Journal of Artificial Intelligence and Engineering Applications

Website: https://ioinformatic.org/

15th October 2025. Vol. 5. No. 1; e-ISSN: 2808-4519

Arduino Microcontroller-Based Automatic Irrigation System for Grape Cultivation

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Abstract

Grapes are an agricultural product with high market value in Indonesia, both in the form of fresh fruit and processed products. Grape cultivation requires several important aspects that affect its outcome, such as planting, fertilization, land preparation, watering, and pruning. Planting media, especially soil, plays an important role as a growing medium for plants because it affects temperature and humidity levels. The ideal soil conditions for grapevines are 50-80% humidity and 20-35°C. Improving soil conditions or growing media by implementing irrigation system automation is expected to be one of the solutions to reduce the need for frequent operator control, optimize plant care, reduce dependence on manual control, and efficiently regulate water use. The procedure used in this research begins with the design, fabrication, and application of tools on grape-growing media. The purpose of this research is to design an automatic irrigation system based on soil humidity levels for grapevines that is more adaptable and accurate to support grapevine cultivation in Indonesia's tropical climate.

Keywords: *Grape Cultivation, Internet of Things, Irrigation System, Soil Humidity Sensor, Microcontroller*

1. Introduction

In Indonesia, grapes are one of the agricultural commodities that hold high value, both when sold fresh and as processed products. In Indonesia, grapes are an agricultural commodity that has a high selling value, whether in fresh fruit or in the form of a processed product. This is because the grapes have a good flavor, whether they are fresh, sweet, or sour, and are high in vitamins (A, B1, B2, B6, and C)[1]–[3]. In addition, grapes are also one of the plants that are relatively easy to cultivate because they can be grown in greenhouses and backyards and they can be grown well together with various other types of plants. In grape cultivation, several important aspects affect the success of production, including planting, fertilization, land preparation, watering, and pruning [4]. Planting media, especially soil, plays an important role as a growing medium for plants because it affects temperature and humidity levels. The ideal soil conditions for grape plants are with a humidity level of 50-80% and a temperature of 20-35°C[1], [5].

Water has an immediate effect on the photosynthetic process, plant growth and fruit production, and must be properly and regularly irrigated twice daily [6], [7]. The irrigation should be consistent, adequate, and not stagnant. Grapes also need water, but not excessive amounts[8]. Therefore, proper irrigation is a critical factor that directly contributes to the stability and increased productivity of the grapes. Badan Pusat Statistik Indonesia has reported that national grape production experienced considerable fluctuations from 2021 to 2023, at 12,164, 13,516, and 13,405 tons/year, respectively [9]. These variables emphasize the critical need for adaptive cultivation practices and efficient resource management to increase grape yields in Indonesia's tropical environment.

Improving soil conditions or growing media by implementing irrigation system automation is supposed to be one of the solutions in reducing the need for frequent operator control, optimizing plant nurturing, reducing manual control dependency, and managing water usage efficiently [10]. Previous research has developed similar systems using microcontroller-based automatic watering systems such as *Arduino* [11], ATmega328P [12], and ESP8266 [13] have become widely applied methods to improve efficiency in caring for plants[14]. These systems generally use soil temperature and humidity sensors to automatically regulate watering but still have some limitations, such as limited signal range, limited static watering time, and dependence on sunlight intensity as an energy source. Therefore, it is necessary to develop a more adaptive and accurate automatic watering system to support grape cultivation in Indonesia's tropical climate

2. Method

2.1. Components of automatic irrigation system

The components required in this research are as follows: software (VS Code ver. 1.99.3), grapevines (seedlings), growing medium (soil, fertilizer), Pot or bed, *Arduino* microcontroller ATMEGA328P, relay 12V 10A *Songle* SRD-12VDC-SL-C 5 PIN, soil humidity sensor 10A 125VAC, LCD (liquid crystal display) 16 × 2, servo motor, jumper cable male to female, 400-pin breadboard.

