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Design and Implementation of Water Quality Control in Catfish Farming Using Fuzzy Logic Method with IoT-Based Monitoring System.

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ABSTRAK

Lele dikenal sebagai ikan air tawar yang memiliki ketahanan tinggi terhadap kondisi air keruh. Namun, apabila kebersihan air terganggu, dapat menjadi tempat berkembangnya penyakit yang menghambat pertumbuhan ikan bahkan dapat menyebabkan kematian. Oleh karena itu, penting untuk secara rutin mengganti air dalam kolam. Untuk mengatasi masalah ini, penulis mengusulkan solusi berupa pembuatan sistem pemantauan dan kontrol otomatis yang dapat membantu mengatur kualitas air dalam budidaya lele. Sistem ini melibatkan berbagai sensor seperti pH, DS18B20, HC-SR04, kekeruhan, MQ-135, Wemos D1 R32, pompa air, motor servo, dan ESP-32 camera. Terdapat juga aplikasi Android yang berfungsi memantau dan mengontrol sistem baik secara manual maupun otomatis. Sistem ini menerapkan metode logika fuzzy untuk mendapatkan nilai kendali suhu antara 27-29°C, kadar pH antara 6.5 – 8.5, dan kekeruhan kurang dari 32 NTU. Dari hasil pengujian, diperoleh informasi bahwa untuk menurunkan suhu dari 34 °C menjadi 27 – 29°C dibutuhkan waktu 180 menit, menjaga kadar pH dari 9 menjadi 6.5 – 8 memerlukan waktu yang sama, dan menjaga kekeruhan air dari 40.3 NTU hingga kurang dari 32 NTU membutuhkan waktu 187 menit. Pengujian pemantauan dan kontrol melalui Android menunjukkan keberhasilan hampir keseluruhan dalam uji coba.

***Kata Kunci**: Kualitas Air, Fuzzy Logic, Kadar pH, Suhu, Kekeruhan*

ABSTRACT

Catfish is known as a freshwater fish with strong resilience to murky water conditions. However, if water cleanliness is compromised, it can become a breeding ground for diseases that hinder fish growth and can lead to death. Therefore, it is essential to regularly replace the water in the pond. To address this issue, the author proposes a solution in the form of an automated monitoring and control system to regulate the water quality in catfish farming. This system involves various sensors such as pH, DS18B20, HC-SR04, turbidity, MQ-135, Wemos D1 R32, water pump, servo motor, and ESP-32 camera. There is also an Android application that functions to monitor and control the system both manually and automatically. The system applies fuzzy logic to obtain control values for temperature between 27-29°C, pH levels between 6.5 – 8.5, and turbidity less than 32 NTU. From the test results, it is found that lowering the temperature from 34 °C to 27 – 29°C takes 180 minutes, maintaining pH levels from 9 to 6.5 – 8 requires the same amount of time, and keeping water turbidity from 40.3 NTU to less than 32 NTU takes 187 minutes. Testing of monitoring and control via Android shows nearly complete success in the trials.

***Keyword** : Water Quality, Fuzzy Logic, pH Level, Temperature, Turbidity*

1. INTRODUCTION

This research aims to design and produce a prototype for automatic water condition control in catfish farming using Fuzzy Logic with an Internet of Things (IoT)-based monitoring system. Through the implementation of this system, it is anticipated that the water quality in catfish ponds can be effectively controlled automatically, leading to improved catfish harvests for breeders [1]. The objectives of this research include understanding the microcontroller's function in executing the automated water quality control system, assessing the impact of this device on catfish pond cleanliness, and measuring its efficiency in helping control suboptimal water quality. The benefits of this research encompass its use as a tool to control water quality in catfish ponds, accelerate the process of draining and filling pond water, and address issues related to poor water quality. Therefore, this research has the potential to provide a positive impact on catfish farming efforts [2].

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Fuzzy Logic is a branch of artificial intelligence that uses linguistic values to operate artificial intelligence systems[3]. In fuzzy logic, values can have simultaneous membership in both true and false, depending on their membership weights. This logic is employed to address problems involving uncertainty, imprecision, and noise. The advantage of fuzzy logic lies in its ability to perform reasoning in natural language, eliminating the need for complex mathematical equations in the design of controlled systems [4].

