PROJECT OF AIRCRAFT ATTACK AVIONICS ON-BOARD CONTROL SYSTEM WITH AIR-TASK EFFICIENCY ESTIMATION SUBSYSTEM BASED ON FUZZY LOGIC (ROCKETS SUBSYSTEM IN A-G MISSIONS)

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Abstract

In this article author presents the project of aircraft attack avionics on-board control system with fuzzy efficiency of air-task estimation subsystem (rockets subsystem in A-G missions). Conducting extensive analysis and preliminary studies and very wide range of applications of fuzzy logic, the author found that its properties could also be used in aviation. Author's study referred to the development of fuzzy expert aircraft attack avionics on-board control system project used by pilot during the air task (air combat task with use of rockets). One of the projects was presented in the publication. It has been developed based on Matlab (Fuzzy Logic Toolbox) and Simulink software. Complicity of the project and some mathematical calculations required relevant assumptions, which are also reported. At the end author describes his vision about operation of the system and conclusions.

Schematic diagram of aircraft attack avionics system and rockets on-board control subsystem with fuzzy efficiency of air-task estimation subsystem, fuzzy efficiency estimation subsystem schematic diagram, inference and defuzification in rule viewer, fuzzy efficiency estimation control surfaces, dependence of the efficiency of the air- task on the distance from the target for „Rockets fuzzy controller" are presented in the paper.

Keywords: *control, attack avionics, on-board system, fuzzy subsystem, efficiency*

1. Introduction

Research conducted by the author and an analysis of the available literature shows that, in general, fuzzy logic can be admittedly used in aircraft efficiency air-task estimation (but there is a lack of precise information in the field of analysing, monitoring, control efficiency and pilot air control systems support with fuzzy logic controllers based on expert knowledge).

Described the occurrences and imprecise defined terms, using classical mathematical apparatus, based on the methods required to be strictly limits or decisions such as binary logic, in which the elements belong to the set or not. Natural language operates inaccurate and quality concepts, such as „altitude is low" or „air speed is medium". Those concepts are very difficult to translate into machine language without losing of their nature. The values of quality, like a description of the world through words, are more natural to man. For example, determine the distance with the words: small, medium, large is more natural and simpler than the estimation in kilometres or miles. Qualitative description is less precise and depends on the person describing it. Hence the proposal to use fuzzy expert system, where experts determine the criteria and principles of operation of these systems (base of inference rules). Proper selection of the experts is very important procedures in the design process of such systems.

Fuzzy expert system (controller) can be used to evaluate the effectiveness of an air-task (completing the pre-flight analysis and ability to select optimal solutions) and also in on-board decision-making system during combat missions.

In this article author presents his vision of aircraft rockets on-board control system with fuzzy efficiency of air-task estimation subsystem. Pictures and schematic diagrams describe operational and functional ideas of the system work.

Project is characterized by reliable operation, and the ability to adjust to changing environmental conditions.

Due to the complexity of the problem of air-task efficiency estimation, it was necessary to apply appropriate simplifying assumptions.

2. Features of allowing use fuzzy logic in aircraft on-board systems

Variability, dynamism, phenomena and situations that occur in today's battlefield are vague and imprecise. This nonlinearity would significantly reduce the time available and necessary to decide what kind of armament to use during an air-task. Those features characterized fuzzy logic theory. Fuzzy controllers based on expert knowledge could be a significant factor in the decision-making process to use a particular weapon in combat missions. The controllers could be used both to evaluate the effectiveness of various kinds of air-tasks (completing the pre-flight analysis and the ability to select optimal solutions), as well as in the on-board's decision-making system.

The second solution needs to be tested and analysed more precisely, because at any mission time pilot should have opportunity to change his decision.

3. Conception

There are several occurrences during air task:

- A – aircraft reaches the required altitude – H,
- B – aircraft reaches the required distance to a target – D_c,
- C – aircraft reaches the required velocity (air speed) – V,
- D – aircraft reaches the required sighting angle – Θ.

Air task (mission) will be completed only when all occurrences take place. Efficiency, in general, describes the extent to which time, effort or cost is well used for the intended task or purpose. It is often used with the specific purpose of relaying the capability of a specific application of effort to produce a specific outcome effectively with a minimum amount or quantity of waste, expense, or unnecessary effort. „Efficiency" has widely varying meanings in different disciplines.

