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Designing A Prototype of Smart Agricultural System Based on Internet of Things

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Abstract. In the IoT era, traditional agriculture which requires large amounts of labor, has changed to adapt to the emergence of this technology. By doing this, modern agriculture can take advantage of IoT devices and services to replace humans in certain agricultural activities. As a result, the management processes of agricultural administration are standardized, manageable, and can be improved thereby reducing overall operating costs and improving the quality of agricultural products. The urgency of this integrated IoT system is to increase the quality and quantity of crop agricultural production. Currently, most farmers cannot monitor and control the real conditions of their agricultural land either remotely or in real time. For example, based on the soil moisture information obtained from the system created, farmers can anticipate the dry season and take appropriate preparatory and action measures. Because of this the IoT system can help farmers to minimize the possibility of crop failure and inefficient agricultural processes due to bad weather conditions, as well as knowing the condition of soil parameters after the fertilization process.

INTRODUCTION

According to the Food and Agriculture Organization, the overall prosperity and well-being of populations around the world is highly dependent on how well countries manage their agricultural sector. On the other hand, 31.36 percent of Indonesia's land area or around 57 million hectares is currently used for agricultural purposes, which currently contributes to 14.43 percent of national GDP, providing employment for around 41 percent of the total workforce or around 70 million people working in this sector [1]. Weather and soil conditions are key factors for the success of the agricultural sector, so it is necessary to monitor and monitor weather and soil conditions data that can be used for follow-up decision making.

In the IoT era, traditional agriculture which requires large amounts of labour, has changed to adapt to the emergence of this technology. By doing this, modern agriculture can take advantage of IoT devices and services to replace humans in certain agricultural activities [2]. As a result, the management processes of agricultural administration are standardized, manageable, and can be improved thereby reducing overall operating costs and improving the quality of agricultural products.

This IoT system is designed as an integrated system, which uses several agricultural and environmental sensors and is then connected to a 3G / 4G wireless cellular network as a gateway system, which is useful for collecting data from all sensors to cloud storage. Data from cloud storage can be further processed by a specially made Android-based application.

STATE-OF-THE-ART

Many similar studies have been done before. This section aims to compare the existing systems with our system. The first work was found in [3]. This system implemented Internet of Things to monitor and control environment parameters in a greenhouse in order to increase the productivity of plants in it. It applied an Arduino UNO microcontroller, which was used to control several components, such as the DHT11 temperature and humidity sensor, light dependent resistor (LDR) and ESP8266 Wi-Fi module. This system monitored only temperature, humidity, and light intensity in a greenhouse. The data collected of temperature, humidity and light intensity was sent to a database. Compared to our system, his system used 2 sensors and Arduino UNO that has lower memory and processing capacity than Arduino Mega in our system. Our system connected to wireless cellular network that is independent to Wi-Fi network as in [3].

The second work observed is explained in [4]. The researchers monitored air temperature and humidity using DHT22 sensors and automatically turned water pump on through a relay when the condition of temperature and humidity are reached in a greenhouse. Arduino UNO was used to control several components, such as DHT22 sensor, ethernet shield, and relay that was connected to a water pump. This system contained DHT22 sensor as a temperature and humidity sensor, Arduino UNO microcontroller as the program brain, ethernet shield that connected the Arduino UNO via LAN cable with a computer network, relays as a switch for water pump, and a web-based server [4]. In other hand, our system used 7 sensors.

REALIZATION OF THE SYSTEM

This designing of the prototype of smart agricultural system based on IoT agriculture was made with a microcontroller module as a control centre and data processor, namely Arduino Mega 2560 R3 which uses ATmega2560 processor with 16 MHz clock speed and has features like 4 kB EEPROM, 8 kB SRAM, 256 kB flash memory, 54 digital I/O pins, 16 digital I/O with PWM pins, and 16 analog pins. Our system consists of following parts: a microcontroller module, a weather station module, an air quality sensor, a soil moisture sensor, and a soil pH sensor.

The weather station was realized to monitor air temperature and humidity by using DHT11 sensor; wind speed by using anemometer, and rain condition. DHT11 sensor has the range of measuring 20 – 95% humidity and 0 – 50ºC air temperature with an error about 5%. This sensor has 3 pins, i.e. digital output, V_{cc}, and ground. The digital output pin of DHT11 was connected to pin 26 of the Arduino Mega 2560 R3. The output voltage issued by the anemometer is analog data so that its analog output pin was connected to pin A2 of the microcontroller. Rain condition was detected by MD0127 sensor. It has a digital output pin which was connected to pin 28 of the microcontroller. Air quality was detected by using particulate matter (PM) 2.5 sensor which detected tiny particles or droplets in the air that are two and one half microns or less in width and by using MQ 135 gas sensor which detected level of CO_2 and NH_4. Analog output pin of soil moisture sensor was connected to pin A0 of the microcontroller. The output of this sensor was read by microcontroller and then fed to relay to switch the water pump ON/OFF. The pH level of soil was read by the microcontroller (pin A3) from the analog output of pH soil sensor.

