JOURNAL LA MULTIAPP

VOL. 05, ISSUE 04 (440-452), 2024
DOI: 10.37899/journallamultiapp.v5i4.1462

Prototype of Microcontroller Based Water Pump Control System for Lettuce Plants Using Fuzzy Tsukamoto

Mhd. Roji Rifansyah[1], Rakhmat Kurniawan R[1]

[1]*Program Studi Ilmu Komputer, Fakultas Sains Dan Teknologi, Universitas Islam Negeri Sumatera Utara, Medan*

**Corresponding Author: Mhd. Roji Rifansyah*
Email: mhdrojirifansyah3@gmail.com

Article Info

Article history:
Received 3 July 2024
Received in revised form 27 July 2024
Accepted 12 August 2024

Keywords:
Microcontroller
Water Pump Control System
Lettuce Plants
Fuzzy Tsukamoto Method

Abstract

This research aims to design and implement a water pump control system for lettuce plants using a microcontroller based on the Tsukamoto fuzzy method. The system utilizes soil moisture sensors and DHT11 temperature sensors to monitor and control the water supply for optimal plant growth. The fuzzy logic control involves three stages: fuzzification, rule evaluation, and defuzzification. Experimental results demonstrate the system's effectiveness in maintaining the desired soil moisture levels, thus ensuring optimal conditions for lettuce plant development. The prototype includes components such as Arduino Uno, relays, water pumps, and LCD displays, all of which integrate seamlessly to achieve the desired control outcomes. The study concludes that the designed system can significantly aid in automating water supply processes, thus benefiting small-scale agricultural practices.

Introduction

A home garden is a sector of land around the house which is usually planted with plants, one of which is often used by most people as a medium for growing vegetables to fulfill cooking needs or can also be sold. Vegetables are an important commodity that supports food security. The nutritional content of vegetables, especially vitamins and minerals, cannot be substituted for staple foods. To meet the availability of vegetables, this is an opportunity for cultivating vegetable crops. One type of vegetable that can be cultivated is lettuce (Leksono, 2021). Lettuce (Lactuca sativaL.) is a vegetable plant that has high economic value, its attractive shape and high nutritional content make this plant have the potential to continue to be cultivated (Meriaty, 2021; Ariananda et al., 2020; Riski & Ramli, 2022). Lettuce plants are cultivated for their leaves and are used mainly for fresh vegetables, cooking utensils and dish decoration. Plants are living creatures that need water for their development (Khodadad et al., 2020; Lee et al., 2022).

Plant growth and development can be disrupted because the plant's water needs are not met or there is excess water. Fertile plants are a requirement for the plants to grow well. Fertility levels can be influenced by the water it contains (Ahmed et al., 2020). Plants need water to grow and develop. Not only plants, all living creatures need water, because water is a source of life (Dharma et al., 2019).

However, people currently still have difficulty in watering, because they use conventional methods. Not to mention that plant owners have difficulty in watering because they have busy daily lives, this can cause the plants being cared for to wither or die because they are not watered (Triananda, 2021). Because of modern times, watering can be done using tools and

ISSN: 2716-3865 (Print), 2721-1290 (Online)

there is no longer a need to use conventional methods. Based on the above then a microcontroller-based automatic water control system was designed to make work easier (Pambudi et al., 2020). The aim of this research is to design a water pump control system for lettuce plants based on a microcontroller using fuzzy Tsukamoto. The limitation of the problem in this research is that the water needs of plants are met with a system created by applying it to the community.

Methods

This research is quantitative in nature, and concentrates on a specially designed water pump control system using a microcontroller to control water irrigation for lettuce plant. The implementation of the system was done with the help of Tsukamoto fuzzy method to attain a fine degree of control over the Irrigation process, which would depend on the environmental characteristics detected real time. The first step of the research was in the planning and design of the hardware which included the choice of certain sensors and other elements. A soil moisture sensor was used in measuring the level of moisture in the soil whilst the environmental temperature was measured using a DHT11 temperature sensor. These sensors were interfaced with the Arduino microcontroller to analyses the data using Tsukamoto fuzzy logic algorithm so as to switch on the water pump. These sensors were interfaced with the microcontroller which was helpful in the real-time collection of data aiding the system in its irrigation decisions.

In application of the fuzzy logic control the system design proceeded in three major steps. The first step, fuzzification, involve translating the crisp inputs, for instance, of temperature and soil moisture into fuzzy sets with the help of certain membership functions. In the present work, the type of soil moisture and temperature were categorized as ‘dry’, ‘moist’, and ‘wet’ and ‘cold,’ ‘normal,’ and ‘hot’ respectively, which made it easy for the system to understand the state of the environment in a very dynamic manner.