The concept of the Internet of Things (IoT) aims to expand the benefits of continuous internet connectivity. Essentially, IoT refers to objects that can be uniquely identified as virtual representations within an object-based internet structure [5].

A pH water sensor is an electronic device used to measure the acidity level (pH) in liquids. This device consists of a measurement probe connected to electronic equipment [6]. The basic principle involves electrochemical potential between the solution in the glass electrode, known as the inner solution, and the unknown solution outside. The potential is measured between the reference electrode (HgCl) and the KCl solution in the glass electrode, as well as between the sample and the silver electrode. Changes in potential between the sample and the glass electrode reflect the chemical properties of the sample [7].

The DS18B20 temperature sensor is a waterproof sensor with digital data output. Its characteristics include an operating voltage of 3-5V, accuracy level of ±0.5°C, and a temperature range of -10°C to 85°C. The red cable serves as VCC, the black cable as GND, the yellow cable as the data line, with a cable diameter of approximately 4mm [8].

The HC-SR04 sensor is an ultrasonic detection device that converts sound waves into electrical signals to measure distance. Using ultrasonic waves at a frequency of around 20 kHz, this sensor calculates the distance of an object based on the principle of sound wave reflection. Although ultrasonic waves cannot be heard by humans, some animals can detect them. This ultrasonic sensor can be applied to liquids, solids, and gases, but ultrasonic sound waves can be absorbed by certain materials such as foam and textiles [9].

A turbidity sensor is used to detect the turbidity level of water by measuring its optical characteristics. The device compares the reflected light with the incident light to determine the level of water turbidity. Water turbidity is caused by individual particles that are too small to be seen with the naked eye. As the turbidity level increases, the change in sensor output voltage will also increase. This sensor converts the water turbidity level into voltage, which can be processed by a microcontroller to measure water turbidity [10].

The MQ-135 sensor is a chemical sensor sensitive to various compounds such as NH_3, NO_x, alcohol, benzene, smoke (CO), CO_2, and others. This device detects gases by measuring analog resistance changes. MQ-135 exhibits good durability and high energy efficiency. The sensor's sensitivity can be adjusted based on different resistances on the MQ-135 for various gas concentrations. Calibration is required to detect concentrations of NH_3 at 100 ppm or alcohol at 50 ppm in the air [11].

The Wemos D1 R32 microcontroller is a device based on ESP8266, equipped with WiFi module, CH340 USB to serial interface, and compatibility with Arduino shields [12]. This device supports the Internet of Things (IoT) concept for data transmission between devices via the internet network. The ESP8266 module produces TTL serial output with GPIO that can be used independently or with additional microcontrollers. This TTL serial output has Low '0' and High '1' logic levels, where '0' logic is generally equivalent to 0 volts, and '1' logic is equivalent to 3.3 volts or 5 volts (Vcc) [13].

The ESP32 microcontroller, introduced by Espressif System, serves as the successor to the ESP8266 microcontroller. This microcontroller is already integrated with a WiFi module in the chip, thus strongly supporting the development of Internet of Things applications [14].

A servo motor is a type of motor that uses a closed feedback system to provide information about the motor's position to the control circuit [15]. This motor consists of a motor, gears, potentiometer, and control circuit. The motor's angle is adjusted by the width of the pulse sent through the signal. A larger OFF pulse width moves the axis clockwise, while a smaller one moves it counterclockwise. A servo motor is a DC motor equipped with internal control and gears to control its movement and angular position [16].

A pump is a mechanical device used to lift liquid from a low area to a high area or to increase fluid pressure. It creates low pressure on the inlet side and high pressure on the outlet side [17].

An aerator is a tool used to infuse oxygen from the air into a pool or aquarium. By making the water surface contact with the air, this tool increases the oxygen content in the water and removes gases and odorous substances [18]. The aerator creates air bubbles in the water, expanding the water surface in contact with the air for more efficient oxygen absorption.

Solar panels convert solar energy into electrical energy. Monocrystalline solar panels are efficient with efficiency rates up to 15%, although they perform less effectively in shaded areas. Polycrystalline solar panels have a random crystal arrangement, requiring a larger surface area but can generate electricity in cloudy weather [19].

