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FUZZY LOGIC APPROACH TO AIRPLANE PRECISION INSTRUMENT APPROACH AND LANDING

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ABSTRACT

In the precision instrument approach and landing of an airplane where the uncertainty is very frequent due to the high sensitivity of the activity to many factors, Fuzzy logic can be used to produce estimates which take into account the vagueness of the flight environment. In this paper an analysis of the inputs under fuzzy logic approach is considered. The success rate of landing is investigated, when the visibility, pilot experience and air speed are given by a fuzzy function. Precision instrument approach and landing simulations are used and the performance of the fuzzy based system is evaluated with fuzzy logic toolbox under MATLAB's Simulation Block Set which provides a complete set of tools for evaluating the success rate of landing under the given inputs. Comparison of the results from the developed fuzzy based system and flight simulation results show that the proposed fuzzy engine can successfully predict the success rate of landing under the given inputs.

Keywords: airplane, fuzzy logic engine, landing, fuzzy inference system, instrument approach.

1. INTRODUCTION

When pilot is on the approach and landing phase of flight, there are many factors can affect the landing. This is the single most demanding phase of flight, and the one that carries the highest risk. One of the elements in a successful landing is the pilot experience. It is also necessary to keep up with any changes in the runway status or destination weather as the flight progresses therefore visibility is a very important element in a spectacular landing.

Another element in making a spectacular landing is to fly a stabilized approach with the manufacturer's recommended airspeed on final. In this paper 3 elements considered (visibility, pilot experience and airspeed) as the inputs for calculating the success rate of landing.

There are some other important parameters which could significantly influence for successful landing. One of the important parameter is wind speed and wind direction. In all the flight simulations, wind considered to be calm.

The purpose of this paper is to design a fuzzy logic engine to evaluate the success rate of landing of the airplane on approach to land (final leg) under different pilot experience visibility and airspeed.

To train the fuzzy logic system, data were collected by simulation of 100 flight cases under different visibilities, pilot experience and air speed. Two pilots have done the flight simulations, One with 500 hours flight experience and another one with 2000 hours flight experience. In addition to 100 flight simulations applied for training the fuzzy engine, 16 flight simulation data were applied for checking and testing the system and 16 flight cases were evaluated by the created fuzzy logic engine.

2. DESCRIPTION OF THE PROPOSED FUZZY LOGIC ENGINE

Figure-1 shows a graphical map of the input-output. This figure shows the success rate of landing as the output and visibility as one of the inputs. The black box between the input and the output is the proposed fuzzy engine which calculates the success rate of landing.

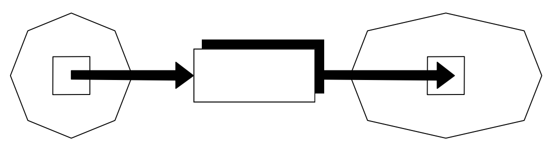

Figure-1. Graphical map of the input-output.

Fuzzy inference process comprises of five parts: fuzzification of the input variables, application of the fuzzy operator (AND or OR) in the antecedent, implication from the antecedent to the consequent, aggregation of the consequents across the rules, and defuzzification. Figure-2 shows the basic structure of the proposed fuzzy logic system.

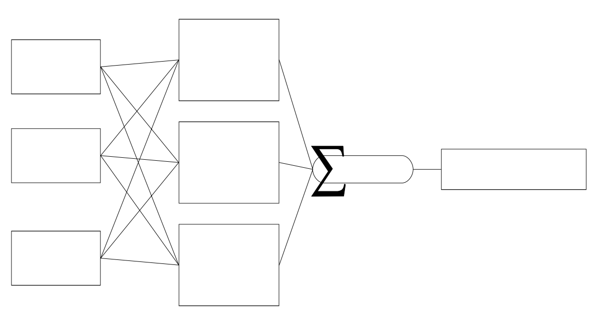

Figure-2. The basic structure of the fuzzy inference system.

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The visibility input is a crisp numerical value from 0 to 15 statue miles and the output of fuzzyfying visibility is a fuzzy degree of MF between 0 and 1. With the AND operator the three different pieces of the antecedent (visibility is good and pilot experience is high and air speed is normal) yielded the fuzzy membership values 0.8, 0.9 and 0.8, respectively. The fuzzy AND operator simply selects the minimum of the three values, 0.8.

The implication process occurs after proper weighting of the rules. After implication process, aggregation occurs by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. With defuzzification process the output (success rate of landing) is a single number. Figure-3 shows the complete fuzzy inference process.

