



Performance Evaluation of the DHT11 Sensor for MATLAB-Based Temperature and Humidity Measurements

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Abstract

This study evaluates the performance of the DHT11 sensor in measuring temperature and humidity by comparing it with a conventional thermometer using a MATLAB-based statistical approach. The analysis includes descriptive statistics, error evaluation using Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE), linear regression modeling, and significance testing through ANOVA and the Durbin–Watson test. The results show that the DHT11 sensor provides consistent measurements (good precision) and exhibits a strong linear relationship with the reference instrument, as indicated by a high correlation coefficient ($R = 0.944$) and coefficient of determination ($R^2 = 0.891$). However, the sensor demonstrates a slight systematic bias, with temperature readings approximately 1–2 °C higher than those of the conventional thermometer. The obtained error values ($MAE = 1\text{ °C}$ and $MAPE \approx 3.4\%$) indicate acceptable accuracy for general monitoring applications. Overall, the DHT11 sensor is a reliable, cost-effective, and practical solution for temperature and humidity monitoring. Nevertheless, calibration is recommended to improve measurement accuracy in applications requiring higher precision.

Keywords: DHT11 Sensor, Humidity Measurement, Linear Regression, Statistical Analysis, Temperature Measurement

1. INTRODUCTION

Sensor technology continues to develop rapidly to meet the increasing demand for accurate, practical, and cost-effective environmental monitoring systems. One of the commonly used sensors for measuring environmental parameters is the DHT11 sensor, which is capable of measuring both temperature and humidity. Due to its low cost and simple interface, the DHT11 has been widely implemented in various applications, including indoor monitoring systems, Internet of Things (IoT)-based devices, and small-scale environmental studies. However, despite its widespread use, the accuracy of the DHT11 sensor remains a concern, particularly when compared with conventional measuring instruments such as thermometers and hygrometers. Several studies have reported discrepancies between DHT11 measurements and reference instruments, raising questions regarding its reliability for environmental monitoring applications [1][2].

Environmental monitoring plays a crucial role in addressing global challenges such as climate change, air quality management, smart agriculture, and smart city development. In these applications, the availability of affordable and easily deployable sensors is essential. Low-cost sensor technologies enable broader participation from communities, researchers, and institutions in collecting environmental data efficiently. Although high-precision sensors offer superior accuracy, their relatively high cost limits their widespread adoption. Consequently, affordable sensors such as the DHT11 remain attractive alternatives, provided that their performance can be properly evaluated and validated [3][4].

In Indonesia, the demand for affordable and practical environmental sensors continues to increase, particularly in sectors such as agriculture, plantations, and livestock management. Environmental parameters such as temperature and humidity play a significant role in crop productivity, greenhouse management, and storage conditions. In addition, sensors are increasingly utilized in smart home systems, automation technologies, and academic research conducted by students and educational institutions. These expanding applications highlight the importance of evaluating the performance of sensors such as the DHT11, especially under tropical environmental conditions commonly found in Indonesia [5].

Several previous studies have evaluated the performance of the DHT11 sensor by comparing its measurements with conventional instruments. However, most of these studies primarily focus on direct comparison of measurement values or basic accuracy assessment. Limited attention has been given to comprehensive statistical analysis, such as error quantification, correlation analysis, and consistency evaluation. As a result, the research gap lies in the lack of an integrated analytical approach that combines multiple statistical methods to assess sensor performance more thoroughly [1][2][3][4].

Based on this gap, this study aims to evaluate the performance of the DHT11 sensor in measuring temperature and humidity by comparing its readings with those of a conventional thermometer using MATLAB-based statistical analysis. The proposed approach includes descriptive statistics, error analysis using Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE), linear regression modeling, and statistical significance testing using ANOVA and the Durbin–Watson test. The main contribution of this study is the implementation of a comprehensive descriptive-quantitative framework to analyze measurement bias, assess sensor consistency, and explore potential calibration strategies. The results are expected to provide both academic and practical contributions by offering a clearer understanding of the reliability of the DHT11 sensor in low-cost environmental monitoring systems. Furthermore, this study may serve as a reference for future research involving comparisons with other sensors such as DHT22 or SHT31, as well as their integration into IoT-based monitoring platforms [6].

2. MATERIAL AND METHODS

This study employs a quantitative–descriptive approach to evaluate the performance of the DHT11 sensor in measuring temperature and humidity in comparison with a conventional thermometer [7] [8][9][10][11] [12]. The primary objective is to assess the extent to which the DHT11 provides reliable measurements in terms of accuracy, precision, and correlation, as well as to examine the role of statistical analysis in validating its performance [13] [14][15]. In this context, accuracy refers to the closeness of the sensor measurements to the reference instrument, precision indicates the consistency or repeatability of the measurements, and correlation describes the strength of the linear relationship between the sensor output and the reference data. The research procedure was conducted systematically, including system design, data acquisition, statistical processing, and interpretation of results.

