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INTERNET OF THINGS AND FUZZY LOGIC BASED SMART BALCONY PLANT CARE SYSTEM FROM A RENEWABLE RESOURCES

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ABSTRACT

This article proposes a smart irrigation system that helps to maintain a balcony plants. The system provides real-time information about the environmental parameters as humidity level of soil, temperature of surrounding environment, and status of the watering reservoir. Fuzzy logic controller is used to compute input parameters like soil moisture, temperature water tank level and to produce outputs of the water pump status. The system allows the collection of rainwater or condensate water from the air conditioner into a tank or, in the last case, from the water supply network. This encourages the use of renewable water sources and minimizes water consumption for irrigation purposes from the water supply network. With the support of this system, it is possible to grow decorative flowers such as geraniums or herbs for your own needs throughout the season. Geraniums (Geranium Pelargonium) are a perennial favourite both on balconies and in the garden. Its wide range of colours, tolerance and low price also contribute to its popularity.

KEY WORDS

fuzzy logic, plant care system, IoT

CLASSIFICATION

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INTRODUCTION

Water management experts have pointed to rainwater harvesting as one under-utilized, renewable alternative water source for water stressed cities around the world. Rainwater harvesting has drawn increasing attention as the number of successful implementations of rainwater harvesting as an alternative urban water source has grown in countries like China, Australia, and the United States [1]. Fuzzy logic can be used in the control 1 of the irrigation systems to regulate and optimize crop watering. The system can be run on renewable energy sources like solar panels and can use sensors to gather information about the plant's surroundings, including temperature, humidity, and light levels. These data can then be used by the fuzzy logic algorithms to decide when and how much to water the plants, as well as when to switch the water pump on and off. This kind of system can aid in resource conservation, enhance plant health, and save energy expenses [2]. The system gathers information on temperature, soil moisture, and other environmental variables, and uses this information to decide how much water to apply. The fuzzy logic algorithms are made to deal with uncertainty and support non-linear input-to-output relations [3]. This makes it easier for the system to respond to dynamic environmental factors and decide how best to meet the unique needs of the crops. The final result is an irrigation system that is more effective and efficient, which can increase plant performances and decrease waste. One of the popular plants for the balcony are geraniums. Geraniums are perennial herbaceous plants. Ornamental plants that thrive in a sunny position are very well-known and popular in our country, so they are particularly suitable for windows, balconies and terraces. Height: 30 cm. It thrives in any type of soil, but it still likes slightly heavier soil (compost mixed with sand), especially because it is exposed to the sun all summer. Geranium is not sensitive and easy to grow. Exposed to the sun, it grows abundantly and flowers a lot (especially the younger ones) from spring to late autumn. It should be transplanted every spring and then its veins and twigs are shortened a bit.

MATERIAL AND METHODS

With increasing complexity, describing systems using exact mathematical functions is an increasing challenge. Nevertheless, humans have the ability to understand complex systems, such as driving a car, without being able to clearly express its dynamic model. The theory of fuzzy sets tries to map this implicit knowledge into sets that can be interpreted by programming languages. Fuzzifier (membership function), fuzzy interface, and defuzzifier rules are the three main components of fuzzy systems.

