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Garden Warden: Garden Watering Automation System to Maintain Soil Moisture Based on IoT (*Internet of Things*)

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Abstract

Water requirements are an important factor in plant growth. Manual watering systems are often ineffective and time consuming. IoT-based garden watering automation systems can be a solution to overcome these problems. The *Internet of Things* (IoT)-based garden watering automation system uses soil moisture sensors and integrates with telegram chat applications that have been developed to maintain soil moisture efficiently. System development methods involve hardware and software design steps, component integration testing, and system performance evaluation. Soil moisture sensors are used to accurately measure soil moisture as well as to detect soil moisture and automatically activate watering only when needed, while the ESP32 microcontroller module acts as the brain of the system that connects the soil moisture sensor with the Telegram app via a Wi-Fi network. Telegram chat app is used as an intuitive user interface to monitor and control the garden watering system. Through this integration, users can monitor and control the garden watering process practically and effectively. Therefore, Garden Warden has the potential to support modern agriculture by increasing water use efficiency and optimal plant growth.

Keywords: telegram application, IoT (*Internet of Things*), ESP32 microcontroller, soil moisture sensor, automation system.

INTRODUCTION

Internet of Things technology has been developed and used in life to date due to its rapid development. Kevin Ashton invented *the Internet of Things* (IoT) technology in 1999, which allows electronic devices around us to connect to the internet network. One of the definitions of the Internet of Things (IoT) is equipment or objects that have the ability to connect to each other through the internet network, have the ability to control and monitor these things from wherever and whenever we are as long as the internet network is available (Dwiyatno *et al.* 2022). With the combination of various wireless technologies, the Internet of Things (IoT) is growing rapidly. Biometric security systems, smart homes, and smart cars are just a few examples of how the Internet of Things can improve various aspects of human life (Saputra dan Juliadi 2023).

With today's technological advancements, automated watering, known as the Internet of Things (IoT), allowing all objects to communicate with each other over the Internet, could change plantation operations to be easier to operate (Abdul Aziz dan Hamid 2024). Modern watering technology uses human labor to water plants (Adinda 2022). Automatic plant watering is a modern watering method that does not require human labor. To get the right nutrients and improve the quality of the plant, the plant must be watered regularly and have an adequate amount of water. This is because plants need sufficient water intake to carry out photosynthesis and to grow and develop (Effendi *et al.* 2022). The framework of the internet of things is able to produce a relevant automatic watering and monitoring system because it is not constrained by distance and does not waste energy in these activities. Plant owners in the garden can do automatic watering and monitoring of the plants in their gardens and use the internet of things to help with human activities such as planting taro plants (Sarwansah *et al.* 2022).

The use of microcontrollers and sensors is an innovation in information and communication technology in the agricultural sector. By using information and communication technology, the level of soil moisture used to grow agricultural crops can be monitored. Knowing the soil moisture level will be very helpful in determining what actions to take on the soil. If the level of soil moisture is less than the threshold required by horticultural plants, then watering will be carried out automatically (Husdi 2018). People who own gardens can use a wireless monitoring system to measure soil moisture automatically. With this system, garden owners do not have to go to the site of the land to check the soil moisture. The soil moisture sensor in this system will detect the soil moisture level and send the data to the garden manager in real-time (Yosep Maulana dan Supardi 2022). To maintain air temperature and humidity and take care of plants, an automatic watering system is essential, especially for gardens that require regular and intensive care. Watering must be done for survival, that is, for photosynthesis or making food (Nazareta *et al.* 2022).

The research of this IoT project was carried out in the Pusaka Nambo Environmental Friendly Village, which is a residential area with various environmentally friendly principles. Meanwhile, the object of research for the Iot project in the village is the taro plantation planted by the village settlement. The project "Garden Warden: An IoT-Based Garden Watering Automation System to Maintain Soil Moisture" aims to develop an intelligent irrigation system that can automatically maintain soil moisture at an optimal level. The system combines soil moisture sensors, ESP32-based control modules, and Telegram bots to provide an efficient and accessible watering solution. This research is expected to provide benefits for the people of Pusaka Nambo Eco-Friendly Village in managing their taro plantations using IoT technology.

METHODS

In this project, the method chosen is a qualitative method. Qualitative methods are used to understand and interpret the data collected from various sensors used in IoT-based garden watering automation systems. Qualitative research is a type of research that uses natural settings to interpret the phenomena that occur. Qualitative research uses a variety of current approaches to find and narratively describe the activities that individuals engage in and how they impact their lives (Rijal Fadli 2021).

Time and Location of Research

1. **Research Location**

   Research Location is the place where research is conducted. Determining the location of research is a very important stage in qualitative research, because the determination of the research location means that objects and objectives have been set, making it easier for the author to conduct research (Wibawa *et al.* 2022). This research was carried out in the environmentally friendly village of Nambo heritage, precisely located in the area of Pusaka Nambo Residence, RW.07, Sukajaya Village, Ciapus, Bogor Regency.

   This IoT project research was carried out in Nambo Heritage Eco-Friendly Village, which is a residential area with various environmentally friendly principles. While the object of research for the IoT project in the village is a taro garden planted by the village settlement. This research is expected to provide benefits for the people of Nambo Heritage Eco-Friendly Village in managing their taro gardens using IoT technology.

2. **Research Time**

   This study was conducted in the period from January to June 2024.

Tools and Materials

To prepare the Garden Warden project, various tools and materials are needed both in the form of hardware and software. A tool is hardware or hardware that presents messages stored in materials. Material is software, or software, that contains learning messages that are usually presented by certain equipment or by themselves (Warsita 2008). Here are the Hardware and Software Specifications used in the garden warden project:

Table 1. Hardware Specifications

Hardware Name	Specifications	Uses
Adaptor	5A 12V	Used for pump power source
ESP32	WIFI Bluetooth Iot Development Bo ard Wroom 4mb Doit Kit	A microcontroller that has integrated WIFI and Bluetooth capabilities. As well as being used to collect soil moisture data from soil moisture sensors installed in gardens.
Module Relay 1 Channel	Active High or Active Low With Optocoupler	Used to control the flow of electricity that drives the water pump
Pompa DC 12 Volt	Sinleader SL4500 5 LPM 100 PSI	Used to drain water from to garden areas that need watering.
Sensor Soil Moisture	1.2 V dan 2 V	Used to measure soil moisture levels around plant areas.
Extension Board ESP	Expansion Board Shield for ESP32	Used to connect all components.
LCD 2004	Lcd 2004 20x4 I2c	Used to display real-time data from soil moisture sensors

In terms of hardware, the main tools needed include microcontrollers such as ESP 32 which will be the control center of the system. In addition, soil moisture sensors will be used to detect soil moisture levels in real-time. An electric water pump connected to a solenoid valve is required to regulate water flow automatically based on data from the humidity sensor. To ensure the system can function properly, additional devices such as relay modules, jumper cables, and power sources (power supply) must also be prepared.

Table 2. Software Specifications

Software Name	Function
Arduino IDE	Create, edit a program code, verify, and upload the program code to the Arduino.
Autodesk Fusion 360	Used for engineering product design, by making 3D models.

Jupyter	To create and share documents containing live code, visualizations, and narrative text and become a developer for data analysis and machine learning.
Fritzing	To create a network schematic
Visual Studio Code	For software development.
Telegram	Used as a user interface or application to remotely monitor and control the watering system.
Xampp	To access the Apache2 local server.
Spreadsheet	It is used to record soil moisture data obtained from sensors.

In terms of software, IoT platforms such as the Telegram application can be used to integrate and monitor sensor data remotely. In addition, software is required for programming microcontrollers such as the Arduino IDE, depending on the type of microcontroller used. This software will be used to write and upload code that regulates the working logic of the system, including reading sensor data and controlling water pumps. For data visualization and real-time system control, mobile or web applications developed using the mentioned IoT platforms can be used. By preparing all these tools and materials, Garden Warden projects can be implemented effectively to maintain soil moisture in the garden automatically and efficiently.

Data Collection and Data Analysis Techniques

Data collection techniques and data analysis are two important stages in a study. The right data collection technique will produce quality data, which can then be analyzed easily and produce accurate research results.

1. **Data Collection Techniques**

   Appropriate data collection techniques and valid research instruments are instrumental in producing accurate and reliable data. In research, there are two main approaches that are often used, namely qualitative research and quantitative research (Ardiansyah *et al.* 2023). In this study using qualitative research, this study aims to understand the phenomenon in depth through interpretation and descriptive analysis, while quantitative research aims to measure and analyze data statistically (Creswell 2014). Qualitative data collection techniques used in this project include:

   A. **Interview**

   Interview is a method carried out by asking directly to informants (Nurdewi 2022). The interview was conducted with the aim of obtaining answers to questions that had been prepared before, namely about strategic location placement and asking about water sources and electricity. Through interviews, it is hoped that useful information can be obtained for IoT projects, as well as to ask for permission and establish cooperation with resource persons related to this IoT project.

