Real-Time Speed Control of a Mobile Robot Using PID Controller

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Abstract. This paper presents PID control of speed implemented by PC on a unicycle mobile robot. The designed control has been applied to a non-holonomic mobile robot dr Robot i90. The results obtained from the experiment show the efficiency of this strategy control, even in the case where we introduce a disturbance for the system such as for example putting an overload for the robot

Keywords: Real-time speed control, Non-holonomic mobile robot, PID Controller.

1 Introduction

The key aspect of the mobile robot is its mobility; however its movement performance strongly affects the performance of the spots. Robots are designed to perform specific tasks in a dangerous and hostile environment. That is why it is important to move at an exact and well defined speed according to the task and the environment.

In recent years, researchers have shown increased interest in the field of mobile robot. Much of the greater part of the literature on robotic has emphasized the importance for path following [1][2] [3] and [4], obstacle avoidance in[5] [6] and [7], speed control[8] [9] ,design and modeling[10][11] [12] [13] [15] and[15],map building[16][17],a large part of the previous works applied in simulation. But the real system never responds in the same way and few study are processed in real time and the material limitation is not taken into account such as, the limitations of the dc motors (currents, voltages, torque, and velocities), the inertia of robot, and the topography of the environment. PID controller consists of three terms; proportional, integral and derivative control. The combined operation of these three controllers gives control strategy for process control.

Our work consists on the application of the PID regulator for the speed control of mobile robot dr robot i90.This paper begins by mobile robot description in section 2. The third section presents the modeling of the mobile robot. Control system description is discussed in section 4. Section V presents experimental approach and gives results. The final section gives a brief summary and discussion of the findings of this work and proposes future pursuit.

2 Mobile Robot Description

Dr Robot i90 is a sophisticated tool for researchers with completely wireless connection for developing advanced applications in robotics, such as remote monitoring of different environments, location for navigation and autonomous patrol and various features.
This robot is a light system, weighing 5 kg, but can carry an additional payload of 15 kg. It is 43 cm wide, 38 cm long and 30 cm high, and has high-resolution camera. Its maximum speed reaches 75 cm per sec. This robot is equipped with two DC motors for making the robot move through its environment, and integrated quadratic encoders placed on the driving wheels which provide a measure of incremental angles over a sampling period [18] [19].
The driving pilot element of dr Robot i90 is the PMS5005 robot card, conceived to work as a component of the WiRobot system. It contains built-in firmware to be used for implementing closed loop position, velocity sensor, data acquisition and wired and wireless communication. Programs running on PC can communicate with the PMS5005 firmware using WiRobot software development kit [20] [21]. Fig.1 shows views of the robot.

Fig. 1. Front and side views of mobile robot.

3 Modeling of the mobile Robot

3.1 Kinematic model

The robot used is a wheeled platform, which can move thanks to two steering wheels located at the rear. The front wheel is a caster wheel. Its role is to maintain the platform in balance. The kinematic equations that express the motion of a robot moving with a linear velocity ν and an angular velocity ω are given in equation(1)

$$\begin{cases} \dot{x} = v\cos\theta \\ \dot{y} = v\sin\theta \\ \dot{\theta} = \omega \end{cases} \qquad (1)$$

x and y are Cartesian coordinates of the center of the robot gear , θ is the orientation angle, ω and ν represent angular and linear velocities respectively [15]

3.2 Actuation model

The actuation model consists of the representation of the robot's speed as a function of the driving wheel speeds and the geometric parameters of the robot [12]..

$$\boldsymbol{v} = \frac{\boldsymbol{v_r} + \boldsymbol{v_l}}{\boldsymbol{2}} \tag{2}$$

$$\boldsymbol{\omega} = \frac{\boldsymbol{v_r} - \boldsymbol{v_l}}{\boldsymbol{L}} \tag{3}$$

L is the distance between steered wheels, v_r and v_l are velocities of right and left wheels representing inputs of the kinematic model[15].The motion of a differential driving robot is characterized by two non-holonomic constraints, obtained by two main hypotheses:

Hypothesis I:

No lateral slip. It simply means that the robot cannot move laterally in its local coordinate system, which is mathematically translated by the equation:

$$\dot{y}_{robot} = 0 \tag{4}$$

Hypothesis II:

The pure rolling constraint represents the fact that each wheel maintains a point of contact P with the ground. There is no slippage of the wheel in its longitudinal or its orthogonal axis.

