WATER LEVEL CONTROL SYSTEM BY USING FUZZY LOGIC

Ivan ŠUŠTER
Darjan KARABAŠEVIĆ
Dragiša STANUJKIĆ
Gabrijela POPOVIĆ
Oliver MOMČILOVIĆ

Abstract: *An overview of fuzzy logic concepts, fuzzy sets, and their workings is given in this paper as it investigates the use of fuzzy logic in water level management systems. It deals about how well fuzzy controllers work to manage water levels and how their control performance and flexibility are superior to those of conventional approaches. Examined are several fuzzy controller types, such as Sugeno, Mamdani, and interval type 2 controllers, demonstrating their suitability for a range of situations. Fuzzy logic is used in case studies to show how it may be used to control water levels in reservoirs, dams, and storage tanks while providing benefits including fault tolerance, non-linearity, and real-time manipulation. The application of fuzzy logic provides a solid solution for accurate and effective water level regulation in industrial settings, and the paper's conclusion highlights this improvement in control performance.*
Keywords: *Fuzzy Logic, Water Level Control, Fuzzy Controllers, Industrial Processes, Control Systems*

INTRODUCTION

Water level control in tanks is important for many industrial plants. It is also very important to have accurate data on the current water level as well as the possibility of setting input parameters such as the maximum and minimum value of water that can be found in the tank. This is of key importance in order to ensure safety, ie. prevent water spills or insufficient water to perform some key processes.

In the first part, the basics of fuzzy logic and fuzzy sets, operations on them as well as relations will be presented, the concept of linguistic variables and other basic terms from fuzzy logic will be described. After that fuzzy controllers will be presented, how they work and some basic types of fuzzy controllers. After the basic terms and an introduction to fuzzy logic, the systems that can be used to control the water level in the tank without and with the application of fuzzy logic will be described and some important researches in that area will be highlighted.

FUZZY LOGIC

Fuzzy logic is increasingly used in various fields (Stanimirović et al., 2023; Ulutas et al., 2023; Karabašević et al., 2022; Aksakal et al, 2022; Tomašević et al., 2020; Stanujkic et al, 2017). Fuzzy logic is a generalization of classical mathematical logic. Unlike classical logic, where an element clearly belongs or does not belong to a set, fuzzy logic allows significantly greater possibilities in terms of expressing the uncertainty of knowledge, whereby fuzzy logic allows an element to belong to a set with a certain degree of membership, which is usually a real number from interval [0, 1]. Fuzzy logic is characterized by the possibility of applying qualitative terms to express the indeterminacy of knowledge, that is, relatively simple quantification of qualitative terms by applying membership functions.

Fuzzy logic as a concept is much more natural than it seems at first glance. There are examples and situations when knowledge about the system cannot be presented in a precise way. In order to present knowledge about such systems, it is necessary to renounce classical (binary) logic in which something is either true or false (black or white) and to use fuzzy logic (everything is a shade of gray) (Pamučar, 2010).

One of the important features of fuzzy logic is that it is based on natural language, on the basics of human communication. Inputs and outputs can have different linguistic names. The usual variables are called descriptive names, such as: water level, water inflow, people of medium height, big earnings, fast cars, short distances, etc. The transformation of such expressions into a form Mathematical representations are enabled by the theory of fuzzy sets (Jovanović, 2018).

FUZZY SETS

Fuzzy logic was introduced by Zadeh in 1960, and by means of fuzzy logic one can determine the membership of a set as already mentioned. Fuzzy sets have attracted much attention in various fields, including control systems, pattern recognition, decision making, and artificial intelligence.

Classical (mathematical) sets are familiar to everyone from mathematics. In mathematics, a set is a basic concept. Sets can be represented in several ways, the first way is by listing all the elements that belong to the set between curly brackets, e.g. the set A can be represented as following.

$$A=\{1,2,3,4,5,6\}$$

For this set can be said to be a finite set with elements 1, 2, 3, 4, 5 and 6. If an element is in the set , it can be represented using the sign of belonging, that is, it can be written that and element x can be said to belong to set A.