2.2. Current research

This research tested the automatic watering device for two months (August-October 2024), with a total of 10 days of watering the grape vines with interval three days [15]. The procedure used in this research begins with a design of the instrument and the fabrication of the instrument [16]. After the instrument is created, the instrument is examined on the plant-growing media. This instrument works by reading soil conditions (soil *humidity*) when the sensor is placed on the soil (planting media). If soil conditions are dry or with a temperature of ≤50%, then the instrument will release water [17], [18], and in wet/moist conditions, the instrument only reads the value of the ground conditions[1]. The measurement of soil temperature and humidity in the tool is made, and the process of watering the planting media occurs. In this study, researchers made observations on grape plants used to use this system so that the results of observations were obtained as in Figure 1. Furthermore, researchers collected data on how much humidity and dryness the plants needed for the watering process. The data is embedded in the humidity sensor and microcontroller in the *Arduino*-based automatic grape plant media watering tool so that it can be processed by the designed system. This is to determine the right time to give an automatic watering command to the plant.

Figure 1. Flowchart of manual watering plant

2.3. System design

The system in this research is designed based on the needs of grapevine owners to overcome manual watering problems, such as missed watering times, mismatches in soil humidity levels, and waste of time and energy. The implementation of an automatic system, watering can be done regularly and in accordance with soil humidity needs so that plant growth becomes more optimal. The system design stages begin with the reading of soil conditions by the humidity sensor[19], then the results are displayed on the LCD screen. If the soil humidity is below the threshold (e.g. water content ≤ 50°C) [17], [20]–[22], the system will activate the water pump through a relay until the soil is moist again. Conversely, if the soil is already moist enough, the pump will remain off. The modeling of this system is presented in diagram form to facilitate understanding of the overall system workflow (Figure 2).

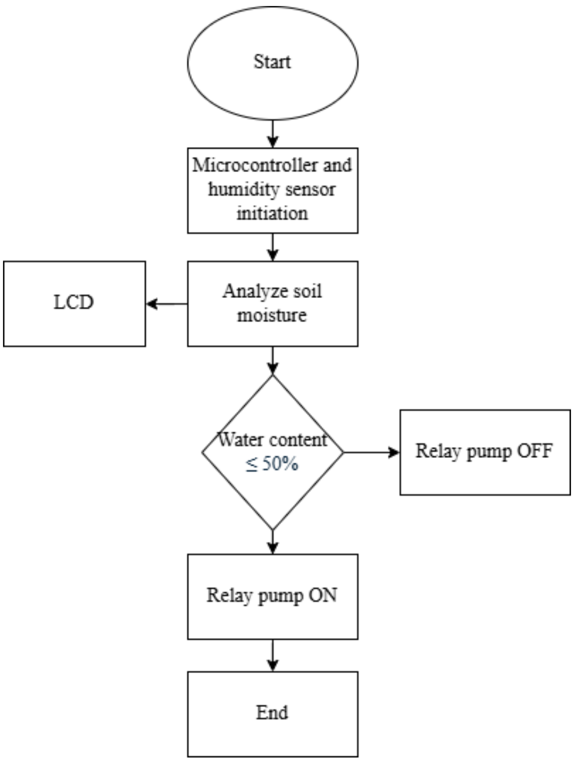


Figure 2. Flowchart of automatic irrigation system

2.4. Block diagram

This automatic grape irrigation system is designed using an Arduino microcontroller and integrated with sensors to optimize the device's performance. The block diagram shows a block diagram consisting of three main components, which are input, process, and output (Figure 3) [23]. The relationship between blocks in the diagram represents the workflow of the system as a whole. Each block has main and supporting components that function to support the system as a whole. The voltage source functions as the main power provider for all devices. Arduino UNO is used as a central controller that regulates the operation of all components automatically. A soil humidity sensor is used to detect the humidity content in the soil. The LCD screen is used to display temperature information detected by the sensor. The relay component functions to activate the servo motor with a voltage of 12V, which is then used to automatically pump water from the container and irrigate the plants.