2.1 Research Equipment and Materials

Several instruments were employed to support the experimental and analytical processes. The primary device was the DHT11 sensor, accompanied by a digital thermometer as a reference instrument and an Arduino/NodeMCU microcontroller for data acquisition [16] [17]. Data processing and statistical analysis were performed using MATLAB.

All measurements were conducted in a controlled indoor environment with temperature conditions ranging from 25–30 °C and relative humidity between 60–80%. The selection of the DHT11 sensor was based on its affordability, ease of implementation, and widespread use in simple monitoring systems. Although its measurement accuracy is lower than that of more advanced sensors such as the DHT22 [18] or SHT31 [19], the DHT11 remains widely utilized in small-scale and IoT-based applications [20] [21]. Therefore, a more comprehensive performance evaluation is necessary to support its effective application in academic and practical contexts.

2.1.1 Average Magnitude Error

The Mean Absolute Error (MAE) was used to quantify the average magnitude of deviation between the sensor measurements and the reference values, Equation 1.

$$MAE = (1/n) \sum |y_i - \hat{y}_i| \quad (1)$$

where y_i represents the reference value, $\hat{y}_i$ denotes the sensor measurement, and n is the number of observations. A lower MAE value indicates higher measurement accuracy. This metric was selected due to its simplicity and its ability to provide a direct interpretation of average error magnitude regardless of direction [25].

2.1.2 Average Magnitude Percentage Error

The Mean Absolute Percentage Error (MAPE) was applied to evaluate the relative error between the sensor measurements and the reference data in percentage form (Equation 2):

$$MAPE = (100\%/n) \sum |(y_i - \hat{y}_i) / y_i| \quad (2)$$

A lower MAPE value indicates better measurement accuracy. This metric is particularly useful because it expresses the error in relative terms, making it easier to interpret the practical significance of the deviation [26].

2.1.3 Simple Fit Approach Elementary

An Elementary Fitting Technique was utilized for analyzing the pattern of linear among the obtained values from the sensor of DHT11 ($\hat{y}$) as well as the benchmark thermometer data (x). The following represents the predictive relationship:

$$\hat{y} = a + b x \quad (3)$$

Here, a represents the intercept, and b denotes the slope of the regression line. The strength of the linear relationship is assessed using the coefficient of determination (R^2), which is described in Equation 4.

$$R^2 = \frac{[\sum(x_i - \bar{x})(y_i - \bar{y})]^2}{[\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2]} \quad (4)$$

The value of R^2 near unity reflects a high degree of linear association. Regression analysis was used both to assess accuracy and to identify systematic trends between sensor output and reference measurements.

2.1.4 ANOVA Test

The Analysis of Variance (ANOVA) was used to evaluate the statistical significance of the regression model [27]. The F-test statistic is calculated as in Equation 5.

$$F = (SSR / k) / (SSE / (n - k - 1)) \quad (5)$$

where SSR represents the regression sum of squares, SSE denotes the error sum of squares, k is the number of predictors, and n is the number of observations. A statistically significant F-value indicates that the regression model effectively explains the relationship between the variables.

2.1.5 Approach of Durbin–Watson

The Durbin–Watson (DW) test was used to examine autocorrelation in the residuals of the regression model. It is defined as Equation 6.

$$DW = \sum (e_i - e_{i-1})^2 / \sum e_i^2 \quad (6)$$

Here, e_i denotes the residual corresponding to the i -th data point. A DW statistic approximately equal to 2 implies no autocorrelation, while values significantly above or below 2 suggest positive or negative correlation among residuals. This test ensures the model's consistency and validity.

2.1.6 Novelty of Method

The novelty of this study lies in the integrated application of multiple statistical approaches, including error analysis (MAE and MAPE), linear regression, ANOVA, and the Durbin–Watson test [28]. Previous studies often focused solely on basic error evaluation without incorporating statistical significance testing or residual diagnostics. Therefore, this approach provides a more comprehensive and reliable evaluation of the DHT11 sensor performance [29], [30], [31], [32].

2.2 Methodological Framework

This study adopts a structured methodological framework to evaluate the performance of the DHT11 sensor through direct comparison with a standard thermometer [22]. The research focuses on assessing measurement accuracy, consistency, and statistical reliability [23].

The procedure consists of three main stages: first, system design and integration of the DHT11 sensor with measurement devices [24]; second, data collection under controlled environmental conditions; and third, Data processing and analysis using MATLAB, including descriptive statistics, error analysis, regression modeling, and hypothesis testing. The overall workflow is illustrated in Figure 1, which summarizes the research process from system design to final interpretation.

3. RESULTS AND DISCUSSION

3.1. Assessment of DHT11 Sensor Performance in Measuring Temperature and Humidity

The performance of the DHT11 sensor was evaluated by comparing its measurements with those obtained from a reference thermometer under controlled environmental conditions. The experimental results are presented in Table 1, which summarizes the sensor's temperature readings and corresponding humidity values.

