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New Viewpoint Era of Weather Monitoring: Arduino Based Portable Weather Station Design

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Abstract
Weather changes play a crucial role in key sectors in Indonesia, such as agriculture and fisheries. However, limited weather data in all regions is an obstacle. This research proposes an innovative Arduino-based weather monitoring instrument that is flexible, economical and increases data availability in Indonesia. The ergonomic and flexible design of the Portable Weather Station allows mobility without dependence on building structures. With real-time monitoring using sensors for temperature, humidity, air pressure, wind speed and wind direction, this tool provides comprehensive information. Field testing shows good operation. The diversity of sensor parameters and efficient design make the Portable Weather Station innovative. Optimizing energy use and integration of advanced technologies, such as remote monitoring and cloud data processing, are recommended. The benefits involve easy and accurate access to weather information, supporting vital sectors. With continuous monitoring and evaluation, the Portable Weather Station has the potential to be an effective solution in dynamic weather monitoring, advancing sectors such as agriculture, fisheries and environmental policy, and creating communities that are more resilient to climate and economic change.

Keywords: Weather Technology, Weather Monitoring Innovation, Weather Change, Sustainable Design.

1. Introduction

Weather changes are natural phenomena that influence atmospheric dynamics throughout the world. Even though Indonesia only experiences two seasons, namely the rainy season and the dry season[1], weather plays a crucial role in the country's daily life. As an agricultural and maritime country, understanding and monitoring weather has a significant impact on the agricultural, fisheries and daily lives of people[2], [3].

Although various weather monitoring methods have been implemented previously, there are still limitations in the coverage and availability of weather data throughout Indonesia. The government relies on the Meteorology, Climatology and Geophysics Agency (BMKG) to provide weather information, but weather measurement infrastructure is limited and the weather data analysis process takes a long time before the information can be used by the public[4]. In addition, the cost of maintaining equipment and limited staff wages at weather stations are also obstacles.

The main objective of this research is to identify and develop innovations in weather monitoring

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instruments that are more flexible in operation and economical. Another goal is to increase the availability of accurate and real-time weather data throughout Indonesia. Apart from that, this research also aims to reduce maintenance costs for weather measurement equipment and speed up the process of sending weather information to the public.

It is hoped that this research will provide significant benefits in several aspects. First, with the innovation of more flexible weather monitoring instruments, more accurate weather information will be more easily accessible to the public. This will support sectors such as agriculture and fisheries in making more informed decisions based on weather conditions[5]. Second, this research is expected to provide implementation results that reduce the burden of maintenance costs for weather equipment, which have been quite high. This will help in the efficient use of government financial resources. Apart from that, this research can open up opportunities for the development of a more advanced weather technology industry in Indonesia.

This research will focus on designing weather monitoring instruments that are more affordable, flexible and efficient in operation. In addition, this research will also explore the potential for collaboration with the private sector in developing more sophisticated weather technology solutions. Thus, this research will fill the gaps in existing weather monitoring and open up opportunities for improvements in natural resource management and resilience to climate change in Indonesia.

The importance of this research cannot be underestimated. Weather plays a role in economic and environmental sustainability in Indonesia[6], and innovations in weather monitoring can help communities and other stakeholders face the challenges of climate change[6], [7]. By producing more effective and affordable weather monitoring instruments, this research has the potential to advance important sectors such as agriculture, fisheries and environmental policy. Along with the use of advanced technology and cooperation between the government and the private sector, Indonesia can be better prepared to face increasingly complex and extreme weather changes. This will help create a society that is more resilient to climate change and a more sustainable economy.