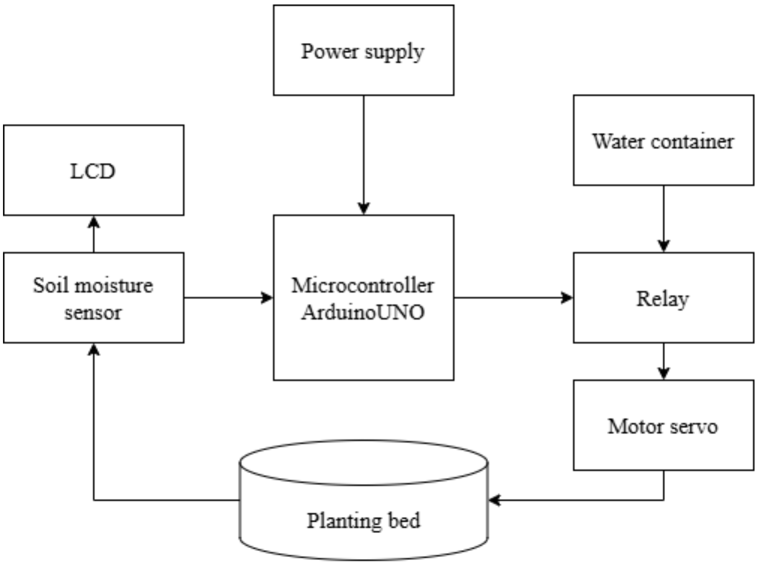


Figure 3. Block diagram and flowchart of Arduino-based automatic grape irrigation design tool

2.5. Schematic of device design

The overall design of the tool circuit consists of four important components that are interconnected, such as the input circuit, controller circuit, output circuit, and integrated software program (Figure 4) [24]. In the overall design of this automatic irrigation tool, all components used are connected to the breadboard using jumper cables without having to adjust the connecting cables between all components and the microcontroller. Thus, it can maximize the function of the instrument without damaging the components if there are several components that are not functioning properly.

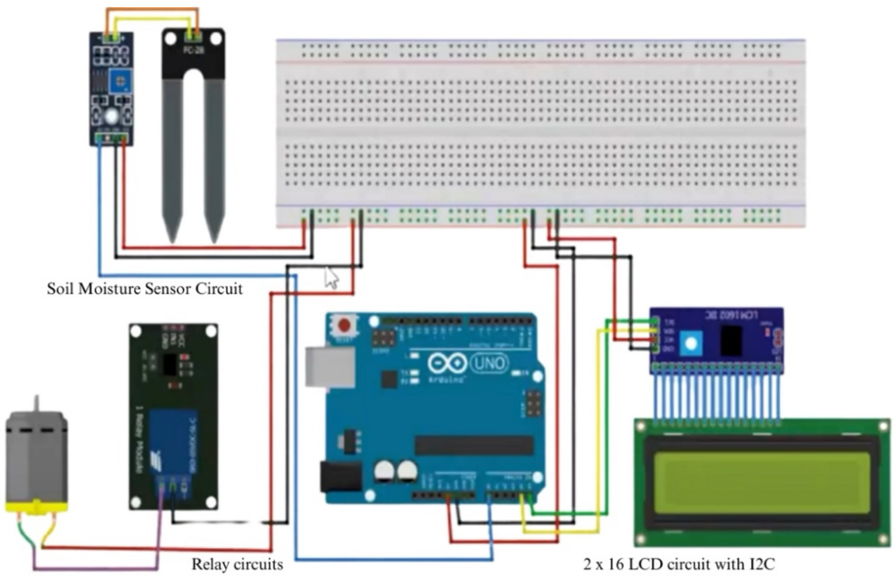
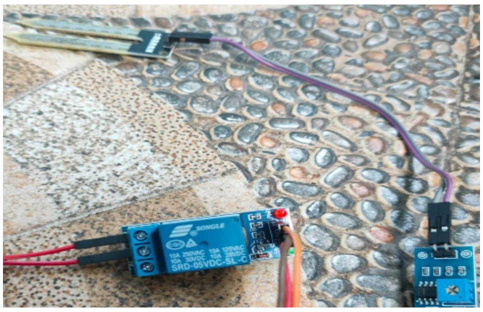


Figure 4. Device design of automatic irrigation system

3. Result and Discussion

3.1. Result of assembly design

Tool with a system running on an *Arduino*UNO microcontroller connected to the soil humidity sensor, LCD (liquid crystal display), relay and servo motor, which is then tested on planting media. The Soil Humidity Sensor is connected to the microcontroller as a humidity reader (Figure 5. (a)) and is then coded to receive and send further commands (Figure 5. (b)). The signal results are then translated in the form of a code (Figure 6. (a)), which is then converted and displayed on the LCD (Figure 6. (b)). Finally, the relay connected to the microcontroller will switch the water pump on/off according to the command (Figure 7 (a) and (b)). If the reading generated by the Soil Humidity Sensor is less than 50, the status will be Low and the relay will switch off the water pump. Otherwise, if the status remains high, the relay will not switch on the water pump. The parts of the system are then assembled into an automatic irrigation system that is placed on the soil or growing medium (Figure 8).



