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Development of Fuzzy PID Controller for Mecanum Wheel Robot

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Abstract

Mecanum wheels increase the capability of a robot to move directly from any configuration in a culled direction. In recent years, due to its flexible mobility, Mecanum wheels have been used in galactic applications with a common plan. Mecanum wheeled robots are three-or four-wheeled in gathering composed predicated on the adaptability to work in a workspace. As far as robot speed control, numerous analysts have created distinctive control calculation, for example, PI, PID and fuzzy logic controllers to name a couple to pass a control flag to accomplish a coveted celerity. Be that as it may, the subsisting frameworks still have issues as far as time replication, vigor and mistake rate. In this way in this examination work, a Fuzzy PID controller for a straightforward Mecanum wheeled robot is created and spoken to in Matlab/Simulink for evaluating its execution. The reenactment model of the Mecanum wheel has been set up with Direct Present (DC) engine gathering using Matlab/Simulink. Four Mecanum wheel models fastened with four DC engines and single Fuzzy PID controller controls each engine. The fuzzy inference engine uses the triangular enrollment work inputs and the fuzzified contribution to broke down using Mamdani. Assist, the yield is de-fuzzified, and a control flag sent to the DC engine. The proposed framework has a superior execution contrasted and the subsisting control calculations, with decreased overshoot rate and settling time

Keywords: fuzzy PID; Matlab/Simulink; Mecanum Wheel; Dc-Motor;PID

INTRODUCTION

The Mecanum wheel also known as Ilon wheel is one plan for a wheel with a progression of rollers attached to its border. The mecanum wheel predicts the guideline of a focal wheel with various rollers put at a point around the outskirts of the wheel which can move toward any path [1].In late years, the Mecanum wheels have been used in mechanical technology, industry, and coordination because of their portability in tight spaces and swarmed situations forecasted with static and dynamic hindrances. Late applications in Mecanum wheeled robots are ending up plainly more injunctively approving each day because of its supplemental mobility and effectiveness. These components are picked up to the detriment of increased mechanical involution and augmented multifaceted nature in control [2]. Definitively commanding applications require an exact dynamical model with a specific end goal to endorse for exact velocity. Dynamical reenactment models are withal fundamental to concentrate the circumscriptions of current mechanical designs and to authorise for further improvements both at controllers level and at mechanical setup level [3]. The investigation of the fuzzy-PID controller for the Mecanum wheeled robot is significant as it can be actualized in numerous applications like tight spaces or swarmed conditions, for example, distribution centres, clinics, and elderly care offices [4]. This paper presents a real-time implementation of an improved Mecanum wheeled robot Using fuzzy PID controller techniques to control DC motors. The different controller has been employed and implemented in real time using Matlab/Simulink to allow a comparative study. Tests show the performance parameters under various modes of operation, and the contributions of the fuzzy PID controller..

MODELING A DC MOTOR

Wherever Times is specified, Times Roman or Times New Roman may be used. Avoid using bit-mapped fonts if possible. True-Type 1 or Open Type fonts are preferred. Please embed symbol fonts, as well, for math, etc.

Closed-Loop System Consideration

To perform reproduction of the controlled Mecanum wheeled robot with DC motor, a perfect model infers DC motor circuit chart as appears in Fig. 1

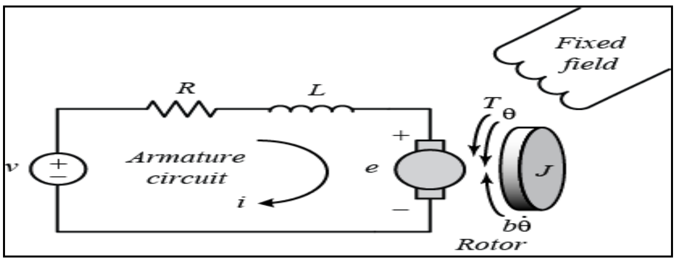

Figure 1: DC Motor Circuit Diagram

System Equation

In general, DC motor generates a torque relative to the armature current and the quality of the attractive field. Expecting that the attractive field is steady, the motor torque corresponds to armature current 'i' by a consistent consider Kt as demonstrated the condition (1). The torque alludes to an armature controlled motor.

$$T = Kti \quad (1)$$

The back emf, *e*, is proportional to the angular velocity of the shaft by a constant factor *Ke*.

$$e = Ke\dot{\theta} \quad (2)$$

In SI units, the motor torque and back emf constants are equal, that is, *Kt* = *Ke*; therefore, *K* will be used to represent both the motor torque constant and the back emf constant.

