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AVIATION
ISSN 1648-7788 print / ISSN 1822-4180 online
2014 Volume 18(1): 9–12
doi:10.3846/16487788.2014.865947

PROJECT OF ON-BOARD CONTROL SYSTEM WITH AIR-TASK EFFICIENCY ESTIMATION SUBSYSTEM BASED ON FUZZY LOGIC FOR UNMANNED COMBAT AERIAL VEHICLE ROCKETS

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Received 11 November 2013; accepted 28 February 2014

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Abstract. In this article, a project of on-board control system with fuzzy efficiency of air-task estimation subsystem for UCAV rockets is presented. Moreover, some features allowing the use of fuzzy logic subsystems in unmanned aviation will be described as well. Complexity of the project and some mathematical calculations required relevant assumptions which are also reported. Finally, prognosis about operation of the system and conclusions are provided. This article is an integral part of authors' scientific research.

Keywords: control, rocket, on-board system, fuzzy subsystem, efficiency.

1. Introduction

Aircraft on-board combat systems are crucial in modern warfare. Air defense systems (guns, missiles and rockets) are continuously being modernized and have become the most dangerous threat in air combat missions (Grzesik 2005). Localization and character of Iraq and Afghanistan conflicts are very strong indications that UCAVs are commonly used. There is no guarantee for completion of a task if on-board defensive and offensive systems are not improved.

Research conducted by the authors and an analysis of the available literature (Piegat 1999; Wójtowicz 2012; Rutkowska *et al.* 1997; Mulawka 1996) shows that fuzzy logic can be used in UCAV efficiency air-task estimation. Fuzzy logic controllers based on expert knowledge can be used in autonomous non-programmed missions.

Fuzzy logic can be used to evaluate the effectiveness of an air-task (completion of pre-flight analysis and ability to select optimal solutions) and also in on-board decision-making system employed during combat missions (Tomaszek, Wróblewski 2001; Grzesik 2012).

In this article authors present their vision of on-board control system with fuzzy efficiency of air-task estimation subsystem for UCAV rockets. It will provide offensive and defensive modes with the highest (optimal) accuracy. Pictures and schematic diagrams illustrate operational and functional ideas of the system's operation.

The 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 (Tomaszek, Wróblewski 2001), it was necessary to apply appropriate simplifying assumptions.

Expectations for on-board control system with fuzzy efficiency of air-task estimation subsystem for UCAV rockets:

- small weight;
- high level of accuracy;
- survivability;
- high level of reliability;
- all weather conditions and day/night use;
- ease to maintain and isolate faults;
- modular construction;
- real-time calculations;
- fully autonomous action with pilot/operator control option (touch screen monitor);
- on-board guided control system with fuzzy efficiency of air-task estimation subsystem should not significantly change UCAV construction.

2. Features allowing the use of fuzzy logic for UCAV 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. Therefore, it is necessary to construct on-board systems operating at higher speed and higher reliability. These features are characterized in fuzzy logic theory (Zadeh 1965, 1975; Yager, Filev 1995). Fuzzy controllers based on expert knowledge (Mulawka 1996) could be a significant factor in the decision-making process of employing a specific weapon in autonomous, previously non-programmed or programmed combat missions. The controllers could be used to evaluate the effectiveness of various kinds of air-tasks (completion of pre-flight analysis and the ability to select optimal solutions), as well as in the on-board decision-making system.

The second solution needs to be tested and analyzed more precisely, because at any time during a mission a pilot/operator should have the opportunity to change his decision.

3. Conception

On-board computer and fuzzy control subsystem are the main elements of the project. Gathering and analysis of air navigation data and mission control are its main tasks. All necessary information is sent to ground control station displays (air data and particular system efficiency estimation). It is the pilot/operator's duty to control mission progress and make corrections if needed. The corrections are transferred to UCAV computer (for example, defining accumulated angle corrections for targeting: target speed, self-speed, altitude, angle of attack, etc.) and then to proper control systems (for example, execution mechanism controllers).

Outside of fire zones, cockpit signalization (information on displays for the pilot/operator in ground control station) is indispensable.

