DC motor control using fuzzy logic for Input to Five Bar Planar Mechanism - A Survey Paper

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ABSTRACT

Need of variable speed and position drives has been growing in the industries. To name a few industries like Robotics, Process, Material Handling or in Manufacturing industries where controlling speed and position of drive is important. DC Servo motors are the most widely used as drives in these types of applications where control of these drives play important role. Conventional P, PI and PID controllers are used to control a drive in industries. Due to robust nature of PID controller and ease of operation it is widely used in industries. In many real time or dynamic conditions PID controller does not give desired results. There are some new methods which can overcome the problem of working in dynamic conditions. Those new methods includes intelligent control techniques, which are Fuzzy Logic Controller (FLC), Artificial Neural Networks, Generic Algorithm, Practical swarm Algorithm etc. In this paper various intelligent control methods are studied and the results are compared with conventional controllers for improving performance of drive. The five bar planar mechanism with rotation constraint requires two input links. The initial position control and angular speed relation is to be implemented by DC motor with FLC.

Keyword: - *DC Servo motor, GA and PA, FLC, PID, Five Bar Mechanism.*

1. INTRODUCTION

DC servo motors are mostly used when wide range of speed is required and accuracy in position control is necessary. Dc servo motors are advantageous because the can give high ratio of starting torque to inertia, also Dc servo motor has fast dynamic response, reliability [1]. DC servo motor is basically used in the Robotics application, Automation industries, or in machine tools etc. Controlling of speed and position is of motor into desired condition is the main aim in the applications. Conventionally used controllers for this purpose are Proportional controller (P), Proportional-Integral controller (PI), or Proportional-Integral-Derivative controller (PID). All the conventional controllers work by tuning the controller parameters. These parameters are tuned either manually or by Ziegler-Nichols (Z-N) tuning method. Z-N tuning method does the adjustment in controller parameters. While using Z-N closed loop tuning method, the system is required to operate into oscillation mode. The controlling parameters in reality may have the limiting value. Hence we are not supposed to exceed this value. During oscillations this value will keep on changing from positive to negative and negative to positive about the limiting value. The positive side of oscillation is not permitted. Hence in such cases oscillations are not permitted. This is the main difficulty of using PID controller in real time operating conditions [2]. The intelligent control techniques given this paper can be used for controlling nonlinear behavior system. The intelligent control techniques such as Fuzzy logic, Generic Algorithm, Practical Swarm Algorithm (PA) are used as an alternative to classical controllers which can give better results compared to P, PI or PID. All intelligent control methods are studied in this paper to and selection has been done based on relative merits and demerits of each method.

2. RELATED WORK

PI and PID are commonly used controller because of the advantages like fast response, simple tuning and ease of operation. Conventional Controller uses mathematical model of system, where as intelligent controllers can provide better dynamic response.

The PID controller can be tuned easily with reference to standard available methods. For effective tuning, the knowledge of mathematical model of plant is necessary. The mathematical modelling becomes complex if plant is complex. In some processes where zero overshoot is required, effective control is not possible due to inherent limitation of PID controller. The five-bar mechanism control system requires the accurate initial position control, as the mechanism is already connected, so dynamic response of controller for this system plays an important role. The conventional PID controller can not provide the required accuracy. The conventional PID controller can not meet the desired performance. Use of PID controller results in reduction in the values of Rise time, Settling time and Percent Maximum overshoot, Precent Error. But these values are not completely eliminated (Reduced to zero).

The intelligent controller is knowledge-based (Rule-Base). It is represented by Rule-Base Matrix. Hence the mathematical model is not required. With proper design of matrix, Percent Maximum overshoot and Precent Error can be reduced to zero.