Equations (3) and (4) state Newton's 2nd law and Kirchhoff's voltage law, respectively.

$$J\ddot{\theta} + b\dot{\theta} = Ki \quad (3)$$

$$L\frac{di}{dt} + Ri = V - K\dot{\theta} \quad (4)$$

Transfer Function

By applying Laplace variables expressed by applying the Laplace transform,

$$s(Js + b)\,\theta(s) = K\,I(s) \quad (5)$$

$$(Ls + R)I(s) = V(s) - Ks\,\theta(s) \quad (6)$$

Equations (5) and (6) produces open-loop transfer function when rearranged.

$$P(s) = \frac{\theta(s)}{V(s)} = \frac{K}{(Js+b)(Ls+R)+K^2} \quad (7)$$

Table 1 represents the DC Motor specification data of V, P, W, La and Ra used in this paper.

Table I: Physical System Parameters.

Physical Quantity	Symbol	Numerical Value	Units
Voltage	V	12	Volt
Power	P	7	Watts
Motor Speed	W	7000	rpm
Inductance	La	1.21^-3	H
Resistance	Ra	2.02	Ω

Before any consideration of the equation (7), the constant values of back-emf constant (Kb), torque constant (Kt), Mecanum wheel inertia (Jw), rotor inertia (Jm) and viscous friction coefficient (B) have to be known. These values are necessary so that the control performs on the Mecanum Wheel

From the values in Table I, the data produced and shown in Table II.

Table II: Calculation Value For Dc Motor

Physical Quantity	Symbol	Numerical Value	Units
Back-emf Constant	Kb	0.0164	Vs/rad
Torque Constant	Kt	0.0164	Nm/A
Motor Speed	B	13.02^-6	Nms/rad
Viscous Friction Coefficient (Per-Unit)	Jw	8.375^-3	Vs/rad

The values in Table II are assigned in model in Fig. 2 [5]

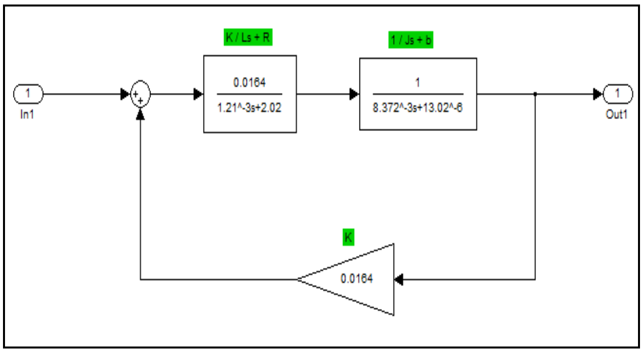

Figure 2: The Overall Block Diagram Of The System

THE PROPOSED CONTROLLER FOR DC MOTOR

Simulink Model

The controller for the DC motor using Fuzzy PID for speed control is simulated using SIMULINK as illustrated in Fig. 3.

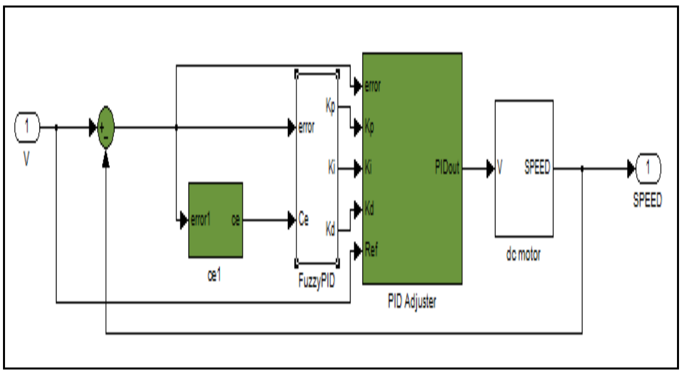

Figure 3: Block Diagram of Fuzzy PID Controller

Fig. 4 illustrates the Fuzzy PID control system with four DC motors for a simple Mecanum wheeled robot. The simulation of the Mecanum wheel is executed utilising Matlab/Simulink platform. The individual Fuzzy-PID controller measures each motor in such a way that the controller utilises the error and transmute by mistake of the DC Motor plant as its input [6-8].

