УДК 004.[827+021]

Р. О. Ткаченко, О.С. Ковалишин
(Національний університет «Львівська політехніка»)

МЕТОД ОЦІНКИ ВІДГУКІВ ПАЦІЄНТІВ МЕДИЧНИХ ЗАКЛАДІВ З ВИКОРИСТАННЯМ НЕЧІТКОЇ ЛОГІКИ

В статті описано проблематику оцінки якості роботи медичних закладів. Подано методи збору відгуку клієнтів клінік. Розглянуто аспекти агрегування та побудови статистики вдоволення пацієнтів процесом лікування. Досліджено можливості використання систем нечіткої логіки з метою для вирішення задачі оцінювання вдоволеності якістю лікування. Побудовано та апробовано контролер нечіткої логіки для консолідації параметрів оцінки якості та надання вимірюваного результату.

Ключові слова: Відук пацієнтів, оцінка відгуків пацієнтів, нечітка логіка, контролер нечіткої логіки.

R. O. Tkachenko, *PhD, Professor*, **O. S. Kovalyshyn**
(Lviv Polytechnic National University)

A METHOD OF ASSESSING OF CLINIC PATIENTS FEEDBACK WITH FUZZY LOGIC

This paper concentrates on problems of assessing the quality of health care facilities process. Research describes methods and approaches of gathering customer feedback. Aspects of patients feedback aggregation and satisfaction statistics building during treatment are considered. Investigated possibilities of using fuzzy logic systems with a view to solving the problem of evaluating the quality of treatment. Constructed fuzzy logic controller in order to consolidate parameters of medication for provisioning of measurable results.

Key words: Feedback, patients feedback evaluation, fuzzy logic, fuzzy logic controller.

Issue definition

The era of globalization has begun and organizations of any kind endeavor to increase their production capabilities. Same statement is fare for medical establishments that experiencing increased patient's influx. So, on the one hand clinics are intended to use available resources in most efficient manner, and on the other hand produce high quality medication which also means increasing of patient's satisfaction about services provided. To achieve the mentioned goal, organizations should increase their productivity as a major strategy in order to improve their performance. In case measuring resources utilization - like medical equipment idle time, or doctors load, quantitative methods can be applied. But patient's feedbacks are mostly expressed in non- [illegible] n this paper, fuzzy logic controller as a robust and easy understanding approach is applied to transform the quantitative variable to linguistic terms in order to measure the medical establishments client`s satisfaction. Four criteria which can influence client`s satisfaction are considered. The criteria are service quality, treatment, decisions and behavior of medical stuff.

Research and publication analysis

Gathering customer feedback is common and powerful approach for evaluation of medication process. It becomes extremely important for medical establishments as quality of their services is crucial. Moreover, regular feedback can be used to identify issues during treatment process, and improve therapy approaches.

Patient feedback consists of the views and opinions of patients and service users on the care they have experienced [1]. Healthcare organizations can gather patient feedback in a variety of ways including surveys, audits, comments and complaints. Staff who work directly with patients can also offer a useful perspective. In addition, reliable evidence can be gathered systematically using a range of techniques including focus groups, one-to-one interviews and mystery shopping.

Research techniques such as surveys enable the gathering and analysis of a large number of views about certain issues. They generate data about the number of people who think about a topic in a particular way [2].

Many people will be familiar with paper-based questionnaires but there are a number of alternative ways of conducting surveys. These include: Online surveys which allow recipients to complete the questionnaire from a personal computer and submit their responses electronically [3]. Telephone surveys which are completed with a trained researcher talking a participant through each question and recording answers on their behalf. Issues can be explored in greater depth as they arise in conversation Hand-held electronic devices can be used for short, tailored surveys in a wide variety of situations such as onwards, in clinics or following consultations.