UCAV receive all mission data directly from ground control station or via satellite (depends on distance and geographic conditions). If the target is unidentified the pilot/operator sends information (position, image of the target) to headquarters via digital transmission channels and waits for further decisions (Fig. 1).

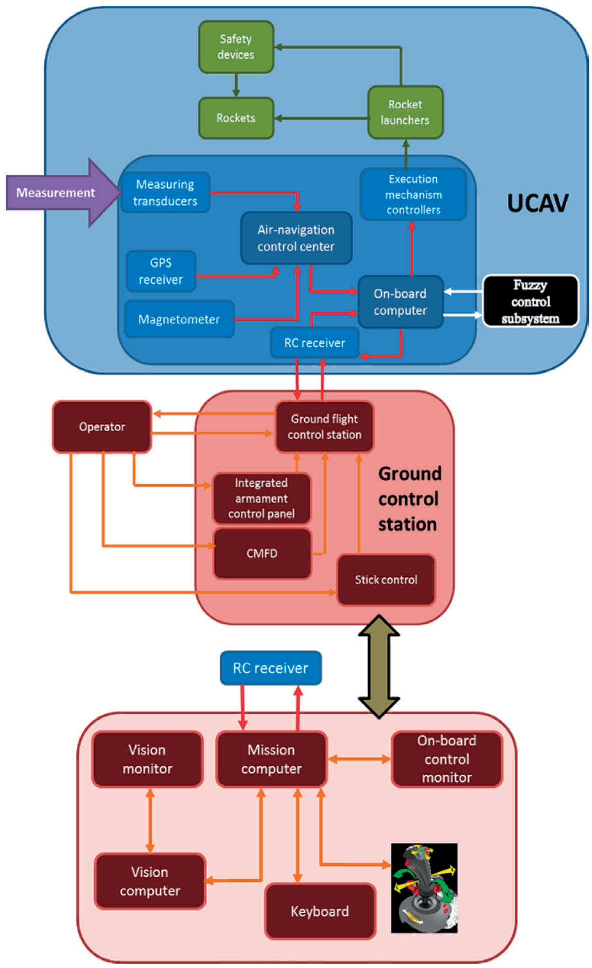


Fig. 1. Schematic diagram of on-board control system and ground control station with fuzzy efficiency of air-task estimation subsystem and ground control station – conception for UCAV rockets

Typical ground control station is controlled by two pilot/operators. It consists of three modules (Wójtowicz 2012):

– A navigator module responsible for:
  - planning of UCAV flight program and its uploading to on-board computer,
  - making changes in flight program during mission,
  - receiving flight program (mission plan) from headquarters and sending it to UCAV,
  - locating UCAV and making reports;
– A pilot/observer module, the primary task of which is to observe UCAV location and control flight parameters;
– An image analyzer module.

There are usually two work stations in a ground control station. The station supports real-time work of pilot/operators (radio communication with UCAV provides reception of all indispensable air data). Vision monitor (Fig. 2, 1) displays flight data, navigation information, armament status and readiness, etc.

Fig. 2. Conception of ground control station

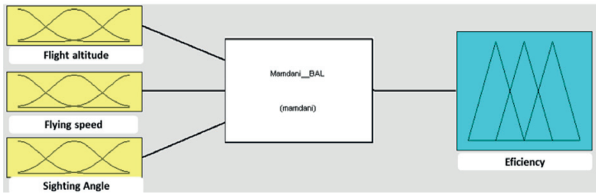
Air, navigation and armament data are displayed in the same way as in manned aircraft (on head-up display and color multifunction display). This enables rapid response and more accurate control of a UCAV.

During an air-task the display shows the parameters and position of a UCAV (aircraft status and progress of a mission) on the camera image or map.

