Fuzzy Inference for Decision Support with fuzzyMorphic.pl

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Abstract—*Problems when dealing with imprecise or uncertain features, e.g., decision-making problems, can be designed as fuzzy systems, since these systems allow the processing of subjective and qualitative argument, usually intrinsic to such problems. This text presents the fuzzyMorphic.pl – a tool for developing of fuzzy inference systems which enable the specification of the modeling and the implementation of these systems – and its use for fuzzy inference decision models applied to decision support assistance.*

Keywords: Fuzzy inference, fuzzy inference system, decision support system, fuzzyMorphic.pl

Several times, the decision support problems cannot be handled by mathematics or logics classical approaches because these traditional methods do not have the necessary techniques or tools for that.

Generally, decision support problems have imprecise or uncertain features - which are sometimes intrinsic - so it becomes necessary to use different approaches with more appropriate tools, like fuzzy inference or fuzzy inference systems.

This text is organized into two parts. Initially, it explains why the fuzzy inference approach rather classical approaches should be used. Therefore, it shows the doubt which can happen in a classification problem and how the fuzzy approach can be more appropriate to deal this kind of problem, when the membership degree concept is used to assign "intensities" to the possible results as a decision support attribute. Next, it presents the use of fuzzy inference from computational modeling for decision support, by means of a set of inference rules.

The second part of this text presents the fuzzyMorphic.pl, a software for developing fuzzy inference systems which enables the specification of modeling of several kinds of fuzzy problems through its own statements and syntax, as briefly described in the fourth section.

The contents of this paper are completed by this introduction, which presents some observations on the problem at hand, and by the conclusion, which summarizes the most important points from text.

1. Fuzzy Inference Approach

Classical approaches are insufficient to resolve problems with imprecise or uncertain features, such as problems with results which have values very close to some limit. Therefore, in circumstances like these, mathematical and logically accurate results, but questionable, can be found.

1.1 Classical Approach Fuzzyness Features

A hypothetical classification problem could be to admit as a person of "medium height", the individual with height between 1.65 m and 1.75 m. Additionally, individuals which height less than 1.65 m will be considered as "short height" and individuals greater than 1.75 m will be considered as "higher height". And, assuming two individuals with heights between 1.66 m and 1.74 m as classified within the "medium height" range.

This decision, logically and mathematically precise, can be questioned, because of the subjectivity involved. Both values, 1.66 m and 1.74 m, are much closer to the limits of their class than between them. Furthermore, they are so close to the limits of the class which they belong to those different interpretations can be taken when classifying these values.

However, traditional approaches of logics and mathematics do not have the necessary tools to handle threshold values, or even imprecision or uncertainty. Specifically, threshold values result in doubt in the "decision" to classify the individual with respect to their heights, which suggests a fuzzy inference system for handling this uncertainty.

Usually, the threshold values problem is not as simple as it may seem, was it simple, the classical approaches could easily solve it, but, the closer to the subjective reasoning for the interpretation and the extraction of an answer or a decision, the more complex it becomes and the apparent simplicity is given by fuzzy logic modeling and by its basis in the theory of fuzzy sets.

1.2 Fuzzy Approach

The subjectivity inherent to reasoning makes it possible to deal with complex situations, which are based on inaccurate, uncertain or approximate information and, therefore, the strategy is to use human operators of an also imprecise nature, which are expressed in linguistic terms or variables.

For instance, common adjectives representing imprecision or uncertainty, such as *high*, *low*, *more*, *less*, or even cluster relation, as *the tall people set*, cannot be expressed using traditional approaches, unless the concept or value determining, in this case, the threshold for a person's height has been exactly defined, the persons can be considered "tall".

However, there is no difficulty in understanding what "being tall" entails if analyzer only two people's conversation.

Such proposal, essentially human, in order to describe or handle problems, generally, does not enable a solution in terms or exact numbers, but, for instance, leads the solution to a qualitative classification, clustering or aggregating into categories or possible solutions set [1]. These solutions can be seen as a result of the "principle of incompatibility" [2].

Fuzzy approach proposes that "intensities" to the data are determined, when comparing them to the thresholds set out, which is equivalent to establishing a membership degree to the information, ranging between 0 and 1 with respect to the sets which the information may belong to.

2. Decision Making with Fuzzy Inference

The subjectivity inherent to reasoning is capable of dealing with complex situations, based on inaccurate, uncertain or approximate information and, therefore, the strategy is to use human operators of an also imprecise nature, which are expressed in linguistic terms or variables.

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The linguistic terms or variables increase the complexity of traditional models and computational systems concerning the ability to handle are numbers, exact and discrete values which sometimes mutually exclusive, suggesting the idea of working with uncertain values, enabling the modeling of complex systems, even if they reduce the accuracy of the result, but not losing credibility.

If uncertainties, when viewed in isolation, are undesirable, when they are associated with other characteristics, they generally allow the reduction of system complexity and increase the credibility of the results [3].

Fuzzy sets theory and fuzzy logics are appropriate to represent, in mathematical terms, the inaccurate information which can be expressed by a set of linguistic rules. And if there is the possibility that human operators are organized as a set of conditional statements of the

if ANTECEDENT then CONSEQUENT

form; therefore, subjective reasoning can be expressed in the form of computationally executable algorithms [4] [2] with the ability to imprecisely classify the variables of the antecedents and consequents conditional statements, as qualitative concepts, instead of quantitative, which represents the idea of linguistic variable [1].

