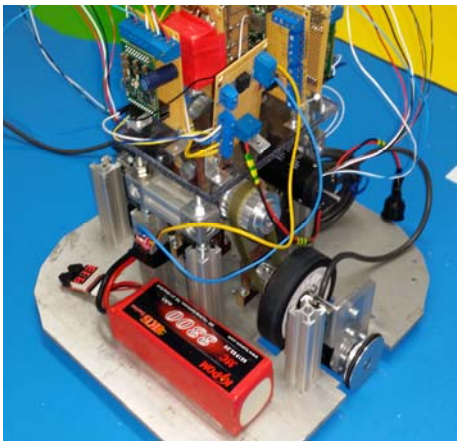

Fig. 2. MEI mobile robot.

The model of the robot has two driving wheels and the linear velocity and azimuth of the two wheels are independently controlled using PID controller. Inputs are obtained from digital encoders mounted on it Figure 4.

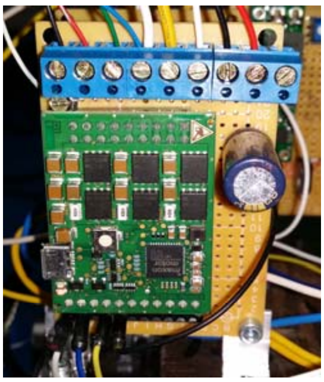

Fig. 3. MAXON driver

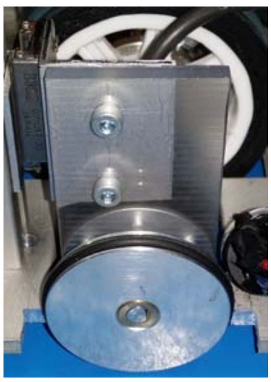

Fig. 4. Digital encoder.

However, dynamic modeling of mobile robots is very important, as they are designed to travel at higher speed and perform heavy duty work. This paper uses dynamic model and propose a control strategy for wheeled mobile robot [6].

It consists of a vehicle with two driving wheels mounted on the same axis, and a front passive wheel for balance. The two driving wheels are controlled independently by motors Figure 5.

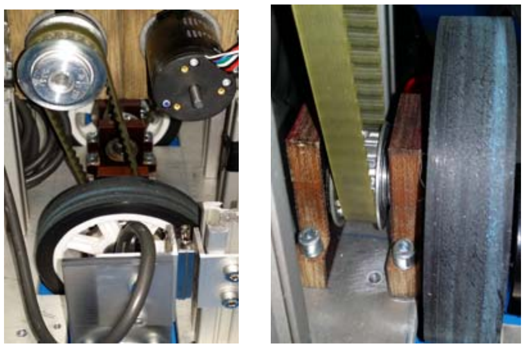

Fig. 5. Robot transmision.

2.1. Kinematic model of mobile robot

In this paper the mobile robot with differential drive is used Figure 6.

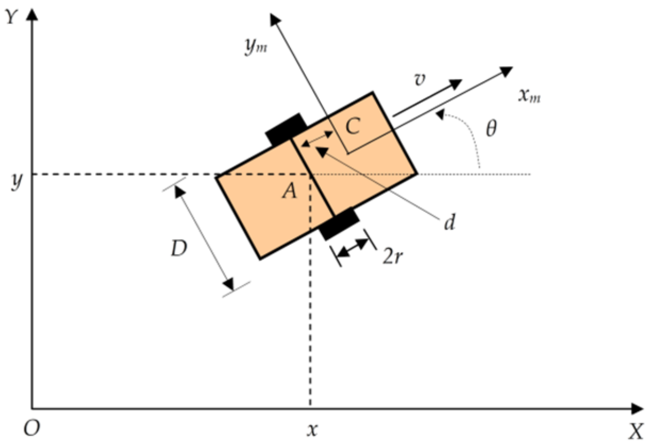

Fig. 6. The representation of a differential drive mobile robot.