   The resource person interviewed in this study was the Head of the Nambo Heritage Eco-Friendly Village (KRL), Mr. Lili Kurniadi. At Pusaka Nambo Residence, he also serves as Chairman of RW 07.

   B. **Field Observation or Survey**

   Field observation is an outdoor study aimed at obtaining data directly in the field. Field observations are carried out so as to get more accurate results (Nikmah 2023). In this project, direct observation was carried out, by visiting the research location directly, namely the Nambo Heritage Eco-Friendly Village. Some of the observations made in field observations or surveys include:

- Taking garden measurements, carried out to determine the needs of soil moisture sensors and sensor cable heights.
- Make observations about the placement of tools and observe the garden area, so that the tools are placed in a safe area and do not disturb plants.
- Conduct a search for water and electricity sources. In this project, a water source is used to deliver water to the plants, and a power source is used to run the circuit.
- Check the internet connection, because this project is integrated with Blynk, where real-time data transmission is required.

C. Documentation

A document is an object of important documentation and contains data or information (Ayumsari 2022). This documentation is carried out to collect several documents needed as supplementary material for data and information. And documentation is also in the form of photos or videos to be material for making teaser videos and project videos.

2. Data Analysis Techniques

According to Patton, data analysis is the process of organizing the order of data and organizing it into patterns, categories, and unity of basic descriptions. According to Bogdan and Bikler (1982), Qualitative data analysis is the process of working with data, organizing it, selecting it into manageable units, synthesizing it, searching and finding patterns, discovering what is important and learned, and deciding what can be mixed (Wandi *et al.* 2013).

After collecting data, a project analysis will be carried out covering several things, namely analysis related to several problems in the placement of tools, water and electricity sources, how tools work, physical design design, physical manufacture of tools, website creation and tool design results. Here are the stages of data analysis techniques, namely:

A. Problem Analysis

After making direct observations, we analyzed the problems that occurred in the nambo heritage eco-friendly village. Based on observations made in observations or field surveys at partner locations, there are several potential problems that can be identified:

- Sensor Requirements and Cable Height: Determination of soil moisture sensor requirements and sensor cable height requires accurate measurements. Problems can arise if measurements are incorrect or if sensors are installed at depths that are not optimal, resulting in inaccuracies in soil moisture measurements.
- Tool Placement: Tool placement should be carefully considered so as not to disturb the plants and remain safe from external disturbances such as wild animals or theft. Problems may arise if the placement of the equipment is inappropriate or does not take into account relevant environmental factors.
- Water and Electricity Sources: The search for water and electricity sources is an important step in carrying out this project. Problems can arise if water or electricity sources are not adequately available at the plantation site, or if the cost of procurement is too high.
- Internet Connection: A stable internet connection is required to transmit data in real-time to platforms like Blynk. Problems can arise if the internet connection is unstable or unavailable at the garden site, disrupting the operation of the watering automation system.

By identifying and understanding these potential issues, the project team can plan appropriate preventive actions or solutions to address issues that may arise during project implementation.

B. **Data Management**

Data processing is the process of obtaining summary data or summary figures by using certain methods or formulas. The purpose of data processing is to convert the raw data derived from the measurement results into finer data, which can then be used for further study (Purnomo 2015). After the research data is collected, the data processing process is then carried out. The way of data processing varies depending on the research design used. Generally, there are two main stages in data processing: editing and coding.

C. **Verification or Conclusion Drawing**

Conclusion drawing or verification is the stage of making conclusions based on data collected from research. Inference or verification includes attempts to discover or understand meaning, regularity, pattern, explanation, causation, or flow. (Engko dan Usmany 2020). At this stage it aims to find conclusions from research activities. Making these conclusions is done by comparing the description that has been formulated with the results of data analysis that has been obtained, so that in the end the researcher can draw conclusions whether to accept or reject the assumptions that have been formulated.

Machine Learning

In the Garden Warden project: Garden Watering Automation System to Maintain IoT-Based Soil Moisture, several machine learning models are used, namely linear regression, ARIMA forecasting, and LSTM.

1. **Regression Linear**

   Regression involving the relationship between one dependent variable and one independent variable or dependent variable (Y) and independent variable (X) (Hamdanah dan Fitrianah 2021). **Function:** A linear regression model is used to understand the relationship between time and soil moisture value. With historical soil moisture data, linear regression can predict future soil moisture values based on linear trends.

2. **Arima (*Autoregressive Integrated Moving Average*) Forecasting**

   The ARIMA model is a model that completely ignores the independent variables in forecasting making. ARIMA uses the past and present values of dependent variables to produce accurate short-term forecasts (Zulhamidi dan Hardianto 2017). **Function**: a statistical model used for time series analysis and prediction of future data. This model is effective in capturing seasonal patterns and trends in time series data.

3. **LSTM (*Long Short-Term Memory*)**

   Long-Short Term Memory (LSTM) is a type of Machine Learning based on the Recurrent Neural Network approach that can predict the current condition of machines by using large-scale data processing engine sparks (Kamal Wisyaldin *et al.* 2020). **Function:** a type of artificial neural network that is effective in handling long-term time-series data and has long-term dependencies. LSTMs can remember important information over a long period of time and forget irrelevant information.

Work Procedure

Work procedures are a series of work procedures related to each other, so as to show a clear and definite sequence of stages, as well as the ways that must be taken in order to complete a task area (Sinaga 2017). The following are a series of work procedures that have been carried out in making this project:

1. **Socialization**

   Socialization is the process of learning about the roles, status, and values needed to participate or be involved in social institutions, the process and delivery of information and education to parties involved in an activity (Ismail 2019). Socialization is carried out by dividing participants into several groups to facilitate the implementation of tasks, determining the theme or material to be discussed in the activity, and appointing lecturers who will guide and direct the group in completing tasks. Socialization is carried out to ensure smooth work procedures and achieve optimal results.

2. **Project Mitra Determination**
   The work procedure for determining project partners is carried out by submitting a cover letter to the partner, obtaining a certificate from the partner, and compiling practical assignments. The chosen partner will be the place to place tools and create tools according to the needs of partners who are integrated with IoT or robotics.
3. **Identify the Problem**
   The work procedure for problem identification is carried out in collaboration with partners, both through direct discussion and lecturer guidance. Discussions with partners aim to explore information and understand the problems faced, while the guidance of lecturers helps in directing and providing direction to solve these problems.
4. **System Design**
   After identifying the problem, the next step in the work procedure is system design by creating a 3D design of the product, electronic circuit design, and flowchart. This stage can be said to be the design stage, where the planning and problem-solving process is carried out carefully to get the optimal solution to the existing problem.
5. **Implementation**
   Implementation is the process of applying ideas, ideas, policies, or innovations into real life with the impact of changing knowledge, skills, values, and attitudes (Magdalena *et al.* 2021). The Implementation Phase is the stage of implementing a pre-designed problem-solving system. The Implementation phase includes the assembly of components and programs to control the set of components.
6. **Testing**
   The Testing Phase is the stage that aims to test the tool system. The testing phase is carried out to prove that the system or prototype tool that has been made can work according to design.
7. **Report Preparation**
   Report preparation is a stage that provides a comprehensive overview of the research process as a whole. In this process, researchers combine research findings with information found in the literature, choose a logical information structure, and write a report in a clear and concise manner (Mayasari 2021). At the Report Preparation stage, this procedure involves the preparation of outputs such as final reports, media articles, journal creation, and copyright or patent registration.
8. **Test**
   The next step is the conduct of exams for the assessment of project results. At this stage, the examining lecturer will be determined and one of the assessment components is the completeness of project administration.
9. **Expo or Exhibition**
   The next stage of the procedure is the last stage, which is the exhibition or expo used to launch the product. At this expo, partners will be invited to attend and see the results of the project.

RESULTS AND DISCUSSION

Garden Warden System Design

The Garden Warden project is a garden watering automation system designed to maintain optimal soil moisture by utilizing Internet of Things (IoT) technology and machine learning. The implementation of this system is carried out in the Pusaka Nambo Eco-Friendly Village Garden, an area that focuses on sustainable and environmentally friendly agriculture. The system uses the Telegram app as an IoT interface, allowing users to monitor and control the watering system remotely. Thus, farmers or garden managers can receive real-time notifications about soil conditions and send watering orders via Telegram, making the garden management process more practical and efficient.

