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THE TUNING OF THE FUZZY CONTROLLERS USED IN THE PERVASIVE SYSTEMS

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Abstract: This paper intends to present the differences appearing between the pervasive systems and other usual systems regarding the tuning of the fuzzy controllers. For the pervasive systems used in the intelligent buildings, the emphasize is on the building's occupant and the used equipment is to be engineered so that the occupant will be as less perturbed by its presence or settings. For the fuzzy controllers used in non-pervasive systems – although the occupants are not working with physical quantities, but with language described variables, the definition of the inputs' and outputs' domain values can be modified only by reprogramming.
The result generated by the research work that lays at the basis of the present paper is the tuning of the fuzzy controllers used in pervasive systems. The occupants role is to describe the sensation they have in the very moment, the sensation they would like to have, and the fuzzy controllers' inputs and outputs will be automatically modified based on different parameters regarding the occupants, for example the clothes worn.
The tuning of the fuzzy controllers for the pervasive systems has not been treated before, the authors intending to make a detailed and deep research in this field.

Keywords: artificial intelligence; comfort; fuzzy logic; predicted mean vote

1. Introduction

One finds the first description of the pervasive systems in The Computer of the Twenty-First Century [1]: „The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it. "This definition is focusing on the human subject and on the technologies that are to be created in order to fit so well his lifestyle, that it is not necessary any more for the user to be aware of the equipments' presence. The usage of the physical values, of the programming languages, the unpleasant look of the equipments, the inadequate setting of these are only a few of the features that were present in the prior, classic systems and that can be disturbing for the users.

According to Pervasive Computing: Trends and Impacts [2], the main characteristics such a system has to achieve are the following: mobility, incorporability, the realisation of the ad-hoc networks, context-sensibility, energetic independence and autonomy. The authors deem that the most important of these is the context-sensibility. The opinions regarding the definition of the context are different from an author to another. A discussion regarding the definition that has been chosen for the context concept can be found in O incursiune în lumea sistemelor pervasive [3], the context being presented as a tetra-dimensional space, composed of the calculus context, the physical context, the temporal context and the user's context.

Starting from the idea of context-sensibility and from the fact the human being is the most important element of the pervasive system, the existing equipments are being adapted in order to be used in the pervasive systems. In this paper, the authors will describe their conception regarding the modifying of a fuzzy controller in order to be usable in a pervasive system.

2. The need of a different tuning modality when the fuzzy controllers are used in pervasive systems

According to Inteligență artificială în instalații. Logica fuzzy și teoria posibilităților [4], while using the fuzzy controller, all the information about the controlled process are described based on linguistic variables. A linguistic variable is a (V, X, Tv) triplet, where V is a variable, by example the temperature or the humidity, defined on a reference set X, its value being any of the elements of X, Tv is a finite or infinite set of fuzzy subsets of X, which is used to define V.

In Contribuții la implementarea inteligenței artificiale în determinarea confortului global din clădirile inteligente [5], the author of the doctoral thesis considers that the occupiers are the best sensors and due to this fact, they are to be introduced in the regulating loop of the intelligent buildings' equipments. As it is about pervasive systems, we do consider that the occupiers can and should be introduced in the regulating loop, but this has to be made in a way that is the least disturbing for them.

The use of a fuzzy controller supposes the use of linguistic variables, so that the users will not be forced to use physical values in order to express their preferences, the language used for programming the equipments being much closer to the human language of expression. Nevertheless, when a fuzzy controller is programmed, it has some inputs and outputs already defined, their redefinition being possible only by a new programming of the controller. In order to assure the context-sensibility, we consider that the inputs and outputs of a fuzzy controller are to be changeable even in a more easy way.

By example, when an occupier considers that in a certain room it is cold, this sensation depends on a lot of parameters and it also depends on the person of the occupier and we do not consider that replacing the physical values used until now with a perception regarding the cold-sensation – valid for all the users – would be a correct approach for the pervasive systems.

3. The tuning of a fuzzy controller used in a pervasive system for setting the speed of the air drifts in a room

We consider that – after the temperature – the speed of the air drifts is one of the most important parameter for the occupiers of a room, having a great importance for the comfort in the respective room. The choice has been the realisation of a fuzzy controller for tuning the speed of the air drifts instead of the realisation of a fuzzy controller for the tuning of the temperature because regarding this parameter there have been completed only a few studies, although when introducing the occupiers in the regulating loop this parameter is possible to be used in order to attain and maintain the comfort in the respective room. It is well-known that in an installation there is not a single parameter to be tuned. As the system also includes human beings, who might be disturbed by the necessity to introduce again and again data in the system, in a first step we decided to modify a single parameter, maintaining the other parameters at constant values.