1.1. Technology and Weather: Dynamics of Climate Control in the Modern Era

Weather constitutes the atmospheric conditions prevailing at a specific location and time, encompassing a myriad of vital elements, such as air temperature, air pressure, humidity, wind speed and direction, and precipitation levels. It plays a pivotal role in the daily existence of humanity and other living organisms, significantly impacting various sectors, including agriculture, transportation, energy, and health [8]. The intricacies of weather are influenced by an array of factors, encompassing regional and global climates, the physical attributes of the atmosphere, solar-earth interactions, and natural phenomena like El Niño and La Niña. Weather studies involve the observation, monitoring, and modeling of atmospheric phenomena, assuming an increasingly pivotal role in the era of climate change due to its ramifications on extreme weather events [9]. When discussing technology and weather, it is important to understand how modern technological developments have had a major impact on the dynamics of climate control[7], [10]. The modern era has seen rapid developments in technology used to monitor, predict and manage extreme weather phenomena.

1.2. The Role of Weather in Improving the Quality of Life

Weather has an integral role in improving the quality of human life, especially in the agricultural, fisheries and other fields. Weather factors such as rainfall, temperature, humidity and wind speed have a significant impact on the productivity and sustainability of these sectors. In the agricultural sector, weather plays a key role in determining crop yields and farmer welfare[11]. Adequate rainfall during the growing season is essential for healthy plant growth, while rainfall imbalances can threaten food security[12]. Extreme temperatures can also damage plants and reduce yields. Unstable weather conditions also have an impact on the overall agricultural process.

In the fisheries sector, weather also has a significant impact. Fluctuations in sea water temperature, ocean currents and bad weather can affect fish movements and the condition of aquatic ecosystems. Fishermen often face extreme weather

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challenges that have the potential to endanger their safety and hinder fishing[11], [13]. Bad weather also affects fish supplies and fishermen's catches, which in turn affects food availability and the fishermen's economy[14]. Apart from agriculture and fisheries, other sectors such as tourism, energy and transportation are also highly dependent on the weather[9], [15]. Increasingly unpredictable climate change can disrupt the sustainability of life.

In dealing with weather impacts, it is important to increase understanding and preparedness to face increasingly extreme weather changes due to global climate change[3]. The use of advanced technology and weather information can help society and economic sectors manage weather impacts more effectively[7], [16], [17]. Cross-sector collaboration and ongoing weather research are key to improving the quality of life and resilience of sectors to increasingly complex weather variations.

2. Materials and Methods

2.1. Methods

Design Research approach with qualitative methods[18] used in this research, where the main focus of the research is to gain an in-depth understanding of the product, tool, or system design and development process. The design of this tool was carried out from March to August 2023. The Fuzzy Logic Controller (FLC) method was also used because it can handle the uncertainty and variability inherent in many real world situations. FLC is able to process uncertain information and convert it into actions that correspond to different levels of data distribution[19]. In addition, the prototype data will be tested using the Unified Theory of Acceptance and Use of Technology (UTAUT) model to test the relationship between the constructs that have been designed.[20]

2.2. Instrument Design

The design of this instrument uses six main sensors used for measurements, namely temperature and humidity sensor (DHT11), carbon monoxide sensor (MQ7), light intensity sensor (LDR), rainfall sensor (RGTBA1), air pressure sensor (MPX5500D), sensor wind speed (Anemometer), and wind direction sensor (Wind Vane Director). The data generated by this instrument will go through processing and then be displayed connectedly on a website that has been integrated with the device using Node MCU.

