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Performance of Mamdani Fuzzy Inference System for Tracking Multiple Targets Using Autopilot System

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Abstract: **Now days, terrorism has increased; which includes bombing, missile attack. These attacks are paramount trouble being reason of economic loss, assets damage, and human dying which heavily affects nation's security. This poor security is due to lack of technological progress, that's why India is still developing country. Missile attacks through aerospace are surprise attacks; so creates huge loss of the Nation. Therefore, to find out the solution of this headache is being goal of researchers. Our paper is contributing to the solution of improving nation's security techniques. We are using Mamdani Fuzzy Inference System for the evaluation of multiple target tracking which are fired from our enemies by Missile guidance. Missile guidance concerns the means by which the missile receives commands to maneuver alongside ways to attain a target. For this we are using MatlabR2014a software with simulink8.3 toolbox for the purpose of modeling, scrutinizing, and simulating linear and nonlinear systems. The simulation result gives an idea of missile attack to enemy targets.**

Keyword: **Fuzzy Inference System (FIS), Mamdani Fuzzy Inference System, Missile guidance system, Multiple target tracking.**

I. INTRODUCTION

Employment, population growth, income per capita, productivity, mortality rate, health, technology progress, automation and security techniques are reasons why India is still developing county [1]. Now a day, terrorism becomes a major hurdle in the nation's security which includes bombings and Missile attacks that creates enormous economic loss, assets damage, and human dying; so the nation is trying to get rid of this headache. So research is going on against those attacks and our work creates attention against missile attacks by missile guidance techniques.

Missile guidance concerns the means by which the missile receives commands to maneuver alongside ways to attain a target. These commands are induced internally by the missile computer autopilot, on few missiles, whereas on others, the commands are transmitted to the missile by means of a few external sources; which is used here. The data generated by sensors is fed into the missile computer, which is then processed by the computer and generates guidance commands. Today's widely used sensor types include infrared, radar, and the global positioning system. Based on the relative status between the missile and the target at any given point, the computer autopilot sends commands to the control surfaces to adjust the missile's path.

Conventional design methods need the development of a mathematical model of the control system, and then use this model to construct the controller that is described by the differential equations. Many conventional design procedures require restrictive assumptions like linearity, so even if a relatively accurate model of a dynamic system can be developed, it becomes too complex to use for development of the controller. As opposed to conventional control design, fuzzy logic control focus on gaining an intuitive understanding of how to best control the process [2].

When linearity and time invariance of the controlled process cannot be pretended, when the process lacks a well posed mathematical model, or when human understanding of the process is very different from its model, there Fuzzy logic control appears very useful [3]. Fuzzy logic control provides a formal methodology for representing, handling and implementing a human experience based knowledge about working of control a system [2]. Fuzzy logic uses human knowledge and expertise to deal with uncertainties in the process of control [4]. The concern of the fuzzy models representing nonlinear input-output relationships depends on the fuzzy partition of the input output locations. Therefore, the tuning of membership functions becomes an important issue in fuzzy modeling, which is solve by neutral networks [5]

The Fuzzy logic technique has many features that make it an emphatically evoking and promising approach to give more accuracy. Therefore, in our project, we are using the autopilot system with fuzzy logic controller to launch missile, which will hit multiple targets fired from enemies in aerospace simultaneously. Therefore, human death, property damage and financial losses can be prevented.

To design Fuzzy logic controller we are using Matlab R2014a and simulink8.3 to display information graphically [6]. There are two types of fuzzy inference systems that can be implemented using Fuzzy Logic Toolbox are Mamdani and Sugeno. These two Fuzzy inference systems produce missile paths to track multiple targets by representing knowledge via linguistic if-then rules, allow for exact output inference starting from inexact inputs. Firstly, we are using Mamdani Fuzzy inference systems.

This paper is systematized as follows. In section II and III we describe the concept of Missile Guidance System and Control Missile Guidance System. Section IV describes the Fuzzy Inference System. Section V and Section VI describe Mamdani FIS and the development of Mamdani FIS. Experimental results and discussions are presented in Section VII. Finally, provides some conclusions.