To fuzzify the rules, after the fuzzification the rule evaluation stage, the data from the sensors was used to apply a set of fuzzy IF-THEN rules to decide the right system responses. For example, if the soil moisture is ‘low,’ then the water pump will start as per the rule so that the lettuce plants are watered as needed. On the other hand, if the status was ‘high,’ this meant that the soil was moist and the pump would need to be ‘off’ to avoid over watering the plants. These rules were very important for the control of the irrigation process as well as the condition necessary for the growth of plants.

The last step of their approach was defuzzification of results in which reaching the decision variable that was converted in fuzzy form to give exact command on water pump. Incorporating a weighted average approach, the particular clock the system showed that the pump needed to run this length of time to provide proper irrigation, not too much and not too little. It was crucial in establishing the right soil moisture levels as required in the process and this was due to the following reasons.

The working prototype of the system was rigorously tested or evaluated in order to validate its components’ interoperability within the context of the system. In order to check the functionality of the relay module which is used to turn ON/OFF the water pump with the help of Arduino board, was tested to check the functionality of the relay. Further, the performance of soil moisture and temperature sensors was also investigated under different circumstances. The specific tests were performed on the soil moisture sensor in order to finalize its abilities to properly control the water pump depending on the reading of dryness of the soil. The same was done with the DHT11 sensor to measure the temperature and humidity of the air surrounding the lettuce plants to also control the environment.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

At the same time, the testing of the used system's LCD display was carried out to ensure its operability, showing the values of soil moisture, temperature, as well as the work of the pump. :It was important to have this display for evaluation of the system and the ability to make corrections if needed when testing was being conducted.

During the testing phase data which was collected was properly analyzed to enhance the performance of the system. The values of the soil moisture were scrutinized to tweak the fuzzy logic rules so that the pump is turned on only when the level of moisture affects the beneficial state of the soil. This analysis was aimed at optimizing the irrigation techniques in the production line so as to eliminate over watering and under watering that leads to poor growth of the lettuce crops.

The study took one month at a particular site where several pieces of equipment were tested under controlled environment to determine how the system would help in handling the lettuce plant needs The method used in this study presents an efficient and the fully automated plant water supply system that uses the Tsukamoto fuzzy method to account for the environmental conditions. The combined use of sensors, microcontrollers, and fuzzy logic not only offers a viable solution for small scale agriculture but also improves water use efficiency and provides adequate plant growth.

Results and Discussion

Use logic fuzzy on study This as something taker decision to determine the length of time to retain humidity soil and desired temperature. Soil moisture sensor consisting of two probe to pass current through the ground, then read the resistance to get the humidity level value. This sensor uses a layered plate nickel so that it can extend service life and prevent rust problems. The sensor used to detect environmental temperature is type DHT11. This sensor is included in the smart sensor type because it has an AD Converter in sensors the. Censorship DHT11 is sensors temperature Which Lots used because it has excess Which can measure temperature values and air humidity at once. Fuzzy logic design in control systems Soil moisture and temperature have three stages according to the rules applies, namely fuzification, formation of fuzzy rules, and defuzzification. Stages- stages is explained as follows.

Fuzzification

Fuzzification is the initial stage carried out in the logic method fuzzy. This stage is carried out by the process of changing the crisp (numeric) value to Fuzzy sets use membership functions. In This system design uses two inputs, namely soil moisture and temperature air (d a lam ° C). O utput y a n g dii n g want there is a water pump .

Table 1. Level Humidity Land

No	Level Soil Moisture	Status
1	950-1100	Dry (Low)
2	300-950	Humid (Mid)
3	0-300	It's muddy (High)

Formula from function equation membership variable humidity:

$$\mu dry = \left\{ 1100 - x_{0}^{1} \right. \quad ; x \leq 300 \quad ; 300 \leq x \leq 1100 \quad ; x \geq 1100$$

0

x-300

$$\mu moist = \begin{cases} 6000 - 1100 \\ \dfrac{600 - x}{1100 - 600} \end{cases} \quad \begin{array}{l} ; \leq \ 300 \text{ or } \geq 1100 \\ ; 300 \ \leq x \leq \ 600 \\ ; 600 \leq x \leq 1100 \end{array}$$

ISSN: 2716-3865 (Print), 2721-1290 (Online)

$$\mu\text{muddy} = \begin{cases} 0 & ; x \le 300 \\ \dfrac{x-300}{1100-600} & ; 300 \le x \le 1100 \\ 1 & ; x \ge 1100 \end{cases}$$

Table 1 presents the soil moisture levels categorized into three states: dry, moist, and wet. Each state is associated with a certain range of measured soil moisture values. The soil moisture levels are expressed in different values, with the dry (low) category having a range of 950-1100, moist (moderate) 300-950, and wet (high) 0-300. These categories help in understanding the soil conditions and determining appropriate actions, such as irrigation for agriculture or soil erosion risk assessment.