In addition to this example, some other examples of finite and infinite sets are:

$$A=\{1,2,3,4,...,n\}$$

This set A can be said to be a finite set with a large number of elements that cannot be listed all, and that is why three points are used, which continue the set according to the same pattern. It is important to note that the pattern must be obvious.

Examples of an infinite set is $N=\{1,2,3,4,\ldots\}$ which represents the set of all natural numbers.

Another way of representing sets is by specifying a set property that all its elements must have, and such a set can be represented as following, $A=\{x|x \leq N, x\leq 5\}$, reads: the set A contains elements x such that they are natural numbers less than or equal to the number 5.

Mathematical sets can be illustrated with an example. If it is assumed that 25 to 30 degrees Celsius is warm, and all other values do not represent a temperature that is warm, it can be represented mathematically in the following way.

$$\mu_A(x) = \begin{cases} 1, x \in [25,30] \\ 0, x \notin [25,30]. \end{cases}$$

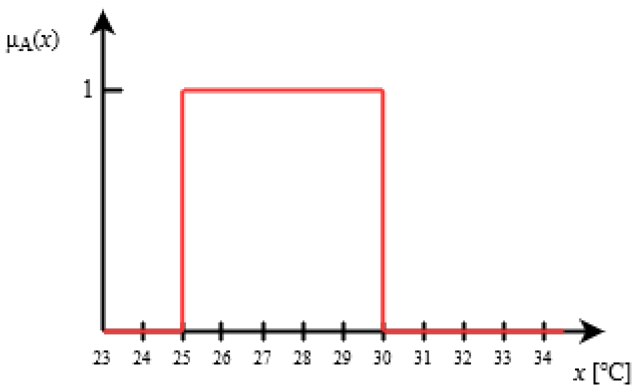

Figure 1 The graph of the temperature interval from the previous function

With fuzzy sets, membership in a set is measured by a real number from the interval [0, 1], which determines how much something belongs to a certain set. Below is the definition of fuzzy sets.

Definition 1. The fuzzy set over the universal set , denoted by , is a set of ordered pairs (Jovanović, 2018):

A={(x,μ_A (x)) | x ∈ X}

where

μ_A: X →[0,1],

represents the fuzzy membership function of set A. This function assigns to each element its degree of membership in fuzzy set A. ■

From the definition, it can be concluded that fuzzy sets are defined by the membership function of its elements.

In order to better illustrate this definition, the previous example with temperature can be used, only this time there will not be a strict limit, i.e. we cannot for example say that it is cold if the temperature is 29.8 degrees Celsius, because the difference is too small to notice, but if the temperature is 15 degrees Celsius, it can already be claimed that it is colder, so it is necessary to determine whether it is fresh, pleasant, hot for each temperature value. Considering these three divisions, it can be said in this example that a pleasant temperature of 20 to 30 degrees Celsius, from 30 to 35 degrees is warm, everything above 35 is hot, and temperatures from 15 to 20 are fresh. Now this fuzzy set A can be described mathematically, i.e. it's membership function.

$$\mu_A(x) = \begin{cases} 0 & x < 15 \\ \dfrac{x - 15}{20 - 15} & 15 \le x < 20 \\ 1 & 20 \le x \le 30 \\ \dfrac{35 - x}{35 - 30} & 30 < x \le 35 \\ 0 & x > 35 \end{cases}$$

