

The IoT Simulation of Watering System for Vanilla Cultivation Using DHT11 and Soil Moisture Sensors with Fuzzy Logic Control

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Abstract

The primary objective of this study is to design and simulate an automatic watering system using DHT11 and a soil moisture sensor for vanilla cultivation with the implementation of fuzzy logic control. The system can effectively adjust watering frequency based on soil moisture and ambient temperature, ensuring optimal plant care and maintaining ideal growth conditions for vanilla without manual intervention. Using the ADDIE development model, this system was designed to meet user needs, including farmers. Testing using MATLAB software using Rule Viewer and Simulink, as well as Arduino IDE software running with Proteus, yielded the same output values when the input values were also identical. Therefore, it can be concluded that the IoT simulation of vanilla cultivation using fuzzy logic control can be implemented according to the research objectives. The results of this study demonstrate the great potential of applying IoT technology to support efficiency and effectiveness in plant maintenance. This system also offers an efficient and accurate monitoring solution compared to manual methods, and operates automatically without requiring human intervention.

Keywords: Vanilla; Fuzzy Logic; IoT; Arduino; ADDIE

Introduction

Vanilla (*Vanilla planifolia*) is a high-value agricultural commodity widely used in the food and cosmetics industries. However, its cultivation requires specific environmental conditions, particularly temperature and soil moisture. In many vanilla-growing regions, traditional irrigation methods are still used, which can lead to overwatering or underwatering, negatively impacting plant health and yield.

Integrating Internet of Things (IoT) technology in agriculture offers a promising solution to these challenges by enabling real-time environmental monitoring and automated decision-making. Specifically, sensors such as the DHT11 (for temperature and humidity) and soil moisture sensors can provide valuable data for managing irrigation efficiently. To handle the uncertainties in sensor data and make intelligent watering decisions, fuzzy logic control offers an adaptive and human-like reasoning approach, ideal for complex systems like agriculture. By simulating an automatic IoT-based watering system using fuzzy logic, this research aims to contribute to

sustainable and intelligent vanilla farming practices that optimize water usage while improving crop productivity.

The objectives of this research are to design and simulate an automatic watering system using IoT sensors (DHT11 and soil moisture sensor) for vanilla cultivation, implement fuzzy logic control for determining the optimal irrigation schedule based on real-time sensor input, and evaluate the effectiveness and performance of the simulated system in maintaining ideal growth conditions for vanilla.

This research provides the following contributions: A prototype simulation model for an intelligent watering system tailored to vanilla cultivation using IoT and fuzzy logic, An approach that demonstrates how low-cost sensors and control algorithms can be effectively integrated for innovative agriculture applications and A reference framework that can be adapted and extended to other precision farming needs or crop types, enhancing sustainability in agriculture through technology.

Literature Review

Vanilla Cultivation

Madagascar, Indonesia, China, and Mexico primarily produce natural vanilla beans. Natural vanillin is extracted from the seed pods of vanilla. Vanillin is used mainly in food, cosmetics, perfume, and to treat intestinal gas and fever (Tan & Chin, 2015).

Cultivating vanilla plants is relatively easy to do. Vanilla plants can be developed in two ways, namely generatively or through seeds, and vegetatively, namely using stem cuttings, but vanilla plants are easier to acquire through cuttings. Cuttings are a commonly used method for propagating vanilla plants. Good cuttings come from mother plants that are fertile and healthy, have dense leaves, dense stem segments, large stem circumference, and have never flowered or fruited. Cuttings should be taken at the beginning of the rainy season (Rahman et al., 2019). The cuttings are usually 1 m or more, with around 7–8 segments. The longer the cuttings are planted, the faster they flower. Vanilla has quite good and stable market prospects. The price of dry vanilla is between 300 to 600 thousand rupiah per kg. Vanilla can be used for various food products, beverages, cosmetics, perfumes, and other applications (Nadzirah et al., 2023).

Internet of Things

The Internet of Things (IoT) refers to a system of interconnected physical devices embedded with sensors, software, and other technologies to collect and exchange data over the internet (Rasheed Abdul Haq & Harigovindan, 2022). These "things" can range from household appliances and wearable devices to industrial machines and environmental sensors. IoT enables these devices to monitor, communicate, and interact with each other or with centralized systems, often without human intervention. The Internet of Things (IoT) refers to a vast network of physical objects, "things", that are embedded with sensors, software, and other technologies, allowing them to connect and exchange data with other devices and systems over the internet or other communication networks (Ramesh, 2021).

At the heart of IoT devices are sensors that collect data from their environment (e.g., temperature, humidity, motion, light, pressure, location). Some devices also have actuators, which allow them to act based on the data received. These "things" communicate with each other and with central systems (often cloud-based) using various wireless and wired technologies like Wi-Fi, Bluetooth, cellular networks (4G, 5G), Zigbee, and LoRaWAN. The primary purpose of IoT is to enable these devices to collect and share data in real-time with minimal human intervention. This data can be anything from vital signs from a health monitor to a car's performance metrics or the occupancy level of a room (Akhilak et al., 2025). The data collected by IoT devices is then processed, analyzed (often using machine learning and artificial intelligence), and used to gain

insights, automate tasks, and make informed decisions. This increases efficiency, convenience, and new possibilities across various sectors (Erwin et al., 2023).

Fuzzy logic

Fuzzy logic is a form of many-valued logic that allows for degrees of truth, rather than the strictly binary (true or false, 1 or 0) values of traditional Boolean logic (Mahasinul Akhlak et al., 2024). In fuzzy logic, the truth value of a statement can be any real number between 0 and 1. A value of 0 means completely false, one means entirely accurate, and values in between represent partial truth. For example, instead of saying a person is either "tall" or "not tall," fuzzy logic can assign a degree of membership to the "tall" set, such as 0.7 for someone who is somewhat tall. It's designed to mimic human decision-making, which often involves imprecise, vague, or subjective concepts (e.g., "hot," "cold," "fast," "slow"). Humans frequently make decisions based on rules that involve these ambiguous terms. Fuzzy logic helps handle uncertainty, ambiguity, and imprecise data in systems. It allows for a more nuanced and flexible approach to reasoning than conventional logic, which requires precise inputs and outputs. In essence, fuzzy logic provides a mathematical framework to deal with the vagueness and subjective judgment common in human reasoning and real-world phenomena (Ma et al., 2021).