1. **Flowchart**

A flowchart is a diagram that shows the logical flow of a program or system process. A flowchart is a representation of a program's algorithm in the form of a flowchart that shows the flow direction of the program (Yulianeu dan Oktamala 2022).

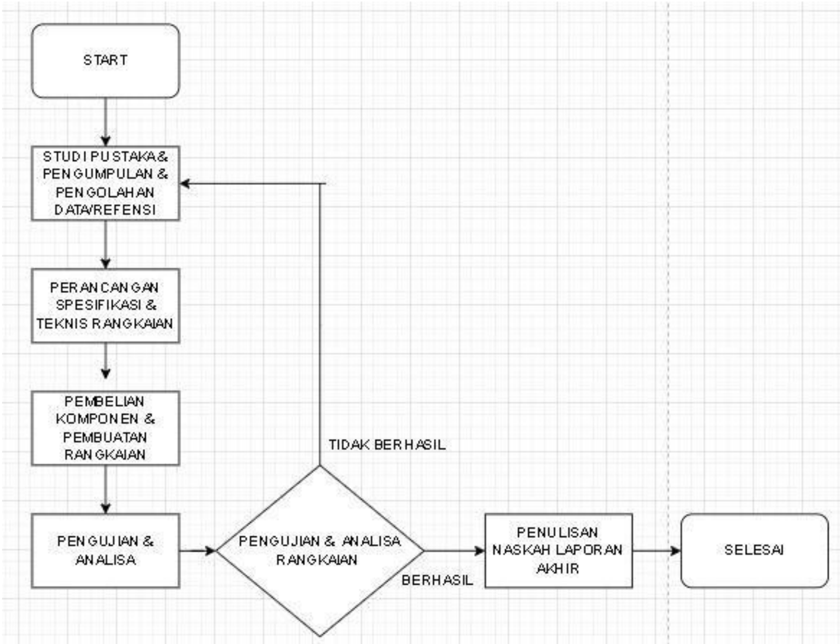


Figure 1. Flowchart Perancangan Alat

The flowchart shown illustrates the steps in a research or technical development project. The process begins with the stage of literature study & collection & processing of reference data, where literature research and collection of relevant data are carried out to understand the topic to be studied. Furthermore, based on the data collected, the circuit specification & technical design stage is carried out to design the specifications and technical aspects of the system or circuit to be made. Once the technical design is complete, the process proceeds to component purchase & circuit manufacturing, where the necessary components are purchased and the circuit or system begins to be built. The next stage is testing and analysis, where a circuit or system is tested and analyzed to ensure its functionality meets specifications. If testing and analysis show that the results are unsuccessful, the process goes back to the initial stage of literature study & collection & processing of reference data to make revisions and improvements. If the results are successful, the process proceeds to the writing of the final report script, where the entire process and results are documented in the final report. This process ends at the completion stage after the final report writing is completed. This flowchart shows an iterative cycle where failure in a test requires revision and repetition of several stages until it achieves success.

2. **Skema Rangkaian**

The circuit scheme is used to automate garden watering by keeping soil moisture at an optimal level. The system utilizes soil moisture sensors to detect moisture content at various garden points and sends that data to the ESP32 microcontroller module.

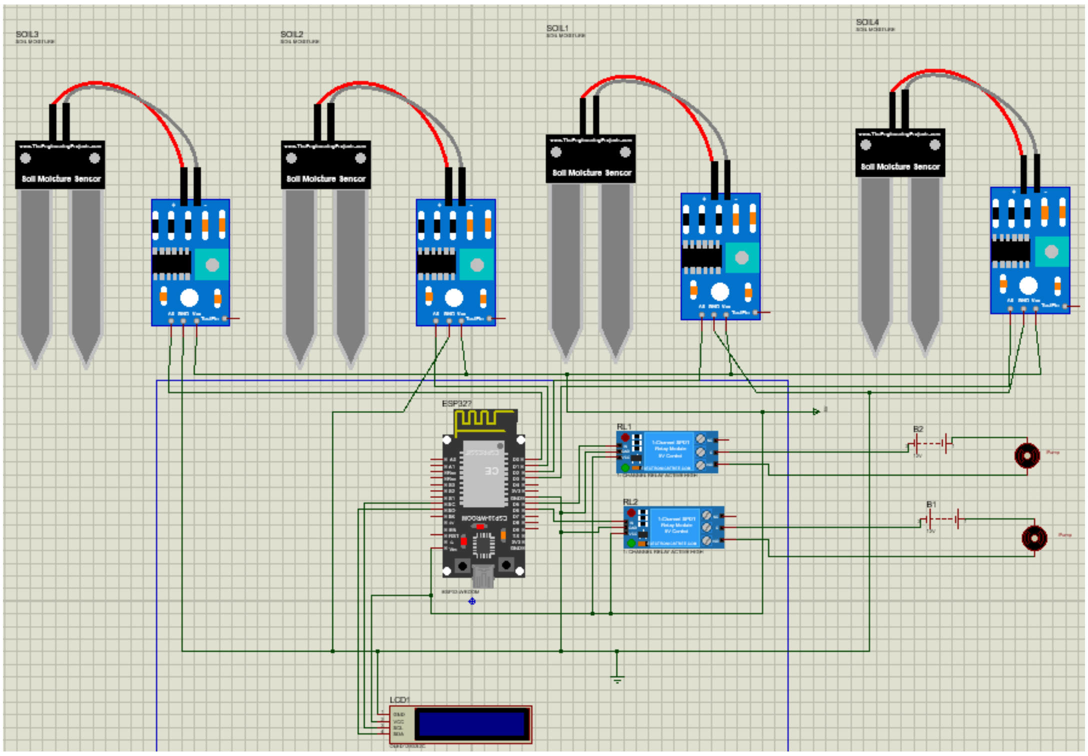


Figure 2. Network Schematics

The ESP32 acts as a control center that collects data from sensors, processes it, and determines if watering is necessary. If the soil moisture is below the specified level, the ESP32 sends a signal to activate the relay connected to the water pump. This relay then controls the flow of water to water the plants. Once the soil moisture reaches the desired level, the ESP32 turns off the relay to stop watering. By using the Telegram app as an IoT interface, the system allows users to monitor and control the watering process remotely, making it easier to manage the garden and ensuring that plants always get the right moisture efficiently and automatically.

3. Use case Diagram

Use Case Diagrams show how information systems will operate. Defining "Actors" and implementing "Use Cases" are two important elements in a use case (Kadarsih dan Andrianto 2022). The use case diagram in Figure 3, illustrates how the "Garden Warden: Garden Watering Automation System to Maintain IoT-Based Soil Moisture" project operates. This system is designed to make it easier for users to manage and automate garden watering to maintain optimal soil moisture levels.

The components and interactions in the Usecase diagram:

a. User: A system user who can control and monitor the device through the interface.
b. System: An entire automation system consisting of several main functions.
c. Telegram bots: These bots serve as a communication interface between the system and the user. These bots provide information and receive commands from users.
d. Moisture Level: This component is in charge of monitoring the soil moisture level. This moisture information is then passed to the telegram bot and can be used to regulate watering.
e. Start/Stop: This feature allows users to manually start or stop the watering system through a telegram bot or other interface.
f. WIFI: A connectivity component that ensures the system is connected to the internet network for communication with telegram bots and other IoT devices.
g. IoT Container System: This is the platform or infrastructure where all components of the IoT system operate and interact.

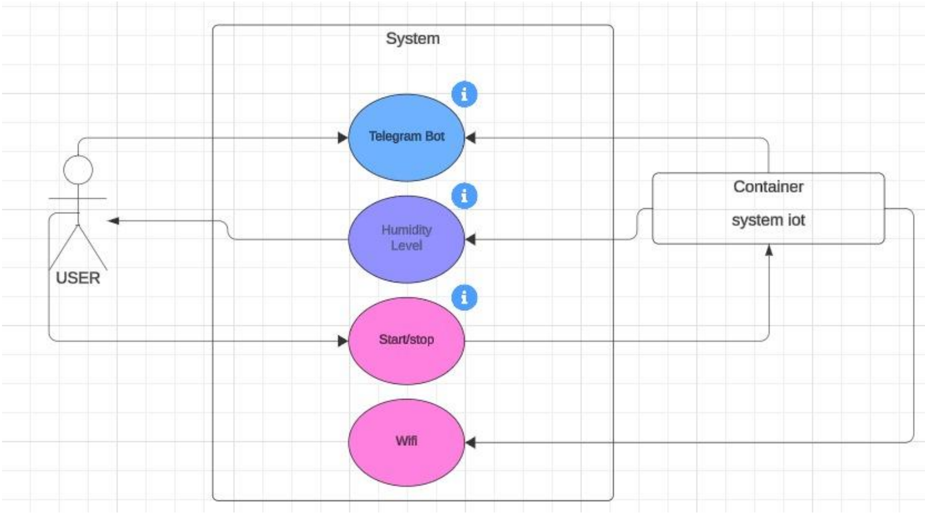


Figure 3. Use case Diagram

Workflow:

- Users can send commands or receive information from telegram bots regarding soil moisture status or system conditions.
- The system automatically measures the soil moisture level and reports it through a telegram bot.
- Based on the humidity data, the system can automatically turn watering on or off to maintain optimal humidity.
- Users also have the ability to manually start or stop watering through a telegram bot.
- WIFI connectivity ensures that the system stays connected and functions properly in the IoT network.

