Fuzzy Model of Human's Performance for Guarding a Territory in an Air Combat

R. Ghasemi [i] *, S.K.Y. Nikravesh[ii], M.B. Menhaj[iii] and S. Akbari[iv]

Received 12 October 2009; received in revised 25 May 2010; accepted 22 September 2010

ABSTRACT

This paper proposes a new method for a three dimensional fuzzy model of pilot's performance for guarding a territory with a short-distance between two aircraft in an air combat task with a gun. A third-order nonlinear point mass vehicle model is considered for an aircraft's flight dynamics. The desired value of the velocity, the flight path and the heading angles are obtained from some derived equations and rule bases developed in this paper. The physical control parameters are computed through a mean square error scheme. To model pilot's performance and generate a complicated offensive maneuver in an air combat, we need to imitate pilot's decisions making performance. The proposed model shows promising performance in all scenarios in which two aircraft can hold in an air combat. This model employs a time optimal combination of classic pursuits when needed. This makes our model very powerful. We consider two cases for modeling, the first one is the model of the pilots with constant specific energy and the other is with time varying specific energy. Finally, this paper proposes a new 3-Dimentional flight simulator.

KEYWORDS

Fuzzy modeling, Guarding a territory, Pilot's performance, Maneuvering Offender, Pursuit Evasion Game, flight simulator.

1. INTRODUCTION

In the past, pilots have to obtain all necessary data and information only through their senses. Technology improvements cause to change the figure of the air combat. Nowadays, electronics and control systems decrease role of pilots in an air combat task.

The first method employed to model an air combat was optimal control strategy. For example, [1] employed concepts of differential game theory for developing an optimal pursuit-evasion problem between two aircraft. Another application of differential game theory to pursuit-evasion problem is an air combat between two aircraft for a long-range missile duel reported in [2]. An optimal guidance law was derived in [3] for a vehicle pursuing a maneuvering evader with the assumption that a complete knowledge of the evader's motions is available to the pursuer. Reference [4] proposed a non-fuzzy based approach that introduces a way to produce an optimal flight path preference in one-to-one air combat in which a multistage influence diagram models the pilot's sequential maneuvering decision.

The model provided by the differential game theory in an air combat modeling is not reliable enough to represent the performance of the pilot. Intelligent based techniques have also been used to imitate the problem of pilot's performance in an air combat. For example, a pilot assistance system used in associated systems offers data and information to pilots [5]. An air combat between many aircraft has also been discussed in [6]. In [7], a guidance law was developed against very high-speed targets. A fuzzy guidance law has been proposed for midcourse phase based on human decision-making. A fuzzy guidance law for 2-D modeling offensive maneuvers is considered for an air combat and a two-

i * Corresponding Author, R. Ghasemi is with the Department of Electrical Engineering, Damavand Islamic Azad University, Damavand, Iran (e-mail: reghasemi@gmail.com).

ii S.K.Y. Nikravesh is with the Department of Electrical Engineering, Amirkabir University of Technology, Tehran, Iran (e-mail: sknikravsh@aut.ac.ir).

iii M. B. Menhaj is with the Department of Electrical Engineering, Amirkabir University of Technology, Tehran, Iran (e-mail: mmenhaj@aut.ac.ir).

iv S. Akbari is with the Department of Electrical Engineering, Kashan University, Kashan, Iran (e-mail: s.akbari@ku.ac.ir).

phase pursuit law was presented as fuzzy "if…then…" rules in [8]. A three-dimensional fuzzy guidance law for generating a complex offensive maneuver against a maneuverable evader is presented in [9]. Reference [10] presented a new method for pilot's performance modeling using both, the classic and the fuzzy methods. These models can be used in a real time manner and its performance is quite the same as the pilot's performance. An intelligent method based on fuzzy computation is presented in [11] and the capture rate of the presented model is higher than that of the one given in [5]. [12] employed 2-dimentional fuzzy differential game theory to model pilot's performance in guarding a territory. A method based on fuzzy differential game theory was developed in [13] for modeling the pilot's performance in guarding a moveable object. The models proposed in [12, 13] perform quite differently from the pilot's performance.

[18] presented a concurrent fuzzy-neural network approach combining unsupervised and supervised learning techniques to develop the Tactical Air Combat Decision Support System. [19] developed an evaluation approach based on the technique for order Performance by similarity to ideal solution to help the air force academy choose optimal initial training aircraft in a fuzzy environment. [20] modeled the air combat effectiveness assessment problem as a multi-criteria decision making problem. An improved Fuzzy C-means algorithm is applied to classify the multi-target in the air combat, and divides them into several colonies averagely in [21].

