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# THE USE OF IOT IN WATER UTILIZATION STRATEGIES FOR SMART IRRIGATION SYSTEMS BASED ON MACHINE LEARNING

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**Abstract:** Water irrigation is a crucial aspect of agriculture that often becomes the primary concern for farmers, especially because suboptimal management can lead to decreased crop yields and reduced income. So far, farmers have been practicing irrigation manually, where plants are watered twice a day, in the morning and evening, based on weather conditions without considering soil temperature or moisture levels. Based on the observations conducted, it was found that excessive water application increases water accumulation, resulting in nutrient loss from the soil and even root diseases. The objective of this study is to develop a system utilizing an ESP32 microcontroller and sensors to detect soil moisture, with a machine learning-based K-Nearest Neighbor (KNN) model, enabling farmers to remotely monitor and control their crops using an Android device. The testing results showed that with input data of 32°C temperature, 40% soil moisture, and 60% air humidity, the system produced a nearest distance of 0.000 and 0.541 from the closest k-nearest neighbors, with a status label of "needs water." As a result, the relay activates the water pump to irrigate the field. Meanwhile, for data with a nearest distance of 0.897, the system identified the status as "does not need water," indicating that the soil remains wet or moist. This study is expected to help reduce farmers' workloads by optimizing water usage according to plant needs and improving crop quality and yield.

**Keywords:** k-nearest neighbor (KNN); mikrokontroller ESP32; machine learning; water irrigation

**Abstrak:** Irigasi air merupakan aspek penting dalam pertanian yang menjadi perhatian utama petani, terutama karena pengelolaan yang kurang optimal berdampak pada penurunan hasil panen dan pendapatan. Selama ini, praktik irigasi oleh petani dilakukan secara manual, di mana penyiraman tanaman dilakukan dua kali sehari pada pagi dan sore berdasarkan kondisi cuaca tanpa memperhatikan suhu atau kelembaban tanah. Berdasarkan hasil observasi yang dilakukan, ditemukan masalah yaitu pemberian air secara berlebih menyebabkan akumulasi air meningkat mengakibatkan kehilangan nutrisi tanah dan bahkan penyakit akar. Tujuan penelitian ini menciptakan sistem yang dirancang menggunakan mikrokontroler ESP32 dan sensor untuk mendeteksi kelembaban tanah, dengan model K-Nearest Neighbor (KNN) berbasis machine learning sehingga memudahkan petani untuk mengontrol tanaman mereka dari jarak jauh menggunakan android. Hasil pengujian yang dilakukan dengan data inputan berupa suhu 32°C, kelembaban tanah 40% dan kelembaban udara 60%, sistem menghasilkan jarak terdekat sebesar 0.000 dan 0.541 dari k-nearest terdekat dengan label status "butuh air". Maka relay akan mengaktifkan pompa air untuk mengairi lahan. Kemudian, pada data dengan jarak terdekat 0.897, sistem mengidentifikasi status "tidak butuh air", menunjukkan bahwa kondisi tanah masih basah atau lembab. Penelitian ini diharapkan dapat membantu meringankan beban kerja petani mengoptimalkan penggunaan air sesuai dengan kebutuhan tanaman dan meningkatkan kualitas hasil panen.

**Kata kunci:** irigasi air; k-nearest neighbor (KNN); mikrokontroller ESP32; machine learning

## INTRODUCTION

Water irrigation is one of the most important issues for farmers, as it leads to a decrease in crop yields and farmers' income. Technology has penetrated various aspects of life, including industry, healthcare, agriculture, and many more. Irrigation is an area of agriculture that requires significant maintenance. Excessive irrigation uses 70% of the available freshwater resources [1]. Sustainable agriculture aims to improve overall agricultural productivity in order to reduce the negative environmental impact caused by inefficient farming practices [2].

The K-Nearest Neighbor (KNN) algorithm is an algorithm known as non-numerical, and can be used for both classification and regression tasks. To perform classification with this algorithm, a dataset consisting of training data and testing data is required [3].