Research Method

The research method used is the research and development method. The development model uses ADDIE. The ADDIE model is a widely recognized instructional design framework utilized, particularly in education, training, and human resource development. It provides a systematic and iterative process for creating practical learning experiences, whether traditional classroom courses, e-learning modules, or other training programs (Mahasinul Akhlak et al., 2024). The acronym ADDIE stands for the five sequential (though often iterative) phases involved: **A**nalysis, **D**esign, **D**evelopment, **I**mplementation, and **E**valuation. While it appears linear, in practice, the ADDIE model is usually applied iteratively, meaning that feedback and findings from later stages can inform and refine earlier stages, leading to continuous improvement. Break down each phase of the ADDIE model when applied as a research and development method:

Analysis Phase

In the ADDIE development model, the first stage is analysing the need for new product development and studying the feasibility and requirements for product development. Product development can begin with problems with existing or implemented products. Problems can arise because the current or available product is no longer relevant to the target market's needs and technology.

In this analysis stage, a problem analysis is conducted using SWOT (Strengths, Weaknesses, Opportunities, and Threats), a Needs Analysis, and a Feasibility Analysis. The evaluation results are used as a guideline for designing an automatic sprinkler system that meets these needs (Akhilak et al., 2025).

Design Phase

The design stage is a systematic process that starts with designing the concept and content of the product, which will form the basis of the development process in the next stage. This study's design stage involves designing software and hardware instruments. The software is Cisco Packet Tracer, MATLAB 2022b, Proteus, and Arduino IDE. Hardware is the electronic components used, consisting of Home Gateway DLC 100, Smartphone, Lawn Sprinkler, Temperature Sensor, Humidity Sensor, Temperature Monitor, and Humidity Monitor. Software instruments are used to design hardware (using Proteus), design Mamdani Fuzzy Logic rules (using MATLAB 2020b), and create program codes (using Arduino IDE). Meanwhile, to design IoT using the Cisco Packet Tracer program and interface design using the Blynk application.

Development Phase

The development stage involves implementing the previously created product design. In this research, the development stage involved developing an automatic plant watering product design consisting of IoT, application interface, hardware, and fuzzy design.

Implementation Phase

Product implementation in the ADDIE research and development model is intended to obtain feedback on the product being created or developed. Initial feedback (initial evaluation) can be obtained by asking questions about product development objectives. Implementation refers to the product design made by creating a table of test scenario questions for the IoT design, application interface design, hardware design, and fuzzy design.

Evaluation Phase

The ADDIE model development research evaluation phase was conducted to provide feedback to product users, allowing revisions to be made based on the product's evaluation results or unmet needs. The ultimate goal of the evaluation was to measure the achievement of development objectives. Ten respondents conducted the system evaluation. The evaluation scenario asked respondents to select the Fuzzy Trainer modules to assemble. Then, they assembled the selected modules following instructions from the manual. Afterward, they were asked to complete an evaluation form. The evaluation form contained the respondents' assessments of the Mamdani Fuzzy Trainer.

This stage was the testing phase of the developed application. In this study, the UI design testing process used Usability Heuristic indicators to observe user activity. Direct user activity observations were conducted with the user and researcher in the exact location at the same time. This was done to obtain feedback on each user activity.

Result

The research results are described through the stages of the ADDIE method as follows:

Analysis

In the ADDIE development model, the first stage is analysing the need for new product development and the feasibility and requirements for product development. Product development can begin with problems with existing or implemented products. Problems can arise because existing or available products are no longer relevant to the target needs and technology. In this analysis stage, a problem analysis is conducted using SWOT (Strengths, Weaknesses, Opportunities, and Threats), a Needs Analysis, and a Feasibility Analysis. The study results are a guideline for designing an automatic sprinkler that meets the needs.

Table 1. SWOT Analysis of IoT Simulation Of Watering System For Vanilla Cultivation Using DHT11 Sensors With Fuzzy Logic Control

Components	Analysis Result
Strengths	Precision Watering: Fuzzy logic allows for nuanced decision-making based on multiple sensor inputs (temperature, humidity), enabling highly precise watering tailored to vanilla's specific needs. This avoids over or under-watering, crucial for vanilla. Resource Optimization: By only watering when necessary and with the optimal amount, the system significantly reduces water waste, a major benefit in agriculture and for sustainability. Reduced Labor Costs and Manual Intervention: Automation eliminates the need for constant manual monitoring and watering, freeing up farmer's time and reducing labor expenses. Suitability for Vanilla: Vanilla is a high-value, sensitive crop. The precision offered by this system directly addresses its specific requirements, potentially leading to higher yields and better quality. Scalability (in principle): Once the simulation is validated and the system is proven effective, it can theoretically be scaled to larger vanilla farms. Cost-Effective Sensors: DHT11 sensors are relatively inexpensive, making the hardware component potentially affordable.