A relay is an electronic switch that conducts high-voltage electricity using low-current electric current. An example is a relay with a 5V 50mA electromagnet that moves the switch contacts to conduct 220V 10A electricity [20].

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2. DISCUSSION

2.1 Method

The stages conducted in this research are illustrated in the flowchart in Figure 1.

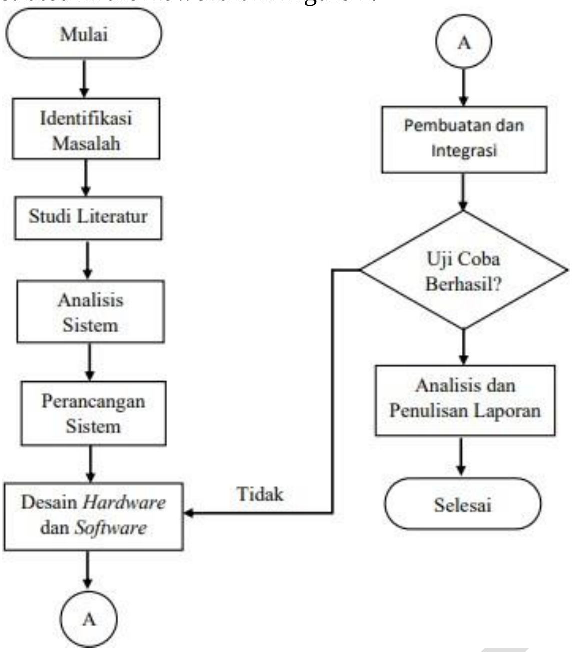

Figure 1. Flowchart of Research

A. Identification and Formulation of Problems

The research activity begins with the application of scientific thinking processes to outline the research problem. During this thought process, problem identification is carried out by reviewing journals from previous studies to understand and revisit the related methods, subjects, and research objects, which can serve as references for this study.

The next stage involves defining the problem statement and research objectives based on the identified issues. The problem statement is derived from the identified topic of concern. This step is crucial to ensure that the research has clear and directed outcomes. In this study, the focus is on the issue of poor water quality in catfish ponds. The objective of this research is to address the problem of poor water quality in catfish ponds by automatically replacing the water.

B. Literature Review

In this stage, the literature review involves studying, comprehending, and analyzing materials related to this research, such as knowledge about Fuzzy Logic Method, Internet of Things, water pH sensor, DS18B20 sensor, HC-SR04 sensor, turbidity sensor, MQ-135 sensor, Wemos D1 R32, ESP-32, and several related literatures through various journal references and senior theses.

C. Design of System

The overall system design consists of input, process, and output elements. In this research, there are five sensors—temperature sensor, distance sensor, pH sensor, turbidity sensor, and ammonia sensor—connected to a microcontroller and ESP-32 Camera for monitoring through live video broadcast. The sensor data will be processed by the microcontroller using fuzzy logic methods. The system output includes controlling actuators and classifying water quality. The simple concept of the system is illustrated in the block diagram in the figure.

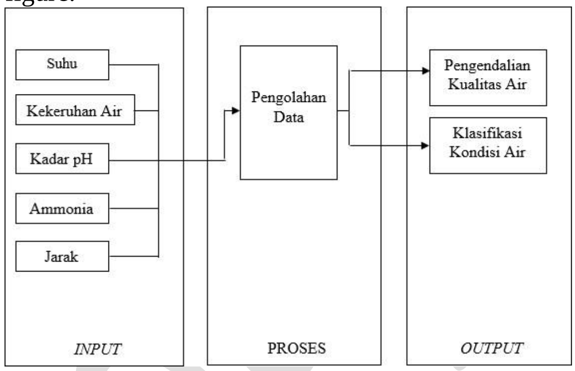

Figure 2. Concept of System

D. Data collection

Primary data refers to information collected directly at the research site. The initial stage in the data processing for this research involves gathering water quality data, including turbidity level, pH, and water temperature, using the Mamdani fuzzy logic method. Data processing is conducted by utilizing a microcontroller that receives input from five data sensors, namely temperature, pH, turbidity, distance, and ammonia sensors.

