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Design of Monitoring System *Gryllus Mitratus* Cricket Cultivation Based Internet of Things

(Case Study: Cricket Cultivation in Penolih Village, Kaligondang Subdistrict, Purbalingga District)

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Abstract

Crickets have various types, one of which is *Gryllus Mitratus*. *Gryllus Mitratus* crickets in Penolih village are cultivated by 16 cricket breeders, with individuals having at least 6 boxes with a size of 200 x 120 x 65 cm and a cage foot height of 25 cm. Cricket cultivation in Penolih village, Kaligondang sub-district, Purbalingga district, is still not optimal due to several factors, such as temperature, humidity, and light intensity, which are not suitable for crickets and cause stress and death. The temperature that crickets can accept is 20 ^{o}C to 32 ^{o}C, humidity is 65% to 80%, and light intensity is 0 lux. A tool is needed to monitor temperature conditions using DHT11, humidity using BME280, and light intensity using BH1750, which is installed in the cricket cage to determine its value and be followed up by cricket breeders. These sensors will send the input data to NodeMCU to be sent to the cloud so that it can be displayed in the Android application. The research method used is waterfall, namely the development of a systematic and sequential information system. Based on testing for 7 days, the average temperature of the cricket cage was 28.26 ^{o}C, the humidity of the cricket cage was 74.72%, and the light intensity of the cricket cage was 5.1 lux.

Keywords: Internet of Things, Sensor DHT11, Sensor BME280, Sensor BH1750, Crickets Cultivation

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I. INTRODUCTION

Crickets are insects that live on the ground, often found in groups in protected areas such as shrubs or under piles of dead tree branches. These crickets are rich in nutrients, including sources of protein, fat, glutamic amino acids, carbohydrates, glycine, cysteine, and minerals [1]. Not a few people use this business opportunity to become cricket breeders. Ahmad Anwari, Leader of the Bekasi Perwira Livestock Group, explained that crickets are insects that have significant economic potential. For example, in the areas of Jakarta, Bogor, Tangerang, and Bekasi, the demand for 8 kg/store/week can be achieved [2].

The time to harvest crickets varies depending on the type and marketing objectives. One example is the cricket breeder Sarman's Cricket Community, which can harvest cricket twice a week, with one harvest producing 20-30 kg of crickets [3]. The yield of crickets depends on superior seeds, high-quality feed, stable temperature and humidity of the cage, and adequate nests to avoid cannibalism. The size of the cage is proportional to the approximate hatching of the crickets and the exact light intensity. The acceptable temperature for crickets ranges from 20^{o}C - 32^{o}C. If the temperature is too high or too low, it will limit the space for the crickets to move, and the crickets cannot withstand temperatures that are too hot or cold, causing death. Cricket quality is also affected by the humidity of the cricket cage. Crickets prefer moderately humid areas with humidity between 60% and 80%. Crickets also actively move, sing, and mate at night or have nocturnal habits, requiring low light intensity. At night, the total light intensity is 2 -5 lux for chirping and mating [4] [5]. The cricket cultivation monitoring system can measure temperature, humidity, and light intensity in cricket cages that are connected to the Internet of Things. IoT itself is a technology that allows devices to connect with programming language commands that use sensors as input and output in the form of displaying data or performing specific actions [6].

This system will be implemented in one of the cricket breeders located in Penolih Village, Kaligondang District, Purbalingga Regency. Penolih Village has 16 cricket cultivators, each of whom has at least 6 boxes of crickets measuring 200 x 120 x 65 cm and a cage 25 cm high. Based on the results of interviews with cricket breeders in Penolih Village, it was revealed that in December 2022, there will be a decline in crop yields of up to around 50%. The amount harvested per box, which used to reach 20kg - 25kg per box, is now only around 10 kg/box. The decline in cricket yields can occur due to several factors, including the temperature conditions in the cage that are not ideal. The temperature of the cage is too hot, which is caused by the cricket cage's location, which is under a roof made of zinc, which tends to absorb heat easily. In addition, humidity that is not ideal and light intensity that is not ideal can also affect cricket productivity, causing crickets to stress and even die.