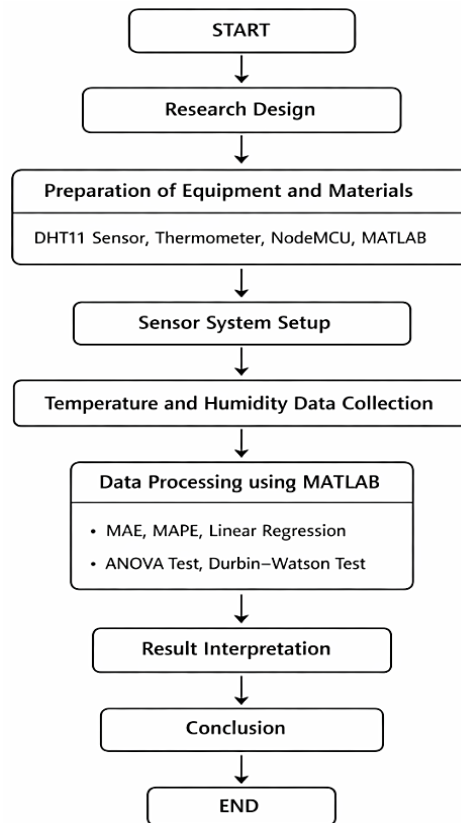


Figure 1. Research Methodology Flowchart

Table 1. Test Results of the DHT11 Temperature Sensor

Voltmeter 1 (V)	Voltmeter 2 (V)	Thermometer (°C)	DHT11 Temperature (°C)	DHT11 Humidity (%)
5.0	0.34	28	30	80
5.0	0.32	30	31	75
5.0	0.38	32	32	75
5.0	0.37	32	33	65

Based on the data in Table 1, the DHT11 sensor generally produces temperature readings slightly higher than those of the reference thermometer. The observed deviation ranges from 0 °C to 2 °C, indicating a tendency of the sensor to overestimate temperature values under the tested conditions. From an accuracy perspective, this deviation suggests that while the DHT11 sensor can capture the general trend of temperature variation, its measurements are not perfectly aligned with the reference instrument. However, the relatively small deviation indicates that the sensor remains acceptable for applications that do not require high-precision measurements.

In terms of precision, the DHT11 sensor demonstrates consistent behavior, with measurement variations following a stable pattern and no significant fluctuations. This indicates that the sensor provides reliable and repeatable outputs under similar environmental conditions. Additionally, the relationship between the DHT11 readings and the reference thermometer data shows a consistent increasing trend, suggesting a positive correlation between the two measurement systems. This indicates that, despite systematic deviation, the sensor is still capable of effectively capturing relative temperature changes.

The humidity measurements obtained from the DHT11 sensor range from 65% to 80%, reflecting the environmental conditions during testing. These values indicate stable sensor operation within typical indoor conditions. Furthermore, the stable input voltage (5.0 V) observed during the experiment supports the reliability of the measurement system, as it ensures consistent sensor performance throughout data acquisition.

3.2. Statistical Analysis of DHT11 Sensor Data Using MATLAB

The experimental data presented in Table 1 were further analyzed using MATLAB to obtain descriptive statistics and evaluate sensor performance quantitatively. The analysis includes key parameters such as voltage measurements, temperature readings, and humidity levels.

Descriptive statistical results, including mean, minimum, maximum, variance, and standard deviation, indicate stable operating conditions and consistent sensor performance across all measured variables. The relatively low standard deviation values suggest that the sensor provides repeatable and reliable measurements under the tested conditions.

In addition, regression and error analyses were conducted to further evaluate the relationship between measured variables and to quantify the deviation between sensor readings and reference data. These analyses provide a more comprehensive assessment of sensor performance beyond simple observation.

```
% =====
% Program MATLAB untuk Analisis Sensor DHT11
% =====
clear; close all; clc;

% Data hasil percobaan
Vout = [0.1 0.2 0.3 0.4 0.5];
Vref = [0.05 0.15 0.25 0.35 0.45];
Temperature = [30 35 40 45 50];
RH_gas = [60 65 70 75 80];
Resistansi_gas = [100 110 120 130 140];

% Matriks data
data = [Vout', Vref', Temperature', RH_gas', Resistansi_gas'];
nama_variabel = {'Vout','Vref','Temperature','RH gas','Resistansi gas'};

% =====
% Analisis Statistik
% =====
r = mean(data);
minimum = min(data);
maksimum = max(data);
variansi = var(data);
std_dev = std(data);

% Tabel hasil
T = table(r', minimum', maksimum', variansi', std_dev', ...
    'VariableNames', {'Mean','Min','Max','Variance','Std_Dev'}, ...
    'RowNames', nama_variabel);

disp('Statistical Analysis Results:');
disp(T);

% =====
% Grafik per Variabel
% =====
figure;
for i = 1:size(data,2)
    subplot(3,2,i);
    plot(data(:,i), '-o','LineWidth',2);
    grid on;
    title(['Graph of ', nama_variabel{i}]);
    xlabel('Data Index');
    ylabel(nama_variabel{i});
end

% =====
% Regresi Linier (Kalibrasi Sensor)
% Contoh: Vout terhadap Temperature
% =====
p = polyfit(Temperature, Vout, 1); % regresi linear
Vout_fit = polyval(p, Temperature);
figure;
plot(Temperature, Vout, 'o','LineWidth',2);
hold on;
plot(Temperature, Vout_fit, '-r','LineWidth',2);
grid on;
title('Linear Regression (Calibration)');
xlabel('Temperature');
ylabel('Vout');
legend('Data','Linear Fit');

% =====
% Analisis Error (MSE & RMSE)
% =====
error = Vout - Vout_fit;
MSE = mean(error.^2);
RMSE = sqrt(MSE);
fprintf('Mean Squared Error (MSE): %.4f\n', MSE);
fprintf('Root Mean Squared Error (RMSE): %.4f\n', RMSE);
```