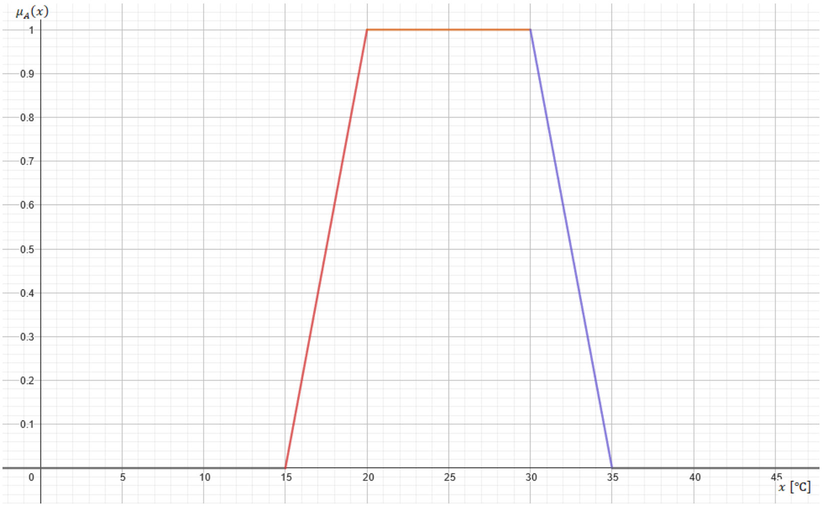

Figure 2 Membership function graph from the example

CHARACTERSTICS OF FUZZY SETS

In order to see the operations on fuzzy sets, it is necessary to first define the characteristics of fuzzy sets (Bergmann, Merrie, 2008).

Definition 2. The support of the fuzzy set A defined on the universal set U, denoted by supp(A), is a subset of the set U such that (Jovanović, 2018):

$$\mathrm{supp}(A)= \{x \in U \mid \mu_A (x)>0\}$$

which means that the support of the fuzzy set A consists of all elements from the universal set U greater than 0.

Definition 3. The core of the fuzzy set A defined on the universal set U, denoted by core(A), is a subset of the set U such that:

$$\mathrm{core}(A)= \{x \in U \mid \mu_A (x)=1\}$$

that is, the core of the fuzzy set A consists of elements from the universal set U whose value of the membership function is equal to unity (Jovanović, 2018).

Definition 4. The height of the fuzzy set A defined on the universal set

U, denoted by hgt(A) or height(A), is defined as (Jovanović, 2018):

$$hgt(A) = \sup_{x \in U} \mu_A\ (x)$$

Definition 5. A fuzzy set A is said to be normalized if and only if hgt(A)=1. Otherwise, it is subnormalized (Jovanović, 2018).

OPERATIONS ON FUZZY SETS

As with ordinary sets in mathematics, fuzzy sets also have operations that can be performed on them.

Let A and B be fuzzy sets in the universal set U.

Definition 6. Let the sets A and B be defined on the universal set U. The membership function of the union of sets in the label is defined by (Subašić, 1997)

$$\mu_{A \cup B}(x) = max\{\mu_A(x), \mu_B(x)\}, \forall x\ \in\ U$$

Definition 7. Let the sets A and B be defined on the universal set U. The membership function of the intersection of sets in the label is defined by (Subašić, 1997)

$$\mu_{A \cap B}(x) = min\{\mu_A(x), \mu_B(x)\}, \forall x\ \in\ U$$

Definition 8. Let the sets A and B be defined on the universal set U, are equal in the notation A=B, if and only if: $\mu_A(x) = \mu_B(x),\ \forall x\ \in U$ that is, if their membership functions are the same for every x from the universal set U (Subašić, 1997).

Definition 9. Let the sets A and B be defined on the universal set U, the fuzzy set A is a subset of the set B in the notation $A \subseteq B$, if and only if: $\mu_A(x) \leq \mu_B(x),\ \forall x\ \in\ U$ (Ross, 2004).

Definition 10. If the set A is defined on the universal set U, the membership function of the complement to the fuzzy of the set $A\ \bar{A}$, in the notation $\mu_{\bar{A}}(x)$ is defined as $\mu_{\bar{A}}(x) = 1 - \mu_A(x), \forall x\ \in U$ (Ross, 2004).

LINGUISTIC VARIABLES

Linguistics, as a science that deals with the study of language, encounters many difficulties when it is necessary to analyze and define some phenomena. Thus, due to the subjective nature of linguistic variables and the lack of clear boundaries, such as cold, pleasant, hot, precise quantification is difficult. The use of fuzzy logic provides an easier and more precise representation of the problem, which overcomes the imprecision and uncertainty of linguistic variables.