This diagram as a whole shows how users interact with IoT-based garden watering automation systems through various components that are integrated with each other, with the goal of maintaining soil moisture efficiently and effectively.

4. Physical Design Results

Tool 3D design is the process of describing and optimizing the physical design of a tool or system. On the other hand, 3D design is the process of turning 2D images into 3D images that are more realistic and easy to understand.

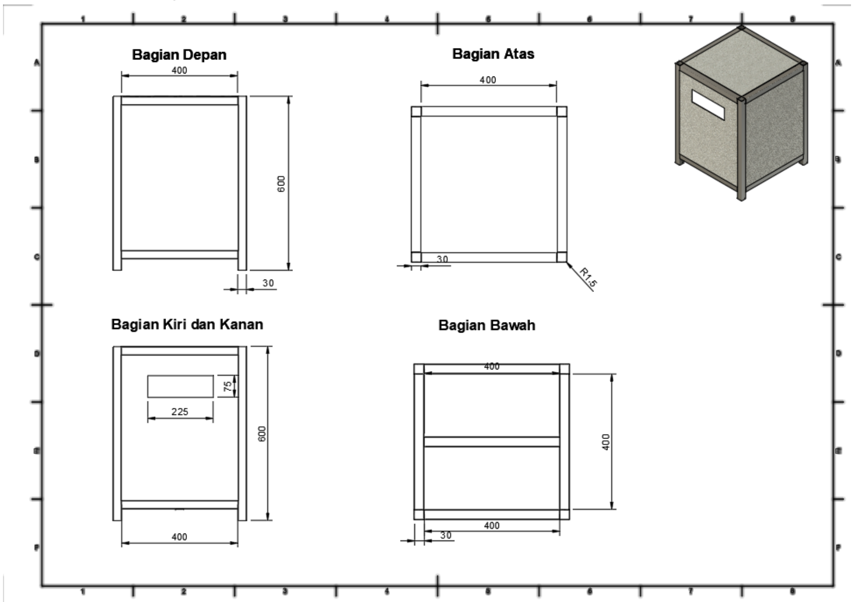


Figure 4. 3D Design Casing Technique

Figure 4 is a technical drawing that depicts a case or box with specific dimensions. Here's a detailed explanation of each on the case display:

- **Front**: The front of the case is 400 mm wide and 600 m high, there is a distance of 30mm from the bottom edge to the bottom of the main box.
- **Top**: The top of the case is 400 mm wide by 400m long, This part shows that the box has a square shape at the top. There is an angular radius (R15) which indicates that the upper corner has an arch with a radius of 15 mm.
- **Left and right**: The front of the case is 400 mm wide by 600 m high, there is a distance of 30 mm from the bottom edge to the bottom of the main box. On the left and right there are rectangular holes with a size of 225 mm x 75 mm, positioned 75 mm from the top edge of the case. Indicates there is some kind of ventilation or opening on these sides.
- **Bottom**: The bottom of the case is 400 mm wide by 400 mm long, the bottom view also shows that the base of this box is square. There is a distance of 30 mm from the bottom edge to the bottom of the main box, just like on the front.

A more detailed 3D Isometric view can be seen in **Figures 5, 6 and 7** which show a case that gives a clearer picture of its shape and structure. It also shows the overall point of view of the case, which helps to understand the orientation and position of each part. This case is a box with consistent dimensions, namely 400 mm wide and long, and 600 mm high. There are openings or vents on the left and right sides with a size of 225 mm x 75 mm, as well as slightly curved corners at the top. This image provides a complete view of all the important aspects to understand the design and dimensions of the case.

Figure 5. Front View Case Design

In **Figure 5**, the 3D design of the front-view case shows the interior of the case equipped with a Project Box. This Project Box serves as a container to store and protect the electronic circuits that control the garden watering automation system. Inside the Project Box, there are several important components such as the ESP32 module, 1-channel relay, and block terminals. This design demonstrates a systematic and organized approach to protecting and operating electronic circuits in garden watering automation systems. With the Project Box containing important components such as ESP32, 1-channel relay, and block terminals, this system can function efficiently and reliably, and make it easier for users to manage their gardens with IoT-based technology.

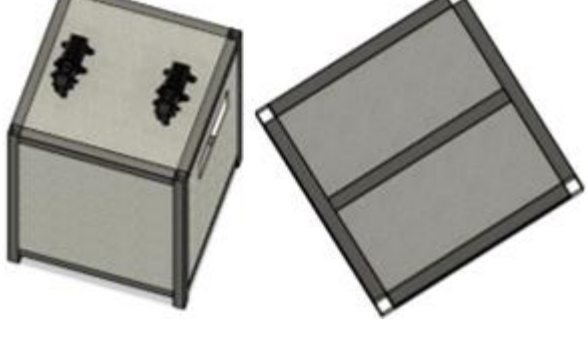


Figure 6. Top and Bottom Case Design

Figure 7. Back and Side View Case Design

In **Figure 6**, there is a 3D design of the case showing the top and bottom. At the top there are two components, namely the DC pump. The DC pump mounted on the top of the casing is designed to regulate the flow of water in an automatic watering system. One side of the pump is connected to a hose connected to the water collection drum, which is equipped with a filter to ensure that the water entering the system is free of dirt and particles that can clog and this water filter is important to maintain the smooth flow of water and prevent damage to the pump or sprinkle nozzle. On the other side of the pump, a connector or amplifier drat is installed that serves to connect the pump to the sprinkle nozzle. This sprinkle nozzle is in charge of spraying water evenly to garden areas that need watering. With this configuration, the system can ensure a stable and clean flow of water from the drum to the garden, supporting an efficient and controlled watering process. The integration of the DC pump with hoses, filters, connectors, and sprinkle nozzles allows the system to operate optimally, maintaining the soil moisture necessary for healthy plant growth.

Garden Warden System Testing

1. **Tool Testing**

On May 31, 2024, we conducted a trial of an IoT-based garden watering automation system. This process involves several important steps to ensure that all components are functioning properly and are perfectly integrated. Conducting several stages of Testing and Integration, namely:

a. **Network Consolidation**

We integrate all electronic circuits, including ESP32 modules, 1-channel relays, block terminals, adapters, and soil sensors. Each component is individually tested to ensure proper connection and correct function.

Figure 8. Penyatuan Rangkaian pada Casing

b. Installation in Project Box

Once the assembly is complete, we install all the components inside the Project Box. This Project Box provides protection against accidental dust, moisture, or water ingress, as well as other physical disturbances. This ensures the safety and reliability of the system. With Project Box, all components are protected from environmental conditions that can damage or interfere with system performance.

Figure 9. Installation on the Project Box

c. IoT Integration with Telegram and Sensors

Figure 10. Testing Iot Integration with Telegram and Sensors

The ESP32 module is connected to a soil moisture sensor and integrated with the Telegram bot. Users can monitor soil moisture conditions and control the watering system through Telegram. We conducted communication tests between sensors, ESP32, and Telegram bots to ensure that data can be received and processed properly, and that commands from users can be executed by the system.

2. Installation of the appliance

After that, On June 1, 2024, after ensuring that all the integrated components are working properly, we installed the tool at the partner location, namely at the Pusaka Nambo Eco-Friendly Village. **The installation stages** include:

1) Case Placement

The casing containing the Project Box and DC pump is placed in a predetermined location when observing the partner's location. The chosen place is a strategic location that is easy to reach and protected from extreme weather or splashing water. This is to ensure that the equipment remains safe and functioning properly over a long period of time.

Figure 11. Case Placement

2) Water Drum and Sprinkle Nozzle Connection

The water source for filling the drum is obtained from the post or post located at the partner's location. Previously, we had conducted an observation stage and obtained permission from the Chairman of KRL / Chairman of RW 07, namely Mr. Lili Kurniadi. This process ensures that water sources are readily available and accessible. After that, make a connection of the water drum to one side of the DC pump connected to a hose connected to the water drum equipped with a filter, to ensure that the water used is clean. The other side of the DC pump is connected to a connector or booster drat connected with a sprinkler nozzle to water the garden.

