Известия вузов России. Радиоэлектроника. 2023. Т. 26, № 3. С. 90–98
Journal of the Russian Universities. Radioelectronics. 2023, vol. 26, no. 3, pp. 90–98

Radar and Navigation
UDC 621.391 Original article
https://doi.org/10.32603/1993-8985-2023-26-3-90-98

A Target Threat Assessment Method for Application in Air Defense Command and Control Systems

Xuan Truong Nguyen [1]✉, Kim Phuong Phung[1], Quang Hieu Dang[1], Xung Ha Vo[2], Hoa Tien Vu[1]

[1]Le Quy Don Technical University, Hanoi, Vietnam

[2]National Institute of Science and Technology, Hanoi, Vietnam

✉truongnx.isi@lqdtu.edu.vn

Abstract

Introduction. This paper presents a solution for threat assessment of air targets using the fuzzy logic inference method. The approach is based on the Sugeno fuzzy model, which has multiple inputs representing target trajectory parameters and a single output representing the target threat value. A set of IF–THEN fuzzy inference rules, utilizing the AND operator, is developed to assess the input information.

Aim. To develop and test an algorithm model to calculate the threat value of an air target for use in real-time automated command and control systems.

Materials and methods. An algorithm model was developed using a fuzzy model to calculate the threat value of a target. The model is presented in the form of a flowchart supported by a detailed stepwise implementation process. The accuracy of the proposed algorithm was evaluated using the available toolkit in MATLAB. Additionally, a BATE software testbed was developed to assess the applicability of the algorithm model in a real-time automated command and control system.

Results. The efficiency of the proposed fuzzy model was evaluated by its simulation and testing using MATLAB tools on a set of 10 target trajectories with different parameters. Additionally, the BATE software was utilized to test the model under various air defense scenarios. The proposed fuzzy model was found to be capable of efficiently computing the threat value of each target with respect to the protected object.

Conclusion. The proposed fuzzy model can be applied when developing tactical supporting software modules for real-time air defense command and control systems.

Keywords: fuzzy logic, fuzzy model, threat value, air defense, command and control system

For citation: Xuan Truong Nguyen, Kim Phuong Phung, Quang Hieu Dang, Xung Ha Vo, Hoa Tien Vu. A Target Threat Assessment Method for Application in Air Defense Command and Control Systems. Journal of the Russian Universities. Radioelectronics. 2023, vol. 26, no. 3, pp. 90–98. doi: 10.32603/1993-8985-2023-26-3-90-98

Conflict of interest. The authors declare no conflicts of interest.

Submitted 26.03.2023; accepted 28.04.2023; published online 29.06.2023

Introduction. Automatic evaluation of the air situation and information updates in automated command and control systems (ACCS) plays a pivotal role in ensuring the effectiveness of combat operations (as depicted in Fig. 1). The threat level of targets with respect to the protected object can be assessed based on target data from radar sources and higher-level information processing. These values are aggregated and filtered to serve as a crucial input parameter for target distribution requests and selection of appropriate combat means, enabling informed decision making using air defense systems [1, 2].

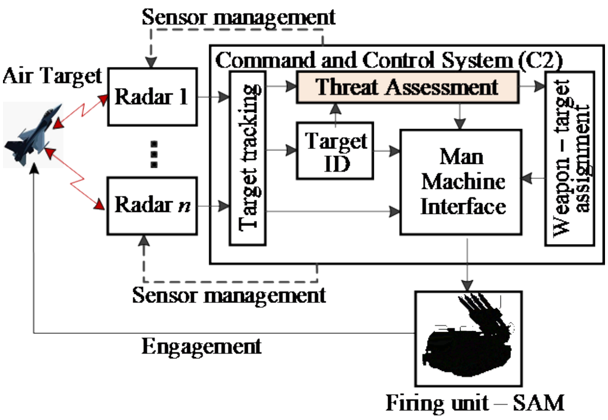

Fig. 1. Function overview of an ACCS

Automatic evaluation of the air situation is a continuous, real-time process that determines the threat value of targets to the protected objects. Calculating the threat value is a challenging task due to the need for high processing performance, information synthesis from multiple sources, and real-time requirements. The information used for situation assessment is frequently obtained from various heterogeneous, uncertain, and interfered sources [3, 4]. Therefore, to ensure reliability, it is necessary to employ estimation algorithms capable of inferring from incomplete or unreliable information sources. Currently, fuzzy logic and Bayesian probability networks are widely used for assessing the threat of air targets [5–9]. In this paper, considering the priority of real-time approaches, we develop a method for automatic target threat assessment based on fuzzy logic methods.

The threat value is evaluated based on the inference ability of fuzzy systems, including linguistic variables, fuzzy sets, fuzzy rules, defuzzification mechanisms, etc. The outstanding advantage of this method consists in its similarity with natural inference mechanisms, thus enabling users to participate in the design processing of inference systems and use their expert knowledge to propose suitable fuzzy rules. At the same time, the fuzzification process contributes to smoothing threat value variations at uncertainty boundaries.

