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Implementation of Fuzzy Method towards Hydroponic Smart Showcase Innovation

Sarmayanta Sembiringm[1], Kemahyanto Exaudi[*,1], Aditya PP Prasetyo[1], Rendyansyah[2], Wardha Nadhira[1]
Jurusan Teknik Komputer/Fakultas lmu Komputer[1], Jurusan Teknik Elektro/Fakultas Teknik[2] – Universitas Sriwijaya
Palembang, Indonesia
[*]kemahyanto@ilkom.unsri.ac.id

***Abstract** – Hydroponics is a technique that allows easy cultivation of fresh and hygienic vegetables, even with limited space. Recent innovations in hydroponic development have resulted in a smart showcase prototype, which is controlled using Sugeno fuzzy techniques. This prototype uses a DC fan to maintain a stable temperature and humidity level. This invention is both ecologically friendly and portable, making it suitable for a wide range of users, including apartment residents. Experimental results using the fuzzy method show that this prototype can effectively support indoor hydroponic techniques, with fan rotation ranging from 180 to 255 rpm based on variations in room temperature and humidity. The showcase successfully maintained a stable temperature range of 28–30 °C and a humidity of 60–70% RH. In addition, out of 12 vegetable samples tested for 14 days, 7 kale stems showed significant growth. Overall, this smart showcase prototype offers the potential to bring hydroponics indoors and promote fresh vegetable cultivation.*

Keywords – *Fuzzy logic; hydroponics; internet of things; Sugeno fuzzy techniques; smart showcase.*

I. Introduction

HYDROPONIC methods usually have an advantage in growing medium as they use water instead of soil. This raises the important question of when and how vegetables grown in soil media should be watered with water [1]. Vegetables can fail if watering is too much [2]. However, using the hydroponic method, the vegetables grown are always submerged in running water. Vegetables produced through hydroponics have a crunchier texture compared to soil media, according to research that has been done [3], [4]. In addition, the growth is faster, and the impact of pests [5] is very small. Therefore, this easy hydroponic technique can give freedom to those who want to consume fresh and hygienic vegetables. This hydroponic method can still be applied in a narrow area [6]. Researchers have developed many hydroponic techniques that can produce high-quality plants and vegetables.

However, portable hydroponics that can be placed indoors continuously have not been solved with an environmentally friendly concept. Therefore, to overcome the problems previously described above, this research makes an innovation by applying the hydroponic method to an Internet of Things (IoT)-based smart showcase.

Hydroponic techniques have been proven to produce faster [7], more hygienic, and excellent [8] yields compared to the yields produced before the application of hydroponic techniques. Producing hydroponic vegetables requires a lot of processes, starting from sowing seeds, transplanting, adjusting nutrients, and adjusting water pH [9]. To get an optimal harvest, high-quality seeds are required [10]. To produce a good harvest, water quality is also very important [11]. Regularly measuring the pH of hydroponic water can help hydroponic vegetables get the nutrients necessary for their growth [12, 13]. Nutrients measured in hydroponic water can make vegetables healthier and crisper than those from soil media [14]. One of the factors that can improve vegetable growth is sunlight intensity [15].

A study conducted in 2020 [16] investigated automated hydroponic plants that can be monitored remotely using the Deep Flow Technique (DFT) system. In this study, water temperature, lights, water capacity, and water pumps were monitored to control plant growth. However, since there is no method to control them, the control system is semi-automatic. As described in research [16], one of the shortcomings of the

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DPT method is that stagnant water inundates the plant roots, causing root damage. Therefore, real-time monitoring of hydroponic plants requires an appropriate control and monitoring method.

Fuzzy methods are very effective in monitoring and controlling hydroponics [17]. However, this study uses an outdoor hydroponic system. Environmental temperature and humidity can be used to implement hydroponic plants [18]. Since it has automatic temperature and humidity control, the showcase can be used as an innovation to implement hydroponic techniques.

Previous research shows that all hydroponic methods are used in open spaces. Therefore, innovations in hydroponic support media are very important to be developed and researched further. One example offered in this research is the smart showcase product, which is easy to carry and environmentally friendly and can be used in closed spaces such as apartments.