By combining cutting-edge technology and data-driven solutions, smart agriculture is transforming traditional farming operations. Smart agriculture helps farmers make informed decisions, maximize crop yields, and enhance farm management through the integration of IoT devices, sensors, machine learning, and real-time data analytics [4].

One example is the application of technology in agriculture, which includes the discovery of superior plant varieties, efficient planting methods, and more advanced harvesting processes [5]. With the population continuing to grow exponentially and the demand for agricultural products rising, farmers now face the challenge of ensuring an adequate water supply for irrigating their land to meet these demands. However, with increasingly scarce water resources, farmers are confronted with the need to seek new solutions that can transform the way they work [6].

Thanks to technological advancements, the concept of the Internet of Things (IoT) in agriculture has become a reality, enabling farmers to adapt and meet demand [7]. Based on the observations conducted by the, one of the issues with excessive water irrigation is that it can lead to water accumulation, which causes nutrient loss in the soil and even root diseases. An uneven irrigation system can result in certain areas of the land becoming too wet, while others become too dry. Lack of water can hinder plant growth and reduce crop yields [8].

A newer system applies various forms of artificial intelligence (AI) to extract trends from data and maximize efficiency, both in terms of crop yields and resource management [9]

The purpose of this research is to provide a positive impact for farmers in their agricultural activities by making it easier for them to control and monitor their crops remotely with the help of Android devices. Additionally, it will enable farmers to simplify the process of supplying water to their plants by predicting soil humidity and temperature using sensor tools, machine learning technology, and Internet of Things (IoT) technology [10].

The previous research titled "Experimental performance of smart IoT-enabled drip irrigation system using and controlled through web-based applications" involved the development of a smart drip irrigation system powered by IoT and controlled through a web-based application. The web application was also designed to take appropriate actions for users during the drip irrigation process [11]. Previous studies generally only used sensors to detect soil moisture and provide measurements of temperature and humidity values based on predetermined parameters. However, this study

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introduces novelty by applying an irrigation system that integrates a combination of sensors with the K-Nearest Neighbor (KNN) method. This approach aims to improve the accuracy of temperature and soil moisture readings, making the results more relevant and in line with the actual soil moisture conditions.

## METHOD

The K-Nearest Neighbor (KNN) algorithm is an algorithm known as non-numerical, and can be used for both classification and regression tasks. KNN is included in the supervised method, which means that this algorithm requires training data as a reference to classify objects based on the closest distance. The working principle of KNN involves finding the closest distance using the Euclidean distance method, considering the value of *k* [12].

The Stages of the K-Nearest Neighbor (KNN) Algorithm:

### Dataset Preparation

The dataset includes historical data with attributes such as temperature (°C), soil moisture, air humidity, and a label indicating water requirement with conditions of "yes" or "no".

Table 1. Dataset Irigasi Cerdas

| Suhu (oC) | Soil Moisture (%) | Air Humidity (%) | Need Water |
|---|---|---|---|
| 28 | 75 | 80 | No |
| 32 | 40 | 60 | Yes |
| 35 | 50 | 55 | Yes |
| 30 | 70 | 85 | No |
| 29 | 65 | 70 | No |

The Euclidean distance formula between two points p and q:

$$di = \sqrt{\sum_{i=1}^{n} (X_{ij} - P_j)^2} \quad (1)$$

Explanation:

$d_i$ : Euclidean distance between data point $X_i$ and reference point or data center $P$.

$X_{ij}$ : The $j$th component of data vector $X_i$. This is the $j$th feature or attribute value of data $X$.

$P_j$ : The jth component of reference vector P. This is the reference feature or attribute value on the same dimension.

N : Number of dimensions or attributes in the data.

$(X_{ij}-P_j)^2$ : The square of the difference between the data feature value $X_i$ and the reference point P on dimension j.