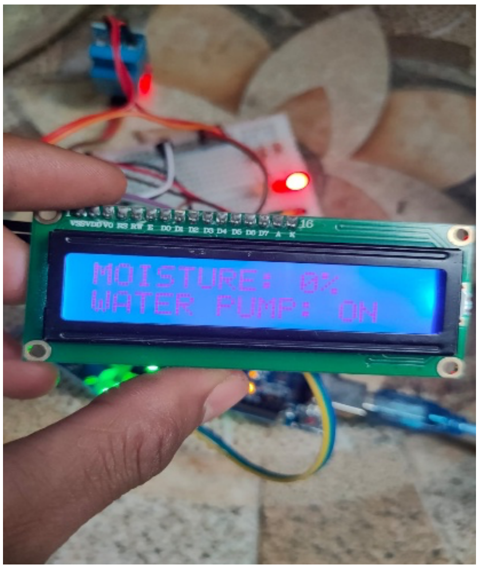
(a)

```
void getMoistureData() {
    int moisture = sensorData;
    int moisturePercentage = 100 - (moisture / 10);

    Serial.println("SOIL MOISTURE = " + String(moisture) + " | " + String(moisturePercentage) + "%");

    moistureStatus(moisturePercentage);
    pumpRunner(moisturePercentage);
    ledStatus(moisturePercentage);
}
```

```
int sensorData() {
    digitalWrite(MOISTURE_SENSOR_POWER_PIN, HIGH); // Turn the sensor ON
    delay(50); // Allow power to settle

    int moisture = analogRead(MOISTURE_SENSOR_PIN); // Read the analog value from sensor

    digitalWrite(MOISTURE_SENSOR_POWER_PIN, LOW); // Turn the sensor OFF

    return moisture;
}
```

(b)

Figure 5. (a) Implementation of soil humidity sensor with microcontroller and (b) coding soil humidity sensor with microcontroller



(a)

```
Serial.begin(115200);

// Initialize LCD
lcd.init();
lcd.backlight();

// Print a message to the LCD.
lcd.setCursor(4, 0);
lcd.print("MOISTURE");
lcd.setCursor(3, 1);
lcd.print("WATCHER V1");
delay(2000);

lcd.clear();
```

```
void ledStatus(int moisturePercentage) {
    concurrent(50, [moisturePercentage]() {
        if (moisturePercentage <= 60) {
            digitalWrite(LED_OK_STATUS_PIN, HIGH);
            digitalWrite(LED_WARNING_STATUS_PIN, LOW);
        } else {
            digitalWrite(LED_OK_STATUS_PIN, LOW);
            digitalWrite(LED_WARNING_STATUS_PIN, HIGH);
        }
    });
}
```

(b)

Figure 6. (a) implementation LCD (liquid crystal display) with microcontroller and (b) coding LCD (liquid crystal display) with microcontroller

(a)

```
void pumpRunner(int moisturePercentage) {
    concurrent(200, [moisturePercentage]() {
        if (moisturePercentage <= 50) {
            digitalWrite(RELAY_PIN, LOW);
            digitalWrite(LED_PUMP_STATUS_PIN, LOW);
            lcd.setCursor(0, 1);
            lcd.print("WATER PUMP: ON ");
        } else {
            digitalWrite(RELAY_PIN, HIGH);
            digitalWrite(LED_PUMP_STATUS_PIN, HIGH);
            lcd.setCursor(0, 1);
            lcd.print("WATER PUMP: OFF");
        }
    });
}
```

(b)

Figure 7. (a) Implementation relay with microcontroller and (b) coding relay with microcontroller