In this paper, we propose a new 3-D fuzzy based method to model pilot's performance for guarding a territory in a short distance air combat with a gun. A set of fuzzy "if …then" rules and some classic equations can model pilot's decisions in an air combat task. The desired value of the velocity, the flight path and heading angles are obtained from some rule bases and equations. The physical control parameters are computed through a mean square error scheme. The computer simulations provide an encouraging validation of the proposed model. Mimicing pilot's maneuvering in an air combat is one of the advantages of the presented model.

The remaining of the paper is organized as follow: Section 2 presents the problem statement. Section 3 discusses the aircraft model. Section 4 presents the linguistic model of pilot's performance. Section 5 presents the fuzzy model of the guarding pilot. Section 6 presents Real-time simulation program. Simulation results are shown in section 7 and finally Section 8 concludes the paper.

2. The Problem Statement

Here, we consider the situation given in figure 1. Two aircraft (P and E) are engaged in a combat task in which the P aircraft tries to guard the territory and the other one is in the offensive mode. The P aircraft has an energy advantage and further two aircraft can maneuver in the three dimensional space. The flight dynamics of both aircraft are governed by the third-order nonlinear point mass equations fully discussed in section 3. Being more realistic, we consider here the two aircraft both have thrust, velocity and turn radius limitations. The problem is to find a model of pilot's performance that puts the E aircraft in its rear hemisphere and then tries to put target in its effective gun envelope before the E aircraft can arrive to the specified territory. The effective gun envelope shall lie between a minimum and maximum range. The maximum range is because of the bullet velocity, the rate fire and bullet aerodynamics. The minimum range is to avoid collision with the target or the target debris. The proposed model must act in a manner in which the P aircraft does not lose any energy in energy constant mode. In addition to reaching a suitable position for shooting, the P aircraft must not let the E aircraft to enter the specified territory.

The pilots always use the constant energy mode. If the energy of the aircraft decreases in an air combat, the pilot may lose his situation advantage. The first case in which the constant energy mode considered, we investigate another case with the almost energy constant mode. With this assumption, we guess that the capture time decrease.

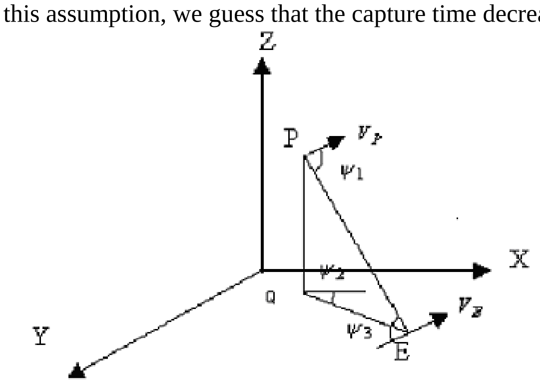

Fig. 1: air combat geometry

Let the position of the P aircraft be $\left(x_p \quad y_p \quad z_p\right)$, the position of the E aircraft be $\left(x_e \quad y_e \quad z_e\right)$ and the position of the territory be at $\left(x_T, y_T, z_T\right)$ and the following is listed.

Flight path angle$\left(\gamma\right)$: the angle between velocity vector and horizontal plane,

Heading angle$\left(\chi\right)$: the angle between projection of the velocity vector in X-Y plane with X-axis,

LOS (Line of sight): direct line between 2 aircraft,

Vertical distance: distance between P and Q point,

Horizontal distance: distance between E and Q point,

Lead angle (ψ_2): angle between projection of the velocity vector of pursuer (V_P) in X-Y plane and LOS, AOT (ψ_3): angle between the velocity vector of evader (V_E) and LOS ,

Off angle (ψ_1): angle between V_P and LOS ,

Δ Distance: the difference distance between two aircraft at times t_k and t_{k-1} ,

Δ Lead angle: the difference lead angle of the P aircraft at time instants t_k and t_{k-1}, X-distance assigned by $(x_p - x_e)$ difference distance along the x-axis, Y-distance presented by $(y_p - y_e)$ is difference distance along the y-axis, Z-distance assigned by $(z_p - z_e)$ is difference distance along the z-axis.

V is the airspeed, T the thrust, D the vehicle drag, L the lift, m the vehicle mass, g the acceleration due to gravity, γ the flight pass angle, χ the heading angle, φ the bank angle, E_S the specific energy, E_e the energy state and H represents the height of the aircraft. The velocity ratio assigned by V_P / V_E in which V_P and V_E are velocity of P and E aircraft. Distance ratio is as $\sqrt{\frac{(x_p - x_e)^2 + (y_p - y_e)^2 + (z_p - z_e)^2}{(x_e - x_T)^2 + (y_e - y_T)^2 + (z_e - z_T)^2}}$. ρ is the atmosphere density, S is the reference area of wing, C_d is the drag coefficient, C_l is the lift coefficient, D is the drag and L denotes the lift.