Research methods.

Basic structure of a fuzzy model. The fuzzy set theory proposed by Lotfi A. Zadeh includes fuzzy logic, fuzzy arithmetic, fuzzy mathematical programming, fuzzy topological geometry, fuzzy graph theory, and fuzzy data analysis. This theory aims to introduce the concept of fuzzy sets. Mathematically, a fuzzy set $\mathbf{A}$ on a basic space $\mathbf{X}$ is defined as $\mathbf{A} = \left\{ \left[\mu_{\mathbf{A}}(x)/x \right] \middle| x \in \mathbf{X} \right\}$. In which, $\mu_{\mathbf{A}}(x)$ is a membership function that quantifies the degree to which elements x belong to the basic set $\mathbf{X}$, expressed as: $\mu_A : \mathbf{X} \to [0,1]$.

The structure of a typical basic processing model conventionally includes an input, an output, and a processor. The processor is essentially a mapping that reflects the dependence of the output variables on the input variables in the system. In a fuzzy model, a certain numerical value can be taken as an input, a fuzzy set or an unambiguous numerical value can be taken as an output. The output–input mapping relationship of a fuzzy model is described by a set of fuzzy rules, rather than by an explicit function. As a rule, a general fuzzy model has numerous inputs and outputs. However, a multi-output model can always be divided into a set of single-output models. In this work, we consider the case of a multiple-input one-output system. Specifically, the basic structure of a fuzzy model consists of five components [10] (Fig. 2).

In Fig. 2, the rule set is a site where the IF–THEN fuzzy rules are stored. This is a set of

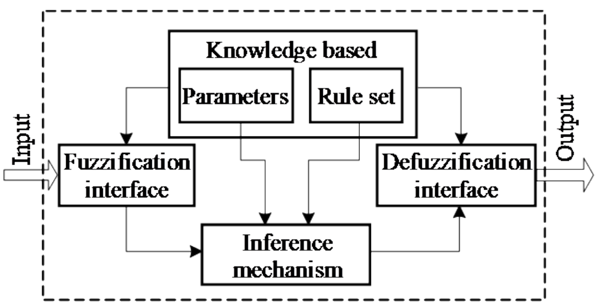

Fig. 2. Schematic diagram of the basic structure of a fuzzy model

Известия вузов России. Радиоэлектроника. 2023. Т. 26, № 3. С. 90–98
Journal of the Russian Universities. Radioelectronics. 2023, vol. 26, no. 3, pp. 90–98

statements or human-understandable rules, which describe the behavior of the system. With an n input–one output fuzzy model, each fuzzy rule can be described as follows:

$$r_{ij}: \text{IF}\left[\left(x_1 \text{ is } A_1^i\right)\text{AND...AND}\left(x_n \text{ is } A_n^i\right)\right]$$
$$\text{THEN}\left[\left(y \text{ is } B^J\right)\left(\omega_{ij}\right)\right],$$

where A_k^i with $k=1,...,n$ and B^J are the language values defined on the input and output variables of the model, respectively;

$$x_k \text{ is } A_k^i;\ k=1,...,n.$$

The hypothesis part of the rule is formed from the intersection (performed by fuzzy AND) between the linguistic statements, referred to as component premises. The conclusion of the rule is mapped from the hypothesis part by fuzzy inference (IF–THEN). Corresponding to each rule, there is a rule confidence $\omega_{ij} \in [0,1]$. The reliability of the rule reflects the correctness of $\omega_{ij}=0$, showing that the rule does not participate in determining the output of the model. Each rule base is a combination of fuzzy OR selection of all fuzzy rules. Rules can be formed from human expert knowledge or obtained from empirical samples. The rule base is the most important component of any fuzzy model.

The model parameter set specifies the shape of the membership function of the linguistic value used to represent fuzzy variables and fuzzy rules. The parameter values can be evaluated by either expert experience or knowledge mining process from an experiment. The rule base and the model parameter set are commonly referred to as the knowledge base. The reasoning mechanism is responsible for performing a fuzzy inference procedure based on the knowledge base and input values to give a predicted value at the output. The fuzzification interface performs the conversion of explicit inputs into degrees of belonging to language values. The defuzzification interface converts the fuzzy inference result into a clear output value.

Constructing a fuzzy model to assess the target threat level. The fuzzy model is constructed as a multiple-input one-output model, with the input data comprising the target trajectory information

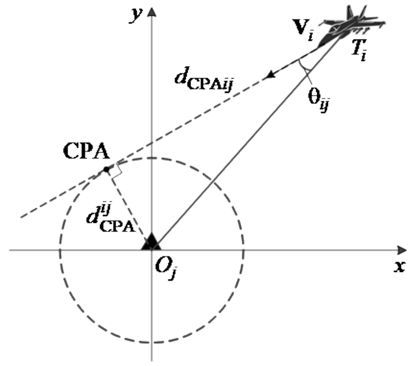

Fig. 3. **Correlation diagram between the air target and the protected object**

and the protected object information. The target trajectory information is obtained from processing and merging the data retrieved from the measuring system, including distance, speed, altitude, flight direction, etc. The protected object information includes position, scope, protected direction, etc. The correlation between the target T_i and the protected object O_j is illustrated in Fig 3.