II. MISSILE GUIDANCE SYSTEM

Missiles are the one of the widely used automotive aerial projectiles weapon containing explosives in the wars. The Latin verb mittere which means "to send" describes Missile [7]. Over the last few years, there have been many studies in the area of missile guidance. Missile guidance means guiding a missile to its predetermined target. To intercept a target with great accuracy in an environment that is uncertain is the basic issue. For this purpose, we are using guidance technologies. Guided missiles have different sections as guidance and control, armament, and propulsion section. Guidance and Control system direct and execute maneuvers as it is brain of the missile. Autopilot is the essential component of Guidance and control system [8]. An autopilot is a system of equations that receives commands and missile state measurements as input after that computes a control command that balances the missile and finally forces missile state to track the command. Previously, the concept of single target tracking by missile using Autopilot explained. The objective of this autopilot is the rapid rotation of the missile, for instance, in order to track a target in the real hemisphere of the missile launch vehicle, and then to allow the missile to achieve a normal direction of flight. Once the normal direction of flight is achieved, existing autopilot techniques may be used to cover the low angle of attack domain [9]. We have designed multiple targets tracking here, in which at high angle of attack missile will blast itself. Four types of Missile guidance systems are Self-contained, Command, Beam-rider, Homing [10]. The self-contained group consists of the guidance system in which all the guidance and control equipment is inside the missile. In command guidance, all commands come from internal/external sources. In the beam-rider guidance system, a device in the missile keeps it centered in the beam. Homing guidance is the most common form of guidance which is used in anti-air missiles. Here, we are using Command Guidance method.

III. COMMAND GUIDANCE SYSTEM

The Command Guidance method is classified as Remote control by Radio and Remote control by Radar. Using these techniques, the control link could be lengthened many miles, and any physical contact between launching platform and the missile removed. But we are using Remote control by Radar method as it replaces the human operator that we needed in the radio remote control system.

One or two radars are used to track the missile and target. As soon as the radar is locked on the target, tracking information is fed into the computer. The missile is then launched and is tracked by the radar. Target and missile ranges, elevations, and bearings are continuously fed to the computer. This information is analyzed and a missile intercept flight path is computed. The appropriate guidance signals are then transmitted to the missile receiver. A computer at the launch point determines whether the interceptor missile is on the proper trajectory to intercept the target. If it is not, steering commands are generated by the ground computer and transmitted to the in-flight missile. Furthermore, the computer compares this computed flight path with the predicted flight path of the missile based on current tracking information, and determines the correction signals required to maneuver the missile control surfaces to change the current flight path to the new one.

The guidance computer can be located on a stationary platform, or on a mobile platform. The guidance computer has the Matlab R2014a software. In that software, Simulink8.3 Toolbox is used for tracking targets and missile position by using Fuzzy Inference System. Fuzzy inference system takes tracking data and issues commands so that the missile will either collide with the target or pass within lethal range of it. Missile is moving based on the angle of attack calculation so feedback loop is there for error calculation and at high angle of attack missile will blast to destroy targets as shown in the Fig.1.