The robot has two driving wheels mounted on the same axis and a free front wheel. The two driving wheels are independently driven by two actuators to achieve both the transition and orientation. The position of the mobile robot in the global frame $\{X, O, Y\}$ can be defined by the position of the mass center of the mobile robot system, denoted by C, or alternatively by position A, which is the center of mobile robot gear, and the angle between robot local frame $\{x_m, C, y_m\}$ and global frame [7].

Kinematic equations of the two-wheeled mobile robot are:

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos(\theta) & 0 \\ \sin(\theta) & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix} \tag{1}$$

and:

$$\begin{bmatrix} v \\ \omega \end{bmatrix} = \begin{bmatrix} r & r \\ \frac{r}{D} & -\frac{r}{D} \end{bmatrix} \begin{bmatrix} v_R \\ v_L \end{bmatrix} \tag{2}$$

where x and y are coordinates of the center of mobile robot gear, θ is the angle that represents the orientation of the vehicle, v and ω are linear and angular velocities of the vehicle, v_R and v_L are velocities of right and left wheels, r is a wheel diameter and D is the mobile robot base length.

Combining equations (1) and (2) yields:

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} r\cos(\theta) & r\cos(\theta) \\ r\sin(\theta) & r\sin(\theta) \\ \frac{r}{D} & -\frac{r}{D} \end{bmatrix} \begin{bmatrix} v_R \\ v_L \end{bmatrix} \tag{3}$$

Inputs of kinematic model of mobile robot are velocities of right and left wheels v_R and v_L .

The constraint that the wheel cannot slip in the lateral direction is:

$$\dot{x}\sin\theta + \dot{y}\cos\theta - d\dot{\theta} = 0 \tag{3}$$

The stability conditions of mobile robot system with PI controller will be investigated in the next subsection.

2.2. Convergence condition of control system

The feedback control system of mobile robot is shown in Figure 7.

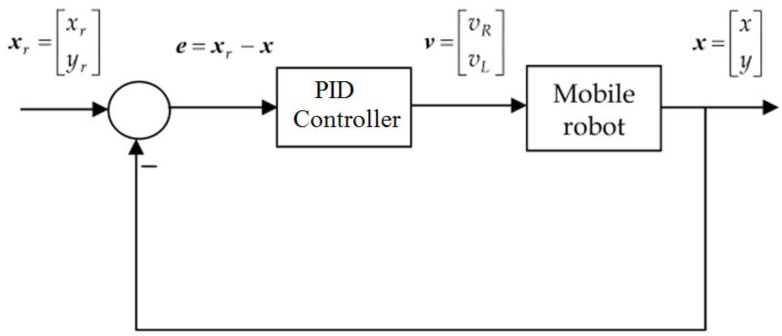

Fig. 7. Mobile robot control system.

3. PID CONTROLLER IMPLEMENTATION

To develop, tune and test the PID controller MATLAB and Simulink software was used. In Figure 8 the entire Simulink model of the robot and the controller is presented. For a better tunning of the PID controller a CAD model of the mobile robot is created under SolidWorks, to replicate the dynamic model of the mobile robot . The Simulink model for the DC motor is presented in Figure 9.

The DC motors used to drive the robot are POLOLU 50:1 Metal Gearmotor 37D × 54L mm with 64 CPR Encoder. This 66.5mm × 36.8mm × 36.8mm gear motor is a powerful 12V brushed DC motor with a 50:1 metal gearbox and an integrated quadrature encoder that provides a resolution of 64 counts per revolution of the motor shaft, which corresponds to 3200 counts per revolution of the gearbox's output shaft. These units have a 15.5 m -long, 6 mm-diameter D-shaped output shaft. This gearmotor is also available without an encoder. Key specs at 12 V: 200 RPM and 300 mA free-run, 12 kg·cm and 5 A stall.

For PID controller tuning we used the Ziegler–Nichols tuning method. This is a heuristic method of tuning a PID controller. It was developed by John G. Ziegler and Nathaniel B. Nichols. It is performed by setting the I (integral) and D (derivative) gains to zero. The "P" (proportional) gain, K_p is then increased (from zero) until it reaches the ultimate gain K_u, at which the output of the control loop oscillates with a constant amplitude. K_u and the oscillation period T_u are used to set the P, I, and D gains depending on the type of controller used [8].