The target trajectory information can be used to determine the vicinity of the target to the protected object, where the CPA distance of the target d_{CPA}^{ij} is the shortest distance to the protected object. The closest point of approach (CPA) is an important parameter for evaluating the target threat level. The target is especially dangerous when its CPA distance is equal to 0. In the case of n targets attacking m protected objects, the closest approach time parameter is calculated as follows:

$$T_{\text{CPA}}^{ij} = \frac{d_{\text{CPA}ij}}{v_i};\ \forall i=1,...,n;\ \forall j=1,...,m, \quad (1)$$

where $d_{\text{CPA}ij}$ is the distance from the target i to the CPA of the protected object j and v_i is the target velocity *i*. The value of the approaching flight direction θ_{ij} ranges within $[0°,180°]$, determined through the azimuth and flight direction. When the target approaches the protected object, the approach flight direction ranges within $[0°,90°]$. The larger the flight direction, the lower the threat level. A fuzzy model to evaluate the threat of a target is constructed following the steps outlined in Fig. 4.

Step 1. Based on the information about the target derived by radar sources and that about the

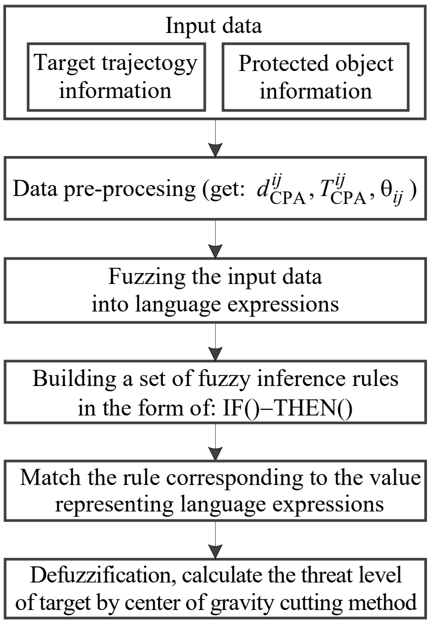

Fig. 4. Fuzzy model diagram to assess the target threat value

protected objects provided by ACCS, the trajectory parameters of the target (position, speed, course, altitude, etc.) are used to determine the CPA distance d^{ij}_{CPA} of the target T_i relative to the protected object O_j, then to calculate the time T^{ij}_{CPA} according to (1). Thus, the input data and expressive language of the proposed fuzzy model are determined as shown in Tab. 1.

Step 2. Fuzzy input information is treated by assigning a membership level to the linguistic expression of the input information. The input clear values of the model are used as arguments to the membership functions that correspond to the linguistic value in the hypothesis part of each fuzzy rule. From [4], the target trajectory parameters are subdivided into different levels, e.g., the target altitude is divided into a small altitude (from 200 m to 1000 m); an average altitude (from 1000 m to 4000 m); a high altitude (over 4000 m). The target speed is divided into a small speed (<80 m/s); a subsonic (<300 m/s) speed; a high speed (<1500 m/s); a supersonic speed (>1500 m/s). Based on dividing the value of the target parameters, the membership functions are formed for each parameter, as shown in Fig. 5.

Tab. 1. Input data and expressive language of the fuzzy model

Input data		Expressive language	
Index (n)	Parameter	Level (l)	Value
1	Distance	1	High (H)
2	Altitude	2	Medium (M)
3	Speed	3	Low (L)
4	CPA distance d^{ij}_{CPA}		
5	Flight direction θ_{ij}		
6	CPA time T^{ij}_{CPA}		

Step 3. A set of fuzzy inference rules is built in the form of IF–THEN by fuzzification of the input information into linguistic expressions. It can be seen that smaller target distances or its larger velocities correspond to higher threat values. Thus, the language of expressing threat levels based on input information is proportional to speed and inversely proportional to distance, altitude, flight parameters, and time to CPA point. The fuzzy inference rule set that evaluates the input information by the fuzzy operator AND, based on combining expert knowledge and the reliability of each