By using language, we are able to define some ideas, that is, linguistic variables, which serve as subjective conceptions. Unlike mathematical sets, fuzzy sets have degrees of membership, in order to take into account progressive changes between different values. As can be seen in the previous examples, different linguistic variables have different degrees of membership, which are used to express linguistic variables.

Fuzzy logic offers a framework for decision-making, as fuzzy membership functions translate linguistic variables into output variables, and fuzzy rules, both of which constitute a fuzzy system. A fuzzy system can successfully handle input and perform tasks using fuzzy rules and fuzzy logic operators.

The use of linguistic variables in fuzzy logic has important practical applications, linguists can better understand and analyze language by using fuzzy logic. Also, the introduction of linguistic factors into computer models helps to create intelligent systems that are capable of understanding natural languages.

RELATIONSHIPS IN FUZZY LOGIC

Unlike ordinary relations that describe a relationship, i.e. connection between two elements, with fuzzy relations it is possible for the elements to be in a certain degree in the relation, that is, it describes the relations between the elements.

Definition 11. Let and be two classical sets, and the fuzzy relation between these two sets is a fuzzy set defined on the Cartesian product:

$$A \times B = \{(a,b) \mid a \in A, b \in B\}$$

then the relation is:

$$\mathcal{R} \subseteq A \times B = \{(a,b), \mu_{\mathcal{R}}(a,b) \mid (a,b) \in A \times B, \mu_{\mathcal{R}}(a,b) \in [0,1]\}$$

where μ_R represents the membership function, that is, it represents the degree of membership of the ordered pair . The degree of affiliation shows the degree to which is related to , in the interval [0, 1] (Bojadziev, Bojadziev, 1999).

That is, the general form of the fuzzy relation definition can be written in the following form:

$$\mathcal{R} = \{((a_1, a_2, \ldots, a_n), \mu_{\mathcal{R}}(a_1, a_2, \ldots, a_n)) \mid (a_1, a_2, \ldots, a_n) \in A_1 \times A_2 \times \ldots \times A_n\}$$

where is the membership function of the relation .

OPERATIONS WITH FUZZY RELATIONSHIPS

Let R_1 and R_2 be two relations defined over A ×B, and membership functions $\mu_{\mathcal{R}_1}(a,b)$ and $\mu_{\mathcal{R}_2}(a,b)$.

Definition 12. Two relations are equivalent in the notation $\mathcal{R}_1 = \mathcal{R}_2$ if and only if for every pair $(a,b) \in A \times B$, $\mu_{\mathcal{R}_1}(a,b) = \mu_{\mathcal{R}_2}(a,b)$, (Bojadziev, Bojadziev, 1999).

Definition 13. For every pair for which $\mu_{\mathcal{R}_1}(a,b) \leq \mu_{\mathcal{R}_2}(a,b)$ holds, $\mathcal{R}_1$ is said to be an inclusion of or that $\mathcal{R}_1 \subseteq \mathcal{R}_2$ is greater than in the notation $\mathcal{R}_1 < \mathcal{R}_2$. If it is true that and at the same time it is true that there is at least one pair $(a,b) \in A \times B$ such that $\mu_{\mathcal{R}_1}(a,b) < \mu_{\mathcal{R}_2}(a,b)$ then $\mathcal{R}_1 \subset \mathcal{R}_2$ (Bojadziev, Bojadziev, 1999).

Definition 14. $\mathcal{R}^C$ is the complement of $\mathcal{R}$ and is defined as (Bojadziev, Bojadziev, 1999):

For each pair $(a,b) \in A \times B, \mu_{\mathcal{R}^C}(a,b) = 1 - \mu_{\mathcal{R}}(a,b)$

Definition 15. The intersection of two relations $\mathcal{R}_1 \cap \mathcal{R}_2$ is defined as (Bojadziev, Bojadziev, 1999):

$$\mu_{\mathcal{R}_1 \cap \mathcal{R}_2}(a,b) = min\{\mu_{\mathcal{R}_1}(a,b), \mu_{\mathcal{R}_2}(a,b)\}, \quad (a,b) \in A \times B$$

