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Implementation of Linear Regression Method in Light Strength Measurement Using GY-30 BH1750 Sensor

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ABSTRACT

The development of light sensor technology has enabled better measurement accuracy. The GY-30 BH1750 sensor, for example, is known for its ability to detect light changes with high sensitivity. Although this sensor has many advantages, the accuracy of its measurements greatly depends on the calibration method used. Without proper calibration, the measurement data may be affected by bias, which can be detrimental to applications relying on it. Linear regression methods can extract the mathematical relationship between the sensor's output and the light intensity on the light sensor. In light sensor calibration, linear regression helps determine the relationship between the signal generated by the sensor (e.g., voltage or current) and the measured light intensity. Thus, we can mathematically map the sensor's response to changes in light intensity, which is used for measurement correction to get closer to the true value. The implementation of linear regression on the GY-30 BH1750 sensor is expected to contribute significantly to improving the measurement accuracy of this sensor. By modeling the sensor's response to actual light intensity, the generated data is expected to become more consistent and accurate, making it suitable for applications requiring high accuracy. The result of this research is more stable light intensity measurements with the application of linear regression on the GY-30 BH1750 sensor, with measurement results closely matching those obtained using a measuring instrument. The error before using linear regression was 1.2%, and after applying linear regression on the GY-30 BH1750 sensor, the error reduced to 0.54%.

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1. INTRODUCTION

The measurement of light intensity has become increasingly important in various sectors, including environmental monitoring, agriculture, lighting systems, and home automation [1]. The need for precise measurements reflects the importance of accurate and reliable data in decision-making processes. For example, in agriculture, light intensity measurements are used to monitor plant growth and help determine the optimal harvest time [2]–[4]. Meanwhile, light sensors are often used in urban environments to manage public lighting systems and save energy. Therefore, sensor calibration becomes a vital aspect to ensure the accuracy of data obtained from these measurements [5]–[7].

The development of light sensor technology has enabled better measurement accuracy. The GY-30 BH1750 sensor is known for its ability to detect light changes with high sensitivity. This sensor is frequently used in practical applications that require a quick response to variations in light intensity, such as lighting automation systems and IoT devices. Although this sensor offers many advantages, its accuracy depends on the calibration method [8], [9]. Without proper calibration, measurement data may be affected by bias or inaccuracies, which can be detrimental to applications that rely on it [10].

Sensor calibration is a process necessary to minimize measurement errors by matching the sensor output to a reference value [11], [12]. A proper calibration method will optimize sensor performance and improve measurement accuracy [13], [14]. Linear regression methods can extract the mathematical relationship between the sensor output and light intensity at the light sensor. Through this process, the measurement results are expected to align more closely with the actual light conditions, providing more reliable data for the end user [15].

Linear regression is a statistical method that has long been used to analyze the relationship between two continuous variables, namely the independent and dependent variables [16]. In light sensor calibration, linear regression helps determine the relationship between the sensor-generated signal (such as voltage or current) and the measured light intensity. This allows for the mathematical mapping of the sensor's response to changes in light intensity, which can be used to correct measurements to more closely approximate the true value [17].

The application of linear regression has been proven to improve the accuracy of light sensor measurements by producing lower RMSE values and better overall performance [18], [19]. Multiple linear regression (MLR) is also used to capture complex relationships and enhance the calibration process [18], [20]. This technique is effective in correcting bias in sensor data by comparing measurements to reference standards [21], [22]. A high coefficient of determination (R^2) indicates the model's fit to the data and helps validate calibration results [23]. However, linear regression has limitations, particularly when facing extreme lighting variations that affect the model's accuracy [24]. The linear regression equation takes the form $Y = aX + b$, and to obtain the sensor input value (X), the formula is $X = (Y - b) / a$ [23].

The application of linear regression to the GY-30 BH1750 sensor, a light sensor, can improve the accuracy of light intensity measurements. Linear regression helps optimize sensor performance and produces a more accurate model [18]. Additionally, linear regression enhances data consistency and reduces variability caused by external factors [25]. Previous studies have been limited, but similar applications in the calibration of other sensors have also proven effective [26]–[28].

Although linear regression has been widely used in light sensor calibration, the novelty of this research lies in its application to the GY-30 BH1750 sensor, which has not been extensively explored in the literature. This sensor has unique characteristics that require specialized calibration methods for optimal performance. Therefore, this study aims to fill the knowledge gap regarding the use of linear regression methods on the GY-30 BH1750 sensor and its potential applications under various lighting conditions.