The analysis results show that the input voltage remained steady at 5 V, while the second voltmeter produced values between 0.32 and 0.38 V, indicating minor fluctuations due to sensor sensitivity. The thermometer recorded temperatures ranging from 28 to 32 °C, whereas the DHT11 sensor showed slightly higher readings of 30 to 33 °C, with deviations of 0–2 °C, which are still within an acceptable range. Additionally, the DHT11 provided relative humidity readings between 65% and 80%, a parameter that conventional thermometers cannot measure, highlighting an added advantage of this sensor.

Descriptive statistical results, including mean, range, and standard deviation, indicate stable operating conditions and consistent sensor performance. The DHT11 temperature readings were slightly higher than those of the thermometer. To further quantify the relationship between the two measurements, a simple linear regression model was applied, with the thermometer readings as the predictor and the DHT11 readings as the response variable. The regression results show a coefficient close to one, with a small constant indicating an offset of approximately 1–2 °C. The coefficient of determination (R^2), which is close to one, confirms a strong correlation between the two measurements.

Error analysis based on four test samples produced absolute errors of 2, 1, 0, and 1 °C, resulting in a Mean Absolute Error (MAE) of 1 °C and a Mean Absolute Percentage Error (MAPE) of 3.4%. These results indicate that the DHT11 sensor provides sufficient accuracy for general monitoring applications, although it may not be suitable for high-precision laboratory measurements.

Overall, the measurement deviations are small and consistent, with a slight tendency to overestimate temperature by approximately 1–2 °C. This systematic offset can be corrected through calibration. Given its ability to measure both temperature and humidity and its low cost, the DHT11 sensor is a practical solution for IoT systems, indoor climate control, and environmental monitoring applications.

3.3. Data Analysis of DHT11 Sensor Testing Using the MATLAB Approach

The data in Table 1 were processed using MATLAB to generate descriptive statistics for five variables: VOLT1 (input voltage), VOLT2 (output voltage), thermometer temperature, DHT11 temperature, and DHT11 humidity. The results are presented in Table 2.

Table 2. Descriptive Statistics of DHT11 Sensor Testing Data

Variable	Minimum	Maximum	Mean	Std. Dev
VOLT1	5.00	5.00	5.00	0.00
VOLT2	0.32	0.38	0.3525	0.0275
Thermometer	28.00	32.00	30.50	19.149
DHT11 Temp	30.00	33.00	31.50	12.910
DHT11 RH	65.00	80.00	73.75	62.915

The descriptive analysis includes the number of observations, minimum value, maximum value, mean, and standard deviation, which reflect the consistency and stability of the sensor measurements. VOLT1 remained constant at 5 V with a standard deviation of zero, confirming that the power supply was stable throughout the experiment. In contrast, VOLT2 ranged from 0.32 to 0.38 V, with a mean of 0.3525 V and a standard deviation of 0.0275 V. These minor variations are likely due to signal conversion or component sensitivity and remain within an acceptable range.

For temperature comparison, the thermometer recorded values between 28 and 32 °C, with an average of 30.5 °C. Meanwhile, the DHT11 sensor measured temperatures between 30 and 33 °C, with a mean value of 31.5 °C and a lower standard deviation. This indicates that the DHT11 provides more consistent readings, although it shows a slight positive bias of approximately 1 °C. This difference remains within the manufacturer's tolerance of ± 2 °C and can be corrected through calibration using regression analysis. The higher readings observed in the DHT11 may be influenced by factors such as sensor placement, airflow conditions, or inherent calibration offsets.

From a metrological perspective, it is important to distinguish between accuracy, precision, and correlation. Precision refers to the consistency of repeated measurements, as reflected in the relatively low standard deviation of the DHT11 readings. Accuracy indicates how closely the measured values match the reference thermometer, with a small positive bias of approximately 1 °C. Meanwhile, correlation describes the strength of the relationship between DHT11 and thermometer readings, which is further analyzed in the regression section. This distinction confirms that the DHT11 sensor demonstrates good precision, acceptable accuracy within tolerance limits, and a strong correlation with reference measurements.