	Adaptability (Fuzzy Logic): Fuzzy logic excels at handling imprecise and uncertain data, which is common in dynamic agricultural environments. It can easily incorporate new rules or adjust to different environmental conditions without extensive reprogramming.
Weaknesses	Simulation vs. Reality Gap: A major weakness is that it's a <i>simulation</i>. The real-world environment (e.g., sensor inaccuracies, extreme weather, system malfunctions, power fluctuations) might behave differently than the simulated one, requiring significant adjustments during actual deployment. Sensor Limitations: DHT11 sensors are entry-level and might have limited accuracy and range. Soil moisture sensors can also be affected by soil type and salinity, potentially leading to inaccurate readings. Connectivity Reliance: The "IoT" aspect means reliance on stable internet or local network connectivity, which can be an issue in remote agricultural areas. Technical Expertise Required: Developing and maintaining a system with IoT components, sensors, and fuzzy logic requires specific technical skills (programming, electronics, AI concepts) which might not be readily available to vanilla farmers. Initial Setup Complexity: Even for a simulated system, setting up the virtual environment, integrating sensor data, and configuring fuzzy logic rules can be complex. Power Dependency: The system requires a reliable power source for sensors, microcontrollers, and pumps. Power outages could disrupt watering schedules. Maintenance and Calibration: Sensors will require regular maintenance, cleaning, and recalibration to ensure accuracy over time. Security Concerns (for real deployment): While a simulation, a real IoT system would face cybersecurity risks, which need to be considered in the design phase.
Opportunities	Growing Demand for Smart Agriculture: There's an increasing global trend towards precision agriculture and smart farming to improve efficiency, reduce waste, and increase yields. High Value of Vanilla: Given vanilla's high market value, even small improvements in yield or quality due to optimized watering can lead to significant financial returns for farmers. Expansion to Other Crops: The core technology (IoT, sensors, fuzzy logic for watering) can be adapted and applied to other high-value or water-sensitive crops. Integration with Broader Farm Management Systems: The system could be integrated with other smart farming tools, such as weather forecasting, nutrient management, or pest control systems, for a more holistic approach. Market for Agricultural IoT Solutions: There's a growing market for specialized IoT solutions in agriculture, creating potential for commercialization of this system. Sustainable Agriculture Initiatives: The water-saving aspect aligns well with global and national efforts towards sustainable agricultural practices and resource conservation. Remote Monitoring and Control: The IoT nature allows farmers to monitor and control their vanilla cultivation from anywhere, which is a significant convenience.
Threats	High Upfront Investment (for real deployment): While sensors are cheap, the full deployment, including microcontrollers, pumps, valves, and communication infrastructure, can represent a significant initial investment for farmers, especially smallholders. Competition: The market for smart irrigation systems is becoming increasingly competitive, with various solutions emerging. Technological Obsolescence: Rapid advancements in IoT and AI mean that current hardware or software solutions could quickly become outdated. Weather Extremes and Natural Disasters: The system's effectiveness can be challenged by unpredictable weather events (e.g., prolonged droughts, heavy rainfall, floods) that might overwhelm its current design capacity. Farmer Reluctance to Adopt New Technology: Some farmers might be resistant to adopting new, complex technologies due to lack of familiarity, perceived cost, or skepticism about benefits. Data Privacy and Ownership Issues: For a deployed system, who owns the collected data and how it's used could become a concern. Maintenance Costs and Technical Support: Long-term maintenance, repairs, and the availability of technical support for the system could be ongoing challenges. Sensor Failure: Malfunctioning sensors can lead to incorrect data, resulting in inappropriate watering and potentially harming the vanilla plants.

Table 1, SWOT analysis provides a comprehensive overview of the factors influencing the success of an IoT simulation of a watering system for vanilla cultivation using DHT11 sensors with fuzzy logic control. It highlights the substantial potential benefits while pointing out critical areas for consideration and mitigation, especially when moving from simulation to actual implementation.

The next stage is the feasibility analysis, which examines the technical and business feasibility of implementing the system. The **TELOS Analysis** (Table 2) is a popular feasibility study framework used to evaluate a project's viability across five key dimensions: **T**echnical, **E**conomic, **L**egal, **O**perational, and **S**chedule (Akhilak et al., 2025). Let's apply this framework to your project: IoT Simulation of a Watering System for Vanilla Cultivation Using DHT11 and Soil Moisture Sensors with Fuzzy Logic Control.

Remember that since it's a "simulation," some aspects (especially Legal and Operational for full deployment) might be less critical for the simulation phase itself, but are crucial for understanding the feasibility of *eventual real-world implementation*.

Table 2. TELOS Analysis of the IoT Simulation of Watering System for Vanilla Cultivation Using DHT11 Sensors with Fuzzy Logic Control

Feasibility	Measurement
Technical Feasibility	Highly feasible. The core technologies (sensors, microcontrollers, IoT communication, fuzzy logic) are mature, readily available, and well-documented. The simulation itself further reduces initial technical risk by allowing for rigorous testing of the logic.
Economic Feasibility	Highly promising. While the simulation phase itself has low costs, the potential economic benefits for vanilla cultivation in a real-world scenario are very attractive, especially concerning water efficiency and yield improvement.
Legal Feasibility	Generally feasible for the simulation. For real-world deployment, potential legal hurdles primarily revolve around data management, environmental impact, and adherence to relevant agricultural technology standards in Indonesia, which would require careful review. Indonesia is also still developing specific regulations for AI in agriculture.
Operational Feasibility	Moderately feasible. While the technical aspects are sound, the operational success heavily depends on user adoption, ease of use, robust design for challenging environments, and reliable technical support in a real-world scenario. The simulation can help refine the operational logic.
Schedule Feasibility	Feasible for the simulation phase. The project's scope for simulation is manageable. However, if moving towards actual deployment, a much more extensive and realistic timeline would be required, factoring in robust testing, regulatory compliance, and user training.

The IoT simulation of a watering system for vanilla cultivation using DHT11 sensors with fuzzy logic control demonstrates **strong technical and economic feasibility**, particularly for the simulation phase and its potential in a real-world high-value crop like vanilla. When considering full-scale deployment in Indonesia, the **operational and legal aspects require more attention**, especially regarding connectivity in remote areas, farmer adoption, data regulations, and long-term maintenance. This TELOS analysis provides a solid foundation for further development, highlighting areas of strength to leverage and areas of weakness/threats to mitigate.

