

DESIGN OF FUZZY CONTROL OF WASTEWATER TREATMENT PROCESSES

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Abstract: *This paper presents how to use in processes the wastewater treatment and the control processes using direct fuzzy control of the process, fuzzy supervision of classic PID regulators and how fuzzy adaptation of classic PID controller. I also mentioned about fuzzy control design for water treatment following steps fuzzification and defuzzification.*

Keywords: pid, controller, fuzzy control

1. Introduction

Wastewater treatment processes are complex bio-chemical processes, which compared to industrial processes, have several elements distinct both in terms of their characteristics and operational objectives. The need to automate these processes stems from their inability to maintain their state of dynamic equilibrium in the presence of disturbances, which may be temporary, cyclical or periodic and often random. The direct or indirect action of disturbances on the purification processes justifies the implementation of automatic control systems, which tend to keep the processes in balance, which is very complicated or impossible for the human operator.

From the point of view of the automatic control theory, a (biological) wastewater treatment unit can be presented as a "black box" with the following sets of inputs and outputs [2] :

1. Input variables:

- waste water flow – Q ;
- the level of influent pollution – xe ;
- chemical reagents used in the process – r ;
- thermal/electrical energy to maintain the process.

2. Output variables: other similar .

3. Disturbances: – factors that act on the input variables (variation of wastewater flow rate, its pollution level, temperature, presence of toxic compounds) force the deviation of the processes from the equilibrium state; - level of residual pollution – x ; - nitrogen and phosphorus concentrations;

4. The amount of excess sludge – Qn for example.

The operating variables are those with which the processes can be kept in balance despite disturbances. In most cases, the driving variable is the amount of recirculated sludge – b , the speed of circulation of polyphase media, the concentration of organic substances and others. The restrictions present in the case of biological purification the limit concentration of oxygen in the aeration basin, the concentrations of nitrogen and phosphorus, as well as the consumption of other reagents.

In current control and automation applications, maintaining processes in equilibrium is

often carried out based on classical proportional-integral-differential (PID) controllers (fig. 3), primarily because it presents an efficient and easy solution implement. Originally designed for linear, time-invariant systems, the PID controller/algorithm has evolved, allowing engineers to control systems with complex dynamics. PID algorithms are implemented in discrete form on microcontrollers and can control fairly fast processes with response times of less than hundredths of a second. On the other hand, in reality, all systems have nonlinear components, which present real challenges in using classical PID control. First, the regulation model must correspond exactly to the process and must be periodically adjusted in case of time variation of the system. This PID tuning procedure is sophisticated and requires a proper approach [5,6,7].

Fuzzy logic control (FLC) is the most active research area in the application of fuzzy set theory, fuzzy reasoning, and fuzzy logic. The application of FLC extends from industrial process control to biomedical instrumentation and securities. Compared to conventional control techniques, FLC has been best utilized in complex ill-defined problems, which can be controlled by an efficient human operator without knowledge of their underlying dynamics.

Fuzzy set theory emergence and development electronic systems have opened the way to application in automatic regulation systems. In this case, the classic PID control algorithms are replaced by a series of IF (premise) THEN (conclusion/action) type rules. There fore, a heuristic algorithm is obtained, which can take into account the experience of the human operator in managing the processes, which is very important in the case of complex processes.

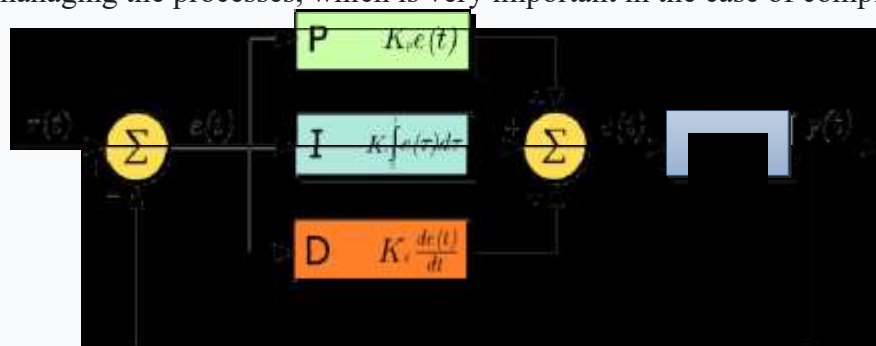


Fig.1. The structure of the classic PID controller.

The application of fuzzy theory in automatic control systems can be in several ways, the most widespread of which are [4]:

- direct fuzzy control of the process;
- fuzzy supervision of classic PID regulators;
- fuzzy adaptation of classic PID controller parameters.

As a result of the analysis of several sources [4, 9], including our own experience, we proposed the application of direct fuzzy control of the processes, which are easier to design, implementing the experience of the human operator and on the other hand – it allows an opening to merge with the other approaches.

We propose the following structure of the direct fuzzy control shown in fig. 3, consisting of the following components. The fuzzification module of the input variables, of the process variables.

The input variables have real values, which must be transformed into fuzzy values, that is, they must be assigned fuzzy values, which become premises. As a result, this premise will determine which rule should be activated along with the degree of membership obtained from each rule. This degree depends on how well the input value and the rule premises match each other. The rule base. This component consists of the entire set of rules of the type "IF (premise) THEN (conclusion/action)". In the premises, the values of the input variables are entered, so that it can be decided, which rule can be activated and which cannot, and then in which way it should be used. The output(s) of the enabled rules are merged and forwarded to the defuzzification interface. As a rule, this base is created by experts in the management issues of the respective processes, taking into account the experience of the human operator. The decision-making/inference module evaluates the rule base based on the fuzzy data in order to obtain the fuzzy decision/conclusion.