According to this definition, the term „Efficiency" can be defined by formula:

$$Z = P(A \cap B \cap C \cap D \cap E) \tag{1}$$

if the occurrences A, B, C, D, E are independent then:

$$Z = P(A)*P(B)*P(C)*P(D)*P(E). \tag{2}$$

Limits of the parameters associated with these occurrences are located in particular aircraft flight manuals.

Fuzzy logic air-task efficiency estimation subsystem is integral part of rockets on-board control subsystem (which is part of aircraft attack avionics system, Fig. 1). All necessary data will be provided from on-board location and identification system (own position in space, target velocity, distance, etc.).

To support correct work of the system (correct calculations and results) fuzzy control subsystem should:

- be completed (fuzzificator, rule base, defuzzificator),
- have completed base of rules,
- have compatibility (consistency) rule base,
- have continuity of the rule base,
- provide the absence of rule base redundancy [3].

The characteristic input parameters of the fuzzy control subsystem and its linguistic equivalents are showed in Tab. 1 below (A-G is under consideration in the article).

Tab. 1. Characteristic input parameters of the fuzzy control subsystem and its linguistic equivalents (o – occurrence of the parameter; n – nonoccurrence of the parameter)

Input parameters	Linguistic equivalents	Air task	
		A-A	A-G
Distance to a target (D_c)	*Distance*	*o*	*o*
Self-air speed (V)	*Flying speed*	*o*	*o*
Self-altitude (H)	*Flight Altitude*	*o*	*o*
Sighting angle Θ	*Sighting angle*	*o*	*o*
Sphere (front or aft of the target)	*Sphere*	*o*	*n*

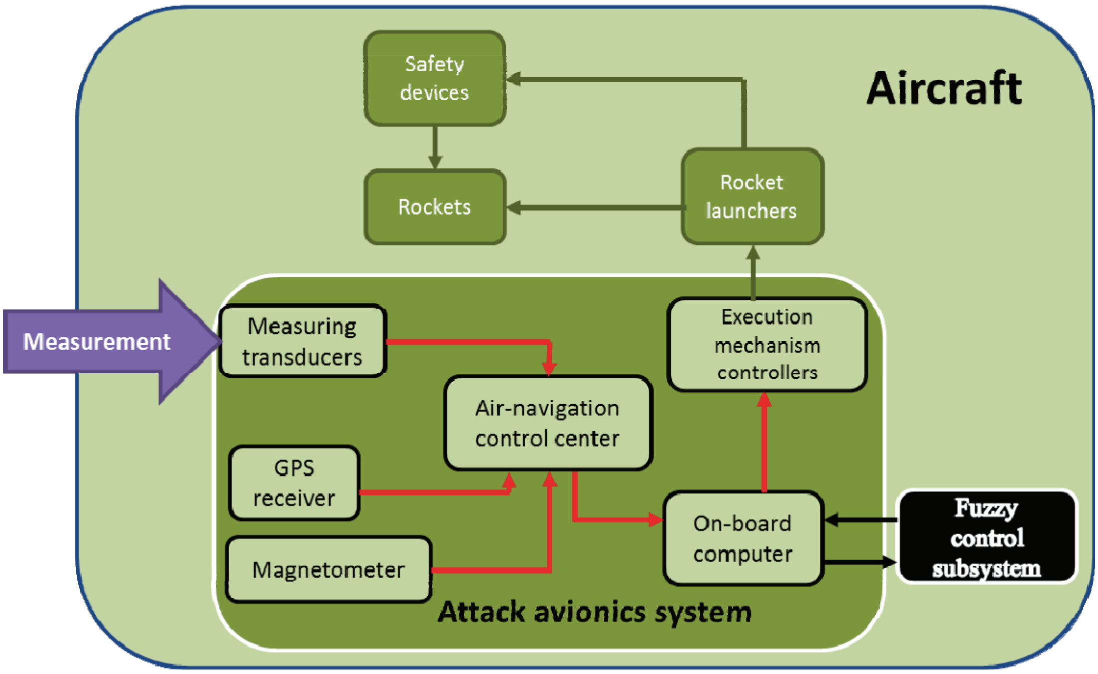


Fig. 1. Schematic diagram of aircraft attack avionics system and rockets on-board control subsystem with fuzzy efficiency of air-task estimation subsystem – conception

After receiving all necessary input data, fuzzy logic controller generates control signal for pilot (air-task efficiency estimation data,) suggesting which on-board armament system in the most effective. Pilot has right to accept, change or reject provided solution (suggestion about the most effective and optimal armament to use). Optimal armament is on-board, ready to use weapon. In addition, correct calculations and results are delivered (the highest efficiency estimation). Fuzzy efficiency of air-task estimation subsystem schematic diagram is presented below (from Matlab Fuzzy Logic Toolbox and Simulink, Fig. 2).