This study will not only test the calibration accuracy of the GY-30 BH1750 sensor using linear regression but will also examine the effectiveness of this method under various lighting scenarios. By testing the sensor under different lighting conditions, this research will provide insights into how changes in light intensity affect sensor performance and the effectiveness of the calibration method used.

Furthermore, this research is expected to serve as a reference for further developments in optical sensor calibration, particularly in the context of industrial applications and automation. With the growing demand for more accurate and reliable sensors, this study could make a significant contribution to improving existing calibration methods and promoting the adoption of the GY-30 BH1750 sensor in various practical applications.

Practically, calibrating the GY-30 BH1750 sensor using linear regression can help improve operational efficiency across various sectors. For example, in the agricultural industry, more accurate sensors can assist farmers in optimizing the light required for plants, thus improving productivity. More accurate sensors can also reduce energy consumption in home automation sectors by providing more efficient lighting control.

Through this study, a more accurate calibration model for the GY-30 BH1750 sensor is expected to be developed. With a calibration model based on linear regression methods, this sensor can be used in various applications with more reliable results. Thus, this research not only contributes theoretically to sensor calibration techniques but also has significant practical implications for applications that require accurate light intensity measurements.

2. METHOD

2.1 Variables of Research

The primary variable of the research is temperature data. This study conducted a literature study of journals, papers, articles, and so on related to the research. This research uses primary data sources obtained or collected directly in the field.

2.2 Tool Working System

The working system of the tool in this study can be seen in Figure 1 below in the form of a block diagram:

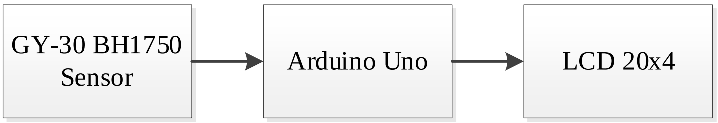

Figure 1. Modeling the tool's working system

2.3 Mechanical Design

This mechanical design discusses how to design a box as a place where components are placed; this box protects electronic components from damage; the size of this box is 18.5 cm long, 11.5 cm wide, and the thickness of this box is 6.5 cm. The mechanical design of this research tool can be seen in Figure 2 below.

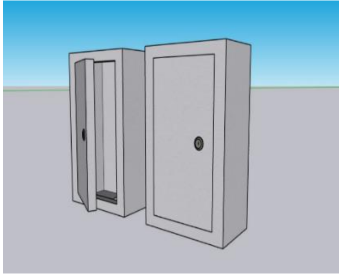

Figure 2. Mechanical Design

Figure 3 is a mechanical design for the location and placement of LM 35 sensor components, 20x4 I2C LCD, on the panel box to protect the components from damage.

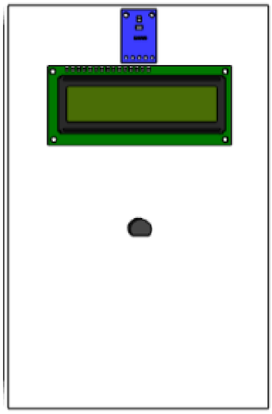

Figure 3. Mechanical Design Component Layout

2.4 Tool Design

2.3.1. LCD I2C 20 X 4

Changing the address of the I2C display module is done by bridging the two contact points provided on the I2C module with solder, which can be seen in the following image, in figure 4.

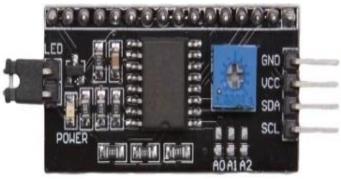

Figure 4. I2C module

Change the address of the I2C display adapter is as follows:

- At A0, A1 and A2 have nothing to do with analog input or output; here, A stands for address by finding contact points on some modules and other I2C modules that can change the address.
- In general, the address of this module without bridged contacts is “0x27”. Bridging one, two, or all three will enable the address change.

- By bridging contacts A0, A1, and A2 one by one, it will get three sets of addresses.
- Bridging two contacts at a time, A0 and A or A0 and A2 or A1 and A2 will result in another address inference.
- Bridging all three contacts will result in one new address, and without bridging, any contacts will result in one address, which is the default “0x27”.