Definition 16. The union of two relations $\mathcal{R}_1 \cup \mathcal{R}_2$ is defined as (Bojadziev, Bojadziev, 1999):

$$\mu_{\mathcal{R}_1 \cup \mathcal{R}_2}(a,b) = max\{\mu_{\mathcal{R}_1}(a,b), \mu_{\mathcal{R}_2}(a,b)\}, \quad (a,b) \in A \times B$$

BASIC MEMBERSHIP FUNCTIONS

Membership functions are simple one-argument parametric functions that calculate the degree of membership of a fuzzy set. Some basic affiliation functions are (Fuzzy Logic Toolbox):

Definition 17. The triangular membership function is determined by three parameters where $a < b < c$ is valid:

$$\mu_x = \begin{cases} 0 & , x < a \\ \dfrac{x-a}{b-a} & , a \leq x \leq b \\ \dfrac{c-x}{c-b} & , b \leq x \leq c \\ 0 & , x > c \end{cases}$$

Definition 18. The trapezoidal membership function is determined by four parameters where $a < b < c$ is valid:

$$\mu_x = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a}, & a \leq x \leq b \\ 1, & b \leq x \leq c \\ \frac{d-x}{d-c}, & c \leq x \leq d \\ 0, & x > d \end{cases}$$

Definition 19. The Gaussian membership function G:X→[0,1] is given by two parameters (Jovanović,2018):

$$G(x;\ \alpha, \beta) = e^{-\beta(x-\alpha)^2}$$

where α represents the center point and β defines the slope of the function.

Definition 20. The sigmoid membership function or σ function, σ:X →[0,1] is defined by two parameters as follows (Jovanović, 2018):

$$\sigma(x; \alpha, \beta) = \frac{1}{1 + e^{-\beta(x-\alpha)}}$$

FUZZY CONTROLLERS

Fuzzy controllers are a type of control system that uses fuzzy logic to make decisions and control processes. Fuzzy logic enables the representation and manipulation of imprecise information. Fuzzy controllers are particularly useful in situations where information is imprecise.

The basic structure of the fuzzy controller consists of three basic components:

• Fuzzifier - converts the input values into a set of fuzzifiers, which represent the linguistic variables used in the control system.

• Inference engine - applies fuzzy logic rules to fuzzy sets to determine what actions to take.

• Defuzzifier - converts the fuzzy output into control signals.

One of the advantages of fuzzy controllers is the ability to control complex and non-linear systems. In this case, the reasoning mechanism, or the algorithm that uses fuzzy logic to make a decision based on the input variables, is called a Fuzzy Logic Controller (FLC).

There are several types of fuzzy controllers that are commonly used, some of them are:

Mamdani type fuzzy controller is one of the most commonly used type of fuzzy controller. This controller uses fuzzy rules that relate input variables to output variables using linguistic variables. Fuzzy rules represent a control strategy, the output of the fuzzy controller is a fuzzy set over which defuzzification is performed to obtain a control signal.

The Sugeon fuzzy controller, also known as Takagi-Sugeon-Kang (TSK), uses fuzzy rules that relate input variables to linear or nonlinear mathematical functions. Unlike the Mamdani-type controller, this controller provides an output that does not need to be defuzzified.

The interval type 2 fuzzy controller is based on the type 1 fuzzy controller that can handle higher levels of uncertainty. They use fuzzy sets, which allow the representation of uncertainty in the membership function (Hassani et al, 2015).

General type 2 fuzzy controllers are also based on type 1 controllers that provide a more detailed representation of uncertainty. They use fuzzy sets that allow uncertainty to be represented in the membership function and in the set of fuzzy rules. These controllers can provide more precise control in complex and uncertain systems.

Each type of fuzzy controller has its advantages and situations in which it can be applied. Mamdani type controllers are widely used in various control systems due to their easy implementation. The Sugeno type of controller is often used when the control strategy can be represented by mathematical functions. Interval type 2 and general type 2 controllers are suitable for systems with a high degree of uncertainty.