γ_{des} the desired value of flight path angle and χ_{des} is the desired heading angle. W is a weighting parameter that is defined in section (5-2-3).

3. AIRCRAFT MODEL

The point mass equations of motion for an aircraft for a flat non-rotating earth, thrust along the path and a quiescent atmosphere are given by the following equations [7].

$$\begin{aligned}
\dot{V} &= \frac{T - D}{m} - g \sin \gamma \\
\dot{\chi} &= \frac{L \sin \phi}{mV \cos \gamma} \\
\dot{\gamma} &= \frac{g}{V}\left(\frac{L \cos \phi}{mg} - \cos \gamma\right) \\
\dot{x} &= V \cos \gamma \cos \chi \\
\dot{y} &= V \cos \gamma \sin \chi \\
\dot{z} &= V \sin \gamma
\end{aligned} \tag{1}$$

The aerodynamics drag and lift are calculated as:

$$D = \frac{1}{2} \rho V^2 S C_d \tag{2}$$

$$L = \frac{1}{2} \rho V^2 S C_L \tag{3}$$

The motion equations of the evader are in the same form as those of the pursuer given in (1). The total "energy state" is sum of the kinetic energy and the potential energy. The “energy state” is calculated as:

$$E_e = mgH + \frac{1}{2} mV^2 \tag{4}$$

Eliminating the weight of aircraft from the energy state calculation causes the "specific energy" defined in (5).

$$E_s = H + \frac{V^2}{2g} \tag{5}$$

Where, H and V stand for the potential and the kinetic energy, respectively.

4. LINGUISTIC MODELS

In this section, we present suitable linguistic models for both P and E aircraft. To do so, we are required to comply with the assumptions made in section (2), expert decisions as well as the pilot's maneuvering skill [14-17]. After some investigations the linguistic models are proposed as follows.

The P aircraft attempt to do the out of plane maneuvers to put the target in its effective gun envelope before the E aircraft arrives at the specified territory. In this air combat, the guarder must avoid loss of energy. The E aircraft offends to the territory by diving toward it.

In an air combat, pilots usually determine the flight path angle as well as the heading angle. The linguistic model of the guarder is summarized below.

A. The flight path angle

In this case, the pilot uses lead pursuit in the flight path angle when the distance between two aircraft is big, but near the target, the P aircraft holds its nose directly on the target.

B. The heading angle

Through some investigations, we reach to the conclusion that the heading angle becomes different when the two aircraft are head on case or head to tail case with the following rules:

If AOT is more than 90^0 and less than 270^0, the aircraft is in head to tail case. Otherwise, it is in head on case.

In the head on case, the pilots employ the lag pursuit when the x-distance is big or the y-distance is small. As the y-distance increases and the x-distance decreases the lag angle decreases.

In the head to tail case, the pilots employ lead pursuit and decrease the lead angle when they are close to the target.

According to the acquired data from [14-17] and pilots as well, the change of the flight path angle and the heading angle do not share the same value of importance. The relative importance of the angles in an air combat is discussed below.

C. The relative importance of the angles

Consider in which the E aircraft starts to dive toward the territory. If either the distance is big and the horizontal distance is small or the heading angle of the E aircraft is big, then the flight path angle becomes important.

On the contrary, the heading angle becomes more important, if both of the vertical distance is small and the horizontal distance is big, Furthermore, we evaluate the importance of the both angles the same, if either of the following two cases is satisfied 1) dangerous overshoot may be occurred, 2) the distance is small, then the degree of importance of both angles become the same.

5. THE FUZZY MODEL OF THE GUARDER

For designing suitable rule bases of fuzzy guidance block, we must use linguistic model of pilot's performance and experimental data as well. The linguistic model is essential for designing a set of proper tables to establish a set of related membership functions. We deliver experimental data to pilots and evaluate its performance in an air combat task. A sample of these tables is given below.

TABLE 1
PILOT'S NUMERICAL DATA

Input Data	X-distance	500
	Y- distance	500
	Z-distance	1000
	Lead angle	50^0
output Data	γ_{des}	60^0
	χ_{des}	45^0

According to the information mentioned in section (4) and numerical data, this section proposes a fuzzy model as depicted in figure (2).

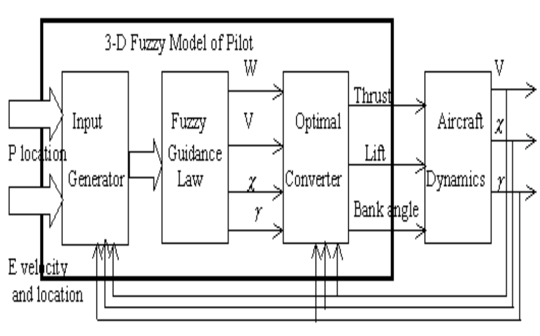

Fig. 2: 3-D fuzzy model of the guarder performance

As observed in figure (2), the proposed model of the pilot has three distinct blocks: Input generator, Fuzzy guidance law (FGL), and the optimal converter. Each block is discussed below.