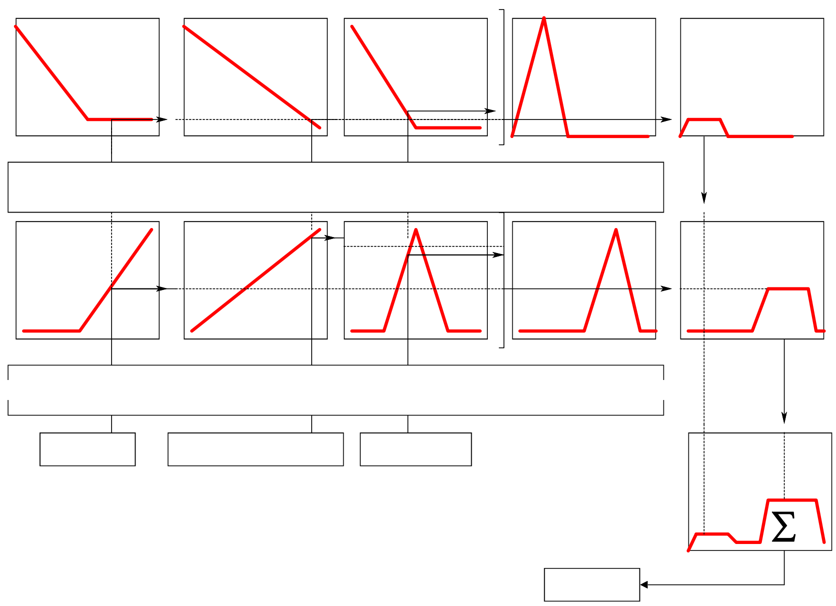

Figure-3. Fuzzy inference process.

3. THE FIS MODELING AND SIMULATIONS

To apply the proposed fuzzy inference to a system for which all the flight simulations have been done rather than choosing the parameters associated with a given membership function arbitrarily, Fuzzy Logic Toolbox neuro-adaptive learning techniques incorporated in the ANFIS command has been used. The training data set collected from the flight simulations is used to train the proposed fuzzy system. Grid partition method is being used to initialize the FIS. Membership type will be trimf and the output membership type is constant. Figures 3 and 4 shows the model structure after the FIS was generated. This figure shows that there are 3 inputs (visibility, pilot experience and air speed), first input (visibility) with 4 membership functions, second input (pilot experience) with 2 membership functions and the last input (Air speed) with 4 membership functions.

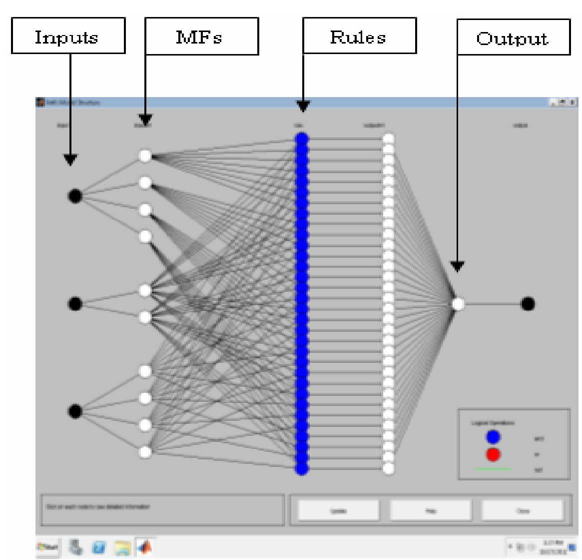

Figure-4. The Model FIS structure.

To train the FIS, the back propagation method was used. Figure-5 shows the checking error and training error. The horizontal axis represents the number of epochs and the vertical axis represents the error