The square root of the total distance calculated.

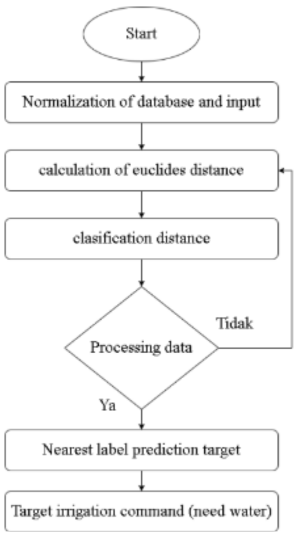


Image 1. Data Visualization of KNN Algorithm Research

### Dataset and Input Normalization

This will normalize all attribute data that can be normalized to the range [0, 1] to ensure the closest distance.

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**The Euclidean Distance Function**

The function of this distance is to calculate the distance between the input data and each data point in the dataset.

**Classification**

Perform classification to determine the prediction label based on the label data values of the K nearest neighbors.

**Output**

The results of the process that has been carried out will display a prediction label and information about the nearest neighbors to determine an accurate prediction for issuing irrigation commands when the soil needs water, with a label indicating whether water is needed (Yes/No).

The hardware used in the research on smart irrigation using the Internet of Things (IoT) system with machine learning (ML) technology.

**Mikrokontroller ES32**

Images 2. Mikrokontroller ESP32

The ESP32 is a microcontroller designed for Internet of Things (IoT) applications and various other computational needs. Inside the ESP32 board, there is a Wi-Fi module and Bluetooth in a single chip, providing access to wireless networks or short-range networks via Bluetooth [13].

**Sensor Soil Moisture**

Image 3. Sensor Moisture

A moisture sensor is a device used to measure the soil's moisture content. This sensor is commonly used in agricultural applications, environmental research, and smart irrigation systems to monitor soil moisture conditions in real time. Changes in soil moisture over time reveal specific patterns that help in understanding the characteristics of soil moisture values [14].

**Temperature Sensor DHT22**

Image 4. DHT22 Temperature Sensor

The DHT22 temperature sensor is designed to measure air humidity with high accuracy. The DHT22 sensor can measure temperatures in the range of 20°C to 80°C, while humidity levels range from 0% to 100% [15].

**Relay**

A relay is an electronic device that functions as a switch, capable of controlling an electrical circuit to operate automatically [16].

**RESULTS AND DISCUSSION**

Several tests were conducted by testing soil humidity temperature data from various levels of soil moisture using a dataset determined by the soil moisture sensor and DHT11 temperature sensor. The tests performed included testing samples of soil humidity temperature data and air temperature data, as well as testing on the microcontroller equipped with the soil sensor and DHT11 temperature sensor. The sample data consists of

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soil humidity temperature and air temperature:

Table 2. Temperature Humidity Values Dataset

| Temperature (oC) | Soil Moisture (%) | Air Humidity (%) | Need Water |
|---|---|---|---|
| 28 | 75 | 80 | No |
| 32 | 40 | 60 | Yes |
| 35 | 50 | 55 | Yes |
| 30 | 70 | 85 | No |
| 29 | 65 | 70 | No |

The table above shows the percentage values of soil temperature humidity, air temperature humidity, and the label indicating whether water is needed or not. There are 5 data points with different values: for the first data, the air temperature is 20°C, soil humidity is 78%, and air humidity is 80%, resulting in a label indicating "no water needed." In the second dataset, the air temperature is 32°C, soil humidity is 40%, and air humidity is 60%, which results in the label "water needed".

After the dataset undergoes training using the KNN algorithm, the KNN algorithm will then search for the most similar historical data (the closest distance) to predict the label.