A. The inputs generator

This block is for generating the inputs of the FGL block. The formulas used in this block are given below.

$$LOS = \begin{bmatrix} x_e - x_p \\ y_e - y_p \\ z_e - z_p \end{bmatrix}$$

$$Off\ Angle =$$

$$\cos^{-1}\left(\frac{(x_e - x_p)\dot{x}_p + (y_e - y_p)\dot{y}_p - (z_e - z_p)\dot{z}_p}{\sqrt{(\dot{x}_p^2 + \dot{y}_p^2 + \dot{z}_p^2)((x_e - x_p)^2 + (y_e - y_p)^2 + (z_e - z_p)^2)}} \right)$$

$$Lead\ Angle = \tan^{-1}\left(\frac{(y_e - y_p)\cos\chi - (x_e - x_p)\sin\chi}{(x_e - x_p)\cos\chi + (y_e - y_p)\sin\chi} \right) \quad (6)$$

B. The fuzzy guidance law

This block is for generating maneuvers of guiding aircraft. This block includes four sub-blocks: for the calculation of the heading angle, for the calculation of the flight path angle, for the calculation of the weighting parameters and also the velocity prediction. The proposed sub-blocks are shown in figure (3). In the following sections, the term set *vs, pb, s, ze, p, la, nb* and *n* are stand for very small, positive big, small, zero, positive, large, negative big, and negative value respectively.

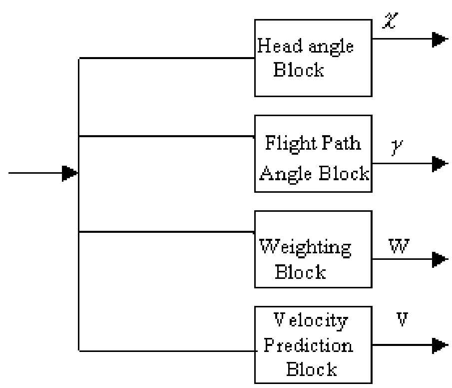

Fig. 3: Fuzzy guidance law block

The next subsections deliver complete details about figure 3.

In the following rule bases, the membership functions are arbitrarily chosen as triangular and trapezoidal shapes. The membership function parameters have been derived through both the information acquired from pilots and references [14-17]. In the following rule bases, the fuzzification method is singleton, the defuzzification method is defined as centroid, the implication method is presented as min, and the aggregation method max.

C. The flight path angle block

This block is for calculation of the flight path angle in an air combat. According to the linguistic model given in section (4), the effective inputs of this block are the vertical and the horizontal distance, the lead angle and the ratio of the distance between two aircraft to the distance of the E aircraft from the specified territory.

This angle has a lead angle that must be assigned by the pilots. The flight path angle without the lead angle can be calculated as considering the definition of the section 2.

$$\gamma_{des} = \tan^{-1}\left(\frac{vertical \quad distance}{horizontal \quad distance}\right) + \gamma_p \tag{9}$$

γ_{des} is the desired flight path angle of the P aircraft and γ_p is the actual flight path angle of the P aircraft. The desired flight path angle with the lead angle is determined as:

$$\gamma_{des} = \tan^{-1}\left(\frac{vertical \quad distance + M}{horizontal \quad distance}\right) + \gamma_p \tag{10}$$

The parameter M indicates the amount of lead angle required for a high capture rate. It is calculated from a set of rule bases developed in this paper and the inputs to these rule bases are the distance between two aircraft, the vertical distance and distance ratio. A sample of the rules is shown below.

if(distance is ze)and(vertical_distance is not ze)then(M is p)

The descending rule base contains 10 rules.

D. The heading angle

This block is for calculation of the desired heading angle of the P aircraft in an air combat task. The inputs of this block are the x-distance, the y-distance, the vertical distance and the distance between two aircraft. The pilots employ the lead angle. The desired heading angle without consideration of the lead angle can be derived as:

$$\chi_{des} = \tan^{-1}\left(\frac{X\_distance}{Y\_distance}\right) \tag{11}$$

According to the linguistic model given in the section (4), in the head on case, the P aircraft uses lag pursuit. The desired heading angle can be calculated as:

$$\chi_{des} = \tan^{-1}\left(\frac{Y - distance}{X\_dixtance + N}\right) \tag{12}$$

A rule base calculates the parameter N. The inputs of this rule base are the distance and the horizontal distance. In the head to tail case, the P aircraft uses the lead pursuit. In this case the desired heading angle can be calculated as:

$$\chi_{des} = \tan^{-1}\left(\frac{Y\_distance + N}{X\_distance}\right) \tag{13}$$

The parameter N is also obtained from a set of rules whose inputs are the x-distance, the z-distance and the y-distance. A sample of the rules is shown below.