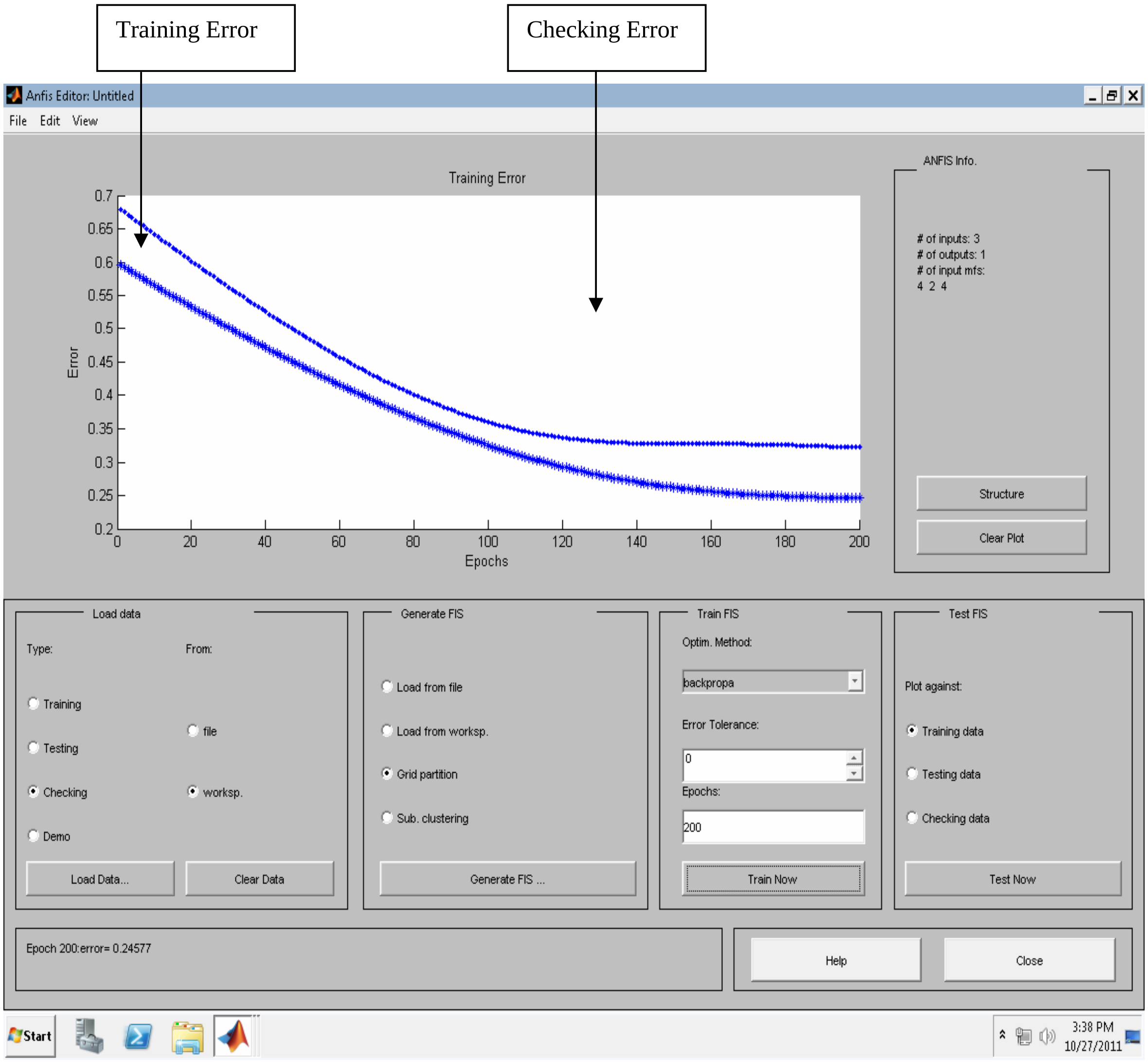

Figure-5. The checking error and training error plot.

Figure-6 shows the information about a fuzzy inference system with the names of each input variable on the left and the output variable on the right. In the proposed FIS, Sugeno type inference used, with 3 inputs and 1 output. The three inputs are visibility, pilot experience and air speed. The one output is success rate of landing.

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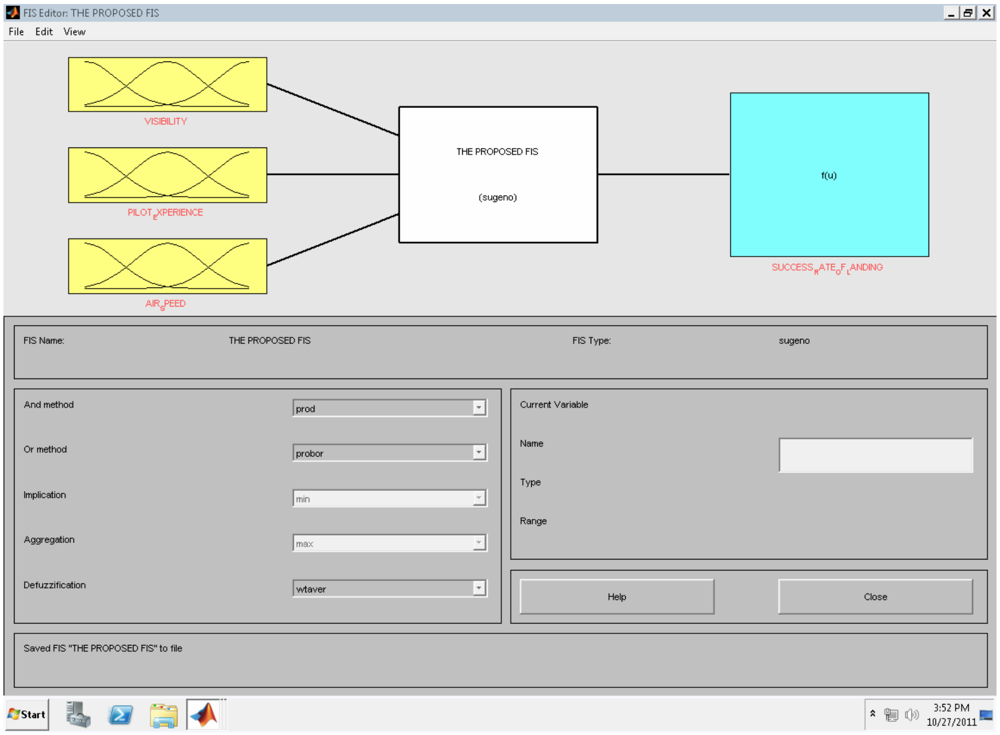