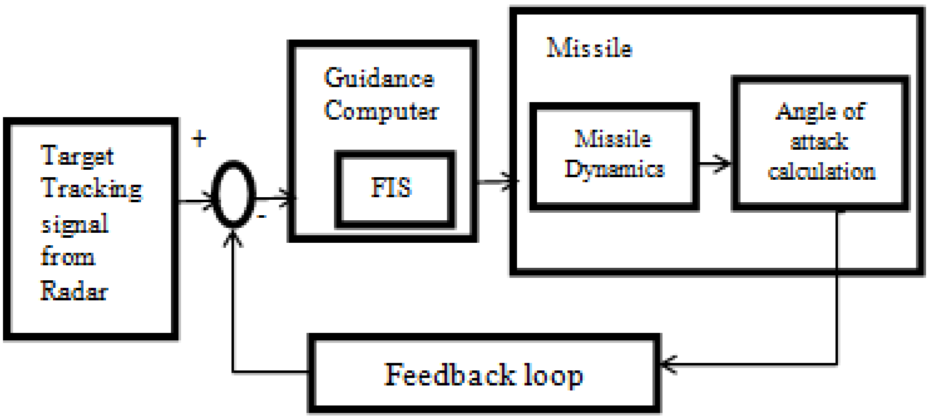


Fig. 1 Command Missile Guidance

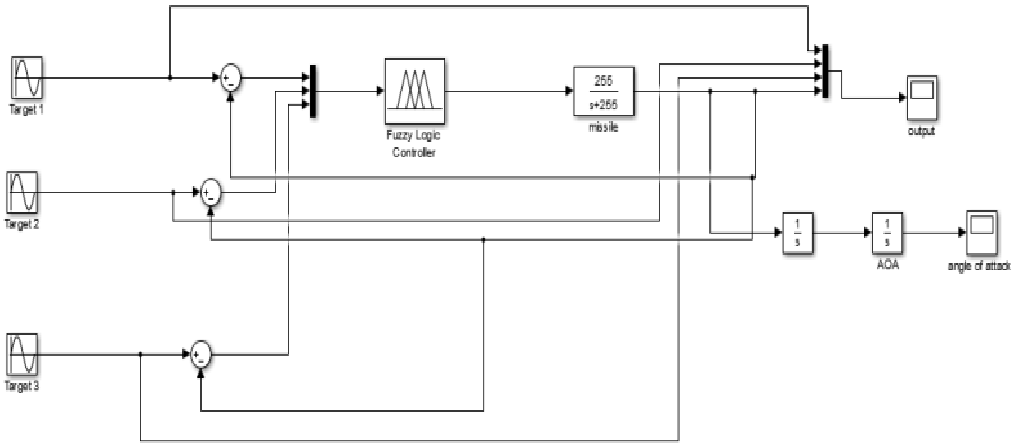


Fig. 2 Simulink model for multiple target tracking

The Simulink model for multiple target tracking is shown below in Fig. 2. First scope gives output of system and second scope gives angle of attack information.

IV. FUZZY INFERENCE SYSTEM

Fuzzy inference is the fuzzy logic approach for mapping from given input(s) to output(s). This mapping provides a decision making basis. It has successfully applied in automatic control, decision analysis, time series prediction, robotics, computer vision, and pattern recognition [11]. Due to its versatile nature, the fuzzy inference system is known by so many names like fuzzy-rule-based system, fuzzy expert system, fuzzy model, and fuzzy associative memory. Time saving and easy way to build, edit and observe the system is the use of graphical user interface rather than working on the command line. Five primaries GUI in the Fuzzy Logic Toolbox are as follows:

1. Fuzzy Inference System or FIS Editor,
2. Membership Function Editor,
3. Rule Editor,
4. Rule Viewer, and
5. Surface Viewer.

Fig.3 shows the Structure of the Fuzzy Inference system [12].

