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Introducing Freedom Space and Wordifier in CW Systems

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ABSTRACT

This paper investigates the fuzzy systems in point of view of computing with words (CW) and introduces the concept of freedom space and wordifier. It is discussed that if present fuzzy systems compatible with CW or not. If not, what are the deficiencies? The solutions are investigated while introducing the concepts of “freedom space” and “worifier” and their roll in CW systems.A novel fuzzification model also is introduced which is more compatible with computing with words than traditional fuzzification models.

KEY WORDS: Computing with words, Fuzzy systems, Wordifier, Freedom space.

1- INTRODUCTION

The only difference between an on-off system and a simple fuzzy system is the application of verbal expressions such as "little" and "a lot" in distinct input and outputs (as described in figure 1). This is where fuzzy logic separates from classic systems, even though this is not fully in line with the historical development of fuzzy systems. What has been presented here is a review of fuzzy logic applications starting with Zadeh's [1] introduction of fuzzy sets. In order to describe fuzzy systems, we will first consider a classic, on-off control – as depicted in Figure 1 which has taken fuzzy shape by describing verbal constraints and applying them to the system's descriptive rules without changing the system's structure. There is no question that the main distinction between fuzzy and classic systems lies in the use of verbal expressions rather than the use of the fuzzy sets. Fuzzy sets are clearly a means for modeling these verbal expressions. Having described a system through verbal expressions, we can now discuss calculations with words. Instead of "calculations with words", we had better use the term "calculations with quantities described by verbal constraints" – a clear counterpart to calculations with numerical quantities. Our use of the term "calculations by means of words" instead of "calculations using quantities described by verbal constraints" is merely for the sake of brevity; otherwise, we would be exaggerating or causing ambiguities in the reader's mind. In any case, regardless of the historical development of the presentation of calculations with words and their relevance to fuzzy sets, the issue of calculations with words generally must precede the relevant fuzzy theories and sets, which provide means for modeling words.

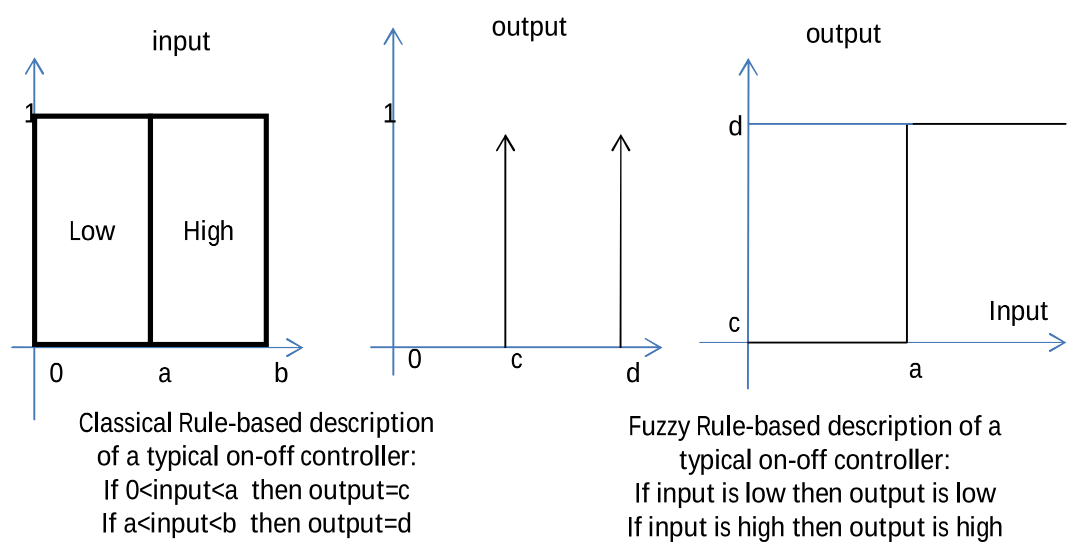

Figure 1: A sample of on-off controller described with fuzzy controller concept

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2- The concept of "wordifier"

A comprehensive look at all of the industrial and non-industrial domains where fuzzy theories and sets have been used from 1965 through 2012 [3 up to 13], we will realize that the development, generalization and use of fuzzy theories have either not been confined to calculations with words or not wholly inclined toward calculations with words.

The time has come for fuzzy systems to ramify into more specialized sub-branches, each with its own specific, defined framework. A fairly detailed discussion of verbal calculation has been presented in [2]; there is no final consensus, however, on the issue being resulted by the nature of the subject and the lack of considerable progress and insufficient evidence for it. In any case, the writers of this article – alongside other issues dealt with in this research – agree with some of the items discussed in [2], whereas they challenge some of the others.

