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THE FUZZY CONTROL OF A CAR'S GASOLINE CONSUMPTION*

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Abstract. *The process by which we obtain conclusions from existing data is called inference, meaning to deduce conclusions based on available knowledge.*

The complexity of the inference mechanisms in the context of fuzzy logic is of much higher complexity in the processes of inference which are effectuated by the calculation of classical logic sentences.

A fuzzy inference system involves changing the truth values corresponding to different assertions on the established system of rules.

Keywords: *fuzzy logic, fuzzy control, fuzzy inference, Mamdani and Sugeno inference system.*

1. INTRODUCTION

Fuzzy inference systems are systems based on fuzzy rules and are referenced to in terms of expert systems or fuzzy models. Inference systems formulate appropriate rules which are used in decision making. The main component of a fuzzy system is represented by all the rules which are built on inference processes that are ultimately support in decision making and taking any action.

The rule structure is generally simple, for example of type "if-Then", the complexity resulting from the use of operators" and "and" or ".

The fuzzy inference system accepts input variables fuzzy or crisp values and the result obtained is a fuzzy one.

The components of a system of fuzzy inference are fuzzification interface, a rule base, a database, a decision-making unit and finally a defuzzification interface.

A fuzzy inference system consists of 5 functional blocks. These blocks have the following functions:

- a rule base -contains a set of fuzzy rules of IF-THEN type;
- a database- defines the membership functions corresponding to a set fuzzy used in fuzzy rules;
-a decision-making unit which performs the inference operations on the rules;
-a fuzzification interface: which transforms the crisp inputs into degrees of match with linguistic values;

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-a defuzzification interface: which transforms the fuzzy results of the inference into a crisp data.

The working mode of a fuzzy inference system is: input crisp values are converted into a fuzzy variable using a fuzzy-making method.

The combined rule base and the database is usually referred to as the term knowledge base. The process of defuzzification generates crisp data on fuzzy values resulting from corresponding processing applied.

A fuzzy inferential process steps are:

1) fuzzification represents the comparison fuzzy input variables with the membership function corresponding to each linguistic label;

2) combining(using an operator-specific t-norm, usually the product or min) the belonging values to obtain the weight of each rule;

3) generating the system of weights corresponding to the rules in the rule base, based on degrees of membership using a t-norm operator default;

4) defuzzification: generating a result expressed on a crisp type datum. The result produced has the significance of conclusion or decision relating to the particular considered problem.

2. FUZZY INFERENCE METHODS

The most commonly used fuzzy inference methods have been introduced by Mamdani and Sugeno.

The steps necessary to build a Mamdani inference system are:

1) Determine a set of fuzzy rules;

2) Fuzzifying the inputs using the input membership functions;

3) Determine the intensity level corresponding to each fuzzy rules based on fuzzy entries and rules of rule base;

4) Identify the conclusion type parts for each rule by inter-combining the degree of intensity corresponding to the rules with output membership function;

5) Combining the conclusions of the previous step and derive an output distribution;

6) Defuzzifying distribution resulting if the output is wanted on a crisp value.

Fuzzy rules are expressed in terms of linguistic labels designating vague concept (e.g. large, small, very large etc.) and their possible significance is of the decision or conclusion in the context described by the system of labels that refer to language.

The general form of fuzzy rules is the following:

If ($x \in A, \mu_A(x)$) and/or ($y \in B, \mu_B(x)$)and/or...then($y_n \in B, \mu_{B_n}(x)$).

Example: If the temperature is high, humidity is also high when the room is warm.

According to the example, we must have membership functions that define high temperature (input 1), high humidity (input 2) and a warm room (output 1). The process that is regarded as a temperature input and processed by the membership function to determine how large it is, is called decision-making.

Identifying the consequence component of a fuzzy rule is made in the following way:
a) an assessment of intensity level corresponding to fuzzy rules is performed by applying fuzzy operators to fuzzied entries. For example: "AND" operator is used to combine membership functions that make up power rule.
b) clipping the output membership function at the rule strength.

The defuzzification process can be accomplished in several ways, the most frequently used methods are:

a) Method based on centroids which generates a crisp value:

$$z = \frac{\sum_{j=1}^{q} Z_j u_c(Z_j)}{\sum_{j=1}^{q} u_c(Z_j)}$$

b) Method based on average maximum values, where the crisp value is calculated by the expression:

$$z = \sum_{j=1}^{l} \frac{z_j}{l}$$

Mamdani inference system uses the operator "AND" for inter-combining input values in order to establish the degree of intensity. The inter-combining of two rules is made by the operator "OR".

A typical rule of Sugeno type inference system has the structure:

If x is A and Y is B then z = f(x,y), where A and B are fuzzy sets and z = f(x, y) it is a function f: [0,1] x [0,1]]→R. When f(x, y) is a first-order polynomial we have the first-order Sugeno fuzzy model. When f is constant, we then have zero-order Sugeno fuzzy model, which can be viewed either as a special case of the Mandami FIS where each rule's consequent is specified by a fuzzy singleton.

Building the rules and database components of a Sugeno system is accomplished in a manner similar to Mamdani model construction.

An example of the Sugeno system rule is:

If the input l = x AND 2 = y Then output is z = ax + by + c.

For the zero-order model of Sugeno type, the result z is constant (a = b = 0). Z_i level of intensity of each rule is weighted w_i corresponding to the rule.

