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Development and Performance Evaluation of Arduino-Based Environmental Monitoring System Integrating BME280 Sensor and BN-220 GPS

Pengembangan dan Evaluasi Kinerja Sistem Pemantauan Lingkungan Berbasis Arduino yang Mengintegrasikan Sensor BME280 dan GPS BN-220

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ABSTRACT

The development of BME280 sensor and BN-220 GPS module based on Arduino Uno is a device that can measure temperature, humidity, air pressure and location coordinates in real-time. This research aims to compare the performance of the device with temperature, humidity, and air pressure sensors, as well as the Arduino Uno-based GPS module with the performance of existing measuring instruments at BMKG, Climatology Station. This research was conducted from September to December 2024 at the Sub-Laboratory of Agricultural Energy, Department of Agricultural Technology, Faculty of Agriculture, Sriwijaya University and BMKG, Class I Climatology Station, South Sumatra. The research method used, namely quantitative descriptive method which includes the development of hardware, software, testing, and measurement data displayed in the form of tables and graphs. The research was conducted by taking data per 1 hour starting from 08.00 to 16.00 WIB, the data obtained was compared with data from BMKG. This tool combines to measure environmental condition parameters, namely temperature, humidity, and air pressure, as well as location coordinates that can be used portable because it does not need to use the internet network to be able to display the measured parameters. The results obtained will appear on the LCD and the measurement data is stored directly on the SD card. This tool is able to provide real-time data and generate measurement data for each parameter simultaneously, so that farmers or users in remote areas can know the environmental conditions directly and take appropriate action. The comparison results show that the temperature parameter gets an average percentage difference of 4.01%, humidity is 11.2%, air pressure is 0.03%, and location coordinates have an average difference value of 2.9m. This tool is able to provide measurement data that is consistent and relatively the same as the data generated by BMKG.

Keywords: *Arduino uno; BME280; GPS BN-220; planting environment.*

ABSTRAK

Pengembangan sensor BME280 dan modul GPS BN-220 berbasis Arduino Uno merupakan perangkat yang dapat mengukur parameter suhu, kelembaban, tekanan udara dan koordinat lokasi secara *real-time*. Penelitian ini bertujuan untuk membandingkan kinerja alat dengan sensor suhu, kelembaban, dan tekanan udara, serta modul GPS berbasis Arduino Uno dengan kinerja alat ukur yang ada di BMKG, Stasiun Klimatologi. Penelitian ini telah dilaksanakan pada bulan September sampai dengan Desember 2024 di Sub Laboratorium Energi Pertanian, Jurusan Teknologi Pertanian, Fakultas Pertanian, Universitas Sriwijaya dan BMKG, Stasiun Klimatologi Kelas I, Sumatra Selatan. Metode penelitian yang digunakan, yaitu metode deskriptif kuantitatif yang mencangkup pengembangan perangkat keras, perangkat lunak, pengujian, dan data hasil pengukuran yang ditampilkan dalam bentuk tabel dan grafik. Penelitian dilakukan dengan pengambilan data per 1 jam mulai dari jam 08.00 sampai 16.00 WIB, data yang di dapat dibandingkan dengan data yang dari BMKG. Alat ini penggabungan untuk mengukur parameter kondisi lingkungan yaitu suhu, kelembaban, dan tekanan udara, serta koordinat lokasi yang dapat digunakan secara portable karena tidak perlu menggunakan jaringan internet untuk dapat menampilkan parameter yang diukur. Hasil yang di dapat akan tampil di LCD dan data pengukuran tersimpan langsung pada kartu SD. Alat ini mampu memberikan data secara *real-time* dan menghasilkan data pengukuran setiap parameter secara bersamaan, sehingga petani atau pengguna pada daerah terpencil dapat mengetahui kondisi lingkungan secara langsung dan mengambil tindakan yang tepat. Hasil perbandingan menunjukkan bahwa pada parameter suhu mendapatkan persentase selisih rata-rata yaitu 4.01%, kelembaban yaitu 11.2%, Tekanan udara 0.03 %, dan koordinat lokasi memiliki nilai selisih rata-rata yaitu 2.9m. alat ini mampu memberikan data hasil pengukuran yang konsisten dan relatif sama dengan data yang dihasilkan BMKG.

