The Function Analysis and its Application to Determination of Fuzzy Subsets for Model Helicopter Fuzzy Control

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***Abstract*— In this study, an analysis of the function that determines the sub-clusters of the fuzzy controller for model helicopter control is performed.**

For this purpose, a model helicopter and a test platform were established in which the results of the function analysis can be seen and the application results will be examined. Arduino control card is used for model control. Analysis results are analyzed on computer using c # program. The computer connection with the model is carried out via the Usb port.

Input parameters for control are obtained from the sensors on the model. The output values are calculated as net values to control the motors on the model.

Real-time application results are seen as simulations on the model.

***Keywords*— Fuzzy subset function, fuzzy control, fuzzy logic control system, model helicopter control**

I. INTRODUCTION

Thanks to their ability to move, helicopters, which are preferred aircrafts in aviation sector, are preferred aircrafts tools in many sectors.

The helicopters, which are called rotating wing aircrafts, are very difficult to control compared to fixed wing aircrafts. It is very difficult to control the vehicle to keep it on the desired position, on a specified direction. In order to control the helicopters at a certain position, it is necessary to make multi-directional control movements and to develop control systems to support these movements [1].

When helicopter-specific movements, such as suspension, vertical mobility, lateral movement, hirling around, etc., are needed, it is advantageous to use unmanned helicopters or model helicopters where cost and safety precautions are important [2].

When the studies done in this context are examined, the performance studies of the helicopters and the nonlinear fuzzy controls are examined in the sources[3], [4], [5], [6], the control exercises performed on the test platforms and the helicopter models are examined in the sources [7], [8], [9].

II. MATERIALS AND METHODS

In this section, the functions that determine the sub clusters of the fuzzy controller that performs the helicopter control have been examined.

In order to test the results produced by the controller according to the function results, a model helicopter was used and real time application results were obtained on the model.

Coordinate and altitude data were taken as the input value for the controller; Servo servo and main motor controls are made done as output values.

A. *Fuzzy Controller Structure*

The fuzzy controller, which will perform the helicopter control, consists of a structure that blur the actual values read from the sensors, interpreting the obtained values according to the rules in the rule base and correcting the interpreted values and obtaining net motor values.

The values read from the helicopter as input values are transferred to the computer via the control card. The net control values obtained from these values analyzed by C # program on the computer are sent to the model helicopter to perform the control process. Figure 1 shows the block structure of the fuzzy controller.

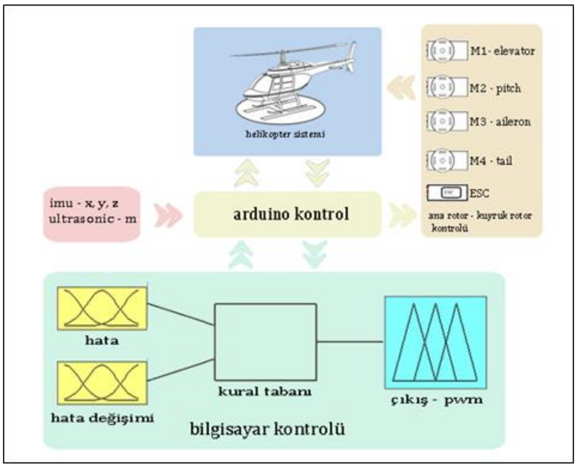

Figure 1. Block structure of the fuzzy controller

1) Definition of Input and Output Parameters

For the real-time application of the controller system, the data obtained from the sensors located on the model are sent to the controller program as input parameters. The values separated by the control card are used in the function as input parameters in the control program.

The naming and decomposition of input values has been clarified as a result of long-term studies.

The motor values to be checked for the final output are obtained when the input values are processed in the expert system. The output values consist of the pwm signal values to be applied to the motors that will enable the model to be controlled in practice to move within the specified position.

The engines are verbally defined as output variable values.

2) Fuzzy Inference

Fuzzy rules are defined that will best describe the system and provide the best performance of the system, taking into account the different possibilities and scenarios that may arise from the test results obtained in the studies related to model control.

There are 49 fuzzy rules available to be applied to the error and error change value for each parameter in the system. These rules are stated in the source [2], where the work is attached.

3) Rinsing

In this area, where the obtained fuzzy output values are converted into numerical expressions, the membership scores of error and error change values are calculated for each rule.