2.3.2. I2C 20x4 LCD Circuit

LCD is used to display temperature values. LCD I2C has four pins: SCL, SDA, GND, and VCC. The connection to the I2C LCD and the LCD pin configuration on the Arduino Uno can be seen in figure 5 below.

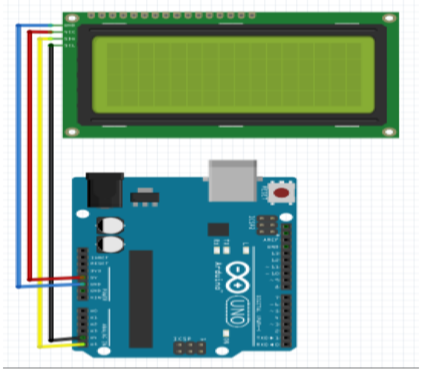

Figure 5. Arduino uno pin installation scheme to LCD

The pin configuration used to connect the LCD to the Arduino Uno can be seen in Table 1 below.

Table 1. Arduino UNO pin configuration with I2C LCD

Pin Arduino Uno	Pin Lcd
Vcc	Vcc
SCL	SCL
SDA	SDA
Gnd	Gnd

2.3.3. GY-30 BH1750 Sensor Series

The GY-30 BH1750 sensor measures the light intensity in the lecture hall. The GY-30 BH1750 sensor has four connection pins that will be connected to the Arduino Uno. The following is an image of the electronic design and pin configuration of the GY-30 BH1750 Sensor below in figure 6:

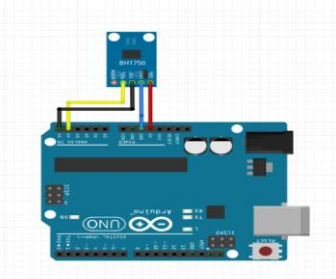

Figure 6. Arduino Uno pin installation scheme to the GY-30 BH1750 sensor

The pin configuration used to connect the GY-30 BH1750 sensor to the Arduino Uno can be seen in the table 2 below.

Table 2. Arduino pin configuration for the GY-30 BH1750 sensor

Pin Arduino Uno	Pin Lcd
Vcc	Vcc
SCL	SCL
SDA	SDA
Gnd	Gnd

2.5 Program Design

2.4.1. GY-30 BH1750 Sensor

Arduino UNO R3 can be connected to the GY-30 BH1750 sensor, as shown in Figure 6; preparing a program to be uploaded into the circuit is necessary. The purpose of this design is to verify whether the sensor can operate accurately or not. The design used on the GY-30 BH1750 sensor is below to find out whether the sensor is running and accurate in capturing data.

```
#include <Wire.h>
#include <BH1750.h>
#include <LiquidCrystal_I2C.h>

// Initialize BH1750 sensor
BH1750 lightMeter;

// Initialize the LCD with I2C address (usually 0x27 or 0x3F)
LiquidCrystal_I2C lcd(0x27, 20, 4);

// Number of readings for average
const int numReadings = 10;
float readings[numReadings]; // Array to store lux readings
int readIndex = 0; // Reading index
float total    = 0; // Total readings
float averageLux = 0; // Average lux

// Calibration factor to adjust lux readings
float calibrationFactor = 0.76; // Adjust this value based on the
measurement results.

// Variable for the maximum voltage you want to achieve (e.g., 1000 lux =
5V)
float maxLux = 1000.0;

void setup() {
Wire.begin();

// Start communication with BH1750 sensor
lightMeter.begin();

// LCD initialization
lcd.begin(20, 4);
lcd.backlight();

// Initial message
lcd.setCursor(0, 0);
lcd.print("Mengukur Lux & V...");

// Initialize readings array
for (int thisReading = 0; thisReading < numReadings; thisReading++) {
readings[thisReading] = 0;
}
}

void loop() {
// Remove old readings from total
total -= readings[readIndex];

// Read lux from BH1750 sensor and calibrate
readings[readIndex] = lightMeter.readLightLevel() * calibrationFactor;

// Add new readings to total
```

```
total += readings[readIndex];

// Increase the reading index
readIndex++;

/* If the reading index reaches the end of the array, return to the
beginning*/
if (readIndex >= numReadings) {
readIndex = 0;
}

/* Calculate the average lux averageLux = total / numReadings;
   Convert the lux value to a proportional voltage */
float voltage = (averageLux / maxLux) * 5.0;
if (voltage > 5.0) voltage = 5.0; // Batasi tegangan maksimum ke 5V

// Display the result on the LCD
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Cahaya: ");
lcd.print(averageLux);
lcd.print(" Lux");

lcd.setCursor(0, 1);
lcd.print("Tegangan: ");
lcd.print(voltage, 2); // Display voltage with 2 digits after the comma
lcd.print(" V");

delay(500); // Wait 500 ms before next reading
}
```