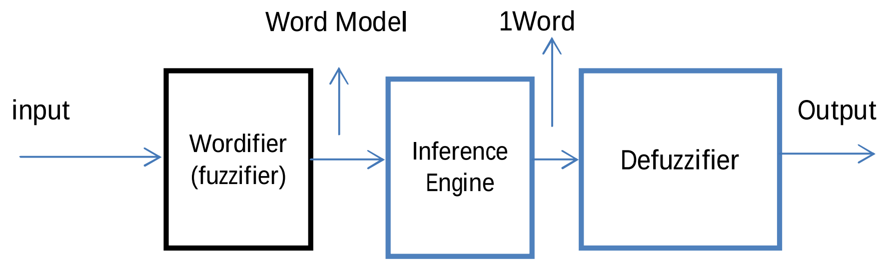


Figure 2: A fuzzy system, three main stages with emphasize on computing with words

Since it is not possible to find verbal interpretations for all defuzzification methods, we will focus upon verbal calculations as an independent branch here. Furthermore, among the issues studied in fuzzy domains, only a part fall into pure verbal calculations. The main characteristic of verbal calculations is that all mapping, decomposition, combination and analysis need to be based upon the concepts of quantities described verbally. The second characteristic requires the reasoning method and the type of output created to follow human reasoning behaviors. Projects which, in spite of being described by means of fuzzy sets, still lack appropriate verbal interpretations in all parts or clearly involve pure numerical calculations without the preliminary use of verbal quantities cannot fall into the framework of verbal calculations – even though they can still be regarded as part of fuzzy sets.

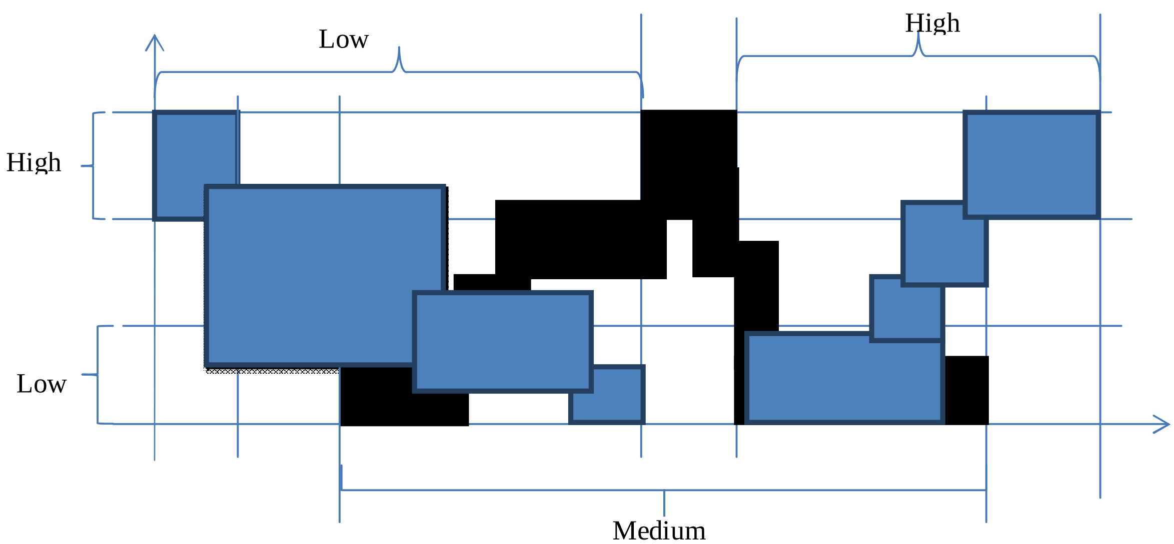


Figure 3: Proposed fuzzifier model

Based on the explanations provided above, in order to emphasize the characteristics of the branch of verbal calculations, the authors would prefer to use the term *wordifier* – (as shown in figure 3) which clearly reiterates modeling words – rather than *fuzzification*; this also implies, to some extent, Mendel's first condition for verbal calculations in [2]. Considering figure 2, fuzzification can be referred to in its general sense, and wordifying can be regarded as a specific, definite case of fuzzification.