By clarifying these calculated values on the logical combination set, the net values to be applied to the control system of the fuzzy logic controller are obtained. In practice, the center of gravity method is used for rinsing.

4) Application Models and Control

For testing and inspection of the application results, two model helicopters are used; in HK 450 and T-REX 500 models. The controls of the models are disabled and their controls are done by the control program on the computer. Arduino control card is used for the communication between computer and model helicopter. The control program is written in the Visual Studio 2010 program in with the C # programming language.

B. *Subset Determination Function Analysis*

The coordinate values and the distance position data (x, y, z and m) read out for the input values are determined as the target values to be protected and the fuzzy subsets that represent each output value error and error changes are calculated with the sensitivity value to determine the subset . The sub-sets to be determined for the input parameters are calculated according to the formula (1) [2].

$$\sum_{n=0}^{t}\left(\left(m \pm \left|\frac{m}{t} * \frac{n}{s}\right|\right)\right) - m \tag{1}$$

In the fuzzy subsets determined for the output values, the change in the pwm signal values that affect the motor values to be controlled as the output parameters is controlled.

The main motor speed and propeller angles are considered as target values for the start and the motor movements that will achieve the movement are determined as the target

The control operation is performed by calculating the fuzzy subsets which will indicate the error and error change values between the current state and the motion state.

The fuzzy sets to be determined for the output parameters are calculated according to the formula (2).

$$\sum_{n=0}^{t}\left(\left(m \pm \left|\frac{t*n}{s}\right|\right)\right) - m \tag{2}$$

When the values expressed in formulas (1) and (2) are examined, the number of sub-sets to be controlled in the definition of fuzzy subset is limited; the exchange range to be used for the density parameter s; the normal target value for the control, namely, the desired target position is expressed by m values.

The t parameter remains at the limit value as the number of sub-sets to be controlled will start from 0 and is calculated as t = n-1 for the number n of sub-sets. For example, if the target subset number is 7, the t parameter that will be specified will be expressed as 6.

The input parameters change intervals of the fuzzy sets when he number of sub-sets will be 7 (the value that can vary according to the user's request) are shown in Table 1; output parameter change intervals are shown in Table II.

TABLE II

CHANGE INTERVALS FOR INPUT PARAMETERS

Girdi	Bulanık Kümeler	Değişim Aralığı
Giriş parametreleri	Sözsel ifadeler (etiketler)	$\sum_{n=0}^{6}\left(\left(m - \left\|\frac{m}{5} * \frac{n}{5}\right\|\right)\right) - m$ – $\sum_{n=0}^{6}\left(\left(m + \left\|\frac{m}{5} * \frac{n}{5}\right\|\right)\right) - m$

TABLE II

CHANGE INTERVALS FOR OUTPUT PARAMETERS

Girdi	Bulanık Kümeler	Değişim Aralığı
Çıkış parametreleri	Sözsel ifadeler (etiketler)	$\sum_{n=0}^{6}\left(\left(m - \left\|\frac{t*n}{5}\right\|\right)\right) - m$ – $\sum_{n=0}^{6}\left(\left(m + \left\|\frac{t*n}{5}\right\|\right)\right) - m$

The fuzzy subsets calculated according to the calculation formula of input parameters (1) and the calculation formulas of output parameters calculation formula (2) are getting + and – symmetrical values with respect to center (middle) value.

'n' value with the condition of having values from 0 to the 't' value of limit;

n = 0 to - 6 value ranges, for input value

rm[6 + n] = ((m_value + (m_value / t_control * n / s_control))) - m_value;

rm[6 - n] = ((m_value - (m_value / t_conrol * n / s_control))) - m_value;

n = 0 to - 6 value ranges, for output value

cm[6 + n] = ((mc_value + (tc_control * n / sc_control))) - mc_value;

cm[6 - n] = ((mc_value - (tc_control * n / sc_control))) – mc_value;

with these formulas, fuzzy sub-sets are calculated.

Computed fuzzy sub-sets are selected symmetrically from the clusters obtained by the specified cluster value.