*if(distance is ze)and(*horizontal_*distance is not ze)then(N is p)*

The heading angle rule base contains 10 rules.

E. The weighting parameter

According to the linguistic model discussed in section (4), the inputs to this block are the horizontal and the vertical distance, the velocity ratio, the lead angle, the change of the lead angle, the flight path angle of the P aircraft and the change of the lead angle. A sample of the rules is shown below.

If(horizontal_distance is not s)or(gama is not s)or(velocity_ratio is not la)then(W is teta)

"W is teta" in the above rule, means that χ is important in this situation. The climb weighting parameter rule base consists of 17 rules.

F. Velocity prediction

This block is for the velocity prediction in which the specific energy is constant. According to the constancy of energy in the P aircraft, we first take the derivative of (2) and then use the equation (1) to obtain (14).

$$\begin{aligned} \dot{V} &= -g \sin\gamma \\ T &= D \end{aligned} \tag{14}$$

According to this equation the maximum values of the thrust and the drag are equal. Here, we must consider a velocity limitation as follows.

If the velocity given in (14) is smaller than V_{pMin}, we must use the following equation.

$$\dot{V} = 0 \tag{15}$$

G. The optimal converter block

If the specific energy is constant then this block is for converting the desired values of the state variables to corresponding the physical inputs of the aircraft dynamics such as the thrust, the lift and the bank angle. These variables should satisfy the following relationship.

$$\begin{aligned} &Min\{W\,(\gamma(k+1) - \gamma_{des})^2 + (\chi(k+1) - \chi_{des})^2\} \\ &\text{s.t.} \quad L \le L_{Max}, -90 \le \varphi \le 90 \end{aligned} \tag{16}$$

The condition $L \le L_{\max}$ states that the P aircraft will not lose any energy, L is the required lift and L_{Max} represents the valid maximum lift that can be obtained as:

$$\begin{aligned} L_{Max} &= \sqrt{(T_{Max} - 0.5 C_{D0} S \rho V^2)\frac{\rho S V^2}{2K}} \\ L &= \sqrt{(mV\dot{\chi}\sin\gamma)^2 + (mV\dot{\gamma} + mg\cos\gamma)^2} \end{aligned} \tag{17}$$

where K is a constant value. In the varying specific energy, we can input the derived the specific energy in equation (16). If the specific energy is almost constant then the previous equations and the prediction block is not valid and the velocity, the thrust, the lift and the bank angle are determined as follow.

$$\begin{aligned} &Min\{W_1(E_s(k+1)-E_s(k))^2 \\ &\quad +W_2(\chi(k+1)-\chi_{des})^2 \\ &\quad +(\gamma(k+1)-\gamma_{des})^2\} \\ &s.t.\quad 0<T\le T_{max}, L\le L_{max}, -\frac{\pi}{2}\le\varphi\le\frac{\pi}{2} \end{aligned} \tag{18}$$

$$V(k+1)=V(k)+T_S\left(\frac{T-D}{m}+g\sin\gamma(k)\right) \tag{19}$$

where W_1, W_2 are the energy constancy parameter and the weighting parameter, respectively. The L_{Max} can be determined from V-n Diagram as mentioned in [14]. By using the equations (1) through (5), we can rewrite the equation (18) as:

$$\begin{aligned} &Min(W_1(z(k+1)-z(k)+\frac{V^2(k+1)-V^2(k)}{2g})^2 \\ &+W_2(\chi(k)-\chi_{des}-\frac{T_s LSin\varphi}{mVCos\gamma})^2+ \\ &(\gamma(k)-\gamma_{des}-\frac{gT_s}{V}(\frac{LCos\varphi}{mg}-Cos\gamma(k)))^2) \\ &s.t.\quad 0<T\le T_{max}, L\le L_{max}, -\frac{\pi}{2}\le\varphi\le\frac{\pi}{2} \end{aligned}$$

(20)

6. Real-time simulation program

In order to visually represent the simulation process in real-time, we developed a computer program under Windows operating system using C++ language. This program has two major modes. The first mode is real-time simulation of the flight, which user can change input values using the provided GUI controls and see the effects instantly. The second mode is simulation of two airplanes in fight, which gets simulation results from MATLAB and updates the scene, respectively. In both modes, we can see the scene in 3D.

Program consists of two main blocks, the primary one handles GUI events and updates 3D scene, and the secondary one solves equations of motion. The relationship between the two threads is shown in figure (4).