R. Manikanand and R. Arulmozhiyal gives comparative study of conventional PI and Fuzzy Logic Controller for DC servo motor Drive Position control.[1] The experimental and simulation results given in the paper shows how FLC has better dynamic response than PI controller. Munadi and M. Amirullah state the effectiveness of using FLC for position control for servo motor than PID controller. The simulation results given in the paper are compared for Arm Robot Manipulator application. DC servo motor is used as an actuator for the application. The controller used is Arduino The simulation given in the paper is done using Matlab/Simulink[2]. G. Sudha and Dr. Anita have given design of Fuzzy-PID controller for position control of servo drive [3]. Author gives intelligent techniques for tuning PID parameters using Fuzzy Logic technique. The results of Conventional PID controller and Fuzzy-PID controller for system are compared. Her-Terng Yau1, Po-Hsien Yu and Yuan-Hung Su have stated methods of Generic Algorithm and Evolutionary Programming for optimal design of Fuzzy-PID controller for DC servo motor [4]. The control methods given by authors are for optimum tuning of PID parameters. The same algorithms are again tuned using Fuzzy Logic controller. The results are compared for improving transient response of Servo motor. Paper name author says that The Five bar planer mechanism has second degree of freedom. In the paper author has reduced the degree of freedom (DOF) to one, by putting rotational constraint on two input link. Further he says that two input links can have same speed ratio and same direction of rotation or they have some relation between them that is speed ratio can be changed and direction of rotation can be same or opposite. In the same paper he says that the initial orientation of the input link also plays important role using software technique the author has generated a wide verity of coupler curves.[5] Being a mechanical system the speed ratios are govern by the gears and hence has the first limitation.

3. FIVE BAR PLANAR MECHANISM: A STUDY

Fig.1 shows the five bar planar mechanism. 1,2,3,4 and 5 are the hinges. The five links (bar) are 1-2, 2-5, 3-4, 4-5 and the fixed link 1-3. Links 1-2 and 3-4 are the input links. Their initial orientation is $\square_1$ and $\square_2$ respectively.
Point 6 is just the extension of the link 2-5 to obtain the coupler curve.

The Five bar planer mechanism has second DOF. One link is always fixed and when the input link connected to it, is set to a predefined position, it is not possible to deterministically find the positions of other three links. Where as in four-bar mechanism there is a unique position of remaining two links. Hence it is the most popularly used mechanism. The mechanism has wide number of applications in the field of Material handling, Robotics and applications where coupler curve is very important. The five bar mechanism with rotation constraint reduces the DOF to one. The mechanism uses two input links connected to the fixed link. These input links have initial positional relation among themselves mentioned as $\theta_2 = f(\theta_1)$. Further there is a relation in the speeds of input links as $\omega_2 = g(\omega_1)$. Thus the constraints are specified in terms of angular positions and angular velocity.

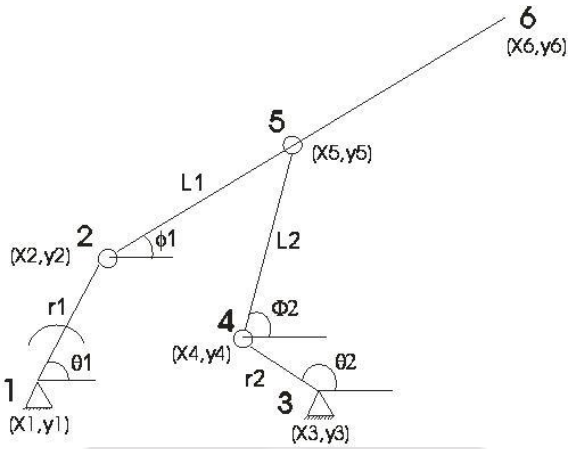

Fig -1: Five Bar Planar Mechanism

The following data is known
(x_1,y_1) and (x_3,y_3) :The ends of the fixed link
r_1, r_2 : The lengths of link 1-2 and 3-4
θ_1 θ_2 : The orientation of link 1-2 and 3-4

Using angles at any moment as θ_1 and θ_2
We can find (x_2,y_2) and (x_4,y_4) as

$x_2-x_1 = r_1 \cos(\theta_1)$ $y_2-y_1 = r_1 \sin(\theta_1)$
$x_4-x_3 = r_2 \cos(\theta_2)$ $y_4-y_3 = r_2 \sin(\theta_2)$

Circles with centers 2 and 4 having radius L_1 and L_2, will intersect at point 5.
$(x - x_2)^2 + (y - y_2)^2 = L_1^2$
$(x - x_4)^2 + (y - y_4)^2 = L_2^2$

Above equations are to solved to obtain x and y.

