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INTERVAL TYPE-2 FUZZY LOGIC SYSTEMS TOOLBOX

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Abstract – Type-2 Fuzzy systems has been becoming the focus of research in the field of fuzzy logic in recent years. Comparing with type-1 systems, type-2 fuzzy systems are more complex and relatively more difficult to understand and implement. In this paper we presents the design and development of a software tool for for construction, edition and observation of Interval Type-2 Fuzzy Inference Systems. The Toolbox's best qualities are the capacity to develop complex systems and the flexibility that permits the user to extend the availability of functions for working with the use of type-2 fuzzy operators, linguistic variables, interval type-2 membership functions, defuzzification metods and the evaluation of Interval Type-2 Fuzzy Inference Systems.

Index Terms –Interval Type 2 Fuzzy Inference Systems, Interval Type-2 Fuzzy Logic Toolbox, Karnik-Mendel algorithms, Membership Functions

INTRODUCTION

On the past decade, fuzzy systems have displaced conventional technology in different scientific and system engineering applications, especially in pattern recognition and control systems. The same fuzzy technology, in approximation reasoning form, is resurging also in the information technology, where it is now giving support to decision making and expert systems with powerful reasoning capacity and a limited quantity of rules.

The fuzzy sets were presented by L.A. Zadeh in 1965 to process/manipulated data and information affected by unprobabilistic uncertainty. There were designed to mathematically represent the vagueness and uncertainty of linguistic problems; thereby obtaining formal tools to work with intrinsic imprecision in different type of problems; it is considered a generalization of the classic set theory.

Intelligent systems based on fuzzy logic are fundamental tools for nonlinear complex system modeling. The fuzzy sets and fuzzy logic are the base for fuzzy systems, where their objective has been to model how the brain manipulates inexact information.

Type-2 fuzzy sets are used for modeling uncertainty and imprecision in a better way. These type-2 fuzzy sets were originally presented by Zadeh in 1975 and are essentially "fuzzy fuzzy" sets where the fuzzy degree of membership is a type-1 fuzzy set. The new concepts were introduced by Mendel and Liang allowing the characterization of a type-2 fuzzy set with a superior membership functions and an inferior membership function. These two functions can be represented each one by a type-1 fuzzy set membership function. The interval between these two functions represent the footprint of uncertainty (FOU), which is used to characterize a type-2 fuzzy set.

The uncertainty is the imperfection of knowledge about the natural process or natural state The statistical uncertainty is the randomness or error that comes from different sources as we use it in a statistical methodology.
There are different sources of uncertainty in the evaluation process. The five

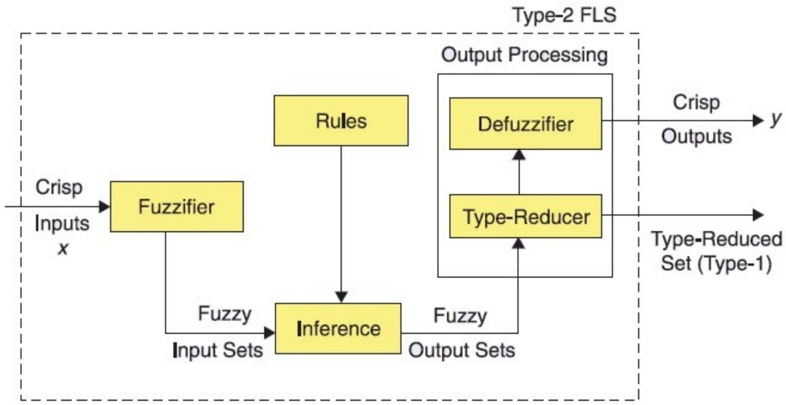


Fig. 1. Type 2 Fuzzy System Structure

types of uncertainty that emerge from the imprecise knowledge natural state are :

- Measurement uncertainty. It is the error on observed quantities
- Process uncertainty. It is the dynamic randomness.
- Model uncertainty. It is the wrong specification of the model structure
- Estimate uncertainty. It is the one that can appear from any of the previous uncertainties or a combination of them, and it is called inexactness and imprecision.
- Implementation uncertainty. It is the consequence of the variability that results from sorting politics, i.e. incapacity to reach the exact strategic objective.

This paper presents development and design of a GUI toolbox for construction, edition and observation of interval type-2 Fuzzy Inference Systems. The toolbox covers all phases of Interval Type 2 Fuzzy Logic Toolbox from first phase till the last. The toolbox best qualities are the flexibility which enables the user to add new file and user friendly which makes it suitable for versatile range of user from beginner to advance.

