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TEWA Interface with Fuzzy Logic

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Abstract*— It is an important task to determine the degree of threat of threats in military applications and in the war environment. Small mistakes that can be made during the threat evaluation phase can cause great loss of life and property. Mistakes that can be made at this stage can lead to serious consequences that are difficult to compensate. For this reason, it is of great importance to accurately calculate the threat degree of the detected aircraft. For this purpose, computer decision support systems provide significant support to the operators in the decision-making process in order to increase the cognitive ability of the operator and to implement the decisions taken quickly. In this study, a decision support system is designed to contribute to the decision-making processes of the operators. In order to perform calculations in the decision support system; A threat assessment interface was created with the help of C# programming language using Microsoft Visual Studio. In the study, calculations were made using the speed, altitude and distance parameters of an aircraft classified as a threat to be used in the threat evaluation and weapon assignment interface. Fuzzy logic method was used to calculate the threat degree.

***Index Terms*— Threat Evaluation, Weapon Assignment, TEWA, Fuzzy Logic**

I. INTRODUCTION

Today, every country has various purposes in the field of security and defense. The main objective among these objectives is to immediately identify targets that can be considered as threats against regions of critical importance for the country and to destroy these threats when necessary. For this purpose, air defense systems are used to detect and destroy targets in military operations. Air Defense in the North Atlantic Treaty Organization (NATO) Glossary of Terms and Definitions, AAP-6 document; It is defined as "all measures designed to eliminate or reduce the effectiveness of enemy air operations" [1]. Basically, an air defense system consists of radars/sensors that enable the detection of the air target, the defensive weapons available in the inventory for the purpose of destroying the air target, and the command-control center where decisions are made. In air defense systems, decisions are made after a series of decision processes operated by the operator. Today, with the development of technology, a lot of data about the target can be obtained by means of radars or sensors. With the use of radar or sensors, when the target data starts to be provided, the operator may be faced with a large amount of data [2]. At this stage, the operator has to make real-time and fast decisions in the light of many and uncertain data within the scope of his personal experience and ability. Computer decision support systems provide significant support to the operators in the decision-making process in order to increase the cognitive ability of the operator and to implement the decisions taken quickly. Threat Evaluation and Weapon Assignment (TEWA) is a computerized air defense decision support system in which the degree of threat of a detected target is determined according to the protected area (Threat Evaluation) and defensive weapons or engagements suitable for use in the inventory are suggested (Weapon Assignment) to this target, taking into account the threat degree. In this study, a decision support interface was created using C# language to calculate the threat degree of the detected target. There are two methods for calculating the threat level in TEWA applications. These are calculations based on mathematical method and calculations based on artificial intelligence applications. In calculations based on the mathematical method, calculations are performed with the help of an algorithm. In the computation method based on artificial intelligence applications, applications such as Fuzzy Logic, Bayesian Networks and Artificial Neural Networks are carried out [3]. Kumar and Tripathi [4], Johansson and Falkman [5] use Bayesian Networks method for calculating threat degree, whereas Rizwan et al. [6], Liang [7], Azimirad and Haddadnia [8], Dongfeng et al. [9] used Fuzzy Logic method. In this study, fuzzy logic method was used to calculate the threat level.

II. TEWA

TEWA system is a decision support system that contributes to the operator in determining the threat level of air targets and allocating appropriate resources against detected air targets. In the TEWA system, a threat degree is assigned to each of the air targets according to the degree of danger they pose to the defended asset. It then tries to optimize the allocation of weapon systems to threats so as to minimize the survivability of air threats based on the calculated degree of threat. These weapon allocations are transmitted to the operator via the Human Machine Interface HMI for the final decision and execution of the applications. At this stage, the weapon allocation procedures proposed by the TEWA system only provide support to the operator and the final decision is made by the operator. Although many TEWA systems are currently used around the world, detailed explanations about the operation of these systems are not