Kata kunci: Arduino uno; BME280; GPS BN-220; lingkungan tanam

INTRODUCTION

Indonesia is an agricultural country that relies heavily on the agricultural sector in resource utilization activities that act as food providers and industrial raw materials. Plant growth factors are influenced by internal and external factors, internal factors are usually genetic and hormones from plants, while external factors that can affect plant growth are environmental conditions. The environment has an important role in determining the success of plant growth, because environmental factors directly affect the physiological functions of plants. Good environmental conditions can support optimal plant development. In order to grow optimally, many types of plants require certain environmental conditions. Environmental conditions that are not in accordance with plant needs can inhibit plant growth (Andani et al., 2022).

The advancement of technology is very rapid and has a good impact on the progress of agriculture. Currently, most environmental condition measurement tools use internet-based technology to access and process real-time data, the use of which is often limited to areas that do not have a stable internet network (Rehman et al., 2022). Remote areas often have great potential for agriculture, by utilizing accurate environmental data, farmers can determine the right actions such as determining planting land and choosing suitable crops. Farmers in remote areas who have challenges in limited access to internet resources to obtain information, one of the challenges is the difficulty of obtaining real-time data on environmental conditions that are very important in decision making (Muda Harahap et al., 2024). One technology that is growing rapidly is the use of sensors and microcontrollers that can provide precise and fast data information. The connection with the microcontroller will facilitate monitoring and controlling the environmental conditions around the planting site and knowing what plants are suitable for these environmental conditions (Montoya et al., 2020). Advances in information technology such as wireless sensor networks provide great benefits, especially in real-time environmental data collection. The development of microcontroller technology is also becoming increasingly sophisticated at a low cost, such as Arduino, providing tools that can optimize to control input and output processes. Microcontrollers require lower power compared to other processors (Nallusamy & Rukmani, 2023).

Arduino Uno is a microcontroller board based on the ATmega328P IC. It has all the components needed to support microcontroller functions (Sulayman et al., 2024). The user only needs to connect it to a computer via a USB cable or supply power using an AC-DC adapter or battery to start using it. The name “UNO,” which means “one” in Italian, was chosen to commemorate the launch of Arduino Software (IDE) version 1.0. The Arduino Uno is the first board in the USB Arduino lineup and serves as the reference model for the entire Arduino platform (Abdurrohman et al., 2020). Arduino Uno uses an ATMega328P microcontroller that can be programmed using C-based programming through the Integrated Development Environment (IDE). The IDE has the ability to compile code and upload programs directly to the microcontroller without the need for additional tools. The completeness of features and ease of programming can be used in various applications such as monitoring systems (Boruah & Pathak, 2021; Wahyuni et al., 2021).

According to Wijaya et al. (2020), in their research showed that the ATMega16 microcontroller-based portable device is able to measure temperature, humidity, and air pressure with relatively the same results compared to standard measuring instruments and is easy to use in the field due to low power consumption. According to Perkasa et al. (2019), used a BN-220 GPS for their research which worked well and the coordinate readings were quite accurate. Tests show that the tool can provide accurate coordinate information at the closest distance of 1.3 km and the farthest 13 km within 1 to 5 minutes with an average distance difference of 2.5m. According to Saptadi & Kiswanto (2020), who conducted research for quality comparison between air humidity sensors, from the results obtained this study concluded that the BME280 sensor has superior performance than the other sensors in his research, with the highest level and accuracy and has the smallest average error of 3.78% (Araújo et al., 2020; Chodorek et al., 2022).

Therefore, the purpose of this study is to design, implement, and evaluate an Arduino-based environmental monitoring system that integrates the BME280 sensor and BN-220 GPS module to collect environmental data (temperature, humidity, pressure) and geolocation. The system also uses an Arduino Data Logger Shield for SD card data storage and a 20x4 I2C LCD display for real-time visualization. This research assesses the accuracy of the device by comparing it with official BMKG data and evaluates whether the observed deviations are within scientifically accepted tolerance levels for field application.

METHODOLOGY

Tools and Materials

The tools and equipment used in this research are drill, multimeter, solder, cutting pliers, screwdriver, while the materials to be used in the research are adapter, arduino uno R3, arduino data logger shield, lithium battery, GPS BN-220, jumper cable, USB cable, laptop, LCD I2C, BME280 sensor, stevenson box.