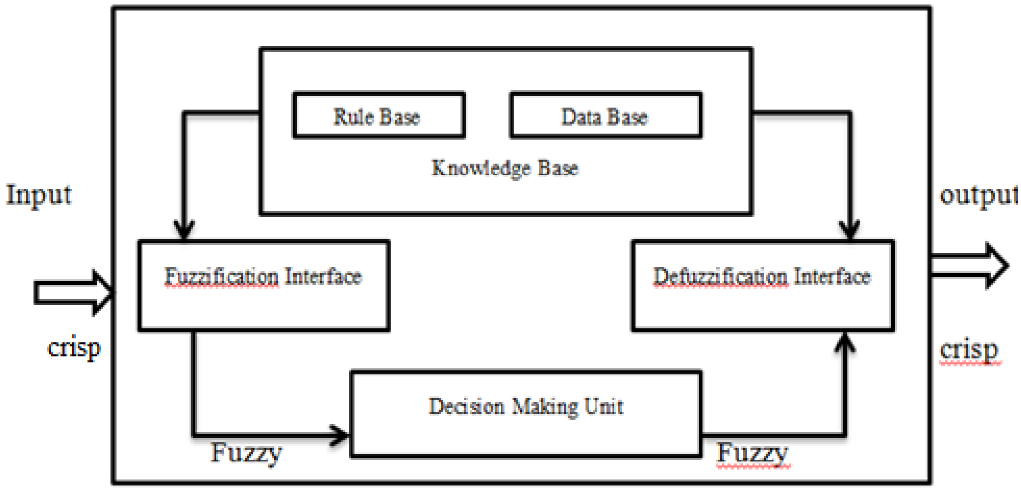


Fig. 3 Structure of the Fuzzy Inference system

There are two types of FIS editors such as Mamdani FIS and Sugeno FIS which includes membership functions, fuzzy logic operators, and if-then rules. Here Mamdani FIS is used. Rule base has fuzzy if-then rules and database illustrates the membership functions of the fuzzy sets used in fuzzy rules together known as the knowledge base. A membership function defines how each point in the input range and output range is mapped to a membership value between the range 0 and 1. The different forms of membership functions for different application are triangular, Gaussian, trapezoidal, and bell shape which is problem depended. The gaussian membership function has the advantage of being smooth and nonzero throughout, so we are using it. The decision-making unit performs the inference operations such as Logical AND, Logical OR, Logical NOT on the rules. We want to perform an intersection operation so Logical AND operator is used. Fuzzification interface acts as input interface which converts the crisp inputs into degrees of match with linguistic values with membership functions. The resulting fuzzy set must be converted to a number that can be sent to the plant as a control signal through defuzzification interface which act as output interface. There are different defuzzification methods such as bisector of area, mean of max, and centroid. We are using centroid method for Mamdani FIS as it relates to the moments. Fuzzy if-then rules are expressions in the implication form as If x is A (antecedent) Then y is B (consequent) where, x and y are input and output linguistic variables respectively. Fuzzy values A and B are membership functions. Here we are using twelve membership functions, logical AND as fuzzy logic operators, and twelve if-then rules.

V. MAMDANI FUZZY INFERENCE SYSTEM

Mamdani's fuzzy inference method is the popular and most commonly seen fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory, which was proposed by Ebrahim Mamdani as an effort to control a steam engine and boiler combination by synthesizing a set of linguistic control rules, in 1975. Mamdani's attempt was depends on Lotfi Zadeh's paper on fuzzy algorithms for complex systems and decision processes in 1973.

In Mamdani type model, the inputs and outputs are defined in fuzzy sets by membership functions which also define the range of the inputs and outputs beyond which the controller will be ineffective. The basic process involves fuzzification, fuzzy inference where the fuzzy sets are mapped according to the fuzzy rules, and defuzzification [13]. It allows us to describe the expertise in more visceral, more human friendly manner [14].

However, Mamdani-type FIS entails a substantial computational burden. Mamdani is widely accepted for capturing expert knowledge [15]. Due to the interpretable and intuitive nature of the rule base, Mamdani-type is widely used in particular for decision support application. This is best suitable for linear systems. For MIMO systems the Mamdani FIS is more appropriate, i.e. it can deal directly with MIMO.

VI. DEVELOPMENT OF MAMDANI FUZZY INFERENCE SYSTEM

The proposed FIS for tracking multiple targets consist of three inputs and one output. Number of Inputs depends upon number of reference signals send by Radar. These signals represent the path of targets fired from other countries. Here we are considering three targets. The system has one output that indicates the path of our missile to hit all those targets. So the path of missile is the output of FIS. The primaries GUI in the Fuzzy Logic Toolbox for Mamdani are explained below. The fuzzy inference system or FIS Editor for the Mamdani shown in Fig. 4; then add two input variables from Edit and named them as Target1, Target2, Target3 and output as a missile. Reference Signals of Target1, Target2, Target3 which was send by Radar are taken to be in the ranges of -0.9525 to 0.9512, 1.1489 to 1.1482, and -1.1249 to 1.1239, respectively. Each of the selected input and output variables is expressed by a set of twelve linguistic fuzzy values, defined by a Gaussian membership function as shown in Fig 5 for target1 by membership Editor; where "p" represents positive, "n" represents negative and "z" represents near to zero similar for target2 and target3 and then the fuzzification interface takes place followed by the Centroid Defuzzification method. Fig. 6 shows a missile membership function.