All values from the above sensors were sent by the microcontroller through GSM module to a 3G / 4G cellular wireless network that was connected to a cloud server which stored the data. In receiving command data from the cloud server, commands were used to control the automatic water sprinkling module. Block diagram of our designed system can be seen in Figure 1.

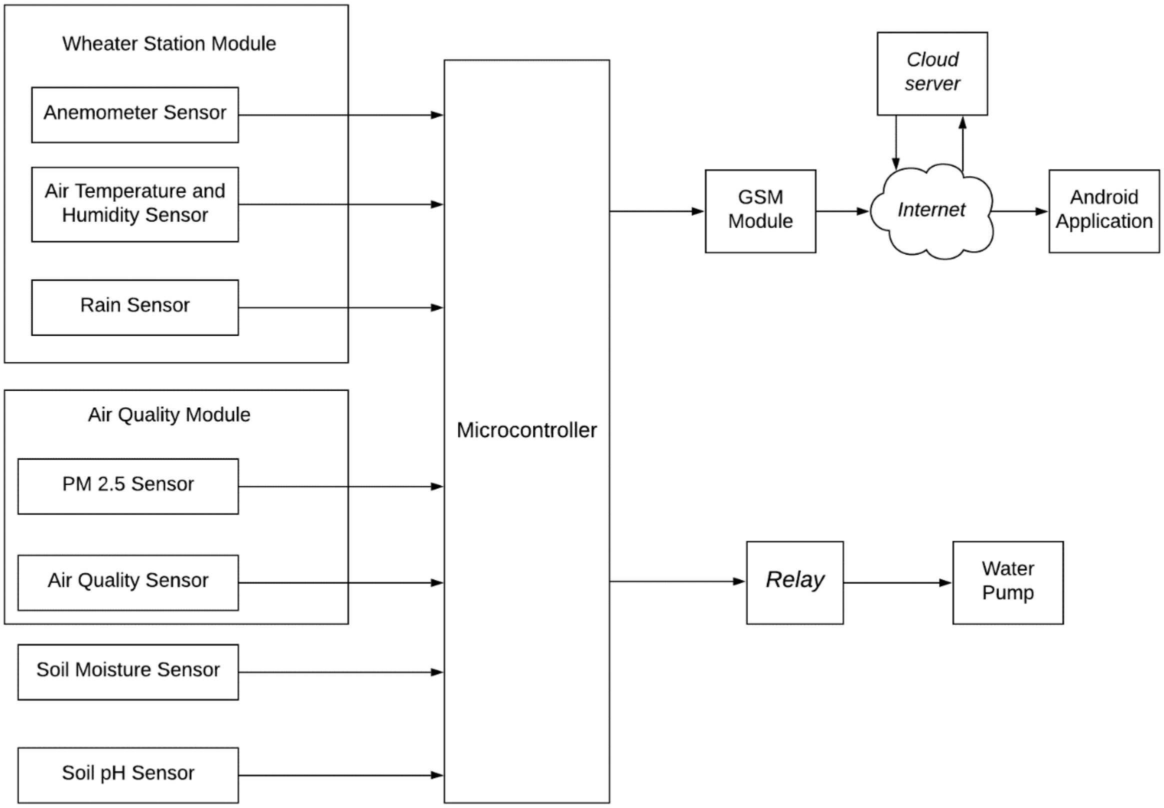

FIGURE 1. Block diagram of the designed system

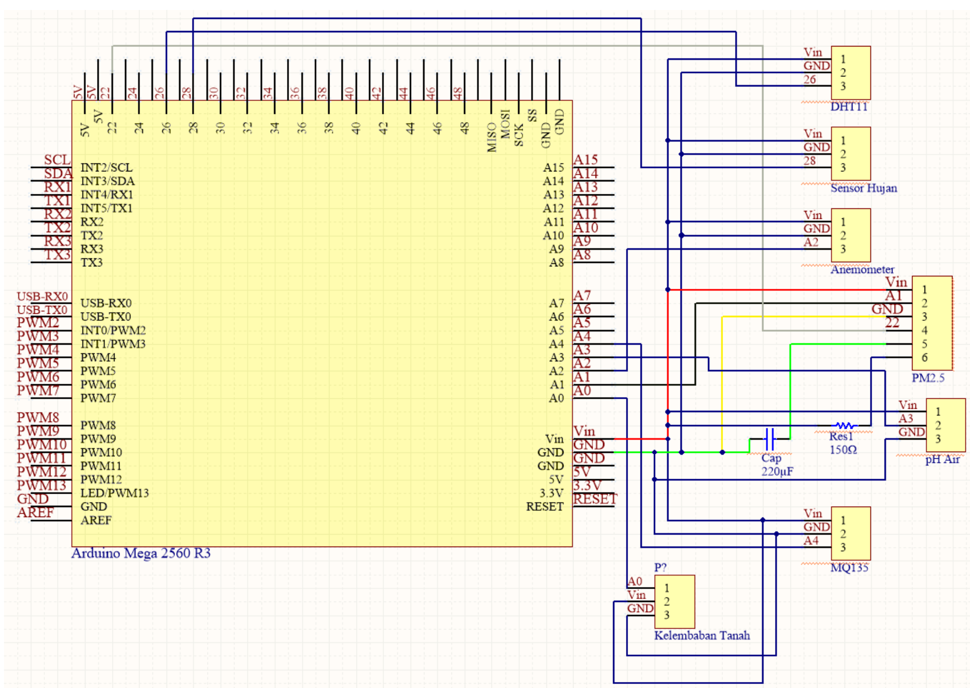

FIGURE 2. Schematic diagram of a whole system circuit.

The realization of the whole system is by combining all modules to the microcontroller with the dimensions of the circuit in a box measuring 21 cm x 14 cm x 5 cm. The schematic of the whole system realization circuit is shown in Figure 2.

The power of the whole system was supplied by a solar panel power source. The solar panel used is a 20 Wp polycristallin type which functions to convert sunlight intensity into electrical energy. This solar panel measures 485x360x25 mm and has 9x4 = 36 cells and a maximum power supply of 20 watts per hour. The power supply module used consists of a solar panel, solar controller, and a 12 V, 7 Ah battery.

RESULTS AND DISCUSSION

Testing the whole system is done by connecting all existing modules. Solar panel was used as an energy source to power all modules designed in the system. The weather station module, air quality module, water sprinkler module and water pH module were all connected to the Arduino Mega 2560 R3. The test step is carried out by monitoring the weather station module which consists of an anemometer sensor, a DHT11 sensor and a rain sensor. Air quality module consisting of an MQ-135 sensor and a PM2.5 sensor. Water sprinkler module consisting of soil moisture sensor and water pump. The output from the sensors will be displayed as the results of monitoring and controlling on the serial monitor of the Arduino IDE. Then the data will send the results of monitoring and control with the GSM module to the android application made by other researchers. The test results in monitoring environment condition of the whole system can be seen in Table 1. This table shows the condition of air temperature, humidity, and air quality on a particular day.