There are three membership functions for each input parameters (Tab. 1). Shapes of the membership functions are trapezoidal and triangular (triangular membership function is used in input data „sighting angle", because optimal angle is 20°). According to formula:

$$r = z^{w}, \tag{3}$$

where:
r – number of rules,
z – number of subsystem fuzzy sets,
w – number of inputs,
fuzzy control subsystem has 81 rules.

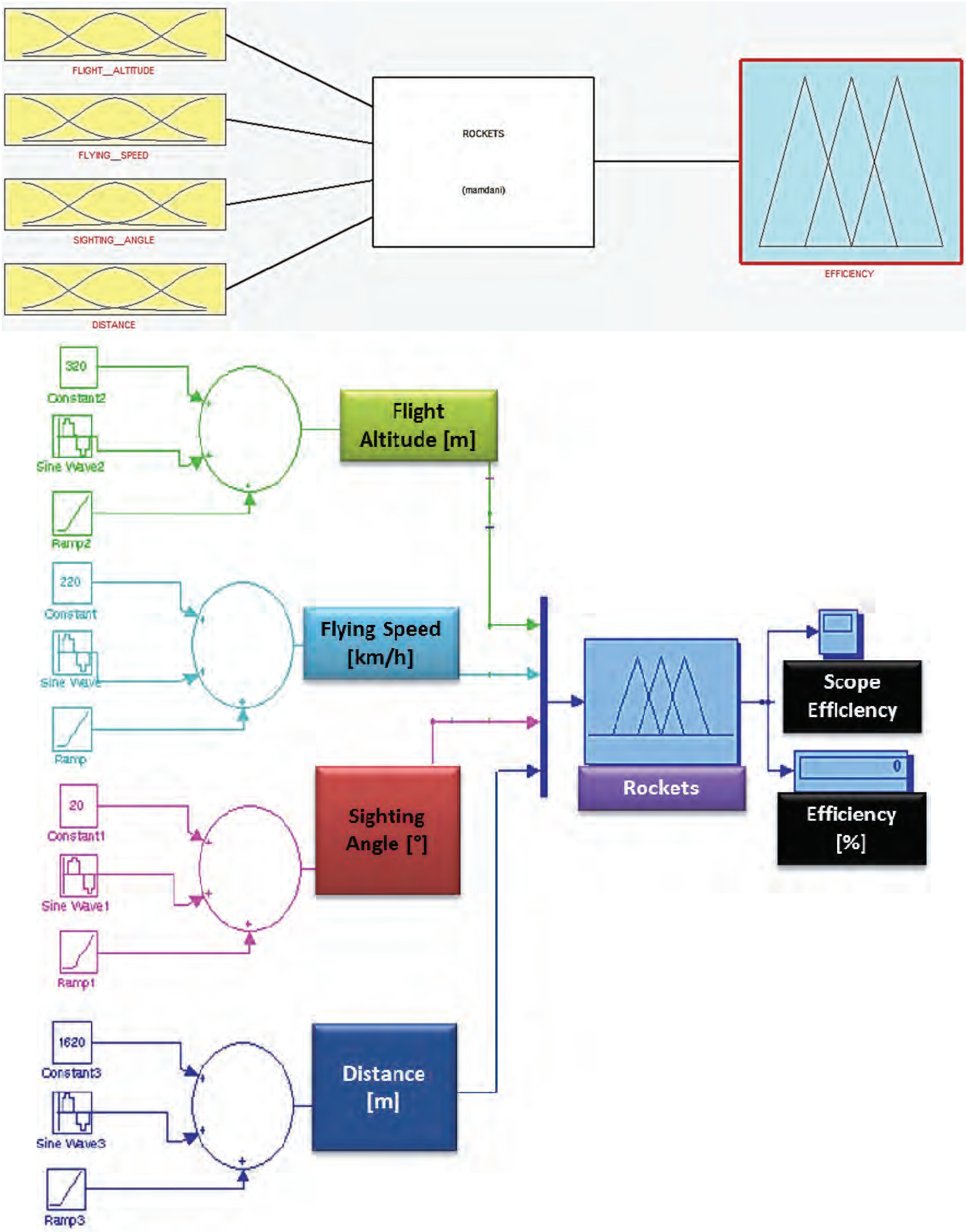
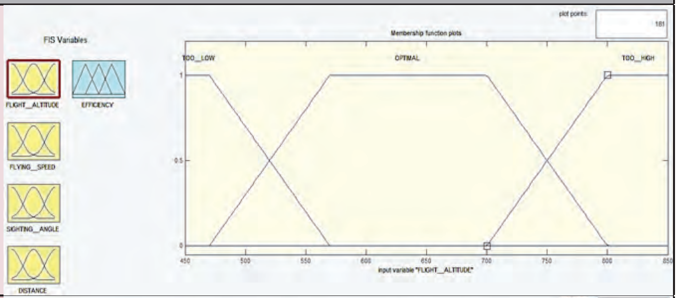
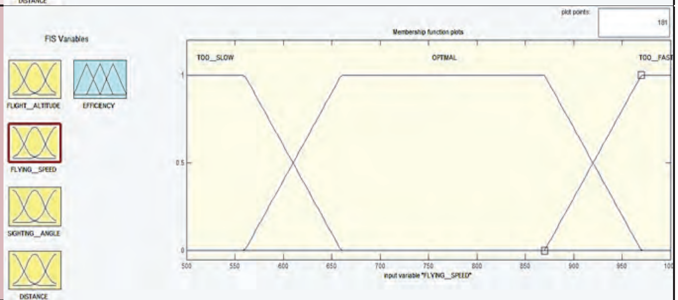
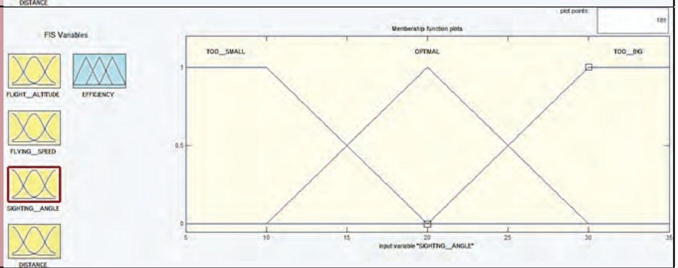
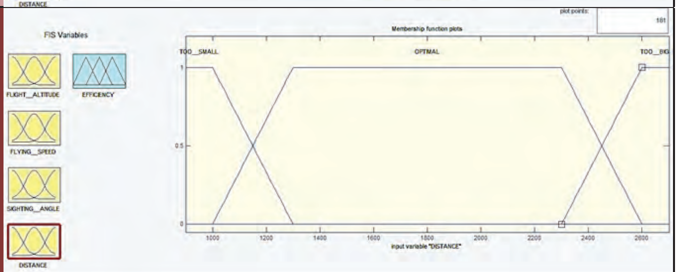
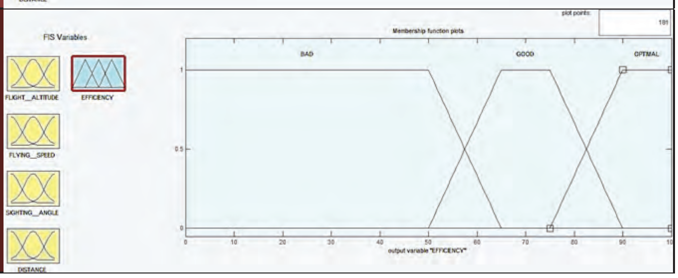