Figure-6. Fuzzy inference system model.

4. RESULTS AND DISCUSSIONS

Silulation results of the propsed ANFIS system are shown from Figure-7 to Figure-13. Figure-7, Figure-8 and Figure-9 are membership functions of visibility, pilot experience and air speed in the propsed fuzzy logic engine. They are triangular shaped membership functions.

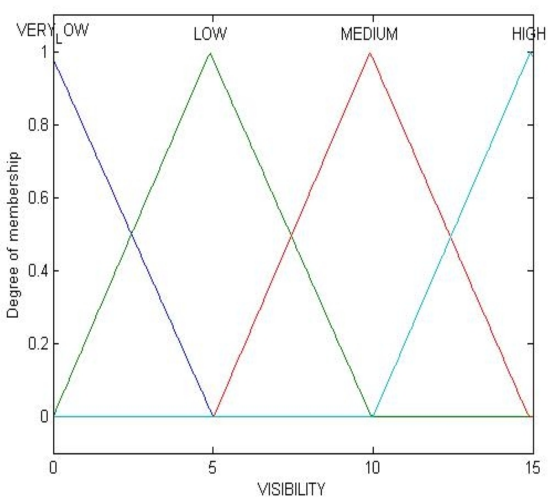

Figure-7. Visibility membership function.

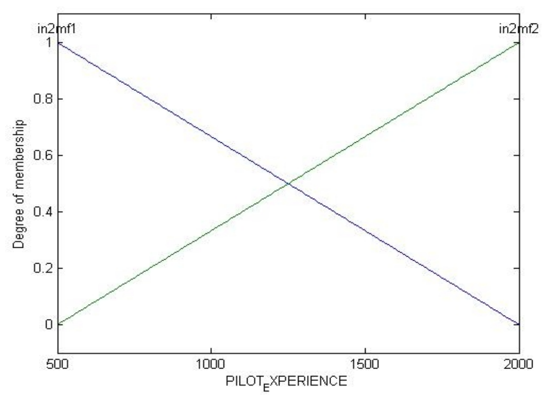

Figure-8. Pilot experience membership function.

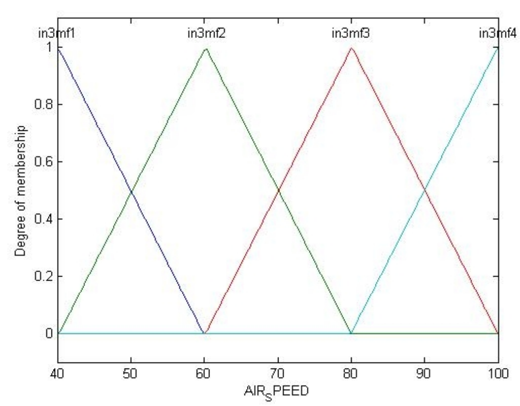

Figure-9. Air speed membership function.

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Figure-10 shows the Rule Viewer of the proposed fuzzy logic system. Each rule is a row of plots, and first column is the visibility, second column is the pilot experience and the third column is the air speed. The fourth column of plots shows the membership functions referenced by the consequent, or the then-part of each rule. This decision will depend on the input values for the system.