In most cases survey contains number of questions with answers that indicates satisfaction level by using patient friendly language in order to receive the most precise evaluation of concrete area of clinic functioning. Survey example represented in Table I. Such approach gives the most appropriate evaluation from customer perspective, but hardly can be aggregated and built into statistics trends. Also, establishments are often interested in single measure of satisfaction over time. As the result there is a need to transform unclear data into computable information[4].

Table I.

Clinic patient survey example

1. Did the healthcare provider explained about treatment being carried out for your patient?	
A	Excellent
B	Very Good
C	Good
D	Fair
E	Poor
2. Did anybody explained about decision taken by concerned specialist?	
A.	Never
B.	Sometimes
C.	Very often
D.	Always
3. Are you satisfied with the behavior of doctors?	
A.	Very rude
B.	Rude
C.	Blunt
D.	Neutral
E.	Excellent

This issue can be handled by using fuzzy logic systems - mathematical systems that emerged as a tool to deal with uncertain, imprecise, or qualitative decision-making problems.

Short Description of Fuzzy Inference System Approach

In the literature, this fuzzy logic system is often called the fuzzy logic controller since it has been mainly used as a controller. It was first proposed by, and has been successfully applied to a variety of industrial process and consumer products.

Instead of using a classic mathematical model to describe system, controllers incorporate integrated expert knowledge that are represented in structure close to the spoken language and described by linguistic variables and fuzzy sets. **Fuzzy system** performs reasoning on the input data by following a predefined inference method.

General fuzzy-controller structure contains the following components [5]:

– fuzzification unit;
– fuzzy logic rule base;
– decision making unit;
– defuzzification unit.

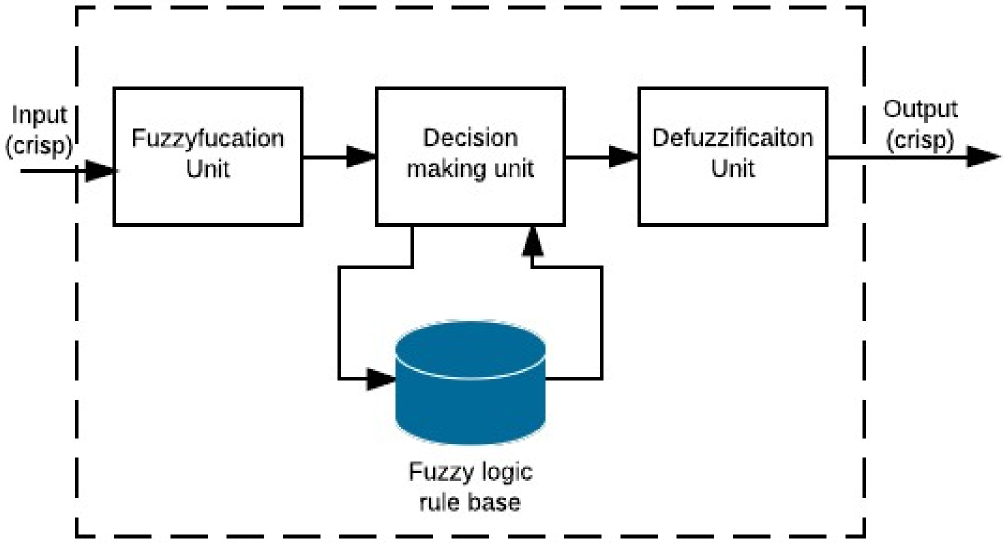

***Fig 1.** General Fuzzy inference system structure*

A fuzzifier is responsible for mapping any crisp value into proper values in fuzzy logic space. Fuzzy sets are indeed an extension of the classical sets in which only full membership or no membership exist. Fuzzy sets on the other hand, allow partial membership [6]. This work is done by using transactions from false to true (0 to 1) Mathematically, a membership function associates each element $\mu X(x)$ in the universe of discourse $U$with number in the interval $[0,1]$ as shown in (1):

$$\mu X: U \to [0,1] \quad (1)$$

Therefore, a fuzzifier maps crisp data $x \in U$ into a fuzzy set $X \in U$, and $\mu X(x)$ gives the degree of membership in the range [0, 1].