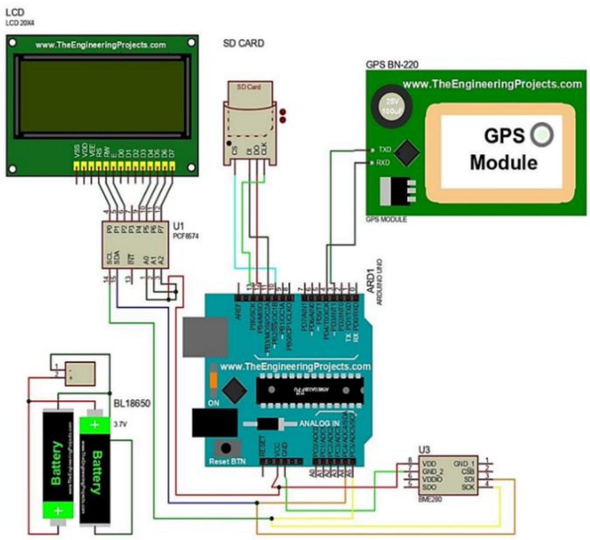

Figure 1. Schematic of hardware incorporation with Proteus

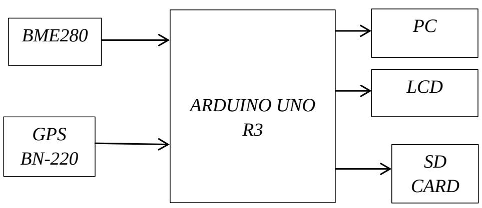

Figure 2. Hardware coupling diagram

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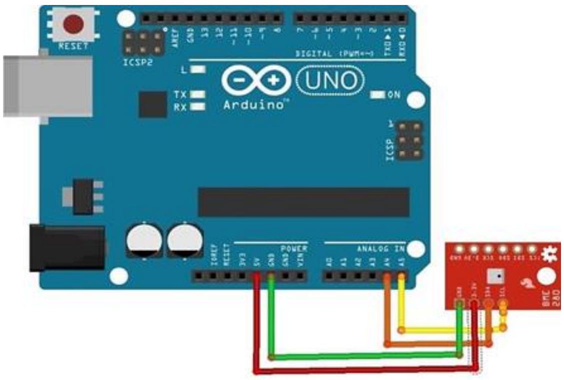

Figure 3. Schematic of BME280 sensor installation on Arduino Uno

Research Procedure

The method used in this research is a quantitative descriptive method that includes combining hardware, software, testing, and analyzing the measurement results of the tools that have been combined and compared with tools at BMKG, the data is displayed in the form of tables and graphs. Data collection in this study per 1 hour starting from 08.00 to 16.00, the data obtained in the form of CSV.

Preparation of Tools and Materials

Hardware Merger

The way the tool of Figure 1 is combined is as follows:

1. The device will start measuring when connected to a battery and can also be connected to a laptop with a USB cable.
2. The tool will perform port initialization on all combinations so that the tool is ready to read data.
3. The BME280 sensor will immediately read the environmental condition parameters, while the BN-220 GPS will search for signals to read the location coordinates in 1-5 minutes.
4. The read measurement data will be sent and displayed on the LCD.
5. Each measurement if the location coordinates have been read it will be directly stored on the memory card and can also be seen from the Arduino IDE serial monitor.

Arduino Uno R3

Arduino Uno is a microcontroller board that uses the ATmega328P chip as its core. This board is equipped with 14 digital pins for input/output, with 6 of them can function as PWM outputs. In addition, there are also 6 pins for analog input, a 16 MHz crystal oscillator, USB connector, power jack, ICSP header, and reset button. Arduino Uno provides everything needed to run a microcontroller, making it easily connected to a computer via a USB cable or powered using an AC to DC adapter or battery to start its operation (Ardiyansyah and Abdullah, 2022).