4 Control system description

PID correction is a closed-loop control and is most common in industries and academic research because it is easy to implement while achieving good performance. The PID control law consists of three basic actions; proportional, integral and derived. The objective of feedback control is to reduce the error signal; the difference between the measured value of the velocity and the reference speed. The proportional action is to generate an action that varies proportionally to the error signal [22]. The advantage of the integral controller is that it eliminates the regulation error which persisted with a proportional regulator alone [22]. The derived action makes it possible to anticipate the future variations of the measurement signal by applying a proportional action to its rate of variation. The derived action has a predictive effect [22].A PID controller calculates the error value as the difference between a measured process variable and a desired value .Figure 2 shows the control scheme

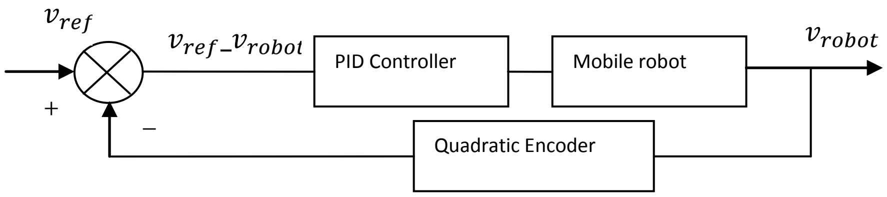


Fig.2.PID Control scheme

The output of the PID controller is given by equation (5).

$$Output = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \qquad (5)$$

K_p , K_d and K_i are the proportional, derivative and integral parameters of the PID controller and e is the error, it is the difference between the reference speed and the measured speed [23].

The PID regulation consists in the choice of the regulator parameters in such a way as to reduce the error to zero and to keep the system fast and stable. For the choice of the coefficient of the regulator we cannot apply Nichols-Ziegler because for this approach the system must be already regulated in closed loop and the fact of bringing the system to an oscillatory state risks destroying our robot. For this we proceeded to follow the flowchart given in figure 3 to design our PID regulator.

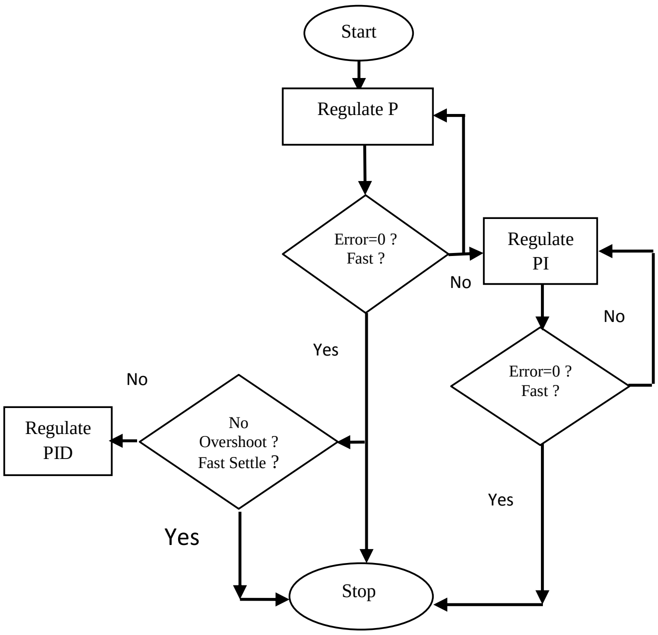
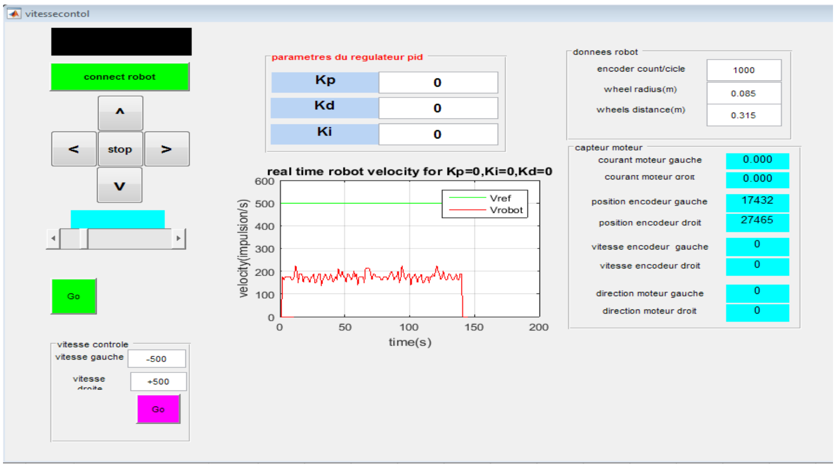


