Application of Fuzzy Set Theory in Controlling of Urban Storm Drainage Systems

by

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1. Introduction

The way of using fuzzy control brings some essential advantages like the use of algorithms in the case of defining affirmations by (logical) expressions. During the past several years, fuzzy control has emerged as one of the most active and fruitful research in the applications of fuzzy set theory, especially in the realm of industrial processes, which do not lend themselves to control by conventional methods because of a lack of quantitative data regarding the input-output relations. The construction of a fuzzy logic controller for a dedicated application based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into an automatic control strategy [1].

Fuzzy control algorithms are constituted of many control rules that will form the rule base of a fuzzy logic controller. To calculate these statements means to evaluate a succession of Min and Max expressions. By choosing the maximal value among these statements the final decision is made. Even in fuzzy control statements, only one value should be chosen to guarantee the steady output. Though fuzzy algorithms are based on fuzzy sets of ambiguous concepts, fuzzy control algorithms must provide only one determined value when a fixed input is applied to a fuzzy control system. If plural results are produced, then exact control is not expected [2], [3].

2. Fuzzy Logic Controller Structure

In this application, general fuzzy controller architecture is used, as it is shown in Fig.1.

The fuzzy logic controller comprises four main components: a fuzzification interface (FI), a knowledge base (KB), a decision - making logic (DML), and a defuzzification interface (DI) [4], [5].

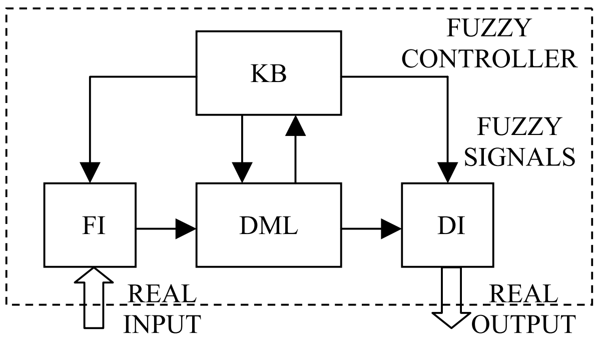

Fig.1 The fuzzy logic controller structure

The fuzzification interface involves the following functions:
- measures the values of input variables;
- performs a scale mapping that transfers the range of values of input variables into corresponding universes of discourse;
- performs the function of fuzzification that converts input data into suitable linguistic values which may be viewed as labels of fuzzy sets.

The knowledge base comprises knowledge of the application domain and the attendant control goals. It consists of a database and a “linguistic (fuzzy) control rule base”, which have the following functions:
- the database provides necessary definitions, which are used to define linguistic control rules and fuzzy data manipulation in a fuzzy logic controller;
- the rule base characterizes the control goals and control policy of the domain experts by means of a set of linguistic control rules.

The decision-making logic is the kernel of a fuzzy logic controller. It has the capability of simulating human decision-making based on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic.

The defuzzification interface performs the following functions:
- a scale mapping, which converts the range of values of output variables into corresponding universes of discourse;
- defuzzification, which yields a non fuzzy control action from an inferred fuzzy control action.

FCDS (Fuzzy Control Design System) is a collection of powerful software tools, which permits the control system designers to test fuzzy logic specific mechanisms. This development product is made up of several interfaces, functions, procedures, and algorithms that implement particular technics, which are very useful in the configuration process of control applications having as support the fuzzy set theory and the associated concepts.

3. Fuzzy control of the sewer system. Case study

The fuzzy logic controller implementation is a remarkable solution due to the following characteristics: the vagueness of data, the linguistic description of model and the possibility of solving the system, even the information is incomplete or contradictory.
Using specialized simulation software like HydroWorks, the critical points in the system can be found. In these points, in the next step will be placed measuring and output elements. The following example considers the installation of tree measuring points and six output elements (pumps, sluice gates) in configuration of a part of sewer system. In cases of ground with variations in level we prefer to use pumps for raising the water. In other cases pumps evacuates the excess of rainfall water, which exceed the capacity of sewer toward treatment plant.

Fuzzy logic control of a sewer system was tackle with FCDS and with corresponding module WNC-Water Network Control [6]. A friendly graphic interface permits the description of the network topology and some defining parameters (fig. 2). Constructive elements, like inputs in the system, ramifications, pipes, measurements points, overflows, gates and pumps can be used. One selected element is placed in the defined field from the configuration of the system. The specific features of the physical elements corresponding to graphical elements are introduced in “fuzzy controller’s structure editor” window. Different types of elements offered by designer are used to build the network. A name and parameters referring to maximum and minimum carried flow are assigned to each object.