Secondary data refers to information gathered from previous research journals and pre-existing data. In this study, secondary data consists of standards for good water quality for catfish, aiming to enhance catfish productivity and optimize the water quality control system in catfish ponds.

E. Data Processing

The next step after collecting all the data is to input all the data into fuzzy logic, either using Matlab or Arduino programming, with the results to be compared. This process aims to determine the actuator response and classify water quality based on input data from the sensors. Fuzzy logic applied in the system uses the Mamdani method with Weight Average defuzzification. Fuzzy processing in this system will be carried out on the microcontroller using 5 input data from temperature, pH, turbidity, distance, and ammonia sensors, each with 7 memberships for each input. The output consists of 5 components, namely controlling the inlet water pump, outlet water pump, aerator, servo motor, and water quality classification.

After that, the researcher conducts fuzzy testing by comparing the fuzzy results using Matlab and the fuzzy results using Arduino programming, as well as manual calculations. If the results have a small error value, then the use of fuzzy logic in the program

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created on Arduino is aligned with the toolbox in Matlab because the resulting error value is small. However, if the results have a large error value, further testing will be carried out until obtaining results with a small error value.

Once the fuzzy testing is confirmed to align with the research design, the author can conduct manual control system testing through the Android application and automatic control. This process aims to determine the estimated time for controlling water quality in the catfish pond. After determining the estimated time for controlling water quality in the catfish pond, the next step is to analyze and interpret the results of object detection.

2.2 Results and Discussion

This research compiles datasheets on the water quality in catfish farming ponds. Data collection is carried out through sensor experiments connected to Arduino. The gathered data includes water turbidity, water temperature, and water pH. This information will serve as input in the system and will be compared with fuzzy logic results using Matlab. There are four sets of data used in the fuzzy logic comparison between Arduino and Matlab.

Table 1. Quality Water

No	Suhu	Kekeruhan	pH	Kualitas Air	
				Arduino	*Toolbox* Matlab
1	35,8	21,3	8,3	22,38	24,1
2	16,7	32,9	5,5	19,5	20,3
3	29,6	31,4	7,9	34,43	34,53
4	22,6	30,3	6,7	32,03	32,7

There are four datasets utilized for comparing fuzzy logic between Arduino and Matlab. These inputs involve five sensors: temperature, turbidity, pH, distance, and ammonia. These sensors will be connected to a microcontroller using the fuzzy logic method. Sensor data will be processed on the microcontroller using fuzzy logic, then transmitted to an Android application linked to the Google Firebase database. The application can be accessed through a smartphone or laptop. Within the application, there are commands available to control actuators responsible for manual or automatic draining and filling of the pond water.

Fuzzy testing is conducted by comparing the results of fuzzy logic using Matlab and Arduino, along with manual calculations. Table 3.2 provides a comparison between fuzzy results from Matlab and Arduino. In the fuzzy logic testing on Arduino and Matlab, there is an error value of 3.35% for the water quality output, 2.8% for the inlet water output, 1.13% for the outlet water output, and 0.52% for the aerator output, which is then compared with Matlab's toolbox. This indicates that the use of fuzzy logic in the program created on Arduino is in line with the toolbox on Matlab because the resulting error values are relatively small.

Table 2. Comparison of Arduino and Matlab Fuzzy Results

Suhu	**Kekeruhan**	**pH**	**Kualitas Air**		**Air Masuk**		**Air Keluar**		**Aerator**	
			Arduino	***Toolbox* Matlab**	**Arduino**	***Toolbox* Matlab**	**Arduino**	***Toolbox* Matlab**	**Arduino**	***Toolbox* Matlab**
35,8	**21,3**	**8,3**	**22,38**	**24,1**	**17,62**	**16,4**	**40**	**40**	**60**	**60**
16,7	**32,9**	**5,5**	**19,5**	**20,3**	**20,5**	**20,2**	**55,25**	**55,8**	**70**	**69,6**
29,6	**31,4**	**7,9**	**34,43**	**34,53**	**11,43**	**11,43**	**45,6**	**46,6**	**65,6**	**66,6**
22,6	**30,3**	**6,7**	**32,03**	**32,7**	**10,33**	**10,1**	**51,3**	**50,6**	**70**	**70**