TABLE 1. Test results of environment condition

Time	Serial monitor output						
	Temp. (°C)	**Humidity (%)**	**Wind Speed (m/s)**	**Rain**	**CO_2 (ppm)**	**NH_4 (ppm)**	**PM2.5 (μg/m³)**
09.00	25	90	20	No	0.05	0.1	120
12.00	31	80	20	No	2	2.5	150
17.00	30	75	30	No	1.55	2.67	135
21.00	26	85	20	No	1.89	3.04	122

TABLE 2. Test results of soil condition and watering

Soil Fertilizer	Soil pH	Soil Condition	Serial monitor output	
			Soil Moisture (%)	**Water Pump**
Urea	6.45	dry	40	ON
Compost	11.37	dry	45	ON
No fertilizer	7.2	wet	80	OFF

TABLE 3. Test results of the overall functionalities of the system

Not.	Type of testing	Result
1.	Solar panels can supply the whole set	succeed
2.	The weather station module can monitor the weather	succeed
3.	The air quality module can monitor air quality	succeed
4.	The water sprinkler module can monitor and control the water pump	succeed
5.	The GSM module can connect the system to the network	succeed
6.	The GSM module can send data over the internet	succeed

As can be seen from Table 2, the observed pH level of soil is suitable for each type of used fertilizer, i.e. urea and compost. When the soil moisture sensor has detected that the soil is dry, then the water pump will be turned on. Table 3 shows that all designed modules of the system are functioning properly.

CONCLUSION

Based on the testing results, several conclusions can be drawn from our system, as follows:

1. The weather station module can take data on air temperature, humidity, wind speed, and weather conditions properly;
2. The air quality module can perform data retrieval of the level of CO_2, NH_4, and PM2.5 in the air, as expected;
3. The water pump will automatically start when the soil is dry and stop when the soil is wet, which data was obtained from soil moisture sensor;
4. The output on the serial monitor can be sent to the cloud server. This data then can be obtained successfully via Internet by an Android application made by other researchers in our research group.

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