CHAPTER 4

ANFIS MODEL FOR INVERSE KINEMATICS

This Chapter lays attention on the usage of a hybrid artificial intelligent technique called ‘ANFIS’. Since the conventional methods for inverse kinematics solutions of multi-degree of freedom robotic manipulators are very iterative and time consuming in nature, thus, artificial intelligent techniques finds their importance in the area of robotics.

The reported literature consists of ANFIS method being applied on planar robotic manipulators. Here, ANFIS method has been used to find inverse kinematic solutions of two different multi-DOF robotic manipulators moving in three dimensional spaces. Two ANFIS architectures of first order Sugeno fuzzy inference system based upon two different membership functions (MF’s): generalized bell MF and Gaussian MF have been considered. A comparative study of these two MF’s is presented in subsequent Chapters.

4.1 ANFIS Model for 3-DOF Omni-Bundle Robotic Manipulator

As per the advantages of ANFIS (discussed in section 1.9 of Chapter 1), ANFIS method has been applied on the 3-DOF Omni-Bundle Robotic Manipulator. ANFIS architecture of first order Sugeno Fuzzy Inference System has been considered. Fuzzification level consists of (a) generalized bell and (b) Gaussian membership functions along with product inference rule while defuzzification is done using weighted average method.

In trained ANFIS data, the (x, y, z) coordinates and joint angles act as the input. Here, three training data sets comprising of coordinates and joint angles has been considered as (x, y, z, \( \theta_1 \)), (x, y, z, \( \theta_2 \)) and (x, y, z, \( \theta_3 \)), respectively. For data set 1, a total of 4 membership functions have been considered with 64 rules. Similarly, for data set 2, a total of 3 membership functions with 27 rules have been considered. For data set 3, a total of 2 membership functions with 8 rules have been considered. The difference between the joint angles calculated using forward kinematic equations and joint angles calculated using ANFIS acts as the individual data set for validation of proper functioning of ANFIS. A total of 68971 observation points in work-volume
have been considered to plot the joint angle errors. Once the Fuzzy Inference System is generated, the structure of ANFIS model can be viewed as shown in Figure 4.1.

![ANFIS model image](image)

**Figure 4.1** ANFIS model used for 3-DOF Omni-Bundle robotic manipulator

### 4.2 ANFIS Model for 5-DOF Pravak Robotic Manipulator

Here, ANFIS method has been used to find inverse kinematic solutions of 5-DOF Pravak robotic manipulator including 2-DOF wrist motion and moving in three dimensional spaces. In trained ANFIS data, the \((x, y, z)\) coordinates and joint angles act as the input. Here, five training data sets comprising of coordinates and joint angles has been considered as \((x, y, z, \theta_1)\), \((x, y, z, \theta_2)\), \((x, y, z, \theta_3)\), \((x, y, z, \theta_4)\) and \((x, y, z, \theta_5)\), respectively. Then, the respective membership functions and rules have been assigned as data set 1: 7 and 343; data set 2: 6 and 216; data set 3: 5 and 125; data set 4: 4 and 64 and; data set 5: 3 and 27. A total of 500 observation points in work-volume have been considered to plot the joint angle errors. Once the Fuzzy Inference
System is generated, the structure of ANFIS model can be viewed as shown in Figure 4.2.

**Figure 4.2** ANFIS model used for 5-DOF Pravak robotic manipulator

### 4.3 Conclusions

ANFIS, an artificial intelligent technique plays a critical role in finding inverse kinematic solutions of multi-DOF robotic manipulators. In this Chapter, ANFIS model has been used for both 3-DOF Omni-Bundle and 5-DOF Pravak robotic manipulators. The results obtained after applying ANFIS model have been later used in Chapter 6 to carry out the comparative analysis for joint angle errors and positioning errors of end-effector for desired trajectory.