When the operation is applied on the real time value obtained from the application;

For n = 0 - 6 input values
n = 0 için rm[6] = 0
n = 1 için rm[5] = -1,57 ve rm[7] = 1,57
n = 2 için rm[4] = -3,14 ve rm[8] = 3,14
n = 3 için rm[3] = -4,70 ve rm[9] = 4,70
n = 4 için rm[2] = -6,27 ve rm[10] = 6,27
n = 5 için rm[1] = -7,84 ve rm[11] = 7,84
n = 6 için rm[0] = -9,41 ve rm[12] = 9,41

For n = 0 - 6 output values
n= 0 için cm[6] = 0
n= 1 için cm[5] = -0,86 ve cm[7] = 0,86
n= 2 için cm[4] = -1,71 ve cm[8] = 1,71
n= 3 için cm[3] = -2,57 ve cm[9] = 2,57
n= 4 için cm[2] = -3,43 ve cm[10] = 3,43
n= 5 için cm[1] = -4,29 ve cm[11] = 4,29
n= 6 için cm[0] = -5,14 ve cm[12] = 5,14

Limit values are obtained. The fuzzy set value ranges to be created here are selected according to the membership function to be used. In practice, triangular membership functions are chosen and the range of values of the function is determined between the pair of values of n value n.

The determination of the resultant fuzzy sets on the sensor data read as input value and the change intervals are shown in Table III.

TABLE III

FUZZY CLUSTERS AND CHANGE INTERVALS

Label	Explain	X axis (x)	Y axis (y)	Z axis (z)	Distance (m)
NHB	Negative Error Big	[< -9,41 v -6,27]	[< -9,48 v -6,32]	[< -12,23 v -8,15]	[< -15,00 v -10,00]
NHO	Negative Error Middle	[-9,41 v -3,14]	[-9,48 v -3,16]	[-12,23 v -4,08]	[-15,00 v -5,00]
NHK	Negative Error Small	[-6,27 v 0,00]	[-6,32 v 0,00]	[-8,15 v 0,00]	[-10,00 v 0,00]
HS	Error Zero	[-3,14 v 3,14]	[-3,16 v 3,16]	[-4,08 v 4,08]	[-5,00 v 5,00]
PHK	Positive Error Small	[0,00 v 6,27]	[0,00 v 6,32]	[0,00 v 8,15]	[0,00 v 10,00]
PHO	Positive Error Middle	[3,14 v 9,41]	[3,16 v 9,48]	[4,08 v 12,23]	[5,00 v 15,00]
PHB	Positive Error Big	[6,27 v 9,41 >]	[6,32 v 9,48 >]	[8,15 v 12,23 >]	[10,00 v 15,00 >]

As an output value, the determination of the blurred clusters of the output changes affecting the motors and the change intervals are shown in Table IV.

TABLE IV

OUTPUT CLUSTERS AND CHANGE INTERVALS

Etiket	Açıklama	Çıkış
NB	Negative Big	[-5,14]
NO	Negative Middle	[-3,43]
NK	Negative Small	[-1,71]
S	Zero	[0]
PK	Positive Small	[1,71]
PO	Positive Middle	[3,43]
PB	Positive Big	[5,14]

The mathematical functions of the fuzzy sets were constructed to compute the density parameters that specify the rate of change of each input and output value. The generated mathematical functions are shown in Table V and the function representations are expressed as M.

TABLE IV

FUNCTIONAL REPRESENTATION OF INPUT AND OUTPUT VALUES

Label	Function
μ_{NHB} (M)	1/rm[0] + 0.5/rm[1] + 0/rm[2]
μ_{NHO} (M)	0/rm[0] + 0.5/rm[1] + 1/rm[2] + 0.5/rm[3] + 0/rm[4]
μ_{NHK} (M)	0/rm[2] + 0.5/rm[3] + 1/rm[4] + 0.5/rm[5] + 0/rm[6]
μ_{HS} (M)	0/rm[4] + 0.5/rm[5] + 1/rm[6] + 0.5/rm[7] + 0/rm[8]
μ_{PHK} (M)	0/rm[6] + 0.5/rm[7] + 1/rm[8] + 0.5/rm[9] + 0/rm[10]
μ_{PHO} (M)	0/rm[8] + 0.5/rm[9] + 1/rm[10] + 0.5/rm[11] + 0/rm[12]
μ_{PHB} (M)	0/rm[10] + 0.5/rm[11] + 1/rm[12]

III. REAL-TIME IMPLEMENTATION OF FUNCTION ON HELICOPTER CONTROL

This section includes observing and evaluating the results of the control work carried out using model helicopters.