Fig - 2: The mathematical Model for Five Bar Planar Mechanism

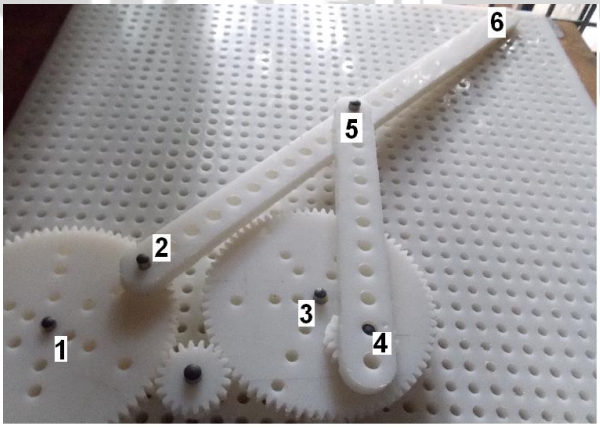

Fig -3: Five Bar Planar Mechanism implemented using rotation constraint: Same Speed and Direction

When the mechanism is implemented using gear-trains for the input links the system becomes rigid and looses the flexibility offered by five bar planer mechanism with rotation constraint. The rotation constraint itself becomes rigid due to gear-trains and hence resetting the new values of initial orientation becomes difficult. In case when the

mechanism reaches the locking position, it may result in serious damage. The intelligence needed can be provided by replacing the gears using DC motors with fuzzy logic controller.

To achieve the flexibility, it is proposed that the position and rotation is to be implemented with DC servo motors. The simulations described in the paper can be practically implemented with the use of DC servo motor. As we can set the initial angular positions of the input links without any mechanical work and implement a wide range of speed ratios (eliminating the rigid gear-trains), we can provide a flexible five bar planer mechanism for the use in the real world. In the current project work it is proposed that the dimensions of the five links remain unchanged. The simulation indicates that a large verity of coupler curves can be generated for the same mechanism.

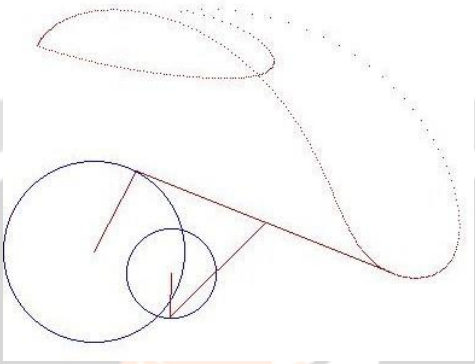

Fig -4: Example of Coupler curve generated

To make it a flexible system if instead of single driving motor if two different DC servo motors are provided then the same verity of curves can be easily generated. The DC servo motors provide us the position and speed variations. If the PID controller is used it results in oscillations that is crossing the limiting position. In the above implementation it is expected that every new position of mechanism becomes a temporary limiting position that is no overshoot is allowed. During locking, the PID control action may cause severe damage to the system, but FLC can deal effectively with such situations. Because of typical requirements of control system for Five Bar Mechanism, the rule based control (FLC) can be effective, hence I propose to choose this application for my project work.

4. INTELLIGENT CONTROL TECHNIQUES:

4.1 Fuzzy Logic Controller

The design of FLC is based on Fuzzy Set theory. Mathematical model of the system is not required to deign FLC. The Fuzzy Logic Controller (FLC) is used where control parameters are difficult to control or parameters are imprecise in nature. The FLC therefore uses Fuzzy inference model to represent this imprecise plant parameter data using If-Then rule-base. Fuzzy set theory uses membership functions ranging from [0, 1] / [false, true]. The fuzzy logic theory based on this membership function provides mathematical base to check uncertainties connected with human like thinking or reasoning. Therefore it is easy to apply FLC for higher order systems also. It basically includes four parts.