This table is equipped with the moisture variable membership function formula, which is used in fuzzy logic to measure the degree of membership of a soil moisture value in a certain category. For example, the membership function for dry soil (µdry) is given by a linear equation that decreases from 1100 to 300. If the soil moisture value is between 300 and 1100, the membership of dry soil is calculated as 1100−300 1100−x. This membership function helps in determining how "dry", "moist", or "wet" the soil is based on the measured moisture values.

The use of this membership function formula allows for a more flexible and dynamic assessment of the soil moisture condition. In this way, even if the soil moisture value does not fall strictly into one particular category, we can still determine the degree of membership in each category. This is important in practical applications such as automatic irrigation systems, where irrigation decisions can be adjusted more accurately based on more realistic and dynamic soil conditions.

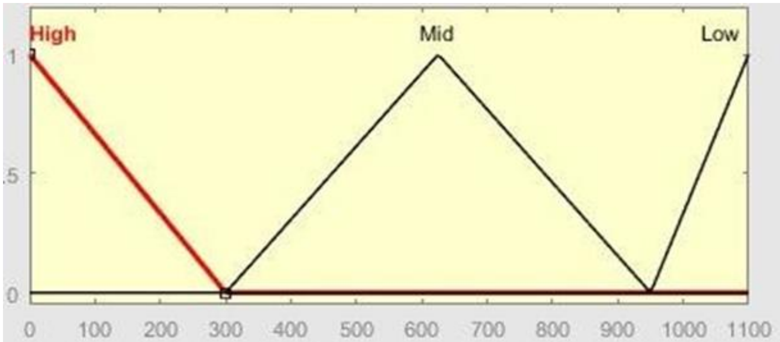

Figure 1. Function Membership Humidity Land

Mark membership variable humidity

µdry (800) = (1100-800) / (1100-300) = 300/800 = 0.375

µmoist (800) = (600-800) / (1100-600) = -200/500 = -0.4

µmuddy (800) = (800-600) / (1100-300) = 200/ 800 = 0.25

Variable temperature

Table 2. Level Degrees Temperature

No	Temperature (˚ C)	Status
1	0-15	Cold
2	12-31	Normal
3	30-40	Hot

ISSN: 2716-3865 (Print), 2721-1290 (Online)

1

$\mu Cold = \{\frac{40-x}{0}$; x ≤ 15

; 15 = ≤ 15

0 ; x ≥ 40

$\mu normal = \begin{cases} x - 15 \\ \frac{30 - x}{40 - 30} \end{cases}$; ≤ 15 or ≥ 40

; 15 : : 30

; 30 : :40

0

$\mu hot = \{\frac{x-15}{40-15}$; X ≤ 15

; 15 ≤ X ≤ 40

; X ≥ 40

1

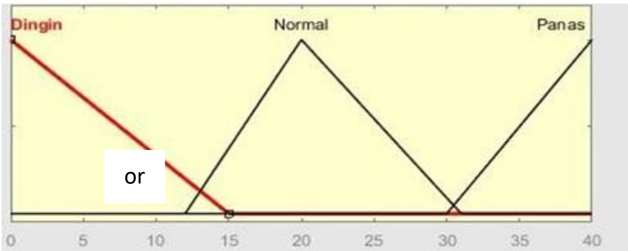

Figure 2. Function Membership Temperature

Mark membership variable temperature

μtemperature cold (29) = (40-29) / (40-15) = 11 / 25 = 0.44

μtemperature normal (29) = (30-29) / (40-30) = 1/ 10 = 0.1

μtemperature hot (29) = (29-15) / (40-15) = 14 / 25 = 0.56

Variable Pump

1

$\mu Cold = \{\begin{cases} 5x \\ 5 - 0 \end{cases}$; x ≤ 0

; 0 ≤ x ≤ 5

; x ≥ 5

0

0

; ≤ 0 atau ≥ 5

$\mu normal = \begin{cases} \frac{x - 0}{3 - 5} \\ \frac{3 - x}{5 - 0} \end{cases}$; 0 ≤ X ≤ 3