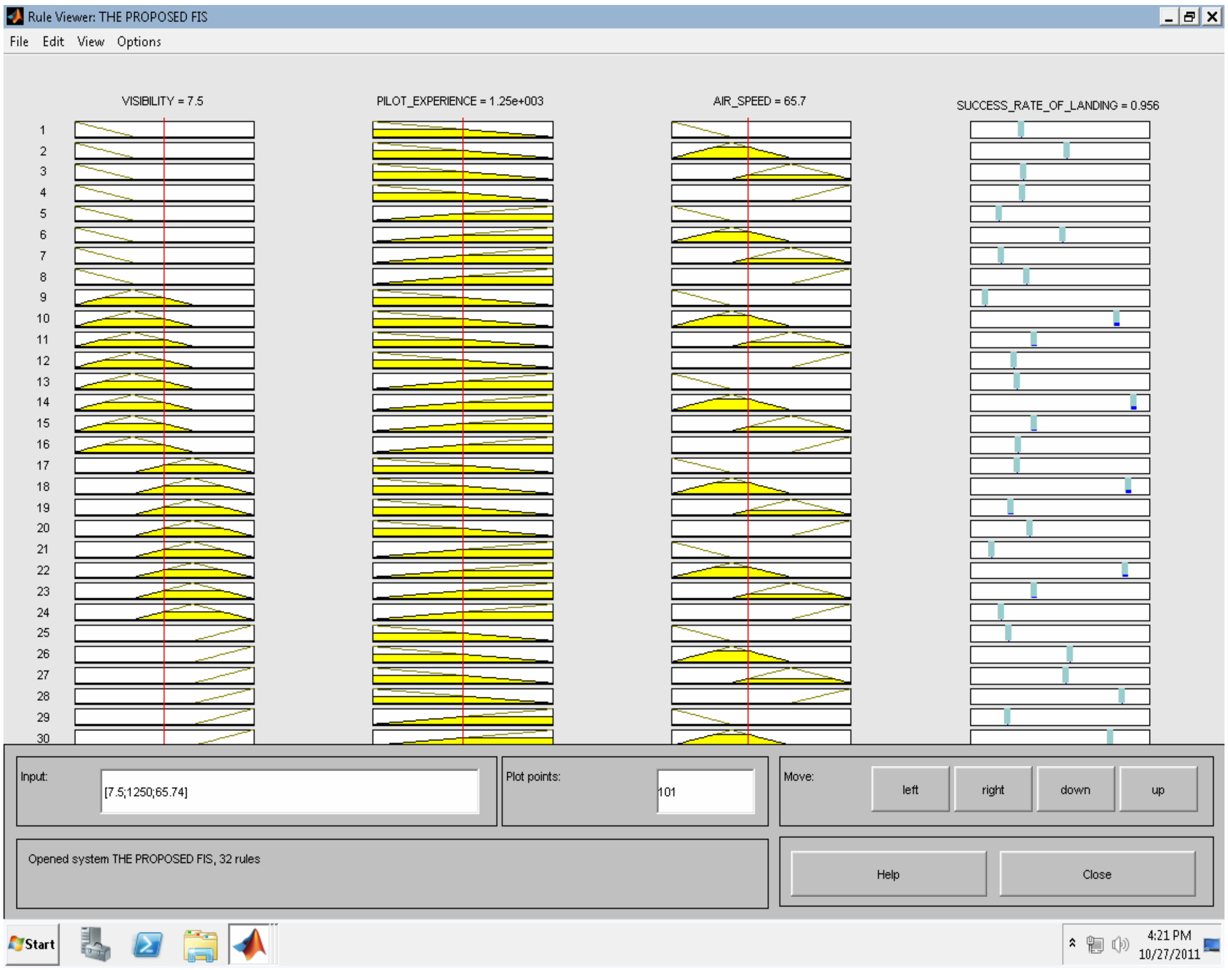

Figure-10. Rule formation for fuzzy model.

Figure-11 shows the surface view of the proposed FIS for visibility and pilot experience. This curve represents the mapping from visibility and pilot experience to success rate of landing. It shows the success rate of landing remains slightly steady high after the visibility is high enough.