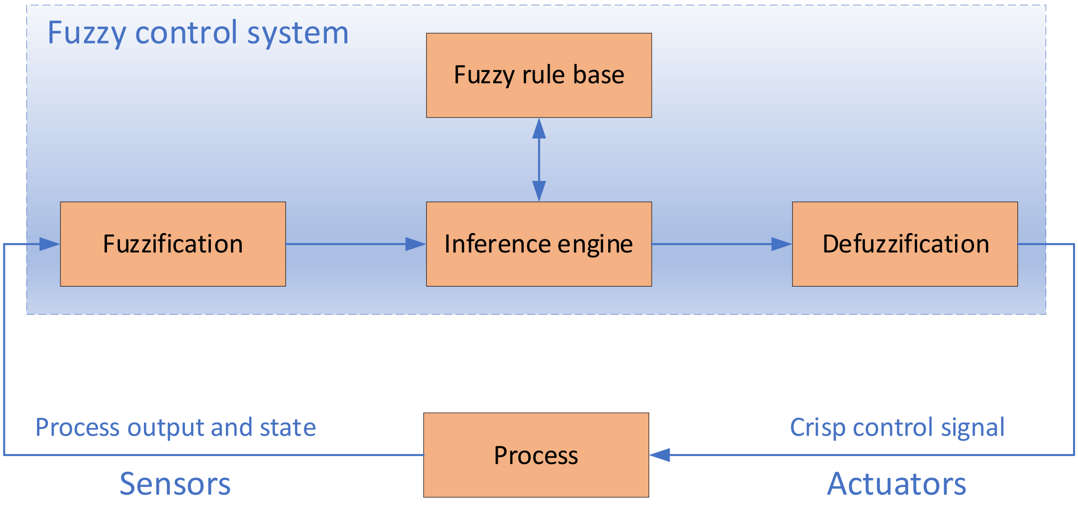

Figure 1. The fuzzy control system.

Decision-making is a process of evaluating alternatives that meet a specific set of established goals or criteria. The problem is to select the alternative that is most (best, strongest, etc.) satisfying to the set of goals. The decision-making process is typically reduced to determining numerically expressed weight values of alternatives in relation to sub-goals, sub-goals to goals, and goals in relation to some overarching objective. Syntheses ultimately determine the weights of alternatives in relation to the overarching objective, while local weights determined in previous stages can be used for subsequent reviews of decision-making structure, possible additions or deletions of elements, or, in some situations, repeating the decision-making process from the beginning.

Fuzzy sets, which describe imprecise concepts, and fuzzy logic, which focuses on linguistic variables to enable approximate reasoning with imprecise propositions, form the basis of fuzzy systems [4]. The basis of all fuzzy systems is the following three procedures:

- *fuzzyfication* – the process of transforming input distinct values into membership degrees of input fuzzy sets. The central part of that procedure is the determination of input and output (language) variables, the determination of the definition area of said variables, and the determination of the number and form of membership functions that cover the definition area of individual language variables,
- *inference or decision process* – the process of transforming input fuzzy sets into fuzzy output sets. The central part of that procedure is determining the basis of behavior in the form of IF-THEN rules. The base of behavioral rules represents a formalized form of expert or operator knowledge,
- *defuzzyfication* – the process of transforming fuzzy output sets into distinct output values. This procedure is necessary for fuzzy regulators, considering that the executive member (actuator) can only work with distinct values.

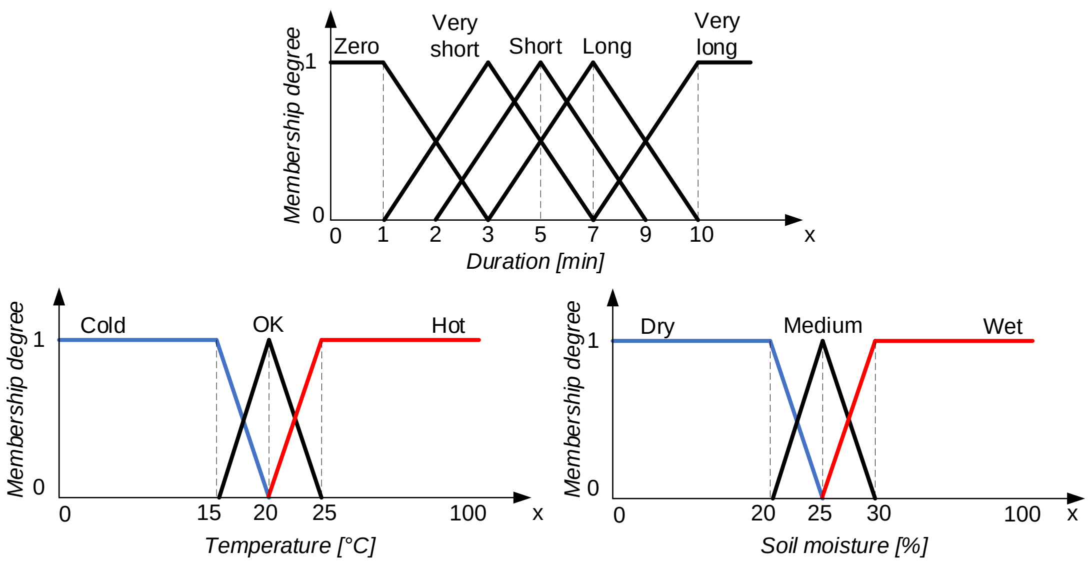

Figure 2. The irrigation system membership functions.

The temperature input variable is defined with the help of three linguistic variables, namely Cold, OK, and Hot, as shown in Table 1.