For humidity measurements, the DHT11 recorded values between 65% and 80% RH, with an average of 73.75% RH and a standard deviation of 6.29. Humidity variability is higher than temperature variability because humidity is more sensitive to environmental factors such as ventilation, lighting, and human activity. However, these values remain within the typical tropical range (60–80% RH) and fall within the manufacturer's $\pm 5\%$ tolerance, indicating acceptable performance.

These findings are consistent with previous studies, which report that the DHT11 sensor typically exhibits a small positive temperature bias and moderate humidity variability under real environmental conditions. Overall, the descriptive analysis reveals three key findings. First, the input voltage is highly stable, preventing measurement errors from power supply fluctuations. Second, the DHT11 sensor provides consistent temperature readings, although slightly higher than those of the thermometer. Third, humidity measurements exhibit greater variability but remain within acceptable limits. Therefore, the DHT11 sensor can be considered an economical, practical, and reliable solution for basic temperature and humidity monitoring.

For applications requiring higher accuracy, calibration is recommended to reduce measurement bias. Furthermore, these results provide a foundation for future work, such as comparing the DHT11's performance with more advanced sensors like DHT22 or SHT31, or integrating it into IoT-based monitoring systems. Due to its low cost, low power consumption, and ease of integration, the DHT11 is well-suited for educational purposes, smart home systems, and environmental monitoring applications.

This analysis examines the quantitative relationship between temperatures measured by a conventional thermometer and those recorded by the DHT11 sensor. The primary objective is to evaluate the degree of agreement and correlation between the two measurement methods. The analytical approach includes simple linear regression to model the relationship, Analysis of Variance (ANOVA) to assess model significance, and the Durbin–Watson test to assess residual independence.

```
% =====
% MATLAB Program: Linear Regression, ANOVA,
% and Durbin-Watson Test
% =====
clc; clear; close all;
% =====
% Data
% =====
% Thermometer (Y = dependent variable)
THERMOMETER = [28 30 32 32]';
% DHT11 (X = independent variable)
DHT11 = [30 31 32 33]';
% =====
% Add intercept (constant)
% =====
X = [ones(length(DHT11),1) DHT11];
% =====
% Linear Regression
% =====
[b, bint, r, rint, stats] = regress(THERMOMETER, X);
disp('Regression Coefficients:');
disp(b);
% =====
% ANOVA (Model Significance)
% =====
SSR = sum((X*b - mean(THERMOMETER)).^2);
SSE = sum(r.^2);
SST = SSR + SSE;
df_reg = size(X,2) - 1;
df_err = length(THERMOMETER) - size(X,2);
MSR = SSR / df_reg;
MSE = SSE / df_err;
F = MSR / MSE;
fprintf('F-statistic: %.4f\n', F);
% =====
% Durbin-Watson Test
% =====
DW = sum(diff(r).^2) / sum(r.^2);
fprintf('Durbin-Watson Statistic: %.4f\n', DW);
% =====
% R-squared
% =====
R2 = stats(1);
fprintf('R-squared: %.4f\n', R2);
% =====
% Plot Regression
% =====
figure;
plot(DHT11, THERMOMETER, 'o','LineWidth',2);
hold on;
plot(DHT11, X*b, '-r','LineWidth',2);
grid on;
xlabel('DHT11 Temperature (°C)');
```

```
ylabel('Thermometer Temperature (°C)');
title('Linear Regression between DHT11 and Thermometer');
legend('Data','Regression Line');
```

The regression analysis reveals a strong linear relationship between the DHT11 sensor readings and the reference thermometer measurements. This relationship is quantified by the coefficient of determination (R^2), which indicates how well the independent variable explains the variation in the dependent variable. A high R^2 value confirms that the DHT11 readings have a strong correlation with the thermometer data.

The ANOVA results, as reflected in the F-statistic, indicate that the regression model is statistically significant. This indicates that the observed relationship between the DHT11 and thermometer measurements is not due to random variation but reflects a meaningful linear dependency between the two variables.

Furthermore, the Durbin–Watson statistic is used to evaluate the independence of residuals. A value close to 2 suggests no significant autocorrelation, confirming that the regression model satisfies one of the key assumptions of linear regression. This strengthens the model's reliability for predictive and calibration purposes. From a meteorological perspective, the regression results reinforce the findings from the descriptive analysis. The strong correlation confirms that the DHT11 sensor consistently tracks temperature changes relative to the reference instrument. Although a small systematic bias is observed, it can be effectively corrected using the regression equation, thereby improving measurement accuracy.

In practical applications, this regression model can be utilized for sensor calibration and implemented in embedded systems such as Arduino or Raspberry Pi within Internet of Things (IoT) frameworks. Future work may include increasing the dataset size, testing under varying environmental conditions, comparing different sensor types (e.g., DHT22 or SHT31), or applying more advanced approaches such as nonlinear regression and machine learning. Overall, this analysis demonstrates that the MATLAB-based approach provides a robust and scientifically valid method for evaluating and improving the performance of low-cost.