II. Research Methods

Before determining the fuzzy parameters used, initial data testing was conducted on the air temperature and humidity in the test room. Subsequent data testing was conducted on the temperature and humidity of the air inside the smart hydroponic showcase. The temperature and humidity in the hydroponic smart display can be adjusted automatically based on the difference in values generated by the sensor and the reference value of the DC fan rpm. The creation of fuzzy sets (fuzzification), creation of rule bases, reasoning (fuzzy inference), and affirmation are all parts of fuzzy logic design in the decision-making process [19] [20].

i. Temperature Variables

The temperature variable consists of three sets, each with a fuzzy set: less, medium, and most. The membership function of the less domain ranges between 0 and 2, while the med domain ranges from 1 to 3, and the most domain is greater than 2. The membership function of the temperature variable is shown in Figure 1.

Figure 1 shows that the three temperature variables are determined based on the temperature difference, namely a less difference (10°C), med (10°C to 30°C), and most (30°C). Equations (1), (2), and (3) show the resulting equations of temperature membership.

$$\mu(\text{sw}_{\text{less}}) = \begin{cases} 1, & \text{if sw} \leq 1 \\ \frac{2-\text{sw}}{2-1}, & \text{if } 1 \leq \text{sw} \leq 2 \\ 0, & \text{if sw} \geq 2 \end{cases} \tag{1}$$

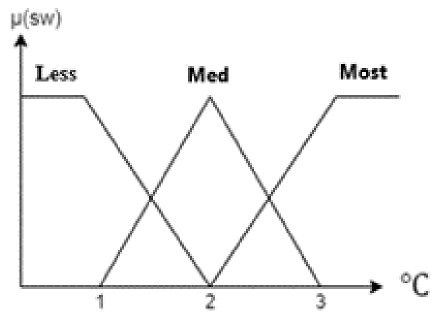


Figure 1: Visualization of Temperature Variable Membership Function

$$\mu(\text{sw}_{\text{med}}) = \begin{cases} 0, & \text{if sw} \leq 1 \text{ or sw} \geq 3 \\ \frac{\text{sw}-1}{2-1}, & \text{if } 1 \leq \text{sw} \leq 2 \\ \frac{3-\text{sw}}{3-2}, & \text{if } 2 \leq \text{sw} \leq 3 \end{cases} \tag{2}$$

$$\mu(\text{sw}_{\text{most}}) = \begin{cases} 0, & \text{if sw} \leq 2 \\ \frac{\text{sw}-2}{3-2}, & \text{if } 2 \leq \text{sw} \leq 3 \\ 1, & \text{if sw} \geq 3 \end{cases} \tag{3}$$

ii. Humidity Variables

The humidity variable is divided into two sets with dry and humid fuzzy domains. The modeled humidity variables inside and outside the Smart showcase are 0% to 100%, as shown in Figure 2.

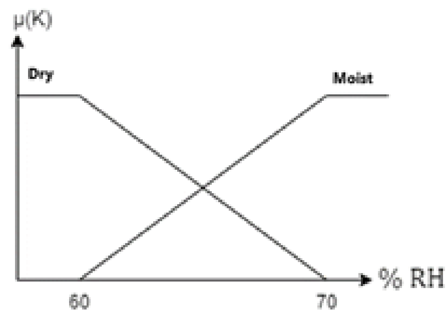


Figure 2: Visualization of Humidity Variable Membership Function

From the graph shown in Figure 2, the humidity membership degree equation is obtained, which is shown in Equations (4) and (5).

$$\mu(k_{\text{dry}}) = \begin{cases} 0, & \text{if } k \leq 60 \\ \frac{k-60}{70-60}, & \text{if } 60 \leq k \leq 70 \\ 1, & \text{if } k \geq 70 \end{cases} \tag{4}$$

$$\mu(k_{\text{moist}}) = \begin{cases} \frac{70-k}{70-60}, & \text{if } 60 \leq k \leq 70 \\ 0, & \text{if } k \geq 70 \end{cases} \tag{5}$$

Based on the predetermined temperature and humidity variables, the fuzzy output generated from this research is the rpm speed of the DC fan on the Smart showcase hydroponic, which is depicted in the singleton graph in Figure 3.

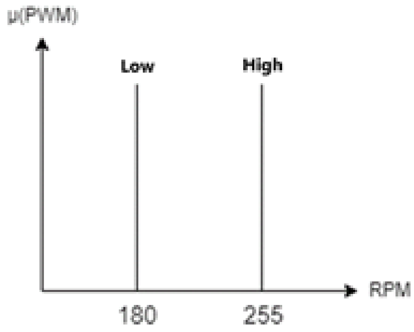


Figure 3: DC Fan Speed (RPM) Output

iii. Fuzzy Rule Base

The rule base is designed to run the system properly and consists of rule sets based on an IF-THEN structure. This study uses six rule bases from two inputs, where each input has three and two sets. Table 1 shows the rule bases used.