Table 1. Description of Input Variable Temperature.

Number	Temperature	Threshold, °C
1	Cold	[0 20]
2	OK	[15 25]
3	Hot	[20 100]

The relative humidity input variable is defined with the help of three linguistic variables, namely Dry, Medium, and Wet, as shown in Table 2.

Table 2. Description of Input Variable Humidity.

Number	Relative humidity	Threshold, %
1	Dry	[0 25]
2	Medium	[20 30]
3	Wet	[25 100]

The relationship between air temperature, soil moisture, and the watering pump can be modeled using fuzzy logic. The system inputs would be air temperature and soil moisture, and the output would be the amount of water that should be pumped to the plants. Fuzzy logic can be used to define the relationship between the inputs and the output by creating fuzzy rules that determine the watering pump behavior based on the current conditions. The rules might consider the soil moisture level and the air temperature to determine whether to turn the pump on or off, or to regulate the flow of water. The system would continuously monitor the inputs and update the output according to the defined rules, resulting in an optimized and efficient irrigation system [5]. The fuzzy rules for the relation between air temperature and soil moisture with the watering pump could be as follows.

- If air temperature is cold and soil moisture is dry, then the watering pump should be turned on high.
- If air temperature is cold and soil moisture is medium, then the watering pump should be turned on low.
- If air temperature is cold and soil moisture is wet, then the watering pump should be turned off.
- If air temperature is ok and soil moisture is dry, then the watering pump should be turned on medium.
- If air temperature is ok and soil moisture is medium, then the watering pump should be turned off.
- If air temperature is ok and soil moisture is wet, then the watering pump should be turned off.
- If air temperature is hot and soil moisture is dry, then the watering pump should be turned on high.
- If air temperature is hot and soil moisture is medium, then the watering pump should be turned on medium.
- If air temperature is hot and soil moisture is wet, then the watering pump should be turned off.

These rules are based on the assumption that a cold air temperature will require more watering to maintain a moist soil, while a hot air temperature will require less watering to prevent over-watering and root rot. The soil moisture level will also affect the amount of watering needed, with dry soil requiring more and wet soil requiring less [6]. These rules can be adjusted based on specific requirements and the environment of the plant system.

RESULTS AND DISCUSSION

Automated systems based on the Internet of Things (IoT) supplement the capabilities of traditional automated systems with the intensive exchange of data between system units via the Internet and the processing of data even in the cloud [7]. Among the IoT-based automated systems, an application can be imagined in which, based on the measurement data, the system makes various decisions as to whether irrigation should be carried out in order to meet certain prescribed conditions. The most popular systems for plant growing are the following types of hydroponics system:

- wick system,
- Deep Water Culture - DWC,

- Nutrient Film Technology - NFT,
- EBB and Flow,
- Drip System,
- Aeroponics.

The plants are placed directly within perlite or vermiculite, which is an absorbent substance. In this case, the drip irrigation method is used. The following is a description of the irrigation system's structure, Figure 3. The controller processes the data from the soil moisture sensor that is positioned next to the plant and the weather station to determine how much water needs to be applied [8]. The fuzzy controller applies the well-designed rules based on the values the sensors have collected to arrive at the best irrigation decision. Szabo et. al. [9] show a descriptive model of the operative control of plant cultivation, which can be the basis of further research work and the development of computer software if financial circumstances allow it. Khan et. al. [10] main objective is to demonstrate the significance of urban horticulture, combined with new technologies to meet the needs of people in urban settings, for safeguarding community livelihoods, food security, and the environment.

