

REPORT FOR FUZZY LOGIC CROSS-COUPLING CONTROL OF WHEELED MOBILE ROBOTS

As a project work for Course

SOFT COMPUTING TECHNIQUES (INT 246)

Name : Ankit Kumar
Registration Number : 11907132
Program : CSE B.Tech
Semester : Fifth
School : School Of Computer
Science and Engineering
Name of the University : Lovely Professional University

Date of submission : 10th november 2021

Lovely Professional University
Jalandhar, Punjab, India.



ABSTRACT

In order to decrease the orientation error induced by motion control of a differential-drive mobile robot, a fuzzy logic cross-coupling motion controller that integrates the cross coupling control and fuzzy logic techniques together is presented. Cross-coupling control can directly minimize the orientation error by coordinating the motion of the two drive wheels. Experimental results show that the proposed fuzzy logic cross coupling controller can be successfully applied to enhancing the motion accuracy of the robot.

ACKNOWLEDGEMENT

I would like to express my gratitude towards my university as well as Pooja Rana Mam for providing me the golden opportunity to do this wonderful Project, which also helped me in doing a lot of homework and learning. As a result, I came to know about so many new things.

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INTRODUCTION

With the recent advances in sensors and microelectronics, researchers are beginning to focus on autonomous mobile robots equipped with more intelligent capabilities such as learning from the environment and performing automatically and accurately. Now, mobile robots are mainly used in planet exploration, medicine, Agriculture, nuclear waste clean-up, hazardous materials, defence applications, industry, etc. Motion control is the very heart of any robotic systems and essential to build robust and interesting behaviour. Whether the performance is good or not directly influences the application range of robots as well as the reliability of the whole control system. Wheeled mobile robots can be considered as multi-axis drive servomechanisms. To achieve a coordination control, two kinds of basic approaches have been developed. The first approach is the distributed control. In the multi axis control system, even if each axis is equipped with high performance tracking controller, the error of one axis influences the whole motion of the system. If this phenomenon is not considered and each axis is controlled independently, the motion error is occurred. As a result, it depreciates the whole system performance. The feasible algorithm to achieve a high accuracy of multi-axis motion control is cross-coupling control (CCC) of speed or positioning servomechanisms. In CCC, the whole multi-axis system is considered as a single system. Compensations are calculated by taking into consideration of the mutual influences among axes to increase the degree of matching among axes and consequently reduce the error in the resultant motion control.

Let's take an example of a robot which is a differential-drive mobile robot. Conventional motion control method prescribes separate velocities to the left and right wheels. Under normal conditions there are short transient times, during which the motors try to get up to the commanded speeds. However, external disturbances and slippage will interfere with the commanded speeds and result in additional transient times, during which the wheels don't follow the commanded speeds

exactly. This situation is exacerbated when driving at very slow speeds, because the internal friction in gears and bearing causes significant disturbances all the time. The CCC method compares the actual encoder pulses from the left and right wheel of a robot and issues corrective commands to the motors to slow down the motor that is faster and speed up the motor that is slower than the other. The overall effect of this method is that the velocities of the left and right wheels of the robot are matched more tightly even in the presence of internal and external disturbances. In this project, a fuzzy logic cross coupling controller for wheeled mobile robots is explained.

KINEMATIC MODELING AND MOTION ERROR ANALYSIS

The kinematics of a differential-drive mobile robot can be described by :

$$x = (v_l + v_r)/2 * \sin \theta$$

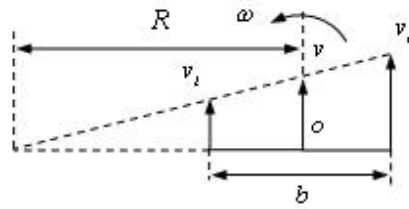
$$y = (v_l + v_r)/2 * \cos \theta$$

$$\theta = (v_r - v_l)/b$$

where (x, y) are the Cartesian coordinates of rear-axle midpoint, θ measures the orientation, v_l , v_r are the linear velocities of the left and right wheels, and b is the distance between the two drive wheels.

Due to the inherent nonholonomic constraints, motion of a differential-drive robot can be classified as linear and curved motion. The linear motion is a particular curved case in which radius $R = \infty$. In order to generate a circular path, the reference point of the robot must move along a circle of radius R . The coordination of velocities is provided in

Fig , where (v, ω) represent respectively the linear and the angular velocities of the robot.



Coordination of velocities

The following equations can be concluded from Fig

$$v_l = \omega(R - b/2) = v(1 - b/2R)$$

$$v_r = \omega(R + b/2) = v(1 + b/2R)$$

MOTION ERROR

Error sources which influence the accuracy of motion control can be classified into two categories: internal errors and external errors. The internal errors are the errors that can be detected by the wheel motion information. The external errors are the errors that only become apparent when the robot wheels interact with the environment. That is, external errors can only be detected by absolute robot motion measurements. In this study, motion of robot is detected only by the encoder feedback and consequently internal errors are considered. The main sources resulted in internal errors are:

1. unmatched closed-loop gains and parameters. The inherent nonlinear and time-varying parameters in motors and time-varying loads which depend on control task both account for the different responses of the two loops and motion errors in the resultant path.