The deduction motor functions based on the words, leading to a compound word which must be mapped into similar words in the output. When we refer to verbal calculations specifically, however, the defuzzification phase falls apart from the common methods of defuzzification in most cases. As in many industrial and non-industrial applications, where a fuzzy system provides man with the final data for decision making, it does not seem logical for a user operating fuzzy data to use defuzzification methods. In such a case, it would be better

3- Concept of freedom space

In industrial and engineering systems also, as we know, all existing fuzzy systems – type 1 and type 2 – create a clear, one-to-one mapping between the input and the output. However, we already know that decisions made by humans lack a one-to-one correlation between the input and the output. For instance, consider a driver driving along a range of the road. With every movement his coordinates change, whereas a fuzzy mapping – whether type 1 or type 2 – provides a controlling surface of which only one of the controlling surfaces is available. In general, when converting verbal words into numerical quantities, setting a number will not be proportionate to the real patterns of human decision making. One of its characteristics requires a similarity between the shapes of the output with what man shows in his reasoning behavior; therefore, the output of a verbal calculation system should not always be confined to a fixed number. The output may consist of words which are describable by a set of weighted numbers.

To further clarify this issue, suppose the whole area displayed in Figure (4) be equal regarding the error resulting in or quality control. Now let us say the fuzzy system has created one of these curves for us. The curve may be desired, but the freedom existing in the entire space has not been used. Considering the innate lapses existing in verbal quantities, the degrees of freedom within the selection of fuzzy components, and given the vast surfaces provided by the original descriptive rules of the system, it is wrong to claim that this curve is the only desired curve created for us by the fuzzy system. Although,the ANFIS synthesis method can generates any curve with an infinite number of components involved in the design of a fuzzy system. However, we must note that this is the synthesis of the problem; with specific controlling surfaces, there are easier ways to create it.

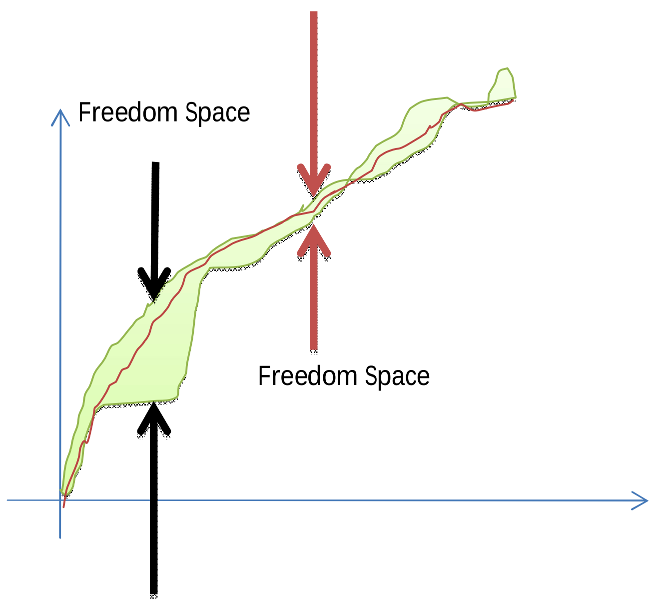


Figure 4: A Sample of Freedom Space

The total shape of the desired curved and the single curved generated is common for basic systems, and for the single-input, single-output system, the shade around the curve is the innate ambiguity in the system, which is either due to unreachable parameters (complexity) or a kind of ambiguity caused by the variety in parameters, variations with time, the complex mutual interactions between parameters, or the appearance or absence of parameters; such parameters are even influential when we are examining and studying the systems, and these ambiguities cannot be resolved. However, such ambiguities are like the ones we live with every day; like the continual existence of atmospheric pressure on the body, they are a kind of necessity, and part of our systematic activities.

The desired curves comprise an area like the above diagram, in which there are several output points for each input point. The green space (light colored in figure 4), however, is by no means indicative of error; in fact, it presents a desired freedom space in the output. When the system is controlled by a human being, such a space is brought about by the point of view and the verbal expressions used, like a cook pouring rice into a hundred containers with the phrase “Pour little,” and is controlled and confirmed by a chef. Now if we were to weigh these hundred containers, the weights would be in a space – not necessarily a point, which is generally not an error, since the command was not “Pour 100 grams,” but a desired freedom space rooted in the phrase “Pour little”.

Drivers do not have as much freedom making decisions when driving on wide roads as they do when driving around sharp turns. In the diagram above (figure 4), the two shown points have been displayed with different degrees of freedom space.