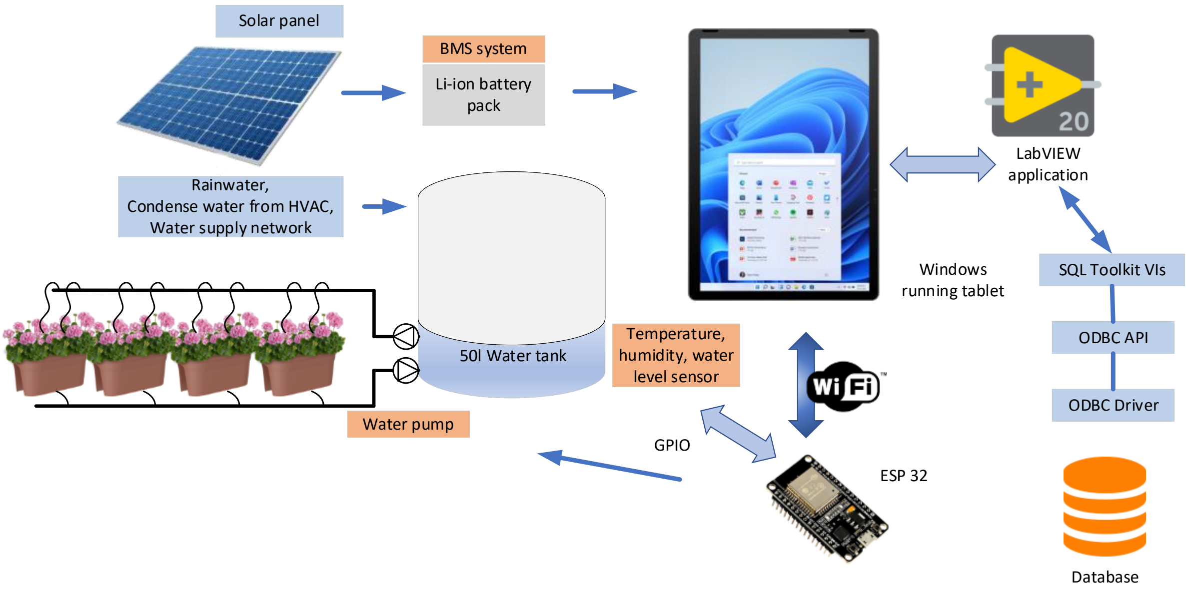

Figure 3. System architecture of the proposed system.

The control and simulation loop of a tank level controller consists of the following steps.

- Measurement of the tank level: The current level of the tank is measured using a sensor, such as a float sensor or a pressure sensor.
- Calculation of the control error: The control error is calculated as the difference between the desired level and the actual level of the tank.
- Control action determination: Based on the control error and the control strategy, the control algorithm determines the required control action, such as opening or closing a valve or adjusting the flow rate.
- Implementation of the control action: The control action is implemented in the real system, either through manual adjustment or through automated control systems.
- Simulation of the system response: The system response to the control action is simulated using a mathematical model, taking into account the dynamics of the system and the disturbance inputs.
- Comparison of the simulation results with the actual results: The simulation results are compared with the actual results to evaluate the accuracy of the control system and the control algorithm.

- Adjustment of the control strategy: Based on the comparison of the simulation and actual results, the control strategy may be adjusted to improve the performance of the system.

The control and simulation loop is an iterative process, and it continues until the desired level of performance is achieved [10]. The optimal control parameters are determined through this process, which leads to the efficient and effective control of the tank level.

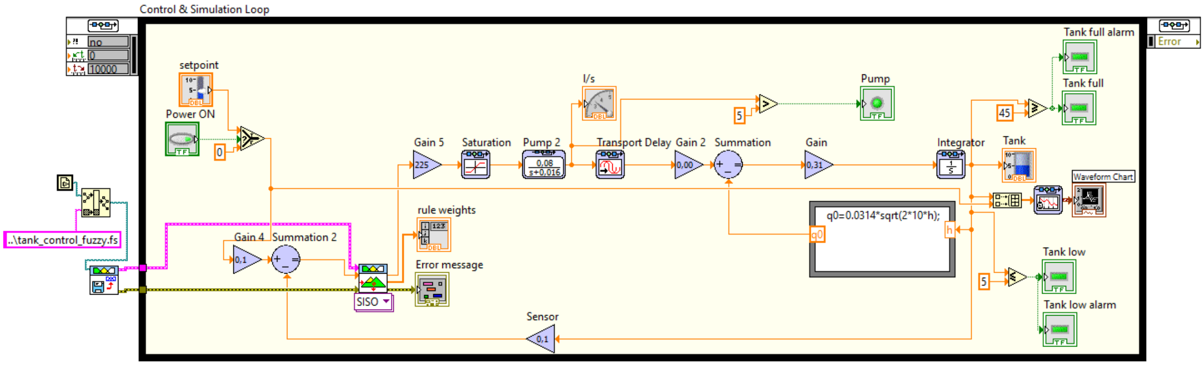

Figure 4. The control and simulation loop of the tank level controller.