Fig. 2. Fuzzy efficiency estimation subsystem schematic diagram (Matlab Fuzzy Logic Toolbox and Simulink)

Inference mechanism is MIN-MAX method (Zadeh' method, MIN – MAX, assessment of premises – MIN, aggregation – MAX.) [2, 3].

The membership functions and its boundaries of the fuzzy control subsystem input parameters sets are showed in Tab. 2 below.

Tab. 2. The membership functions and its boundaries of the fuzzy control subsystem input parameters sets [2, 3, 5]

A-G air-task	**Fuzzy controller „Rockets"**	
Flight Altitude [m]	Too low: 0-570, Optimal: 470-800, Too high: 700-5000,	
Flying speed [km/h]	Too slow: 0-660, Optimal: 560-970, Too fast: 870-2400,	
Sighting angle [°]	Too small: 0-20, Optimal: 10-30, Too big: 20-90,	
Distance [m]	Too small: 0-1300, Optimal: 1000-2600, Too big: 2300-5000,	
Efficiency - Rockets [%]	Bad: 0-65, Good: 50-90, Optimal: 75-100.	

Inference and defuzification in rule viewer (for some examples of input parameters) and fuzzy efficiency estimation control surfaces, from Matlab Fuzzy Logic Toolbox, are presented on Fig. 3 and 4 (efficiency dependency of flying speed, flight altitude and sighting angle of attack).

As an example, in Fig. 5, there is presented dependence of the efficiency of the air- task on the distance from the target for „Rockets fuzzy controller".

When aircraft is closing to target (starting from 3000 m to 2100 m from a target) efficiency is increasing from 28.7 to 80%. The biggest efficiency is between 1500-2000 m from target (about 91%). Further approach to the target make efficiency decreased from 80% to about 29%.

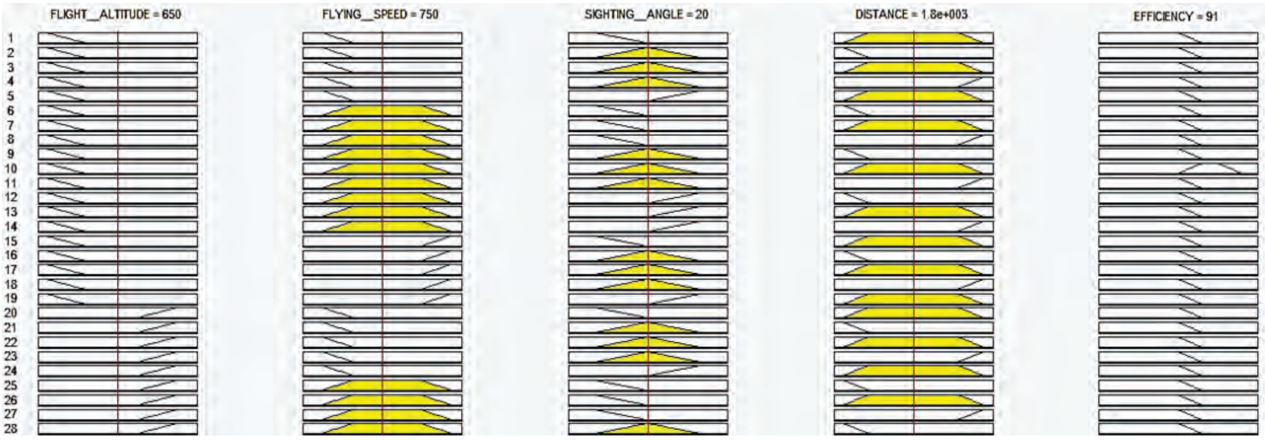


Fig. 3. Inference and defuzification in rule viewer (Matlab, Fuzzy Logic Toolbox, part of all rules)

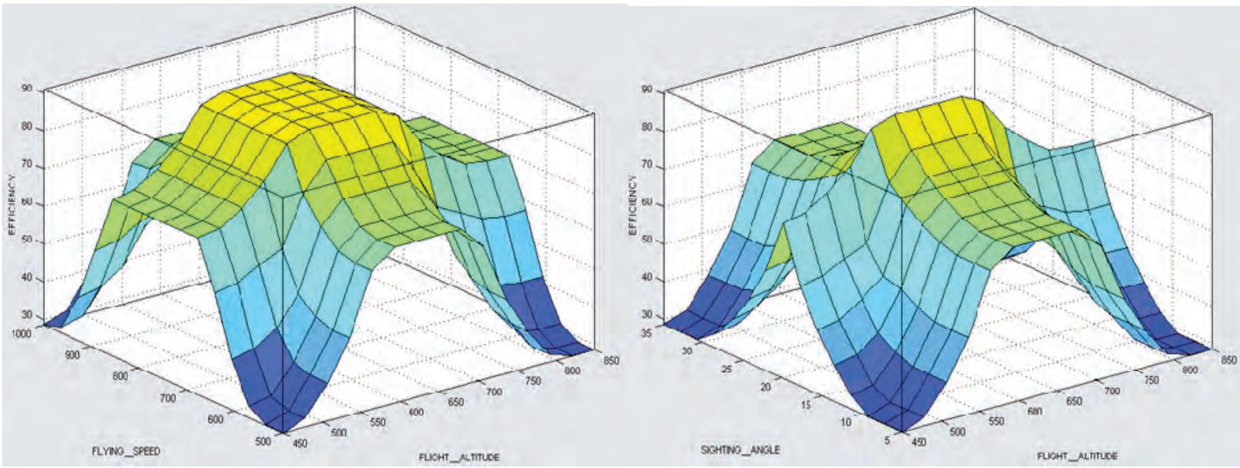


Fig. 4. Fuzzy efficiency estimation control surfaces (Fuzzy Logic Toolbox)