Rules	Temp	Hum	RPM
1	Less	Dry	Low
2	Less	Moist	Low
3	Med	Dry	Low
4	Med	Moist	High
5	Most	Dry	High
6	Most	Moist	High

Table 1: Fan Speed Rule Base

The rule base generated from the fuzzification process, as shown in Table 1, can be translated into the following six rules:

1. **Rule 1**: IF the temperature difference between outside and inside the showcase is less AND the humidity inside the showcase is dry, THEN output a low fan speed.
2. **Rule 2**: IF the temperature difference between outside and inside the showcase is less AND the humidity inside the showcase is moist, THEN output a low fan speed.
3. **Rule 3**: IF the temperature difference between outside and inside the showcase is med AND the humidity inside the showcase is dry, THEN output a low fan speed.
4. **Rule 4**: IF the temperature difference between outside and inside the showcase is med AND the humidity inside the showcase is moist, THEN output a high fan speed.
5. **Rule 5**: IF the temperature difference between outside and inside the showcase is most AND the humidity inside the showcase is dry, THEN output a high fan speed.
6. **Rule 6**: IF the temperature difference between outside and inside the showcase is most AND the humidity inside the showcase is moist, THEN output a high fan speed.

III. Results and Discussion

The results of this research consist of two parts: the creation of a hydroponic smart showcase prototype and the application of fuzzy methods based on room temperature and humidity. This research begins with sketching the Smart Showcase Hydroponic prototype to implement various devices in it. In the Showcase, there are grow lights, DC fans, DHT22 sensors, hydroponic plants, and mini water pumps. The prototype design is shown in Figure 4 below.

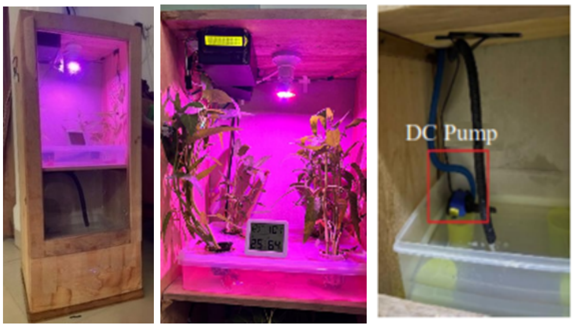
(a) **(b)**

Figure 4: Smart Showcase Prototype 3D Design; (a) Front view, (b) Side view

This hydroponic Smart Showcase has a volume of 140,000 cm^3, and its size is 100 cm high, 35 cm wide, and 40 cm long. Figure 5 shows the results of the prototype design.

Temperature and humidity tests were conducted based on the output of the DHT sensor. The objective was to determine the percentage error of the DHT sensor readings using an HTC1 digital thermometer, which was taken simultaneously with the data from the sensor in the showcase and the thermometer inside the showcase, as shown in Figure 5. For seven days, the tests were conducted indoors with normal temperatures. The results of the temperature and humidity comparison on the seventh day are shown in Table 2.

The results of the smart showcase temperature and humidity comparison with the HTC-1 thermometer are



(a) **(b)** **(c)**

Figure 5: Hydroponic Smart Showcase Prototype; (a) Smart Showcase, (b) Sample plants using kale, (c) Nutrient tank and irrigation pump.

Data	DHT (%)	DHT (°C)	HTC-1 (%)	HTC-1 (°C)	Error (%)
1	81.6	29.8	82.0	29.7	0.49
2	81.8	29.7	82.0	29.7	0.24
3	81.9	29.8	82.0	29.6	0.12
4	81.5	29.9	82.0	29.7	0.61
5	79.1	28.9	79.0	28.9	0.13
6	79.6	29.6	79.0	29.4	0.76
7	79.0	30.0	79.0	29.9	0.00
8	79.7	30.1	80.0	30.1	0.37
9	79.1	30.2	79.0	30.2	0.13
10	79.1	30.1	79.0	30.1	0.13
11	80.3	29.3	80.0	29.2	0.37
12	80.5	29.1	80.0	29.1	0.63
13	80.6	29.1	80.0	29.1	0.75
14	82.9	29.2	82.0	29.0	1.10
15	83.9	29.4	83.0	29.0	1.08
16	84.6	29.4	84.0	29.0	0.71
17	85.3	29.3	85.0	29.0	0.35
18	86.8	29.2	86.0	29.0	0.93

Table 2: Measurement Results of Temperature and Humidity in Showcase

based on hourly data samples from 06:00 WIB to 23:00 WIB every day. In the hardware and component technology laboratory of Fasilkom Sriwijaya University, the location of the smart showcase was tested. This location was chosen based on Smart Showcase users who are in an apartment environment. Table 2 shows an error rate of 0.456% for temperature and 0.494% for humidity. With an error rate of less than 10%, the temperature and humidity data validation of this study is good and can be used as input for the fuzzy system. Figure 6 shows how the DC fan rpm reacts to the temperature and humidity in the showcase.