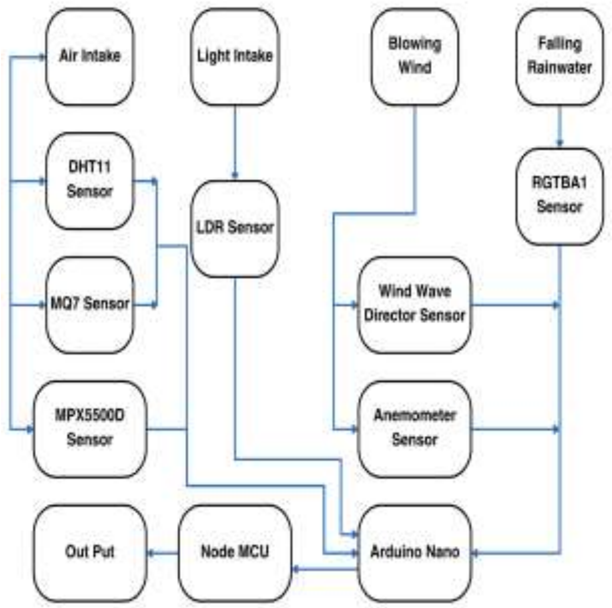

Figure 1. Portable Weather Station Design Framework

2.3. Proposed Prototype Design

The design proposed in this research is based on a design concept that prioritizes flexibility and ease of use[21]. With its lightweight and ergonomic design, this tool is very easy to move to various locations without dependence on certain building structures. This flexibility gives users the freedom to organize and allocate this tool according to changing weather monitoring needs. In addition to ease of mobility, the Portable Weather Station also stands out in its ability to monitor real-time weather with high accuracy. Weather parameters measured by various sensors integrated into this tool provide accurate and up-to-date information about the weather at the location being observed.[22]. This provides advantages in dynamic weather monitoring and is important in various contexts, such as agriculture, fisheries and environmental monitoring[2].

The variety of sensor parameters integrated in this design, such as measuring temperature, humidity, air pressure, wind speed, wind direction, and light radiation levels, allows this tool to provide a comprehensive picture of weather conditions in

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different locations.[23]. This allows users to take appropriate steps in response to weather changes that may affect their activities and decisions[24]. Thus, the Portable Weather Station is a solution that offers great benefits in weather monitoring and various applications related to weather and climate aspects (figure 2).

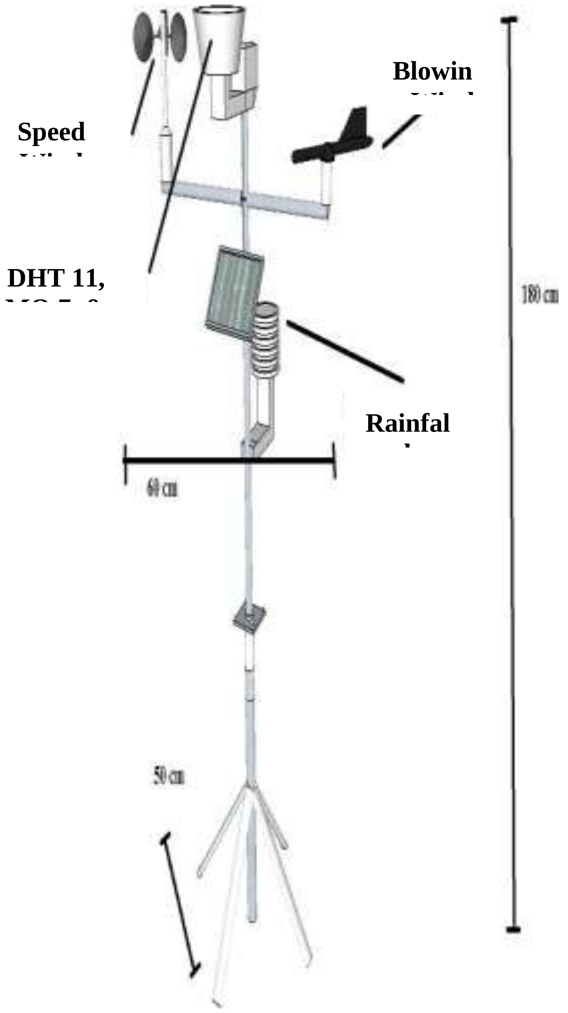

Figure 2. Prototype Design

3. Results & Discussion

3.1. Operation

Prototype operations were carried out in a free field to test the performance of the tool for 90 minutes on two different days, namely 28 and 29 August 2023. From the two days of field testing it was found that the tool worked well without any problems (see table 1).