This research was created to create and develop devices and applications that use the Internet of Things technology to monitor conditions of temperature, humidity, and light intensity in cricket cages. Thus, all the information needed to monitor the condition of the cricket cages can be seen through the Android application.

II. RESEARCH METHOD

A. Research Flowchart

Research begins by identifying research topics that attract the public's attention. After the problem is identified, the researcher conducts a literature review to gain a deeper understanding of previous research related to the research topic being researched by the researcher. To gain a better understanding of the research location, the researcher also made direct observations. Furthermore, interviews were conducted with cricket breeders. The interview is a question-and-answer interaction process between the researcher and the cricket breeders to gather the necessary data regarding the factors that affect the yield and quality of the crickets. After going through all these stages, the next step is to determine the tools and materials needed to build the system. After that, the researcher determines the research method that is suitable for use on the research topic. Then, after obtaining the research method, the implementation of the method is carried out on the research topic. After implementation, system testing is carried out to check the results of system implementation and look for possible obstacles that may occur. If there are problems after testing, the researcher will make improvements and re-implement the system. The final step after re-implementation is to evaluate the entire system. System evaluation is a process carried out to evaluate the performance, effectiveness, and efficiency of a system in achieving the goals that have been set. The research flowchart can be seen in Fig 1.

B. Block Charts

In this system, careful planning is needed to develop the tool, including designing both the hardware and software used. A block diagram is made to provide a basic overview of system design. The sensors used in the system include DHT11 sensors, BME280 sensors, and BH1750 sensors. The DHT11 sensor is used to detect the temperature inside the cricket cage [7], the BME280 sensor is used to detect humidity in the cricket cage [8], and the BH1750 sensor is used to measure the light intensity inside the cricket cage. [9]. All of these sensors will be connected to NodeMCU. At NodeMCU, the input results will be processed and sent to the database using Firebase [10]. Internet access is required to transmit data. In this case, NodeMCU will be connected to the nearest Wi-Fi in the cricket cage environment. In Firebase, data will be stored in real-time, but this study only displays data in real-time by overwriting old data with a 1-second delay. It is in Firebase that applications are built using Android Studio to retrieve data in real-time, display temperature, humidity, and light intensity, and add temperature, humidity, and light intensity statuses. The application will only be opened by the user if the date entered is correct according to the monitoring day.

If the input is incorrect, the user must re-enter the date until the date entered is correct. The system design block diagram can be seen in Fig 2.