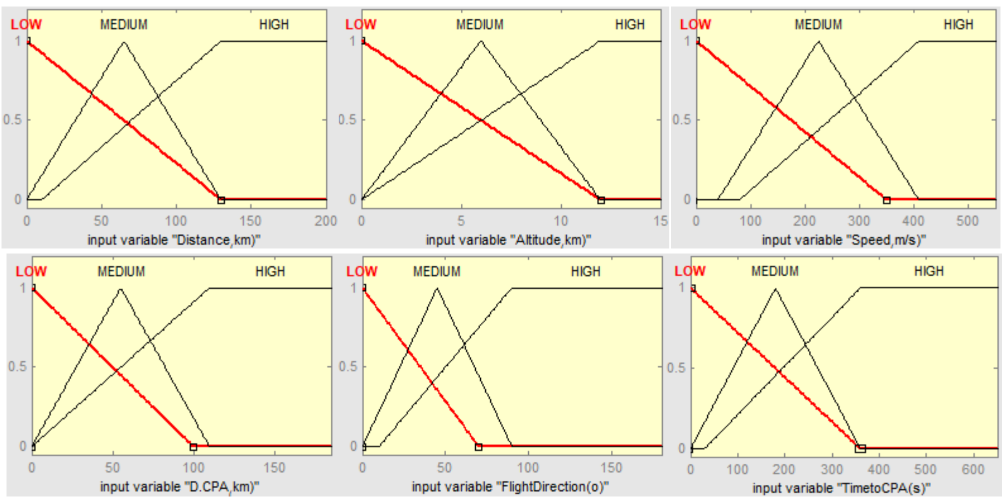

Fig. 5. Membership functions established based on expert knowledge

Tab. 2. Fuzzy inference rule set in the form of IF–THEN to evaluate input data by AND operator based on expert knowledge

No.	Reliability ω_i	AND						Target threat value
		Range, m	Altitude, m	Speed, m/s	Distance d_{CPA}^{ij}, m	Flight Direction θ_i, …°	Time to CPA T_{CPA}^{ij}, s	
1	1.0	L	L	H	L	L	L	H
2	1.0	H	H	L	H	H	H	L
3	1.0	M	M	M	M	M	M	M
4	0.5	H	L	H	L	L	M	M
5	0.5	M	L	H	L	L	M	H
6	0.5	L	H	M	H	H	H	L
7	0.1	H	H	M	L	L	H	H
8	0.1	M	M	H	M	L	M	M
9	0.1	L	L	L	L	L	H	L

rule, $\omega_i \in [0,1]$ is built as shown in Tab. 2.

Tab. 2 shows that each evaluation rule for determining the target threat value is the minimum value of the membership level of the fuzzy set for each input. According to Tab. 1, the linguistic expression l of the input information n is defined as nl and the relative degree of the target x is $\mu_{nl}(x)$, then the satisfaction H_k for each input clearly value vector is calculated as follows:

$$H_1 = \min\{\mu_{13}(x), \mu_{23}(x), \mu_{31}(x), \mu_{43}(x), \mu_{53}(x), \mu_{63}(x)\};$$
$$H_2 = \min\{\mu_{11}(x), \mu_{21}(x), \mu_{33}(x), \mu_{41}(x), \mu_{51}(x), \mu_{61}(x)\};$$
$$\ldots$$
$$H_9 = \min\{\mu_{13}(x), \mu_{23}(x), \mu_{33}(x), \mu_{43}(x), \mu_{53}(x), \mu_{61}(x)\}.$$

Step 4. Each evaluation rule in Tab. 2 generates a satisfaction H_k. In case where all the rules in Tab. 2 are activated at the same time, there will be rules that produce the same satisfaction H_k. For example, rules 1, 5 and 7 generate the target threat level with the language expression High (H); rules 3, 4 and 8 generate the threat level with the language expression Medium (M); rules 2, 6, and 9 produce a hazard level with the language expression Low (L). Therefore, it is necessary to integrate the rules that produce the same linguistic expression of the threat level, using the fuzzy $\bigcup$ operator ProbOR according to the following formula:

$$\beta_l = \bigcup_{\forall k} H_k^l \omega_i,$$

where H_k^l is the satisfaction corresponding to a linguistic expression of threat level l ($l = 1$: High (H); $l = 2$: Medium (M); $l = 3$: Low (L)). Then, for the rules in Tab. 2, their combined members are:

$$\beta_1 = H_1\omega_1 + H_5\omega_5 + H_7\omega_7 - H_1\omega_1 H_5\omega_5 - $$
$$- H_5\omega_5 H_7\omega_7 - H_7\omega_7 H_1\omega_1 + H_1\omega_1 H_5\omega_5 H_7\omega_7;$$
$$\beta_2 = H_3\omega_3 + H_4\omega_4 + H_8\omega_8 - H_3\omega_3 H_4\omega_4 - $$
$$- H_4\omega_4 H_8\omega_8 - H_8\omega_8 H_3\omega_3 + H_3\omega_3 H_4\omega_4 H_8\omega_8;$$
$$\beta_3 = H_2\omega_2 + H_6\omega_6 + H_9\omega_9 - H_2\omega_2 H_6\omega_6 - $$
$$- H_6\omega_6 H_9\omega_9 - H_9\omega_9 H_2\omega_2 + H_2\omega_2 H_6\omega_6 H_9\omega_9.$$

Step 5. Defuzzification and the target threat value is calculated using the Center of Gravity (CoG) method. CoG is the most prevalent and physically appealing of all the defuzzification methods [Sugeno, 1985, Lee 1990]. The membership function at the model output with three linguistic expressions (High, Medium, Low), corresponding to the target threat value is $\nu_n \in [0,1.0]$. To calculate a specific value, it is necessary to combine the relevant members $(\beta_1, \beta_2, \beta_3)$ followed by its conversion to a scalar value, through a truncation to remove the uncertain components and the final form of the membership function $\mu_C(\nu_n)$ to the determined threat level.