There are two extreme cases: $\mu X(x) = 0$ means $x \notin X$and $\mu X(x) = 1$ means $x \in X$ in the classical sense. But µX(x) = 0.2 means x belongs to X only with grade 0.2, or equivalently, x does not belong to X with grade 0.8.

For example, Fig. 2 shows different grades of an element, x, belonging to the set, X, specified by several sample (normalized) membership functions, $\mu X: X \to [0,1]$. A membership function differs from a probability density function in at least two aspects: the area under a membership function curve need not be one.

A set, X, along with a membership function defined on it, $\mu X(x)$, is called a fuzzy set and is denoted $(X, \mu X)$. This process of transforming a crisp value of an element (say x = 0.3) to a fuzzy set (say x = 0.3 ∈ X = [0, 1] with µX (x) = 0.2) is called fuzzification [7].

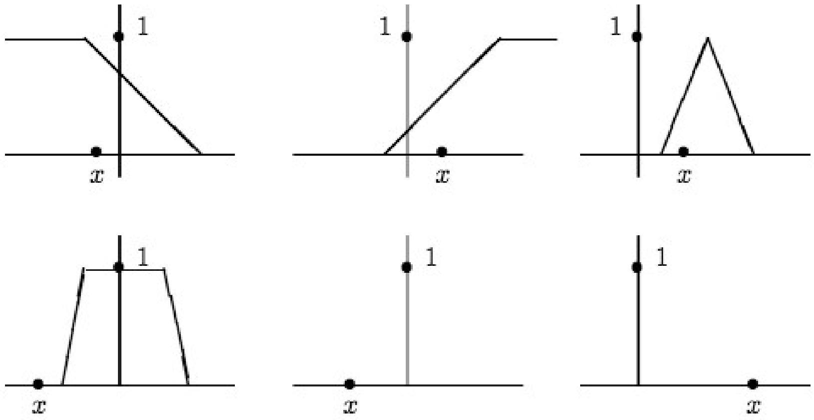

***Fig 2.** Examples of membership functions*

Fuzzy logic rule base

The majority of fuzzy logic control systems are knowledge based systems. This means that either their fuzzy models or their fuzzy logic controllers are described by fuzzy logic IF-THEN rules. These rules have to be established based on human expert's knowledge about the system, the controller, and the performance specifications, etc., and they must be implemented by performing rigorous logical operations.

The collection of all such "if … then …" principles constitutes a fuzzy logic rule base for the problem under investigation [8].

In terms of our domain logic simplified rule base can have following representation:

R(1): IF **Doctors Behaviour** is **Rude** THEN **Satisfaction** is **Low**
R(2): IF **Decision Explained** is **Sometimes** THEN **Satisfaction** is **Medium**;
R(3): IF **Treatment Explanation** is **Excellent** THEN **Satisfaction** is **Excellent**

Of course, this description only illustrates the basic idea, which is by no means a complete and effective design for feedback evaluation.

In general rule base of r rules has the form:

$$R(k): IF\ x_1\ is\ X\ k_1\ AND\ \cdot\cdot\ AND\ xm\ is\ Xkm\ THEN\ u\ is\ Uk \qquad (2)$$

where $m \geq 1$ and $k = 1, \cdots, r$

Decision making block use fuzzy rules (if - then) that are contained in rule base in order to convert fuzzy input to the necessary control actions that also has fuzzy nature. The amount of rules depends on both the number of inputs and membership functions associated to each input [9].

Once the input data have been numerically processed by fuzzy reasoning then they are converted back to the crisp values. This task to convert data into the crisp data is done by **defuzzifier**, or we can say that the defuzzifier combines together mathematically the result of each rule into a single crisp value [10].