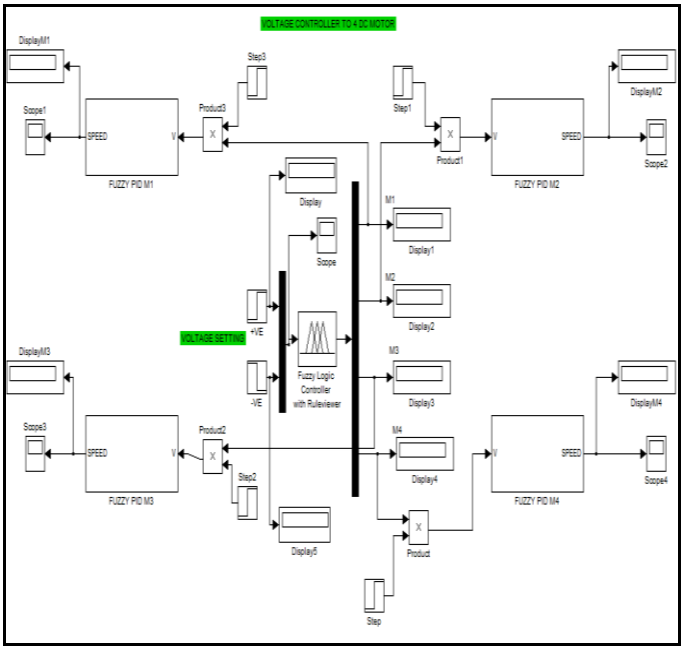

Figure 4: Fuzzy PID control system with four DC motors [12]

The fuzzy surmising motor uses the triangular enrollment work inputs, and the Fuzzyfied info is broke down utilising Mamdani sort calculation. Promote, the yield is de-fuzzified, and pass a control flag to the DC engine [9-10]. The proposed framework has a superior execution contrasted and the subsisting control calculations with lessened overshoot and settling time. Moreover, a Fuzzy basic rationale predicated demonstrate has been produced to control the heading of the Mecanum wheel robot.

Fig. 5 shows, the developed voltage controller for the DC motors. The DC Motor will turn clock insightful if the positive voltage was given and hostile to clockwise if negative volts. Six basic motions are tested as follows:

- Forward – every one of the four wheels turns forward
- Backward – every one of the four wheels turns backwards
- Right slide – wheel 1 and four backwards, wheel 2 and 3backward
- Left slide – wheel 1 and four forward, wheel 2 and three backwards
- Clockwise – wheel 1 and three forward, wheel 2 and three backwards
- Counter-clockwise – wheel 1 and three backwards, wheel 2 and four forward

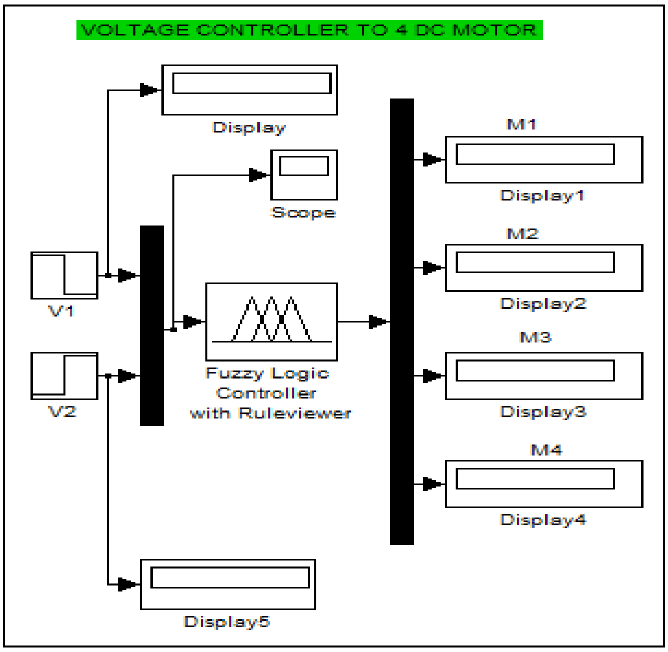

Figure 5: Four DC Motor Controller

There are six Mamdani rules as shown in Table 3 based on the following conditions:

- If (+VE is hp) then (M1, M2, M3, M4 are ph) (1)
- If (-VE is nh) then (M1, M2, M3 and M4 are nh) (1)
- If (+VE is mp) and (-VE is nm) then (M1 is nm) (M2 and M3 are pm) (M4 is nm) (1)
- If (-VE is pm) and (+VE is nm) then (M1 and M4 are pm) (M2 and M3 are nm) (1)
- If (+VE is zp) & (-VE is pz) then (M1 and M3 are pm) (M2 and M4 are nm) (1)
- If (-VE is nz) and (+VE is zn) then (M1 and M3 are nm) (M2 and M4 are pm) (1)

Table III: Regulator Output Of Four Dc Motors

V1	**V2**	**M1**	**M2**	**M3**	**M4**	**MOTIONS**
12V	**0V**	12V	12V	12V	12V	FORWARDS
6V	**-6V**	-6V	6V	6V	-6V	RIGHT SLIDE
1V	**1V**	6V	-6V	6V	-6V	CLOCK WISE
0V	**-12V**	-12V	-12V	-12V	-12V	BACK WARDS
-6V	**6V**	6V	-6V	-6V	6V	LEFT SLIDE
-1V	**-1V**	-6V	6V	-6V	6V	ANTI-CLOCK WISE

In Table III, it shows the controller output of four DC motors M1, M2, M3 and M4. For example, when the voltage controller, V1 and V2 remain at 12V and 0V, respectively, the fuzzy system will give 12V to each of the four motors making the motor in the forward direction. The combination of the four DC motors rotated in a forward motion causing the robot to move in a forward direction. If V1 and V2 change voltage values, the robot will move differently.

RESULTS

Fig. 6 and 7 display the output of DC motors when they receive +12Vand -12V. The purple line represents the step input while the yellow shows the step response of DC motor.Table IV provides the comparison of the performance of the DC motors.

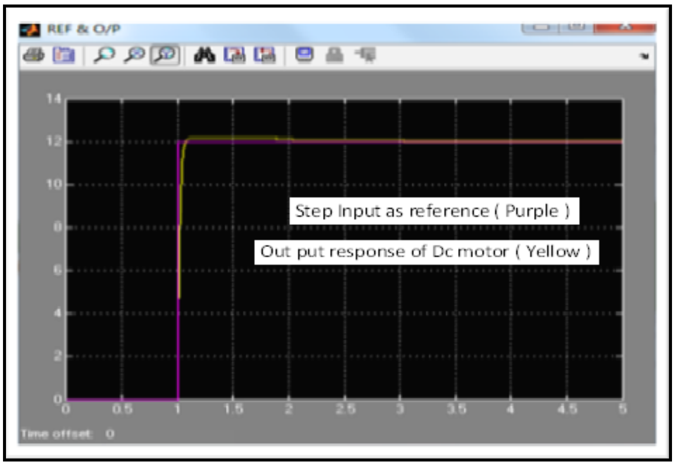

Figure 6: Response of DC motor at input references 12 V

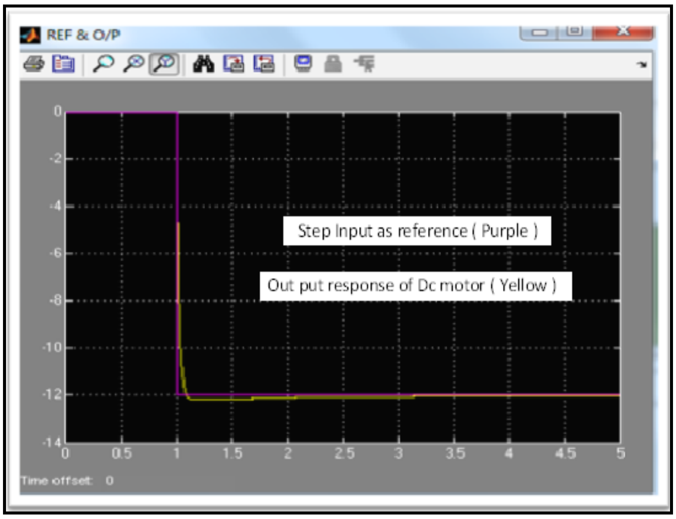

Figure 7: Response of DC motor at input references -12V

Table V: Comparison Of The Performance Of Four Dc Motors With Fuzzy Pid Controller