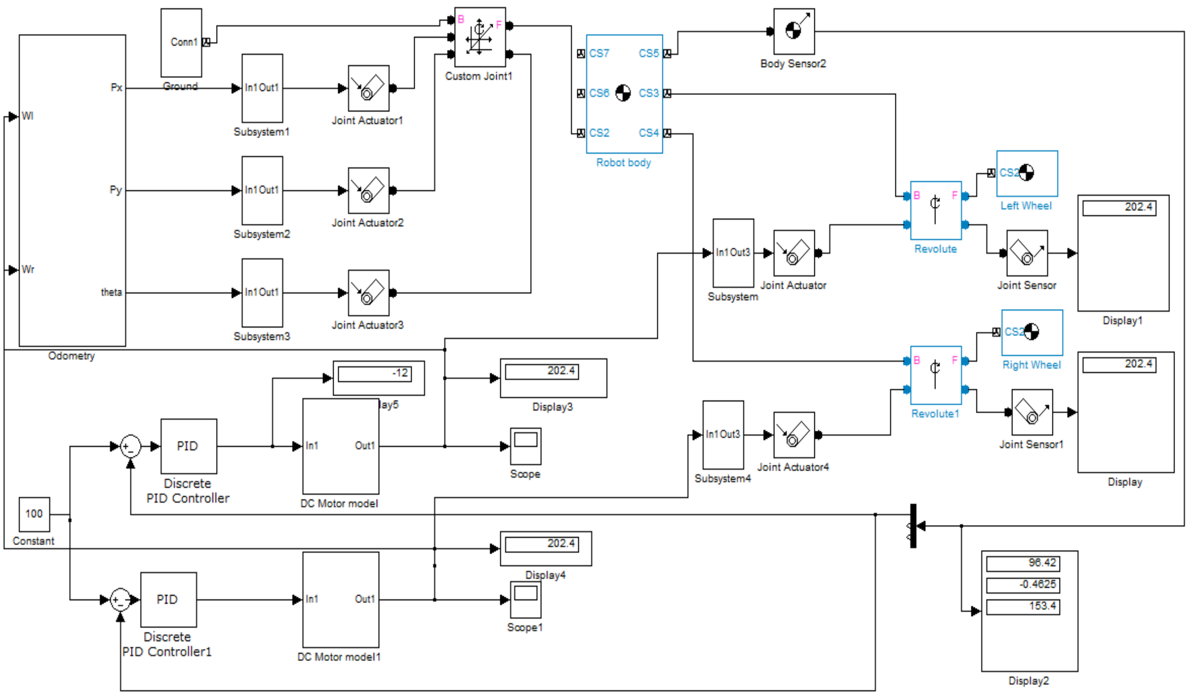

Fig. 8. Block diagram for tuning and testing the PID controller.