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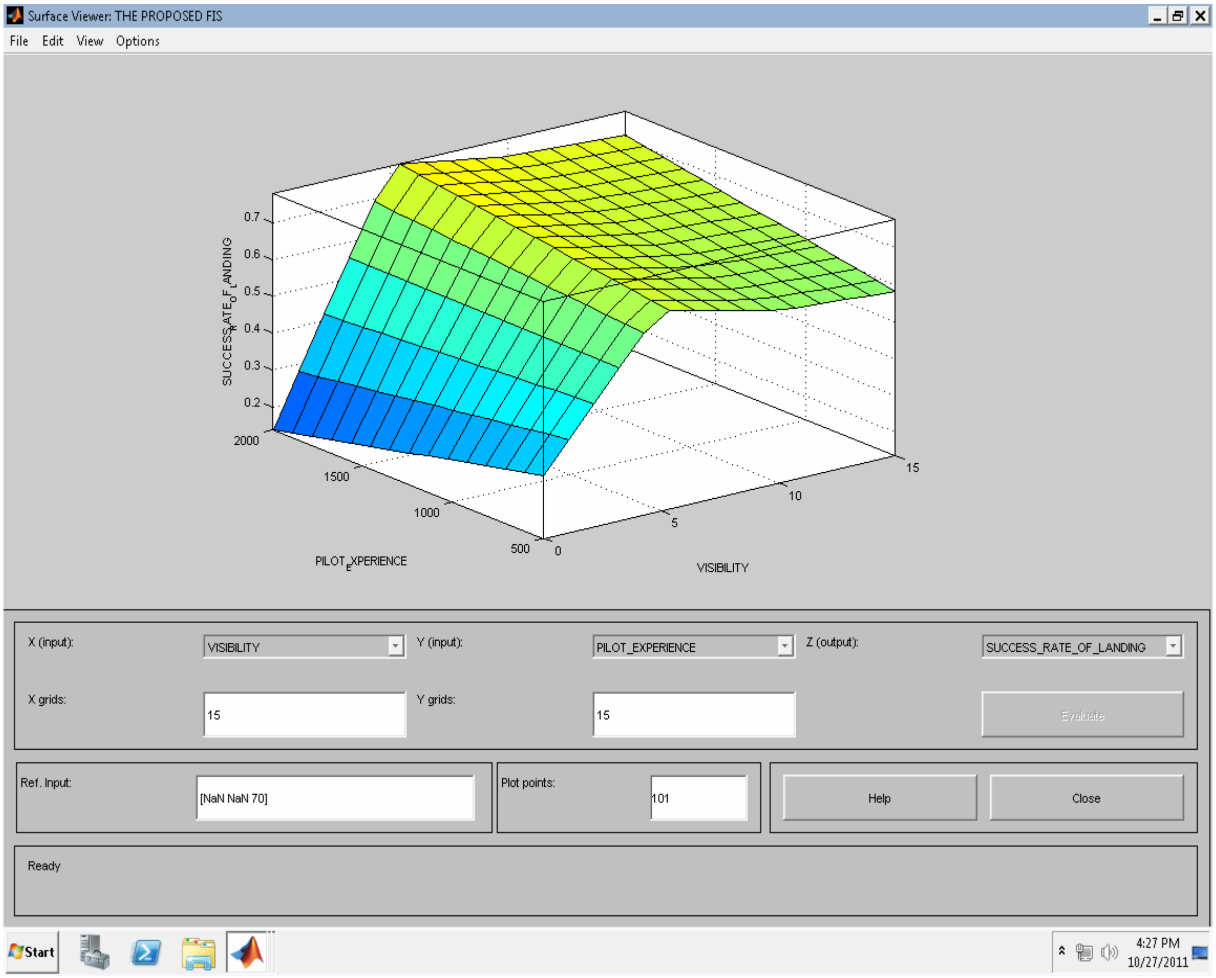

Figure-11. Visibility VS pilot experience surface plot.

Figure-12 shows the surface view of the proposed FIS for air speed and pilot experience. This curve represents the mapping from air speed and pilot experience to success rate of landing. This symmetrical surface shows that success rate of landing is more sensitive to the air speed.