Design

The design stage is a systematic process that begins with developing the concept and content of the product, which will form the basis for subsequent development stages. In this study, the design stage involved designing instruments consisting of software and hardware. Cisco Packet Tracer, MATLAB 2020b, Proteus, and the Arduino IDE were used. The hardware comprised electronic components, including the Home Gateway DLC 100, smartphone, lawn sprinkler, temperature sensor, humidity sensor, temperature monitor, and humidity monitor. Software instruments were used to design the hardware (using Proteus), design the Mamdani Fuzzy Logic rules (using MATLAB 2020b), and create the program code (using the Arduino IDE). The IoT design used Cisco Packet Tracer, and the interface design used Blynk (Figure 1).

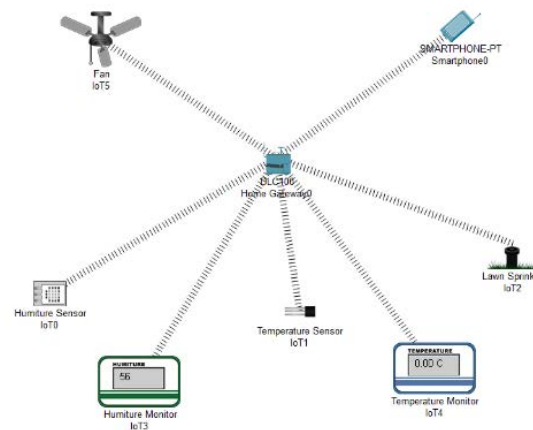


Figure 1. Schematic Design of an IoT-based Vanilla Plant Watering System using Cisco Packet Tracer Software

The devices used are the Home Gateway DLC 100, a smartphone, a Lawn Sprinkler, a temperature sensor, a humidity sensor, and a temperature monitor. The functions of each device are in Table 3.

Table 3. Devices are used in an IoT Simulation of a Watering System for Vanilla Cultivation Using DHT11 Sensors with Fuzzy Logic Control

Device Name	Function
Home Gateway DLC 100	A device that acts as a control center for a smart vanilla cultivation system. It connects various smart devices with sensors and monitors to the internet and allows users to control them remotely through an app or other connected devices.
Smartphone	A smartphone is a device used by users to access and control smart vanilla cultivation systems through a dedicated app. This allows users to receive notifications, view device status, and remotely control smart devices.
Lawn Sprinkle	the primary function of a lawn sprinkler is to provide efficient, uniform, and often automated irrigation, thereby promoting healthy plant growth, conserving water, and reducing manual labor.
Electronic Fan	Electronic fans play a crucial role in maintaining an optimal growing environment within a greenhouse. Their primary function is to create airflow and regulate the internal climate , which directly impacts plant health and productivity.
Humiture Sensor	The term "humiture sensor" is essentially a colloquial or informal term that refers to a combined temperature and humidity sensor . It's not a distinct category of sensor technology, but rather a descriptive label for devices that perform both functions in a single unit. So, in this project, the humiture sensor's function goes beyond just "measuring temperature and humidity"; it provides a vital piece of environmental data that allows the fuzzy logic system to make smarter, more adaptive, and predictive watering decisions for optimal vanilla cultivation.
Humiture monitor	A "humiture monitor" implies a system that not only <i>measures</i> temperature and humidity but also <i>displays, logs, and potentially acts upon</i> that data. So, the function of a humiture monitor is to continuously track, display, record, and provide insights into the ambient temperature and relative humidity of an environment , enabling informed decision-making or automated control.
Humidity soil sensor	This is the core function. Instead of directly measuring the weight of water (which would require drying and weighing soil samples), soil moisture sensors indirectly measure VWC by using other properties of the soil that change with moisture content.
Humidity soil monitor	The primary function of a soil moisture monitor is to measure the volumetric water content (VWC) of the soil . In simpler terms, it tells you how much water is present in a given volume of soil.

After designing the Internet of Things device for the Vanilla Plant Watering System with Fuzzy Logic Control, the next step is to create the system's operational rules. The Table 4 shows

the rules for the Vanilla Plant Watering System with Fuzzy Logic Control based on the Internet of Things.

Table 4. Rules for the IoT Simulation of Watering System for Vanilla Cultivation Using DHT11 Sensors with Fuzzy Logic Control

Rule	Action
Rule 1	If the soil moisture sensor detects humidity of less than 40% and the temperature sensor detects an ambient temperature of more than 30°C, then Lawn Sprinkle (IoT 2) will turn on or True to water the surrounding plants until it reaches the second condition/rule.
Rule 2	If the soil moisture sensor detects humidity of more than 80% and the temperature sensor detects an ambient temperature of less than 15°C, then Lawn Sprinkle (IoT 2) will turn off or False and will stop watering the surrounding plants until it reaches the first condition/rule.

Next, the above rule's development is implemented in the Cisco Packet Tracer software. Figure 2 is an image of the rule from the IoT simulation of a watering system for vanilla cultivation using DHT11 sensors with Fuzzy Logic Control.

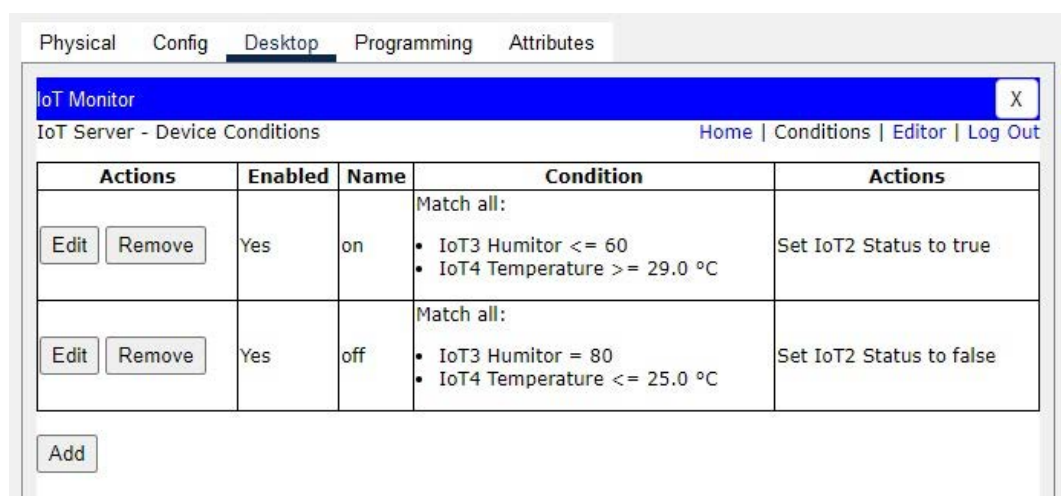


Figure 2. The rule from the IoT Simulation of Watering System for Vanilla Cultivation using DHT11 Sensors with Fuzzy Logic Control