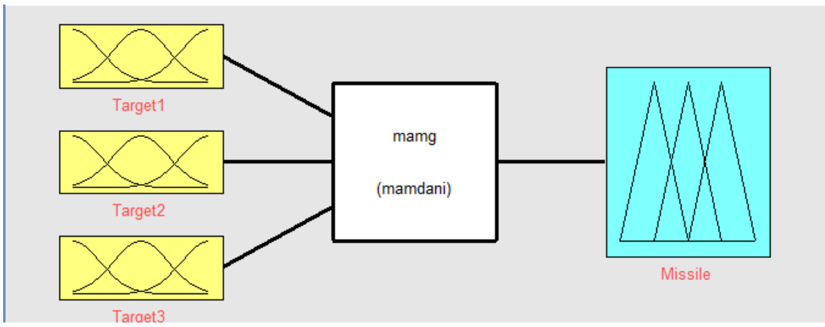


Fig. 4.Mamdani FIS

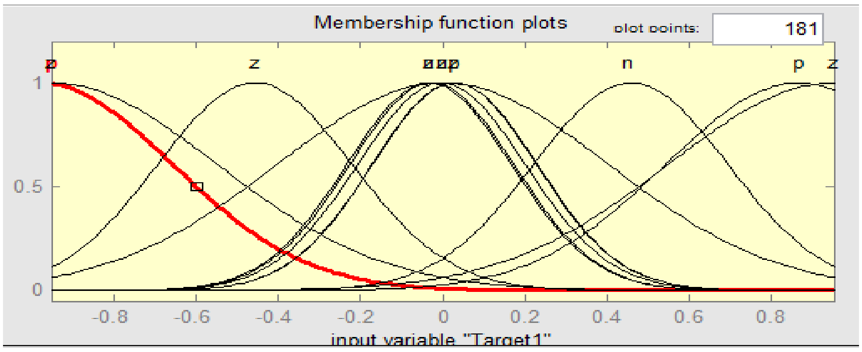


Fig. 5 Target1 Membership function

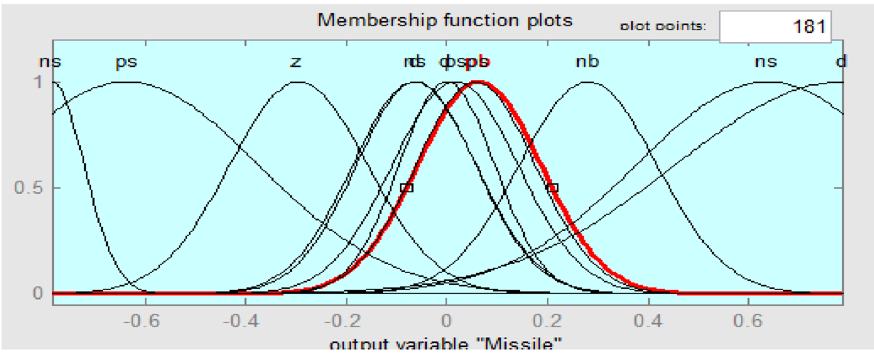


Fig. 6 Missile Membership function

The fuzzy inference rules for multiple Target tracking are derived from the concept that the missile will move in positive domain or in the negative domain depends on maximum targets in either domains, which are represented by "pb" for positive big , "ps" for positive small, "nb" for negative big, and "ns" for negative small. If two targets are in either of the two domains and one target close to zero, then the missile will move to the domain where target close to zero moving, which is represented by "d" for depends and if all targets are near to zero then missile blasts itself, which is represented by "z" for zero. The fuzzy inference rules for multiple target tracking are described Table I.

