final decision height range for landing. Weather such as micro blast, crosswind and poor visibility due to mist are the completely unpredicted situation. For these circumstances, maximum decision height is one of the variables for better and efficient landing.

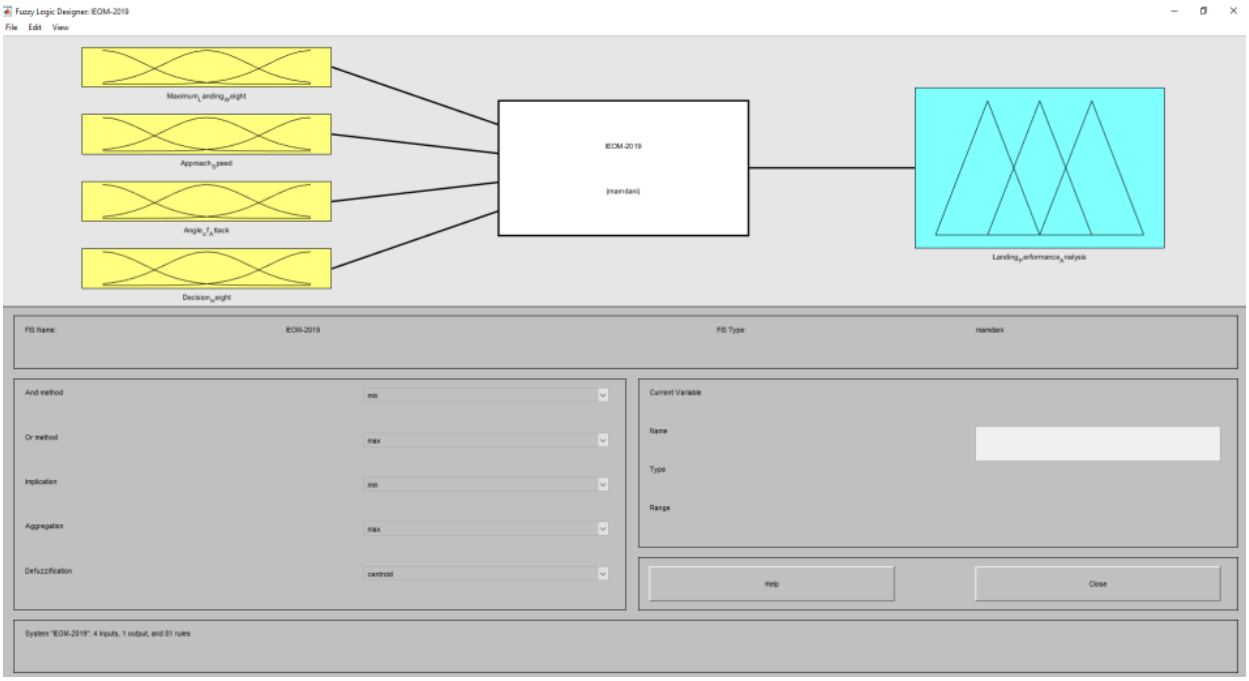


Figure 1. Fuzzy Inference Systems (FIS)

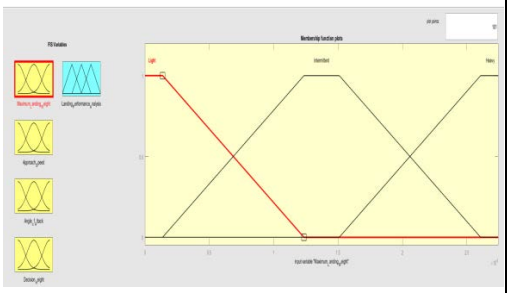
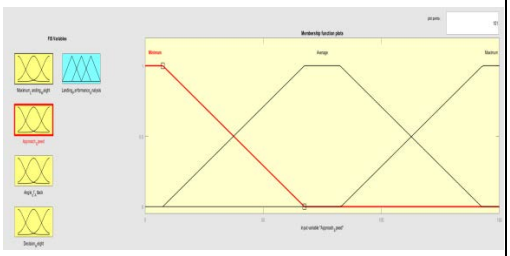
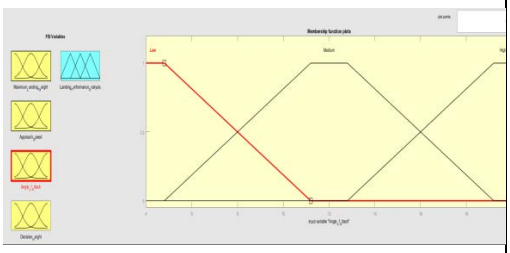
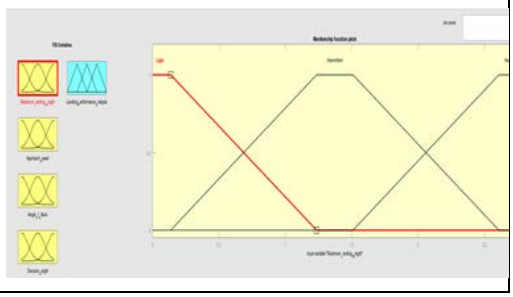
2. Membership Functions