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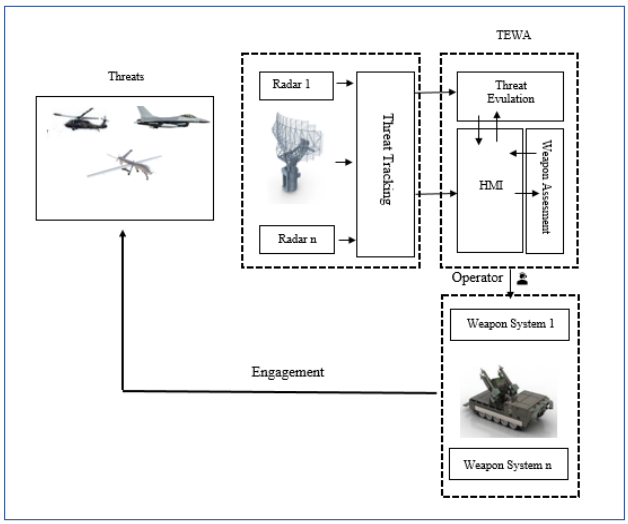
available in open sources due to the degree of confidentiality of these systems [10].

A. Threat Evaluation

Threat has been defined as an expression of intent to harm or destroy. Threat evaluation, on the other hand, is the process of determining whether a threat is intended to harm or destroy a country's defense forces or interests [11]. It is important to determine and prioritize the threat level of air targets according to the assets defended in a war environment where there are many threats. The threat degree, known as the threat value, takes a value between 0 and 1, with 0 (least threat) and 1 (highest threat). Higher threat means more dangerous target. For this reason, in a war environment where there are more than one threat, it is an important task to rank the threats according to their degrees. Threat evaluation also appears as an input to the weapon assignment process. Prioritizing a smaller threat target over a larger threat level target at this stage can have serious consequences [12]. Therefore, the threat evaluation process is a challenging and complex process. The operator has to process large volumes of complex and uncertain data. To calculate a more accurate threat degree, properly selected and highly accurate parameters of the target should be used. The operator performs the calculation of the degree of threat using various parameters of the target obtained from radars or sensors. When the literature is examined, although various parameters have been used in the calculation of the threat degree, these parameters are generally gathered under the headings of proximity, capability and intent [4].



Figureure. 1. Threat Evaluation and Weapon Assignment

Table I. Threat Evaluation Parameters

Parameter	Definition
Altitude	Approximate feet above ground or an indication of change.
CPA	Closest Point of Approach
IFF Mode	Identiy Friend or Foe
Maneuevers	Indicates the number of recent maneuvers.
Speed	Approximate airspeed or an indication of change.
Countermeasueres	Using techniques or tools to avoid radar signals, thermal or infrared guided systems.
Range	The track's distance from the defend assets.
ESM	Electronic support measures
Intel	Intelligent report

B. Weapon Assignment

Weapon assignmet (WA) means matching threats detected with existing weapons in compatible pairs. Paradis et al., in their study; define WA as "the reactive assignment of weapon systems against threats to respond to or counter detected threats" [11]. WA; It is an optimization process where m weapons and n threats are matched to each other. In this process, WA is fulfilled in real time and in accordance with the rules of engagement. In the WA process;

- Minimizing the target's expected survival value after all engagements have been accomplished,
- Minimizing damage to defended assets; or
- Weapon assignments are performed to maximize the survivability of defended assets.

III. TEWA INTERFACE

In this study, a decision support system is designed to contribute to the decision-making processes of the operators. In order to perform calculations in the decision support system; Threat evaluation and weapon assignment interface was created with the help of C# programming language using Microsoft Visual Studio. By using the speed, altitude and distance parameters of the air targets classified as threats in the interface, the threat level of the targets was calculated within the framework of the relevant scenarios with the help of fuzzy logic. Speed is one of the parameters that indicates the intent of the threat to harm the defended asset. In the threat evulation phase, higher speeds indicate a greater degree of threat. Another parameter that indicates the threat's intent to harm the defended entity is altitude. In the threat evulation phase, lower altitude indicates a greater degree of threat [13]. In the threat evulation phase, the threat level increases as the target gets closer to the defended asset. The interface basically consists of 3 parts, the part where the values of the input and output variables are entered by the operator and the part where the calculations are made. Operations in the interface are carried out in 3 stages;

1- First of all, the values of the input and output variables are entered by the operator.