Input Merger

1. BME280 Sensor

There are 4 connecting cables to operate the sensor in Figure 3, namely:

1. The Vcc pin is attached to the Vcc pin on the Arduino Uno
2. The Ground pin is attached to the Ground pin on the Arduino Uno
3. The SDA (Serial Data) pin is attached to the A4 pin on the Arduino Uno
4. The SCL (Serial Clock) pin is attached to the A5 pin on the Arduino Uno

The BME280 sensor is a sensor that can measure 4 features, namely temperature, humidity, and air pressure. This sensor has a voltage limit of 4.25V with a temperature of -40 ° C to 85 ° C. BME280 sensors also have the main advantage of being small in size only 2.5 x 2.5 mm^2 and 0,93 mm high. This sensor will also be used in this study to measure 4 parameters of environmental conditions simultaneously namely temperature, humidity, air pressure, and altitude. With other advantages, low power consumption, and fast response.

2. BN-220 GPS

GPS BN-220 is a module used to capture GPS signals that can provide latitude and longitude data. This GPS is used to determine the coordinates of the data collection site so that the data obtained becomes valid and accountable data. Position data from GPS is processed in the Arduino Uno microcontroller first so that it can be read. There are 4 connecting cables to operate the GPS in Figure 4, namely:

1. The Vcc pin is attached to the 5V pin on the Arduino Uno
2. The RX pin is attached to pin 3 on the Arduino Uno
3. TX pin is attached to pin 4 on the Arduino Uno
4. The Ground pin is attached to the Ground pin on the Arduino Uno

Output Merging

LCD (Liquid Crystal Display) is a component that can display numeric characters, letters with low current consumption. The LCD size used is 20x4, which is 20 characters and 4 lines. The LCD is installed with an I2C (Integrated Circuit) module to facilitate incorporation into Arduino Uno. There are 4 pins on the I2C module, namely:

1. The Ground pin is attached to the Ground on the Arduino Uno
2. The Vcc pin is attached to the 5V pin on the Arduino Uno
3. The SDA (Serial Data) pin is attached to the A4 pin on the Arduino Uno
4. The SCL (Serial Clock) pin is attached to the A5 pin on the Arduino Uno

Software Programming

The program used in this research is the Arduino Integrated Development Environment (IDE) can be seen in Figure 6 which is written using a programming language similar to the C language, the version used is Arduino IDE 1.18.18. This program has an outline composed of 2 sub-programs, namely initialization which contains several instructions to be executed for once and repetition which will be given continuous commands when the device is on. This program is also one of the easiest programs to use in uploading code to the microcontroller.

