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ANFIS Implementation System Design on Environmental Control System for Optimizing the Growth of Robusta Coffee Seeds in *the Greenhouse*

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ABSTRACT

The growth of robusta coffee seedlings is greatly influenced by the stability of environmental conditions, especially temperature, air humidity, and soil pH. Dynamic tropical climate change and limitations of conventional control systems cause greenhouse environmental management to not run optimally. This study proposes the design of an *Internet of Things* (IoT)-based greenhouse environmental control system with the application of *the Adaptive Neuro Fuzzy Inference System* (ANFIS) method to support the optimization of the growth of robusta coffee seedlings. This system is able to monitor environmental parameters in real-time through IoT devices integrated with web applications. Environmental data is then processed using ANFIS as the basis for automatic actuator control decision-making to maintain the stability of environmental conditions according to the physiological needs of plants. The web application functions as a medium for data visualization, historical data analysis, and reporting on greenhouse environmental conditions.

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1. INTRODUCTION

Indonesia's economy is heavily influenced by the growth of the coffee industry, particularly robusta coffee, Indonesia is one of the largest coffee producers in the world, and robusta coffee accounts for about 75% of the total national coffee production [1] . However, Indonesia's changing tropical climate, with high rainfall and significant daily temperature changes, often hinders the growth of robusta coffee seedlings to grow properly. These environmental factors, especially unstable soil temperature, humidity, and pH, often hinder the productivity and quality of robusta coffee seedlings [2] .

Greenhouse is here as a solution to create a well-managed environment to mitigate the adverse effects of weather changes. However, the management of soil temperature, humidity, and pH within *the greenhouse* is still often instable due to external factors such as excess sunlight, high humidity levels, or sudden weather changes [3] . Traditional control systems that use on-off or PID *(Proportional-Integral-Derivative)* are often ineffective at handling complex and non-linear variables such as temperature, humidity, and soil pH.

The environmental system in *the greenhouse* is very challenging to change because of the strong relationship between the variables involved. The purpose of this study is to improve the performance of *the grennhouse* environmental regulation through the use of an adaptive neural-fuzzy interference system (ANFIS). ANFIS is a combined method that integrates the principles of fuzzy logic with artificial neural network algorithms. The results of the experiment conducted directly show that the proposed method is able to provide effective tracking, fast response, and high resistance to external disturbances and non-linear behavior of the *greenhouse system* [4]

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In addition, the application of *the Internet of Things* (IoT) allows monitoring and control directly through *the website,* making it easier for farmers and researchers to optimize the growth conditions of robusta coffee seedlings [5] . Based on the problems faced, this study aims to apply *the Adaptive Neuro Fuzzy* (ANFIS) method in the *management of the Internet of Things* (IoT)-based *greenhouse environment* to maximize the growth of robusta coffee seedlings. Through this assessment, it is hoped that it will be able to create consistent environmental conditions and in accordance with the physiological needs of plants, thereby improving the quality and production of robusta coffee seeds in Indonesia.

2. RESEARCH METHODS

This study is divided into several main stages, starting from data collection, design, system creation and system testing. This research aims to implement the *Adaptive Neuro Fuzzy* (ANFIS) method in controlling *the greenhouse* environment to optimize the growth of robusta coffee seeds in the greenhouse can be done practically on the *website platform.* The flow of this research can be seen in Figure 1.