The above rules are then executed to determine whether the rule design works properly according to the system's objectives. Figure 3 shows whether the components and rule conditions are working correctly.

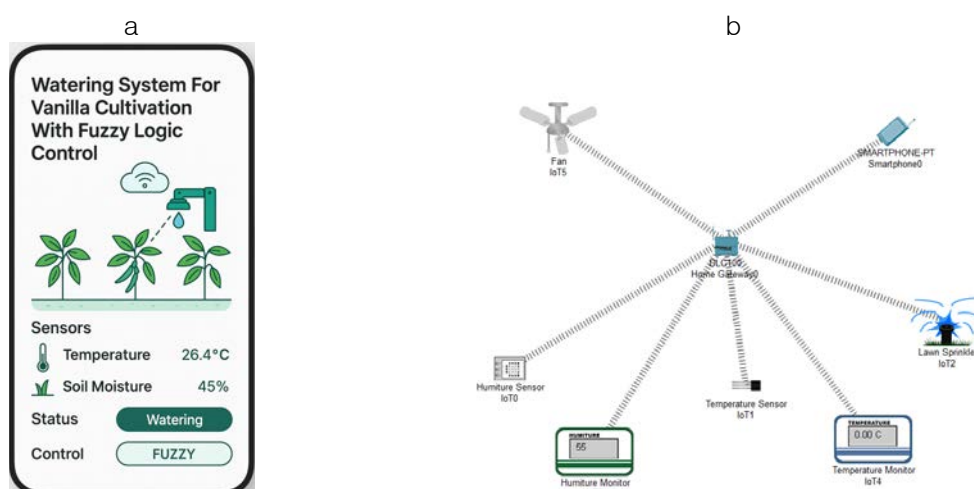


Figure 3. Mobile User Interface Design (a) and Output of the IoT Simulation of Watering System for Vanilla Cultivation Using Fuzzy Logic Control Using Cisco Packet Tracers Software(b)

Development

The development stage involves implementing the previously created product design. In this study, the development stage involved developing an automatic plant watering product design consisting of an IoT design, application interface design, hardware design, and fuzzy design. In this study the calculation process uses fuzzy logic. Table 5 illustrates the rules of fuzzy logic based on the soil humidity and temperature reference ranges.

Table 5. Rules for IoT Simulation of Watering System for Vanilla Cultivation using DHT11 Sensors with Fuzzy Logic Control using Cisco Packet Tracer Software

Temperature Humidity	$\leq 15^{\circ}\text{C}$ (cold)	$19^{\circ}\text{C}-22^{\circ}\text{C}$ (Normal)	$>30^{\circ}\text{C}$ (hot)
<40% (dry)	Off	On	On
40%–80% (Normal)	Off	On	On
>80% (moist)	Off	Off	Off

The next step is to design the input and output displays of the fuzzy system using the MATLAB application. In the fuzzy design, there are inputs, namely humidity and temperature sensors, while for output, there is one, namely a sprinkler/water pump. Figure 4 is an image of the display.

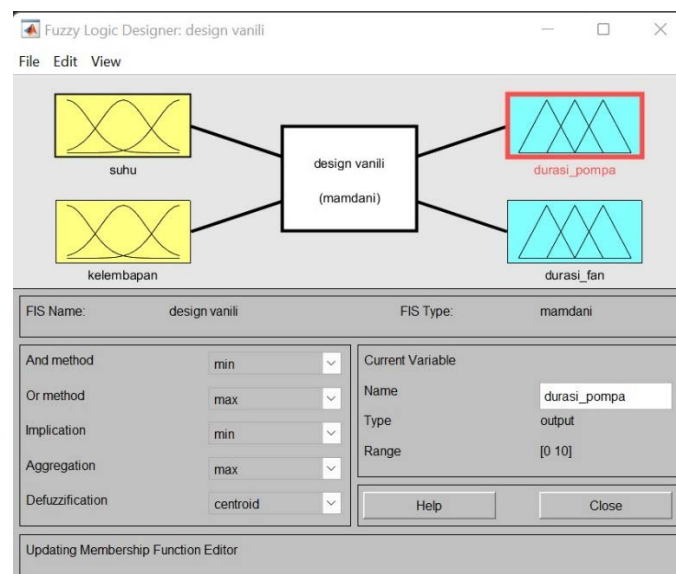


Figure 4. Input and Output of a Vanilla Plant Watering System with Fuzzy Logic Control in MATLAB Software

The input data consists of two inputs: humidity and temperature. The following displays the moisture sensor input in an automatic watering system using fuzzy logic. It has three membership function plots: dry, normal, and moist, with a range of 40%–80%. Next is a fuzzy logic display of the temperature sensor input in an automatic watering system. It has three membership function plots: cold, normal, and hot, with a range of 15°C–30°C. Figure 5 is a screenshot of humidity and temperature range of a vanilla plant watering system with fuzzy logic control in MATLAB software.