Table 3. Fuzzy Error Values for Arduino and Matlab

No	*Error (%)*			
	Kualitas Air	Air Masuk	Air Keluar	Aerator
1	7,14	7,44	0,00	0,00
2	3,94	1,49	0,99	0,57
3	0,29	0,00	2,15	1,50
4	2,05	2,28	1,38	0,00
Rata - Rata	3,35	2,80	1,13	0,52

Fuzzy testing is performed by comparing fuzzy results obtained using Matlab and those achieved through Arduino programming, including manual calculations. Table 3.3 provides a comparison of fuzzy results between Matlab and Arduino. In the fuzzy logic testing between Arduino and Matlab, an average error value of 2.25% is found for water quality output, 4.05% for inlet water output, 2.05% for outlet water output, and 1.36% for aerator output when compared to the Matlab toolbox. This indicates that the use of fuzzy logic in the designed system is in line with the Matlab toolbox. In other words, the use of fuzzy logic in this system aligns with the Matlab toolbox because the resulting error values are relatively small.

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Table 4. Testing Data for Monitoring and Manual Control

Pengujian	Respon				
	Uji Coba 1	Uji Coba 2	Uji Coba 3	Uji Coba 4	Uji Coba 5
Monitoring Pada Aplikasi Android	Berhasil	Berhasil	Berhasil	Berhasil	Berhasil
Pengendalian Pompa Air Masuk	Berhasil	Berhasil	Berhasil	Berhasil	Berhasil
Pengendalian Pompa Air Keluar	Berhasil	Berhasil	Gagal	Berhasil	Berhasil
Pengendalian Aerator	Berhasil	Berhasil	Berhasil	Berhasil	Gagal
Pengendalian Motor Servo 1	Berhasil	Berhasil	Berhasil	Berhasil	Berhasil
Pengendalian Motor Servo	Berhasil	Berhasil	Berhasil	Berhasil	Berhasil

Table 5 outlines the results of the automatic system testing related to temperature parameters. According to the information in Table 5, reducing the temperature to reach the set point takes approximately 146 minutes, with the final measured temperature reaching 27.2 °C. In the subsequent tests, from the second to the fourth, the required time ranges from 152 to 180 minutes. Based on Table 4.4.2, it can be concluded that reducing the temperature from the initial value of 32-34 °C to reach the final temperature of 27-29 °C takes an average time of around 159.5 minutes.

Table 5. Testing of Temperature

No	Nilai Awal	*Set Point*	Nilai Akhir	Waktu (Menit)
1	32,3	27-29	27,2	146
2	33,1		28,9	152
3	33,3		27,8	160
4	34,1		28,4	180
Rata-Rata				159,5

In Table 6, it can be observed that the testing for the pH parameter starts with an initial value of 9.0 in the first trial. To decrease the pH level to be within the set point range, it takes approximately 180 minutes, with the final pH value reaching 7.8. In the second to fourth tests, the required time ranges from 150 to 174 minutes to maintain the pH level within the set point value.

Table 6. Testing oF pH Parameter

No	Nilai Awal	*Set Point*	Nilai Akhir	Waktu (Menit)
1	9,0	6,5-8	7,8	180
2	8,8		7,6	174
3	8,6		8,0	166
4	8,5		7,7	153
Rata - Rata				168,25

In Table 7, it can be observed that the testing for the turbidity parameter begins with an initial value of 40.3 in the first trial. It takes 187 minutes for the turbidity value to decrease below 32, with the final control result reaching 31.7 in the first trial. Based on the table, it can be concluded that for an initial turbidity value of 36-40, achieving a turbidity value less than or equal to 32 requires an average time of around 172.25 minutes.

Table 7. Testing of Turbidity

No	Nilai Awal	*Set Point*	Nilai Akhir	Waktu (Menit)
1	40,3	>32	31,7	187
2	35,5		30,3	156
3	38,7		30,6	178
4	36,6		30,4	168
Rata - Rata				172,25

The implementation of the system is carried out by monitoring the water quality for approximately 14 days. Table 8 shows the results of the automatic control system test compared to a pond without control.