; 3 ≤ X ≤ 5

0

$\mu hot = \{\frac{x-0}{5-0}$; X ≤ 0

; 0 ≤ X ≤ 5

; X ≥ 5

1

Rule Fuzzy

Fuzzy rules are created based on the desired state. Fuzzy rules made in the form of table 3. below. There are 3 inputs for soil moisture Linguistic values are Low, Mid, and High. So there are 3 fuzzy rules that will obtained. Rule fuzzy made with function IF – THEN. For example: IF Soil moisture Low THEN Water Pump On. Based on the data used in The above research obtained rules as follows:

[**R1**] *If* (humidity low) *then* (pump fast)

ISSN: 2716-3865 (Print), 2721-1290 (Online)

$\alpha -$ predicate $_1$ = μ humiditylow $_{(800)}$ =

min(μhuiditylow $_{(800)}$) = min (0.375) (Z1)

Function membership set pump fast

μ $_{\text{Fast pump}}$ = (Z1-0) / (5-0) = 0.375 (5-0) + 0 = 0.375 (5) + 0 = 1,875

[**R2**] *If* (humidity middle) *then* (pump currently)

$\alpha -$ predicate $_2$ = μ humiditymid $_{(800)}$ =

min(μ humiditymid $_{(800)}$) = min (-0.4) (Z2)

Function membership set pump currently

μ $_{\text{midpump}}$ = (Z2-0) / (5-0) = -0.4 (5-0) + 0 = -0.4 (5) + 0 = -0.2

[**R3**] *If* (humidity high) *then* (pump off)

$\alpha -$ predicate $_3$ = μhumidity$high$ $_{(800)}$ =

min(μhumidity$noff$ $_{(800)}$) = min (0.25) (Z3)

Function membership set pump off

μ $_{pump\ o\ f\ f}$ = (Z 1 - 0) / (5- 0) = 0.25 (5 - 0) + 0 = 0.25 (5) + 0 = 1 .25

Defuzzification

So mark z is obtained as following:

$$Z = \frac{\alpha\text{predicate}_1 * Z1 + \alpha\text{predicatet}_2 * Z2 + \alpha\text{predicate}_3 * Z3}{\alpha\text{predicate}_1 + \alpha\text{predicate}_2 + \alpha\text{predicate}_3}$$

$$Z = \frac{((0.375*1.875) + (-0.4 * -0.2) + (0.25*1.25))}{(0.375 + (-0.4) + (0.25)}$$

$$Z = \frac{(0.703+0.008+0.312)}{0.225}$$

$$Z = \frac{1,095}{0.225}$$

Z = 4.866

Testing Tool

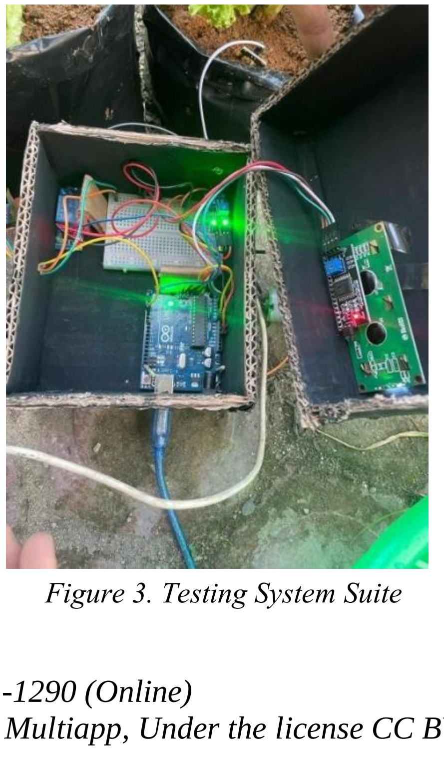

Figure 3. Testing System Suite

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Testing system This is testing from all over system Which aim For know system the Work with Good in accordance The plan that has been made is a prototype of the water pump control system plant lettuce based microcontroller use fuzzy Tsukamoto. Testing this tool starts from measuring the tool, measuring the tool includes voltage that enters the circuit to the voltage that comes out of the circuit, then testing sensors, pump testing water.

Testing Relays

The relay module system functions as switching on/off the pump., because if the process of activating this pump uses an Arduino module, that is Can't. Because input from this mini pump is to use voltage 220 AC while the output from the Arduino module is DC voltage. Therefore Activating this relay module is in line with Arduino commands so it is used intermediary, which means the relay module is controlled by the Arduino module which will activates the relay and pump. The circuit of the Arduino module is as follows picture below this.