For example: the rule AND with Input l = x and Input 2=y, the firing strength is:

w_i = AND (F_1(x), F_2(y)), where F_1 and F_2 are the membership functions for inputs 1 and 2.

The final result is obtained as the average weighted results rules $= \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i}$

3. COMPARISON OF THE METHODS INTRODUCED BY SUGENO AND MAMDANI

The main difference between Mamdani and Sugeno systems is that the Sugeno model membership functions are linear or constant. Also, because the fuzzy rules conclusions and their aggregation way are different, the procedures of unfuzzy for the two systems differ significantly.

For the Sugeno model, fuzzy sets number as well as fuzzy rules number, depend on the number and locations of extremes whose function approximation is intentional.

In terms of complexity and efficiency is found that if Sugeno model allows a low computational complexity, it allows achieving better performance on linear techniques and provides good results in function approximation.

4. EXPERIMENTAL RESULTS

The purpose of the application is to establish the correlation between the gasoline consumption and the weight of the vehicle versus the distance covered. During the test there are used the input linguistic variables: the gasoline quantity in the tank and the weight of the vehicle. The domain of variable values for the gasoline quantity is comprised within the real domain 0-55 l, and the weight of the vehicle is a real variable within the range of 1425 and 1870 kg.

The output variable is the distance, the domain of values is real and it represents the distance which can be covered depending on the input variables taken into consideration.

The fuzzification is realised by calculating the membership functions and the un-fuzzy process by the method of the centre of gravity. While making the application there has been used the Mamdani implication and the inter-combining of the rules is done using the Max operator.

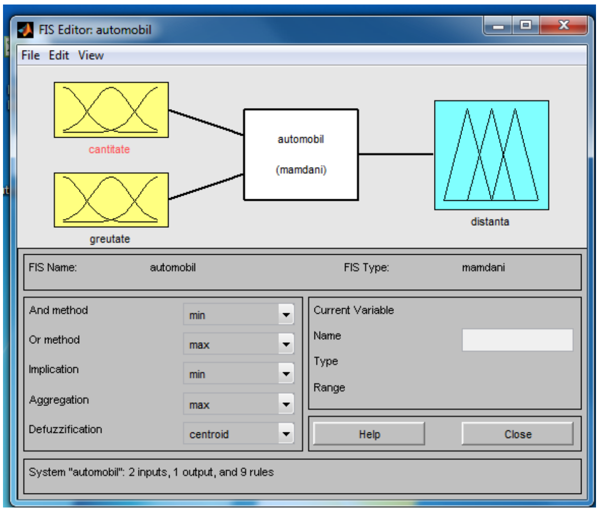

Fig. 1. correlation between the gasoline consumption and the weight of the vehicle versus the distance covered.

The linguistic values corresponding to the variables are {small, medium, large}, and the inference rules are:

If (quantity is small) and (weight is small) than (distance is small)
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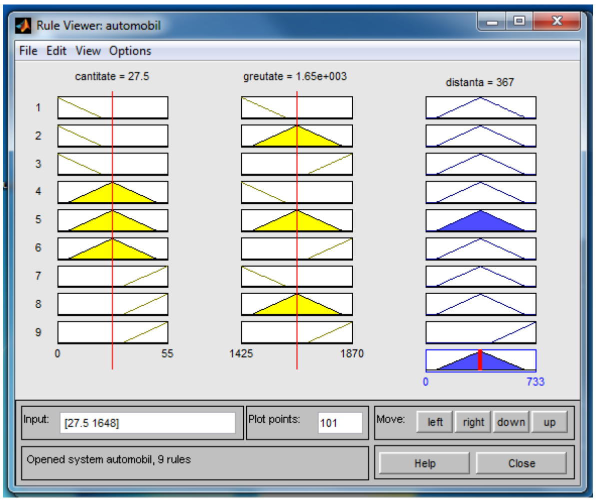

Fig. 2. The linguistic values corresponding to the variables.

The tests are made upon the Mamdani model; the results are visualized in Fig. 3.

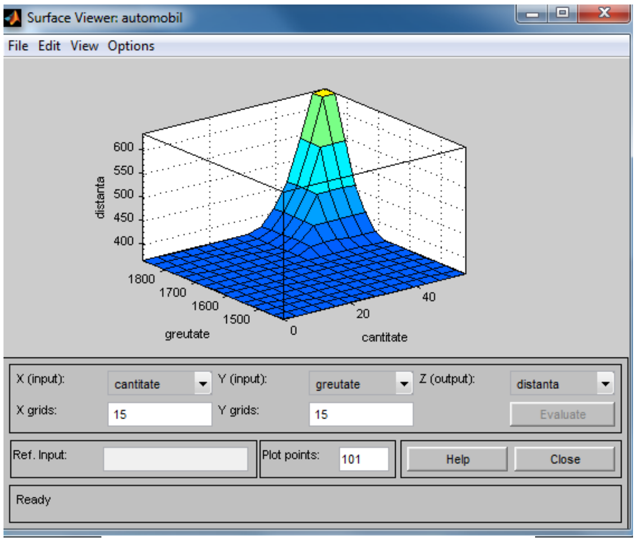

Fig. 3. The results of Mamdani model.

5. CONCLUSION

In the paper there are presented basic elements in moulding the fuzzy control. There have been taken into consideration the Madami and Sugeno models, the application presented at the end of the paper represents a case study upon the Madami model.

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