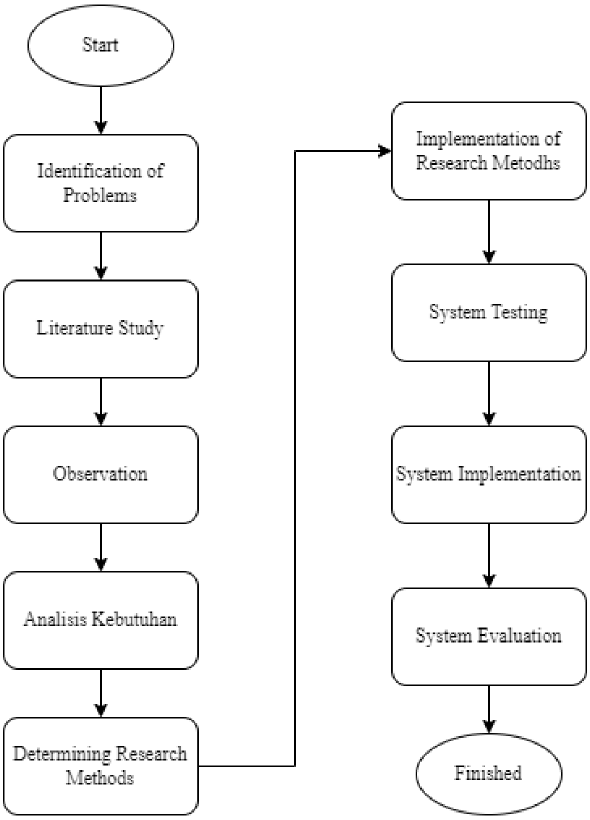

Fig. 1. Research Flowchart

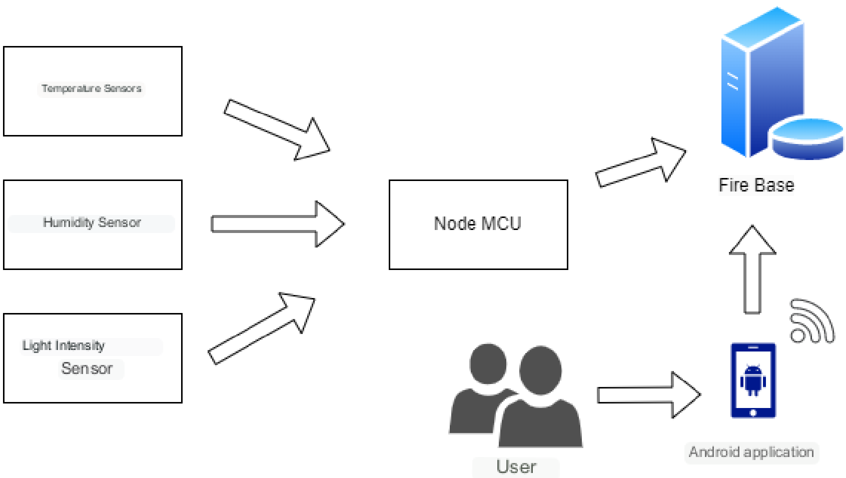

Fig. 2. System Design Block Diagram

C. System Implementation

A monitoring system for temperature, humidity, and light intensity will be placed inside the cage in the position shown in Fig 3. This monitoring system will be connected to a power source using a 9-volt adapter.

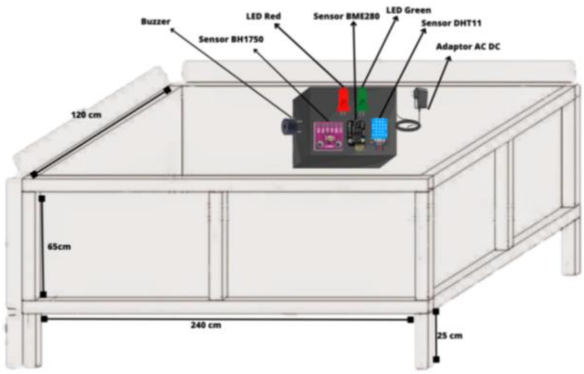

Fig. 3. System Implementation

D. Blackbox Testing System and Sensor Calibration

Blackbox is a device quality testing approach that focuses on software and hardware functionality. The purpose of black box testing is to detect functionality defects, interface errors, data structure errors, and performance errors, as well as initialization and termination errors [11]. Calibration testing is a process to detect and measure the accuracy of a component by comparing it with an actual measuring instrument. Calibration tests are carried out using actual measuring devices, such as temperature sensors and humidity sensors, which have been calibrated with a hygrometer, as well as light intensity sensors, which have been calibrated with a lux meter. Error is the difference between the measured value and the actual value or expected value. When the actual value is displayed on the measuring instrument and compared with the value generated by the sensor, the final result from the sensor will be added up with the difference in the error value to equate the value from the sensor with the measuring instrument. In addition, the percentage of accuracy is used to measure how well the data matches the actual data [12].

Sensor testing involves testing sensor components, such as temperature and humidity sensors, which have been calibrated using appropriate measuring devices (e.g., a hygrometer for humidity sensor calibration). Application testing includes overall application testing by comparing the results generated by the sensors with the actual values displayed on the measuring device. Errors are calculated by comparing the values produced by the sensors with the values displayed on the measuring device. Accuracy percentage is used to measure how well the sensor data aligns with the actual data. [13].