Table I. Rule base of Mamdani-type FIS

Rule	Target 1	Target 2	Target 3	Missile
1	Positive	Positive	Positive	Positive Big
2	Positive	Positive	Negative	Positive Small
3	Positive	Negative	Negative	Negative Small
4	Negative	Negative	Negative	Negative Big
5	Negative	Negative	Positive	Negative Small
6	Negative	Positive	Positive	Positive Small
7	Zero	Zero	Zero	Zero
8	Zero	Zero	Positive	Depends
9	Zero	Zero	Negative	Depends
10	Zero	Positive	Positive	Depends
11	Zero	Negative	Negative	Depends
12	Zero	Positive	Negative	Depends

Fuzzy rules can be shown in three formats such as Verbose, Symbolic, and Index. Rule base in symbolic format is shown in Fig.7 and Rule Base Editor is shown in Fig. 8.

1. If (Target1 is p) and (Target2 is p) and (Target3 is p) then (Missile is pb) (1)
2. If (Target1 is p) and (Target2 is p) and (Target3 is n) then (Missile is ps) (1)
3. If (Target1 is p) and (Target2 is n) and (Target3 is n) then (Missile is ns) (1)
4. If (Target1 is n) and (Target2 is n) and (Target3 is n) then (Missile is nb) (1)
5. If (Target1 is n) and (Target2 is n) and (Target3 is p) then (Missile is ns) (1)
6. If (Target1 is n) and (Target2 is p) and (Target3 is p) then (Missile is ps) (1)
7. If (Target1 is z) and (Target2 is z) and (Target3 is z) then (Missile is z) (1)
8. If (Target1 is z) and (Target2 is z) and (Target3 is p) then (Missile is d) (1)
9. If (Target1 is z) and (Target2 is p) and (Target3 is p) then (Missile is ps) (1)
10. If (Target1 is z) and (Target2 is n) and (Target3 is n) then (Missile is ns) (1)
11. If (Target1 is z) and (Target2 is z) and (Target3 is n) then (Missile is d) (1)
12. If (Target1 is z) and (Target2 is p) and (Target3 is n) then (Missile is d) (1)

Fig.7. Rule Base viewer (Symbolic)

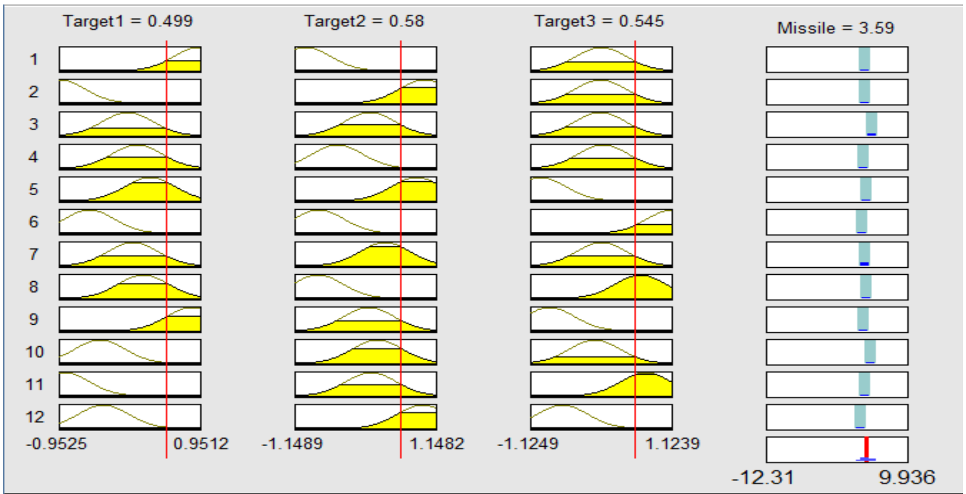
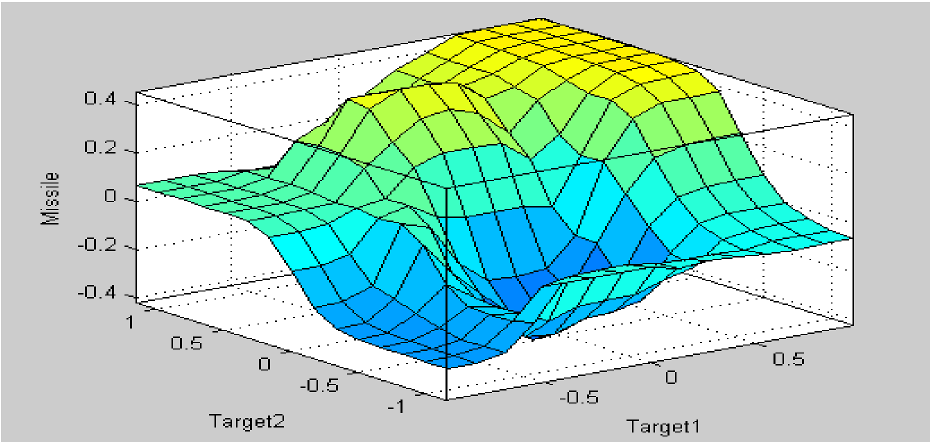