3. RESULTS AND DISCUSSION

3.1 Mechanical Design Results

The mechanical design results are in the form of a control panel that functions as a protector and a place to place the components of the tool used. The control panel uses acrylic material with a thickness of 3 mm, a height of 7 cm, a width of 11.5 cm, and a length of 18.5 cm. The front view of the control panel has a cover equipped with an LCD place measuring 20x4 mm. This box protects electrical components like LM35 temperature sensors, Arduino Uno, and I2C LCDs from unwanted damage. The results of the mechanical design can be seen in Figure 7 below:

Figure 7. Temperature monitoring panel box

3.2 3.2 Electronic Design Results

The electronic design results are designed according to the temperature monitoring system's design. The results of this electronic design include LM35 sensors, a power supply, Arduino Uno, and an LCD I2C 20x4.

3.2.1 Design Results of I2c 20x4 LCD

In this design result, where the Vcc pin is connected to the 5v pin on the Arduino Uno, the Gnd pin is connected to Gnd on the Arduino Uno, the Sda pin is connected to Sda on the Arduino Uno, and the Scl pin is connected to the Scl pin on the Arduino Uno as in table 1. This study uses 1 I2C LCD. In the monitoring system, temperature data values are displayed. The results of the I2C 20x4 LCD design can be seen in Figure 8 below.

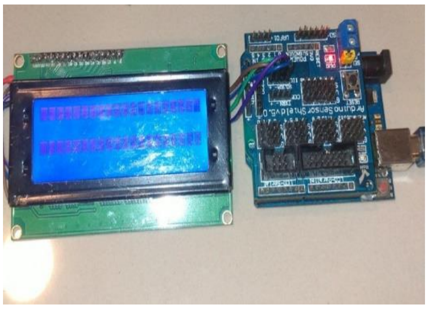

Figure 8. 20x4 I2c LCD Design Results

3.2.2 GY-30 BH1750 Sensor Design Results

In this study, the GY-30 BH1750 Sensor is used to detect the Light Intensity value in the FT. 04.02.03 and FT. 04.02.04 classrooms. The results of this circuit design use the GY-30 BH1750 Sensor and Arduino Uno. The GY-30 BH1750 Sensor has four pins, namely VCC, GND, SCL, and SDA, where the VCC pin is connected to 5v on the Arduino Uno, the Gnd pin is connected to the Gnd pin on the Arduino Uno, the Scl pin is connected to the A4 pin on the Arduino Uno, and the SDA pin is connected to the A5 pin on the Arduino Uno and can be seen in table 3. The results of the GY-30 BH1750 Sensor design can be seen in Figure 9 below.

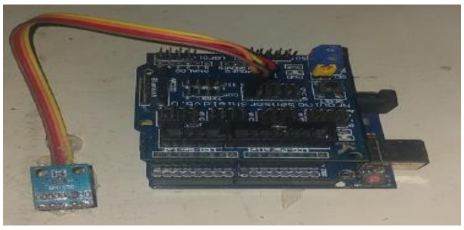

Figure 9. GY-30 BH1750 Sensor Design Results

3.3 Test Results

3.3.1 Test Results of GY-30 BH1750 Sensor

Testing of the GY-30 BH1750 Sensor with the standard Lux Meter LT300 measuring instrument was first carried out by uploading a unique program to the Arduino UNO IDE and creating a test circuit consisting of Arduino UNO IDE, Lcd I2c 20x4, GY-30 BH1750 Sensor and the standard Lux Meter LT 300 measuring instrument, and sufficient connecting cables. The test circuit can be seen in Figure 4.23. The light intensity test was performed ten times, namely 5 lux, 15 lux, 25 lux, 35 lux, 45 lux, 55 lux, 65 lux, 75 lux, 85 lux, and 95 lux. And measured using the standard Lux Meter LT300 measuring instrument. The following documentation of the output of the light intensity test results on the measuring instrument and the production of the GY-30 BH1750 Sensor measurement can be seen in Figure 10 and Figure 11 below.