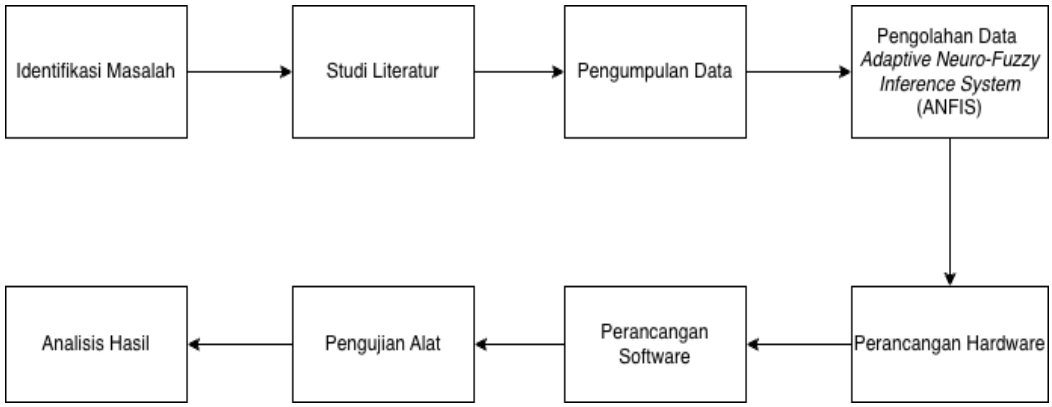


Figure 1. Research Stages

2.1 Problem Identification Stage

In the early stages of the research, the researcher conducts identification to determine the main problem to be solved. The purpose of this process is to understand the needs of the system and gather basic information about the problem faced. Therefore, problem identification is an important step in designing the right solution. The purpose of this identification step is to see the problem that is being faced and find the right solution to it. It is expected to address the problem that exists on site through the identification carried out.

2.2 Literature Study Stage

The next stage, the researcher conducts a literature study to obtain a theoretical basis to support this research. Searching and collecting literature on the subject of this research includes research journals, scientific articles, and other scientific publications available online and in print form. The focus of this literature study is to find information on the instruments, techniques, and technologies used to track and control the quality of temperature, air humidity, and soil pH in the *nursery coffee* greenhouse.

2.3 Stages of Data Collection

The research data was obtained through direct observation activities carried out in the *coffee nursery greenhouse* . This observation aims to identify the environmental conditions in the field, including various factors that affect the greenhouse environment of the coffee nursery. Data collection is carried out to determine the parameters used in the process of controlling the quality of air temperature, air humidity and soil pH to optimize the growth of robusta coffee seedlings. Thus, this stage of data collection is a very important step in ensuring the success of the system to be implemented.

2.4 Data Processing Stage

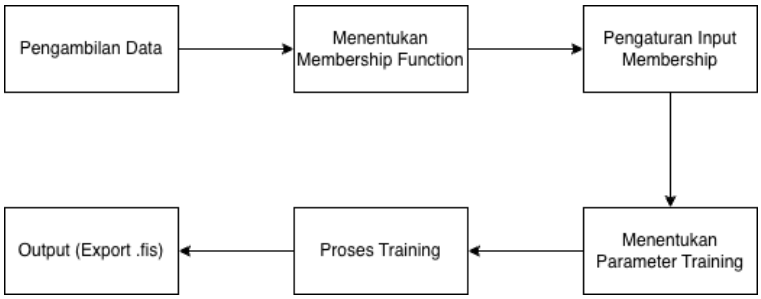


Figure 2 Data Management Flow

At this stage, the data that has been obtained is then processed using the *Adaptive Neuro Fuzzy Inference System* (ANFIS) method. The data processing process is carried out through a series of stages with the help of MATLAB software to produce an output file in *.fis* format, as shown in Figure 2, which is then used in the pump control system. This stage begins with data collection which includes temperature, air humidity, soil pH, and pump status as the basis for the model *training* process.

Next, the membership *function is determined* based on the characteristics of the available data, followed by setting the number and type of membership functions for each input variable. The next stage includes determining training parameters, such as the number of *epoches* and the learning method used, namely *hybrid learning*, to ensure that the training process runs optimally. The training process is then carried out to form a model that is able to recognize the pattern of relationships between input variables and output variables. After the model has been successfully trained and reaches the expected level of accuracy, the final stage is carried out by exporting *the .fis file* containing the fuzzy inference system of the training results to be implemented in the temperature and humidity control system automatically.

2.5 Planning Stage

The design stage is an important phase in this research, because it is at this stage that the system design process begins to be realized both in terms of hardware and software. Hardware design is carried out to build a physical system based on Internet*of Things* (IoT) which functions as a medium for data acquisition and control of *the greenhouse environment*. At this stage, the determination of the main components, such as microcontrollers, air temperature and humidity sensors, soil pH sensors, relay modules, and actuators in the form of water pumps are determined. The *hardware* design aims to ensure that all components can be properly integrated and able to work stably in supporting the real-time *greenhouse* environmental monitoring and control process.