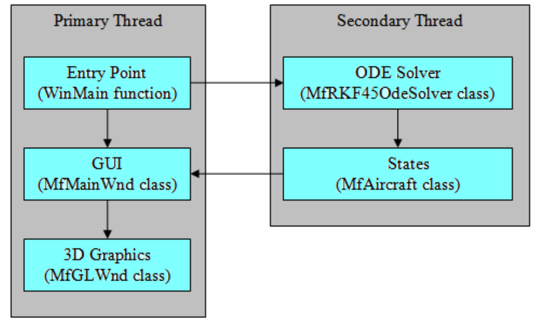

Fig. 4: the view of the simulator programming

As shown in the above diagram, the program has 4 major modules:

GUI module: handles GUI events and user interaction

ODE Solver module: solves system of differential equations

States module: defines state variables of the airplane and equations of motion

3D Graphics module: updates 3D scene

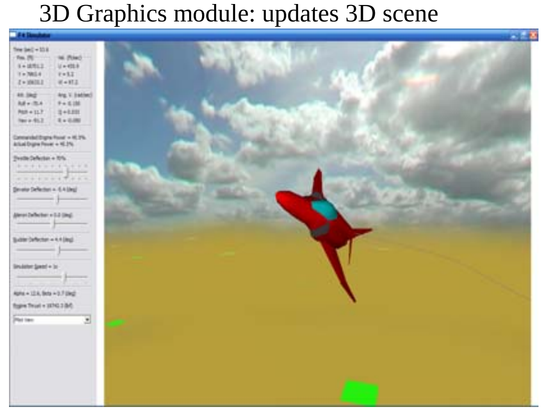

Fig. 5 the view of the simulator

7. Simulation Results

In this section, we consider the performance of the proposed model. The P and E aircraft parameters are given below [7].

$$T_{Max}=10^5 N; k=0.179; V_{p0}=200\,m/s;$$

$$m=10^4 kg,\ S=26m^2; V_{e0}=120\,m/s$$

$$C_{d0}=0.0169; \rho=0.8,\ V_{pMin}=60\,m/s$$

The pilots approved the simulation results of the fuzzy modeling. The simulation results easily approve the high capability of the proposed model for capturing the E aircraft in all cases before the E aircraft enters the guarding territory.

We first consider the case in which the specific energy is constant. The simulation results show that the thrust and lift performance are approximately the bang-bang type and our method performs near time optimal performance. The guarding territory is located at (10000, 0). The following cases are further investigated.

1) Head to tail case: in order to check how good our model performs, we consider the following cases. The P and E aircraft are initially located in (-500, 0, 5000) and (0, 0, 5000), respectively with initial lead angle equal to 0^0. Figure (6) shows the capability of the model in generating a near time optimal performance combination of the vertical lead turn and the horizontal lag turn regularly done by pilots.

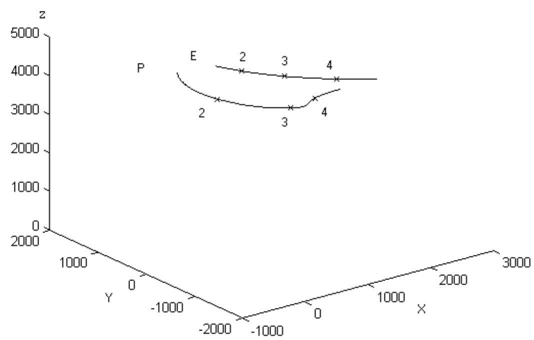

Fig. 6: the path produced by proposed model

2) Head on case: The P and E aircraft initially located in (5000, 4000, 5000) and (0, 0, 5000), respectively and the initial lead angle is 180^0. Figure (7) plots the performance of the proposed model in generating an optimal time combination of the classic maneuver. In this case, we easily see that the P aircraft initially uses out of plane lag turn and then employs a classic maneuver to gain angular advantage. To see how robust our method is against noise, we consider the P and E aircraft initially located in (5000, 5000, 5000) and (0, 0, 5000) respectively while the inputs of the P aircraft are contaminated by noise. We consider the inputs of the input generator block are signals. The signal to noise ratio is 90%. Finally to show the proposed model behaves in a bang-bang mode, at the first simulation, we consider the P and E aircraft initially located in (-2000, 1000, 5000) and (0, 0, 5000) respectively in figure (8). Figure (9) shows the thrust and the lift and the bank angle are the bang – bang type.