LabVIEW and its Fuzzy logic toolbox were chosen for modelling the fuzzy system. Creation begins by defining the type of fuzzy system, and Mamdani is selected, and by selecting the number of input and output variables in the Fuzzy logic designer. Mamdani is a type of fuzzy system suitable for using linguistic variables, while Sugeno uses one-dimensional membership functions (singleton), so inference is faster, which makes it more suitable for adaptive systems that learn from a large amount of data [11]. The next step is to adjust the membership functions. The membership function of each parameter aims to define ranges that will most accurately reflect the actual user experience. For this reason, an expert in greenhouse production was consulted to determine the functions of belonging, who helped determine the limits of the range.

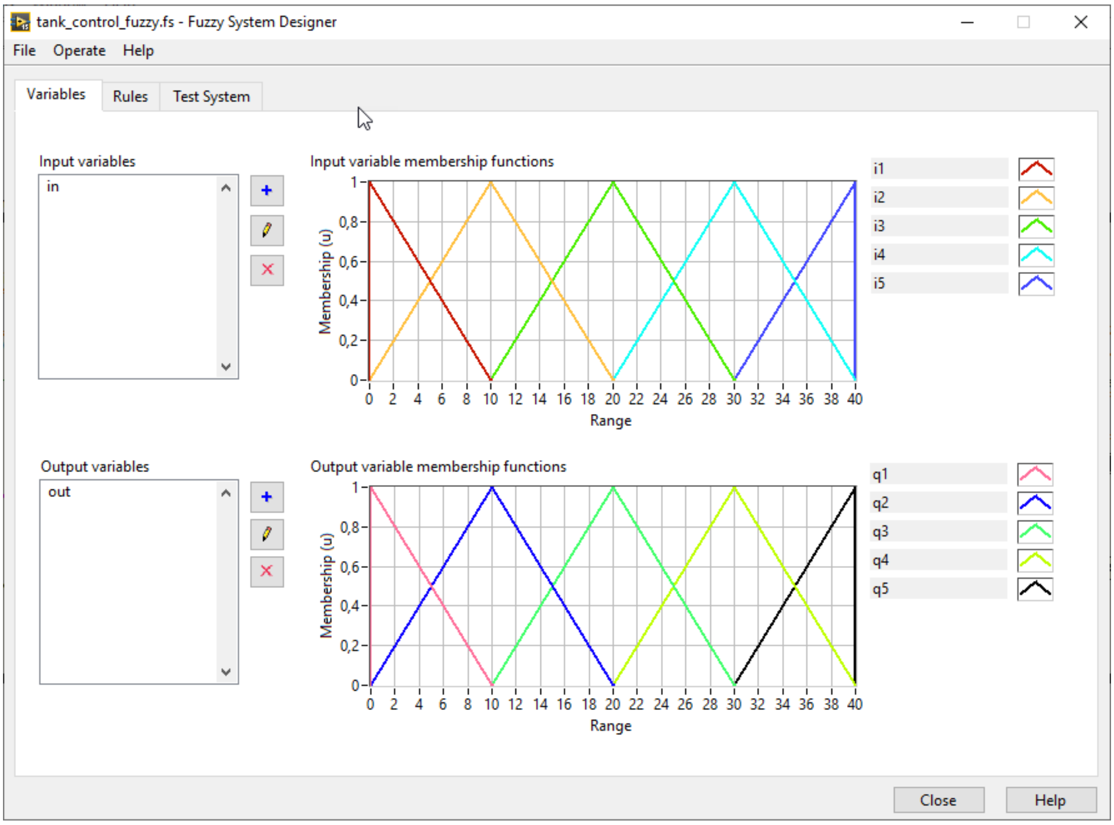

Figure 5. The fuzzy membership functions of the watering tank level control.

As can be seen from the picture, the input parameters are defined, which do not correspond to the default parameter control plan (temperature, air humidity and soil humidity in two places). However, since it was assumed that the characteristics of both locations are identical (properties of the soil, pump flow), and there is no interdependence between them, the data will be passed through the model multiple times for several locations [12]. Other settings in the window concern more advanced adjustment of the inference step and were not used in this work, but the basic settings (center of area defuzzification method) were left. The Rules viewer interface provides a visual representation of decision-making based on input variables, using operations with fuzzy sets according to functions given by membership functions, and the decision for one case, i.e. one set of input variables, is shown in Figure 6.