Several method types are used to do so:

Maxima methods: By far the most common maxima method is to select the mean value of elements with maximum truth degrees (MOM method) The strength of maxima methods lies in their simplicity and speed of execution, but their major weakness is in not being truly fuzzy. They are section invariant and monotonous, but as a consequence of only considering elements of highest membership degrees, information not related to rules of maximal activation is ignored [11].

Area-based methods: A well-known area-based procedure is to select the defuzzification result as the centroid of the output possibility distribution COG method A close variant is the centre of area (COA) method which selects the crisp value as the position where the output area can be split into two equal halves. If the output distribution is symmetrical, the two methods give identical results [12].

Other methods: Modelled on the application of the COG procedure, several learning algorithms have been proposed for output defuzzication. The general idea underlying all these methods is to perform some transformation of the output possibility distribution according to an automatically generated set of parameters. A generic transformation on a fuzzy term X can be written as

$$v_x(x) = \mu(x)T(x) \quad (3)$$

where $\mu(x)$ is the new membership value of the element $x \in X, \mu_x(x)$ is the original value and $T(x)$ is any transformation function. Some examples of such functions are:

BADD method [8, 9]:

$$T(x) = \mu x(x)^{y-1} \quad (4)$$

where g is an automatically learned parameter.

SLIDE method [10]:

$$T(x) = \begin{cases} 1-\beta & (x \le \alpha) \\ 1 & (x > \alpha) \end{cases} \quad (5)$$

where α and β are parameters to be learned.

M -PTD method [11, 12]:

$$T(x) = \left[\sum_{j=0}^{N} \beta_j (\mu_x(x) - 0.5)^j \right]^2 \quad (6)$$

where β_j are parameters that are adaptively tuned and$\mu_x(x)$ and $T(x)$ are discrete functions[13].

In all of the above procedures, the kind of transformation induced by T x is a distortion of the output possibility distribution in order to increase or decrease the weight of elements of higher membership values. The more the transformation magnifies the differences between low and high membership values, the more the defuzzification method will approximate the MOM characteristic[14].

Fuzzy Controller design

In this fuzzy system, three parameters as linguistic variables are used that affect the quality of medication. The arguments which are taken for this research are: **Treatment, Decisions, Behavior**. Medication quality is taken as an output parameter. Figure 1 shows the input variables and output variables.

First that should be done during fuzzy controller design is definition of fuzzy variables. In our case, there are 3 variables: Treatment, Decisions, Behavior. Represented on Fig 3.