The graph indicates that, based on the fuzzy rule base, changes in temperature and humidity greatly affect the RPM of the DC fan in the showcase. Therefore, the temperature and humidity conditions remain stable inside the showcase for the growth of the kale plants.

During seven days, the fuzzy system applied to the smart showcase was tested using 12 kale plants. The experiment results show that the output of the fuzzy system, which calculates inputs based on the temperature and humidity inside the showcase, impacts the fan RPM value. Within the 12 tested kale stems, 3 failed to thrive on the fourth day and 2 failed on the sixth day, but the other 6 stems continued to flourish until the seventh day.

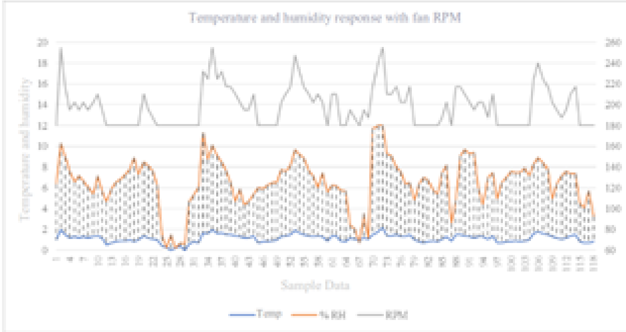


Figure 6: Fan RPM response to temperature and humidity inside the showcase

In addition, this research presents a hydroponic Smart Showcase based on the Internet of Things. The system created, such as DC fan rpm, can be monitored in real-time remotely. Figure 7 shows the results of fan monitoring based on fuzzy input.

Figure 7: Fan RPM Monitoring Results based on Fuzzy system temperature and humidity inputs

Figure 7 shows the RPM monitoring using the Thingsboard platform. The RPM values range from 150 to 255. The green line shows fluctuations in the RPM values within a specific period of 7 days. The average RPM value generated during that period was 194.71 rpm.

Based on the results of this experiment, we claim that this hydroponic smart showcase innovation product, which has a fuzzy system to control temperature and humidity as well as the speed of the DC fan in the showcase room, can be used for vegetable cultivation in low sunlight conditions.

IV. Conclusion

The hydroponic Smart Showcase was successfully deployed in an enclosed space. Based on the RPM value of the DC fan used, the different temperature and humidity values applied to the fuzzy system successfully control the air in the showcase. The kale plants used as research objects have been tested to live and grow inside the showcase with a temperature of 28 to 30 °C and humidity of 60% to 70%. The RPM value of 180 to 255 is a fuzzy-generated output value that is very good at stabilizing the temperature and humidity of the showcase, specifically for kale plants.

References

[1] D. Suswati, E. Dolorosa, and L. Agustine, "Penyiapan media tanam untuk budidaya tanaman sayuran pada lahan gambut di kecamatan pontianak utara," *Jurnal Pengabdian kepada Masyarakat Nusantara*, vol. 4, no. 4, pp. 4603–4609, 2023. [Online]. Available: https://doi.org/10.55338/jpkmn.v4i4

[2] N. Rostini, *6 Jurus Bertanam Cabai Bebas Hama & Penyakit*. Agromedia, 2011.

[3] U. Prastio, *Panen Sayuran Hidroponik Setiap Hari*, 1st ed. Jakarta Selatan: PT AgroMedia Pustaka, 2015.

[4] N. SQ, *Mempercepat Panen Sayuran Hidroponik*, 1st ed. Jakarta: PT AgroMedia Pustaka, 2017.

[5] A. A. Fandi, R. Muchtar, and D. Notarianto, "Pengaruh media tanam terhadap pertumbuhan tanaman terong (solanum melongena l.) dengan sistem hidroponik," *Jurnal Ilmiah Respati*, vol. 11, no. Desember, pp. 1411–7126, 2020.