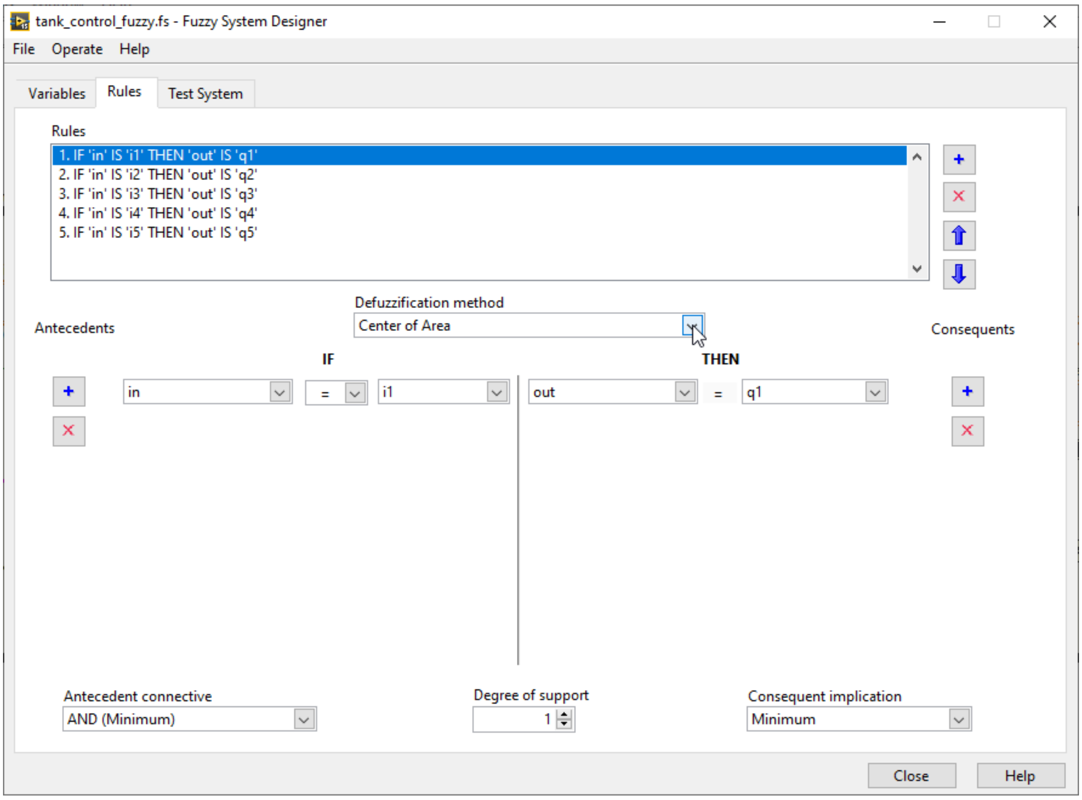

Figure 6. The fuzzy membership functions of the watering tank level control.

After determining the membership functions for the measurement parameters, the membership functions for the responses, for the actuators, must also be determined. The output of the fuzzy system for the actuators is the duration in seconds [13]. The procedure is identical, only the knowledge of the consulted expert is not used exclusively to determine the value, because he does not even have knowledge of the equipment used, but the operation of individual parameter management devices was recorded quantitatively, and the expert made suggestions on the necessary operation based on this data, more precisely, activation times.

It is important to note that the tank is exclusively filled with water from renewable sources such as rainwater or condensate from the HVAC system [14]. In the absence of renewable options, the water level is kept to a minimum from the water supply network as needed.

The idea of the graphic interface is to provide the user with clear information about the state of the measured parameters (temperature, air humidity and soil humidity) immediately after opening, and this is achieved by dynamically changing the colors of the elements depending on the relationship between the defined limit values and the measured parameters.