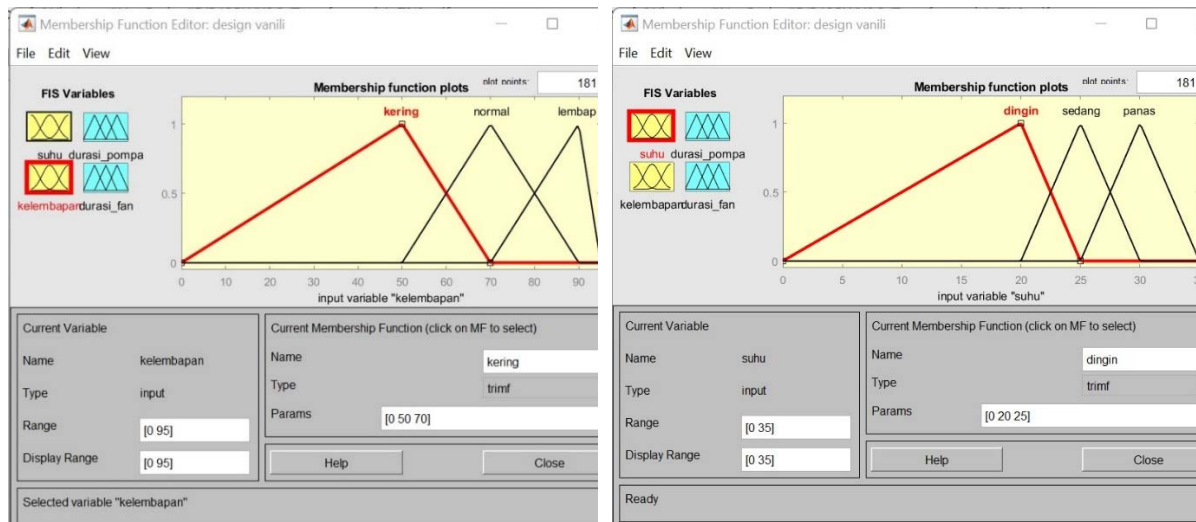


Figure 5. Humidity and Temperature Range of a Vanilla Plant Watering System with Fuzzy Logic Control in MATLAB Software

The output is a sprinkler or water pump for automatic watering and a fan for cooling. The following is a display of the output of an automatic watering system using fuzzy logic, which has two membership function plots: on and off, with ranges of 0 and 1 (Figure 6).

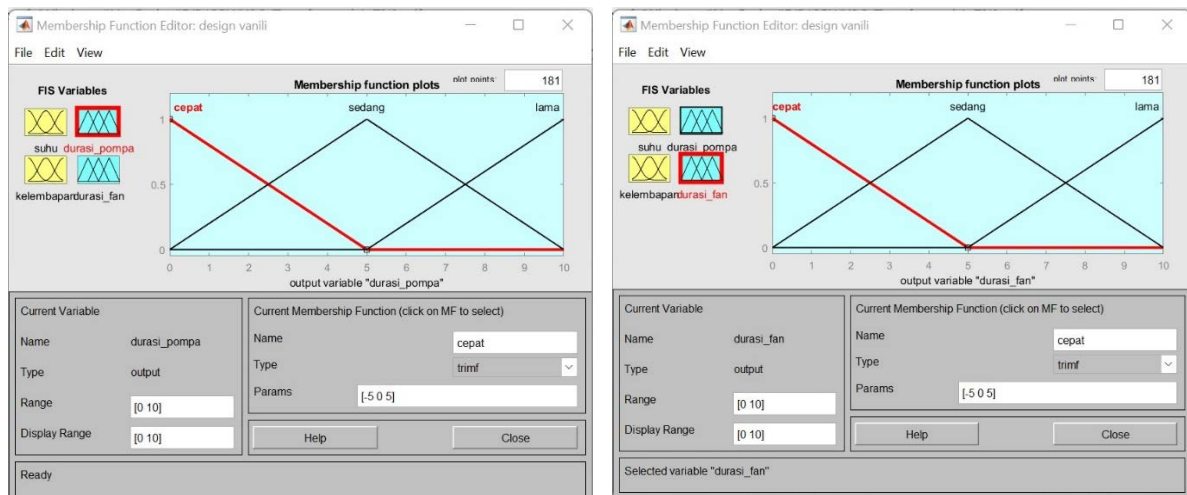


Figure 6. Output Range of a Vanilla Plant Watering System with Fuzzy Logic Control in MATLAB.

The next development stage is creating fuzzy logic rules. The following displays the fuzzy rules for an automatic watering system using fuzzy logic, which consists of nine rules. Figure 7 is an image of the rule display.

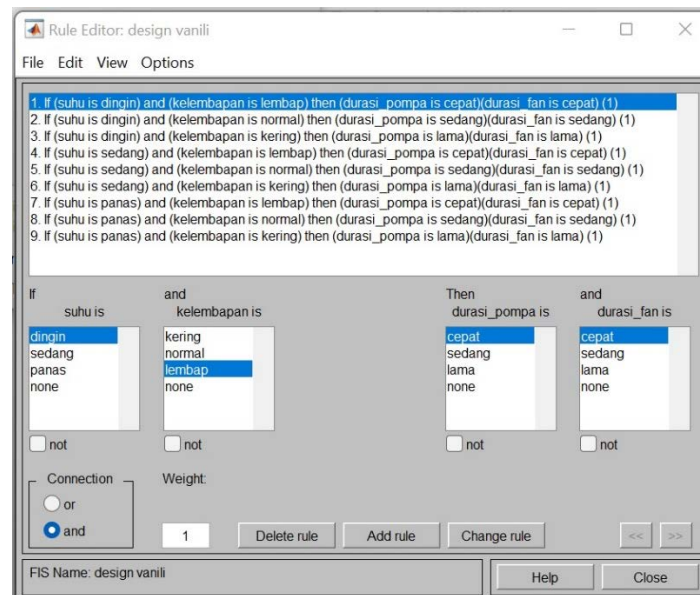


Figure 7. Automatic Watering Rules for Vanilla Plant Watering Systems with Fuzzy Logic Control in MATLAB Software

The results of developing fuzzy logic rules in MATLAB were then converted using Proto software so they could be read in Arduino.de. Figure 8 shows the results of converting a .fis file to an .ino file that can be read in Arduino.ide, which was then uploaded to Proteus.