In Section 2 some topics on Interval Type 2 Fuzzy Logic System is presented, in Section 3 developed loolbox is demonstrated; in Section 4 the toolbox is exploited for water level problem. Finally, conclusion are stated in Section 5.

T2TSK STRUCTURE

Type-2 fuzzy sets have a fuzzy membership function, modeling the imprecise nature of a fuzzy membership grade. As the field has developed, two main categories of type-2 fuzzy set have emerged; generalized and interval. Generalized type-2 fuzzy sets model a fuzzy membership grade as a fuzzy number between zero and one. Type-2 interval fuzzy sets model a fuzzy membership grade as a crisp interval in [0,1].

Type-2 interval fuzzy sets are a limited version of the generalized type-2 fuzzy set where the secondary membership grade is always 1. This limitation allows type-2 interval sets to be processed a great deal more quickly than generalized type-2 fuzzy sets.

An interval type-2 fuzzy logic system contains five components—fuzzifier, rules, inference engine, type-reducer and defuzzifier—that are inter-connected, as shown in Fig. 1. Once the rules have been established, a FLS can be viewed as a mapping from input to output.

The Interval type-2 fuzzy logic system works as follows: the crisp inputs are first fuzzified into either type-0 (known as singleton fuzzification), type-1 or Interval Type2 Fuzzy Systems, which then activate the inference engine and the rule base to produce output Interval Type 2 Fuzzy Systems. These Interval Type-2 Fuzzy Systems are then processed by a type-reducer (which combines the output sets and then performs a centroid calculation), leading to an interval Type 1 Fuzzy System called the type-reduced set. A defuzzifier then defuzzifies the type-reduced set to produce crisp outputs.

Rules are the heart of an FLS. They may be provided by expert or extracted from numerical data. The rules can be expressed as a collection of IF-THEN statements. The IF-part of a rule is its antecedent, and the THEN-part of a rule is its consequent.

The type-reduced set provides an interval of uncertainty for the output of an Interval Type 2 Fuzzy Logic System, in much the same way that a confidence interval provides an interval of uncertainty for a probabilistic system. The more uncertainties that occur in an Interval Type 2 Fuzzy Logic System, which translate into more uncertainties about its Membership Functions, the larger will be the type-reduced set, and vice-versa.

Five different type-reduction methods are described in [5]. Each is inspired by what we do in a Type 1 Fuzzy Logic System and are based on computing the centroid of an Interval Type 2 Fuzzy System.

INTERVAL TYPE-2 FUZZY LOGIC SYSTEM TOOLBOX

The Interval Type-2 files contain the functions to create Mamdani and TSK Interval type-2 Fuzzy Inference Systems (FD newfis.vi), functions to add input-output variabels and their ranges (FD addvar.vi), it has functions to add 8 types of Interval Type-2 Membership functions for input-outpus (FD addmf.vi), functions to add the rule matrix (FD addrule.vi), it can evaluate the Interval Type-2 Fuzzy Inference Systems (FD evalfis.vi), it can generate the initial parameters of the Interval Type-2 Membership Functions (FD Generate FIS from data.vi), it can plot the Interval type-2 Membership functions with the input-output variables (FD plotmftype.vi), it can generate the solution surface of the Fuzzy Inference System (gensurftype.vi).

Figure 2 show the main view of the Interval Type-2 Fuzzy Inference Systems Structure Editor.

Fig. 2 Front Panel of IT2 FLS Toolbox

The Interval Type-2 Toolbox are arranged in six layers : FIS Editor, Membership Function Editor, Rule Editor, Surface Viewer, Simulation and FIS Array. In the FIS Editor the user must define how many input and output variablesand what are their names ? The Interval Type-2Toolbox doesn't limit the number of inputs. However, the number of inputs may be limited by available memory in the machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the Interval Type-2 using this toolbox. Figure 3 show the FIS Editor of the Interval Type-2 Fuzzy Inference Systems. In the left of the front panel is the type of inference used. The default is Mamdani-type inference. Another slightly different type of inference is Sugeno-type inference. Below the name of the fuzzy inference system are the pop-up menus that allow user to modify the various pieces of the inference process. The user can choose In these toolbox, two build-in AND methods are supported : min (minimum) and prod (product). Two build-in OR methods are also supported : max (maximum) and probor (the probabilistic OR method). Three build-in aggregation methods are supported : max (maximum), probor (probabilistic OR) and sum (simply the sum of each rule's output set). And there are five built-in defuzzification methods supported: centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum and smallest of maximum.