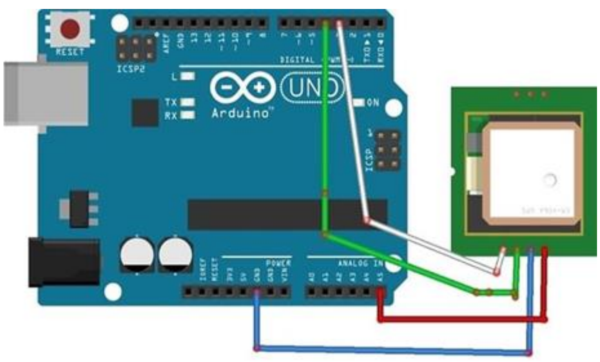

Figure 4. Schematic installation of GPS BN-220 on Arduino Uno

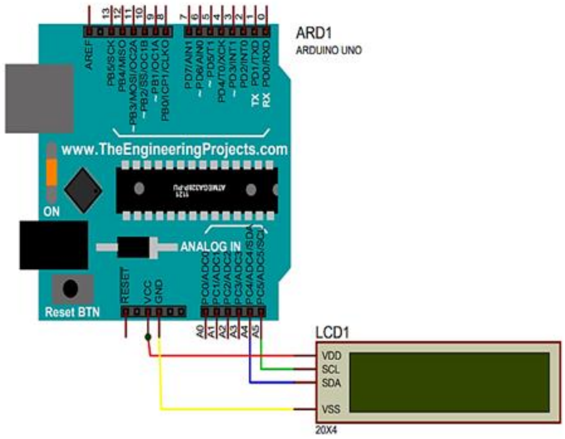

Figure 5. LCD installation scheme on Arduino Uno

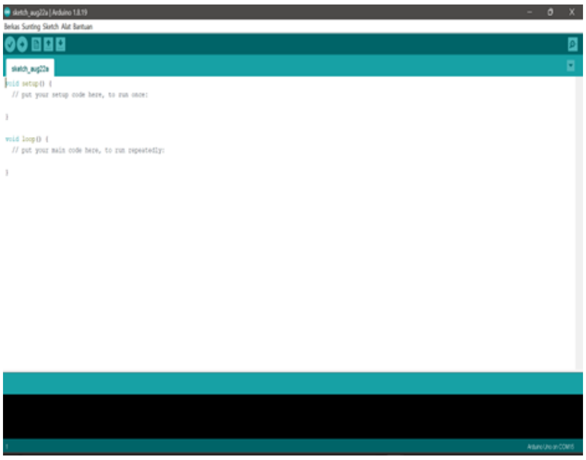

Figure 6. Arduino Integrated Development Environment (IDE)

Tool Testing

1. Prepared measuring instruments that have been combined according to the scheme that has been made.
2. Prepare serial communication and USB cables or can also use batteries to turn on the tools that will be used for measurements.
3. The tool is turned on and data for environmental conditions, namely humidity, temperature, altitude, and air pressure will be read directly on the LCD screen, for location coordinates it takes 1 to 5 minutes to read the coordinates.
4. When the coordinates are read, they will be directly stored on the SD card, according to the program that has been made in the Arduino IDE.
5. Data will be taken according to what is stored on the SD card in the 1st to 5th minute time range.
6. To find out the difference in the tool, a comparison will be made with the standard measuring instrument used by the Meteorology, Climatology and Geophysics Agency (BMKG) in accordance with the observation parameters.
7. Recorded all data generated.
8. The data is analyzed to evaluate the difference from the merged tool.

Measurement and Data Collection

The activities in measuring and collecting data in this study are as follows:

1. Measurements are made per 1 hour during 08.00-16.00 WIB, the tool is placed at BMKG Class I Climatology Station, South Sumatra.
2. Temperature, humidity, air pressure, and location coordinates on measuring instruments at BMKG Class I Climatology Station, South Sumatra.
3. Temperature, humidity, air pressure and location coordinates of the combined measuring instruments.

Data Analysis and Processing

Data analysis carried out in this study uses the data that has been obtained. Data in the form of measurement results and calculation of the difference from each parameter measured. The calculation of the difference aims to determine how large the difference level is in the measurement and determine the condition of the combined tool whether it is good or not to use. The data obtained and collected are then presented in tabulation and graphical methods and data processing using Microsoft Excel applications.

Research Parameters

BME280 Sensor Testing

BME280 sensor testing that measures the feasibility and reliability of the readings on environmental parameters, namely temperature, humidity, and air pressure. The data generated by the merged device is then compared with the data generated by BMKG as a comparison and analyzed using statistical methods in calculation methods (1) and (2).

1. MAD (Mean Absolute Deviation)

MAD is used to calculate the absolute average of the difference between the data from the combined tool and the BMKG tool, using equation (1).

$$MAD = \frac{1}{n}\sum(X_a - X_p) \quad (1)$$

(Source : Azman Maricar, 2019)

Description:
MAD = average absolute difference
Xa = value of the comparison measuring instrument
Xp = value of the combined measuring instrument
N = number of data

2. MAPE (Mean Absolute Percent Error)

MAPE is used to calculate the percentage of the absolute average difference, and find out how well the measuring instruments are combined. The lower the MAPE value means that the ability of the components used is getting better. Finding the MAPE value using the equation (2) method.

$$MAPE = \frac{1}{n}\sum\frac{(X_a - X_p)}{X_a}\, x\ 100\% \quad (2)$$

(Source : Suryanto et al., 2019)

Description:
MAPE = average percent absolute difference (%)
Xa = value of the comparison measuring instrument
Xp = value of the combined measuring instrument
n = number of data

Table 1. MAPE classification table

MAPE Value	Description
$< 10\%$	Excellent tool capability
$10\% \sim < 20\%$	Good tool capabilities
$20\% \sim < 50\%$	Feasible tool capabilities
$> 50\%$	Poor tool capability

(Source: Wulandari et al., 2018)