Figure 12. Connection To Water Drum and Sprinkle Nozzle

3) System Testing

Once all the components are in place, we perform final testing to ensure that the system is working as planned. The soil moisture sensor monitors the soil condition and sends data to the ESP32. Based on the data, the ESP32 controls a relay that activates the DC pump to water the garden. Users can monitor and control the system through Telegram bots. The results of the implementation of IoT and Machine Learning can be seen at the next stage of discussion.

Results of the Implementation of the Iot System in Garden Warden

This Telegram bot allows users to monitor and control their garden watering system remotely. **Figure 13** shows the display of the Telegram Garden Warden app. This application is an IoT (*Internet* *of Things*)-based application used to control the garden watering automation system. This system is designed to maintain optimum soil moisture in the garden.

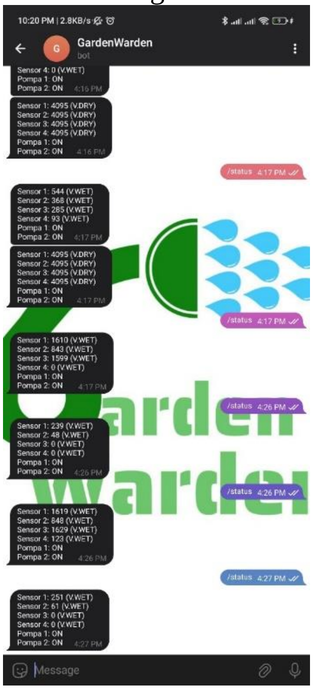


Figure 13. Interface Bot Telegram Garden Warden

Create a bot on Telegram, then you will get an API Key and Chat ID. API Key is the identity of the bot that will be entered into the code. Meanwhile, Chat ID is a Telegram ID, where each Chat ID is associated with a single cellphone number. Once you have obtained your API Key and Chat ID, enter the information into the code that has been generated. With this, the bot can receive commands such as **/status**, **/turnon_pump1**, and **/turnoff_pump2** to monitor the status of the sensor as well as turn the pump on or off. Based on the sensor value, the ESP32 sets the pump status to turn on or off. For Threshold is the threshold value used to determine soil moisture conditions based on sensor readings. **The threshold value** is set at **2600**. If the sensor value is more than 2600, the ground is considered wet. If it is less than 2600, the soil is considered dry.

A. How the Garden Warden Telegram Application Works and Features

Here's an explanation of **how Telegram bots work** with IoT systems for garden watering automation:

1. Pump 1 will turn on if sensor 1 or sensor 2 detects dry soil.
2. Pump 2 will turn on if sensor 3 or sensor 4 detects dry soil.
3. If one set of sensors detects dry soil, and the other set of sensors also detects dry soil, then both pumps will turn on.
4. If no sensor detects dry ground, both pumps will be switched off.

This bot is used to monitor and control IoT-based garden watering automation systems. Here **are the main features** displayed on the Telegram Garden Warden application:

1. **Monitoring data or status on soil moisture sensors**: This application is used to monitor the status of soil moisture sensors in real-time. This soil sensor will measure moisture levels and send the data to the application.
    - Sensors 0 to Sensor 4 display the detected soil moisture value.
    - As shown in figure 19, the Analog Value (0-4095) indicates the soil moisture level. Values lower than the threshold indicate wetter soil, while values higher than the threshold indicate drier soil.
    - Humidity State (WET/DRY): This state provides a simple interpretation of analog values. "WET" indicates wet soil, while "DRY" indicates dry soil.
2. **Controlling the water pump**: It can control the water pump to water the garden automatically and manually turn on the pump which allows to determine the watering time and duration.
3. There are 2 pumps, Pump 1 and Pump 2 will display the status of the watering pump.

The "ON" status means the pump is on, while "OFF" means the pump is inactive.

4. **Receive notifications**: The app will send you sensor and pump status notifications.
5. **Storing data**: This app will store historical data on moisture levels in the soil and watering activity.

Results of Machine Learning Implementation in Garden Warden

Linear regression is a type of prediction used to figure out relationships that are tied to one or more existing independent variables. The Internet of Things (IoT)-based Garden Warden Watering Automation System can be applied by using linear regression to predict soil moisture. The Simple Linear Regression Method is a method used to look at the relationship between an independent variable and has a straight line relationship with its dependent variable (bound) (Muttaqin dan Srihartini 2022).

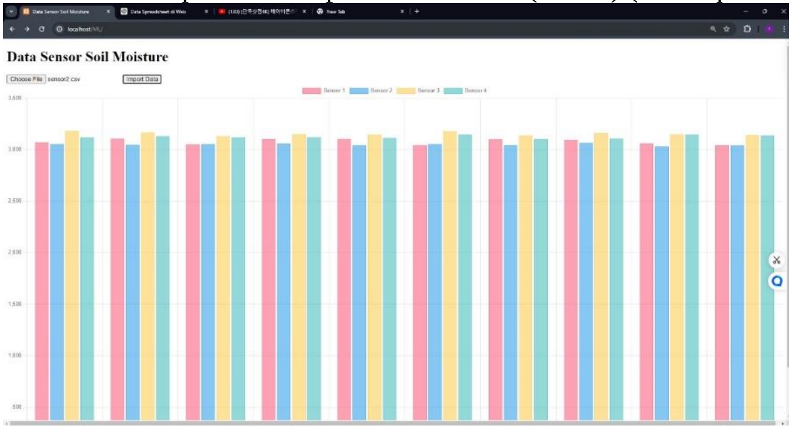


Figure 14. Graphic Data Sensor Soil Moisture

As can be seen in Figure 14, there is a graph that provides visualization in the form of a bar graph that clearly depicts soil moisture condition data at various measurement points and helps in decision-making for efficient irrigation management in the garden. This data comes from a CSV (*Comma-Separated Values) formatted datasheet file* that is imported into a data visualization application.

After obtaining the soil moisture sensor datasheet, the data will be used for the machine learning process by applying the linear regression method. This linear regression method is used to predict soil moisture based on historical data that has been collected. By applying linear regression, we can understand the relationship between independent variables (e.g., time or environmental conditions) and dependent variables (soil moisture). The results of this prediction can help in optimizing the automatic watering system, ensuring the plant gets the right amount of water according to its needs based on future soil moisture predictions.

1. **Manual Prediction-Linear Regression**

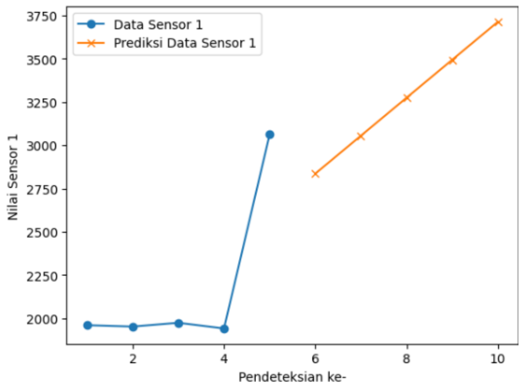
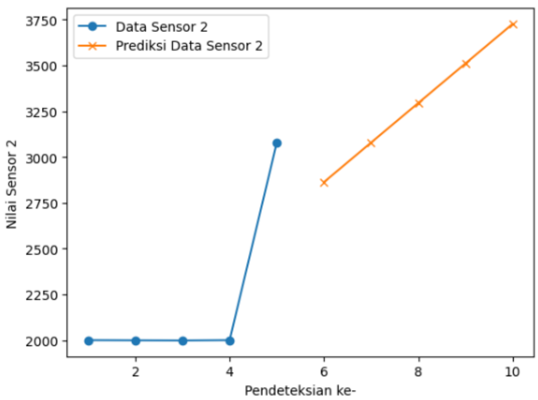
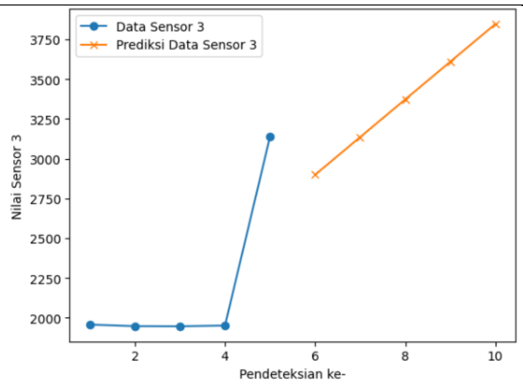
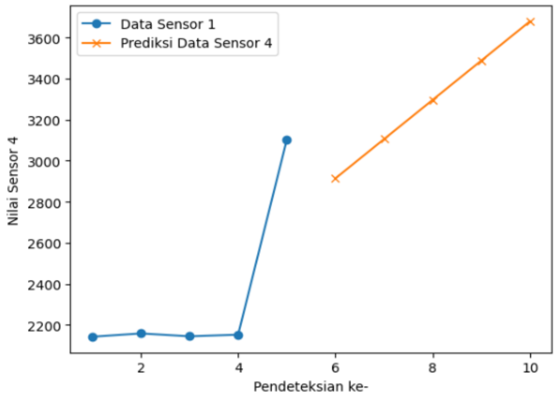
```
# Visualisasi hasil prediksi Sensor 1
print('Prediksi untuk data baru Sensor 1:')
for i, prediksi1 in enumerate(prediksi_baru_X1):
    print(f'Data ke-{len(data_sensor1) + i + 1}: {prediksi1}')

plt.plot(X1, y1, 'o-', label='Data Sensor 1')
plt.plot(X1_pred, prediksi_baru_X1, 'x-', label='Prediksi Data Sensor 1')
plt.xlabel('Pendeteksian ke-')
plt.ylabel('Nilai Sensor 1')
plt.legend()
plt.show()
```