Application testing involves scenarios related to the loading screen, entering a date, and the main display. It is expected that the loading screen will appear within 3 seconds. Next, when entering a valid date, the user should be directed to the main page, while entering an invalid date should redirect back to the loading screen. On the main page, the expected display includes the date, temperature, humidity, and intensity, along with their statuses and the status of the buzzer [14].

System implementation testing includes trial time, sensor values, and status expectations. The following is the explanation. Trial Time: Trial or testing time. DHT11 (°C): DHT11 temperature sensor with values in degrees Celsius. DHT11 Status: Status of the DHT11 temperature sensor (for example, normal or error). BME280 (%): BME280 humidity sensor with values in percentage.BME280 Status: Status of the BME280 humidity sensor. BH1750 (lux): BH1750 light intensity sensor with values in lux.BH1750 Status: Status of the BH1750 light intensity sensor. Expected Status: The expected status (for example, appropriate or not appropriate) [15].

III. RESULTS AND DISCUSSION

A. System Implementation Results in Cricket Cage

Fig. 4 showcases the implementation results of the monitoring system in cricket cages, where it is used to monitor the environmental conditions of the surface where the crickets reside. The system employs three sensors: the DHT11 sensor for temperature, the BME280 sensor for humidity, and the BH1750 sensor for light intensity. These sensors provide real-time data to ensure that the conditions within the cricket cages are optimal for their health and well-being.

The display in Fig. 4 reveals the practical application of the monitoring system in a live environment. Temperature readings from the DHT11 sensor are shown to be stable and within normal ranges, which is crucial for maintaining the metabolic rate and activity levels of the crickets. Similarly, the BME280 sensor reports normal humidity levels, essential for preventing dehydration and maintaining the crickets' respiratory functions. However, the BH1750 sensor consistently records abnormal light intensity values, which could impact the crickets' behavior and stress levels.

By continuously monitoring these environmental parameters, the system helps in creating a controlled habitat that supports the crickets' growth and development. The display in Fig. 4 demonstrates how the monitoring system effectively captures and reports data, providing valuable insights into the conditions of the cricket cages and highlighting areas that may require adjustments, particularly concerning the abnormal light intensity readings.

Fig. 4. System Implementation Results

B. Application View

Fig. 5 illustrates the *Gryllus Mitratus* cricket cultivation monitoring system application, highlighting the user interaction aspect where the user is required to enter the current date. This initial step is crucial for the system to synchronize data and ensure accurate time-stamping of the environmental conditions being monitored.

The interface shown in Fig. 5 is user-friendly and designed to streamline the process of data entry and subsequent monitoring. By requiring the user to input the current date, the system can accurately log and correlate environmental data, facilitating effective tracking and analysis over time. This feature ensures that all recorded data is properly dated, providing a clear timeline of environmental conditions that can be critical for making informed decisions regarding cricket cultivation practices.

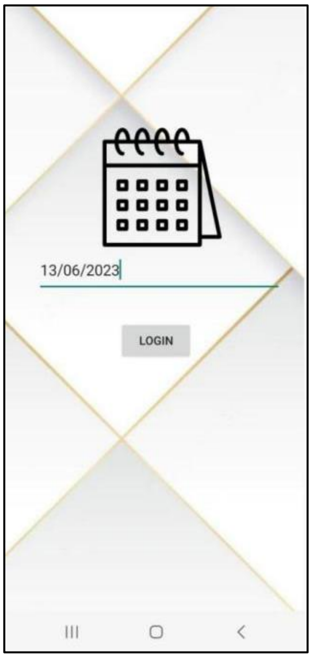

Fig. 5. Input Dates

The main display in Fig. 6 prominently presents these measurements, enabling users to monitor environmental conditions easily. The temperature and humidity sections indicate stable and normal conditions, while the light intensity section highlights the abnormal values, prompting further investigation. This comprehensive view allows users to quickly assess the status of the environment and identify any areas of concern, particularly the consistently abnormal light intensity readings.