WATER LEVEL COTROL SYSTEM USING FUZZY LOGIC

Controlling the water level in the reservoir plays a very important role in many industries. The ability to precisely maintain and regulate the water level in the tank is essential for ensuring performance, safety and efficiency.

Water storage and distribution systems are crucial for various purposes such as use in industrial processes. In industrial plants, tanks are usually used to store and process liquids, including water, fuels, etc. Effective water level management is critical to maintain the integrity of industrial processes. Insufficient water levels can lead to malfunctions, reduced process efficiency, and even safety hazards. In addition, too much water in the reservoir can lead to overflow and loss of resources.

Over the years, numerous researches have been conducted on the topic of applying fuzzy logic in water level control systems. Research has mainly focused on the performance, efficiency and advantage of fuzzy logic over traditional methods. In the following, we will discuss the traditional methods as well as the advantages of using fuzzy logic.

In 2003, Mahabir et al, conducted research on reservoir water level control using fuzzy logic. They implemented a fuzzy controller in the water tank system to improve the control performance. The study used a two-dimensional fuzzy controller based on Fuzzy Logic Controller (FLC) to regulate the water level in the reservoir. The control algorithm is designed to take advantage of the water tank system and improve the control performance compared to the PID controller. The results showed that the fuzzy controller achieved better control performance in terms of reducing the regulation error and maintaining the water level (Mahabir et al, 2003).

Another research in the application of fuzzy logic to control the water level in the tank was done by Ilyas with a group of scientists in 2022. They used a fuzzy logic controller to stabilize the water level in the tank. A fuzzy logic controller was used to control the liquid level by adjusting the flow rate of the liquid entering and leaving the tank. The study showed the effectiveness of the fuzzy logic controller in maintaining the water level in a certain range (Ilyas et al, 2022).

In a study conducted by Castillo in 2016, they compared different types of fuzzy logic systems in control problems and implemented a fuzzy controller to fill a water storage tank. The study used a type 2 generalized fuzzy logic controller with an output called a valve that controlled the opening of the outlet valve based on the water level and opening speed (Castillo et al, 2016).

In 2022, Khairudin and a group of scientists designed a system for automatic control of water levels for dams, using fuzzy logic. The system uses a water flow sensor to measure water discharge, and the sensor reading or data is processed using fuzzy logic to control gate opening and dam condition. The system was intended to evenly distribute the flow of water and provide information or early warning about potential floods (Khairudin et al, 2022).

From the mentioned researchs, it can be concluded that the application of fuzzy logic in the control of the water level in the reservoir gave solid results in improving the control performance and maintaining the desired water level. Fuzzy logic controllers offer advantages such as fault tolerance, non-linearity, real-time manipulation. These controllers can efficiently regulate the water level in the reservoir by adjusting input variables based on linguistic rules and fuzzy inference.

Water level control systems are designed to monitor and regulate the water level in tanks. These systems use a combination of sensors, valves and algorithms that control and precisely maintain the desired water level.

The sensors used to measure the current water level in the tank can be of different types, e.g. there are float sensors, pressure sensors, ultrasonic sensors. These sensors provide real-time water level data, which is of great importance for effective tank water level control.

In addition to the sensors, there are also valves and they are responsible for regulating the water level in the tank based on the signals and data from the sensors. Depending on the requirements, different valves and pumps can be used to help regulate the water level.

The control system consists of electronic and software components that receive input data from sensors, process them with control algorithms and generate output, i.e. signals that are sent to the valves. The control system compares the desired water level with the actual water level to determine what action needs to be taken to bring the level to the desired level. The control system, in addition to controlling the water level, can also broadcast warnings about the water level, store data, etc.

There are several ways to implement a water level control system, the simplest system is when the water level exceeds certain limits the valve opens or closes, the problem with this system is that this process can be repeated often and lead to failure.

Proportional control adjusts the water flow in proportion to the deviation between the desired and current water level. The valve is controlled to open or close based on the size of the error.

PID control uses proportional, integral and derivative control to achieve precise water level regulation. Proportional mode controls the valve based on error, integral mode accumulates error over time to eliminate steady state errors, and derivative mode predicts future changes in water level. PID control is used in many applications that require precise and dynamic water level control.