This method returns a precise value depending on the CoG of the fuzzy set. The overall area of the membership function distribution is divided into a number of sub-areas (such as triangle, trapezoidal etc.) in Fig. 6. Let S_i and v_i denote the area and CoG of i-th sub-region. Where, $S_i = \int \mu_C(v)\mathrm{d}v$ and n is the number of geometrical components. The threat value of the air target T_i to the protected object O_j is calculated as follows:

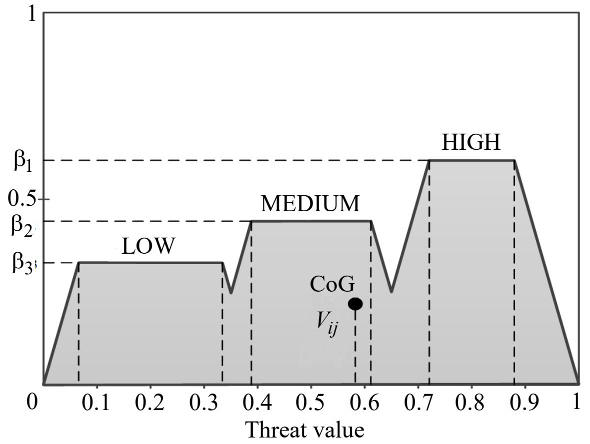

Fig. 6. Output membership function of the fuzzy model after clipping the center of gravity

$$V_{ij}^{\text{CoG}} = \frac{\sum_{i=1}^{n} S_i v_i}{\sum_{i=1}^{n} S_i} = \frac{\int \mu_C(v) v \mathrm{d}v}{\int \mu_C(v) \mathrm{d}v}.$$

Simulation testing and result evaluation.

Input data. Fig. 7 depicts an air defense scenario used to test the proposed fuzzy model when evaluating and comparing the threat levels of different targets. This scenario simulates an air situation with 10 tracks $(T_1, T_2, ..., T_{10})$ with different parameters and the protected object O. The horizontal axis Ox has a positive direction pointing to the East, and the vertical axis Oy pointing to the North.

The trajectory parameters of the targets at the testing time are presented in Tab. 3. Here, the CPA

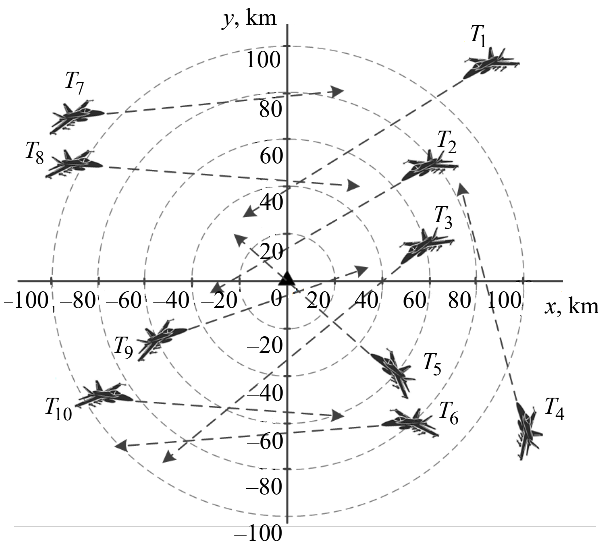

Fig. 7. Air defense scenario for evaluation testing of the proposed model

Tab. 3. Trajectory parameter details

Target, no.	Distance, km	Azimuth, deg	Altitude, m	Speed, m/s	Course, deg
T_1	134.40	43.5	4500	305.6	245.0
T_2	70.43	51.3	3200	250.0	250.0
T_3	54.92	79.5	5800	333.3	220.0
T_4	116.81	122.1	7300	244.4	350.0
T_5	56.57	135.0	9500	261.1	315.0
T_6	80.22	140.1	8200	241.7	265.0
T_7	114.02	307.9	5200	305.6	80.0
T_8	101.07	296.4	6200	319.4	95.0
T_9	59.42	247.8	2700	194.4	75.0
T_{10}	100.12	236.0	9140	216.7	105.0

distance d_{CPA}^{ij}, approach flight direction θ_{ij} and flight time T_{CPA}^{ij} of the target over the approach point are calculated by (1) based on pre-processing of the input data.