Fig. 6. Main Display

C. System Testing

The sensor testing process, as detailed in Table I, involves systematically recording various parameters during the experiment to evaluate the performance and accuracy of the DHT11 sensor. This process captures the following key data points:

1. Experiment Time: The exact time each measurement is taken is recorded, ensuring precise tracking and correlation of data. This time-stamping is crucial for analyzing trends and understanding environmental changes over specific periods.
2. DHT11 Sensor Values: These values represent the temperature readings provided by the DHT11 sensor. The sensor is known for its ability to measure temperature with a reasonable degree of accuracy, making it a popular choice for monitoring environmental conditions.
3. Measuring Device Values: These values are obtained from a reference measuring device, such as a digital hygrometer, which is used to provide benchmark temperature readings. The accuracy of this reference device is typically higher, serving as a standard against which the DHT11 sensor's performance can be compared.
4. Differences: The differences between the temperature values recorded by the DHT11 sensor and the reference measuring device are calculated. These differences highlight the deviations in the sensor's readings, providing insights into its accuracy and reliability.
5. Error Percentage: The error percentage is computed to quantify the deviation of the DHT11 sensor readings from the reference device values in relative terms. This percentage is crucial for understanding the extent of the sensor's inaccuracies and for assessing whether these deviations are within acceptable limits for the intended application.

The data collected and displayed in Table I offers a comprehensive overview of the DHT11 sensor's performance. By meticulously recording the experiment time, sensor values, reference device values, differences, and error percentages, researchers can rigorously evaluate the sensor's accuracy. This detailed analysis helps identify any consistent patterns of deviation, assess the sensor's reliability under different conditions, and make informed decisions about its suitability for specific monitoring tasks.

TABLE I. DHT11 SENSOR TESTING

No	Trial Time	DHT11 sensors (°C)	Digital Hygrometer (°C)	Difference	Error (%)
1	05/06/2023 11.49	28.9	30.6	1.7	6
2	05/06/2023 11.51	28.9	30.6	1.7	6
3	05/06/2023 11.52	28.9	30.6	1.7	6

No	Trial Time	DHT11 sensors (°C)	Digital Hygrometer (°C)	Difference	Error (%)
4	05/06/2023 11.55	28.9	30.6	1.7	6
5	05/06/2023 11.56	29.1	30.8	1.7	6
6	05/06/2023 11.57	29.3	30.8	1.5	5
7	05/06/2023 11.58	29.3	30.8	1.5	5
8	05/06/2023 12.00	29.3	31	1.7	6
9	05/06/2023 12.02	29.3	31	1.7	6
10	05/06/2023 12.03	29.5	31.2	1.7	6
	Average	29.14	30.8	1.66	6
			Accuracy (%)		94

The data collected from ten trials on June 5, 2023, compares temperature readings from DHT11 sensors and a digital hygrometer. The DHT11 sensors consistently measured temperatures between 28.9°C and 29.5°C, while the digital hygrometer recorded temperatures between 30.6°C and 31.2°C. The differences between the two devices' readings ranged from 1.5°C to 1.7°C, resulting in an average discrepancy of 1.66°C. The error percentage for most trials was around 6%, with a slight reduction to 5% in two instances. Overall, the DHT11 sensors demonstrated an accuracy of 94% when compared to the digital hygrometer's readings.

The humidity sensor testing will record the trial time, values from the BME280 sensor, values from the measuring instrument, differences, and error percentages, as shown in Table II.