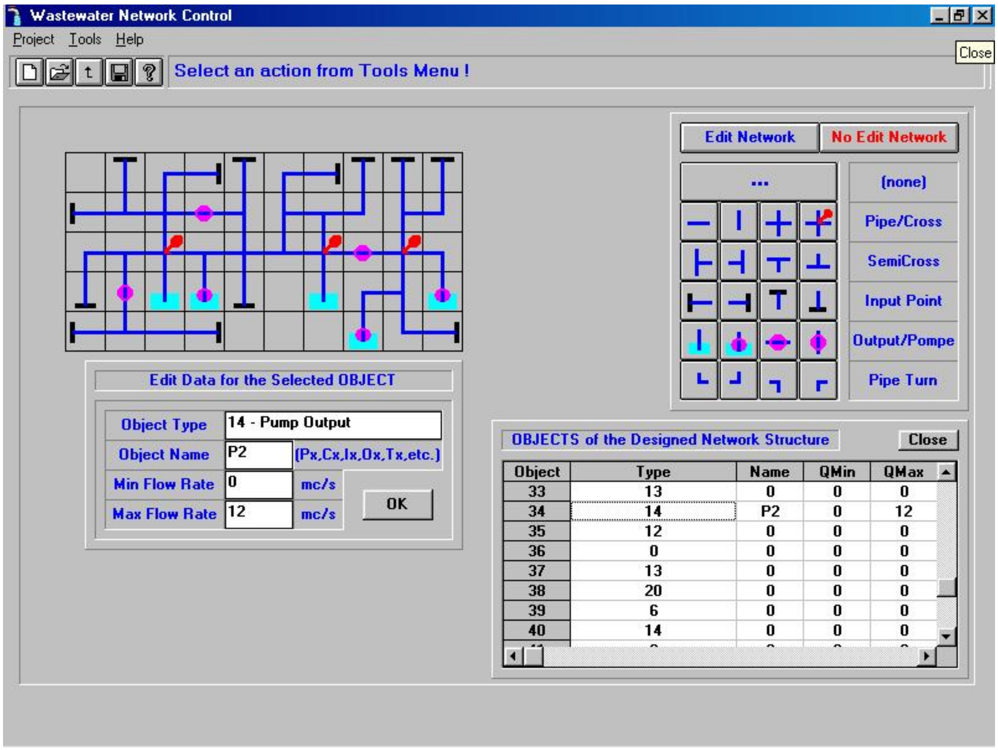

Fig. 2 The interface for network configuration

The elements of the network are displayed each apart or in a list form. The settled configuration can be saved in a file for further use or modification. The number of inputs and outputs of the fuzzy controller is set using the window presented bellow (fig.3).

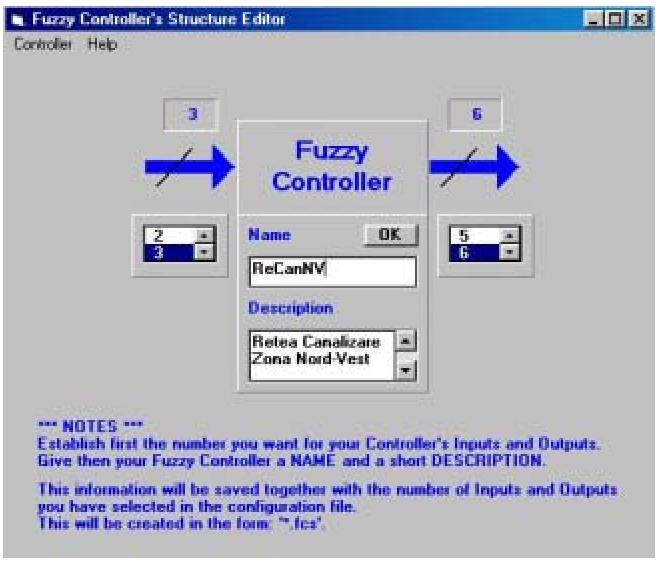

Fig. 3 Fuzzy controller's structure editor

The operator can define:

- The number of input variables (i.e. flow measuring points) placed on branches of the designed network;
- The number of output variables placed on action points where there are regulators.

All the information is stored in a database that can be accessed for viewing or editing.

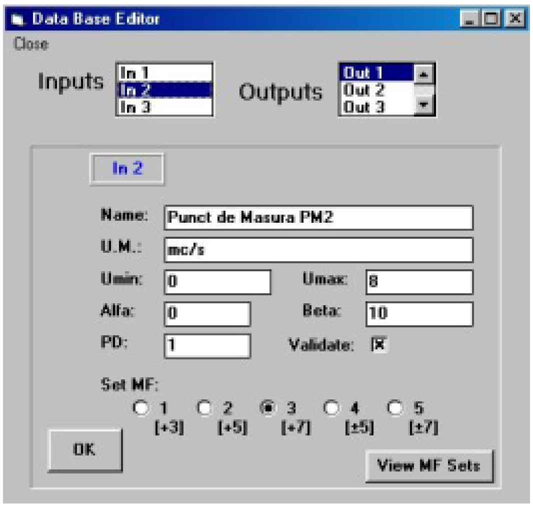

Fig.4 Database editor

For each variable we can modify the name, measuring unit, universe of discourse, normalization interval and the discretization step (Fig. 4). We can also select the set of predefined linguistic terms for each variable and the modification of membership function. The software offers many predefined sets of membership functions (fig. 5).