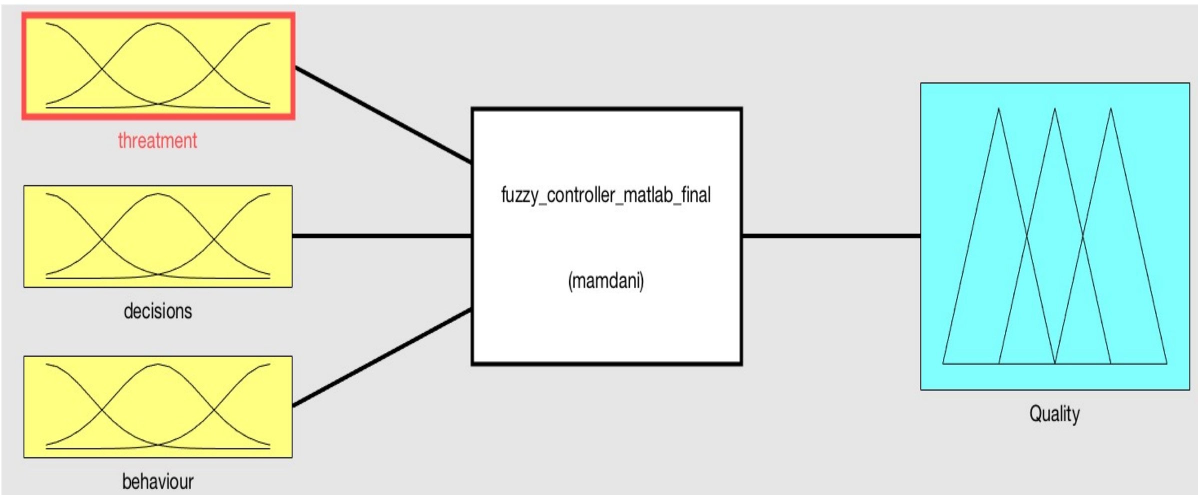

Fig.3. *Fuzzy inference system structure for evaluation of customer's feedback*

Based on the description of input and output variables number of rules are defined. Following is the description of some of the rules:

- 1. If (threatment is Poor) and (decisions is never) and (behaviour is Very_rude) then (Quality is Unsatisfactory) (1)
- 2. If (threatment is Excellent) and (decisions is Always) and (behaviour is Excellent) then (Quality is Excellent) (1)
- 3. If (threatment is Poor) or (decisions is never) or (behaviour is Very_rude) then (Quality is Unsatisfactory) (1)
- 4. If (threatment is Fair) or (decisions is Sometimes) or (behaviour is Rude) then (Quality is Neural) (1)
- 5. If (threatment is Good) or (decisions is Often) or (behaviour is Blunt) then (Quality is Good) (1)
- 6. If (threatment is Excellent) and (decisions is not never) and (behaviour is not Rude) then (Quality is Excellent) (1)

Input Membership Functions

As was mentioned, there are three input variables (**Treatment, Decisions, Behavior)**. Each is taken in this research based on fuzzy system. These variables use different membership functions.

For instance, Treatment has four membership functions to represent Poor, Fair, Good and Excellent as shown in Fig. 3. These functions are triangular. Membership functions for other variables shown on Fig.4 -5.