Figure 10. Results of the Light Intensity Test Series

Figure 11. Light Intensity Test Output Results

From the output results of the light intensity value on the measuring instrument and each sensor tested, the measurement results data will be recorded, which can be seen in Table 3. After the light intensity output data is obtained from the ten tests, the error value, average, and measurement deviation are searched with the addition of Microsoft Excel. The results of the calibration carried out can be seen in the following table 3:

Table 3. Output Results Without Linear Regression of Light Intensity Values

No	Voltage	Light (Lux)	Average Light Intensity (Lux)	
			GY-30 BH1750 Sensor	Measuring Instrument
1	0.03	5	10.11	9.12
2	0.08	15	23.05	23.05
3	0.13	25	37.51	39.19
4	0.18	35	50.94	51.27
5	0.23	45	67.10	66.11
6	0.28	55	81.94	80.92
7	0.33	65	95.14	94.85
8	0.38	75	107.21	102.13
9	0.44	85	130.18	122.26
10	0.48	95	141.88	138.47

The overall test results of the GY-30 BH1750 sensor from all ten tests can be seen in Table 4 below.

Table 4. Output Results of Light Intensity Value Testing with Linear Regression

No	Voltage	Light (Lux)	Average Light Intensity (Lux)	
			GY-30 BH1750 Sensor	Measurement Instrument
1	0.03	5	6.29	6.36
2	0.08	15	16.35	15.75
3	0.13	25	25.65	26.69
4	0.18	35	35.94	35.47
5	0.23	45	45.16	45.60
6	0.28	55	55.74	55.92
7	0.33	65	65.24	65.45
8	0.38	75	75.58	75.43
9	0.44	85	85.38	87.21
10	0.48	95	95.38	98.32

From Table 4 above, we can see a comparison of the use of the LT300 standard lux meter measuring instrument with the GY-30 BH1750 sensor used in a graphic image form so that we can analyze it quickly. To see the comparison, we can see Figure 12 below.

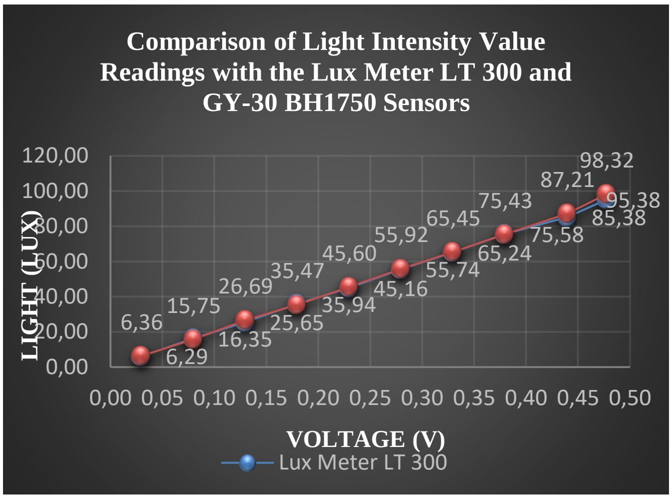

Figure 12. Comparison Chart of Light Intensity Values Using the Lux Meter LT 300 and GY-30 BH1750 Sensors

Figure 12 above compares light intensity readings with the Lux Meter LT 300 and GY-30 BH1750 sensors. The x-axis shows the voltage (V), while the y-axis shows the light intensity value (Lux). It can be seen that both measuring instruments show fairly linear results, but there is a slight difference in the measured values. The Lux Meter LT 300 shows a slightly higher value than the GY-30 BH1750 sensor at the same voltage.

4. CLOSING

Measurement of Light Intensity by applying linear regression on the GY-30 BH1750 sensor is more stable. The resulting comparison is just a short distance from the measurement results using a measuring instrument. The error produced before using linear regression is 1.2%, and when using linear regression on the GY-30 BH1750 sensor, it becomes 0.54%.

DAFTAR PUSTAKA

[1] M. Y. N. Shahrosi, A. Harijanto, and L. Nuraini, “Rancang Bangun Prototype Sistem Monitoring Suhu, Kelembaban Dan Intensitas Cahaya Pada Tanaman Cabai Berbasis IoT,” *String (Satuan Tulisan Ris. Dan Inov. Teknol.*, vol. 7, no. 3, p. 300, 2023, doi: 10.30998/string.v7i3.15139.