Figure 15. Source Code Visualization of Sensor Prediction Results 1

As an example of the result, in **Figure 15** there is a source code visualization of the prediction results of sensor 1. The part of the code that is responsible for displaying the prediction results for the new data from Sensor 1. Print the title "Prediction for Sensor 1 new data:". Then, for each prediction in prediksi_baru_X1, which is the prediction result for Sensor 1's new data, the code prints an index of the predicted data along with its prediction value. Next, the code uses matplotlib to create plots from the already observed data (X1 and y1) and predictions for new data (X1_pred and prediksi_baru_X1). Provides visualizations that allow to compare actual data with predicted results.

The following is an output table of the manual prediction of sensor data 1-4 with the linear regression method and its explanation:

Table 3. Output Manual Prediction Data Sensor

Output Manual Prediction	Prediction Data
	Each row shows a predicted Sensor 1 value for each new data entered into the model. **Predictions for Sensor 1's new data:** 6th data: 2835.8999999999996 7th data: 3055.0 8th data: 3274.1 9th data: 3493.2 10th data: 3712.2999999999997
	Each row shows a predicted Sensor 2 value for each new data entered into the model. **Predictions for Sensor 2's new data**: 6th data: 2863.1 7th data: 3078.8 8th data: 3294.5 9th data: 3510.2 10th data: 3725.9
	Each row shows a predicted Sensor 3 value for each new data entered into the model. **Predictions for Sensor 3's new data**: 6th data: 2899.2 7th data: 3136.2 8th data: 3373.2 9th data: 3610.2000000000003 10th data: 3847.2000000000003
	Each row shows a predicted Sensor 4 value for each new data entered into the model. **Predictions for Sensor 4's new data:** 6th data: 2914.0 7th data: 3105.2000000000003 8th data: 3296.4000000000005 9th data: 3487.6000000000004 10th data: 3678.8

Thus, manual prediction can take appropriate actions based on sensor predictions to keep the state of the garden or plants in optimal condition. For example, they can adjust the volume of water sprayed or make improvements if there is a large difference between the actual value and the predicted value.

2. Linear Regression

The output below in Table 4, is the result of predicting the future values for the new data from the four sensors (Sensor 1 to Sensor 4). To achieve this output, several stages are carried out in the linear regression model as follows:

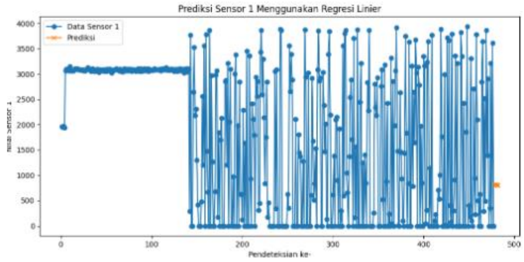
```
# Mengambil data dari masing-masing sensor

sensors = ['Sensor 1', 'Sensor 2', 'Sensor 3', 'Sensor 4']

# Siapkan ukuran gambar plot
plt.figure(figsize=(20, 10))

for i, sensor in enumerate(sensors):
    data_sensor = df[sensor].values

    # Siapkan data untuk regresi linier
    X = np.array(range(1, len(data_sensor) + 1)).reshape(-1, 1)
    y = np.array(data_sensor)

    # Latih model regresi linier
    model = LinearRegression()
    model.fit(X, y)

    # Prediksi nilai masa depan (misalnya untuk 5 data kedepan)
    X_pred = np.array(range(len(data_sensor) + 1, len(data_sensor) + 6)).reshape(-1, 1)
    prediksi_baru = model.predict(X_pred)

    print(f'Prediksi untuk data baru dari {sensor}:')
    for j, prediksi in enumerate(prediksi_baru):
        print(f'Data ke-{len(data_sensor) + j + 1}: {prediksi}')

    # Plot data asli dan prediksi
    plt.subplot(2, 2, i + 1)  # Atur subplot untuk setiap sensor
    plt.plot(X, y, 'o-', label=f'Data {sensor}')
    plt.plot(X_pred, prediksi_baru, 'x-', label='Prediksi')
    plt.xlabel('Pendeteksian ke-')
    plt.ylabel(f'Nilai {sensor}')
    plt.title(f'Prediksi {sensor} Menggunakan Regresi Linier')
    plt.legend()

plt.tight_layout()
plt.show()
```

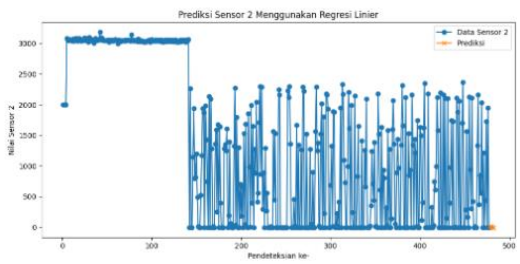
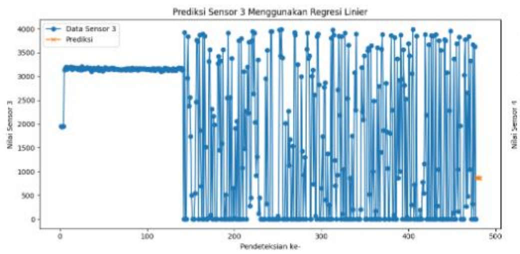
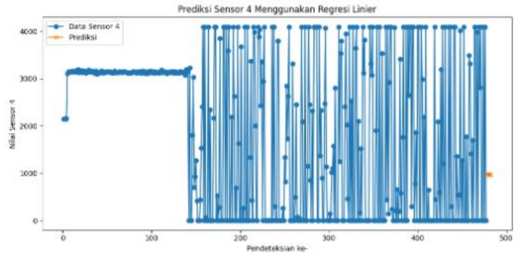
Figure 16. Stages of Linear Regression Sensor Data Prediction

This part of the code performs a loop for each sensor:

1. Prepare the data: The sensor data for the current sensor is extracted from the data_sensor array.
2. Preparing the data for linear regression: The sensor data is converted into a NumPy array and reshaped to fit the format required for the linear regression model.
3. Train a linear regression model: A linear regression model is created and trained using sensor data and prediction of future data values for the next 5 data.
4. Show predictions: Predictions for new data are displayed in the console.
5. Create a plot: A plot is created for the current sensor, showing the actual sensor data (blue dot), prediction (orange cross), axis label, and title.

Table 4. Ouput Data Sensor Regressioni Linear

Sensor Prediction Output	Prediction Data
	**Predictions for new data from Sensor 1:** 478th data: 821.6804872892549 479th data: 817.336001551485 480th data: 812.9915158137146 481st data: 808.6470300759443 482nd data: 804.3025443381739

	**Predictions for new data from Sensor 2:** 478th data: 15.619100470376907 479th data: 9.720635613525246 480th data: 3.8221707566740406 481st data: -2.07629410017762 482nd data: -7.9747589570288255
	**Predictions for new data from Sensor 3:** 478th data: 878.3859732572273 479th data: 873.9495471039127 480th data: 869.5131209505985 481st data: 865.0766947972838 482nd data: 860.6402686439696
	**Predictions for new data from Sensor 4:** 478th data: 982.5323450134772 479th data: 978.4870999635348 480th data: 974.4418549135926 481st data: 970.3966098636504 482nd data: 966.351364813708

These predictions are generated using a linear regression model, which has been trained on historical data from each sensor. Each row in the output shows a predicted sensor value for the next five detection data. For example, for Sensor 1, the predicted value on the 478th detection is 821.68, and this prediction continues until the 482nd detection. The same is true for Sensor 2, Sensor 3, and Sensor 4 with predictions on the 478th to 482nd detection, respectively.