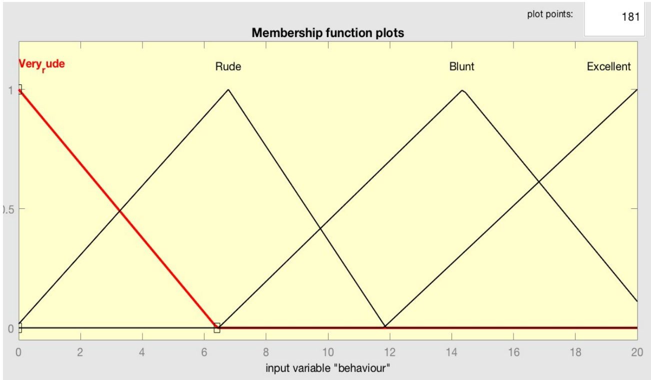

Fig 3. *Membership functions for fuzzy Variable “Behavior”*

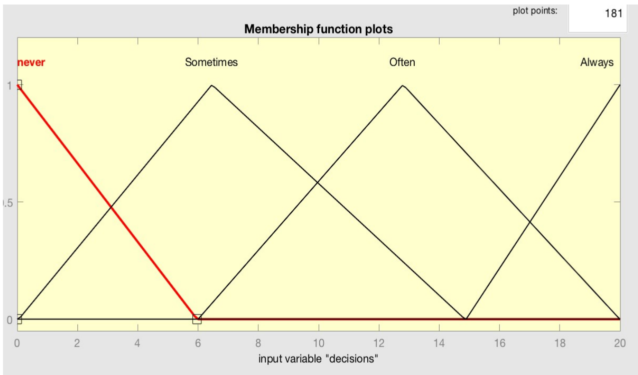

Fig 4. *Membership functions for fuzzy variable “Decisions”*

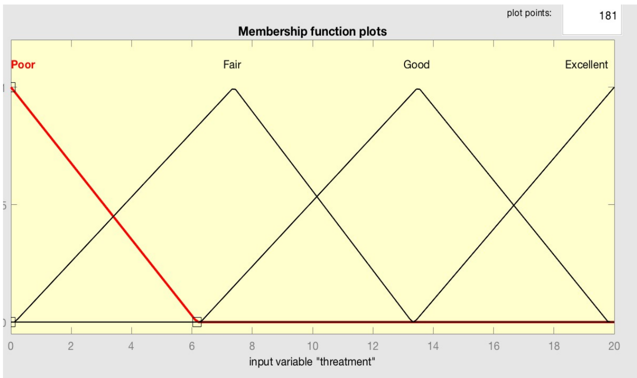

Fig 5. *Membership functions for fuzzy variable “Threatment”*

Output Membership Function

There is one variable named Quality is used as an output which has four levels: Unsatisfactory, Neural, Good, Excellent as shown in Figure 6. All these four levels are defined by the triangular membership function.

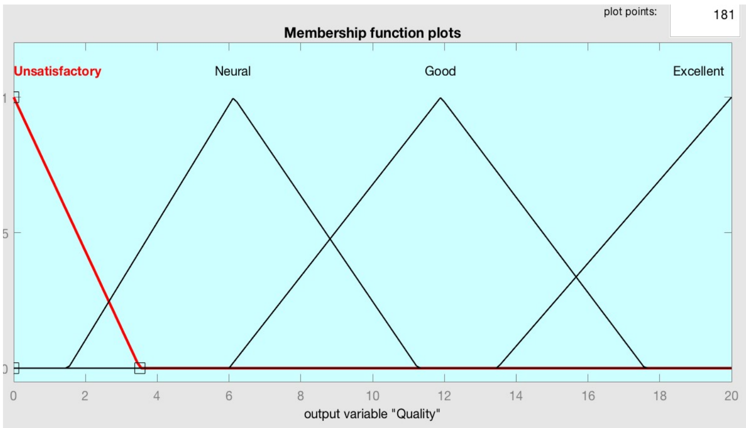

Fig 6. *Output fuzzy variable "Quality"*

The input-output graph for the fuzzy controller shown Fig. 7-8.

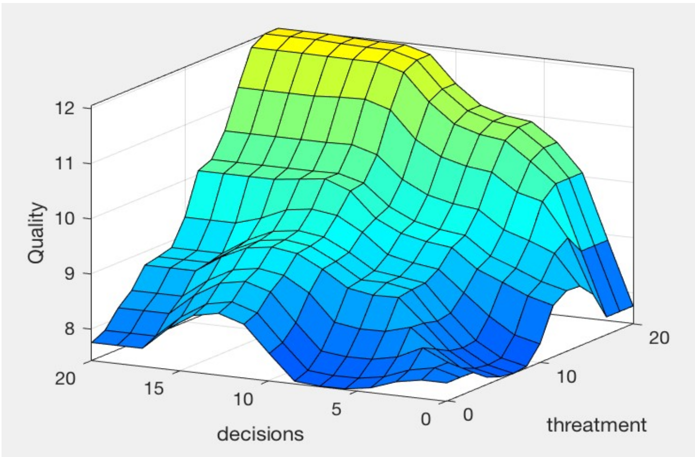

Fig. 7. *Decisoins, Threatment, Quality input –output graph of fuzzy controller.*