Fig.3.PID controller design process

5 Experimental Results

This application is implemented using Matlab, and tested on real robot system in indoor environment using dr Robot i90. Matlab allows building these interfaces thanks to GUIDE (Graphical User Interface Development Environment). This tool is able to build high level applications. A graphical interface makes it possible to control an application interactively with the mouse rather than by launching the commands with the keyboard. It also makes it possible to click on images, graphs or objects to modify the value of a variable, to release functions or simply to make the information appear. The User Interface created for this work is shown in Fig .4



parametres du regulateur pid

Kp 0

Kd 0

Ki 0

donnees robot

encoder count/cicle 1000

wheel radius(m) 0.085

wheels distance(m) 0.315

capteur moteur

courant moteur gauche 0.000

courant moteur droit 0.000

position encodeur gauche 17432

position encodeur droit 27465

vitesse encodeur gauche 0

vitesse encodeur droit 0

direction moteur gauche 0

direction moteur droit 0

vitesse controle

vitesse gauche -500

vitesse droite +500

Fig.4. Control user interface

In the first time we tested the robot with all coefficients equal to zero and for two values of speed reference, 100pulse per second and 500pulse per second. We noticed that the speed for both cases is far from the desired speed with a very unstable system, results are shown in Figure.5 for $v_{ref} = 100 impl/s$ and $v_{ref} = 500 impl/s$ in Figure.6

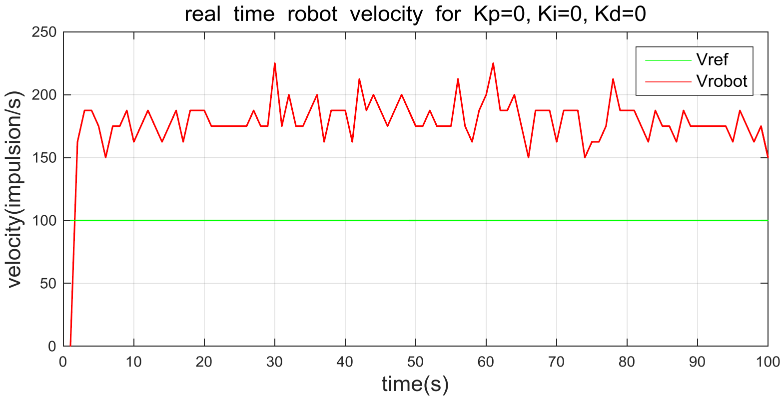


Fig.5. Speed control with $K_p = 0$,$K_d = 0$ $and K_i = 0$ for $v_{ref} = 100 impl/s$

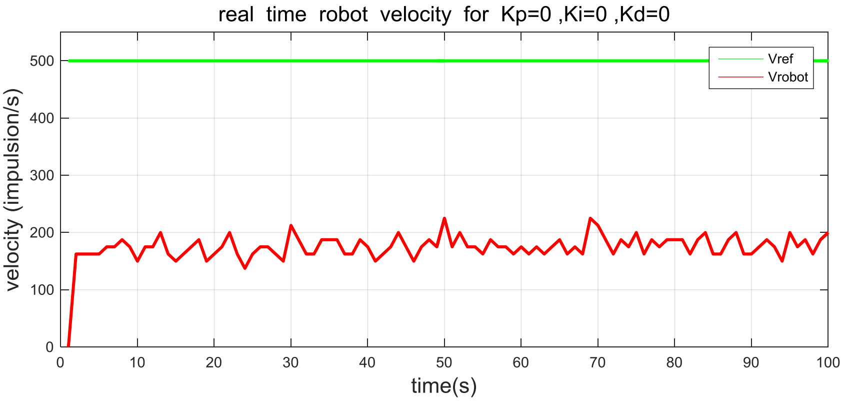


Fig.6. Speed control with $K_p = 0$,$K_d = 0$ and$K_i = 0$ for $v_{ref} = 500 impl/s$

For the choice of our parameters we proceeded as follows: We have increased the value of Kp keeping the value of Ki and Kd equal to zero We noticed that the speed is far from the reference but it becomes more stable for a value of Kp = 5.After, we proceeded to increase the value of Ki keeping the value of Kd equal to zero and we reached the speed reference for Ki = 5 and for the values of Ki> 10 we note the existence of overflow and the robot becomes unstable. We have opted for the choice of the value of Kd in the same way for a value of Kd = 2 and we notice that the system loses its stability by increasing Kd with overruns of the speed reference. We noticed that the effect of our regulators on the response time of the system is insignificant since our robot responds very quickly to the order of a few seconds. Figure (7) and (8) show the results for well-chosen parameter values and Figure (9) shows results for poorly chosen parameters.

