

## PAPER INFORMATION

**Title:** FUZZY BASED ROBUST CONTROLLER DESIGN FOR ROBOTIC TWO-LINK MANIPULATOR.

This Paper comes under the following domains:

**AI Methodology:** Fuzzy Logic

**AI Application** : Robotics

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# FUZZY BASED ROBUST CONTROLLER DESIGN FOR ROBOTIC TWO-LINK MANIPULATOR

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## EXTENDED ABSTRACT

Robotic manipulators are highly coupled, nonlinear and time-varying systems that are generally subjected to both structured and unstructured uncertainties. This makes the accurate positioning of the robotic arms very complicated and difficult. The overwhelming demand for the accurate position control calls for a method that compensates by and large the adverse effects of the uncertainties on the positioning of the robot arms. The inertia, gravity and Coriolis effect have been identified as the major contributors for the inaccuracy in the positioning of the robot arms. This paper attempts to design a fuzzy logic controller for controlling the position of the arms of a two-link manipulator taking into account the disturbances caused by inertial loading, coupling reaction forces between joints (Coriolis and centrifugal), and gravity loading effects. This paper also analyses the performance of the compensated fuzzy controller in comparison with the conventional fuzzy controller and optimized PID controller by simulating the position control of two-link manipulators using MATLAB.

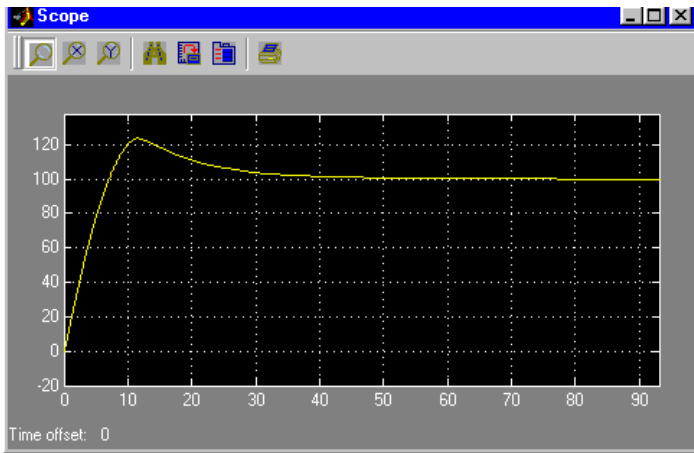
The computer simulation of the robot arm requires accurate equations of motion for the manipulators. These equations can be derived using known laws of Newtonian and Lagrangian mechanics. The dynamic equations in this case are derived using the Lagrange-Euler (L-E) formulation. Since the computational complexity of L-E formulation varies with 4<sup>th</sup> power of the number of degrees of freedom, we have taken the case of two-link manipulator with revolute joints for simulation purposes. The generalized torque equation for two-link manipulator derived using L-E formulation is expressed in matrix form as  $\tau(t) = D(q(t)) \ddot{q}(t) + h(q(t), \dot{q}(t)) + c(q(t))$ . This equation gives the torque required for a joint 'i' actuator to drive the i<sup>th</sup> link of the manipulator where the other symbols have their usual meanings. The elements of the inertial loading acceleration matrix  $D(q)$ , centrifugal force vector  $h(q, \dot{q})$  and gravity loading force vector  $c(q)$  are then derived from their respective mathematical equations. Finally the individual torque equations for the arms of the two-link manipulator are derived using these matrices. These equations thus take into account the adverse factors of centrifugal force, inertia and gravity loading on the position control.

The Fig 1 shows the block diagram of our compensated fuzzy logic controller for the position control of two-link robotic manipulator as implemented in SIMULINK. Here we have incorporated a C-Logic (Compensation logic) block, which compensates for the torques due to inertial, gravity and centrifugal effects. This block can be expressed as a combination of the L-E torque computation block and a torque to voltage converter (T-V converter). The torque computation block calculates the torque experienced in the joints 1 and 2 from the generalized angular coordinate position of the arms. The torque outputs are then fed to the T-V converter. The T-V converter calculates the voltage that corresponds to a particular combination of torque ( $\tau$ ) and the time derivative of the angular position of the arm ( $\dot{\theta}$ ) as given by the formula  $v = (\dot{\theta} K_{fb} + (\tau * R_m) / K_{torque}) * \text{Gear Ratio}$  where  $K_{fb}$ ,  $K_{torque}$  represent the feedback and torque constants. In the proposed method, we designed a fuzzy controller with the error and the first derivative of the error as fuzzy inputs. The inference engine uses a 7 X 7 rule base for the control decision. The robot dynamics model used for the simulation is outlined in Fig 2.