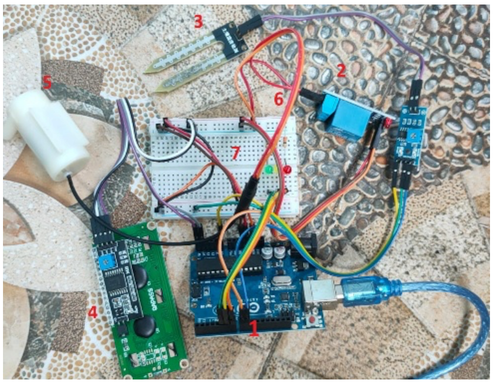


Figure 8. Hardware design of irrigation system

The system design for each feature is tested directly for capability and functionality, as well as its validations. The aim of this test is to create a tool system that is suitable for use. Then, testing was performed directly on the planting media for a total of 10 days with a time interval of 3 days (Figures 9 (a) and (b)).

3.2. Results of system installation and testing

The experiment was conducted by observing the humidity changes that occur in the grape growing media. Data collection is performed by using a jumper cable to connect the soil humidity sensor with the ATMEGA328P microcontroller *Arduino* circuit in the box, then from the ATMEGA328P microcontroller *Arduino* through a USB cable connected to the power supply to run. When everything is connected, plug the soil humidity sensor into the ground. After that, observe the measurement results when the water pump is ON and OFF and the soil humidity value (%) displayed on the LCD, if the soil humidity sensor reads soil humidity below 50%, then the servo motor or water pump will work.

(a) (b)

Figure 9. (a) Sensor soil humidity plugged in the ground and (b) LCD showed the humidity value

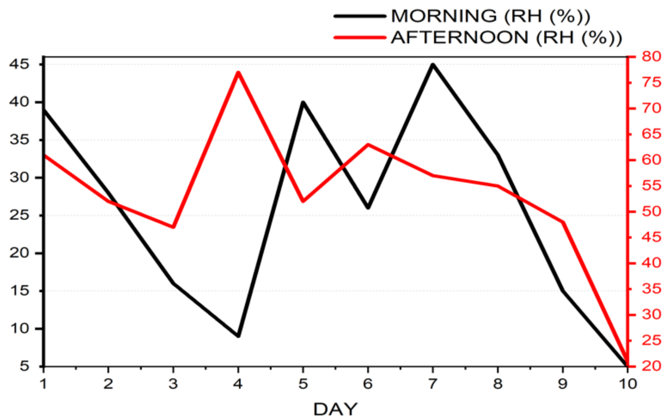


Figure 10. Graph of soil humidity sensor testing on grape plants for 10 days (morning and afternoon)

The observations of humidity are shown in graph in Figure 10. Irrigation was carried out in the morning and in the afternoon. Based on the graph, during the 10 days of observation (3 days apart), soil humidity in the morning showed sharp fluctuations, with a significant decrease from around 40% to 5%, while in the afternoon it was stable with a peak of 74% before decreasing slowly. This difference indicates that automatic watering is more effective towards noon. The low RH in the morning but high in the afternoon could be due to watering that has not had time to penetrate or the influence of temperature that accelerates evaporation [15], [25], [26]. This confirms that the current 3-day morning-evening automatic watering system is not able to maintain soil humidity within the ideal range (around 50-60% RH) for optimal growth of grapevines [8], [27]. Meanwhile, studies show that *Arduino*-based automatic irrigation systems can maintain soil humidity around 60% consistently and irrigation automation research with soil humidity sensors has proven effective in improving water management in plants[28]–[30]. However, the design of the automatic irrigation system has been successfully made and implemented. Therefore, it is necessary to adjust the frequency of watering (e.g. from every 3 days to 2 days) and further research to optimize the irrigation settings so that the humidity needs of grapevines can be achieved.

4. Conclusion

The conclusion of this research shows that the automatic irrigation system can determine changes in soil moisture. The system in this study can give commands to activate and turn off the watering system as needed. This system uses the latest microcontroller, namely Arduino Uno with ATMEGA328P type. The utilizing the soil humidity sensor as a benchmark or radar reading of soil conditions.

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