Software *design* is carried out as the main support for the system in managing data, executing control logic, and providing a monitoring interface for users. This stage includes designing software on the microcontroller side to read sensor data, send data to the server, and execute control decisions based on the results of the *Adaptive Neuro Fuzzy Inference System* (ANFIS) method. The integration between *software* and *hardware* is designed in a structured manner so that the system is able to display environmental information accurately, support automatic decision-making, and provide convenience for users to monitor and control *greenhouse* conditions efficiently.

2.6 Testing and Analysis Stages

The tool testing stage is carried out to ensure that the system that has been designed and implemented can function optimally according to the research objectives. The test includes a thorough evaluation of the performance of hardware and software, including the accuracy of sensor readings, the stability of data

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communication, and the ability of the actuator to respond to control commands. The test process is carried out based on a predetermined scenario, so that each system function can be tested systematically. Through this stage, the level of reliability of the system in monitoring and controlling environmental parameters in real-time can be known.

The result analysis stage is carried out to review the data obtained from the tool testing process. The data is analyzed to assess the performance of the system in maintaining environmental conditions in accordance with the parameters that have been set, as well as to evaluate the effectiveness of the methods used in the decision-making process. The results of this analysis are used as a basis for drawing conclusions about the success of the developed system, as well as to identify potential for further improvement and development. Thus, the result analysis stage plays an important role in ensuring that the resulting system meets the research objectives and has relevant applicative value.

3. RESULTS AND DISCUSSION

3.1. System Requirements Analysis

Based on the results of observations on *greenhouse* Robusta coffee nursery, there are several needs that must be met. The thing that must be met is that the system must be able to control the environment *greenhouse* including air quality such as temperature, humidity, and soil pH level for planting seedlings. Then, the system must be able to provide warnings in the form of accurate notification about environmental conditions *greenhouse* and monitoring *real-time.* The system must also be able to control the condensation pump automatically to maintain optimal temperature and humidity for the growth of robusta coffee seedlings.

3.2. Workflow Planning

The system is designed by integrating *Internet of Things* (IoT) technology and web applications based on the Laravel framework to support the application of *the Adaptive Neuro Fuzzy Inference System* (ANFIS) method in *robusta coffee nursery greenhouses. The IoT device functions as an environmental data acquisition system by reading temperature, air humidity, and soil pH parameters using sensors installed on seedling planting media. The sensor reading data is sent to the server through* Application Programming Interface *(API)-based communication for further storage and processing.*

On the server side, the data is processed using the ANFIS method as a decision-making system in determining greenhouse environmental control actions. The results of ANFIS processing are used to control the actuator in the form of an automatic condensation pump, in order to maintain optimal environmental conditions for the physiological growth of coffee seeds. In addition, the web application built with Laravel functions as a *real-time data monitoring* and visualization medium, so that users can monitor the environmental conditions of *the greenhouse* and the performance of the control system in an integrated manner.