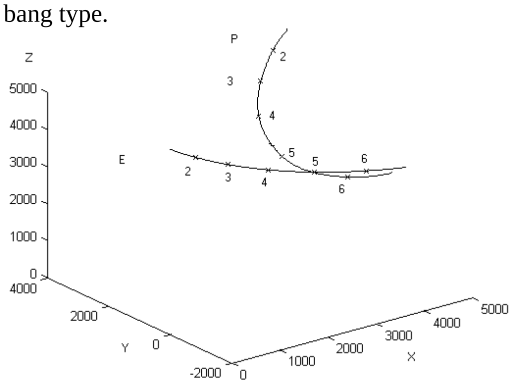

Fig. 7: the path produced by proposed model in first simulation

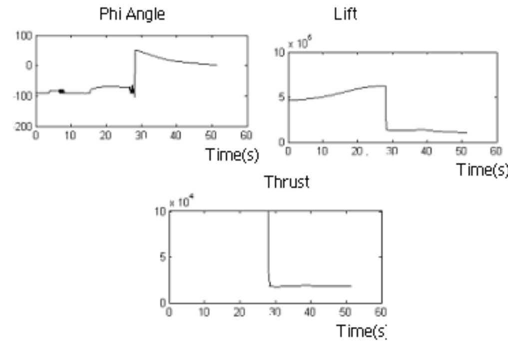

Fig. 8: Thrust, Lift and bank angle variation of aircraft P during a maneuver in the first simulation

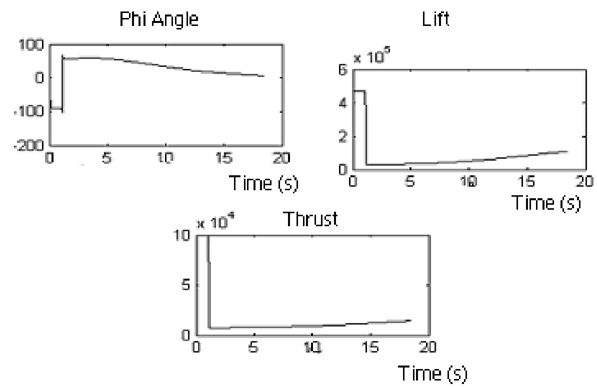

Fig. 9: Thrust, Lift and bank angle variation of aircraft P during a maneuver in the second simulation

Then in the second simulation, we consider the situation in which the specific energy is almost constant. At the third simulation, we consider the following cases. The P and E aircraft are initially located in (-1000, 500, 5000) and (0, 0, 5000) respectively with initial lead angle of 0^0 and $W_1 = 1$. Figure (10) shows the capability of the proposed model in generating a near time optimal performance combination of the vertical lead turn and the horizontal lag turn regularly done by pilots. In this case, the Thrust, the Lift and the bank angle are shown in figure (11).

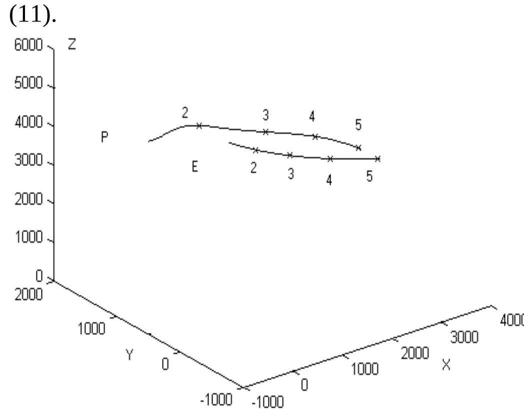

Fig. 10: the path produced by proposed model with almost constant energy in the third simulation

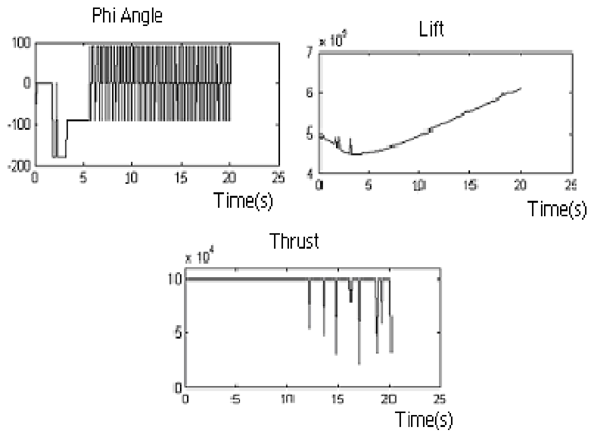

Fig. 11: Bank angle, Thrust and Lift aircraft P during a maneuver with almost energy constant in the third simulation

From figure (11), it is clear that the change in the bank angle, the thrust and the lift are not acceptable. This shows that the model with this assumption is not correct. Finally the proposed model applied in software simulator is shown in figure (12) where the red aircraft wants to pursuit the blue one.