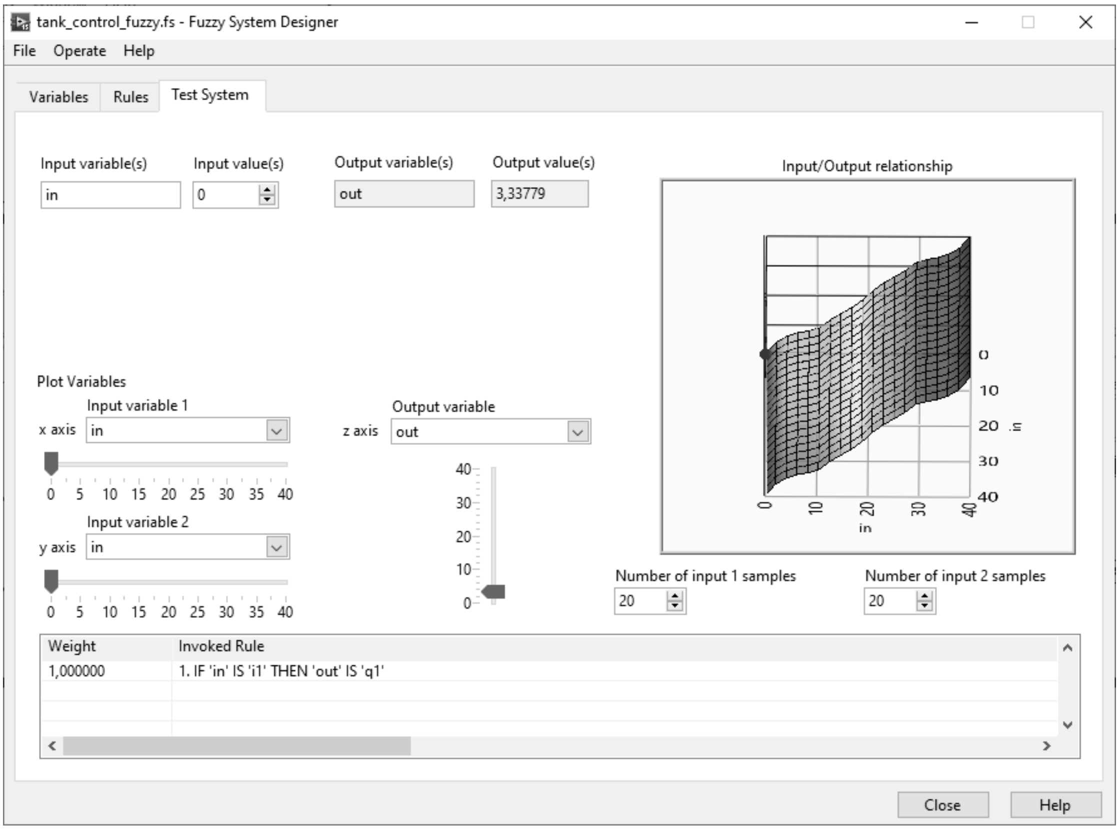

Figure 7. The fuzzy input – output relation of the watering tank level control.

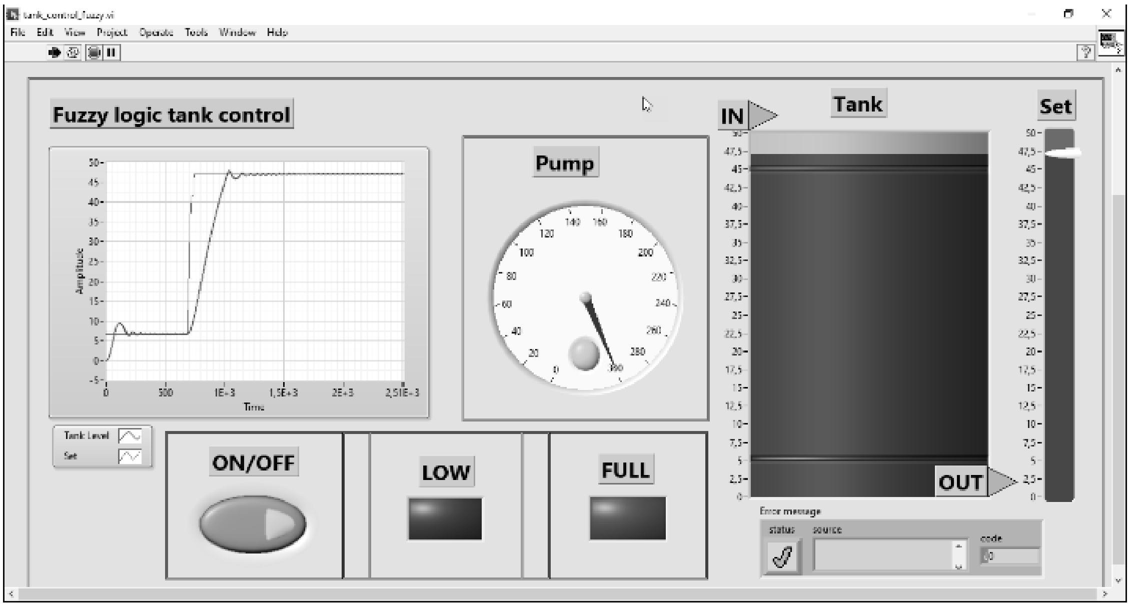

Figure 8. The watering tank level control GUI.