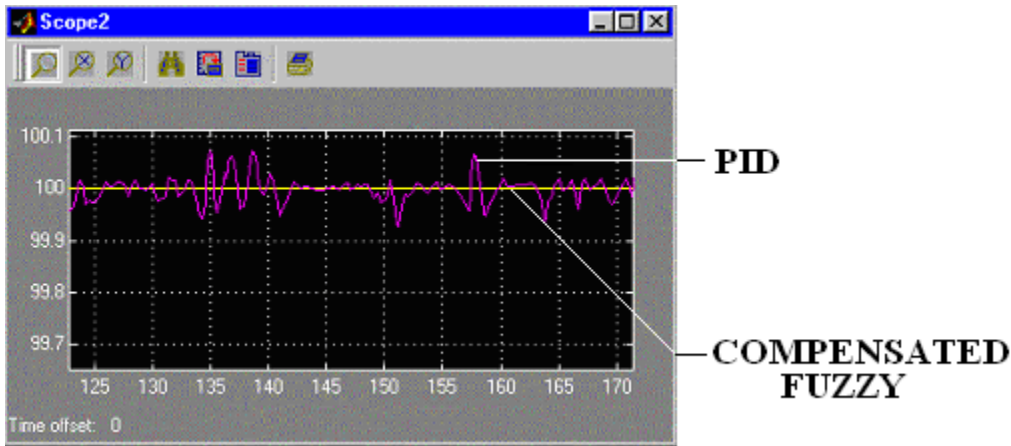
The robustness of the controller was verified by introducing load disturbances in the system by changing the transfer functions involved in the dynamics of the manipulators. The performance indices calculated showed clearly that the compensated fuzzy logic controller showed much better performance in terms of both accuracy and robustness of the system as compared to optimized PID controllers and uncompensated fuzzy logic controllers. Hence the proposed design of controller has the following advantages over the conventional controllers:

1. More accurate tracking of the set point variations.
2. Reduced oscillations about the set point.
3. Settling time is comparatively smaller.
4. Better performance when the system is subjected to load disturbances due to changes in the dynamics.

SOME SNAP SHOTS OF SIMULATION RESULTS:



Step Response for the Compensated Fuzzy Logic Controllers (Step magnitude=100).



Zoomed graph showing the Oscillations about the SP experienced by the arm in the case of PID controller. It can be noted that the Compensated Fuzzy Logic model has a much steady response after the settling time.

FIGURES:

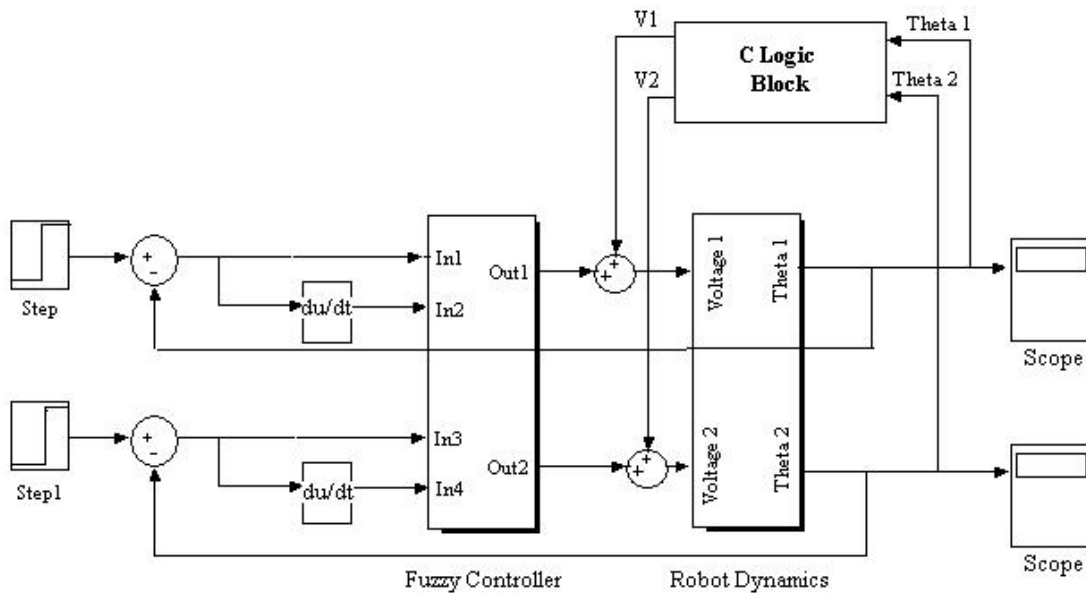


FIG 1: Block Diagram of the Compensated Fuzzy Logic Controller for the position control of two-link robotic manipulator as implemented with SIMULINK.