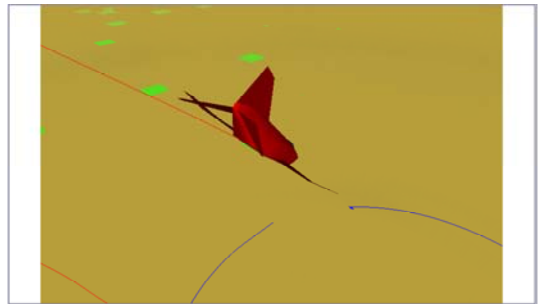

Fig. 12: the view of the simulator

8. CONCLUSION

In this paper, an intelligent model for modeling of the pilot’s performance for guarding a territory is finally derived. This model is a combination of the classic model and the fuzzy modeling in which the fuzzy model allows us to model uncertainty and imprecision of the pilot’s knowledge; this is suitable for guarding a territory and generating complex maneuvers in an air combat task. The model employs a near time optimal combination of the classic pursuits. The pilots approved that the fuzzy model can mimic the pilot's performance in an air combat. This is the advantages of the proposed model. The computer simulations provided an encouraging validation of the proposed model in the constancy energy mode. The simulation results showed that the proposed model is not performable when the specific energy is almost constant. The proposed simulator has promising performance.

9. REFERENCE

[1] Hammer J.M., Small R.L., An intelligent interface in an associate system, In Rouse W B (ed.) Human / technology interactions in complex systems, vol.7, pp. 871-882, 1996.

[2] Rodin E.Y., Geist D., Lirov Y., Flight and fire control knowledge representation, proceeding 28th IEEE CDC, 1989, pp.779-780.

[3] Lin C.L. and Chen Y.Y., Design of fuzzy logic guidance law against high speed target, Journal of guidance, control and dynamics, No.1, Vol.23, pp.17-25, 2000.

[4] Akbari S., Menhaj M.B., A fuzzy guidance law for modeling offensive air-to-air combat maneuvers, IEEE conf, IFSA World congress and 20th NAFIPS international conference, pp.3027-3031, 2001.

[5] Akbari S., Qualitative model of pilot performance in air to air combat task: fuzzy set theory approach., Phd dissertation, Electrical Department, AUT, Iran, 2002.

[6] Virtanen K., Raivio T., Hamalainen R.P., Modeling pilot's sequential maneuvering decisions by multistage influence diagram, Proceeding of AIAA guidance, control and dynamics conference, pp. 175-181, 2001.

[7] Menon P.K. and Duck E.L., Time optimal pursuit evasion with weapon envelope constraint, journal of guidance, control and dynamics, vol. 15, No.2, 1992, pp.448-456.

[8] Jamark B., A missile duels between two aircraft, journal of guidance, control and dynamics, vol.8, No.4, 1985, pp.508-513.

[9] Guelman M. and Shinar J., Optimal guidance law in the plane, Journal of Guidance, Control and Dynamics, vol.8, No.4, 1985, pp.471-476.

[10] K. H. Hisa and J. G. Hsieh, “A first approach to fuzzy differential game problem: guarding a territory,” fuzzy sets and system, vol. 55, 1993, pp. 157-167.

[11] H. J. Chu, J. G. Hsieh, K. H. and L. W. Chen, “Fuzzy differential game of guarding a movable territory,” Information Sciences, vol. 91, pp. 113-131, 1996.

[12] Ghasemi R, Nikravesh SKY, Menhaj MB, Akbari S, “A near optimal fuzzy model of pursuit-evasion in an air combat”, WSEAS TRANSACTIONS ON MATHEMATICS, Issue 3, Volume 3, 2004, pp 514-521.

[13] Ghasemi R, Nikravesh SKY, Menhaj MB, Akbari S,” A 3-D fuzzy model of pilot’s performance in the dogfight”, WSEAS TRANSACTIONS ON MATHEMATICS, Issue 3, Volume 3, 2004, pp 625-631.

[14] Anderson J.D., *Introduction to flight*, McGrow Hill, 3rd edition, 1989.

[15] Shaw R.L., *Fighter combat: Tactics and Maneuvering*, 1st edition, United States Naval Inst., 1988.

[16] Rappier, ACM, training: Angle Tactics, http://www.musketeers.org.

[17] Crenshaw D., How to live and die in the virtual sky, http://www.sci.fi/~fta/acmintro.htm.

[18] Tran C., Abraham A. and Jain L.,” A Concurrent Fuzzy-Neural Network Approach for Decision Support Systems”, IEEE International Conference on Fuzzy Systems, pp. 1092-1097, 2003

[19] Wang T.C., Chang T.H., “Application of TOPSIS In Evaluating Initial Training Aircraft Under A Fuzzy Environment”, Expert Systems with Applications 33, pp. 870–880, 2007

[20] Wang J., Fan K., Su Y., Liang S., and Wang W., “Air Combat Effectiveness Assessment of Military Aircraft Using a Fuzzy AHP and TOPSIS Methodology”, IEEE 7th intl. conf. on system simulation and scientific computing, pp. 655-662, 2008.

[21] Zhang K., Zhou D., “Application of Improved FCM on Classification of Multi-Target Guided by AWACS”, IEEE computer Society, Fifth International Conference on Fuzzy Systems and Knowledge Discovery, pp. 47-51, 2008.