This relay test aims to find out whether the relay can operate works as expected via the Arduino output pin. When pumping water is on or the water pump is off, i.e. it is given high or low logic is results of relay circuit testing.

Table 3. Data Testing Relays

No	Logic	Relays	Pump
1	High	Off	Off
2	Low	On	On

Figure 5. Pump Dead

The image above shows information that the pump is dead, the pump is dead because sensors soil moisture detect that land Already own humidity Which desired. Censorship send signal to Arduino For turn off the relay and the pump will automatically turn off following the relay. And vice versa If sensors soil moisture detect land with humidity Which low, The sensor will send a signal to the Arduino to turn on the relay and automatically pump will light up.

Figure 6. Pump Light up

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Testing Censorship DHT 11

In designing this tool, the DHT 11 sensor is used for detect temperature. This sensor test aims to detect air temperature in the environment around the plant due to growth and development Lettuce plants will be disturbed if the air temperature is too high which makes the leaves Lettuce spoils easily and tastes a little bitter. Following is the sensor circuit Which will be tested

From Suite on so obtained results:

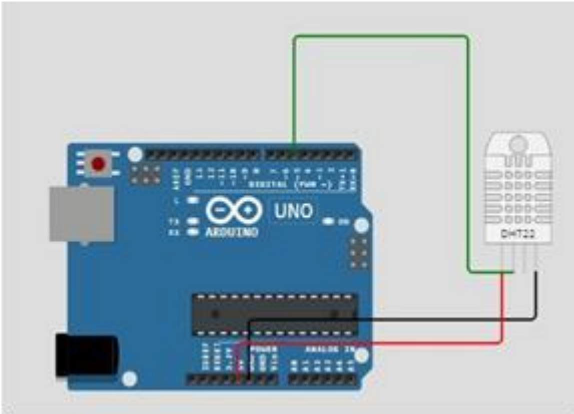

Figure 7. Temperature sensor circuit

Table 4. Results Testing Censorship Temperature

No	Time	Temperature air	Humidity air
1	Morning	29 ˚ C - 30 ˚ ˚ C	75%-79%
2	Afternoon	34 ˚C-35 ˚C	78%-79%
3	Afternoon	34 ˚C-32 ˚C	78%-79%

By Because That mark Which detected on sensors will is displayed on LCD.

Figure 8. Testing Temperature in Around Plant

Testing Censorship Soil Moisture

In designing this tool, a soil moisture sensor was used to detect soil moisture which is intended to regulate scheduling on pump, Which where will send order to Arduino For arrange module relays Which works For turn on pump water as well as turn off pump water. Following is a series of sensors soil moisture Which will be tested:

ISSN: 2716-3865 (Print), 2721-1290 (Online)

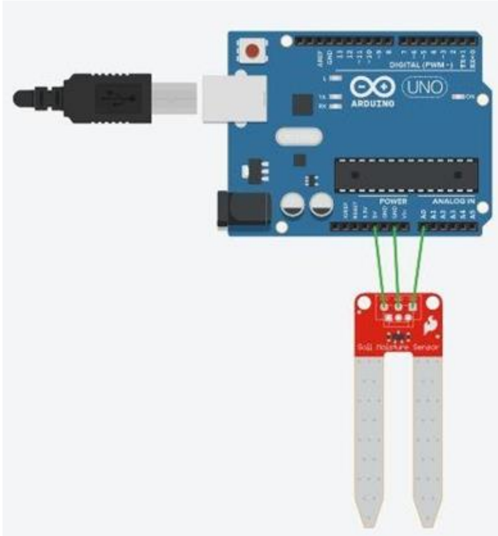

Figure 9. Network Soil Moisture

From Suite on in get results testing on sensors soil moisture:

Table 5. Results Testing Soil Moisture

No	Soil Moisture	Range Mark	Information
1	Low	>950	Pump on
2	Mid	>300&<950	Pump off
3	High	<300	Pump off

From data mark on, the more big value the more tall level soil dryness, and vice versa, the lower the value, the more tall also soil moisture level.