RIGHT SLIDE	**V1=6 ; V2=-6**			
	RiseTime	**SettlingTime**	**Overshoot %**	**rpm**
M1	0.0439	1.0732	1.2146	-35.02
M4	0.0439	1.0732	1.2146	-35.02
M2	0.0382	1.0609	1.3751	35.01
M3	0.0382	1.0609	1.3751	35.01
LEFT SLIDE	V1=-6 ; V2=6			
	RiseTime	**SettlingTime**	**Overshoot %**	**rpm**
M1	0.0382	1.0609	1.3751	35.01
M4	0.0382	1.0609	1.3751	35.01
M2	0.0439	1.0732	1.2146	-35.02
M3	0.0439	1.0732	1.2146	-35.02
FORWARD	V1=12 ; V2=0			
	RiseTime	**SettlingTime**	**Overshoot %**	**rpm**
M1	0.0404	1.0626	1.4695	69.9
M4	0.0404	1.0626	1.4695	69.9
M2	0.0404	1.0626	1.4695	69.9
M3	0.0404	1.0626	1.4695	69.9
BACKWARD	**V1=0 ; V2=-12**			
	RiseTime	**SettlingTime**	**Overshoot %**	**rpm**
M1	0.0439	1.0732	1.1462	70.01
M4	0.0439	1.0732	1.1462	70.01
M2	0.0382	1.0609	1.1462	70.01
M3	0.0382	1.0609	1.1462	70.01
CLOCK WISE	V1=1 ; V2=1			
	RiseTime	**SettlingTime**	**Overshoot %**	**rpm**
M1	0.0382	1.0609	1.3751	35.01
M4	0.0382	1.0609	1.3751	35.01
M2	0.0439	1.0732	1.2146	-35.02
M3	0.0439	1.0732	1.2146	-35.02
ANTI-CLOCKWISE	V1=-1 ; V2=-1			
	RiseTime	**SettlingTime**	**Overshoot %**	**rpm**
M1	0.0439	1.0732	1.2146	-35.02
M4	0.0439	1.0732	1.2146	-35.02
M2	0.0382	1.0609	1.3751	35.01
M3	0.0382	1.0609	1.3751	35.01

The system only can be stable after a proper control. For the simulation, PID controller gives high overshoot and settling time with zero steady-state error. On the other hand, simulation results show that the fuzzy PID control has better static and dynamic performance. Control accuracy also rises greatly compared with the traditional PID control. Unlike the PIC, the fuzzy PID controller gives less overshoot, smaller settling time, and zero steady-state error. The fuzzy PID controller with simple design approach and smaller rule base can provide better performance compared to the PID controller.

Table IV shows all the four controllers' results. Analysis has been carried out, and it is clear that the fuzzy PID controller gives the best performance output controller regarding overshoot percentage, settling time and rise time. Since the overshoot generates a higher voltage than a DC motor rated voltage, it can make a direct adverse impact on the motor. Hence the fuzzy PID logic control is the more practical controller than the PID.[15,16]

Table IV: Comparison Of Controller Output Response

	RiseTime	SettlingTime	SettlingMin	SettlingMax	Overshoot	Peak	PeakTime
Open Loop	2.9927	4.9072	0.3851	0.4279	0	0.4279	5
Closed Loop	0.2744	3.1701	0.8851	1.2848	30.6926	1.2848	1.6621
PID	0.0551	1.1876	0.901	1.0961	9.5239	1.0961	1.1178
Fuzzy PID	0.0326	1.0563	0.9014	1.0127	1.2013	1.0127	1.1742

CONCLUSION

This paper presented an intention method based on two inputs and three outputs self-tuning fuzzy PID controller. A Fuzzy-PID controller for a simple Mecanum wheel robot is developed in Matlab/Simulink. The fuzzy controller balanced the proportional, integral and derivate (KP, KI, KD) additions of the PID controller as indicated by speed error and change in speed error. From the reproduction comes about it can be reasoned that contrasted and the regular PID controller, Fuzzy PID controller, has a superior execution in both transient and enduring state reaction. The self-tuning FLC has better different reaction bend, shorter reaction time (0.0326), small overshoot (1.2013), short settling time (1.0563) and high steady precision compared to the conventional PID controller.

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