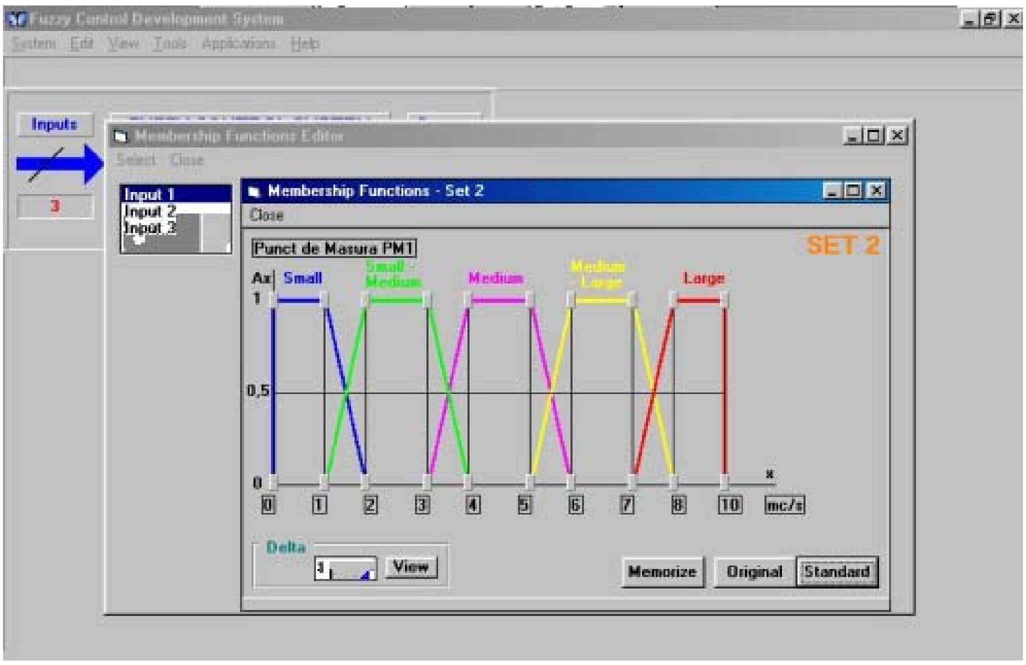

Fig. 5 Membership functions editor

The rule database can be changed using the interface presented in figure 6, which allow the rules selection and editing.