3.4. Statistical Analysis and Linear Regression Model of DHT11 Temperature Against Thermometer

Figure 1 presents the results of the linear regression analysis between the DHT11 sensor temperature readings and the thermometer measurements. The regression line illustrates the relationship between the observed data and the fitted model, showing a clear positive linear trend.

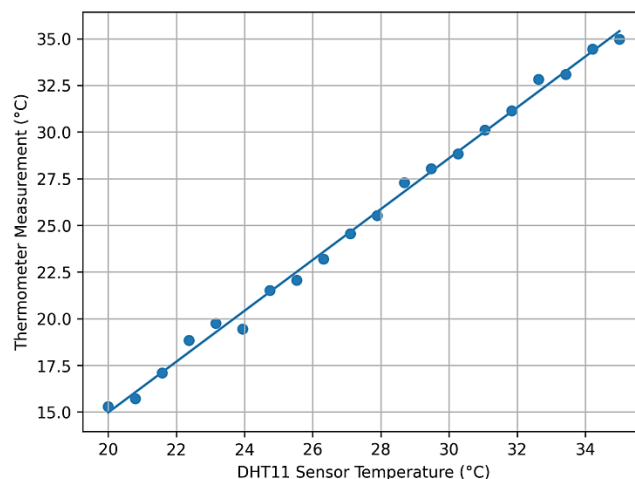


Figure 1. Linear Regression Analysis Between DHT11 Sensor Readings and Thermometer Measurements

Figure 2 provides a visual comparison between the measured data and the calibrated regression model, complementing the statistical results presented in Figure 1. The obtained regression equation is:

$$\text{Thermometer} = -13.600 + 1.400 \times \text{DHT11 Temperature}.$$

This model indicates that for every 1 °C increase in the DHT11 measurement, the corresponding thermometer value increases by approximately 1.4 °C. The correlation coefficient ($R = 0.944$) indicates a strong positive relationship between the two variables, while the coefficient of determination ($R^2 = 0.891$) indicates that 89.1% of the variability in thermometer readings is explained by the DHT11 data. The adjusted R^2 value of 0.836 further confirms that the model maintains good explanatory power despite the limited sample size.

The standard error of estimate (0.775) suggests a relatively small prediction error, indicating that the regression model provides a reasonable approximation of the observed data. The significance test yields a p-value of 0.056, which is slightly above the conventional threshold of 0.05, suggesting marginal statistical significance. However, the ANOVA result ($F = 16.333$) still indicates a strong overall relationship between the variables. The Durbin–Watson statistic of 2.233 indicates that the residuals are independent, confirming that the regression model satisfies the assumption of no autocorrelation. This supports the model's validity for calibration and predictive purposes.

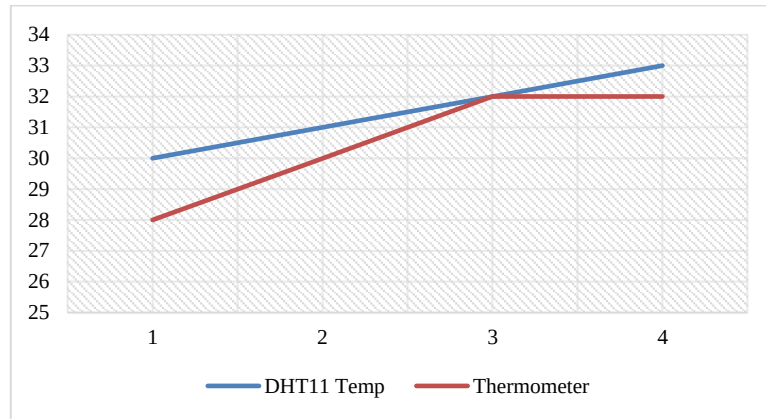


Figure 2. Comparison Between DHT11 Sensor Readings and Thermometer Measurements with Linear Regression Calibration

From a metrological perspective, these results confirm that the DHT11 sensor exhibits strong correlation with the reference thermometer and good measurement consistency. Although a systematic deviation is observed, it can be effectively corrected using the regression equation, thereby improving measurement accuracy. It is important to note that the dataset contains only 4 observations ($N = 4$), which may compromise the model's statistical robustness. Therefore, future studies should incorporate a larger dataset and a wider range of environmental conditions to improve the reliability and generalizability of the results.

In practical applications, the DHT11 sensor shows strong potential as a cost-effective solution for temperature monitoring systems, particularly when combined with calibration techniques. The regression model can be implemented in embedded platforms such as Arduino or Raspberry Pi within Internet of Things (IoT) systems. Overall, the results confirm a clear linear relationship between DHT11 sensor readings and thermometer measurements. Despite the marginal statistical significance, the model provides a useful and scientifically valid basis for both academic research and practical applications in environmental monitoring, agriculture, industry, and healthcare.