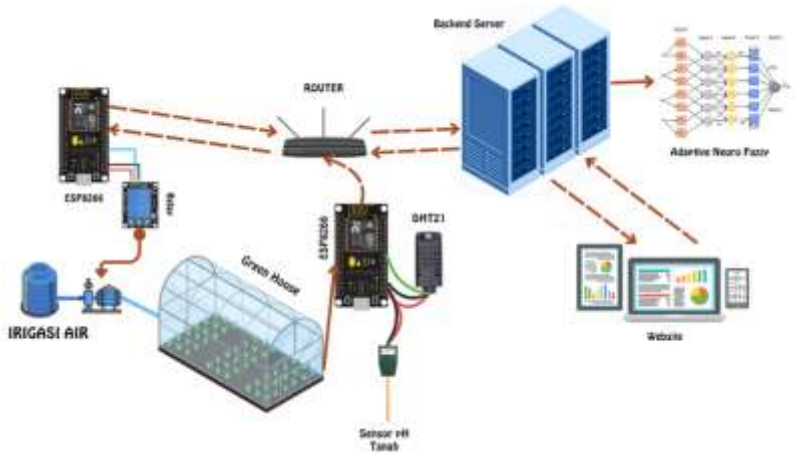


Figure 3 System Flow Design

3.3. Interface Design

The design of the system interface is carried out with the aim of making it easier for users to monitor the environmental conditions of *the greenhouse* thoroughly. The main page of this system is in the form of a dashboard that presents information on environmental parameters, including temperature, air humidity, and soil pH, obtained from each *Internet of Things* (IoT) hardware installed in each *greenhouse* tunnel. The dashboard functions as a monitoring center that displays sensor data in *real-time* so that users can monitor environmental conditions in each tunnel accurately and continuously. The dashboard interface is shown in Figure 4.

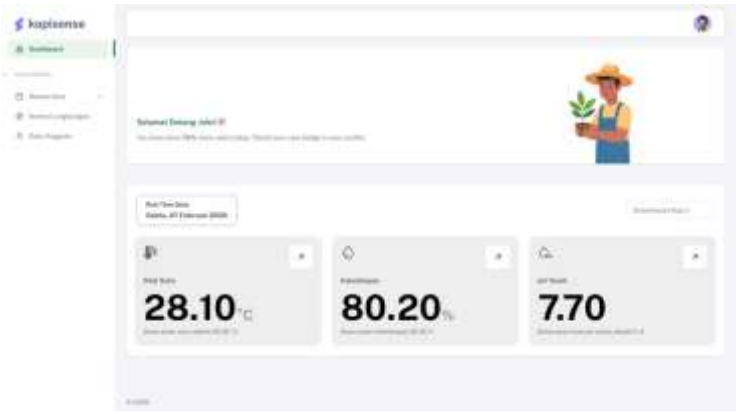


Figure 4. Dashboard Page Design

The data recording page on this website is designed as a supporting feature for the analysis of historical greenhouse environmental conditions. The data recording feature is divided into three subsections, namely temperature data, air humidity data, and soil pH data. On this page, users are presented with data visualization in the form of a bar chart that displays the daily average values of each environmental parameter. The presentation of data in the form of a daily average aims to make it easier for users to observe trends and patterns of changes in greenhouse environmental conditions over time.



Figure 5. Halam Design Record Air Temperature Data

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Figure 6. Soil pH Data Record Page Design



Figure 7. Air Humidity Data Record Page Design

In addition, the system also provides visualization in the form of a radial chart that depicts the average increase in temperature, air humidity, and soil pH. This visualization helps users in understanding the development of greenhouse environmental conditions in a concise and intuitive manner. The data record page is also equipped with a data filtering feature based on a specific date range, so that users can analyze environmental conditions in the desired period. To support documentation and reporting needs, the system provides a data download facility in Microsoft Excel file format, which makes it easier for users to process further data.

3.4. Discussion of the Plan

The design of this system integrates Internet of Things (IoT) technology, website platforms, and methods *Adaptive Neuro Fuzzy Inference System* (ANFIS) as a solution to improve the efficiency of the environmental monitoring and control process in the robusta coffee nursery greenhouse. The integration aims to ensure the creation of optimal environmental physiological conditions so as to support the optimal growth of coffee seedlings. Architecturally, this system is designed to maintain the stability of greenhouse environmental parameters more effectively and efficiently, so as to improve the quality of environmental management in robusta coffee nurseries.

4. Conclusion

Based on the results of the design, implementation, and testing of the system, it can be concluded that the integration *of Internet of Things* (IoT) technology, *website* platforms, and *the Adaptive Neuro Fuzzy Inference System* (ANFIS) method has been successfully implemented as an environmental control system for robusta coffee nursery greenhouses. The developed system is able to monitor and control the parameters of temperature, air humidity, and soil pH in real-time and provide adaptive control responses to environmental conditions. A Laravel-based web application makes it easier for users to monitor, analyze historical data, and report on greenhouse environmental conditions.

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