As input values in the fuzzy controller we have chosen the current sensation regarding the air drifts and the desired sensation regarding this air drifts, the users expressing their preferences in this regard. The controller's output value is the air drifts speed relative to the human body.

The membership functions for the fuzzy controller's input values are described by the following trapezium functions:

$$\begin{aligned} &\textit{strong air drift } (-3; -3; -1; -0{,}7);\\ &\textit{weak air drift } (-1{,}5; -1; -0{,}7; 0);\\ &\textit{neutral } (-0{,}7; -0{,}7; +0{,}7; +0{,}7);\\ &\textit{a slight lack of air drift } (0; +0{,}7; +1; +1{,}5);\\ &\textit{a great lack of air drift } (+0{,}7; +1; +3; +3). \end{aligned} \tag{1}$$

The membership functions for the fuzzy controller's output value are described by the following triangle functions:

o1: the speed is of 0,1 m/s (0; 0,1; 0,2);
o2: the speed is of 0,2 m/s (0,1; 0,2; 0,3);
o3: the speed is of 0,4 m/s (0,2; 0,4; 0,6);
o4: the speed is of 0,6 m/s (0,4; 0,6; 0,8);
o5: the speed is of 0,8 m/s (0,6; 0,8; 1). (2)

Both for defining the inputs and for defining the outputs of the fuzzy controller there has been used the data from [6], the inputs and outputs being defined in order to permit the easiest comparison with these data. Figures 1-6 present the implementation of the fuzzy controller in Matlab.