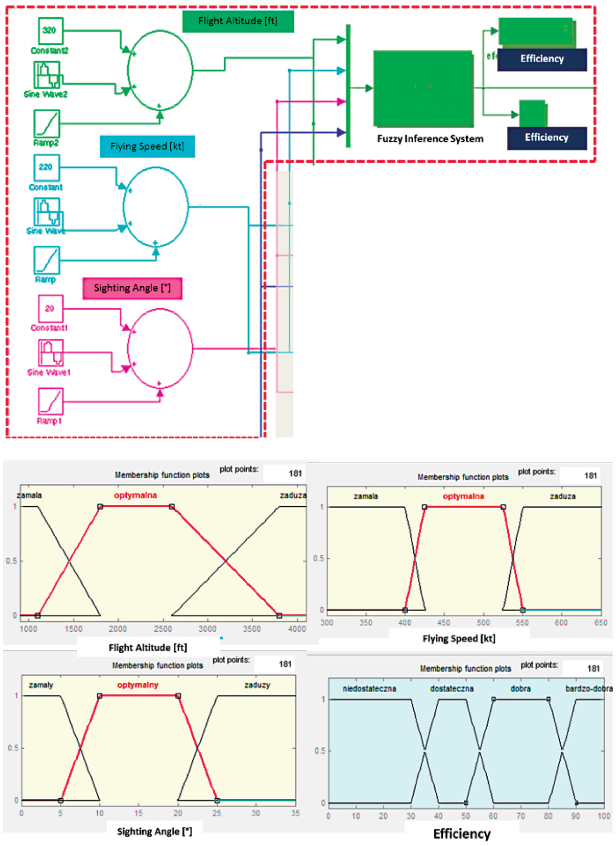
UCAV communication system and telephone are located between work stations. Stick control, keyboard, mouse and integrated armament control panel support control of flight and on-board weapon.

Ground control station is also equipped with flight indicators. Flight indicator readings are the same as in manned aircraft. This introduces an impression of real flight.

Fuzzy control subsystem provides information about efficiency estimation of air-task and suggestion on which system must be used (for highest efficiency). Pilot/operator has to make the decision whether he/she approves the suggestion or refuses it. Schematic diagrams of fuzzy efficiency of air-task estimation subsystem and control surfaces are presented below. The project was made using Matlab and Fuzzy Logic Toolbox (Figs 3 and 4) (Mrozek, B., Mrozek, Z. 1994, 2001; The Math… 1995–1998).

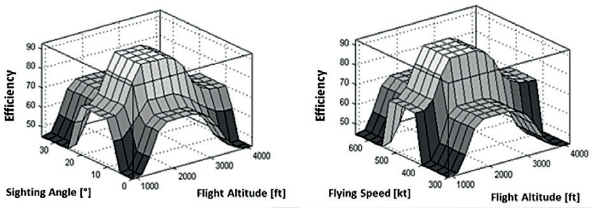


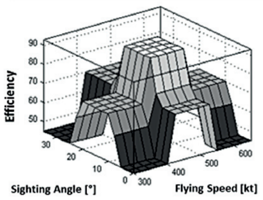
a)



b)

Fig. 3. Schematic diagram of fuzzy efficiency estimation subsystem: a) diagram from Fuzzy Logic Toolbox; b) diagram from Matlab Simulink (part of a bigger project), fuzzy sets and membership functions





	Flight Altitude [ft]	Flying Speed [kt]	Sighting Angle [°]	Efficiency [%]
1	4200	410	20	70
2	3900	430	25	78
3	3000	450	23	80
4	2200	490	20	93
5	1500	500	15	64
6	1200	510	12	45
7	900	520	10	32
8	700	550	10	27
9	1200	530	8	17
10	2000	470	5	45

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

4. Conclusions

This paper describes the authors' vision about using fuzzy control sets in UCAV on-board armament systems. After close research authors conclude that the primary problem is to assure communication (mission computer and fuzzy subsystem), real-time data computing and visualization of the calculation results. Selection of adequate fuzzy inference system and method of defuzification are secondary problems to be solved. Weight of all necessary units should be a crucial factor.

In further analysis of the project, the authors will try to construct a model of fuzzy efficiency of air-task estimation subsystem and test it in laboratory conditions. Results of the tests should give all required data.

Complexity of the project requires the involvement of many specialists.

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