Four variables are important for economical flight operation, such as maximum landing weight, air speed, angle of attack and decision height. In this Fuzzy Inference Systems (FIS), the variables are interpreted and implemented with help of 3 membership functions (Table-1). The natural language operates quality and inaccurate concepts, such as “altitude is high” or “air speedis high”. Those concepts are very difficult to translate into machine language without losing of their nature. For example, determine the angle of attack with the words: small, medium, large is more natural and simpler than the estimation in degree. Qualitative description is less precise and depends on the person describing it, based on inference rules where experts determine the criteria and principles of operation and design process of such systems. The inference options also influence the shape of the mapping between inputs and outputs. The most used inference method is max-min method. Where the minimum operator is used for determining the degree of fulfillment. Also, implication, and the maximum operator for rule aggregation. Fuzzy rules combine two or more input fuzzy sets called antecedent sets and associate with them an output, or consequent, set. The antecedent sets are combined by means of operators that are analogues to the usual logical conjunctions "and", "or", etc.(Roger Jang, 1997).

3. Fuzzy Systems Implementations

The inputs are described in Mamdani-type Fuzzy Inference System. The range of each input is mentioned accordingly and with respect to that the limits to the membership function are given. The rule base is determined through which outputs membership functions are enabled from the inputs and the values which are applied to them. According to the defuzzification method, a unique discrete value is computed for output (Abdel-fadil and Eid, 2015). The output result will show the aircraft landing performance efficiency analysis in percentage, which is a very realistic simulation of the actual typical aircraft landing evaluation (Pasieka, Grzesik and Kuźma, 2017).

Table 1. Membership Variables Range (Typical Value) (*Homepage | Bombardier Commercial Aircraft*, no date) Editor in Fuzzy Inference System

Variables	Units	Range	Membership Function Interface
Maximum Landing Weight	Kg	Light:0-12,350 Intermittent:1,372-26,070 Heavy:15,000-27,442	
Approach Speed	Knots	Minimum: 0-50 Average: 25-130 Maximum: 82-150	
Angle of Attack	Degrees	Low: 4-10 Medium: 5-19 High: 13-20	
Decision Height	Feet	Minimum: 0-450 Average: 50-950 High: 550-1000	

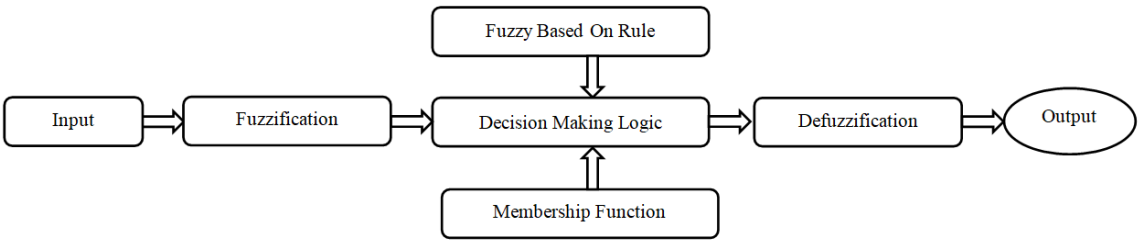


Figure 2. A Block Diagram of Fuzzy Implementation Process

4. Rule Editor

The flight operation description is complex for aircraft landing performance analysis. In general language, "decision height is high" or "airspeed" is low, which is very difficult to convert or translate into the machine language without misplacing their characteristics. As a result, any system description, the qualitative explanation is not precise and accurate. In these circumstances, FIS methodology interprets the qualitative data accurately. The Mamdani type FIS does not contain any crisp values form variables in the form of equations(Raj and Tattikota, 2013). Also, both in input and output, trapezoidal membership function is used because of its computational efficiency and reduced complexity. The range of each input data limit was mentioned in the membership functions accordingly. Subsequently, if-then rules were used for designing of this fuzzy logic controller(Juang, Lin and Chin, 2006). These FIS model contains in total 81 rules for 4 inputs each with 3 memberships function were applied. Finally, the landing performance was analyzed in terms of percentage.

Here, the following rule indicator indicates (Figure: 3) the interrelation between input variables with an output variable for a specific landing condition. Suppose, if aircraft landing weight is heavy, approach speed is minimum, angle of attack is low, decision height is minimum, in this case, landing efficiency result is poor.