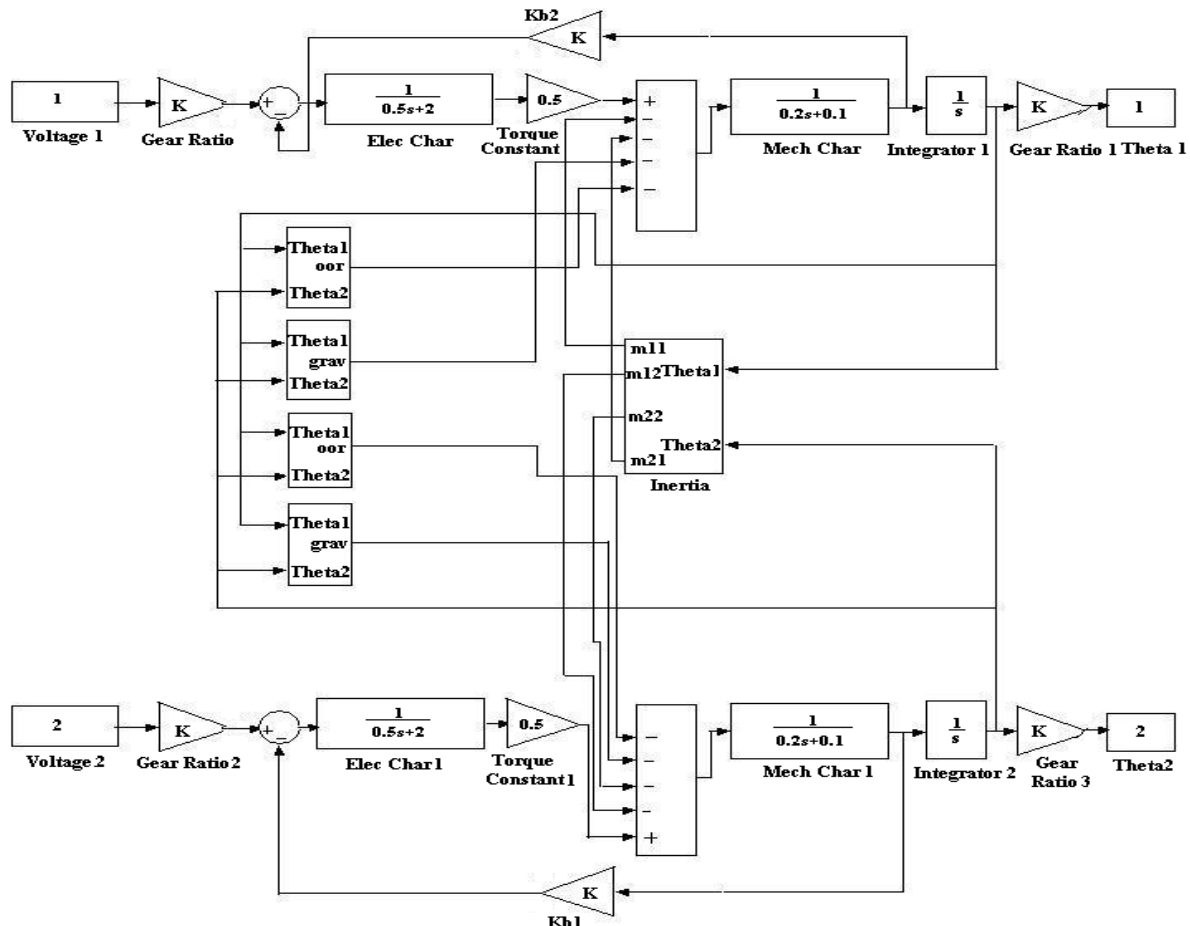


FIG 2: Dynamic Model of the Two-link robotic manipulator