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BN-220 GPS Module Testing

Testing the feasibility and reliability of the BN-220 GPS module in measuring location coordinates by conducting tests that are compared with location coordinate data that has been determined by BMKG. Calculation of distance difference using the Haversine equation method (3) and (4). Haversine is one method that is often used to measure the distance between two axes of coordinate points with comparative data of latitude and longitude. In this study, the Haversine method was used to calculate the difference in distance between the coordinates of the BMKG climatology park location as a comparison (Setiadi et al., 2023).

$$a = \sin^2\left[\frac{\Delta lat}{2}\right] + \cos(lat1)\cos(lat2)\sin^2\left[\frac{\Delta long}{2}\right] \quad (3)$$

$$d = 2r\sin^{-1}(\sqrt{a}) \quad (4)$$

(Source: Nabila et al., 2023)

Description;

Lat1 = Latitude of the comparator (rad)
Lat2 = Latitude of the combined device (rad)
Long1 = Comparator longitude (rad)
Long2 = Longitude of the tool combined (rad)
D = Distance (m)
R = Radius of the earth (6371 km)
Δ_{lat} = Magnitude of latitude change (rad)
Δ_{long} = Magnitude of change in longitude (rad)

RESULTS AND DISCUSSION

BME280 Sensor Testing Results

This test is to determine the readiness of the BME280 sensor as a measure of environmental conditions, namely temperature, humidity, and air pressure. Each parameter will be compared with existing measuring instruments at the Climatology Station, for temperature and humidity parameters with Thermohygrograph DR. A Muller and air pressure parameters with a digital barometer. All tools are located in the weather cage in the Climatology Station Tool Park.

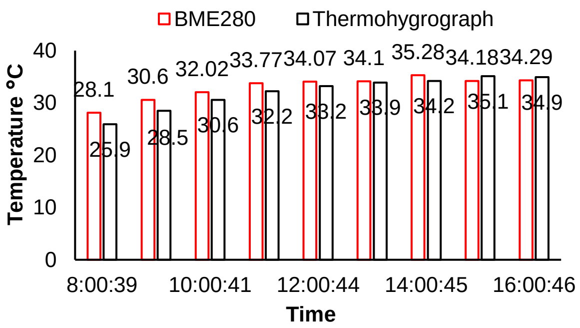

Figure 7. Temperature data graph

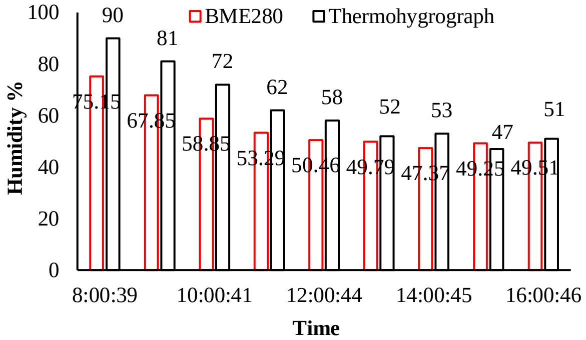

Figure 8. Humidity data graph

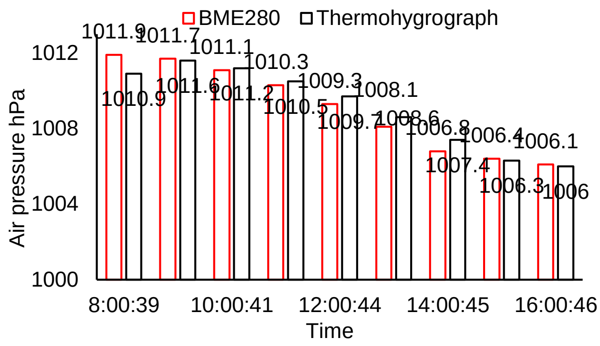

Figure 9. Graph of air pressure data

Temperature

Temperature is the level of heat or coldness of an environment expressed on a certain scale, one unit of temperature is degrees Celsius (°C) which is the international standard. Temperature is one of the factors that affect the process of photosynthesis, and plant growth, so the importance of good temperature measurement in determining the type of plant that is suitable in a planting environment. This test is to get the temperature difference value of the combined tool, compared to Thermohygrograph DR. A Muller. Thermohygrograph is a measuring instrument for air temperature and humidity levels for 24 hours. The unit of temperature on Thermohygrograph is Celsius, while the unit on humidity / Relative Humidity (RH) is %.

