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# Software Architecture Evaluation of Unmanned Aerial Vehicles Fuzzy Based Controllers – A Survey

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**Abstract:** In this survey paper we discuss the recent techniques for software architecture evaluation methods for Unmanned Aerial Vehicle (UAV) systems that use fuzzy control methodology. We discuss the current methodologies and evaluation approaches, identify their limitations, and discuss the open research issues. These issues include methods used to evaluate the level of risk, communications latency, availability, sensor performance, automation, and human interaction.

**Keywords**: evaluation methods of UAVs, Fuzzy Based Controllers, autonomy evaluation method, full autonomy, performance.

## 1. INTRODUCTION

Researchers around the world have carried much research into the evaluation of unmanned systems, each having their own clear application objectives. Our review of the existing software architecture evaluation methods of the autonomy of unmanned systems has found that these methods include the level evaluation method, double-axis method, three-axis method, look-up table method and formulation method.

There are many different researches work relate to the software architecture evaluation of autonomous navigation control of UAVs; and it content different techniques to develop UAVs control system, **include :**

a) Fuzzy control technique.
b) Adaptive control technique.
c) Neural networks technique.
d) Genetic algorithms technique.

Then in this survey we focus on the papers that using fuzzy control technique to control all system components.

Fuzzy logic (FL) will be used to tune the PD or PID control gains according to the readings of the sensors, which monitors the condition of the structure and the engine. Since the development of such a hybrid system proves to be time consuming and involves generating many algorithms and models, we only focus on one strand of the hybrid scheme, which is the fuzzy logic control in this research survey. This artificial intelligence system is quite favored for automatic control because it avoids complex non-linear equations and can utilize the best pilot expertise available. Fuzzy logic that is based on the mathematical theory of fuzzy sets circumvents complex differential equations by offering a collection of if-then rules that operates as a linear function even though the function itself is not known. and this logic does not operate on binary output such as true or false, up or down, left or right, but rather facilitates for the entire intermediate spectrum of outputs to be included. In this research survey, previous fuzzy logic controllers (FLC) are reviewed. [10]

## 2. SURVEY OF THE CURRENT SOFTWARE ARCHITECURE EVALUATION METHODS

Several classical software architecture methods have been widely applied and cited, including *Sheridan's*LOA[22, 25], the US military's Autonomous Control Level (ACL)[22] , and Huang's ALFUS[22]. Researchers have extended the above software architecture evaluation methods to various degrees.

For example, using Yang and Zhang [22] put forward the assessment of the autonomy level of unmanned systems by considering four aspects the degree of change in the environment, the degree of task completion, the degree of state stability of the system, and the degree of human computer interaction and then introduced fuzzy theory to this method by quantifying the autonomy level of unmanned systems with a fuzzy decision. Nevertheless the UAV components are not controlled by fuzzy control technique.

From analysis of the mechanism of human intelligence and with in-depth study of the autonomy control-level classification of the UAV, Chen et al.[22] proposed measures of nine-level that evaluate the autonomy control of an unmanned system, and then enriched the content of the autonomy control evaluation level with an autonomy function, autonomy types, intelligence attributes, information sharing capabilities and other aspects. HOWEVER there is no using of fuzzy theory.

*Suresh and Ghose* [23] carried out measures on 11 levels of autonomy control from single system autonomy to group autonomy, and they provided detailed explanations of each level through published extensive literature on autonomy. They divided each level into several sub layers, and they believed that communication and information would play a key role in realizing the autonomy of an UAV. However there is no using of fuzzy theory.

Many of papers are concerned with the flight of UAVs. proposes fuzzy logic based autonomous flight and landing system controllers. All of them using the same three fuzzy logic modules and these modules are developed under the main navigation control system and three more for the autonomous landing control system to control of the altitude, the speed, and the position against the runway, through which the global position (latitude-longitude) of the air vehicle is controlled. A SID (Standard Instrument Departure) and TACAN (Tactical Air Navigation) approach is used and the performance of the fuzzy-based controllers is evaluated with time based diagrams under MATLAB's standard configuration and the (Aerosim) Aeronautical Simulation Block Set which provides a complete set of tools**.**

The Aerosonde UAV model is **always** used in the simulations in order to demonstrate the performance and the potential of the controllers. Additionally, some visual tools are deployed in order to get visual outputs that help the designer in the evaluation of the controllers. [4][5][8]

*SeferKurnaz ·Omer Cetin · OkyayKaynak* describes other design of compact, and inexpensive fuzzy logic controllers and fuzzy inference systems which estimates the attitude of (UAV), and this attitude refers to parameters of UAV such as longitude latitude, and altitude and angles of rotation known as pitch and roll.