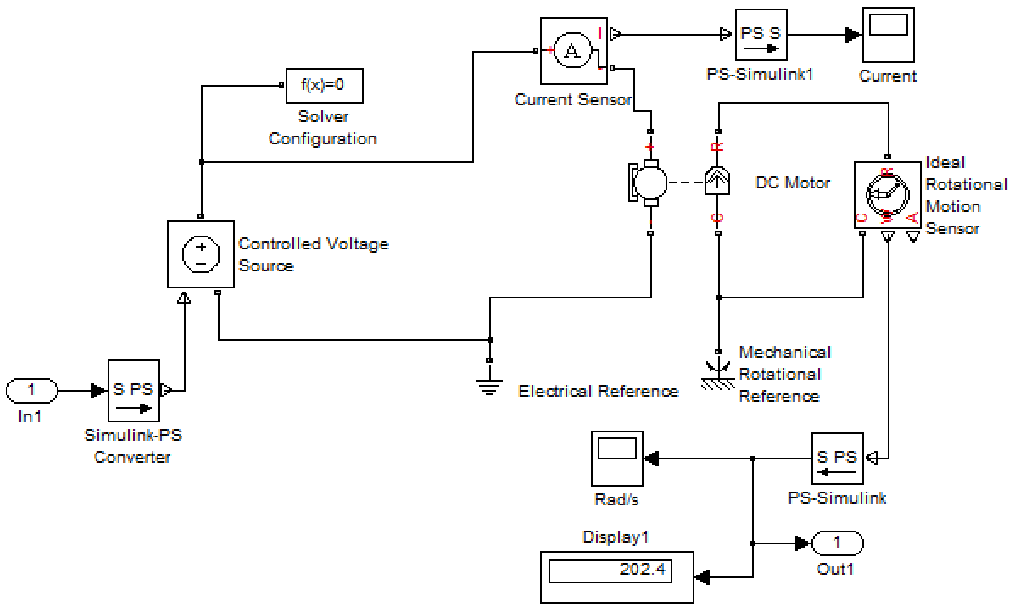

Fig. 9. Bock diagram for the DC motor.

CONCLUSIONS

This work deals with the modeling and control strategies of the motion of wheeled mobile robots. A new control scheme is developed for the mobile robot motion in an unknown environment. This work revealed the success of the proposed PID control scheme for robot navigation in unknown environment as shown in the simulation results in Figures 10. Also results show that using such control scheme , the mobile robot can effectively achieve many tasks.

The best results after the PID controller tuning are presented in Figure 10.

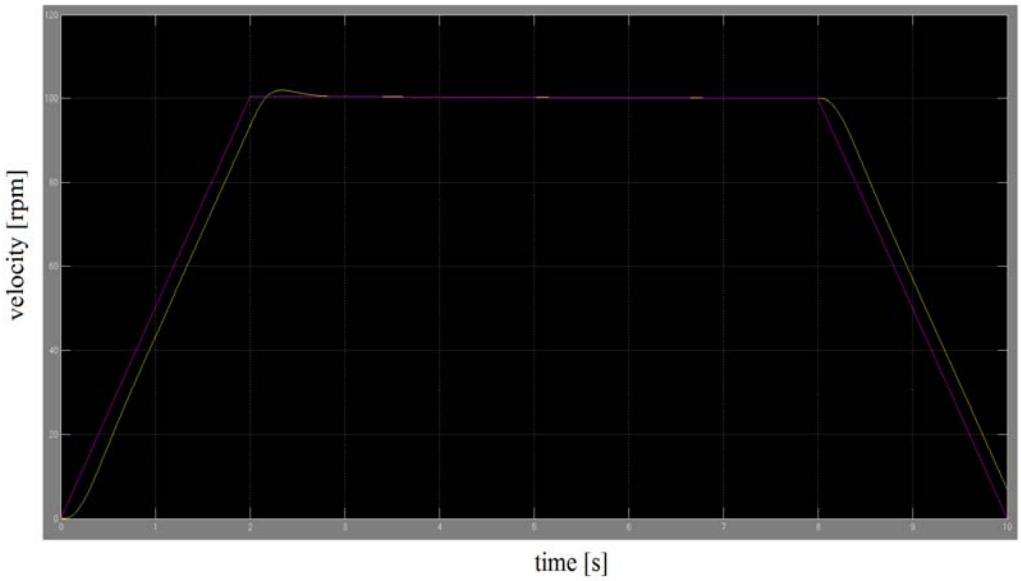

Fig. 10. Results after PID implementation for robot drive Kp = 0.5, Kd = 3.

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IMPLEMENTAREA CONTROLERULUI PID PE O PLATFORMA MOBILA

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Rezumat: Lucrarea de faţă prezintă paşii parcurşi în dezvoltarea unui controler PID pentru o platformă mobilă, construită în cadrul Departamentului de Maşini şi Echipamente Industriale al Facultăţii de Inginerie din Sibiu. Într-o primă fază este prezentată o scurtă descriere a cinematicii robotului mobil, urmată de descrierea diferitelor principii ce stau la baza controlerului PID implementat. Finalul lucrării conţine câteva principii legate de odometrie precum şi descrierea părţilor componente ale robotului mobil dezvoltat.