Simulation testing and result evaluation. *Experiment 1*. In the first test, to evaluate the accuracy of the proposed fuzzy model based on the Sugeno model and the proposed fuzzy rules in Tab. 2, we use the FIS Edition toolkit in MATLAB. Fuzzy rules are established according to the values of the input information (Fig. 8). Following the establishment of fuzzy rules, the Simulink toolkit in MATLAB is used to construct a fuzzy model for calculating the threat level of the targets in Tab. 3. The testing results of this model with the target trajectory parameters are presented in Fig. 10.

Experiment 2. To evaluate the computational performance of the proposed fuzzy model, we developed a BATE software testbed, which simulates the real-time ACCS. BATE is implemented in Microsoft Visual Studio C++, capable of simulating and displaying an air situation picture [11] on a digital map (Fig. 9). Then the calculation time complexity of the proposed method is estimated. We created various air defense scenarios with increasing complexity to calculate execution time.

Comments. According to Fig.10, the threat value of target T_5 is the highest $V_{5j} = 0.783$, the threat value of target T_7 is the lowest $V_{7j} = 0.213$. From the calculation results of the threat value, it is possible to arrange the targets in terms of their threat levels from high to low, which is convenient for imple-

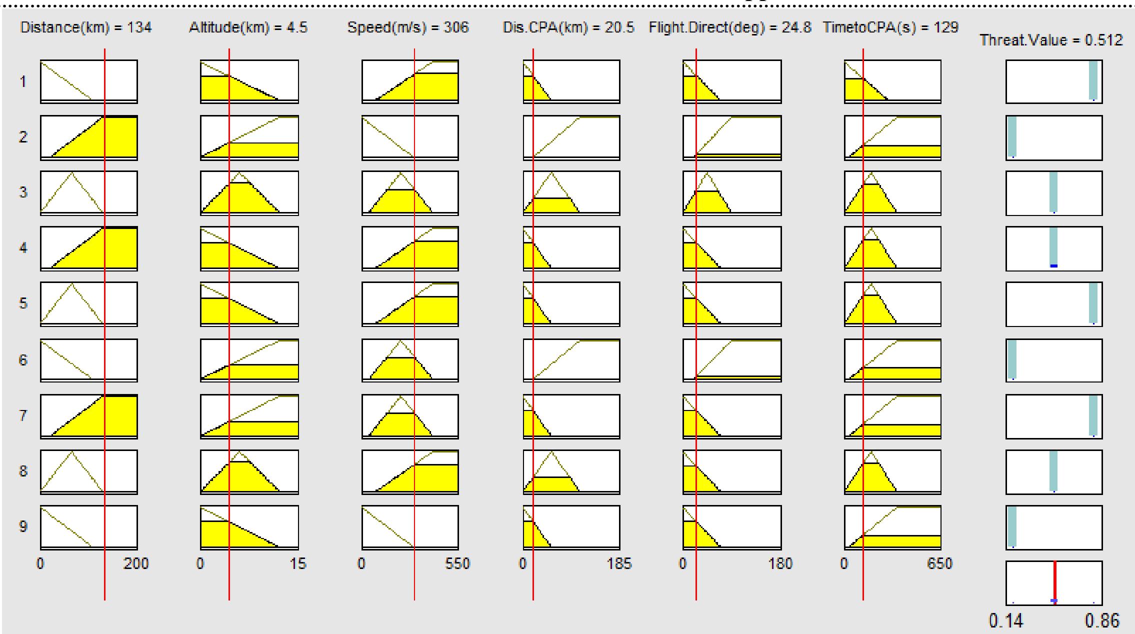

Fig. 8. Testing simulation of the proposed fuzzy model using the FIS EDITOR tool

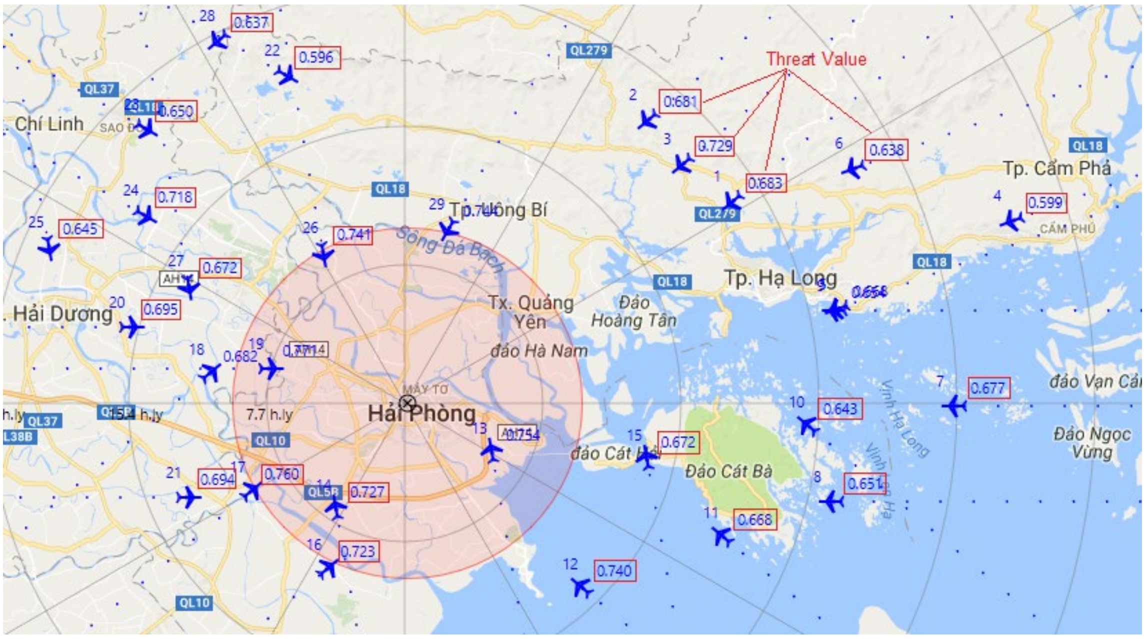

Fig. 9. Air defense scenario for evaluation testing of the proposed model

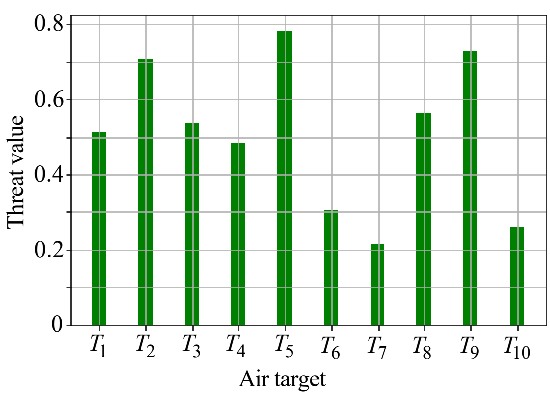

Fig. 10. Threat level values of the target in the testing of an air defense scenario

menting the function of automatically distributing the target data to firing units in an ACCS [12, 13].

Fig. 9 presents the proposed algorithm model calculated and updated for the threat values of dozens of targets in each data update cycle (less than 1 s) [14, 15]. The threat values are displayed directly on a digital map. This confirms that the proposed algorithm model can be applied in real-time ACCS.

Conclusion. This paper presents a method for solving the issue of calculating the threat value of air targets based on the fuzzy logic inference method. The proposed model utilizes the Sugeno fuzzy model, which features multiple inputs (target trajectory parameters) and a single output (target threat value). A fuzzy inference rule in the IF–THEN format is established to evaluate input information using the AND operator, incorporating expert knowledge. The fuzzy rules and defuzzification, implemented through the clipped center of gravity method, are combined to determine the clear threat value of a target.