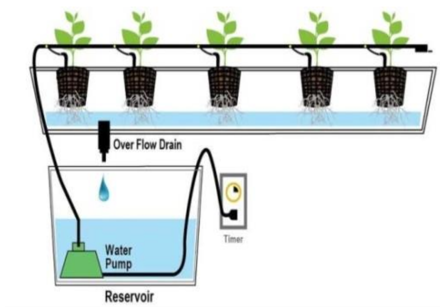


Image 5. Diagram Irrigation Water Plant Watering

Smart irrigation for plant watering to provide moisture at soil temperature using several hardware components and systems equipped with Internet of Things (IoT) technology and utilizing the KNN (K-Nearest Neighbors) machine learning (ML) algorithm.

**The Testing of ESP32 and Soil Sensor**

This test was conducted to measure the soil temperature and humidity using a soil moisture sensor. The soil humidity was measured using the ESP32, which processes data from the sensor to provide the soil temperature and humidity values. Below is the testing table:

Table 3. The Testing of Soil Temperature and Humidity Detection Sensor

| Soil Conditions | Soil Moisture | Nilai Data | Need Water |
|---|---|---|---|
| Wet | 80% | 0 | No |
| Moist | 65% | 0 | No |
| Dry | 40% | 1 | Yes |

Based on the test results table, there are three different soil conditions: wet, moist, and dry. The sensor detects the soil condition based on the readings of soil moisture parameters. In the tested soil conditions, it was found that in the third condition, the soil was dry. Therefore, the system sends a command to flow water to the area where low moisture is detected.

**The Testing of the Data Sending System**

This test is conducted to provide information to farmers through an Android application in real-time. With the presence of a smart irrigation monitoring and control application, farmers can easily manage water usage efficiently, thereby supporting the optimization of water resource utilization for crops.

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Image 6. The Smart Water Irrigation Usage Monitoring Application

Tabel 4. The Testing of DHT22 Sensor

| No | Weather Conditions | Air temperature |
|---|---|---|
| 1 | Hot | >= 35$^0$C |
| 2 | Rain | <= 29$^0$C |
| 3 | cloudy damp | 30$^0$C - 32$^0$C |
| 4 | Dry Cloudy | 33$^0$C - 34$^0$C |

In this test, different weather conditions were simulated. If the sensor value is ">=350C," the weather condition is hot. If the sensor value is "<=280C," the weather condition is rainy. If the sensor value is between "300C – 320C," the weather condition is cloudy and humid. Lastly, if the sensor value is between "330C – 340C," the weather condition is cloudy and dry.

Tabel 5. Data Testing On Sensors

| No | Weather | Temperature | | | Need Water |
|---|---|---|---|---|---|
| | | °C | Humidity | Land | |
| 1 | Hot | 35 | 80% | 35% | Yes |
| 2 | Rain | 29 | 60% | 75% | No |
| 3 | Humid | 30 | 65% | 65% | No |
| 4 | Dry Cloudy | 31 | 70% | 45% | Yes |
| 5 | Hot Rain | 31 | 65% | 80% | No |

The testing was conducted by utilizing the data obtained through the sensors, which had been previously tested. The data was then analyzed using the K-Nearest Neighbor (KNN) model. This testing involves an algorithm running on the ESP32 microcontroller, which is integrated with sensors to detect soil moisture, soil temperature, and air temperature. The analysis process is performed through dataset visualization, and with the predefined data, it can be directly used for training the KNN model.


Image 7. The Results of the Nearest Distance Test for Predicting Water Needs

## CONCLUSION

The sensor functions well in predicting weather conditions. The K-Nearest Neighbor (KNN) algorithm applied to the ESP32 microcontroller processes inputs such as air temperature, soil humidity, and air humidity to produce accurate decisions. In one test, with input data of 32°C temperature, 40% soil humidity, and 60% air humidity, the system generated the closest distances of 0.000 and 0.541 from the k nearest neighbors with the status label "needs water." Therefore, the relay will activate the water pump to irrigate the land. Then, with data showing the closest distance of 0.897, the system identified the status as "does not need water," indicating that the soil condition is still wet or moist.

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