TABLE II. BME280 SENSOR TESTING

No	Trial Time	DHT11 sensors (°C)	Digital Hygrometer (°C)	Difference	Error (%)
1	5/06/2023 22.09	85.77	83	-2.77	-3.23
2	5/06/2023 22.10	85.21	83	-2.21	-2.59
3	5/06/2023 22.11	85.34	84	-1.34	-1.57
4	5/06/2023 22.12	85.18	85	-0.18	-0.21
5	5/06/2023 22.13	84.87	85	0.13	0.15
6	5/06/2023 22.14	83.72	86	2.28	2.72
7	5/06/2023 22.15	83.38	87	3.62	4.34
8	5/06/2023 22.16	84.17	89	4.83	5.74
9	5/06/2023 22.17	83.94	90	6.06	7.22
10	5/06/2023 22.18	84,22	90	5.78	6.86
	Average	84.58	86.2	1.62	1.94
			Accuracy (%)		98.06

On June 5, 2023, ten trials were conducted to compare temperature readings between DHT11 sensors and a digital hygrometer. The DHT11 sensors recorded temperatures ranging from 83.38°C to 85.77°C, while the digital hygrometer recorded temperatures between 83°C and 90°C. The differences between the two devices varied from -2.77°C to 6.06°C, corresponding to error percentages from -3.23% to 7.22%. Notably, the DHT11 sensor readings were slightly lower than the hygrometer's at the beginning, but this trend reversed in later trials. The average temperature recorded by the DHT11 sensors was 84.58°C, compared to the hygrometer's 86.2°C, resulting in an average difference of 1.62°C and an overall error percentage of 1.94%. The DHT11 sensors exhibited an accuracy of 98.06% in these trials.

The light intensity sensor testing will record the trial time, values from the BH1750 sensor, values from the measuring instrument, differences, and error percentages, as shown in Table III:

TABLE III. BH1750 SENSOR TESTING

No	Trial Time	DHT11 sensors (°C)	Digital Hygrometer (°C)	Difference	Error (%)
1	05/06/2023 11.49	20	17	3	15.00
2	05/06/2023 11.51	22	19	3	13.64
3	05/06/2023 11.52	25	25	0	0.00
4	05/06/2023 11.55	37	37	0	0.00
5	05/06/2023 11.56	39	39	0	0.00
6	05/06/2023 11.57	40	39	1	2.50
7	05/06/2023 11.58	43	41	2	4.65
8	05/06/2023 12.00	68	58	10	14.71
9	05/06/2023 12.02	47	48	1	2.13
10	05/06/2023 12.03	50	50	0	0.00
	Average	39.1	37.3	2	5.12
			Accuracy (%)		94.88

On June 5, 2023, ten trials were conducted comparing temperature readings between DHT11 sensors and a digital hygrometer. The DHT11 sensors recorded temperatures from 20°C to 68°C, while the hygrometer recorded from 17°C to 58°C. The differences ranged from 0°C to 10°C, with corresponding error percentages between 0.00% and 15.00%. Notably, the largest discrepancies occurred at lower and higher temperatures, with the DHT11 readings being higher than the hygrometer's in these cases. The average temperature recorded by the DHT11 sensors was 39.1°C, compared to the hygrometer's 37.3°C, resulting in an average difference of 2°C and an overall error percentage of 5.12%. The DHT11 sensors demonstrated an accuracy of 94.88% across these trials.

Application testing involves scenarios related to the loading screen, date input, and main display. Table IV shows the results from the application testing.

TABLE IV. APPLICATION TESTING

No	Case	Test Scenario	Expected results	Test result
1	*Loading Screen*	The user opens the application	Displays the application logo for 3 seconds	valid
2	*Enter dates*	The user enters the date (correct)	Users will be redirected to the main page	valid
		The user enters date (incorrect)	The user will be directed to *the loading screen*	valid
3	main page	Displays the current date and time in *real-time*	the date and time displayed are in accordance with the actual	valid
		Displays the temperature value	temperature values as per those in Firebase	valid
		Displays humidity value	humidity value according to the one in Firebase	valid
		Displays the light intensity value	light intensity value according to the one in Firebase	valid
		Displays temperature status	temperature status according to the one in Firebase	valid
		Displays humidity status	humidity status according to the one in Firebase	valid
		Displays the status of light intensity	light intensity status as per Firebase	valid
		Display *buzzer status* (ON/OFF)	*buzzer* status that is displayed according to what is there on Firebase	valid