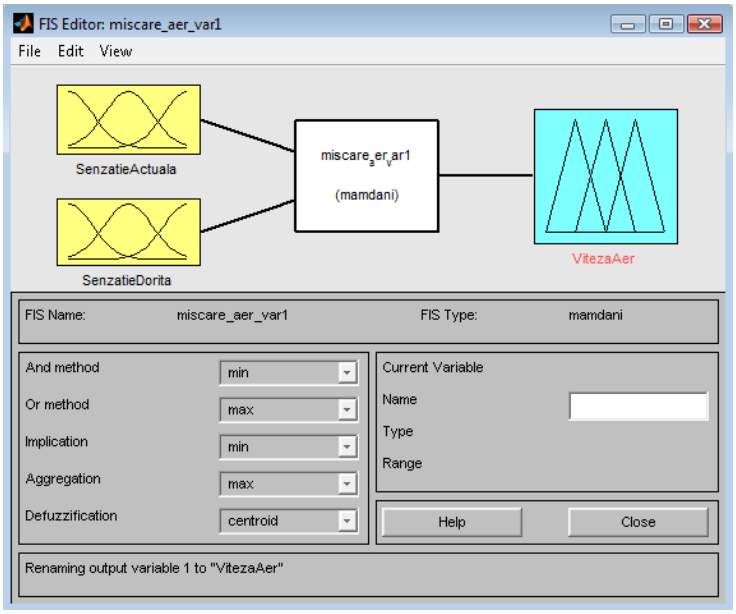

Fig.1 - The fuzzy controller implemented in MATLAB

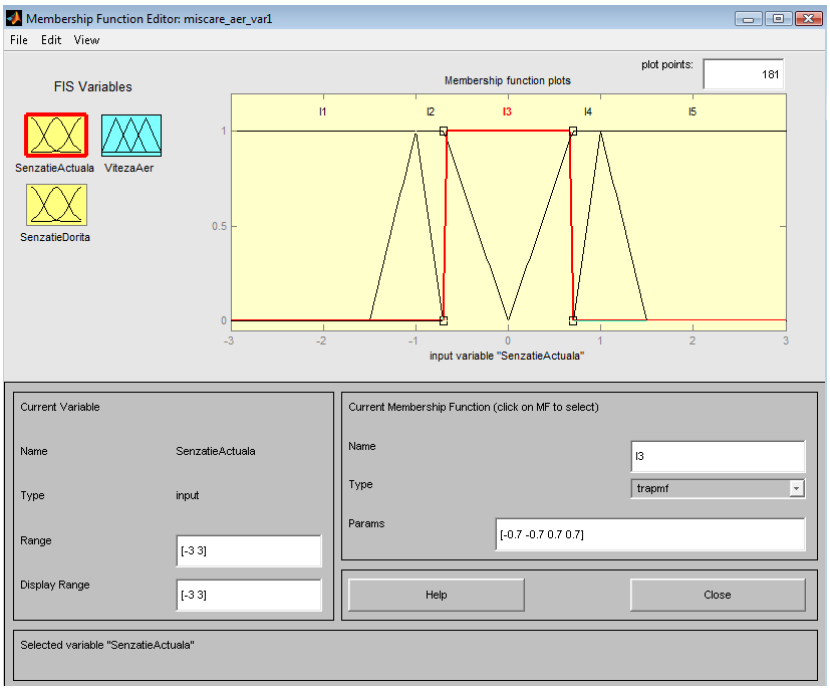

Fig. 2 - The definition of the membership functions for CurrentSensation and DesiredSensation