The defuzzification module -the fuzzy decision obtained by the inference module has a complex form, due to the fact that it reflects a combination of fuzzy sets with limited degrees of membership. The destination of this module is of the form a single real value, comprising the output fuzzy set.

3. Design of fuzzy control for water treatment

Fuzzy control design consists in making a heuristic process management algorithm, which can take into account the experience of the human operator in managing these processes. The design includes a series of development stages, the most important of which are the following [4, 7]:

- structural and functional research of the regulation process to determine its behavior to various input variables and disturbances;

- choosing the regulation scheme, the number and types of fuzzy regulators;
- selection of input and output variables, respectively, and their variation domains;
- the definition of the linguistic variables associated with the sizes of the input and output variables, as well as the definition of the corresponding membership functions;
- the creation of the rule base, which connects the premises of decisions/conclusions, in accordance with the linguistic description of the behavior of the regulator;

- computer simulation of the entire automatic regulation system and adjustment of the regulator in order to optimize its operation. In the following, we will exemplify the design of direct fuzzy control for the regulation of the sludge level in the biological water treatment process. Fuzzy control, which directly uses fuzzy rules, is the most important application in fuzzy theory. Using a procedure by Ebrahim Mamdani P, we must perform the following steps:

- fuzzification - creation of membership functions to describe input variables in fuzzy (linguistic) terms;

- defuzzification – establishing the way to transform fuzzy values into real results;

- creation of the base of fuzzy rules, which are applied in decision-making.

Analyzing the informational resources, as well as our own experience, we determined that in the process of biological purification it is very important to maintain a balance of the activated sludge level in the purification basin.

Decision making/inference is done based on fuzzy data with evaluation of the rule base in order to obtain the fuzzy decision/conclusion There are several ways to define the result of

a rule, one of the most frequently applied and simplest is the "MIN-MAX" deduction method, where the membership function.

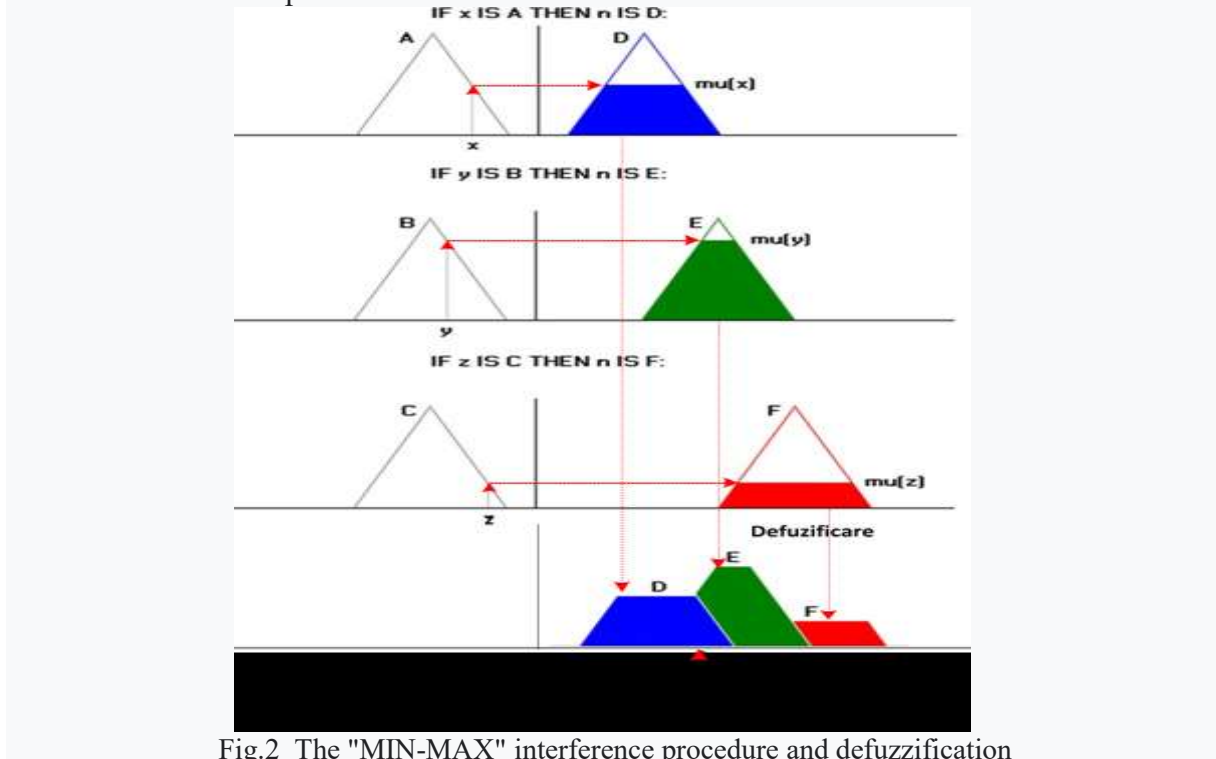


Fig.2 The "MIN-MAX" interference procedure and defuzzification

4. Conclusions

Conclusions the use of FUZZY applications and design of FUZZY control in automation processes brings important benefits in terms of efficiency and use in operation, especially in the case of technological wastewater treatment processes.

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