1) Fuzzification:

In this step all the Crisp (input) values are converted in Fuzzy values. Fuzzification step allows mapping of Crisp values (input values) to Universe of Discourse (U) (Universal Fuzzy Set).

2) Knowledgebase or Rulebase:

In Second step based on fuzzy values, rules are set. Decision making is based on these Rulebase.

3) Decision Making:

Based on Rulebase decision making table is formed. This is called as Logic Rule Table. Interface is provided between process and decision making block.

4) Defuzzification:

In the last step again fuzzy values are converted into crisp values. This is because output of step 3 is in Fuzzy value format. Many methods for this step are available.

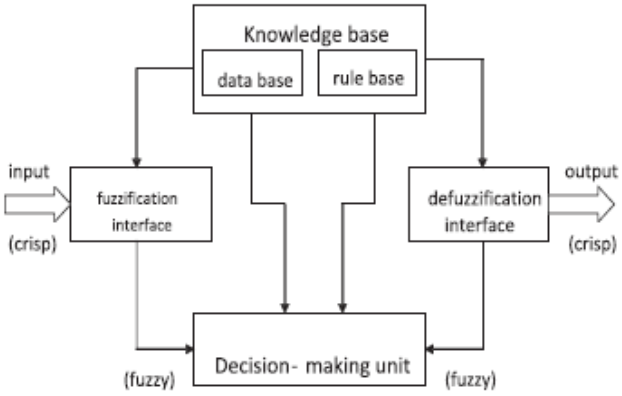

Fig. -5: Structure of Fuzzy Logic Controller

4.2 Fuzzy-PID Controller

This is hybrid controller which uses both Conventional and Intelligent technique for controlling servo motor. The parameters of PID controllers i.e. the gain constants are found out using Fuzzy Logic technique in this type to improve performance.

4.3 Generic Algorithm

Basic idea of Genetic Algorithm is Chromosome. GA is used for optimal tuning of PID Parameters. GA tries to give genetic information for given solution and it is coded as binary string. In first step population of Chromosome is created randomly. This represents no of solution to give problem. In nest step "Fitness Function" is used to select the best solution from population. This best selected solution becomes parent to the offsprings. These offsprings will contain next generation. The process will repeat itself. In every step fitter parent will get survived. Further population will get updated.

Evolutionary Programming

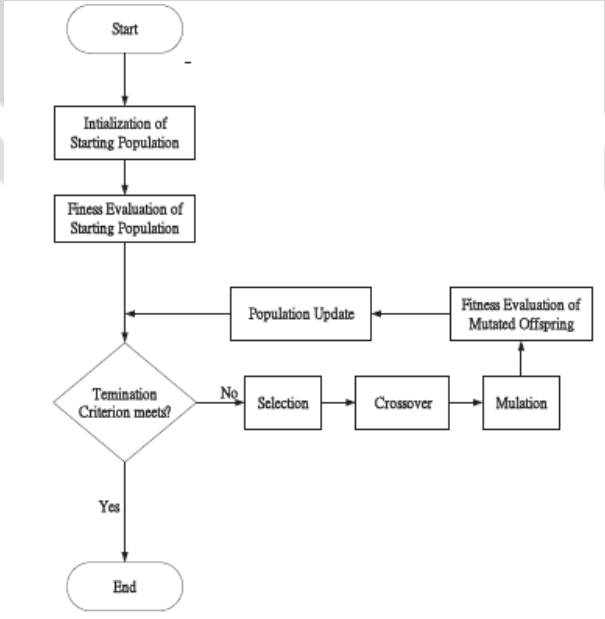

Fig. -6: GA Flowchart

5. CONCLUSION

The gear driven five bar mechanism has inherent limitations due to mechanical arrangement. The DC servo motor can effectively eliminate this limitation. The DC servo motor can provide accurate position and speed control. The FLC controller for DC servo motor has better dynamic response and can overcome the drawbacks of conventional PID controller.

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