[2] Y. A. Nugraha, S. Sumaryo, and M. Ramdhani, “Sistem Monitoring Parameter Lingkungan Tanaman Wortel Menggunakan Field Server Monitoring System of Carrot Plant Environmental Parameters Using a Field Server,” *e-Proceeding if Eng.*, vol. 7, no. 3, p. 8758, 2020.

[3] A. Fanindi, P. B R, and A. D, “Pengaruh intensitas cahaya terhadap produksi hijauan dan benih Kalopo (Calopogonium mucunoides),” *J. Ilmu Ternak dan Vet.*, vol. 15, no. 3, pp. 205–214, 2010.

[4] H. A. Ahmed, T. Yu-Xin, and Y. Qi-Chang, “Optimal control of environmental conditions affecting lettuce plant growth in a controlled environment with artificial lighting: A review,” *South African J. Bot.*, vol. 130, pp. 75–89, 2020, doi: https://doi.org/10.1016/j.sajb.2019.12.018.

[5] R. Sk, J. Julsam, K. Kartika, A. Fendri, and M. Mulyadi, “Implementasi Mini CNC Router 3 Axis untuk Pembuatan Huruf dan Gambar Berbasis GRBL 3.6.1,” *Proceeding Semin. Nas. Politek. Negeri Lhokseumawe*, vol. 3, no. 1, pp. A95–A102, 2019.

[6] T. Saputra and U. Surapati, “Analisis Efektivitas Sistem Kendali Otomatis PJU Berbasis IoT Menggunakan Mikrokontroler ESP32 Dengan Metode Regresi Linier,” *J. Indones. Manaj. Inform. Dan Komun.*, vol. 5, no. 3, pp. 2582–2595, 2024, doi: 10.35870/jimik.v5i3.932.

[7] A. Hasibuan, A. Qodri, K. Kartika, and M. Isa, “Temperature Monitoring System using Arduino Uno and Smartphone Application,” *Bull. Comput. Sci. Electr. Eng.*, vol. 2, no. 2, pp. 46–55, 2021, doi: 10.25008/bcsee.v2i2.1139.

[8] T. H. Purwanto, “Pemanfaatan Foto Udara Format Kecil Untuk Ekstraksi Digital Elevation Model Dengan Metode Stereoplotting,” *Maj. Geogr. Indones.*, vol. 31, no. 1, p. 73, 2017, doi: 10.22146/mgi.24246.

[9] B. A. Sakti, S. Prasetya, and I. Nuriskasari, “Analisis Pemilihan Sensor dan Ketelitian pada Rancang Bangun Weather Station Sebagai Monitoring System Cuaca Area Politeknik Negeri Jakarta,” *Pros. Semin. Nas. …*, pp. 651–655, 2022, [Online]. Available:

https://prosiding.pnj.ac.id/index.php/sntm/article/view/91%0Ahttps://prosiding.pnj.ac.id/index.php/sntm/article/download/91/88

[10] M. R. Giordano *et al.*, “From low-cost sensors to high-quality data: A summary of challenges and best practices for effectively calibrating low-cost particulate matter mass sensors,” *J. Aerosol Sci.*, vol. 158, p. 105833, 2021, doi: https://doi.org/10.1016/j.jaerosci.2021.105833.

[11] K. Fathoni, A. P. Pratama, N. A. Salim, and V. N. Sulistyawan, “Implementasi Kendali Keseimbangan Gerak Two Wheels Self Balancing Robot Menggunakan Fuzzy Logic,” *J. Tek. Elektro*, vol. 13, no. 2, pp. 89–97, 2021, doi: 10.15294/jte.v13i2.33414.

[12] J. G. Webster and H. Eren, *Measurement, Instrumentation, and Sensors Handbook*. Boca Raton: CRC Press, 2018. doi: 10.1201/9781315217109.

[13] R. T. Putra and M. A. R. Pohan, “Penerapan Jaringan Syaraf Tiruan Untuk Meningkatkan Akurasi Sensor Arus PZEM-004T,” *Telekontran J. Ilm. Telekomun. Kendali Dan Elektron. Terap.*, vol. 12, no. 2, pp. 119–129, 2024, doi: 10.34010/telekontran.v12i2.9687.

[14] F. A. Zahra and G. A. Darleen, “Perancangan Dan Implementasi Sensor Kelembapan Untuk Mendeteksi Hujan Pada Rumah Tangga,” *Elektr. Borneo*, vol. 10, no. 1, pp. 28–33, 2024.