[6] A. P. Lestari, A. Riduan, Elliyanti, and D. Martino, "Pengembangan sistem pertanian hidroponik pada lahan sempit komplek perumahan," *SAINTIFIK*, vol. 6, no. 2, pp. 136–142, Aug 2020. [Online]. Available: https://doi.org/10.31605/saintifik.v6i2.259

[7] Y. S. Tri, "Strategi pemanfaatan media air (hidroponik) pada budidaya tanaman kangkung, pakcoy, dan sawi sebagai alternatif urban farming," *Journal on Education*, vol. 6, no. 1, pp. 5835–5848, 2023.

[8] A. L. Hidayah, S. Dwiratna, B. M. P. Prawiranegara, and K. Amaru, "Kinerja dan karakteristik konsumsi energi, air, dan nutrisi pada sawi pagoda (brassica narinosa) menggunakan sistem fertigasi deep flow technique (dft)," *Jurnal Keteknikan Pertanian Tropis dan Biosistem*, vol. 8, no. 2, pp. 125–134, Aug 2020. [Online]. Available: https://doi.org/10.21776/ub.jkptb.2020.008.02.02

[9] S. Fuada *et al.*, "Narative review pemanfaatan internet-of-things untuk aplikasi seed monitoring and management system pada media tanaman," vol. 9, no. 1, pp. 40–45, 2023.

[10] N. S. Wibowo, M. Aziziah, I. G. Wiryawan, and E. Rosdiana, "Desain sistem informasi monitoring nutrisi tanaman hidroponik kangkung dengan menggunakan metode regresi linear," *Jurnal Ilmiah Inovasi*, vol. 22, no. 1, pp. 51–58, 2022. [Online]. Available: https://doi.org/10.25047/jii.v22i1.3115

[11] D. K. P. Aji, U. Nurhasan, R. Arianto, and O. D. Triswidrananta, "Smart ecosystem for hydroponic land in the hydroponic farmers group guided by csr pt. otsuka indonesia as an improved quality and quantity of harvest results," *IOP Conf Ser Mater Sci Eng*, vol. 1073, no. 1, p. 012030, 2021. [Online]. Available: https://doi.org/10.1088/1757-899x/1073/1/012030

[12] F. Putra and A. Nasuha, "Prototyping of an automation system for hydroponic strawberry nutrient dosing," 2023.

[13] F. A. Pambudi, H. Oktavianto, and T. Timur, "Sistem pengawasan waktu pemberian nutrisi dan suhu pada tanaman hidroponik berbasis internet of things," *Jurnal Smart Teknologi*, vol. 4, no. 2, pp. 210–219, 2023.

[14] D. Tangkesalu, H. Rasyid, F. Hidayat, A. Melisa, and L. Listiyani, "Inovasi teknologi dalam peningkatan produktivitas dan keberlanjutan agribisnis: Analisis penerapan sistem hidroponik di sektor pertanian," *Jurnal Cahaya Mandalika*, vol. 4, no. 3, pp. 1835–1845, 2023.

[15] M. A. Afandi, F. Fadhlan, R. A. Rochmanto, and H. Widyantara, "Perangkat budidaya microgreen berbasis internet of things," *ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika*, vol. 10, no. 3, p. 581, 2022. [Online]. Available: https://doi.org/10.26760/elkomika.v10i3.581

[16] Rosdiana and M. Shofan, "Pembuatan aplikasi monitoring tanaman hidroponik otomatis dengan koneksi wifi berbasis arduino," pp. 1–17, 2020.

[17] M. C. Untoro and F. R. Hidayah, "Iot-based hydroponic plant monitoring and control system to maintain plant fertility," *INTEK*, vol. 9, no. 1, pp. 33–41, 2022.

[18] E. Kurniawan and Z. Arifin, "Metode smart hydroponics sebagai upaya peningkatan kualitas dan kuantitas produksi panen," *JRST (Jurnal Riset Sains dan Teknologi)*, vol. 7, no. 1, p. 71, Mar 2023. [Online]. Available: https://doi.org/10.30595/jrst.v7i1.15209

[19] X. Chen *et al.*, "Temperature and humidity management of pem fuel cell power system using multi-input and multi-output fuzzy method," *Appl Therm Eng*, vol. 203, no. August 2021, p. 117865, 2022. [Online]. Available: https://doi.org/10.1016/j.applthermaleng.2021.117865

[20] T. P. Fiqar, F. Fitriani, and R. K. Abdullah, "Implementasi sistem monitoring tanaman hidroponik menggunakan metode fuzzy sugeno," *JTIM: Jurnal Teknologi Informasi dan Multimedia*, vol. 5, no. 2, pp. 109–121, Aug 2023. [Online]. Available: https://doi.org/10.35746/jtim.v5i2.372