Based on BME280 sensor testing in measuring temperatures that have been carried out starting from 08.00-16.00, in Table 2 T1 is the BME280 Sensor and T2 is Thermohygrograph, and the average absolute difference (MAD) result is 1.22 ° C, and with the test results of the percentage of absolute difference (MAPE) of 4.01% which is a low MAPE value indicating that the temperature gauge on the BME280 sensor is very good at approaching the measurement value performed by the standard gauge. This result shows that although there are variations in the temperature measurement results, the combined tool can still provide reliable results and can be used properly for measurements in locations far from internet and communication network access. The graph in Figure 7 is the temperature fluctuation during the test, which shows the stability and reliability of the temperature measurement produced by the BME280 sensor.

Humidity

Humidity is the ratio of the mass of water vapor to the unit mass of air. Humidity greatly affects the physiological processes of plants, namely with air humidity that is too low can cause stress in plants and while humidity that is too high can increase the risk of plant disease. Humidity testing is carried out to obtain the difference value by comparing the measurement results of the BME280 sensor with a standard measuring instrument as a comparison using the Thermohygrograph in the Climatology Station Tool Park. Testing is carried out in a weather cage within 1 hour starting from 08.00-16.00 WIB with the results of humidity testing in Table 3.

The humidity test results can be seen in Table 3 which shows the humidity values measured by the BME280 sensor and Thermohygrograph, and the absolute difference. BME280 sensor, in Table 3 RH1 is the BME280 Sensor and RH2 is Thermohygrograph in the same way as the previous parameter test, obtained a MAD value of 7.66%, and a MAPE value of 11.2%, indicating that the measurement of the humidity parameter is in good condition for use based on the

MAPE classification table, although variations can be caused by uncontrolled environmental conditions.

Air Pressure

Air pressure testing is carried out to obtain the value of the difference in air pressure by comparing the combined device with a standard measuring instrument as a comparison using a digital barometer at the Climatology Station.The results of the air pressure test are in Table 4. Based on the results of air pressure testing on the BME280 Sensor above, Pressure 1 is the value of the BME280 sensor and Pressure 2 is the value of the digital Barometer. Based on the results of testing air pressure on the BME280 Sensor Table 4, Pressure 1 is the value of the BME280 sensor and Pressure 2 is the value of the digital barometer. The results obtained show the absolute difference value or MAD is 0.35 hPa, and from MAPE 0.03%. These results show a low MAD value and a MAPE value below 10% that the BME280 sensor is very good at measuring reliable air pressure.

BN-220 GPS Module Testing

Testing is carried out to calculate the difference value on the BN-220 GPS sensor by determining whether the sensor used in this study is in good condition. To find out the difference with the Haversine method in Equations (3) and (4). According to Farid & Yunus (2017),, the Haversine formula is a method of calculating the distance between two points of the earth based on the length of a straight line connecting the two points, taking into account the curvature of the earth. Haversine Method The coordinate formula that is usually used in determining the position on the map is latitude and longitude. Latitude is a horizontal line connecting the east and west of the earth at the equator, while longitude is a vertical line connecting the north and south poles of the earth. Latitude and longitude coordinates are used to be variables to calculate the distance between two location points by drawing a straight line connecting the two (Miftahuddin et al., 2020).

Table 2. Temperature test data on BME280 sensor

Measurement Results and Data Processing				
Time	T1 (°C)	T2 (°C)	Absolute Difference (°C)	Percentage of Absolute Difference (%)
8:00:39	28.1	25.9	2.2	8.49
9:00:40	30.6	28.5	2.1	7.37
10:00:41	32.02	30.6	1.42	4.64
11:00:42	33.77	32.2	1.57	4.88
12:00:44	34.07	33.2	0.87	2.62
13:00:44	34.1	33.9	0.2	0.59
14:00:45	35.28	34.2	1.08	3.16
15:00:45	34.18	35.1	0.92	2.62
16:00:46	34.29	34.9	0.61	1.75
MAD			1.22	
MAPE				4.01%

T1 : Temperature data from BME280 sensor
T2 : Temperature data from Thermohygrogram