Hari ke-	Kolam yang Dikendalikan			Kolam yang Tidak Dikendalikan		
	Suhu	pH	krh	Suhu	pH	Krh
1	27,8	7,9	31,9	29,4	9	47,3
2	27,3	7,3	31,9	27,4	7,7	47,9
3	28,6	7,9	32	27,7	8,8	45,3
4	27,7	8	30,7	28,3	7,8	49,4
5	28,6	7,7	31,3	29,5	8,2	46,2
6	28,5	6,9	31,9	29,5	7,9	46,3
7	27,2	7,6	30,7	29,8	8,8	46,7
8	28,1	7,2	31,7	27,6	8,8	49,8
9	27,7	7,7	31,1	28,5	8,8	49,4
10	27,2	7,5	31,6	27,7	8,2	48,9
11	27	7,6	30,5	27,4	8,6	31
12	28,9	7,2	31,7	28,1	7,7	31,3
13	27,8	7,1	31,3	29,1	7,8	33,6
14	27,7	7,3	30,5	30,2	7,7	30,7

From the table, it can be concluded that automatic water quality control effectively maintains the values of water quality parameters according to the established standards. Compared to uncontrolled ponds, these parameters are better preserved, ensuring the quality of the water is maintained.

3. CONCLUSION

Based on this research, it can be concluded that the system design successfully maintains the water quality parameters, such as temperature, pH, and turbidity, at the desired values. The application for monitoring water quality parameters also operates

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effectively. Manual monitoring and control through the Android application in the cultivation of tilapia fish have been successfully implemented, despite some test failures. The implementation of fuzzy logic as an automatic controller takes a considerable amount of time due to the use of a low-flow pump. Recommendations include adding sensors for more precise monitoring, utilizing a cloud server for camera streaming, optimizing the water drainage system, and increasing the number of test samples during sensor calibration for more accurate results.

REFERENCES

[1] Ammari, S., Wildian, W., & Harmadi, H. (2019). Rancang Bangun Sistem Peringatan Dini Banjir Berdasarkan Tingkat Kekeruhan Air Hulu Sungai dengan Turbidity Sensor SEN0189 dan Transceiver nRF24L01+. Jurnal Fisika Unand, 8(3), 240–244. https://doi.org/10.25077/jfu.8.3.240- 244.2019

[2] Aritonang, W., Bangsa, I. A., & ... (2021). Implementasi Sensor Suhu DS18B20 dan Sensor Tekanan MPX5700AP menggunakan Mikrokontroller Arduino Pada Alat Pendeteksi Tingkat Stress. Jurnal Ilmiah Wahana …, 7(1). https://doi.org/10.5281/zenodo.4541278 Barus, E. E., Pingak, R. K., & Louk, A.

[4] C. (2018). OTOMATISASI SISTEM KONTROL pH DAN INFORMASI SUHU PADA AKUARIUM MENGGUNAKAN ARDUINO UNO DAN RASPBERRY PI 3. Jurnal Fisika : Fisika Sains Dan Aplikasinya, 3(2), 117–125. https://doi.org/10.35508/fisa.v3i2.612

[5] Dandi, M., & Hidayat, T. (2020). Analisis Prediksi Problem Virtual Machine Server Menggunakan Metode Fuzzy Logic. Teknokom, 3(1), 1–6. https://doi.org/10.31943/teknokom.v3i1.41

[6]Moh. G. P. A. Sugianto and A. T. Nugraha, "Implementasi sensor cahaya sebagai level bahan bakar pada tangki harian kapal," Journal of Computer Electronic and Telecommunication, vol. 2, no. 1, Jul. 2022, doi: https://doi.org/10.52435/complete.v2i1.191.

[7]Chusnia Febrianti and Anggara Trisna Nugraha, "Implementasi Sensor Flowmeter pada Auxiliary Engine Kapal Berbasis Outseal PLC," Journal of Computer, Electronic, and Telecommunication, vol. 3, no. 2, Dec. 2022, doi: https://doi.org/10.52435/complete.v3i2.188.

[8]Fahmi Ivannuri and Anggara Trisna Nugraha, "Implementation Of Fuzzy Logic On Turbine Ventilators As Renewable Energy," Journal of Electronics, Electromedical Engineering, and Medical Informatics, vol. 4, no. 3, pp. 178–182, Jul. 2022, doi: https://doi.org/10.35882/jeeemi.v4i3.236.