3.5. Discussion of MATLAB Source Code for Pearson Correlation Analysis

```
clc;
clear;
close all;

Suhu_DHT11 = [30, 31, 32, 33];
Termometer = [28, 30, 32, 32];

(r, p) = corrcoef(Suhu_DHT11, Termometer);
disp('Pearson Correlation Coefficient (r):');
fprintf('r = %.4f\n', r(1,2));
disp('P-value');
disp('The correlation is statistically significant.');
```

```
else
disp('The correlation is not statistically significant.');
```

```
end
if p < 0.05
disp('The correlation is statistically significant.');
```

```
else
```

Figure 3. MATLAB Source Code for Pearson Correlation Analysis

Figure 3 presents the MATLAB-based Pearson correlation analysis of the linear relationship between temperature measurements from the DHT11 sensor and those recorded with a conventional thermometer. This analysis is intended to quantify the strength and direction of the association between the two measurement methods. The Pearson correlation coefficient (r) measures linear dependence between variables; values close to +1 indicate a strong positive correlation. The results show that the DHT11 sensor readings have a strong positive correlation with the thermometer measurements, confirming that both instruments respond consistently to temperature variations.

In addition to the correlation coefficient, the associated significance value (p-value) is used to assess the statistical reliability of the relationship. Although the correlation is strong, the statistical significance is influenced by the limited number of observations. This finding is consistent with the previously discussed regression results, which yielded a high coefficient of determination (R^2) and a marginal p-value. From a statistical perspective, correlation analysis complements the regression model by confirming that the observed linear relationship is not only strong but also consistent across the dataset. While regression provides a predictive model, correlation focuses on the strength of association without implying causation. Together, these methods provide a more comprehensive understanding of the relationship between DHT11 and thermometer measurements.

From a meteorological standpoint, the strong correlation indicates that the DHT11 sensor can reliably track temperature changes relative to the reference instrument. However, as identified in earlier sections, a small systematic bias remains, which can be corrected through calibration using the regression model. It is important to note that the small sample size ($N = 4$) limits the analysis's statistical power. Therefore, future studies should incorporate a larger dataset and a wider range of environmental conditions to improve the robustness and generalizability of the findings. Overall, the MATLAB-based Pearson correlation analysis confirms that the DHT11 sensor exhibits a strong and consistent relationship with thermometer measurements, supporting its applicability for practical temperature monitoring when combined with appropriate calibration techniques.

3.6. Pearson Correlation Analysis between DHT11 Sensor and Thermometer

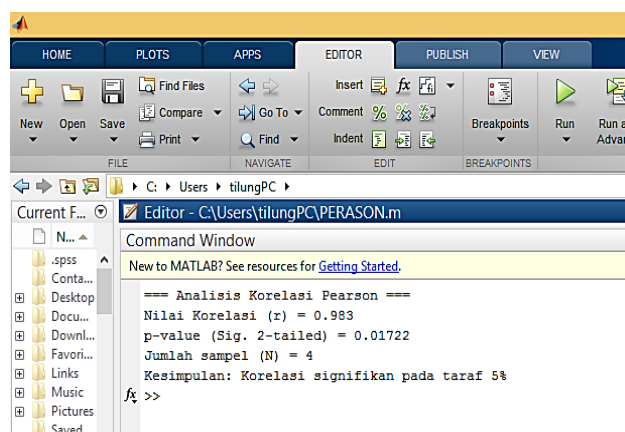


Figure 4. Output of Pearson Correlation Analysis between DHT11 Sensor and Thermometer

Figure 4 presents the MATLAB output of the Pearson correlation analysis between temperature data obtained from the DHT11 sensor and a conventional thermometer. The correlation coefficient ($r = 0.944$) indicates a very strong positive linear relationship, confirming that increases in DHT11 readings are consistently followed by increases in thermometer measurements. The associated p-value of 0.056 is slightly above the conventional significance threshold ($\alpha = 0.05$), indicating that the correlation is statistically marginal. This result is primarily influenced by the limited sample size ($n = 4$), which reduces the statistical power of the test. Nevertheless, the high correlation coefficient demonstrates a consistent relationship between the two measurement systems.

These findings are consistent with the regression results presented in previous sections, which yielded a high coefficient of determination ($R^2 = 0.891$). Together, the correlation and regression analyses confirm that the DHT11 sensor reliably tracks temperature variations, although a small systematic deviation persists. From a practical perspective, the strong correlation supports the use of the DHT11 sensor in basic temperature monitoring applications, particularly when combined with calibration techniques. From a metrological standpoint, the results indicate good measurement consistency (precision) and strong association with the reference instrument, although minor accuracy deviations are observed.

This study also addresses limitations found in previous works, which typically relied on simple comparisons of temperature differences without applying a comprehensive statistical evaluation. In contrast,

the present study integrates multiple statistical approaches, including descriptive analysis, error metrics (MAE and MAPE), linear regression, ANOVA, and the Durbin–Watson test. This comprehensive framework enables a more rigorous assessment of sensor performance in terms of accuracy, precision, and reliability.