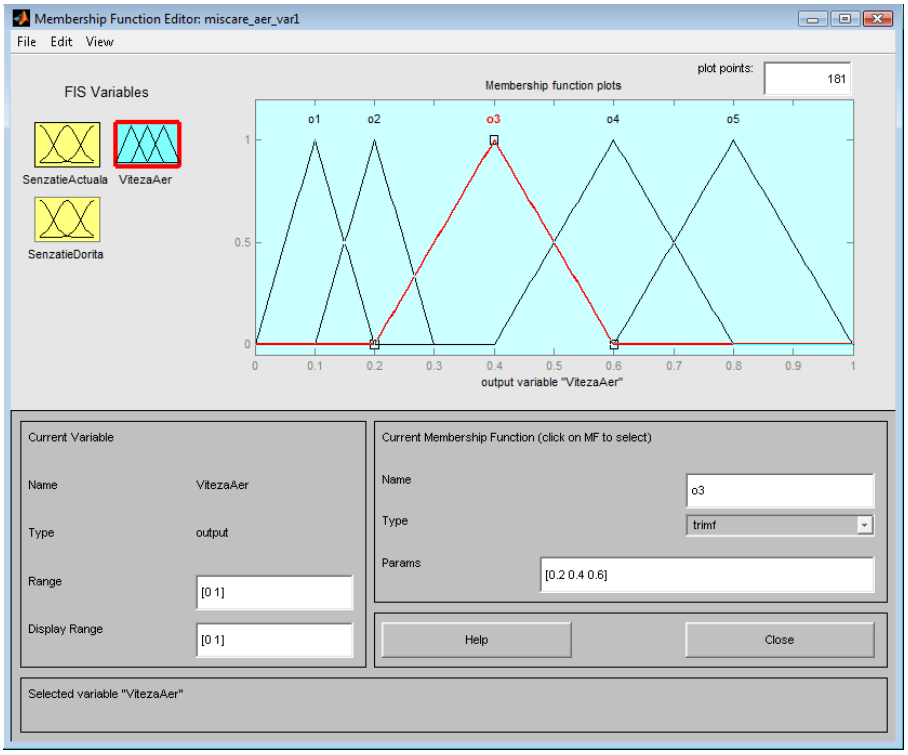

Fig. 3 - The definition of the fuzzy membership functions for the output value

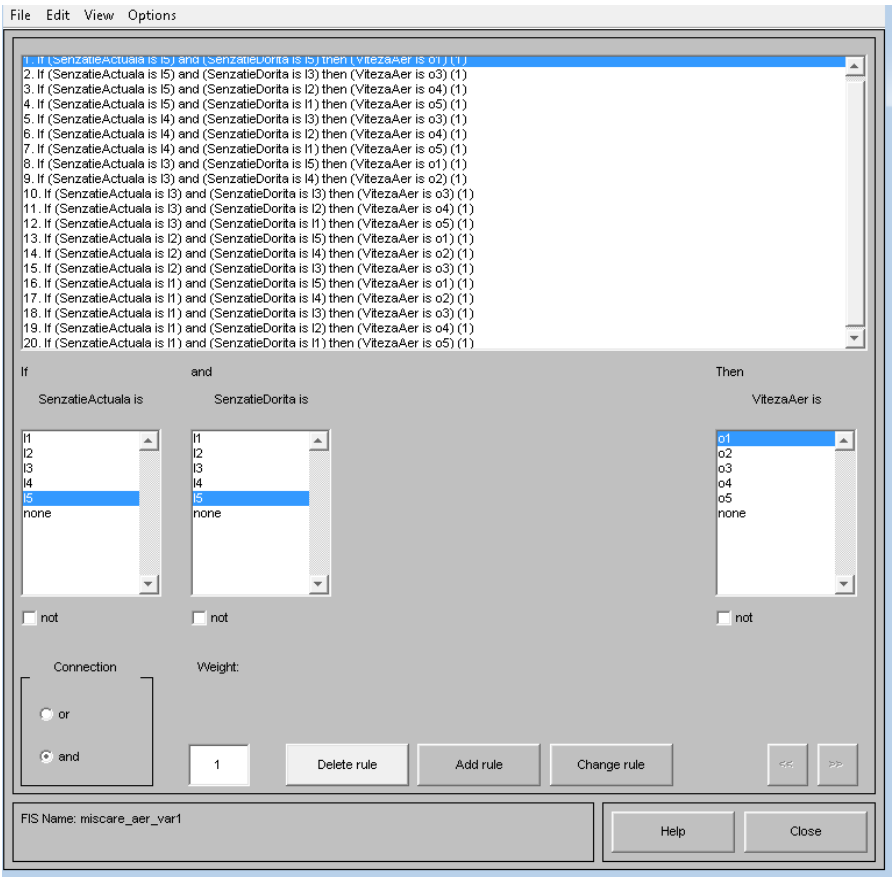

Fig. 4 - The fuzzy rule-editor with the used rules. Totally 20 rules have been defined.