The application testing involved several scenarios to validate its functionality. In the first case, upon opening the application, the loading screen correctly displayed the application logo for three seconds, as expected. In the second scenario, entering a correct date redirected the user to the main page, while an incorrect date input redirected the user back to the loading screen; both outcomes were valid. On the main page, several elements were tested: the current date and time displayed in real-time, temperature, humidity, light intensity values, and their respective statuses, along with the buzzer status (ON/OFF), all accurately reflected the data from Firebase. Each of these elements performed as expected and was validated successfully, ensuring the application's reliability in real-world usage.

In the system implementation testing table, the trial time, test results of DHT11, BME280, and BH1750 sensors, and their normal or abnormal status will be displayed. The results can be seen in Table V.

TABLE V. SYSTEM IMPLEMENTATION TESTING

Trial Time	DHT11 (°C)	Status	BME280 (%)	Status	BH1750 (lux)	Status
15/06/2023	27.98	Normal	76.03	Normal	5.00	Abnormal
16/06/2023	27.53	Normal	74.25	normal	5.84	Abnormal
17/06/2023	27.95	Normal	76.53	Normal	4.73	Abnormal
18/06/2023	28.37	Normal	74.28	Normal	3.47	Abnormal
19/06/2023	28.77	Normal	72.77	Normal	5.97	Abnormal
20/06/2023	28.50	Normal	75.24	Normal	4.03	Abnormal
21/06/2023	28.75	Normal	75.63	Normal	6.53	Abnormal
Average	28.26	Normal	74.72	Normal	5.10	Abnormal

Between June 15 and June 21, 2023, a series of trials were conducted to monitor environmental conditions using three sensors: DHT11 for temperature, BME280 for humidity, and BH1750 for light intensity. The DHT11 consistently reported normal temperature readings ranging from 27.53°C to 28.77°C, with an average of 28.26°C. Similarly, the BME280 sensor recorded normal humidity levels between 72.77% and 76.53%, averaging 74.72%. However, the BH1750 sensor detected abnormal light intensity values in every trial, with measurements varying from 3.47 lux to 6.53 lux, averaging 5.10 lux. Despite the normal temperature and humidity status, the light intensity remained consistently abnormal throughout the testing period.

The data from the trials conducted between June 15 and June 21, 2023, provide a comprehensive view of the environmental conditions monitored by DHT11, BME280, and BH1750 sensors. The DHT11 sensor reliably measured temperature, consistently showing normal readings between 27.53°C and 28.77°C, with an average of 28.26°C. The BME280 sensor also performed well, recording normal humidity levels between 72.77% and 76.53%, averaging 74.72%. However, the BH1750 sensor indicated abnormal light intensity values across all trials, with measurements ranging from 3.47 lux to 6.53 lux and an average of 5.10 lux.

IV. CONCLUSION

From the results of the study entitled "Design of Monitoring System *Gryllus Mitratus* Cricket Cultivation Based Internet of Things", it can be concluded that the implementation of the system in cricket cages is running well and smoothly, even though there is an error in the DHT11 sensor of 6%, the BME280 sensor is 1.94 %, and the BH1750 sensor is 5.12%. Application design also runs well and smoothly. The results of testing the implementation of the system, which involved subtracting the error difference after calibration, showed that the monitoring system for temperature, humidity, and light intensity in the *Gryllus Mitratus* cricket cage for seven consecutive days resulted in an expected average output for temperature (28.26 ^{o}C) and humidity (74.72 %). However, the light intensity shows an abnormal output with a light intensity value of 5.10 lux.

These findings suggest that while temperature and humidity conditions were stable and within normal ranges, there is a recurring issue with light intensity as measured by the BH1750 sensor. This consistent anomaly in light intensity readings indicates a potential problem either with the sensor itself or the environmental light conditions, warranting further investigation to determine the cause and address any underlying issues.

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