[9]Anggara Trisna Nugraha, "TRACKING QUADCOPTER MENGGUNAKAN METODE COMMAND-GENERATOR TRACKER DENGAN EFEK INTEGRATOR," Jurnal Teknologi Elektro, vol. 8, no. 2, p. 143151, May 2017, doi: https://doi.org/10.22441/jte.v8i2.1608.

[10]Anggara Trisna Nugraha, "DESAIN KONTROL OUTPUT FEEDBACK DENGAN COMMAND GENERATOR TRACKER BERBASIS LOS PADA JALUR LINGKARAN MENGGUNAKAN QUADCOPTER," Jurnal Teknologi Elektro, vol. 9, no. 2, pp. 73–78, Oct. 2018, doi: https://doi.org/10.22441/jte.v9i2.4070.

[11]A. T. Nugraha and T. Agustinah, "Quadcopter Path Following Control Design Using Output Feedback with Command Generator Tracker LOS Based At Square Path," Journal of Physics: Conference Series, vol. 947, p. 012074, Jan. 2018, doi: https://doi.org/10.1088/1742-6596/947/1/012074.

[12]Anggara Trisna Nugraha and Trihastuti Agustinah, "Quadcopter path following control design using output feedback with command generator tracker based on LOS," Aug. 2017, doi: https://doi.org/10.1109/isitia.2017.8124090.

[13]A. T. Nugraha and T. Agustinah, "Quadcopter Path Following Control Design Using Output Feedback with Command Generator Tracker LOS Based At Square Path," Journal of Physics: Conference Series, vol. 947, p. 012074, Jan. 2018, doi: https://doi.org/10.1088/1742-6596/947/1/012074.

[14]Anggara Trisna Nugraha and Trihastuti Agustinah, "Quadcopter path following control design using output feedback with command generator tracker based on LOS," Aug. 2017, doi: https://doi.org/10.1109/isitia.2017.8124090.

[15]R. Rahim et al., "Congklak, a traditional game solution approach with breadth first search," MATEC Web of Conferences, vol. 197, p. 03007, 2018, doi: https://doi.org/10.1051/matecconf/201819703007.

[16]Anggara Trisna Nugraha and Jamaaluddin, "Setting Neuro-Fuzzy PID Control In Plant Nonlinear Active Suspension," Journal of Physics: Conference Series, vol. 1114, no. 1, pp. 012063–012063, Nov. 2018, doi: https://doi.org/10.1088/1742-6596/1114/1/012063.

[17]Anggara Trisna Nugraha, "DESAIN KONTROL OUTPUT FEEDBACK DENGAN COMMAND GENERATOR TRACKER BERBASIS LOS PADA JALUR LINGKARAN MENGGUNAKAN QUADCOPTER," Jurnal Teknologi Elektro, vol. 9, no. 2, pp. 73–78, Oct. 2018, doi: https://doi.org/10.22441/jte.v9i2.4070.

[18]Anggara Trisna Nugraha, "DESAIN KONTROL OUTPUT FEEDBACK DENGAN COMMAND GENERATOR TRACKER BERBASIS LOS PADA JALUR LINGKARAN MENGGUNAKAN QUADCOPTER," Jurnal Teknologi Elektro, vol. 9, no. 2, pp. 73–78, Oct. 2018, doi: https://doi.org/10.22441/jte.v9i2.4070.

[19]A. T. Nugraha, "DIRTY AIR FILTER SYSTEM USING BOXED EQUALIZER MQ-8 AND MQ-9 WHEELED ROBOT," JEEMECS (Journal of Electrical Engineering, Mechatronic and Computer Science), vol. 1, no. 1, Jul. 2018, doi: https://doi.org/10.26905/jeemecs.v1i1.2301.

[20]Anggara Trisna Nugraha and Jamaaluddin, "Setting Neuro-Fuzzy PID Control In Plant Nonlinear Active Suspension," Journal of Physics: Conference Series, vol. 1114, no. 1, pp. 012063–012063, Nov. 2018, doi: https://doi.org/10.1088/1742-6596/1114/1/012063.