Fig.8. Rule Base viewer Editor

VII. RESULTS AND DISCUSSIONS

The following results were acquired during the simulation of Mamdani fuzzy inference systems. Fig. 9 illustrates the three-dimensional surface view of the relationship between the Target1, Target2 and missile; like this three dimensional surface view of other combination of targets with missile is possible. Fig. 10 illustrates two dimensional view of the relationship between the Target1 and missile; in the similar manner two dimensional surface views of other targets with missile are possible.



Fig, 9 Surface view of Target1, Target2 and missile

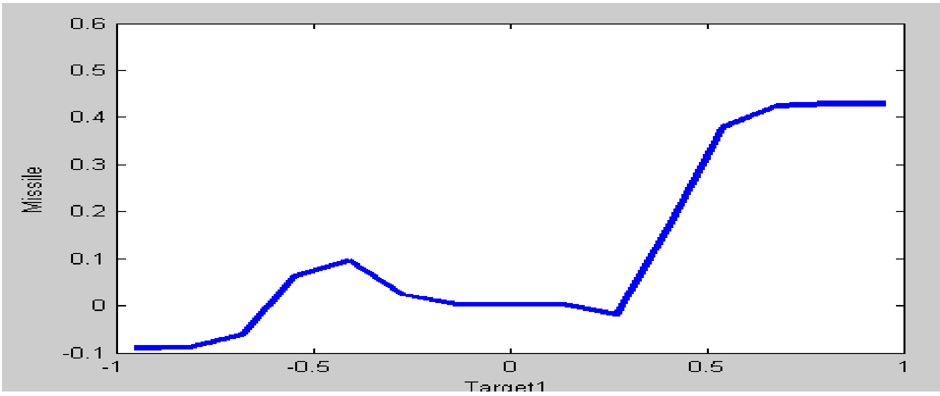


Fig. 10 Two dimensional relationship between Target1 and missile

The following results were obtained after the simulation of simulation model using Mamdani FIS. Fig. 11 illustrates the angle of attack. Fig. 12 illustrates the output of the multiple targets tracking system.

