CHAPTER 6 CONCLUSIONS AND FUTURE SCOPE

Having established through the literature survey we can say that an efficacious FLC design depends on various parameters like: membership function estimation, formation of rule (knowledge) base and selection of fuzzy logic controller architecture. Among these factors estimation of fuzzy membership function has always been a key area of research for control engineers. Because of the nonexistence of empirical tuning method one of the main challenges encountered by system designers is to determine the fuzzy sets for a specific fuzzy variable.

Membership function estimation consists of following parts:

1. To estimate optimum support for fuzzy sets associated with a given fuzzy variable.
2. To estimate the optimum mathematical functions (shape) for fuzzy sets associated with a given fuzzy variable.

An important aspect of membership function formulation which is generally overlooked is estimation of support for fuzzy sets [36]. The current research emphases on improving scope of the fuzzy logic controllers by proposing an optimization method to compute support for a fuzzy set.

6. 1 Research objectives

The proposed work successfully achieves the following objectives:

1. A generalized algorithm is depicted to estimate the optimized support for fuzzy sets.
2. The optimization objective function utilizes standard deviation as the statistical parameter to computed to entropy for the fuzzy sets, in turn acquiring the optimized support.
3. The proposed algorithm is successfully implemented to control a class of real-time non-linear/cross-coupled system by treating the test system as black-box system and improvement in controller response parameters has been observed.

6. 2 Experimental setups for result verification

The optimized controller is implemented for control of real-time test systems. Performance of the controlled system is validated by rigorous testing and response for following setups has been analyzed:

- Inverted pendulum system: Being a benchmark non-linear control problem swing up stabilization control of inverted pendulum represents an ideal system for testing the proposed controller.
- Twin rotor MIMO system: Owing to its significant cross-coupling between its two axes of rotation the set-point tracking of TRMS opens up a new paradigm of control system design.
- Magnetic levitation of steel ball: To further emphasize on the non-linear system handling capability and robustness towards noise rejection the position control of magnetically levitated steel ball is employed to test proposed controller.

6. 3 Performance evaluation

The results acquired for real-time optimized fuzzy control were than compared with results obtained for real-time PID and fuzzy logic control. Response for the proposed controller is further compared to referenced work employing optimized FLC for control of above mentioned real-time systems. The reference work is chosen carefully to authenticate the comparison between results obtained, for the reference systems which employs a similar setup for real-time control of above mentioned systems has been chosen. This ensures all the comparison parameters lie in the similar range.

Performance evaluation comparison consists of following parameters:

- Transient parameters (rise time and peak overshoot)
- Steady-state parameters (settling time and error)
- Error indices (ISE, ITSE, IAE, ITAE).

6. 3. 1 Inverted Pendulum System

The performance comparison for inverted pendulum is depicted in section 3. 5 and the performance parameters are depicted in Table 3-9 and Table 3-10. The settling time for proposed optimized FLC is 12.7 seconds (73.41%) faster when compared to PID controller and is 2.8 seconds (37.83%) faster when than FLC. The peak overshoot for optimized FLC is 0.49 radians (8.15%) less when compared with PID controller, however it is 0.62 radians (11.23%) higher when compared with FLC. Error indices for optimized FLC exhibit lower values when compared to FLC and PID controller. The comparison indicates an improvement in transient & steady-state characteristics for proposed controller. Thus the proposed controller exhibits improved set-point convergence for the inverted pendulum system.

6. 3. 2 TRMS

The performance comparison for TRMS is illustrated in section 4. 8 and performance parameters are portrayed in Table 4-8 & Table 4-9. The peak overshoot for pitch angle response is reduced to 20% for optimized FLC, as compared with 42% for FLC and 50% for PID controller. The overshoot for yaw angle set-point tracking is reduced to 29% for optimized FLC, as compared with 30% for FLC and 50% for PID controller. The rise time for pitch angle response with proposed controller is 0.5 seconds (25%) less when compared to PID & is same for FLC. The rise-time for yaw angle response toproposed controller is 1 second (33.33%) less when compared to PID and is same for FLC. The settling time for pitch angle response with proposed controller is 12 seconds (52.17%) less when compared to PID controller & is 4 seconds (26.67%) less when compared to FLC. Settling time for yaw angle response with proposed controller is 9 seconds (33.33%) less when compared to PID controller and is 4 seconds (18.18%) less when compared with FLC. Error indices for optimized FLC exhibit lower values as compared with FLC or PID controller. The comparison indicates an improvement in transient & steady-state characteristics for the proposed optimized fuzzy logic controller respose. Thus the proposed controller exhibits improved trajectory tracking for the TRMS system.

6. 3. 3 Maglev system

The performance comparison for maglev system is portrayed in section 5. 5 & parameters are illustrated in Table 5-9 & Table 5-10. Here the steady-state error exhibited by: (a) PID controller is 1mm (11.11%), (b) FLC is 0.62mm

(6.89%), and (c) Optimized FLC is 0.2mm (2.22%). Following this the set-point is changed & steady-state error exhibited by: (a) PID controller is 0.8 mm (14.54%), (b) FLC is 0.5mm (9.09%), and (c) Optimized FLC is 0.02mm (0.36%). The comparison indicates a substantial improvement in set-point tracking ability for the proposed optimized fuzzy logic controller.

6. 4 Scope for further research

For current research work the proposed algorithm is employed for obtaining the optimized support for triangular sets, however this algorithm can be extended for optimization of other sets too, like Gaussian, s-function etc. There is possibility of interesting observations.

With the positive results obtained for proposed controller performance the next step will be to test the algorithm for industrial applications, to test the robustness and applicability of the proposed algorithm.