The results show that the DHT11 sensor provides consistent measurements but tends to overestimate temperature by approximately 1–2 °C compared to the thermometer. The mean absolute error (MAE) of 1 °C and the mean absolute percentage error (MAPE) of approximately 3.4% indicate acceptable accuracy for general monitoring purposes. Furthermore, the regression model (Thermometer = $-13.600 + 1.400 \times \text{DHT11 Temperature}$) further reinforces the strong linear relationship, with a high correlation ($R = 0.944$) and an explanatory power ($R^2 = 0.891$).

Overall, these findings confirm that the DHT11 sensor is a reliable and practical solution for low-cost temperature monitoring. Although the statistical significance is marginal due to the small dataset, the consistent results across multiple analytical methods provide strong evidence supporting its applicability. Future studies should incorporate larger datasets and more diverse environmental conditions to further improve the robustness and generalizability of the results. A comparative analysis of earlier studies and the present research is presented in Table 3.

Table 3. Comparative Analysis of Earlier Studies and the Present Research

Previous Studies	This Study
Previous studies primarily focused on simple comparisons between DHT11 sensor readings and conventional thermometer measurements, typically reporting temperature differences of 0–2 °C.	In contrast, this study adopts a comprehensive MATLAB-based analytical approach that includes the evaluation of voltage, temperature, and humidity parameters, along with advanced statistical techniques such as error analysis, linear regression, ANOVA, and the Durbin–Watson test.
The analysis in these studies was generally limited to basic descriptive statistics, without the application of more advanced statistical methods for validation.	The descriptive analysis encompasses key statistical measures, including minimum, maximum, mean, and standard deviation, and is further strengthened by detailed error evaluation using metrics such as mean absolute error (MAE), mean absolute percentage error (MAPE), absolute error, and relative error.
As a result, the conclusions were mostly restricted to confirming that the DHT11 sensor is capable of measuring temperature and humidity, while lacking deeper evaluation in terms of measurement accuracy, precision, and overall reliability.	The results indicate that the DHT11 sensor provides consistent measurements, although it exhibits a slight overestimation of approximately 1–2 °C compared to a conventional thermometer. With an MAE of 1 °C, a MAPE of approximately 3.4%, a strong correlation coefficient ($R = 0.944$), and a high coefficient of determination ($R^2 = 0.891$), the DHT11 sensor can be considered reliable, cost-effective, and suitable for Internet of Things (IoT) applications and indoor environmental monitoring.

Overall, this study confirms that the DHT11 sensor is suitable for temperature monitoring applications, despite certain limitations. The results demonstrate that the sensor provides consistent measurements with acceptable accuracy when evaluated using comprehensive statistical methods. However, to improve the robustness and generalizability of the findings, future studies should incorporate larger sample sizes and a wider range of environmental conditions. Such improvements would enhance the statistical significance and reliability of the results. By integrating descriptive analysis, error metrics, regression modeling, and correlation analysis, this study offers a more rigorous and comprehensive evaluation framework compared to earlier research, thereby contributing meaningful insights to the existing body of knowledge.

4. CONCLUSION

This study evaluated the performance of the DHT11 sensor in measuring temperature and humidity by comparing it with a conventional thermometer using a comprehensive statistical approach. The results demonstrate a strong linear relationship between the DHT11 sensor and the reference instrument, as indicated by a high correlation coefficient ($R = 0.944$) and a high coefficient of determination ($R^2 = 0.891$), confirming a strong association and consistent tracking of temperature variations. In terms of measurement characteristics, the DHT11 sensor exhibits good precision, as reflected by consistent readings with relatively low variability. However, a slight systematic bias is observed, with the sensor tending to overestimate temperature by approximately 1–2 °C. The obtained error metrics (MAE = 1 °C and MAPE $\approx$ 3.4%) indicate that the sensor provides acceptable accuracy for general monitoring applications. Overall, the DHT11 sensor is a reliable, cost-effective, and practical solution for temperature and humidity monitoring, particularly in applications where high precision is not critical. Nevertheless, calibration is recommended to reduce measurement bias and improve accuracy for more demanding applications. Despite these promising results,

the study is limited by the small sample size, which affects the statistical significance and generalizability of the findings. Therefore, further investigation is required to strengthen the robustness of the conclusions.

To enhance the quality and applicability of future research, several improvements are recommended: (1) Future studies should utilize a larger dataset to enhance the robustness and generalizability of the analysis. (2) Experiments under varying environmental conditions (e.g., different humidity levels, temperatures, and airflow conditions) are necessary to evaluate sensor performance more comprehensively. (3) Comparative studies with higher-precision sensors (such as DHT22 or industrial-grade sensors) are recommended to better assess the relative accuracy of the DHT11. (4) The implementation of calibration techniques or correction models (e.g., regression-based calibration) should be explored to reduce measurement bias.

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