Testing LCD

On stage This module LCD 16x2 used For communication microcontroller Arduino, on tool This module LCD 16x2 used as monitor to find out the monitoring working conditions more easily. Apart from for displays the pump off or on, also displays temperature and humidity land. Here's the sequence on LCD:

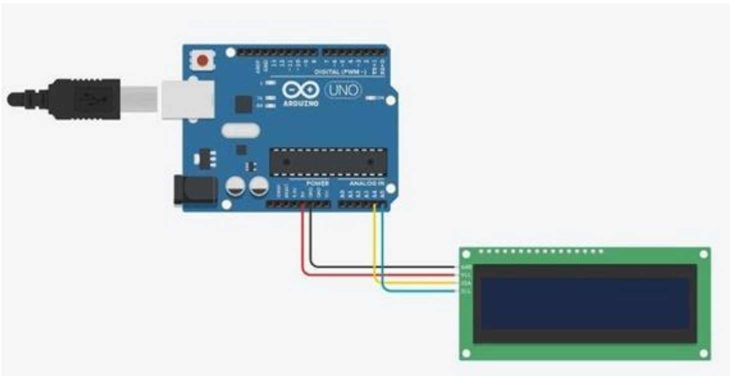

Figure 10. Suite On LCD

From Suite on, following This is results testing LCD, Which Where LCD displays Temperature around 32.30 ˚C as well as level humidity air 75.00%

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Figure 11. Appearance Temperature On LCD

The proposal of the development of an automated water pump control system for lettuce plants by a microcontroller using the Tsukamoto fuzzy method can be regarded as a C-solution that is useful for innovations in precision farming including small-scale farmers. From the findings of this study, it can be seen that the provided system plays its role of regulating the right amount of moisture to the plant's soil hence consistent growth (Ahluwalia et al., 2021; El-Beltagi et al., 2022). This is done by incorporating the real-time environmental data in the form of actual soil moisture content which is then translated by the fuzzy logic algorithm and changes the irrigation schedule accordingly to meet the requirements of the plants. This approach can be accredited for its effectiveness with the increasing trend in agricultural automation, which deals with the location of intelligence over resource.r (Afrin et al., 2021; Singh et al., 2024; Hwang et al., 2022).

This study discovers the fact that the system can very well manage the amount of water being supplied through the mechanical management of the water pump depending on the level and status of the incorporated soil moisture and temperature sensors. This method reduces water wastage to a greater extent, which is one of the biggest challenges that is faced today's agriculture due to lack of sufficient water supply. Fuzzy logic seems to provide a mechanism to facilitate an evaluation of sensor data which is suitable within agriculture where conditions are not black and white. It is worth mentioning that such flexible control systems play a role not only within the framework of resource saving measures, but also within the framework of increasing agricultural yields, as indicated by recent investigations (Zhang et al., 2020; Lieder & Schröter-Schlaack, 2021).

The study also shows how effective the Tsukamoto fuzzy method is useful in the processing of environmental data as well as the making of real-time decisions. The fuzzy logic scheme is perhaps the most advantageous for the applications where the net effect of environmental factors is constantly fluctuating, and the input data are not sharp and accurate in terms of value. This aspect of the system is elaborated by Abdullah et al. (2020) who noted that fuzzy systems are particularly useful for agricultural systems because they are very versatile and accurate even under changing circumstances. This is in support of the claim being placed forward whereby; fuzzy logic has the practical applications to support precision agriculture as illustrated by the success observed in the implemented system tending for the desired soil moisture levels.

Further, the inclusion of the DHT11 sensor for monitoring temperature also provides an extra means of control over the environment to facilitate lettes growth. The fact that the system can make adjustments to irrigation depending on the prevailing temperatures makes it greatly

ISSN: 2716-3865 (Print), 2721-1290 (Online)

applicable to the rest of the agricultural sector especially areas where temperature changes are a major issue. This feature is quite suitable for climate change situations that are expected to enhance the variety and severity of temperature changes making conventional farming difficult (Shahzad et al., 2021; Santos et al., 2020).

On this account, the practical implications of this research can evidently be said to be enormous. By automating the process of watering crops, the system also saves a lot of effort in crop management while also avoiding human error that may result in either under watering or over watering the crops (Tian et al., 2020). This is in line with the studies done by Tsolakis et al. (2023) as they assume that automation of farming activities not only optimizes the trade but also makes farming more sustainable. The use of these systems is especially appropriate for small farmers, who cannot afford installation of more elaborate systems of irrigation. Most of its components cost relatively low and are uncomplicated to assemble meaning that these farmers can easily afford to adopt this system thereby increasing its adoption within this farming sector (Rodriguez et al., 2009; Gil et al., 2023). But, on the same note, several researchers have noted that the system's proficiency is tested under rigid conditions and consequently, further studies are still required to determine real life viability of the given approach in various environmental contexts (Lindgren et al., 2004. The differences in soils, climate condition, and crop plants that may be grown could affect the performance of the system, thus may require to be optimized depending on the type of agriculture. Future works ought to investigate the extent to which the Tsukamoto fuzzy method can take variations of crops and environmental conditions, thus possibly giving rise to a generalized irrigation control system.