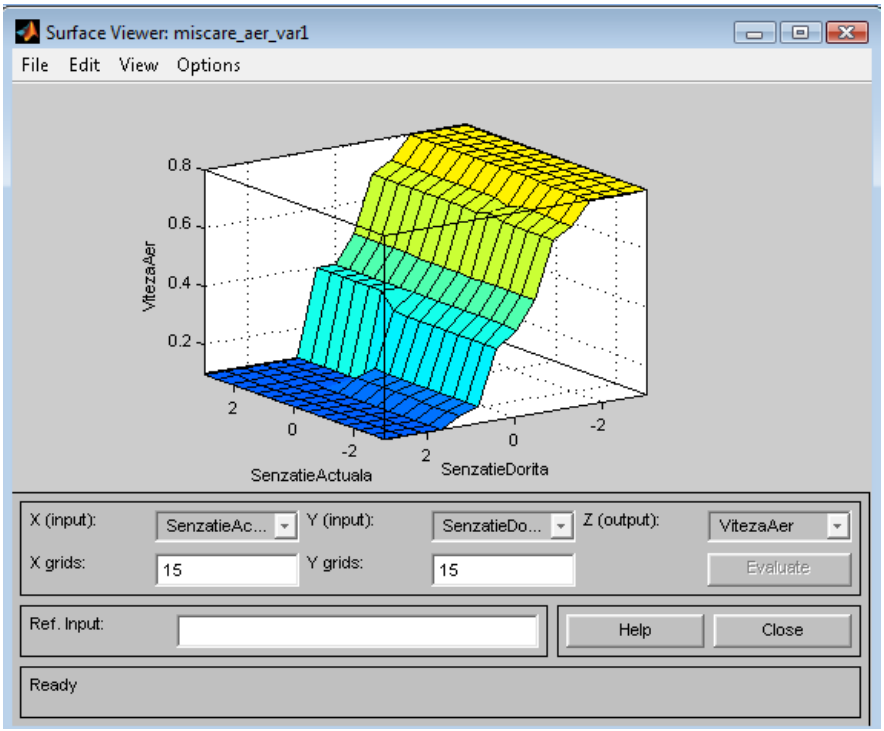

Fig. 5 - The surface of the fuzzy rules

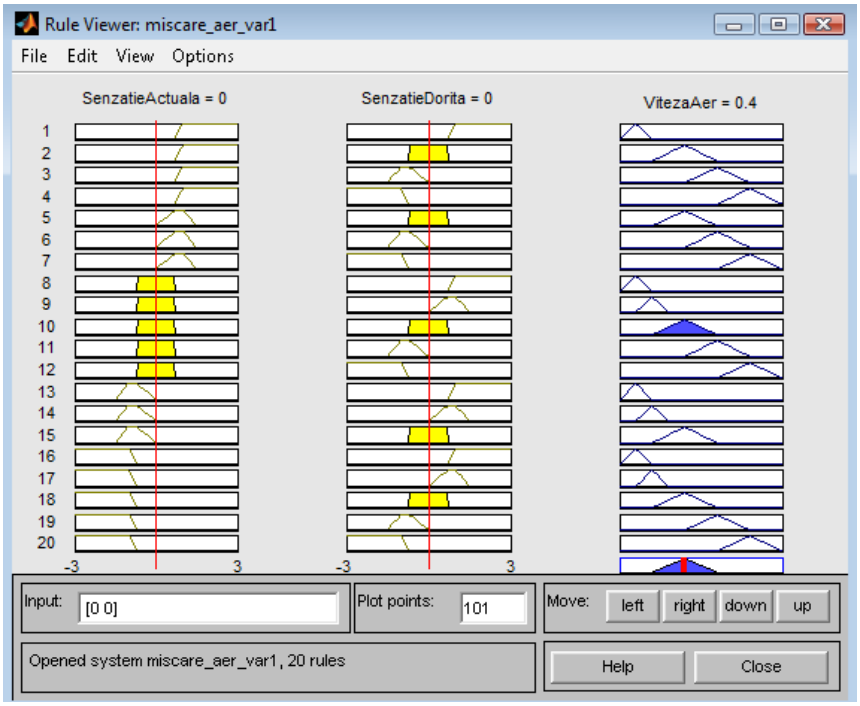

Fig. 6 - The visualisation of the fizzy rules

Compared to the non-pervasive systems, we consider that a fuzzy controller is tuned if after introducing all the required parameters and waiting for 10 minutes, the occupier will not need to do a new tuning in the next 30 minutes. These time intervals can be modified if the experiences prove that they are not adequate, this being only the first study regarding the tuning of the fuzzy controllers used in pervasive systems.

In order to tune a controller used in a pervasive system easier, a PMV (Predicted Mean Vote) will be used ([6]). The PMV is dependent on the clothes worn by the occupier, on the metabolic rate, on the activity carried on, on the air temperature, on the average radiant temperature, on the relative air drift and on the relative humidity. As this controller is dealing only with the regulation of the air drifts' speed, the other parameters will be introduced according to Appendix

E from [6], so that the neutral sensation's output is correspondent to that air drift speed which is the closest to the 0 value of the PMV.

By example, for an activity level of 46,4 W/m^2, for the clothes worn 1 clo, the temperature of 27^{o}C and the speed of 0,3 m/s, according to Appendix E from [6] we have PMV=0,01. Such, we are looking for a controller which has at the output a value of 0,3 m/s for the neutral sensation. This is a preliminary tuning, that will then adapted for each person.

How will the above designed controller be modified? Its outputs will be modified as following: for o3 the mean value will be of 0,3 m/s, and the other values will be modified proportionally.

o1: the speed is of 0,075 m/s (0; 0,075; 0,15);
o2: the speed is of 0,15 m/s (0,075; 0,15; 0,225);
o3: the speed is of 0,3 m/s (0,15; 0,3; 0,53); (3)
o4: the speed is of 0,53 m/s (0,3; 0,53; 0,76);
o5: the speed is of 0,76 m/s (0,53; 0,76; 1).

For an activity level of 46,4 W/m^2, for worn clothes of 1 clo, for the temperature of 27 ^{o}C, the air dirfts' speed of 0,3 m/s and a PMV=0,01, we consider that an adequate tuning algorithm is the following:

1. The introduction in the program of the values regarding the activity level, the worn clothes and the temperature.
2. The modification of the controllers' outputs according to the above example.
3. After ten minutes the occupier is asked whether he is satisfied with the situation or not. If yes and if in the following 30 minutes the occupier does not want a new change, it means that the controller is tuned for these values. If a new setting is required, this will be performed and these steps will be repeated until the occupier is satisfied. The value of the air drifts' speed that triggers the occupier's satisfaction will be used to modify the outputs.
4. The controller's outputs will be again modified according to the values determined at the former step.

4. Conclusions

As the tuning of the fuzzy controllers used in the pervasive systems has not been studied before, this topic requires a thorough and attentive research in order to find a method that will be accepted by most of the pervasive systems' experts. Being a new subject, even the meaning of the tuning of the controllers in the pervasive systems may be different from an author to another.

The authors of this paper do consider that the tuning of the fuzzy controllers of the pervasive systems is an interesting topic because in a pervasive system the most important element is the human subject, the entire system being designed as to be the least disturbing for him.

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