Thus, as systems capable of efficiently processing inaccurate and qualitative information, fuzzy inference models are suitable in situations which require decision making [1].

3. The fuzzyMorphic.pl

Fuzzy inference systems are implementations of able models to efficiently compute inaccurate and qualitative information, thus, for instance, they are appropriate for problems which require decision making [1].

3.1 Introducing the fuzzyMorphic.pl

The fuzzyMorphic.pl is a software tool for modeling and implementation of fuzzy inference systems – developed on Perl language – for which it is possible:

1) for fuzzyfication, to represent the membership functions on standard format sets – like trapezoidal or triangular shapes;
2) for implementation of inference machine, to use Mamdani's or Larsen's models;
3) for defuzzyfication, to represent output function on standard format sets; and
4) to use Center of Maxima as defuzzyfication method.

Two information sets are needed for fuzzyMorphic.pl to work, which could be in a single flat file or in different files. The first set refers to the description directives of the inference model, as a whole, and the second one is the input data itself.

The fuzzyMorphic.pl has the advantage of not having been developed for any specific problem, so, it is possible to utilize it to develop fuzzy inference systems for several inference problems and models.

Furthermore, its description inference systems way allow an easy the investigation of a problem under several and different respects and it is very important and intended in research procedures.

In the other hand, a constraint of the fuzzyMorphic.pl is to enable deffuzyfication by a single method, the Center of Maxima method.

Originally, the fuzzyMorphic.pl was developed as a part of a research project called "Computational models for the identification of genomic information associated to the resistance to cattle tick" [5] and was used to implement a fuzzy inference system for decision support assistance, from verification and analysis of two previous results.

The fuzzyMorphic.pl is in 1.0 version, release 20090111, and it needs the fuzzyInference.pm module, currently in 1.1 version, and in the same release.

3.2 The fuzzyMorphic.pl Structure

Generally, the structure of fuzzy inference systems has three large sections:

1) fuzzyfication, to converter of crisps values to fuzzy values;
2) inference, to run the machine inference with the inference rules; and
3) deffuzyfication, to convert outcome, from fuzzy values to crisps values;

and these structure can be implemented with the fuzzyMorphic.pl through of its descriptions directives, as explain them below.

The description directives are organized in six groups and if they are in the same input data flat file, then they have to occupy the first lines of such file. These directives describe the input data file, define the membership functions, set up relations among crisp values and membership functions, define the inference rules, set up the inference model, and define the output file.

As a result, under these conditions, from flat file with description directives of input data and system model elements, fuzzyMorphic.pl can easily do data mining and discover knowledge. Actually, it can infer knowledge from the inference rules described in the directives.

The six directives groups are explained below:

1) the first group has the $\_ID$ identifier, is composed of just one directive and must be the first row of the directive file, but it can be preceded by blank or comment lines. This directive shows format file, including field separator, fields themselves, fields which participate of the fuzzy inference model as crisp variables and the result field;
2) the second group defines the membership functions. Each row represents one membership function and it must begin with $\_F_i$ (i = 1, 2, ...) for each function;
3) the third group assigns crisp variables – reported in the first directive group – with their membership function. As is known, the same membership function can be associated with more a one crisp variable. Each row determines one relationship between a crisp variable and a membership function;
4) the fourth group lists the inference rules set. Each row brings one rule and must begin with $\_R_i$ (i = 1, 2, ...) for each rule;
5) the fifth group is composed of just one directive and it defines the inference model. This directive must informs $\_IM : Mamdani$ or $\_IM : Larsen$, depending on the choice of inference machine for the model;
6) the sixth group is composed of just one directive too and it defines the output function. This row must begin with $\_O$ and should be followed by output function description.

The observations below should also be considered when using the fuzzyMorphic.pl:

- if a row has with a "#", then all text wrote below it will be considered comments and this text will be ignored;
- all blank lines or lines with only space characters, such as tab characters, will be ignored;
- the input file fields must be separated with a field separator, as described in the $\_ID$ directive;
- the $\_ID$ directive must be the first directive, but the other directives can listed in any order or be mixed and matched;
- if the directives and data are in the same file, then all of the set of description directives – such as the six groups of directives – must be before the first input data record.

4. Conclusions

Generally, fixed and precise classification criteria are not suitable when studies show results which are very close to a certain limit, for instance, a division into classes. But, these cases can be approached by fuzzy inference systems, which are also convenient, as well as able, to handle problems characterized by uncertainty and imprecision for decision making actions.

Furthermore, problems featuring imprecision or uncertainty can be designed as fuzzy systems, since these systems allow the processing of subjective and qualitative arguments, usually intrinsic to such problems.

The fuzzyMorphic.pl is a tool for developing fuzzy inference which enables model description and implementation of fuzzy inference systems for solving different problems. Although, originally, the fuzzyMorphic.pl was developed to implement a fuzzy inference model decision support applied to bioinformatics, specifically for the identification of single nucleotide polymorphisms, based on results from two other single nucleotide polymorphisms discovery tools.

More information about this software or the inference model proposed can be seen in the quoted research project "Computational models for the identification of genomic information associated to the resistance to cattle tick" [5].

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