Conclusion

Based on the results of the design and test results of the tool as well as the discussion in the previous chapter, it can be concluded that: (1) The tool designed has been made in accordance with the research objectives, namely that it can function as a tool to control automatic water pumps in lettuce plants; (2) The *on/off operation* of the pump based on the level of soil moisture through soil moisture detection can be regulated using the Arduino sketch program created; (3) Controlling water needs for plants can be fulfilled so that plant growth and development is not hampered; (4) The DHT 11 sensor has been applied as a temperature detection tool, so that the temperature around the plant is not too high; (5) The higher the value detected by the soil moisture sensor, the lower the soil moisture level and vice versa, the lower the value, the higher the humidity level; (6) The entire system consisting of Arduino Uno, Relay, mini water pump, LCD, DHT 11 Sensor, Soil Moisture Sensor can work and integrate well.

References

Abdullah, N., Durani, N. A. B., Shari, M. F. B., Siong, K. S., Hau, V. K. W., Siong, W. N., & Ahmad, I. K. A. (2020). Towards smart agriculture monitoring using fuzzy systems. *Ieee Access*, *9*, 4097-4111. https://doi.org/10.1109/ACCESS.2020.3041597

Afrin, M., Jin, J., Rahman, A., Gasparri, A., Tian, Y. C., & Kulkarni, A. (2021). Robotic edge resource allocation for agricultural cyber-physical system. *IEEE Transactions on Network Science and Engineering*, *9*(6), 3979-3990. https://doi.org/10.1109/TNSE.2021.3103602

Ahluwalia, O., Singh, P. C., & Bhatia, R. (2021). A review on drought stress in plants: Implications, mitigation and the role of plant growth promoting rhizobacteria. *Resources, Environment and Sustainability*, *5*, 100032. https://doi.org/10.1016/j.resenv.2021.100032

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Ahmed, M., Hasanuzzaman, M., Raza, M. A., Malik, A., & Ahmad, S. (2020). Plant nutrients for crop growth, development and stress tolerance. *Sustainable agriculture in the era of climate change*, 43-92. https://doi.org/10.1007/978-3-030-45669-6_3

Ariananda, B., Nopsagiarti, T., & Mashadi, M. (2020). Pengaruh pemberian berbagai konsentrasi larutan nutrisi AB mix terhadap pertumbuhan dan produksi selada (Lactuca sativa L.) hidroponik sistem floating. *Green Swarnadwipa: Jurnal Pengembangan Ilmu Pertanian*, *9*(2), 185-195.

Dharma, I. P. L., Tansa, S., & Nasibu, I. Z. (2019). Perancangan Alat Pengendali Pintu Air Sawah Otomatis dengan SIM800l Berbasis Mikrokontroler Arduino Uno. *Jurnal Teknik*, *17*(1), 40–56. https://doi.org/10.37031/jt.v17i1.25

El-Beltagi, H. S., Basit, A., Mohamed, H. I., Ali, I., Ullah, S., Kamel, E. A., ... & Ghazzawy, H. S. (2022). Mulching as a sustainable water and soil saving practice in agriculture: A review. *Agronomy*, *12*(8), 1881. https://doi.org/10.3390/agronomy12081881

Gil, G., Casagrande, D. E., Cortés, L. P., & Verschae, R. (2023). Why the low adoption of robotics in the farms? Challenges for the establishment of commercial agricultural robots. *Smart Agricultural Technology*, *3*, 100069. https://doi.org/10.1016/j.atech.2022.100069

Hwang, W. Y., Guo, B. C., Hoang, A., Chang, C. C., & Wu, N. T. (2022). Facilitating authentic contextual EFL speaking and conversation with smart mechanisms and investigating its influence on learning achievements. *Computer Assisted Language Learning*, 1-27. https://doi.org/10.1080/09588221.2022.2095406

Khodadad, C. L., Hummerick, M. E., Spencer, L. E., Dixit, A. R., Richards, J. T., Romeyn, M. W., ... & Massa, G. D. (2020). Microbiological and nutritional analysis of lettuce crops grown on the international space station. *Frontiers in Plant Science*, *11*, 199. https://doi.org/10.3389/fpls.2020.00199

Lee, J. S., Chandra, D., & Son, J. (2022). Growth, physicochemical, nutritional, and postharvest qualities of leaf lettuce (Lactuca sativa L.) as affected by cultivar and amount of applied nutrient solution. *Horticulturae*, *8*(5), 436. https://doi.org/10.3390/horticulturae8050436