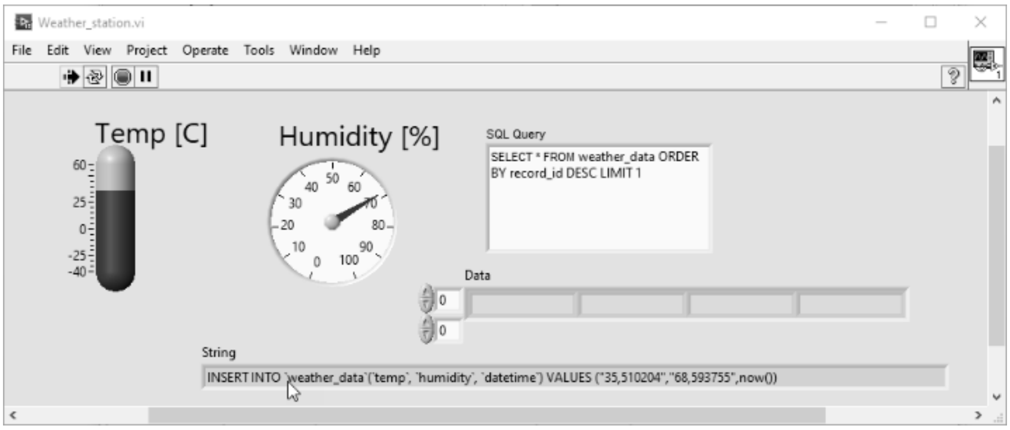

Figure 9. The weather station GUI.

With remote irrigation, the soil cannot be seen, so the intensity of watering is very low so that excessive watering does not occur by mistake. The pumps themselves have a low flow, and the water also passes through the sprinklers, so the flow is further reduced, so it takes about one minute of pump activity to water completely dry soil [15]. This makes it possible for watering to take place in steps and to check the effect of one interval on the humidity value from the sensor (it would be much more difficult to turn on watering three times for three seconds than three times for 15 seconds, there is much less room for mis judgment). In the case of automatic watering, not even a visual overview of the situation is available, and the experience is difficult to translate into a numerical format, because in reality it is more often a matter of feeling than of a clear plan. For this reason, with automatic modes, parameter values are constantly checked and corrective measures are taken.

Figure 10. The irrigation system.

IoT technology can help the Geranium Pelargonium balcony irrigation system by supporting its database. IoT sensors can be used to gather information on environmental factors such as humidity, temperature, and soil moisture levels. The performance of the irrigation system can then be optimized by sending this data to a relational database, where it can be kept and examined [16]. IoT-enabled irrigation systems may also be monitored and managed remotely, giving consumers more flexibility and control over the watering requirements for their balconies. A relational database can also be used to guarantee that data is correctly organized and saved, making it simpler to obtain and analyze the data as needed. Figure 10 shows the process of watering plants as a result of fuzzy control.

Figure 10. The Geranium Pelargonium at the end of the season.

IoT technology can be used to create a Pelargonium balcony irrigation system with remote access functionality. This may entail integrating sensors, communication components, and a platform that runs in the cloud and enables remote access and management [8, 17]. The sensors can gather data on air temperature and soil moisture, sending this information to the cloud platform via a communication module like Wi-Fi or cellular connectivity [18-20]. The user can then remotely control and monitor the system by accessing the platform via a web interface or mobile app. Even when the user is not physically present, this can help to guarantee that the plants receive the appropriate amount of water.

CONCLUSIONS

Pelargonium is a really beautiful plant that is quite common in indoor gardening. In addition, gardens, balconies and terraces are decorated with geraniums. And this is not surprising. The flower has a wonderful appearance, lush flowering and will decorate the balcony for a long time. The use of the fuzzy control maintains the soil moisture above the user-defined value and eliminates the risk of under-irrigation. The obtained results show the efficiency and reliability of the system during both summer and fall seasons. If we are planning a longer vacation and can't find anyone to take care of watering our plants regularly, we have to arrange for the plants to get water on their own. The proposed system provides a solution for this as well.

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