In addition to these, there are more advanced systems, such as predictive model control or adaptive control. These systems use mathematical models and algorithms to control the water level based on the dynamics of the process.

Control systems using fuzzy logic have emerged as an effective way of solving water control problems or in some other systems where control is required. These systems use fuzzy sets, linguistic variables, rule-based decision-making to achieve precise and highly adaptive control, which is very similar, in terms of decision-making, to humans.

Control systems are based on fuzzy sets, which allow representing imprecise and uncertain information. Compared to traditional control systems that rely on precision values, fuzzy logic control systems use linguistic variables and membership functions to determine the output value.

A control system that uses fuzzy logic consists of components, and these components are:

• Fuzzification - is the process of translating numerical values into linguistic variables using the membership function. As mentioned membership functions determine the degree of membership of some input variable.

• Rule-based inference - includes defining a set of rules, the relationship between input and output linguistic variables.

• Defuzzification - is the process of translating the fuzzy output from rule-based inference into a numerical value. The output value represents the action that is applied to the system that needs to be controlled, in this case the water level control system, i.e. valve adjustment.

The advantages achieved by using a fuzzy logic control system are (Jibril, Mustefa, 2014):

• The system is adaptable, i.e. it can manage imprecise information and this makes it suitable for application in different conditions,

• Non-linear functions of arbitrary complexity can be modeled with fuzzy logic to the desired degree of accuracy,

• Works better than classic PID controllers,

• It provides a better way to map the input space to the output space,

• Used for multi-input, multi-output modeling,

• Simple design and implementation.

CONCLUSION

Finally, it should be noted that the use of fuzzy logic in water level control systems has significantly improved control performance and the ability to maintain target water levels. Fuzzy logic controllers are superior to conventional techniques in a number of ways, including fault tolerance, adaptation to non-linear systems, and real-time manipulation capabilities, as demonstrated by numerous research projects.

Fuzzy logic controllers offer a strong foundation for accurate and flexible control. They are distinguished by elements like defuzzification, rule-based inference, and fuzzification. They make efficient use of membership functions and linguistic variables to handle vague and imprecise information.

Research has demonstrated the effectiveness of fuzzy logic controllers in several scenarios related to water level control, including reservoir management and dam flood control systems. By modifying input variables in accordance with linguistic norms and fuzzy inference, these controllers provide precise regulation of water levels, guaranteeing the integrity and effectiveness of industrial processes that depend on water management.

Furthermore, fuzzy logic systems are more adaptable, simple to design and implement, and have the capacity to describe complex non-linear functions than standard control systems like PID controllers. This makes them ideal for a wide range of uses that call for accurate and dynamic control, such as managing the water level in tanks and reservoirs.

REFERENCES

"Fuzzy Logic Toolbox" in MathWorks Documentation Available: https://www.mathworks.com/help/fuzzy/ (Accessed: 29.06.2023.)

Aksakal, B., Ulutaş, A., Balo, F., & Karabasevic, D. (2022). A new hybrid MCDM model for insulation material evaluation for healthier environment. Buildings, 12(5), 655.

algebras, and derivation systems, Cambridge University Press, 2008.

Bergmann, Merrie. *An introduction to many-valued and fuzzy logic: semantics,*

Bojadziev G., Bojadziev M.; Fuzzy logic for business, finance and management, World Scientific 1999.

Castillo, O., Amador-Angulo, L., Castro, J., García-Valdez, M. (2016). A Comparative Study Of Type-1 Fuzzy Logic Systems, Interval Type-2 Fuzzy Logic Systems and Generalized Type-2 Fuzzy Logic Systems In Control Problems. Information Sciences, (354), 257-274.

Hassani, Hossein and Jafar Zarei, (2015). „Interval Type-2 Fuzzy Logic Controller Design For the Speed Control Of DC Motors", Systems Science & Control Engineering(3), 1:266-273.