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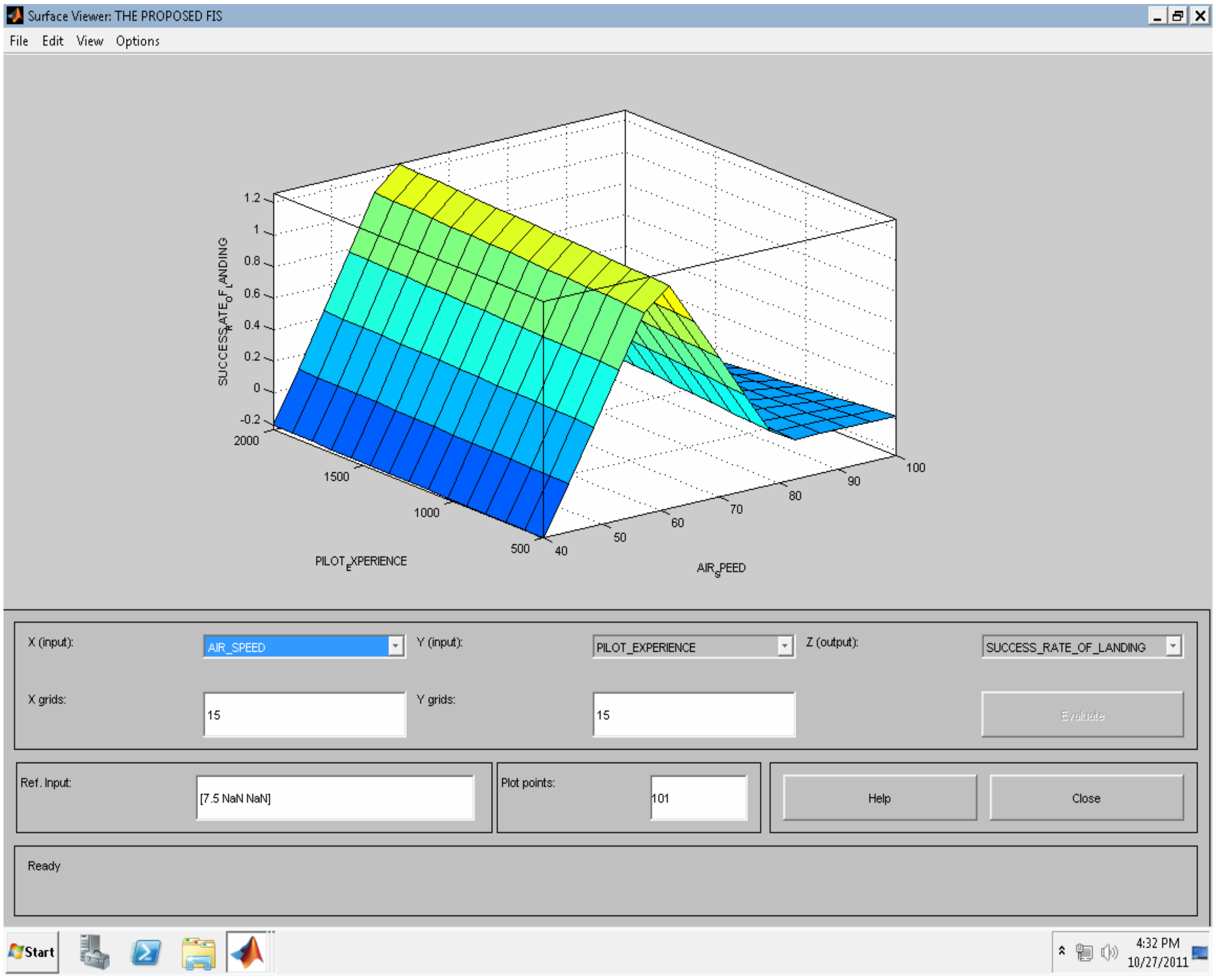

Figure-12. Air speed VS pilot experience surface plot.

Figure-13 shows the surface view of the proposed FIS for air speed and visibility. This curve represents the mapping from air speed and visibility to success rate of landing. This symmetrical surface also shows that the success rate of landing is more sensitive to the air speed.