Coordinate data received from model helicopters for any time period are processed and graphical representations of the net value that affect the engine drivers are made.

According to position data in vertical motion control; Figure 2 is a graph of the changes in the distance and distance variation values that will occur with time in the pitch angle of the processing by the controller. In another control application, the error and error change graph which takes place in the distance data in time is shown in Figure 3. Figure 4 shows the graph of the change in the pwm signal value over time, which will affect the esc value and pitch angle values that will determine the rotor rotation speed within any time period.

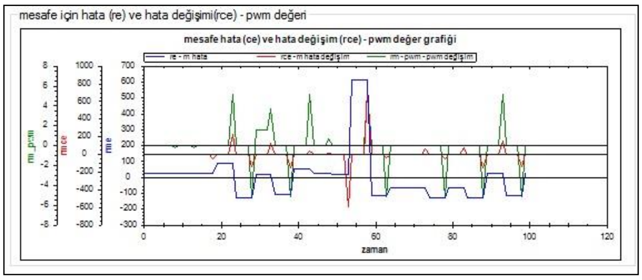

Figure 2. Pitch angle time variation graph

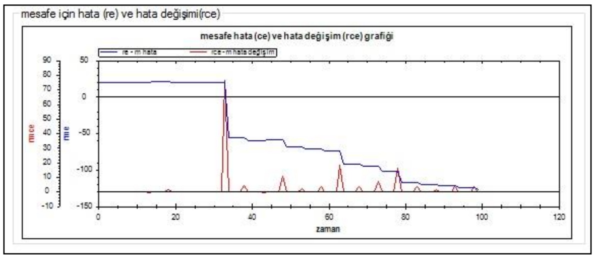

Figure 3. Distance error and error change chart

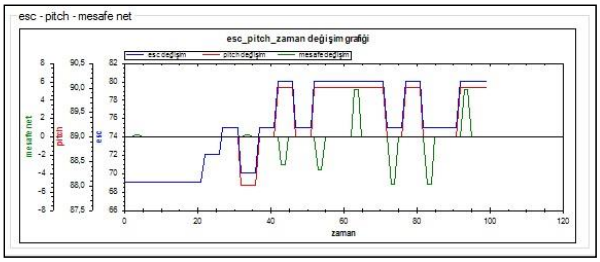

Figure 4. Pwm signal value change which affect Pitch and esc values

A graph of the time-dependent change in the value of the pwm signal, which occurs on the queue servicing the rotation of the spindles over any time period, is shown in Figure 5.

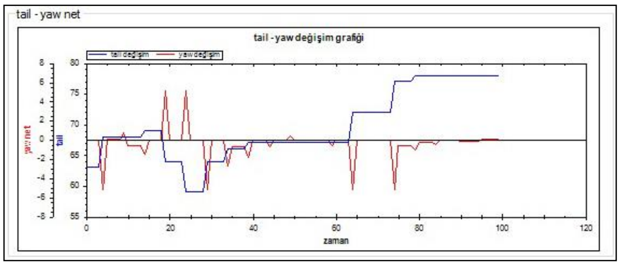

Figure 5. Tail service pwm signal change chart

The time change graph of the error and error change is shown in Figure 6, according to the motion of the model on the x axis at any time period.

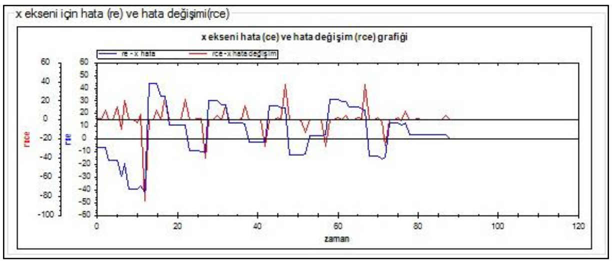

Figure 6. Change chart on the X axis

Examples of other time-varying graphs that come to fruition on the models are given in detail in [1].

IV. CONCLUSIONS

In this study, subcluster determination function used in fuzzy control of model helicopters and the results obtained by applying this function on models are investigated. Graphical representations of the results are done by using the results obtained from the applications.

An arduino control card was used to control the models and the controller program was developed on the computer using Visual Studio 2010 with C # programming language.

The fuzzy subset detection function is designed to control the helicopters. It was first used in the application specified in

[1]. The function is still in development. Work on different control areas are in progress for the development t and general acceptance of the function.

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