Table 3. Humidity test data on BME280 sensor

Measurement Results and Data Processing				
Time	RH1 (%)	RH2 (%)	Absolute Difference (%)	Percentage of Absolute Difference (%)
8:00:39	75.15	90	14.85	16.5
9:00:40	67.85	81	13.15	16.2
10:00:41	58.85	72	13.15	18.3
11:00:42	53.29	62	8.71	14.0
12:00:44	50.46	58	7.54	13.0
13:00:44	49.79	52	2.21	4.3
14:00:45	47.37	53	5.63	10.6
15:00:45	49.25	47	2.25	4.8
16:00:46	49.51	51	1.49	2.9
MAD			7.66	
MAPE				11.2%

RH1: Humidity data from BME280 sensor
RH2 : Humidity data from Thermohygrograph

Table 4. Air pressure test data on BME280 sensor

Measurement Results and Data Processing				
Time	*Pressure* 1(hPa)	*Pressure* 2(hPa)	Absolute Difference (hPa)	Percentage of Absolute Difference(%)
8:00:39	1011.9	1010.9	0.96	0.10
9:00:40	1011.7	1011.6	0.11	0.01
10:00:41	1011.1	1011.2	0.13	0.01
11:00:42	1010.3	1010.5	0.22	0.02
12:00:44	1009.3	1009.7	0.41	0.04
13:00:44	1008.1	1008.6	0.54	0.05
14:00:45	1006.8	1007.4	0.60	0.06
15:00:45	1006.4	1006.3	0.09	0.01
16:00:46	1006.1	1006	0.09	0.01
MAD			0.35	
MAPE				0.03%

Pressure 1: Air pressure data from BME280 sensor
Pressure 2: Air pressure data from digital barometer

Table 5. Distance difference calculation data with Haversine Formula method

No	Lat (deg)	Long (deg)	Long (rad)	Lat (rad)	d(m)
1	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.0322852	104.722282	1.827748621	-0.052923361	1.28
2	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.032293	104.72229	1.827748761	-0.052923497	2.52
3	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.032295	104.722282	1.827748621	-0.052923532	2.25
4	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.032313	104.722282	1.827748621	-0.052923846	4.19
5	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.032329	104.72229	1.827748761	-0.052924125	6.12
6	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.032321	104.722282	1.827748621	-0.052923985	5.06
7	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.032292	104.722259	1.82774822	-0.052923479	2.51
8	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.03228	104.722282	1.827748621	-0.05292327	0.90
9	-3.032276	104.722275	1.827748499	-0.0529232	
	-3.032265	104.722274	1.827748481	-0.052923008	1.23
	Average				2.9

Lat (deg) : latitude with degree unit
Long (deg) : longitude with degree unit
Lat (rad) : latitude with units of radians
Long (rad) : longitude with units of radians
d (m) : distance difference

(Source: BMKG Class I, South Sumatra)

Figure 10. Coordinates of the climatology station tool park location

This study uses the Haversine method to calculate the distance between the readings on the tool and the location coordinates determined by the Climatology Station, at the location coordinates determined by the Climatology Station at the Climatology Station Tool Park point, while the designed tool is placed on the weather cage in the Climatology Station Tool Park, this study uses Google Earth to find and use the location coordinates on the weather cage. The data obtained is 3°01'56.2 "S, 104°43'20.2 "E. Based on Table 5. the results on the average difference in distance between coordinate readings with the Haversine method is 2.9 m, with the smallest difference in distance in the data is 0.9 m and the most distant in the data is 6.1m. This distance difference is still within reasonable limits because the difference in numbers on the rear coordinates can produce variations in distance.

CONCLUSION

The combination of temperature, humidity, and air pressure sensors (BME280), and Arduino Uno-based GPS module (BN-220) is able to measure temperature, humidity, air pressure, and location coordinates in real-time. Comparison of the performance of the measuring instrument made and the existing measuring instrument at BMKG, produces data on the parameters of temperature, humidity, air pressure, and location coordinates that are relatively the same. The average percentage difference data generated on the parameters of temperature, humidity, and air pressure are included in the MAPE classification table which is very good to good for use. The average percentage value of the difference in the BME280 sensor in the temperature parameter is 4.01%, humidity is 11.25%, and air pressure is 0.003%. The data obtained from the BN-220 GPS module with the Haversine calculation method produces a distance difference with an average of 2.9 m.

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