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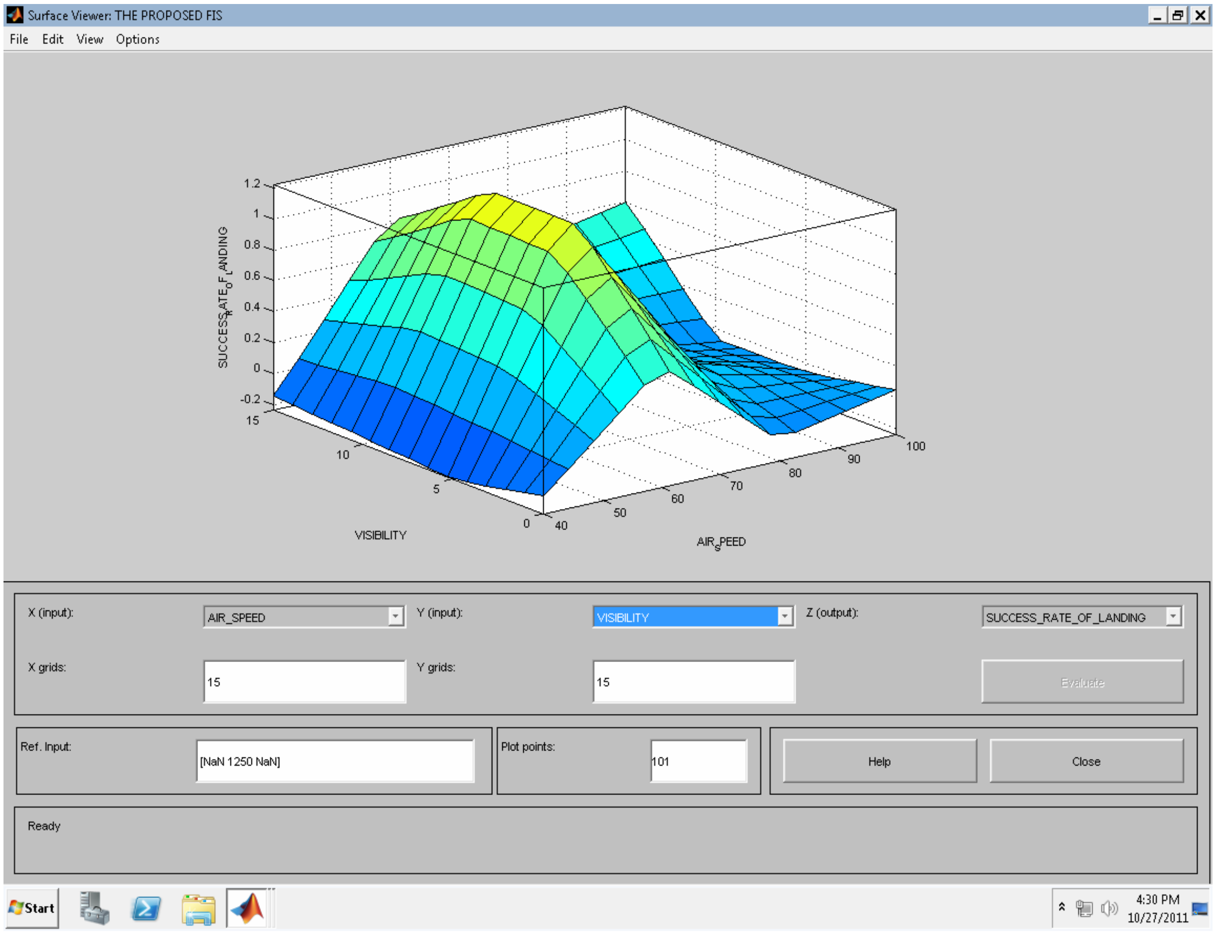

Figure-13. Air speed VS visibility surface plot.

In order to validate the proposed approach for the fuzzy inside instrument approach and landing several cased had been conducted based on simulated experimental data. Three inputs (visibility, pilot experience and airspeed) were used to provide the measurable inputs to the fuzzy system through the simulations. To evaluate the output of the proposed fuzzy logic system for a given input, 16 cases were evaluated. The following Table shows the results from fuzzy logic system were compared with the simulated results. The presented simulation results have confirmed the ability of the proposed fuzzy logic system to calculate the success rate of landing. By comparing the FIS results and the simulated results, it can be noticed that the proposed fuzzy engine is able to accurately calculate the success rate of landing under different cases.

Table-1. The FIS and Simulation Results.

Case #	Visibility	Pilot experience	Airspeed	FIS results	Simulated results
1	0	500	100	0.0035	0
2	1	500	90	0.0099	0
3	2	500	80	0.0121	0
4	3	500	77	0.0170	0
5	4	500	65	0.9588	1
6	5	500	62	0.9523	1
7	6	500	59	0.9347	1
8	7	500	48	0.0044	0
9	8	2000	66	0.9995	1
10	9	2000	59	09654	1
11	10	2000	56	0.9540	1
12	11	2000	53	0.8995	1
13	12	2000	49	0.0215	0
14	13	2000	46	0.0133	0
15	14	2000	43	0.0098	0
16	15	2000	40	0.0059	0

5. CONCLUSIONS

The current research has been carried out for developing a fuzzy logic engine to estimate the success rate of landing under the set conditions. By using a fuzzy inference system in the framework of an adaptive Neuro-Fuzzy Inference System (ANFIS), it provides a tool which makes the success rate of landing more accurate because by ANFIS fuzzy logic, it would be possible to estimate the fuzzy inference system parameters. The performance of the model with respect to the estimation made by evaluation and test data has been satisfactory.

It was also illustrated that the fuzzy logic engine is able to calculate the success rate of landing under the assigned inputs. It is also concluded the ANFIS technique could be used as a very accurate, reliable and fast method for calculation of the success rate of landing.

The methodology presented in this paper explored and combined two concepts: Fuzzy Logic and airplane instrument approach and landing where the uncertainty is very frequent. The proposed fuzzy engine can successfully calculate the success rate of landing based on different visibility, pilot experience and air speed.

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