Table 1. Operation Results*Portable Weather Station*

Parameter	Average Results	Average Results
Light intensity	50 (Dark)	50 (Dark)
Carbon monoxide	2.69 (Light)	2.69 (Light)
Temperature	33,36 (Hot)	33,36 (Hot)
Humidity	56,95 (Ideal)	56,95 (Ideal)
Pressure	987.5739 (Low)	987.5739 (Low)
Wind velocity	0 (Slow)	0 (Slow)
Wind direction	88,15	88,15
Rainfall	0 (No rain)	0 (No rain)
The weather	Sunny Cloudy	Sunny Cloudy
Air quality	Good	Good
Time	2023-08-28 13:38:45	2023-08-29 14:05:47

Source: Author data, 2023

3.2. Prototype Testing

The prototype testing method uses the UTAUT model (see**Figure 3**) to find out how feasible the prototype is before it can be patented and mass produced.

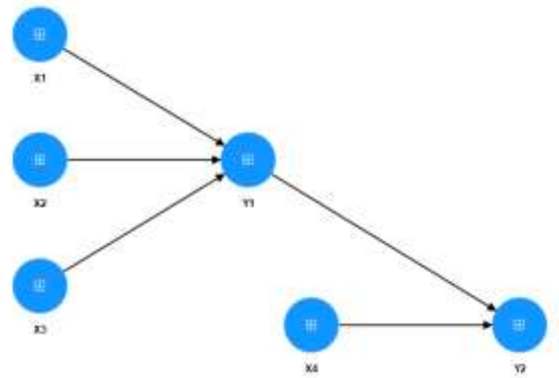

Figure 3. UTAUT model

Data was taken based on a survey of users after carrying out a prototype demonstration with a sample size of 100 people. The data was then analyzed using the SmartPLS 4.0 application to determine the feasibility of the prototype. The data validity test uses a standard of >0.7 for composite reliability and >0.5 for Average Variance Extracted

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(**Table 2**) which shows valid and reliable data results, so that the data in this research can be tested again at the next stage.

Table 2. Test the validity and reliability of the data
Source: Author's elaboration, 2023

Variable	Indicator	CR	AVE
X1 (Performance Expectancy)	X1.1. Accurate Weather Monitoring X1.2. Efficiency of Use X1.3. Weather Prediction Accuracy X1.4. Ease of Operation	0.869	0.625
X2 (Effort Expectancy)	X2.1. Ease of Use Understanding X2.2. Difficulty Level of Use X2.3. Simple User Interface	0.808	0.587
X3 (Social Influence)	X3.1. Recommendations from others X3.2. Opinions from Weather Experts X3.3. Social media X3.4. Tool Needs Intervention	0.847	0.581
X4 (Facilitating Conditions)	X4.1. Availability of Manual Book X4.2. Availability of Technical Support X4.3. Tool Accessibility X4.4. Availability of Spare Parts and Maintenance	0.823	0.539
Y1 (Behavioral Intention to Use)	Y1.1. Regular Use Intent Y1.2. Intention To Use Additional Features Y1.3. Willingness to Recommend	0.848	0.651
Y2 (Actual Use Behavior)	Y2.1. Routine Use Y2.2. Utilization of Additional Features Y2.3. Tool Usage Satisfaction Y2.4. Level of Adherence to Directions for Use	0.878	0.643

Further data testing uses model fit criteria to gain a better understanding of the construct. Can be seen at **Table 3** that the results of the model evaluation show that the SRMR (Standardized Root Mean Square Residual) of the model is 0.154, which indicates the level of suitability of the model to the observation data. This value is lower than the threshold of 0.156, indicating a good model. Furthermore, the d_ULS (d_ULS Value) of the model is 5.986, reflecting the similarity of the model to the data covariance. Even though d_G (d_G Value) is not available, Chi-square results are irrelevant because SmartPLS does not rely on normal distribution. Lastly, NFI (Normed Fit Index) is also not available, but this method focuses on a bootstrap approach without reliance on a normal distribution. Overall, the model evaluation shows a good degree of agreement with the observed data.