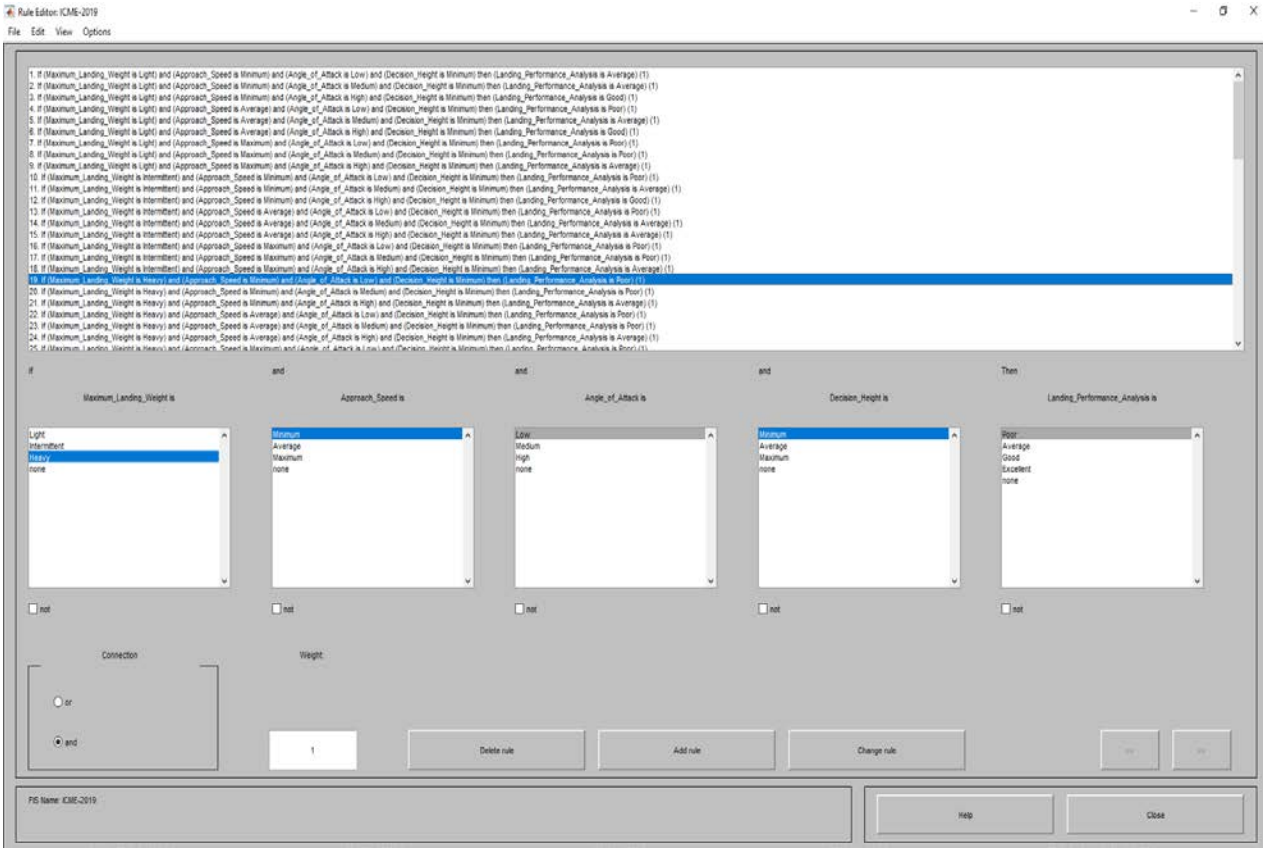


Figure 3. FIS Rule Editor for Aircraft landing Performances Analysis

5. Results

Generally, the following rule viewer (Figure: 4) is used to demonstrate the FIS model results. The two different colours indicate the input and output variable. At this point, the yellow column indicates the input and blue colour indicates the output variable by the help of rules. In this plot, the red line can slide the position and generate different output results. Finally, each rule of output can aggregate output and then defuzzified accordingly.