2- Afterwards, the parameter values that are the basis for the calculations to be performed by the interface are entered by the operator.

3- Threat level calculation with fuzzy logic method is

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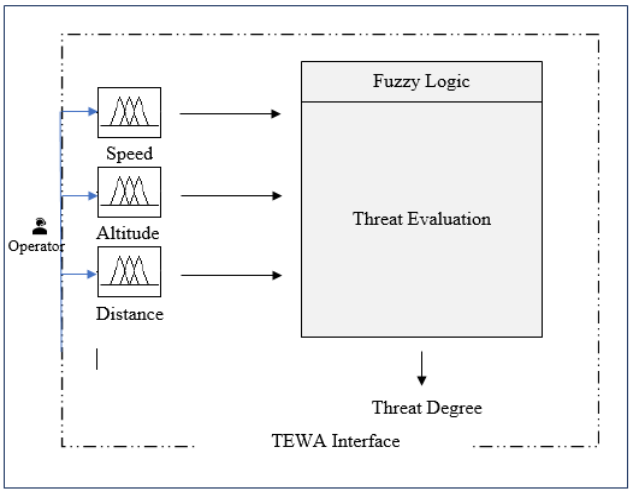
performed by the interface.



Figureure. 2. TEWA Interface Diagram

Table II. Threat Evulation Parameters

Speed (knot)	Altitude (feet)	Distance (km)
Too Slow	Low	Too Close
Slow	Medium	Close
Medium	High	Medium
Fast		Far
Too Fast		Too Far

In the fuzzy logic system created to perform calculations on the interface; speed, altitude and distance values were determined as input variables. The level of threat was determined as the output variable. The linguistic expressions in Table II is assigned to each variable. Then, the values for each variable of the fuzzy subsets are defined by the operator. The membership function of the variables was chosen as the triangular membership function. In the calculations section of the interface, firstly, the crisp values of speed, altitude and distance parameters were entered by the operator and the membership degrees were calculated by performing fuzzy inference operations. After the calculation of membership degrees, the operator was informed about the visually active rules on the interface and the threat degree calculation process, which has a crisp output value, was carried out.

IV. CALCULATIONS WITH TEWA INTERFACE

In this study, the threat degree was calculated using the TEWA Interface Application, taking into account the parameters of speed, altitude and distance of an aircraft classified as a threat. Calculations were made within the scope of scenarios created by considering the attack profiles of the aircraft.