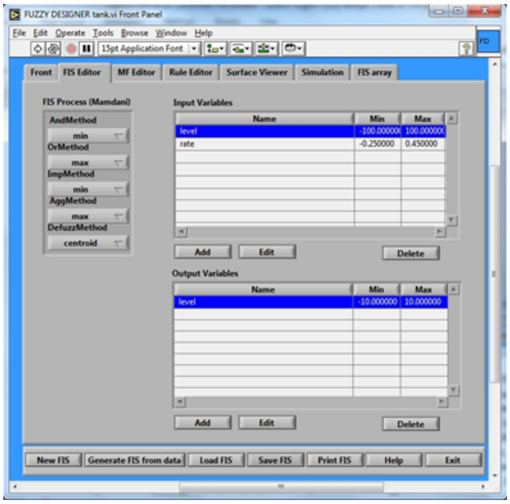


Fig. 3. FIS Editor of IT2 FLS Toolbox

The Membership function Editor is used to define, display and edit all of the membership functions associated with all of the input and output variables for the entire fuzzy inference system.. Figure 4 show the Membership Function Editor of the Interval Type-2 Fuzzy Inference Systems. The types of membership functions are triangular mf, trapezoidal mf, gaussian mf, two-gaussian mf, sigmoid, mf, D-sigmoid mf, P-sigmoid mf and generalized bell membership function.

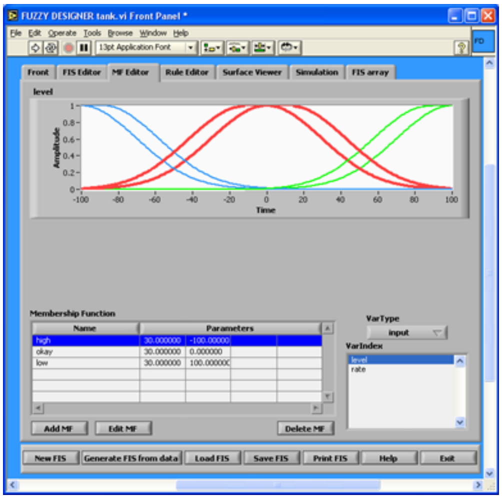


Fig .4. MF Editor of IT2 FLS Toolbox

The Rule Editor is for editing the list of rules that defines the behavior of the system. Figure 5 show the Rule Editor of the Interval Type-2 Fuzzy Inference Systems.

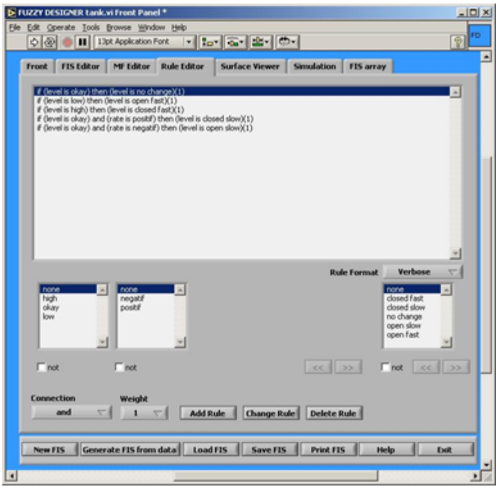


Fig. 5. Rule Base of IT2 FLS Toolbox

The Surface Viewer is used to display the dependency of one the outputs on any one or two of the inputs. It generates and plots an output surface map for the system. Figure 6 show the Surface Viewer of the Interval Type-2 Fuzzy Inference Systems. The Surface Viewer has a special capability that is very helpful in cases with two inputs (or more) and one output; the user can actually grab the axes and reposition them to get a different three-dimensional view on the data. If the user have four-input one output system and would like to see the output surface, the Surface Viewer can generate a three-dimensional output surface where any two of the inputs vary, but two of the inputs must be held constant since the computer monitors cannot display a five dimensional shape.