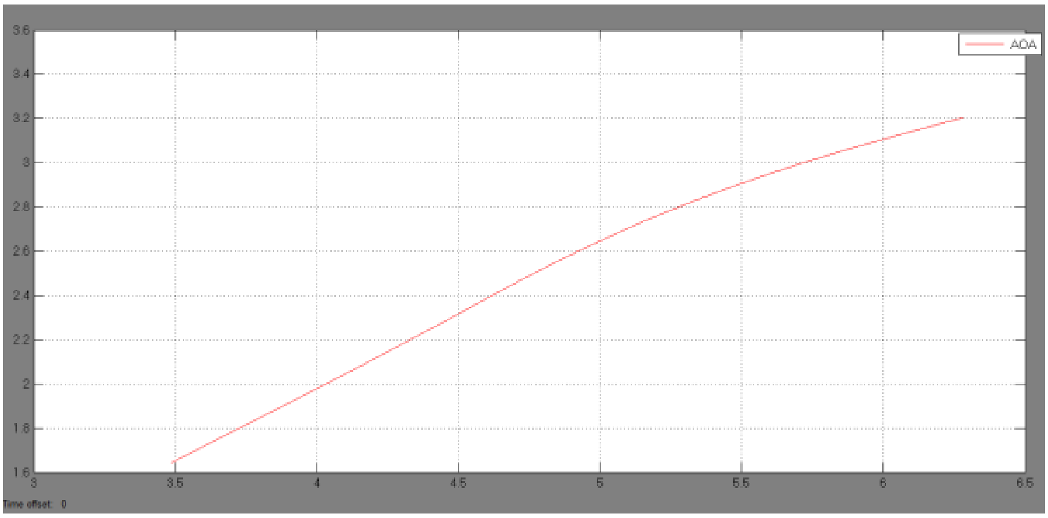


Fig. 11 angle of attack

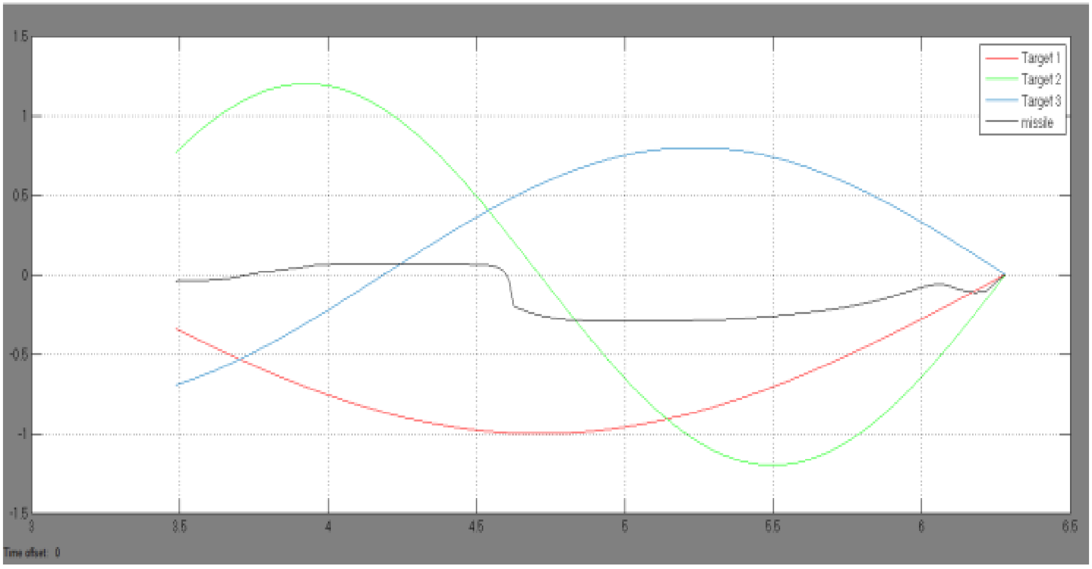


Fig. 12 output of multiple targets tracking system

VIII. CONCLUSION

A variety of fuzzy inference systems exists and employed these days for many applications. In Mamdani inference, the first process is fuzzifying the crisp values of input variables into according to appropriate fuzzy sets membership values; the consequent of if-then rule is defined by fuzzy set. The output fuzzy set of each rule will be reshaped by a matching number, and defuzzification is required after aggregating all of these reshaped fuzzy sets. Thus Mamdani inference is more popular.

Primarily Mamdani fuzzy inference system has been used to evaluate the missile's course for destroying targets. But this Mamdani fuzzy inference system does not follows concept behind rule base accurately as two dimensional relationships and output of system is not smooth. Mamdani FIS deals with both MIMO and MISO systems; but more accurately with MIMO systems. It is intuitive. It has widespread acceptance of capturing expert knowledge. It is well suited to human input as it is user friendly. Mamdani-type is widely used in particular for decision support application. This is best suitable for linear systems. Mathematical concepts within fuzzy reasoning are very simple. It is less flexible in system design and time consuming because of defuzzification process. So we will replace Mamdani fuzzy inference system with other type of fuzzy inference system for more precise output.

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