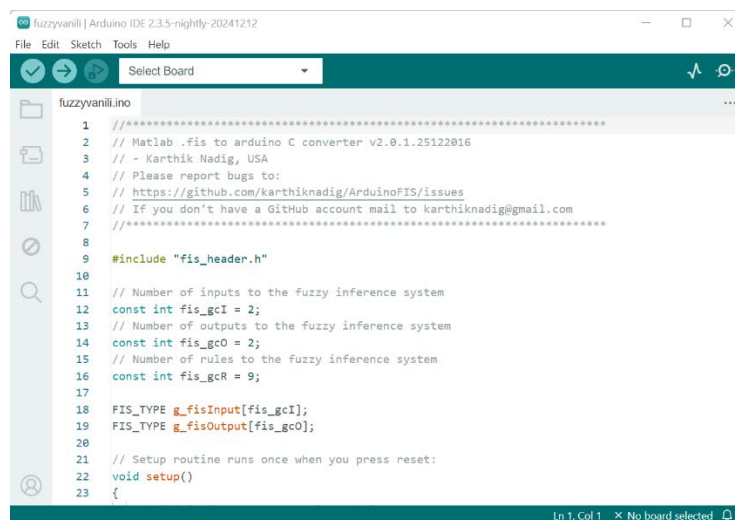


Figure 8. Code of Automatic Watering System Program for Vanilla Cultivation with Fuzzy Logic Control in Arduino IDE Software

Implementation

Product implementation in the ADDIE research and development model is intended to obtain feedback on the product being created or developed. Initial feedback (initial evaluation) can be obtained by observing results related to the product development objectives. The following is the result of the system implementation.

The following is a display of the Proteus simulation, whose components consist of a simlino UNO, POT–HG for humidity and temperature control, and a virtual terminal for displaying humidity and temperature results and turning the pump on or off. The following is a display of the Proteus simulation before it starts.

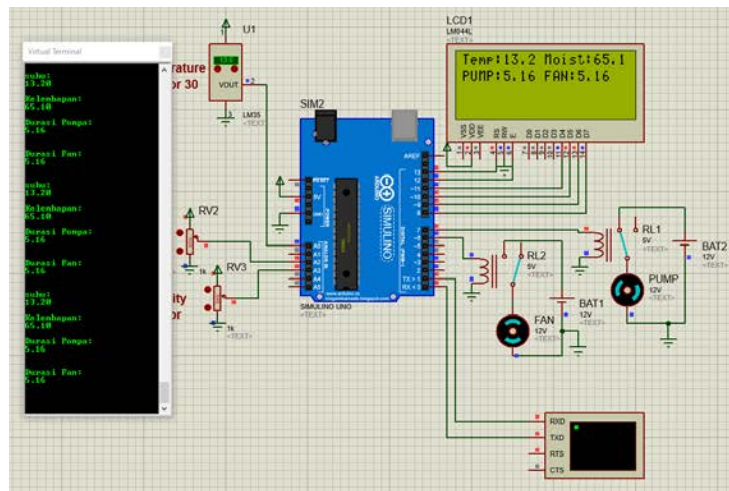


Figure 9. System Simulation in Proteus Software Before Starting

Figure 9 displays the Proteus simulation after it has been started. It can be seen in the virtual terminal that the soil humidity is 75%, the air temperature is 25°C, and the sprinkler percentage is 0.77, the same as in Simulink. The pump output is not on or off. The pump is off because the system reads the soil humidity as high, and the air temperature is not hot.

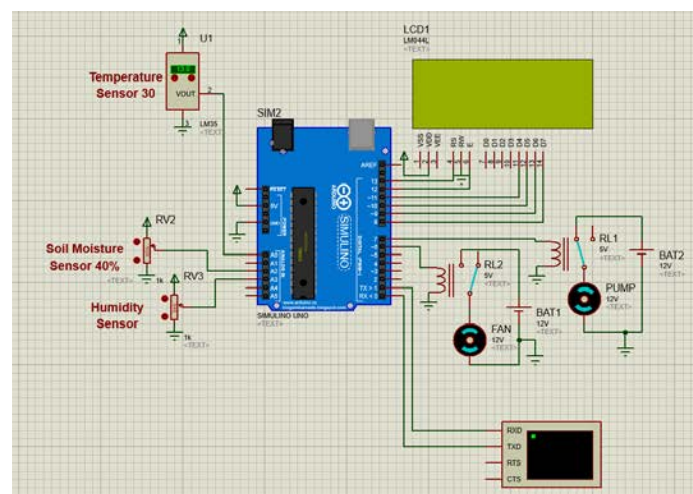


Figure 10. System Simulation in Proteus Software at Startup

Figure 10 is a display of the Proteus simulation after startup. It can be seen in the virtual terminal that the soil moisture is 32,1% and the air temperature is 34,2°C, with the sprinkler percentage set to 7,72 and the pump output is ON. The pump is ON because the system detects low soil moisture and a hot temperature (Figure 11).