[15] Roswaldi Sk, J. Julsam, K. Kartika, A. Fendri, and Mulyadi Mulyadi, “Implementasi Mini CNC Router 3 Axis untuk Pembuatan Huruf dan Gambar Berbasis GRBL 3.6.1,” *Proceeding Semin. Nas. Politek. Negeri Lhokseumawe*, vol. 3, no. 1, pp. A95–A102, 2019.

[16] N. H. Bingham and J. Fry, “Linear Regression,” *Springer Undergrad. Math. Ser. 1-32*, pp. 1–32, 2010, doi: 10.1007/978-1-84882-969-5_1.

[17] M. D. Syafputra, B. Rahmadya, and R. Hadelina, “Otomatisasi Lampu Belajar Sesuai Prosedur Kesehatan Mata Dan Kecerahan Ruangan Berbasis Mikrokontroler,” *Chipset*, vol. 4, no. 02, pp. 191–198, 2023, doi: 10.25077/chipset.4.02.191-198.2023.

[18] H. Li *et al.*, “Evaluation of the Performance of Low-Cost Air Quality Sensors at a High Mountain Station With Complex Meteorological Conditions,” *Atmosphere (Basel).*, vol. 11, no. 2, p. 212, 2020, doi: 10.3390/atmos11020212.

[19] S. Schmitz *et al.*, “Unravelling a Black Box: An Open-Source Methodology for the Field Calibration of Small Air Quality Sensors,” *Atmos. Meas. Tech.*, vol. 14, no. 11, pp. 7221–7241, 2021, doi: 10.5194/amt-14-7221-2021.

[20] P. Ferrer-Cid, J. M. Barceló-Ordinas, J. García-Vidal, A. Ripoll, and M. Viana, “Multisensor Data Fusion Calibration in IoT Air Pollution Platforms,” *Ieee Internet Things J.*, vol. 7, no. 4, pp. 3124–3132, 2020, doi: 10.1109/jiot.2020.2965283.

[21] S. Mahajan and P. Kumar, “Evaluation of Low-Cost Sensors for Quantitative Personal Exposure Monitoring,” *Sustain. Cities Soc.*, vol. 57, p. 102076, 2020, doi: 10.1016/j.scs.2020.102076.

[22] A. Chattopadhyay *et al.*, “Low-Cost Formaldehyde Sensor Evaluation and Calibration in a Controlled Environment,” *IEEE Sens. J.*, vol. 22, no. 12, pp. 11791–11802, 2022, doi: 10.1109/jsen.2022.3172864.

[23] N. Roustaei, “Application and Interpretation of Linear-Regression Analysis,” *Med. Hypothesis Discov. Innov. Ophthalmol.*, vol. 13, no. 3, pp. 151–159, 2024, doi: 10.51329/mehdiophthal1506.

[24] K. R. Smith *et al.*, “An Improved Low-Power Measurement of Ambient NO_2 and O₃ Combining Electrochemical Sensor Clusters and Machine Learning,” *Atmos. Meas. Tech.*, vol. 12, no. 2, pp. 1325–1336, 2019, doi: 10.5194/amt-12-1325-2019.

[25] F. Concas *et al.*, “Low-Cost Outdoor Air Quality Monitoring and Sensor Calibration,” *Acm Trans. Sens. Networks*, vol. 17, no. 2, pp. 1–44, 2021, doi: 10.1145/3446005.

[26] P. Nowack, L. Konstantinovskiy, H. Gardiner, and J. Cant, “Machine Learning Calibration of Low-Cost NO_2 and PM_{10} Sensors: Non-Linear Algorithms and Their Impact on Site Transferability,” *Atmos. Meas. Tech.*, vol. 14, no. 8, pp. 5637–5655, 2021, doi: 10.5194/amt-14-5637-2021.

[27] T. Kashiwao, M. Hiro, K. Hayashi, and M. Deguchi, “Machine-Learning-Based Prediction of the Three-Dimensional (3D) Position Coordinates of 3D Proximity Sensing Frames,” *Ieej J. Ind. Appl.*, vol. 12, no. 4, pp. 800–807, 2023, doi: 10.1541/ieejjia.22004763.

[28] C. Malings *et al.*, “Development of a General Calibration Model and Long-Term Performance Evaluation of Low-Cost Sensors for Air Pollutant Gas Monitoring,” *Atmos. Meas. Tech.*, vol. 12, no. 2, pp. 903–920, 2019, doi: 10.5194/amt-12-903-2019.