The proposed fuzzy model was simulated and tested using MATLAB tools on a scenario involving 10 target trajectories with varying parameters. Additionally, the BATE software is used to test the model via different air defense scenarios. The testing results suggest that the proposed fuzzy model is capable of timely calculating the threat value of each target to the protected object, thus being suitable for developing tactical supporting software modules for real-time air defense command and control systems.

Author's contribution

Xuan Truong Nguyen, synthesize and analyze approaches to solving the threat assessment problem in automated command and control system; building and evaluating an algorithm model to calculate the threat value of the air target based on fuzzy model. Developing a testbed software BATE in Microsoft Visual Studio C++, that simulates the real-time automated command and control system.

Kim Phuong Phung, scientific support including: evaluating fuzzy algorithm model to calculate the threat value of the air target that can be applied in a real-time automated command and control system.

Quang Hieu Dang, scientific support including: programming the software module to display the air situation picture in Microsoft Visual Studio C++, simulation and evaluation of the results.

Xung Ha Vo, scientific support including: simulation model by the MATLAB and evaluation of results.

Hoa Tien Vu, scientific guidance, scientific consulting on mathematical models in the field of radar data processing; target tracking, guidance in conducting experimental studies.

References

1. Roux J. N., Van Vuuren J. H. Threat Evaluation and Weapon Assignment Decision Support: A Review of the State of the Art. ORiON. 2007, vol. 23, no. 2, pp. 151–187. doi: 10.5784/23-2-54

2. Pavlovskii A. V. *Osnovy teorii upravleniya ognem. (Sistemnyi analiz. Teoriya prinyatiya reshenii. Teoriya effektivnosti)* [Fundamentals of the Theory of Fire Control. (System Analysis. Decision Theory. Efficiency Theory)]. Smolensk, *AV VPVO VS RF*, 2016, 234 p. (In Russ.)

3. Lyaskovskii V. L. *Osnovy proektirovaniya i ekspluatatsii avtomatizirovannykh sistem upravleniya voennogo naznacheniya* [Fundamentals of Design and Operation of Automated Control Systems for Military Purposes]. Moscow, *Izdatel'stvo MGTU im. N. E. Baumana*, 2016, 188 p. (In Russ.)

4. Liplianin A. Yu., Shein A. S., Khizhniak A. V. Method of Accounting Importance of the Goal in Task of Aircraft Distribution Between Firepower. *Doklady BGUIR*. 2017, no. 2, pp.77–83. (In Russ.)