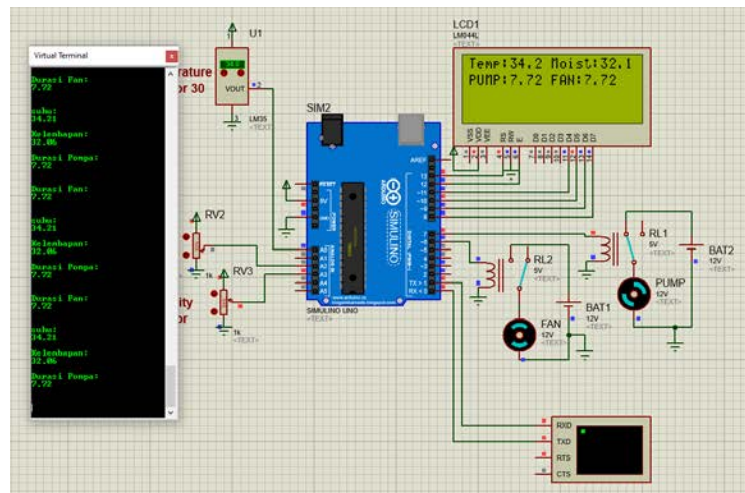


Figure 11. System Simulation in Proteus Software During Start-up and Pump ON

Evaluation

The ADDIE model development evaluation stage is conducted to provide product users feedback, allowing revisions based on the evaluation results or any unmet needs. The goal of the evaluation is to measure the achievement of development objectives. This stage is the testing process for the developed application. Direct user activity was observed, with the user and researcher in the same location at the same time. This was done so the researcher could obtain feedback on each user activity.

This study evaluated the results of programs run in MATLAB software, namely Rule Viewer and Simulink, with those run in the Arduino IDE using Proteus. Figure 12 displays the Rule Viewer and View Surface fuzzy system.

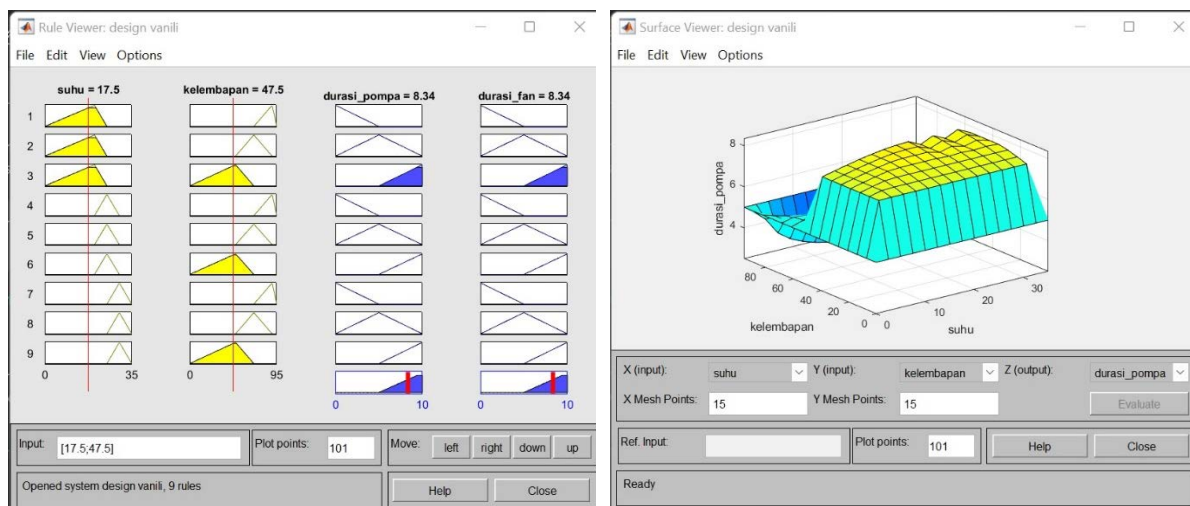


Figure 12. Rule Viewer and Surface View of an Automatic Vanilla Cultivation Watering System with Fuzzy Logic Control in MATLAB Software

Figure 13 display of the Simulink fuzzy model and virtual terminal for the automatic watering system. The simulation below has two inputs: humidity and temperature, and one output: a monitor that monitors the pump's on/off percentage. If soil humidity is 32,1 % and the temperature is 34,2 °C, the result of Pump Duration is 7,984 and the result of Fan Duration is 7, 984. The results displayed on the monitor display the percentage of when the pump turns on and off.

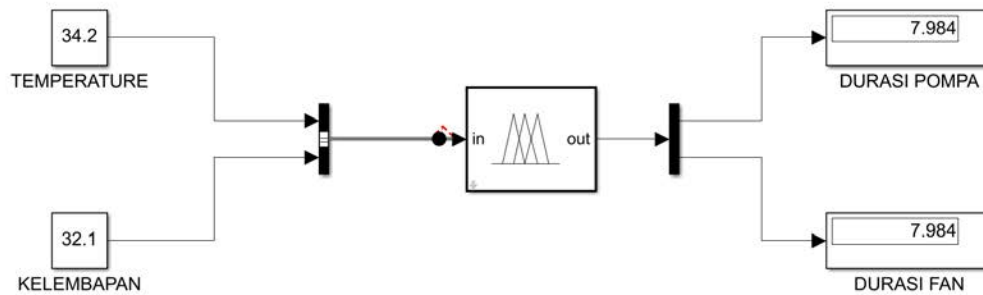


Figure 13. Simulink Model of a Vanilla Plant Irrigation System with Fuzzy Logic Control in MATLAB.

Following testing in MATLAB using Rule Viewer and Simulink, and in Arduino IDE software running in Proteus, the results showed the same output values when the input values were also the same. Therefore, the ornamental plant watering system simulation with IoT-based fuzzy logic control can be implemented per the research objectives.

Conclusion

This research successfully created an IoT simulation of vanilla cultivation using fuzzy logic control. The system can effectively adjust watering frequency based on soil moisture and ambient temperature, ensuring optimal plant care without manual intervention. Using the ADDIE development model, this system was designed to meet users' needs, including farmers, by simplifying the watering process and ensuring healthy, well-grown plants. Testing using MATLAB software, Rule Viewer, Simulink, and Arduino IDE software running with Proteus yielded the same output values when the input values were identical. Therefore, the IoT simulation of vanilla cultivation using fuzzy logic control can be effectively implemented per the research objectives. The results of this study demonstrate the great potential of applying IoT technology to support efficiency and effectiveness in plant maintenance. This system also provides an efficient and accurate monitoring solution compared to manual methods, operating automatically without human intervention.

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