Fuzzy Logic is used to design the Fuzzy Logic Controllers and Fuzzy Inference Systems. Visual simulation tool and Aerosim (Aeronautical Simulation Set) Flight gear interface are used for Simulation purpose.[5]However one UAV mission model used in the simulations

*L. Doitsidis, K. P. Valavanis*they has been developed two module fuzzy logic controller that also includes a separate error calculating box is derived for autonomous navigation and control of small manned – unmanned aerial vehicles demonstrating ability to fly through specified way-points in a 3-D environment repeatedly, perform trajectory tracking, and, duplicate another vehicle's trajectory. A *MATLAB* standard configuration environment and the Aerosim Aeronautical Simulation Block Set are utilized for simulation studies, presented through a visualization interface; results illustrate controller performance and potential. However this design is currently based on human pilot experience and not on flight performance observations. [7].

*Kimberly Bickraj* discusses the integration of health monitoring and flight control systems for small (UAVs). After briefly reviewing previous fuzzy logic controllers (FLC) of air vehicles, there is very low cost integration method is proposed. The proposed fuzzy logic (FL) selects the best gain values for the operation of PD or PID controllers of the autonomous flight system according to the health of the components. any gain adjustments help the UAV to execute maneuvers in a more conservative manner when the system have structural or proportion system problems. However Once this is successfully established, we will be one-step closer to achieving a completely self- sufficient UAV. [9]

*James K. Kuchar* civil airspace requires new methods of ensuring collision avoidance. Concerns over command and control latency, vehicle performance, reliability of autonomous functions, and interoperability of sense-and-avoid systems with the Traffic Alert and Collision Avoidance System (TCAS) and Air Traffic Control must be resolved. his paper describes the safety evaluation process that the international community has deemed necessary to certify such systems. The process focuses on a statistically-valid estimate of collision avoidance performance developed through a combination of airspace encounter modeling, fast time simulation of the collision avoidance system across millions of encounter scenarios, and system failure and event sensitivity analysis.

However, all aircraft are required to be transponder -equipped. Extensive flight testing is required to support modeling communications latency and availability, sensor performance, automation, human interaction with CAS advisories, and flight characteristics.[ 1 ]

*Meng-Lun* fixed-wing UAV based spatial information acquisition platform is developed and evaluated .the evaluation Approach used is comparing DG results with checking points with precisely known coordinates. To evaluated direct Georeference( DG) accuracy, Interior Orientation Parameters (IOP) and Exterior Orientation Parameters (EOP). However the Extended Kalman Filter(EKF) trajectory is not smooth [ 2 ].

*DemozGebre*develop a framework for the design of CONOPs, which take these SUAS limitations into account. The method outlined shows, in part, how these vehicle/infrastructure collision risks can be estimated or conservatively bounded. his evaluation Approach used is resorting and multi-sensor on board to evaluate Risk, vehicle states, traffic management parameters, and sensor performance. However the performance specifications provided by manufactures does not provide sufficient information to allow precisely quantifying or bounding the collision risk.[3]

*Roopashree.S, Shubha Bhat*. they estimates the attitude of UAVs. they used Kalman filter fuzzy approach to generate fuzzy rules. (Kalman Filtering is a form of optimal estimation characterized by recursive evaluation) and they have internal model of dynamics of system being estimated. However The attitude of UAV may oscillate because the controller design is based on human pilot experience.[6]

## 3. OPEN ISSUES

After having studied the literature on evaluating autonomous control of UAVs we can say that :

a. There was no systematic study that could provide a full autonomy evaluation method for fuzzy logic based control system of UAVs.

b. There are still many problems with the adaptability of existing evaluation methods, which need to be improved for ***general utilization***.

c. The autonomy evaluation method of the UAV must consider the *diversity*, *multidimensionality*, *hierarchy*, and primary and secondary natures of the application target and the system itself, so that it can avoid *ambiguity* in the formulation and description of the autonomy of autonomous UAV.