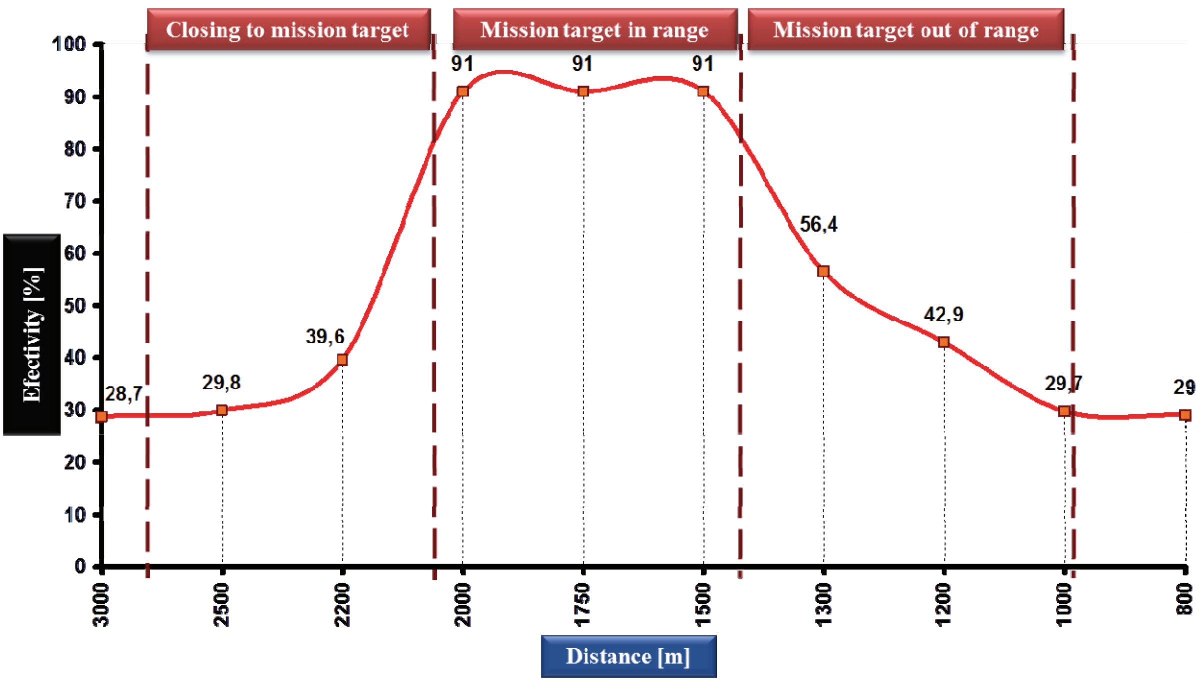


Fig. 5. Dependence of the efficiency of the air- task on the distance from the target for „Rockets fuzzy controller"

4. Conclusions

This paper describes the author's vision about using fuzzy control sets in aircraft on-board attack avionics system (rockets on-board control subsystem is one of the subsystem in aircraft attack avionics system). After close research author concludes that the primary problem is to assure communication (between mission computer and fuzzy subsystem), real time data computing and visualization of the calculation results. Proper selection of the experts, adequate fuzzy inference system and method of defuzification are next problems to solve.

Some of the conclusions are presented below:

- using of fuzzy expert systems in on-board control and decision making support systems permits to analyse and interpret of dependence between input parameters (flight parameters) and air-task efficiency,
- the methodology and fuzzy controller (as a research tool) allow to conduct research in the field of increasing aircraft on-board systems efficiency,
- modifications to existing attack avionics on-board control systems are possible and could provide minimization of components, relief pilot (support during decision making procedures) and perform various tasks in any weather and battlefield conditions,
- using of fuzzy expert systems in on-board control systems may decrease pilot's decision making time (suggestion of use the most effective armament subsystem),
- design project can also support:
  - air-task efficiency evaluation during mission planning procedures,
  - air-task efficiency evaluation during training missions (basic and advanced training on aircraft simulators),
  - pilots/operators decision making procedures during UCAV air-tasks (recommendation of use the most effective armament subsystem).

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