Ilyas, Muhammad, Syed Ali Raza Shah, Arshad Rauf, Yousaf Khalil, and Muhammad Ayaz, (2022). „Stabilization Of Liquid Level In a Tank System Based On Fuzzy Logic Controller", IJRA(11), 4:315.

Jibril, Mustefa. (2014). Water Level Control using Fuzzy Logic System. 10.13140/RG.2.2.17812.42885.

Jovanović R., 2018, *Fazi upravljački sistemi*, Beograd, Mašinski fakultet u Beogradu, 2018. (In Serbian)

Karabašević, D., Ulutaş, A., Stanujkić, D., Saračević, M., & Popović, G. (2022). A new fuzzy extension of the simple WISP method. Axioms, 11(7), 332.

Khairudin, M., M. L. Hakim, O. A. Rahmawan, W. N. Alfiati, A Widowati, and E. Prasetyo, (2022). „Design Of Automatic Water Level Control System Using Fuzzy Logic", J. Phys.: Conf. Ser.(2406), 1:012006.

Köse, Utku & Deperlioglu, Omer. (2015). FL-LAB v2: Design and Development of an

Easy-to-Use, Interactive Fuzzy Logic Control Software System. Applied Mathematics & Information Sciences. 9. 883-897. 10.12785/amis/090237.

Mahabir, C., Hicks, F., Fayek, A. (2003). Application Of Fuzzy Logic To Forecast Seasonal Runoff. Hydrol. Process., 18(17), 3749-3762.

Pamučar, D. (2010). Primena fuzzy logike i veštačkih neuronskih mreža u procesu donošenja odluke organa saobraćajne podrške. Vojnotehnički glasnik, 58(3). (In Serbian)

Ross, T.J., 2004, Fuzzy Logic with Engineering Applications. John Wiley & Sons, Ltd, 2004.

Stanimirović, P. S., Ivanov, B. D., Stanujkić, D., Kazakovtsev, L. A., Krutikov, V. N., & Karabašević, D. (2023). Fuzzy Adaptive Parameter in the Dai–Liao Optimization Method Based on Neutrosophy. Symmetry, 15(6), 1217.

Stanujkic, D., Zavadskas, E. K., Karabasevic, D., Urosevic, S., & Maksimovic, M. (2017). An approach for evaluating website quality in hotel industry based on triangular intuitionistic fuzzy numbers. Informatica, 28(4), 725-748.

Subašić, P., *Fazi logika i neuronske mreže*. Tehnička knjiga, Beograd, 1997. (In Serbian)

Tomašević, M., Lapuh, L., Stević, Ž., Stanujkić, D., & Karabašević, D. (2020). Evaluation of criteria for the implementation of high-performance computing (HPC) in Danube Region countries using fuzzy PIPRECIA method. Sustainability, 12(7), 3017.

Ulutaş, A., Topal, A., Karabasevic, D., & Balo, F. (2023). Selection of a forklift for a cargo company with fuzzy BWM and fuzzy MCRAT methods. Axioms, 12(5), 467.

Notes on the authors

Ivan ŠUŠTER, B.Sc., is a M.Sc. student at the Faculty of electronic engineering, University of Niš. E-mail: ivansu995@gmail.com

Darjan KARABAŠEVIĆ, Ph.D. is a Full Professor and Dean of the Faculty of Applied Management, Economics and Finance, University Business Academy in Novi Sad. E-mail: darjan.karabasevic@mef.edu.rs

Dragiša STANUJKIĆ, Ph.D. is a Full Professor of Information Technology at the Technical Faculty in Bor, University of Belgrade. E-mail. dstanujkic@tfbor.bg.ac.rs

Gabrijela POPOVIĆ, Ph.D. is a Full Professor at the Faculty of Applied Management, Economics and Finance, University Business Academy in Novi Sad. E-mail: gabrijela.popovic@mef.edu.rs

Oliver MOMČILOVIĆ, Ph.D., is a Full Professor and a Vice-dean at the Faculty of Applied Management, Economics and Finance, University Business Academy in Novi Sad. E-mail. oliver.momcilovic@mef.edu.rs