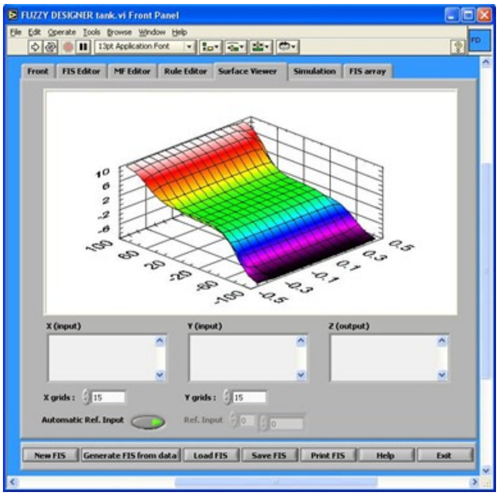


Fig 6. Surface Viewer of IT2 FLS Toolbox

The Interval Type-2 Fuzzy Toolbox can apply to for data modeling. The structur and membership function parameters can be chosen automatically using Generate FIS From Data Editor. These editor provide a method for the fuzzy modeling procedure to learn information about a data set, in order to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. Figure 7 show the Generate FIS From Data Editor of the Interval Type-2 Fuzzy Inference Systems.

The Print submenu offers documentation facilities for printing information about the active project as shown in Figure 8. Figure 9 show printed pages from the example project.

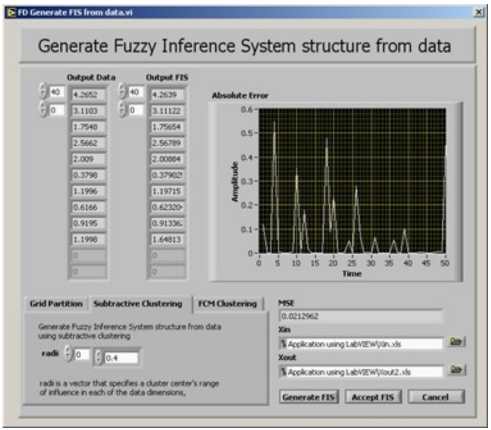


Fig 7. Generate Rule from Data

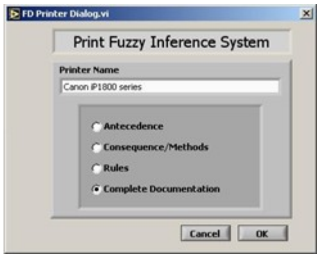
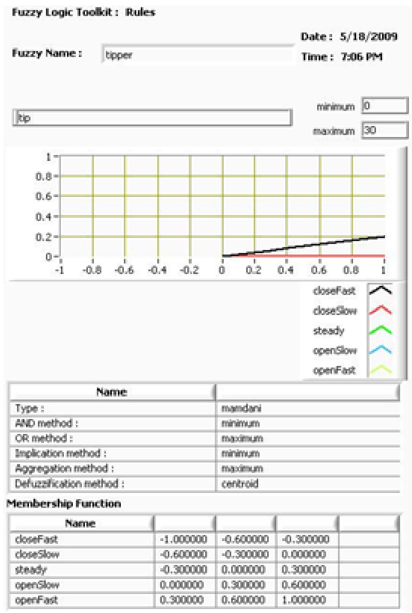


Fig. 8. Printer Dialog of IT2 FLS Toolbox



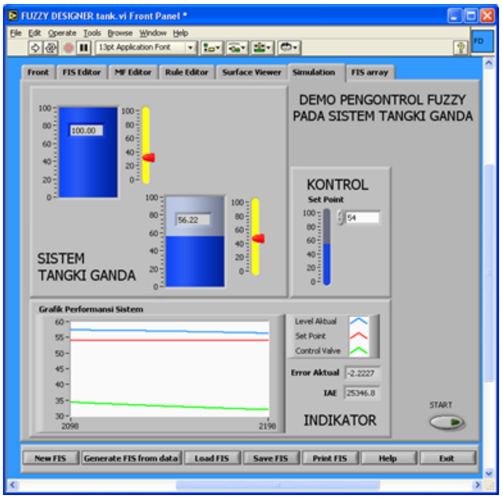


Fig. 9. Print Out of Documentation

SIMULATION RESULTS WITH THE INTERVAL TYPE-2 TOOLBOX

We present a level water simulation with interval type-2 fuzzy logic systems using Interval Type-2 Fuzzy Logic Systems Toolbox. The application of the interval type-2 fuzzy control scheme to the level water gives good control results, which can be appreciated in Figure 10.

Fig. 11. Water Level Control Example

CONCLUSION

The design and implementation done in the Interval Type 2 Fuzzy Logic Systems Toolbox is potentially important for research in the interval type-2 fuzzy logic area, thus solving complex problem on the different applied areas.

Our future work is to design interval type-2 fuzzy neural network hybrid models.

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