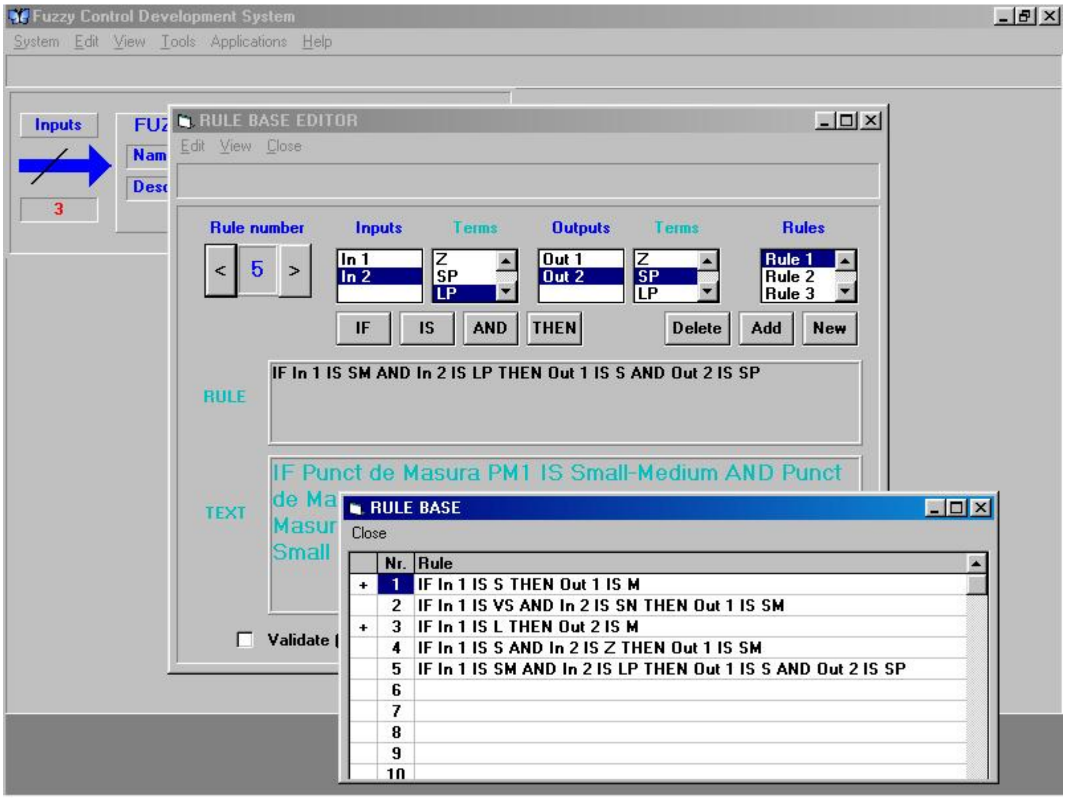

Fig. 6 Rulebase editor

The state of the process is presented in "Control panel" window (fig.7).

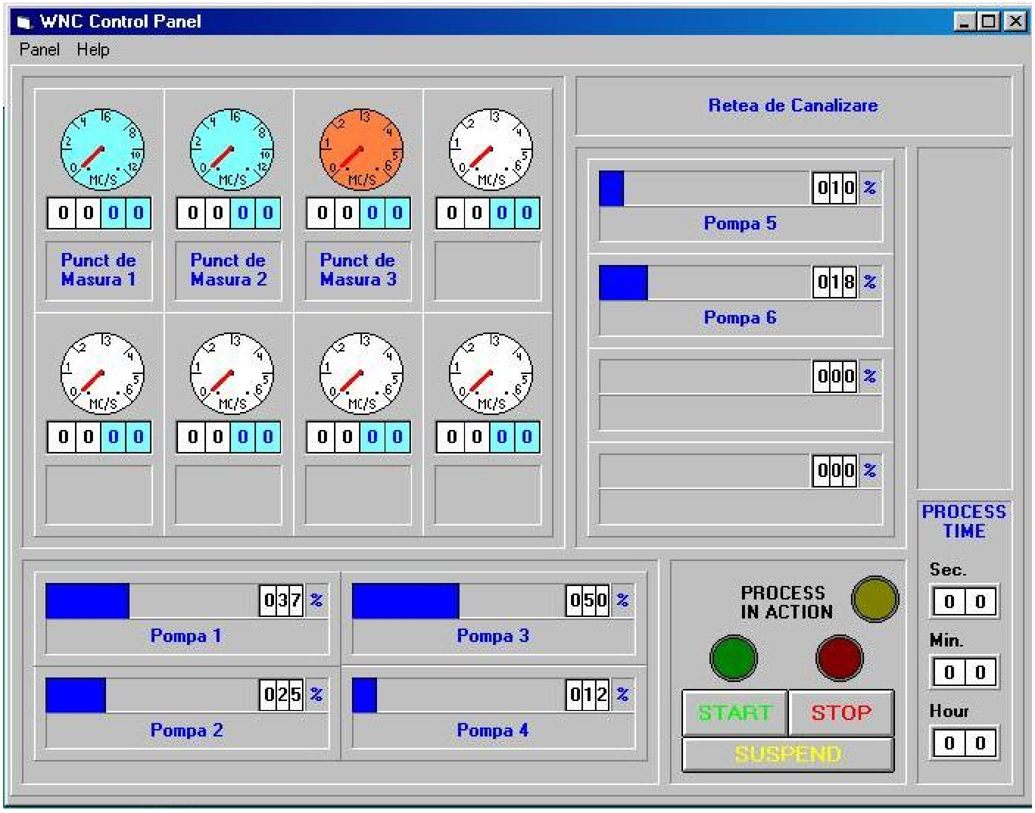

Fig. 7 The control panel window

The operator panel displays the state at different moments, enabling START, STOP, and time recording facilities. Thus, the process signals and the commands transferred to the controller could subsequent be memorized and revised. The control panel could be displayed from the simulation module too, thus we can supervise the process evolution, command elaboration and transmission.

The simulation interface uses a database containing the network structure, control panel, rulebase and the inference engine. For the moment, the commands are executed by an operator that use the software, in manual regime only. The possibility of automatic regulation will be considered in future developments of this software pack.

4. Conclusions

Fuzzy logic is closer by human thinking and by natural language, so is easier to use in many fields. Thus fuzzy logic controller provides an algorithm that can transform the control linguistic strategy, based on an expert knowledge into an automatic strategy.

Fuzzy logic controller has better results comparing to conventional controllers, especially in complex systems with uncertain or inexact information. In this context fuzzy logic offers a flexible and promising alternative, easily accepted by operators due to expert knowledge incorporated.

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