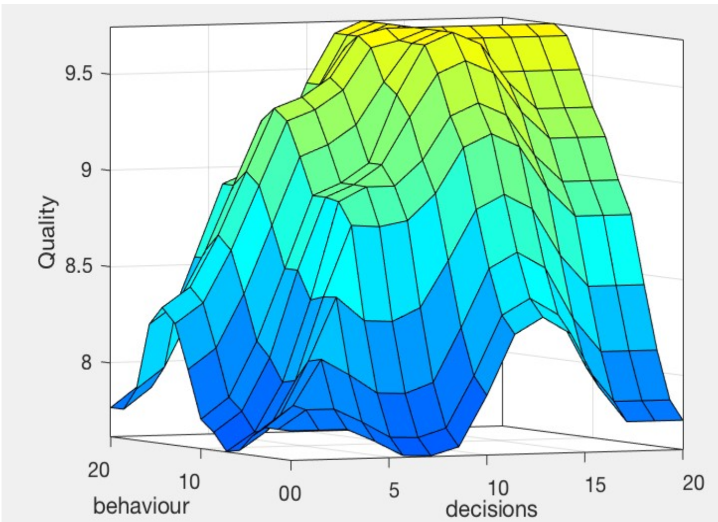

Fig 8. *Behaviour, Decisoins, Quality input –output graph of fuzzy controller.*

For controlling the inferred fuzzy control action to real value, centroid method is used.

Conclusions:

1. Measures of patient experience vary widely, and measurement is not routinely conducted in a standardized way.
2. Several challenges exist to measurement of patient experience, in part, because it is a complex, ambiguous concept that lacks a common or ubiquitous definition and because there are multiple cross-cutting terms in health care that make conceptual distinction (and therefore measurement) difficult.
3. Fuzzy logic can be effectively used to consolidate number of medication parameters and provide meaningful result of medication quality and patients satisfaction. Patients feedback can be expressed in form of linguistic variables processed by fuzzy reasoning system and transformed into measurable representation of medical establishments clients satisfaction.

References:

1. Institute of Medicine. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington, DC: The National Academies Press; 2001. 2. (in Eng.)
2. Centers for Medicare & Medicaid Services (CMS). Hospital Consumer Assessment of Healthcare Providers and Systems (HCAPS) Fact Sheet. Baltimore; 2013. (in Eng.)
3. Lee H, Vlaev I, King D, Mayer E, Darzi A, Dolan P. Subjective well-being and the measurement of quality in healthcare. Soc Sci Med; 2013. (in Eng.)
4. Wolf J.A., Niederhauser V., Marshburn D., LaVela S.L., Operationalizing and defining the patient experience. Patient Experience Journal. 2014. Vol. 1; pp. 7-19. (in Eng.)
5. C. C. Lee. ―Fuzzy logic in control systems: Fuzzy logic controller- part 1, II IEEE trans. Syst., Man, Cybern., Vol. 1. (in Eng.)
6. L. A. Zadeh, "Fuzzy sets," Inform. and Contr., 1965. Vol. 8, pp. 338-353. (in Eng.)
7. K. S. Rattan, G. S. Sandhu, ―Analysis and design of proportional plus derivative fuzzy logic controller, Proc. National Aeronautics and Electronics Conference, Dayton, 1996. (in Eng.)
8. Mamdani, E. H., Assilian, S., An Experiment in Linguistic Synthesis with a Logic Controller, Int. J. Man – Machine Studies 8. 1975. pp. 1 – 13. (in Eng.)
9. J. Zhang, S. LANG, ―Explicit self-tuning control for a class of nonlinear systems, II Automatica, 1989. Vol. 25, pp.593-596. (in Eng.)
10. M. Sugeno, Industrial Applications of Fuzzy Control, North-Holland. 1985. (in Eng.)
11. T. Takagi, M. Sugeno, Fuzzy Identification of Systems and Its Application to Modeling and Control, IEEE Trans. on Sys. Man and Cybernetics. 1985. Vol. 15, No.1, pp.116-132. (in Eng.)
12. L. J. Huang, M. Tomizuka, "A Self-Paced Fuzzy Tracking Controller for Two-Dimensional Motion Control, IEEE Trans. Syst. Man Cybem., Vol. SMC-20, no. 5, pp. 1115-1124, Sept./Oct. 1990. (in Eng.).
13. B. Kosko, Neural Networks and Fuzzy Systems. New Jersey: Prentice Hall, 1992. (in Eng.)
14. H. T. Nguyen, "Uncertain If-Then Rules Based on Mathematical Conditionals," IEEE International Conference on Fuzzy Systems, 1992. (in Eng.)

❖❖❖