Sensor 1 shows a value that tends to decrease from 821.68 to 804.30, while Sensor 2 also shows a decrease from 15.62 to -7.97, which could indicate a change in conditions detected by the sensor. Sensor 3 and Sensor 4, although also showing a slight decline, maintained more stable values. This explanation is important in the context of the Garden Warden, an IoT-based automated watering system that uses data from various sensors to optimally regulate garden watering. Using linear regression, the system can predict forward sensor values, which allows for proactive adjustments to watering. For example, if the prediction shows a decrease in soil moisture (as Sensor 1 and Sensor 2 can indicate), the system can increase the amount of water watered to ensure the plant stays getting enough water. Conversely, if the prediction shows stable or improved conditions, the system may reduce watering to conserve water.

3. Arima Forecasting

The ARIMA (*Autoregressive Integrated Moving Average*) method is a predictive method in data mining for time series data. ARIMA is said to have a high level of accuracy for short-term forecasting with minimal datasets. The code below is an implementation of the function to train the ARIMA (*AutoRegressive Integrated Moving Average*) model and predict future data from various sensors, and display the prediction results in the form of graphs.

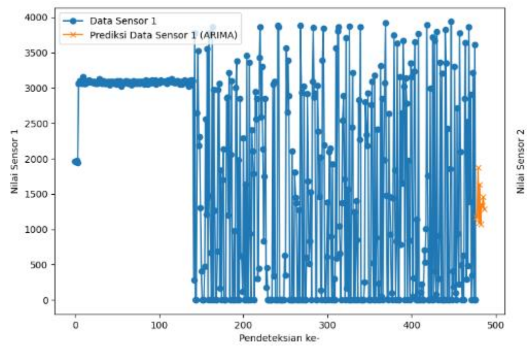
```python
# Fungsi untuk melatih model ARIMA dan memprediksi data masa depan
def train_and_predict_arima(sensor_data, sensor_name, order=(5, 1, 0)):
    model = ARIMA(sensor_data, order=order)
    model_fit = model.fit()

    # Prediksi 10 langkah ke depan
    forecast = model_fit.forecast(steps=10)

    print(f'Prediksi untuk data baru {sensor_name}:')
    for i, prediksi in enumerate(forecast):
        print(f'Data ke-{len(sensor_data) + i + 1}: {prediksi}')

    return forecast

# Visualisasi hasil prediksi untuk semua sensor
plt.figure(figsize=(15, 20))

# Pengulangan untuk masing-masing sensor
for i, sensor_name in enumerate(df.columns[1:]):
    # Mengambil data dari masing-masing sensor
    sensor_data = df[sensor_name].values

    # Melatih dan memprediksi untuk sensor saat ini
    forecast_sensor = train_and_predict_arima(sensor_data, sensor_name)

    # Plot hasil prediksi untuk sensor saat ini
    plt.subplot(4, 2, i+1)
    plt.plot(sensor_data, 'o-', label=f'Data {sensor_name}')
    plt.plot(range(len(sensor_data), len(sensor_data) + len(forecast_sensor)), forecast_sensor, 'x-',
             label=f'Prediksi Data {sensor_name} (ARIMA)')
    plt.xlabel('Pendeteksian ke-')
    plt.ylabel(f'Nilai {sensor_name}')
    plt.legend()

plt.tight_layout()
plt.show()
```

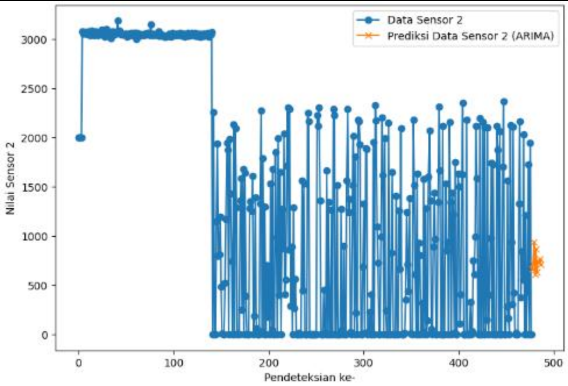
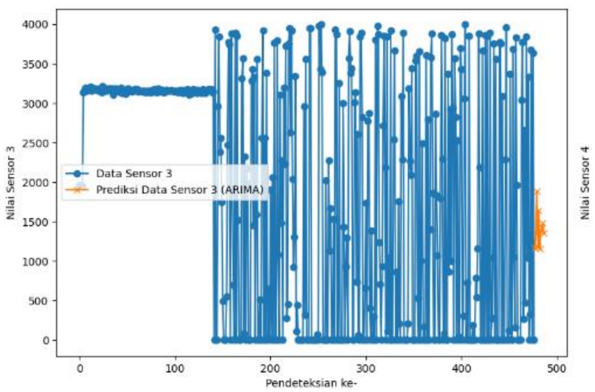
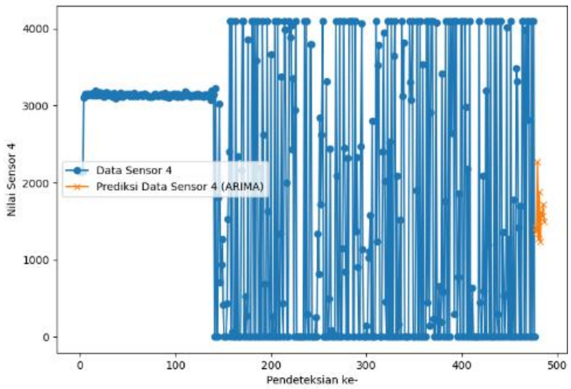
Figure 17. Arima Forecasting Sensor Data Prediction Stages

The code above in Figure 17, is an implementation to train the ARIMA model and predict the future value of the sensor data in the Garden Warden system. The **train_and_predict_arima** function is used to train the ARIMA model on specific sensor data and predict 10 future values. This function accepts sensor data (sensor_data), sensor name (sensor_name), and ARIMA model parameter (order), which by default is set to (5, 1, 0). The function initializes the ARIMA model with sensor data and order parameters that determine the AR, I, and MA components. The train_and_predict_arima function is called to train the ARIMA model and predict the future value for the current sensor.

The prediction results and the original data are plotted in the corresponding subplots. **plt.subplot (4, 2, i+1)** is used to create a 4x2 subplot so that each sensor gets its own subplot. plt.plot (sensor_data, 'o-', label=f'Data {sensor_name}') is used to plot the original data from the sensor, while plt.plot(range(len(sensor_data), len(sensor_data) + len(forecast_sensor)), forecast_sensor, 'x-', label=f'Data Prediction {sensor_name} (ARIMA)') is used to plot the prediction results. Labels for the x and y axes and legends are added to give context to the graph. Here is an output table of Arima Forecasting sensor data 1-4:

Table 5. Output Prediksi Data Sensor Arima Forecasting

Output Prediksi Sensor	Data Prediksi
	**Predictions for Sensor 1's new data:** 478th data: 1172.4865820276955 479th Data: 1185.8070760924693 480th data: 1874.475522622975 481st data: 1088.6108106766242 482nd data: 1633.5538411376524 483rd data: 1077.5866748954866 484th data: 1355.7388460060356 485th data: 1331.1139411520878 486th data: 1458.4566036497997 487th data: 1284.6672830585164

	**Predictions for Sensor 2's new data:** Data -478: 666.4765266047164 479th data: 718.3866838229836 480th data: 942.4174665075523 481st data: 612.761392654262 482nd data: 865.3959329823629 483rd data: 636.0840915947493 484th data: 739.638374471543 485th data: 737.5414474180391 486th data: 770.3717544763379 487th data: 715.5189521298189
	**Predictions for Sensor 3's new data:** 478th data: 1166.4396867539615 479th data: 1360.9598126102642 480th data: 1881.7613444465446 481st data: 1178.1394307853097 482nd data: 1637.9033001086495 483rd data: 1161.9435524900184 484th data: 1387.1961309146018 485th data: 1422.648502464722 486th data: 1484.322746440121 487th data: 1354.2718434658614
	**Predictions for Sensor 4's new data:** 478th data: 1418.3793227533502 479th data: 1363.63578525967 480th data: 2267.051903266814 481st data: 1277.018759906798 482nd data: 1878.104715635936 483rd data: 1237.2477304528638 484th data: 1619.322983599669 485th data: 1571.800593619859 486th data: 1721.4776938473917 487th data: 1497.7558565501365

The output on the table displays predictions for new data from four sensors, obtained using an ARIMA model. This prediction includes ten steps forward from the 478th data to the 487th data for each sensor. The variability in the prediction values between different time steps shows how the ARIMA model accommodates fluctuations in historical data trends and estimates the likelihood of future value changes based on those patterns.