5. Johansson F. Evaluating the Performance of TEWA Systems. Orebro University, Intellecta Infolog, Kallered, 2010, 201 p.

6. Dongfenga Ch., Yu F., Yongxue L. Threat Assessment for Air Defense Operations Based on Intuitionistic Fuzzy Logic. Procedia Engineering, 2012, vol. 29, pp. 3302–3306. doi: 10.1016/j.proeng.2012.01.484

7. Johansson F., Falkman G. A Bayesian Network Approach to Threat Evaluation with Application to an Air Defense Scenario. 11th Intern. Conf. on Information Fusion. Cologne, Germany, 30 June 2008–03 July 2008. IEEE, 2008, pp. 1352–1358.

8. Yang Haiyan, Han Cheng, Tu Congliang. Air Targets Threat Assessment Based on BP-BN. J. of Communications. 2018, vol. 13, no. 1, pp. 21–26. doi: 10.12720/jcm.13.1.21-26

9. Sushil Kumar, Bipin Kumar Tripath. Modelling of Threat Evaluation for Dynamic Targets Using Bayesian Network Approach. Procedia Technology. 2016, vol. 24, pp. 1268–1275.

10. Li-Xin Wang. A Course in Fuzzy Systems and Control. Prentice Hall, 1997, 424 p.

11. Shynar E., Degen U. Methods and Concepts for Air Situation Picture Generation. Proc. of the Third Intern. Conf. on Information Fusion, Paris, France, 10–13 July 2000. IEEE, 2000. doi: 10.1109/IFIC.2000.862455

12. Hasan M. B., Barua Ya. Weapon Target Assignment. 2020. doi: 10.5772/intechopen.93665

13. Johansson F., Falkman G. Real-Time Allocation of Defensive Resources to Rockets, Artillery, and Mortars. 3th Conf. on Information Fusion (FUSION). Edinburgh, UK. 26–29 July 2010. IEEE, 2010. doi: 10.1109/ICIF.2010.5712026

14. Fedyaev V. N. Teoreticheskie osnovy avtomatizirovannogo upravleniya [Theoretical Foundations of Automated Control]. *Tver', VA VKO*, 2007, 204 p. (In Russ.)

15. Roux J. N., van Vuuren J. H. Real-Time Threat Evaluation in a Ground Based Air Defence Environment. ORiON. 2008, vol. 24, no. 1, pp. 75–101. doi: 10.5784/24-1-60

Information about the author

Xuan Truong Nguyen, Master's degree in "Radar Engineering" (2013) of the Russian Federation Armed Forces Army Air Defence Military Academy named after Marshal of the Soviet Union A. M. Vasilevsky. Postgraduate student, Researcher of Institute of System Integration / Le Quy Don Technical University. The author of 5 scientific publications. Area of expertise: radar and radio navigation; telecommunications.
Address: Le Quy Don Technical University, 236, Hoang Quoc Viet, Hanoi, Vietnam
E-mail: truongnx.isi@lqdtu.edu.vn

Kim Phuong Phung, Master's degree in "Computer science " (2014) of the Military Academy of Air and Space Defence named after Marshal of the Soviet Union G. K. Zhukov. Postgraduate student, Lecturer of the Department of Electronic Technologies of Institute of System Integration/Le Quy Don Technical University. The author of 3 scientific publications. Area of expertise: electronic technology; computer science.
Address: Le Quy Don Technical University, 236, Hoang Quoc Viet, Hanoi, Vietnam
E-mail: phuongpk.isi@lqdtu.edu.vn

Dang Quang Hieu, PhD (2022), Senior Researcher of the Institute of System Integration/ Le Quy Don Technical University. The author of 7 scientific publications. Area of expertise: radar and radio navigation; telecommunications.
Address: Le Quy Don Technical University, 236, Hoang Quoc Viet, Hanoi, Vietnam
E-mail: Hieudq@lqdtu.edu.vn

Xung Ha Vo, Master's degree in "Radar System Engineering" (Le Quy Don Technical University (LQDTU), Vietnam, 2007), PhD student in "Radar Systems Engineering". Head of System and Antenna Design/National Institute of Science and Technology. The author of 5 scientific publications. Area of expertise: system engineering; radar data processing; control and automation.
Address: National Institute of Science and Technology, 17, Hoang Sam Str. Cay Giay, Hanoi, Vietnam
E-mail: voxungha@amst.edu.vn

Vu Hoa Tien, PhD in "Radio Electronica and Control Automation" (2005), Associate Professor (2014), Visiting Lecturer of Department of Aerospace Control Systems; a specialist in systems engineering control and automation. Author of 57 publications. Area of expertise: systems automatic control for UAV; electronic technology, systems engineering.
Address: Le Quy Don Technical University, 236, Hoang Quoc Viet, Hanoi, Vietnam
E-mail: hoatien57@lqdtu.edu.vn