**Table 1. Examples of Approaches for Software Architecture Evaluation of UAVs:**

| | Author Name/Year | Objective | evaluation Approach used | Elements or attributes that evaluated | Limitation |
|---|---|---|---|---|---|
| 1 | SeferKurnaz ·Omer Cetin · OkyayKaynak(2009) | provides autonomy to the UAV in all phases of a typical UAV's mission except take off and land on. | MATLAB's standard configuration and the Aerosim Aeronautical Simulation Block Set | performance of the fuzzy based controllers components | there exist some oscillations and errors when wind effects are added to the simulation environment one UAV mission model used in the simulations |
| 2 | Omer Cetin · SeferKurnaz · OkyayKaynak (2011) | Design of Autonomous Landing System for Unmanned Aerial Vehicles | MATLAB's standard configuration and the Aerosim Aeronautical Simulation Block | performance of the fuzzy based controllers components | there exist some oscillations and errors when wind effects are added to the simulation environment.. one UAV mission model used in the simulations |
| 3 | SeferKurnaz , Omer Çetin (2010) | Autonomous Navigation and Landing Tasks for Fixed Wing Small (UAV) | MATLAB's standard configuration and the Aerosim Aeronautical Simulation Block | performance of the fuzzy based controllers components | low tuning of membership functions. Autonomous takeoff not tried. one UAV mission model used in the simulations |
| 4 | L. Doitsidis, K. P. Valavanis (2004) | ability to fly through specified waypoints in a 3-D environment repeatedly | Fuzzy Logic Based | controller performance | Design is currently based on human pilot experience and not on flight performance observations. |
| 5 | KimberlyBickraj,Thierry Pamphile (2006) | selects the best gain values for the operation of PD or PID controllers of the autonomous flight system according to the health of the components. | fuzzy logic based neuro-fuzzy inference system (ANFIS). | performance of the fuzzy based controllers components | Once this is successfully established, we will be one-step closer to achieving a completely self- sufficient UAV. |
| 6 | James K. Kuchar | Safety analysis methodology for (UAV) collision avoidance systems | statistically-valid estimate | Risk ratio, communications latency, availability, sensor performance, automation, human interaction . | 1- UAV concepts need to go through a similar process involving detailed airspace encounter modeling, dynamic simulation of collision avoidance system performance, and system failure and event sensitivity studies. 2 -Flight tests and human-in-the-loop simulation studies are also required to develop models to describe how UAV pilots (or an autonomous system) would respond to collision avoidance |

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|---|---|---|---|---|---|
| | | | | | system advisories. |
| 7 | Meng-Lun (2012) | fixed-wing UAV based spatial information acquisition platform is developed and evaluated. | comparing DG results with checking points with precisely known coordinates | DG accuracy, Interior Orientation Parameters (IOP) Exterior Orientation Parameters (EOP) | EKF trajectory is not smooth |
| 8 | DemozGebre-EgziabherZhiqiang Xing 2011 | develop a framework for the design of CONOPs, which take these SUAS limitations into account. The method outlined shows, in part, how these vehicle/infrastructure collision risks can be estimated or conservatively bounded. | Resorting. Multi- sensor. | Risk. vehicle states . other traffic management parameters. sensor performance. | The performance specifications provided by manufactures does not provide sufficient information to allow precisely quantifying or bounding the collision risk. |
| 9 | Roopashree. S, Shubha Bhat (2012) | estimates the attitude of (UAV) | Kalman filter fuzzy approach is used to generate fuzzy rules. Kalman Filtering is a form of optimal estimation characterized by recursive evaluation | internal model of dynamics of system being estimated. | The attitude of UAV may oscillate because the controller design is based on human pilot experience. |

## 4. CONCLUSION

This survey paper concern with software architecture evaluation of unmanned aerial vehicles fuzzy based controllers.
In the literature many approaches to architecture evaluation can be identified, i.e., simulation, scenarios, mathematical modeling, and experience based reasoning. Here we present some evaluation approach and what are the elements or attributes that evaluated and what is there limitation. Then we find an interesting open issue about the evaluation on autonomous degree and performance of system controller's components of UAVs.

From our survey there are still many problems with the adaptability of existing evaluation methods, which need to be improved for general utilization. The autonomy evaluation method of the UAV must consider the *diversity*, *multidimensionality*, *hierarchy*, and primary and secondary natures of the application target and the system itself, so that it can avoid *ambiguity* in the formulation and description of the autonomy of autonomous UAV.

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