Sensor 1 showed significant variation in predictions with a low of 1077.586 and a high of 1874.475, signaling a large change that may occur in the conditions measured by this sensor. Sensor 2 showed more moderate fluctuations with predictions low at 612,761 and a high at 942,417, indicating more stability compared to Sensor 1. Sensor 3 and Sensor 4 also exhibit significant variability in their predictions, which can indicate sudden and drastic changes in the measured environment or conditions in the prediction period.

4. Long Short-Term Memory (LSTM)

Long-Short Term Memory (LSTM) is a type of Machine Learning based on the Recurrent Neural Network approach that can predict the current condition of machines by using large-scale data processing engine sparks (Kamal Wisyaldin *et al.* 2020).

```
# List untuk menyimpan nilai prediksi
future_predictions = []

for sensor_name in df.columns[1:]:
    # Mengambil data dari masing-masing sensor
    sensor_data = df[sensor_name].values.reshape(-1, 1)

    # Transform data scaler
    scaled_data = scaler.fit_transform(sensor_data)

    # Membuat dataset untuk prediksi
    def create_dataset_for_future_prediction(dataset, time_step=10, future_steps=10):
        X, y = [], []
        for i in range(len(dataset)-(time_step+future_steps-1)):
            a = dataset[i:(i+time_step), 0]
            X.append(a)
            y.append(dataset[i + time_step:i + time_step + future_steps, 0])
        return np.array(X), np.array(y)

    X_future, _ = create_dataset_for_future_prediction(scaled_data, time_step=10, future_steps=10)

    # Membentuk input data menjadi be 3D [samples, timesteps, features]
    X_future = X_future.reshape(X_future.shape[0], X_future.shape[1], 1)

    # Membuat model LSTM
    model = Sequential()
    model.add(LSTM(units=50, return_sequences=True, input_shape=(X_future.shape[1], 1)))
    model.add(LSTM(units=50))
    model.add(Dense(units=10))  # Masukkan nomor yang diinginkan untuk prediksi
    model.compile(optimizer='adam', loss='mean_squared_error')

    # Melakukan prediksi pada data baru
    future_prediction = model.predict(X_future)

    # Inverse transform data prediksi pada original scale
    future_prediction = scaler.inverse_transform(future_prediction)

    # Tambahkan data prediksi pada list
    future_predictions.append(future_prediction)

# Cetak data prediksi
print("Predicted future values:")
for sensor_name, predictions in zip(df.columns[1:], future_predictions):
    print(f"Predictions for {sensor_name}:")
    for i, pred in enumerate(predictions[0]):
        print(f"Data ke-{i+1}: {pred}")
```

Figure 18. Tahapan Prediksi Data Sensor Long Shprt-Term Memory

The above code in figure 18 is designed to perform future value predictions using LSTM (*Long Short-Term Memory*) models on data from various sensors, which may be part of a monitoring or data collection system such as in IoT applications. The code describes the process of using an LSTM model to predict future values from sensor data.

First, the code iterates through each sensor, retrieves its data and changes its shape for the transformation process. By using a scaler, the data is normalized to improve the effectiveness of model learning. A special function is then used to create a dataset that prepares data based on the desired number of historical time steps (time_step) and future time steps (future_steps). Once the dataset is ready, it is formed into a three-dimensional format suitable for the LSTM, and then an LSTM model is built with two layers of LSTM and one layer of Dense for output. The model is used to make predictions on new data, and the results of the predictions are converted back to the original scale using an inverse transform. Finally, the predictions for each sensor are stored in a list and printed, displaying the predicted values for the future. Here is the output table of LTSM sensor data 1-4:

Table 6. LSTM Sensor Data Prediction Output

Sensor Data Prediction Results	Penjelasan Prediksi Data Sensor
Predictions for Sensor 1: 1st data: 45.69805908203125 2nd data: 18.06127166748047 3rd data: -69.59432220458984 4th data: 57.5521125793457 5th data: 127.85105895996094 6th data: 174.6390838623047 7th data: 212.07345581054688 8th data: -393.744873046875 9th data: -187.7792205810547 10th data: 269.7623596191406	This prediction covers ten steps ahead, starting from a value of around 45.70 on the first move and ending with a value of around 269.76 on the tenth move. The range of prediction values shows a huge variation, ranging from high positive values to very low negative values (for example, -393.74 on the eighth step).

Predictions for Sensor 2: 1st data: 141.2412567138672 2nd data: 41.302730560302734 3rd data: 71.82678985595703 4th data: -258.825439453125 5th data: 12.818269729614258 6th data: 84.28394317626953 7th data: 303.38525390625 8th data: 82.1446533203125 9th data: 99.75020599365234 10th data: -39.89442825317383	Predictions start from a fairly high value of 141.24 on the first move and jump to a high of 303.39 on the seventh move. However, there are also much lower prediction values, including significant negative values such as -258.83 in the fourth move and -39.89 in the last move.
Predictions for Sensor 3: 1st data: 40.0893669128418 2nd data: 1.1326844692230225 3rd data: 234.94699096679688 4th data: 94.14588928222656 5th data: 180.0357208251953 6th data: 218.5222930908203 7th data: 102.09385681152344 8th data: -172.95114135742188 9th data: -223.3590850830078 10th data: -207.05020141601562	Sensor 3 shows a tendency for greater fluctuations and sharp changes in predictions. Starting from a value of around 40.09 in the first move, the prediction jumped dramatically to 234.95 in the third move, before declining again in the following steps. Then, there were considerable fluctuations, including significant negative values such as -172.95 in the eighth move and -223.36 in the ninth step.
Predictions for Sensor 4: 1st data: -264.47216796875 2nd data: -320.4223937988281 3rd data: -154.05130004882812 4th data: -75.61951446533203 5th data: 50.417945861816406 6th data: 63.369998931884766 7th data: -2.65576434135437 8th data: -124.11561584472656 9th data: -252.065185546875 10th data: -259.5374755859375	Starting from significant negative values such as -264.47 in the first step and -320.42 in the second step, the prediction then experienced considerable fluctuations, including a sharp change to a positive value in the fifth and sixth steps. However, the range of values remains large, with negative returns on the next step.

In temporal data, the prediction output shows a considerable level of fluctuation, especially with the presence of extreme values such as significant negative values in some prediction steps. This indicates that the LSTM model may face challenges in handling highly dynamic sensor data or require further adjustments to improve prediction accuracy. Nonetheless, these prediction results can still provide valuable insights into understanding future sensor behavior and trends, and can be used as a basis for decision-making or responsive actions in various applications, paying close attention to the uncertainty and limitations of the model.

The conclusion for the three machine learning models that have been used and analyzed is that each model has its advantages and disadvantages.

1. Linear Regression tends to follow the trend of the latest data, so the prediction will increase if the trend is up and down if the trend is down. This model is simple and fast, but it is less effective at capturing complex data patterns.
2. ARIMA Forecasting is able to read the entire historical data, including seasonal and trend components, providing more accurate predictions for complex time series data patterns. However, this model requires more time and resources for training.
3. LSTM (Long Short-Term Memory), which is designed to handle time series data with complex patterns and high fluctuations, shows significant variation in predictions, including negative values that do not match expectations. This may indicate challenges in handling dynamic sensor data or the need for further adjustments to the model.

Overall, the combination of these three models can provide valuable insights and aid in decision-making for automated watering systems, although each model requires specific considerations and adjustments to achieve optimal performance.

CONCLUSION

The project "Garden Warden: Garden Watering Automation System to Maintain IoT-Based Soil Moisture" has successfully demonstrated the potential of using Internet of Things (IoT) technology and machine learning in more efficient and effective garden management. By using the Telegram app as an interface to control and monitor the system, users can easily access information about the condition of their gardens as well as set watering automatically. The use of linear regression as a machine learning method helps in predicting water needs based on the collected soil moisture data, so that watering can be done on time and according to the needs of plants. As a result, this system not only saves time and effort, but also ensures that plants get the optimal amount of water, reducing the risk of overwatering or underwatering.

And for the suggestion of this project is For further development, it is recommended that this system be expanded by adding additional sensors that can measure other environmental parameters such as temperature, light and soil nutrient levels. This will allow for more accurate predictions and more tailored watering to the specific needs of the plant. Additionally, integration with other platforms besides Telegram, such as dedicated mobile apps, can improve user accessibility and convenience. The use of more sophisticated machine learning algorithms, such as decision trees or artificial neural networks, could also be considered to improve prediction accuracy. Finally, testing the system in different climatic conditions and soil types will provide broader insights and ensure it can function optimally in a variety of situations.

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