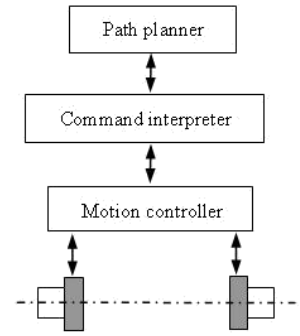
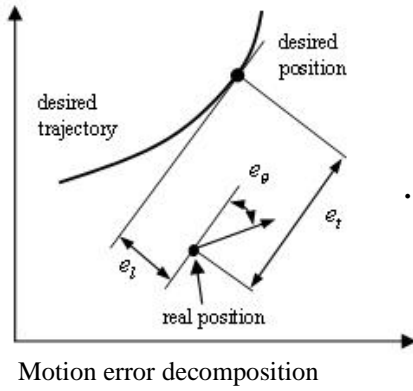
2. Different disturbances acting on individual drives. One example is different bearing frictions. The difference in disturbance leads to different transient response and the steady state response.

3. Inability to track nonlinear trajectories. In tracking a general nonlinear trajectory, the reference inputs to the drive loops are also nonlinear. A conventional control system has lag errors in tracking nonlinear inputs .

CLASSIFICATION OF MOTION ERROR

The motion error of the robot can be decomposed into the components e_θ , e_l and e_t .

- The orientation error e_θ is defined as the difference between the real robot orientation and the desired robot orientation.
- The lateral error e_l is defined as the distance between the actual robot position and the desired robot position in the direction perpendicular to the orientation.
- the tracking error e_t is the distance between the actual position and the desired position in the direction of travel.
- The orientation error is the most important to motion control because the decrease in orientation error can make the lateral error approach to zero. This error is certainly due to the different responses of the two control loop. The tracking error can be controlled by adjusting the robot linear velocity as desired. Therefore, e_θ plays the most important role in motion controls and its decrease can improve the motion accuracy maximally.



CROSS-COUPLING CONTROLLER

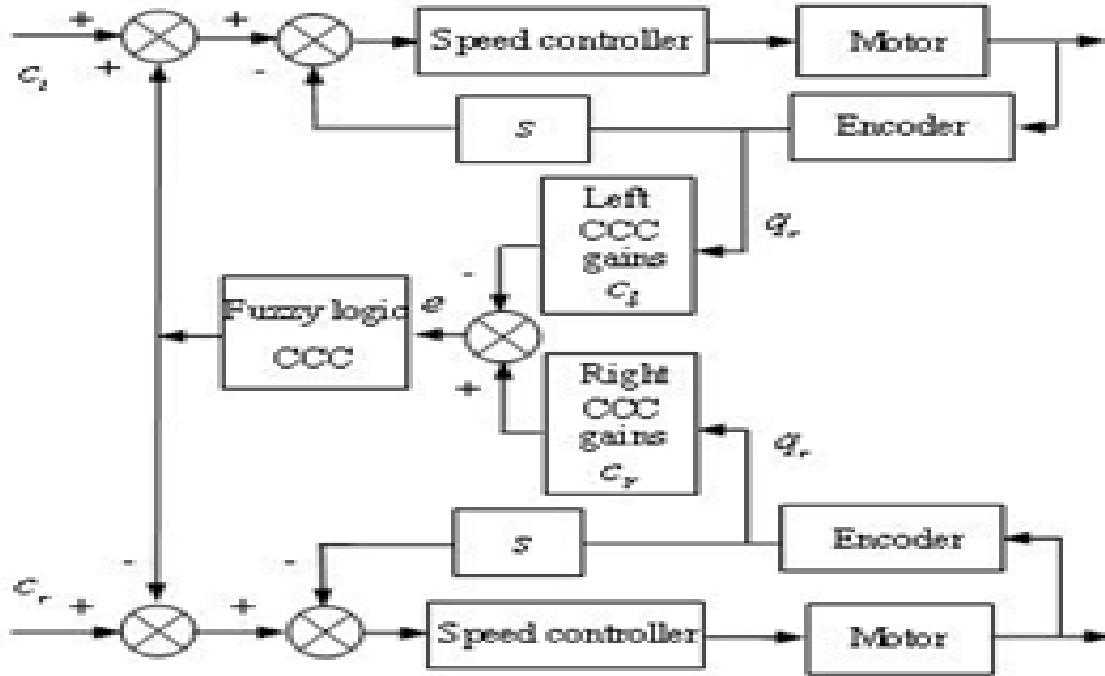
Orientation Error Computation

In the case of a differential-drive robot, motion accuracy depends on the coordination between the two velocity control loops and the control of orientation is achieved by adjusting the linear velocities of left and right wheels. When the robot is in straight line motion, at each sampling period, the change in orientation error Δe_θ is determined by

$$\Delta e_\theta = (\Delta q_r - \Delta q_l) / b$$

here Δq_l and Δq_r are the left and right wheel displacement during the sampling period. Consequently, the total orientation error e_θ .