Leksono, A. P. (2021). Pengaruh Konsentrasi Dan Interval Pemberian Poc Urin Kelinci Terhadap Pertumbuhan Dan Produksi Tanaman Selada (Lactuca sativa L.). *Biofarm : Jurnal Ilmiah Pertanian*, *17*(2), 57. https://doi.org/10.31941/biofarm.v17i2.1610

Lieder, S., & Schröter-Schlaack, C. (2021). Smart farming technologies in arable farming: Towards a holistic assessment of opportunities and risks. *Sustainability*, *13*(12), 6783. https://doi.org/10.3390/su13126783

Lindgren, R., Henfridsson, O., & Schultze, U. (2004). Design principles for competence management systems: a synthesis of an action research study. *MIS quarterly*, 435-472. https://doi.org/10.2307/25148646

Meriaty. (2021). *PERTUMBUHAN DAN HASIL TANAMAN SELADA (Lactuca sativaL.) AKIBAT JENIS MEDIA TANAM HIDROPONIK DAN KONSENTRASI NUTRISI AB MIX*. *4*(2), 75–84. https://doi.org/10.34012/agroprimatech.v4i2.1698

Pambudi, A. S., Andryana, S., & Gunaryati, A. (2020). Rancang Bangun Penyiraman Tanaman Pintar Menggunakan Smartphone dan Mikrokontroler Arduino Berbasis Internet of Thing. *Jurnal Media Informatika Budidarma*, *4*(2), 250. https://doi.org/10.30865/mib.v4i2.1913

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Riski, M., & Ramli, R. (2022). Pertumbuhan dan Hasil Tanaman Selada (Lactuca sativa L.) dengan Pemberian Air Kelapa pada Sistem Hidroponik Substrat. *AGROTEKBIS: JURNAL ILMU PERTANIAN (e-journal)*, *10*(2), 397-405.

Rodriguez, J. M., Molnar, J. J., Fazio, R. A., Sydnor, E., & Lowe, M. J. (2009). Barriers to adoption of sustainable agriculture practices: Change agent perspectives. *Renewable agriculture and food systems*, *24*(1), 60-71. https://doi.org/10.1017/S1742170508002421

Santos, J. A., Fraga, H., Malheiro, A. C., Moutinho-Pereira, J., Dinis, L. T., Correia, C., ... & Schultz, H. R. (2020). A review of the potential climate change impacts and adaptation options for European viticulture. *Applied Sciences*, *10*(9), 3092. https://doi.org/10.3390/app10093092

Shahzad, A., Ullah, S., Dar, A. A., Sardar, M. F., Mehmood, T., Tufail, M. A., ... & Haris, M. (2021). Nexus on climate change: Agriculture and possible solution to cope future climate change stresses. *Environmental Science and Pollution Research*, *28*, 14211-14232. https://doi.org/10.1007/s11356-021-12649-8

Singh, A., Dhanaraj, R. K., & Sharma, A. K. (2024). Personalized device authentication scheme using Q-learning-based decision-making with the aid of transfer fuzzy learning for IIoT devices in zero trust network (PDA-QLTFL). *Computers and Electrical Engineering*, *118*, 109435. https://doi.org/10.1016/j.compeleceng.2024.109435

Tian, H., Wang, T., Liu, Y., Qiao, X., & Li, Y. (2020). Computer vision technology in agricultural automation—A review. *Information Processing in Agriculture*, *7*(1), 1-19. https://doi.org/10.1016/j.inpa.2019.09.006

Triananda, D. (2021). *Pengelolaan Kebun Karet dalam Perspektif Akad Musaqah (Studi di Desa Pisang Baru Kecamatan Bumi Agung Kabupaten Way Kanan)* (Doctoral dissertation, IAIN Metro).

Tsolakis, N., Harrington, T. S., & Srai, J. S. (2023). Leveraging automation and data-driven logistics for sustainable farming of high-value crops in emerging economies. *Smart agricultural technology*, *4*, 100139. https://doi.org/10.1016/j.atech.2022.100139

Zhang, S., Guo, Y., Zhao, H., Wang, Y., Chow, D., & Fang, Y. (2020). Methodologies of control strategies for improving energy efficiency in agricultural greenhouses. *Journal of Cleaner Production*, *274*, 122695. https://doi.org/10.1016/j.jclepro.2020.122695

ISSN: 2716-3865 (Print), 2721-1290 (Online)