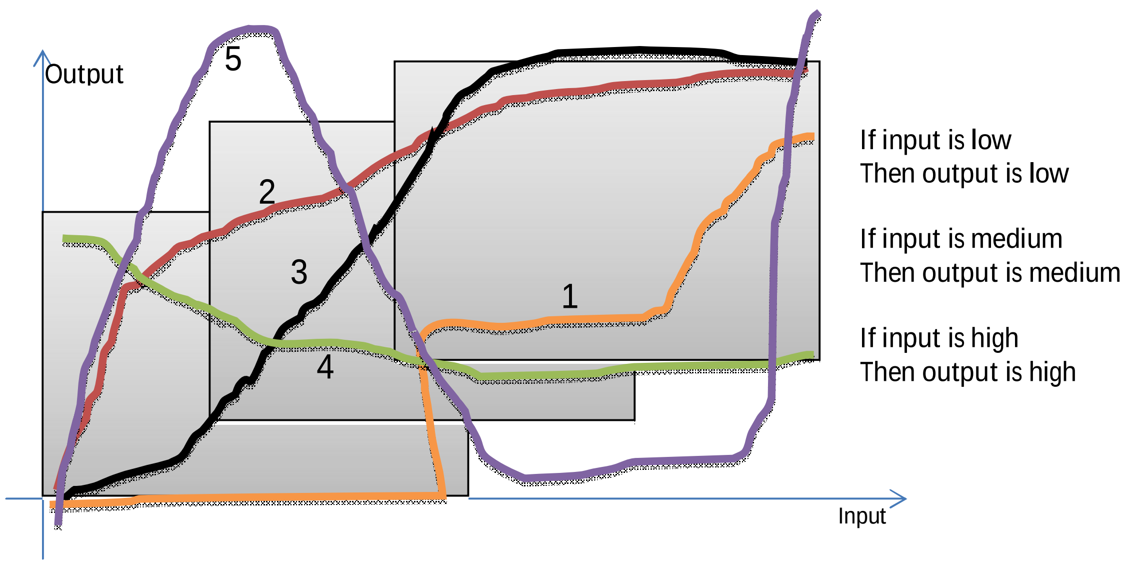
4- Principals for designing computing with words system

The purpose of fuzzy systems – or verbal calculation systems, to be more specific – is to provide a fast tool separate from classic methods for dealing with systems. However, the designer must have at least the following at his disposal:

a. The designer must be able to describe the behavior of the system according to the changes in the input and their effects upon the output by using verbal expressions. The quality of such a description depends on two factors – the complexity of the system and the extent of the designer's knowledge of the system. In the first phase, this description is defined in accordance with the rules governing the system. Considering the vastness of the surfaces created by the descriptive rules, the facilities provided by the fuzzy for the limited selection from these surfaces are as follows:
   1. the interval for each membership function
   2. the number of membership functions
   3. the type of membership functions

b. The type of conjunctions and disjunctions applied

c. The type of defuzzification used; for instance, in the figure 5(rules and diagram), equal circumstances in all cases except for differences in defuzzification led to one of the five curves displayedin figure 5, which are quite different from each other; Three of these curves (number 1, 2 and 3) are probably the answer to the problem, the other two (4 and 5) not only do not



provide the answer, but are in fact wrong choices for the same problem (system).

Figure 5: Several outputs for one set of rules

Two conditions must be met in order to make a defuzzification method usable: 1. It needs to fall inside the general space described by the rules. 2. It must comply the changes and orientations of the rules describing the system (i.e., it must be in line with the verbal interpretations).

Thus, considering the high importance of the selection of the components mentioned above in choosing characteristics more appropriate to the behavior of the system, the designer needs proper knowledge of the behavior of these components as well as sufficient knowledge of system behavior in order to confine the suitable curve; he/she even may have to turn to complex models and approaches at times to design the system. One of these approaches is ANFIS, in which we return to designing the system and selecting components from the mathematical synthesis of the characteristics. Despite being useful, this method usually provides more complicated answers in order to achieve the defined accuracydue to its mathematical nature; these complicated answers are the result of emphasis upon the extraction of a specific curve.

5- Conclusions

We may conclude from what was stated above that:

1. Fuzzy has its main role in calculations involving words. Systems whose answers consist of a series of controlling surfaces had better be analyzed using this method. The definition of membership functions: Any definition of the membership function which provides a better interpretation of the verbal quantities will be more suitable.
2. The more the verbal quantities model (membership function), defuzzification methods and combination methods guide us toward better selections of appropriate controlling surfaces for the behavior of the system without using accessory models such as ANFIS, neural networks, genetic algorithms, etc., and merely through emphasis upon modeling and higher relevance with verbal interpretations, the better.

3. In fuzzy domains, softness can be interpreted as the fuzzy system's higher flexibility against system parameters due to the existence of real freedom space in the system's output. Nevertheless, it a fuzzy system is designed to control two systems of similar control surfaces but different freedom spaces, the proposed fuzzy system will be, in equal circumstances, softer toward the system with higher freedom space. Without discussing the output freedom space, anyhow, it is impossible to discuss the hardness or softness of the system proposed.

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