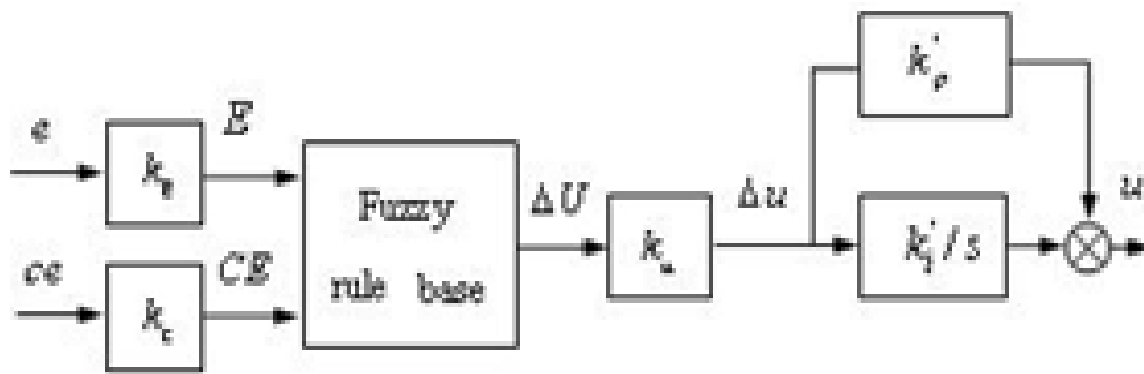
DESIGN OF FUZZY LOGIC CROSS-COUPLING CONTROLLER



The cross-coupling control system

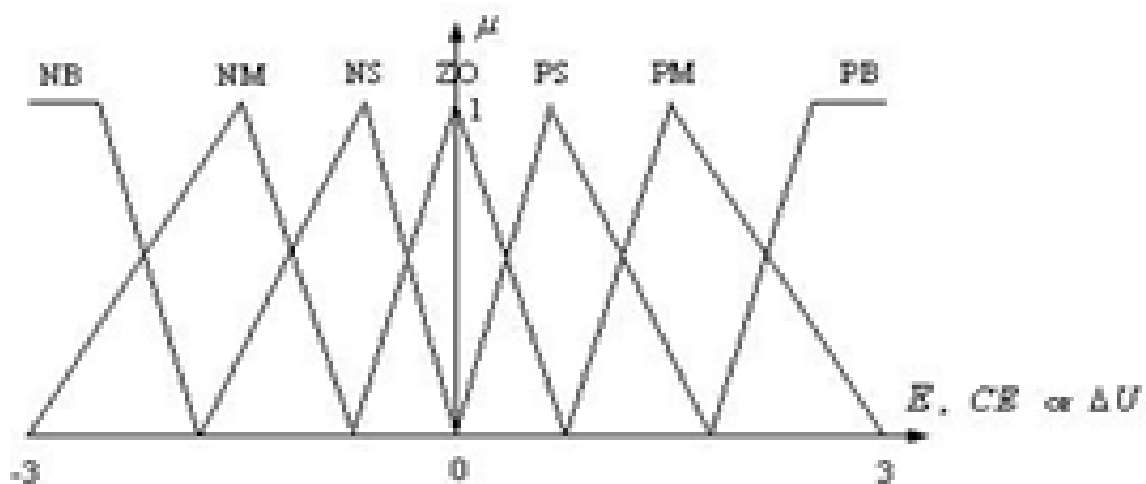
The fuzzy controller inputs are e and ce , and the defuzzification output is Δu . e denotes a control error, i.e., difference between a reference input and an actual process output. ce is the change in error, i.e., the derivative of the error. K'_p and k'_I are the proportional and integral gains of the cross-coupling controller. u is the resultant control signal and defined by

$$u = k'_I \int \Delta u + k'_p \Delta u$$



MEMBERSHIP FUNCTIONS

NB	Negative Small
NM	Negative Medium
NS	Negative Small
ZO	Zero
PS	Positive Small
PM	Positive Medium
PB	Positive Big



Membership function for the variables e , ce and Δu .

FUZZY RULES

Control Action	CE						
	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NM	NM	NS
NM	NB	NB	NM	NM	NS	NS	NS
NS	NM	NM	NM	NS	NS	NS	ZO
E ZO	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PS	ZO	PS	PS	PS	PM	PM	PM
PM	PS	PS	PS	PM	PM	PB	PB
PB	PS	PM	PM	PB	PB	PB	PB

CONCLUSION

In this project, I designed fuzzy logic cross-coupling control algorithm that integrates the cross-coupling control (CCC) and fuzzy logic techniques together is proposed. With CCC, the mutual dynamic effects between the two servomechanisms are taken into consideration to generate an error correction .

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