Table 3. Test model fit

	Saturated Model	Estimated Model
SRMR	0.154	0.156
d_ULS	5.986	6.173
d_G	n/a	n/a
Chi-square	∞	∞
NFI	n/a	n/a

Source: Author's elaboration, 2023

The final model evaluation is the path coefficients obtained from the structural model (**Figure 4**). First, X1 to Y1 has a path coefficient value of -0.113, indicating a negative relationship between X1 and Y1. Meanwhile, X2 towards Y1 has a positive value of 0.371, indicating a positive relationship between X2 and Y1. X3 to Y1 has a path coefficient of 0.401, indicating a positive relationship between X3 and Y1. For variables X4 to Y2, the path coefficient obtained is 0.130, indicating a positive relationship between X4 and Y2. Finally, the path coefficient from Y1 to Y2 is 0.586, illustrating a positive relationship between Y1 and Y2.

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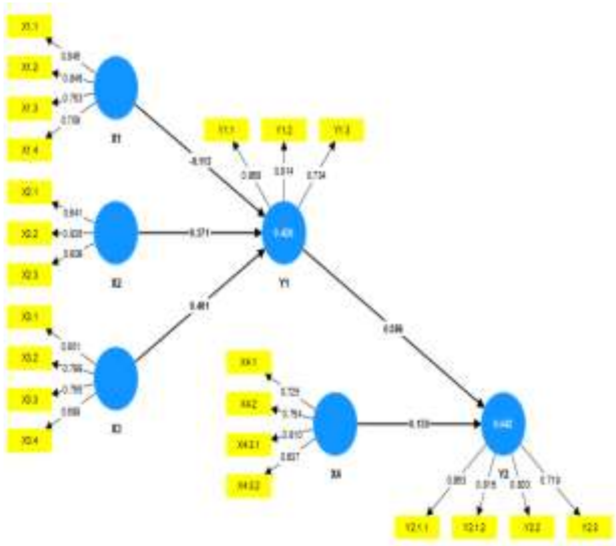

Figure 4. Path Coefficients Result

Overall, this model shows that X2 and X3 have a significant positive influence on Y1, while X1 and X4 have a relatively smaller impact. In addition, the existence of a significant positive relationship between Y1 and Y2 indicates that changes in Y1 can be expected to influence changes in Y2. Evaluation of this model provides an overview of the extent to which the independent variable influences the dependent variable, which can be the basis for further understanding and development.

4. Conclusion

The conclusion of this research shows that the Portable Weather Station design successfully carries the principles of ergonomics and flexibility, with a light weight and ergonomic design that allows this tool to be easily moved without depending on certain building structures. This tool's real-time monitoring capabilities provide accurate weather information with the integration of various sensors, including temperature, humidity, air pressure, wind speed and wind direction, thus providing a comprehensive picture of weather conditions in various locations[25].

Two days of field testing confirmed that the Portable Weather Station operated well without significant issues, confirming the performance and robustness of the tool. However, to increase efficiency, it is recommended to optimize energy use so that the device can operate for longer periods of time without the need to frequently replace the battery. Integration of advanced technologies such as remote monitoring and cloud data processing can be the next step to improve the functionality and reliability of these tools.

Continuous monitoring and evaluation will be key to ensuring the long-term sustainability and accuracy of the Portable Weather Station. User awareness and training campaigns need to be organized, especially in sectors such as agriculture, fisheries, and environmental monitoring, to increase understanding and acceptance of these tools among potential users. With the implementation of these suggestions, the Portable Weather Station has the potential to become an effective and widespread solution in dynamic weather monitoring.

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