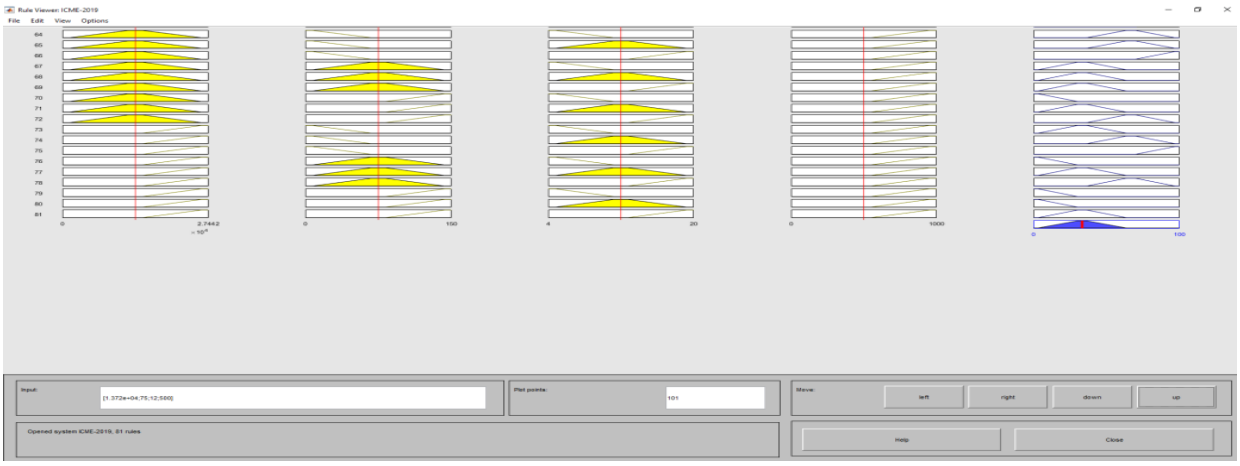
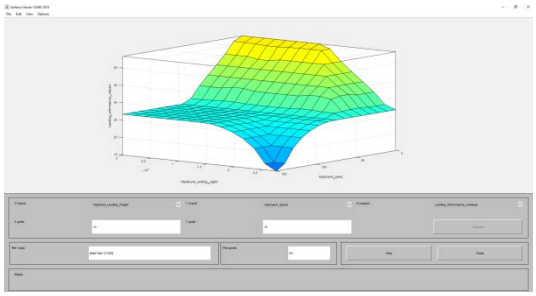
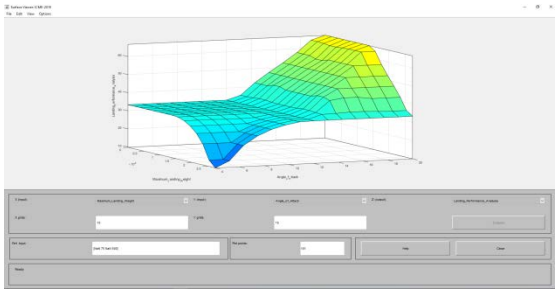


Figure 4. FIS Rule Viewer for Aircraft landing Performances Analysis

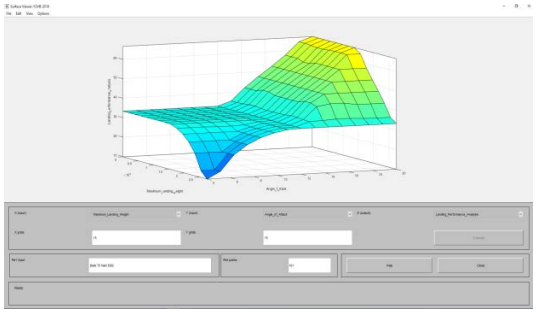
The following figures show different input-output surfaces:



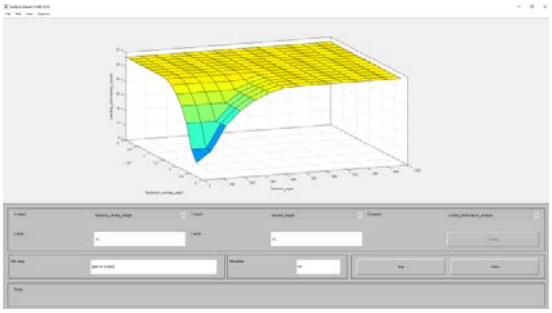
(a) Maximum Landing Weight and Approach Speed



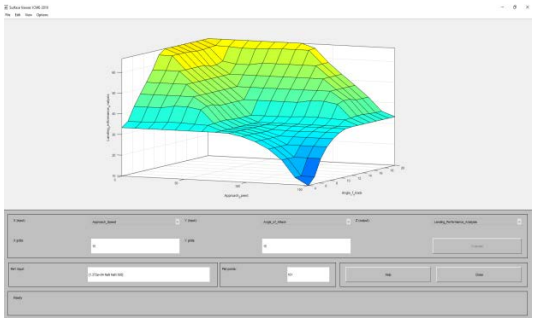
(b) Maximum Landing Weight and Angle of Attack



(c) Maximum Landing Weight and Angle of Attack



(d)Maximum Landing Weight and Decision Height



(e) Approach Speed and Angle of Attack

Figure 5. Different input-output surfaces

4. Conclusion

The typical aircraft landing performance realistic simulation can be determined from this study. On the basis of rule viewer analysis, aircraft designer can improve design factor in future aircraft manufacturing process. In addition with maintenance personnel can predict preventive maintenance on the basis of FIS logic performance result. Therefore, the airlines industry can implement frequently to enhance flight operation quality.

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