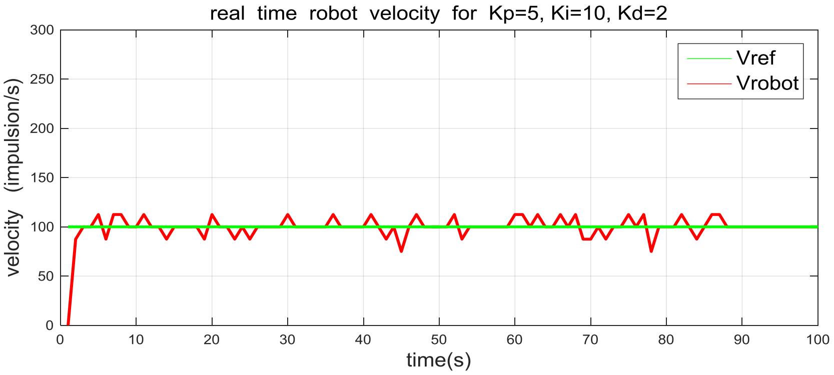


Fig.7. Speed control with $K_p = 5$,$K_d = 2$ and$K_i = 10$ for $v_{ref} = 100 impl/s$

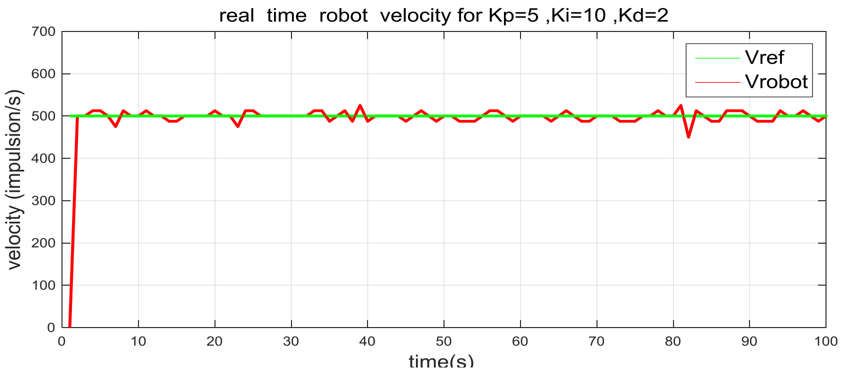


Fig.8. Speed control with $K_p = 5$,$K_d = 2$ $and K_i = 10$ for $v_{ref} = 500 impl/s$

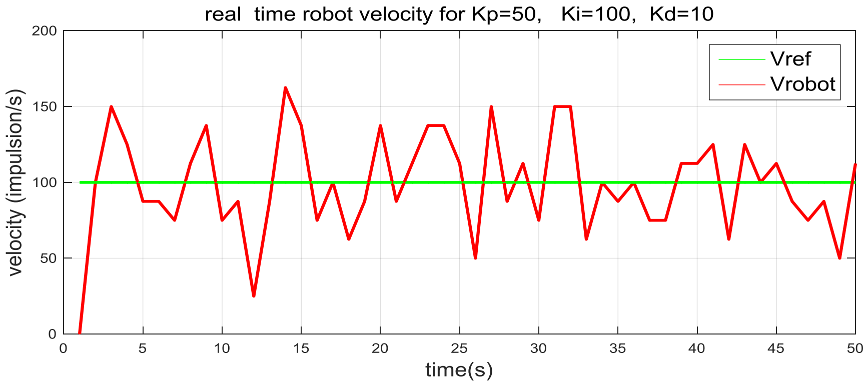


Fig.9. Speed control with $K_p = 50$,$K_d = 10$ $and K_i = 100$ for $v_{ref} = 100 impl/s$

In the last test we did not realize the test for $v_{ref} = 500 impl/s$ for not cause damage for our robot.

6 Conclusion

In this paper we have proposed a controller that can be applied to a large class of system. The application of this command on a non-holonomic mobile robot (real robot) made it possible to highlight the control with PID

The PID controller mode has consequences if one mode dominates. Excessive proportional action causes a faltering, excessive integral action causes overshoot, and excessive derivative action causes an oscillation.

In this work we try to improve the speed performance of the robot i90 and we implement the regulator PID without calculation but by changing PID parameters while trying to keep our system stable and healthy but the application of a fuzzy regulator for the choice of these parameters may be a better solution

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