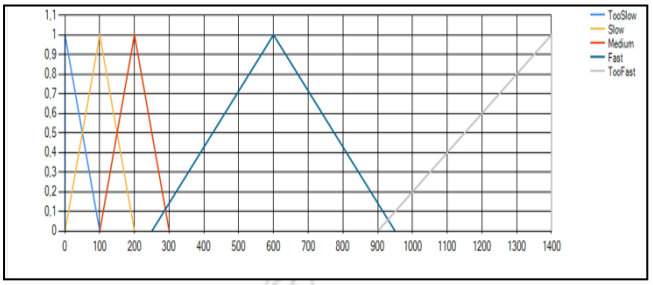


Figure. 3. Speed Membership Function

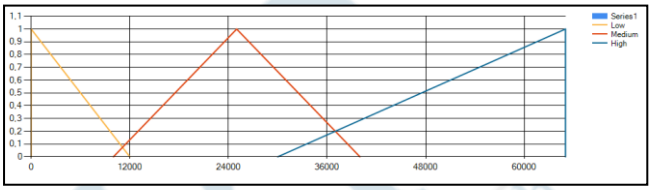


Figure. 4. Altitude Membership Function

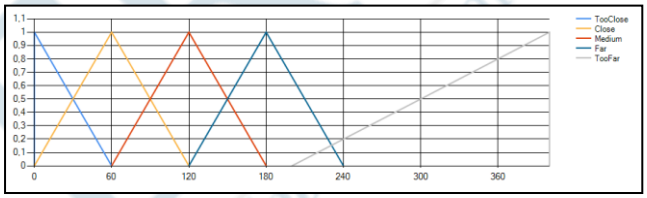


Figure. 5. Distance Membership Function

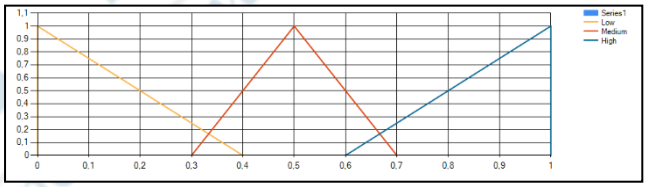


Figure. 6. Threat Degree Membership Function

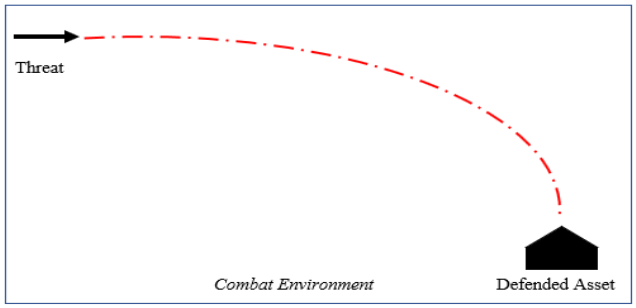


Figure. 7. Combat Scenario

In order to calculate the threat degree of the threat shown in Figureure 7, calculations were made within the framework of the scenario.

In the scenario, the threat level was calculated by considering the speed, altitude and distance from the target in a certain time interval. Speed parameter of the target [70; 187; 295; 450; 792; 955; 1110; 1224] knot; was accepted that it increased in 8 different time intervals. Altitude parameter

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[42755; 37795; 31700; 25680; 12000; 9210; 7430; 4289] feet and distance parameter [250; 222; 153; 103; 70; 47; 30; 21] km, were accepted that it decreases with varying values in 8 different time intervals. Calculations were made via the TEWA interface using the relevant parameter values and the threat ratings were obtained. Threat degrees were calculated in the TEWA Interface program using and the results were given in Table III.

Table III. Threat Degrees in Scenario

Speed	Altitude	Distance	TEWA Interface
70	42775	250	0,15
187	38895	222	0,149
295	33700	153	0,337
450	27680	103	0,5
792	17000	70	0,5
955	10210	47	0,661
1110	7690	30	0,686
1224	5960	21	0,736

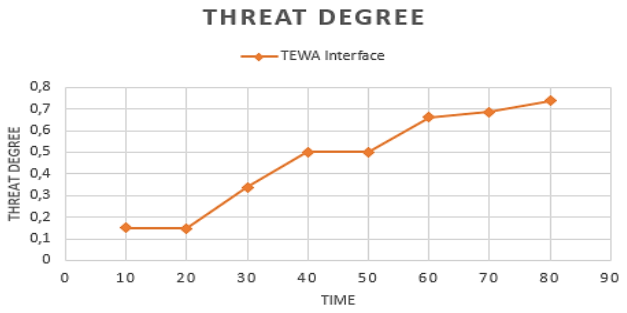

Figure. 8. Threat Degrees Change in Scenario

V. CONCLUSIONS

Determining the degree of threat of threats in military applications and in the war environment is an important task. Small mistakes that can be made during the threat assessment phase can cause great loss of life and property. For this reason, due to the complexity of the problems in the war environment and the risk factors involved, there is a need for reliable decision support systems that can be used to increase the awareness of the operators and enable them to make better and more informed decisions. The results of the decision support systems should be verified and there should be no doubt in the operator that the calculations are carried out correctly. In this study, a decision support system is designed to contribute to the decision-making processes of the operators. In order to perform calculations in the decision support system; A threat evulation interface was created with the help of C# programming language using Microsoft Visual Studio. In the study, calculations were made using the speed, altitude and distance parameters of an aircraft classified as a threat to be used in the TEWA interface. Fuzzy logic method was used to calculate the threat level. As a result, it is evaluated that the threat level calculations support the operator in the decision-making process and the calculations are carried out with an interface that can obtain reliable results. The fuzzy logic method is considered to be a good tool to implement the decision support system and greatly simplifies the task of the operator in the threat assessment process. In future studies, it is considered that it will be beneficial to diversify the parameters used in the calculation of threat levels and to create new interfaces by updating the membership function values.

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