Advances and Applications in Statistics
© 2024 Pushpa Publishing House, Prayagraj, India
https://pphmjopenaccess.com
http://dx.doi.org/10.17654/0972361724009
Volume 91, Number 1, 2024, Pages 111-123 **P-ISSN: 0972-3617**

ANALYZING IMPRECISE DATA FROM WIRELESS TEMPERATURE SENSOR

Usama Afzal*, Muhammad Aslam, Muhammad Ahmed Shehzad and Florentin Smarandache

School of Microelectronics
Tianjin University
Tianjin 300072, P. R. China
e-mail: mohammadusamafzal7@gmail.com

Department of Statistics
Faculty of Science
King Abdulaziz University
Jeddah 21551, Saudi Arabia
e-mail: aslam_ravian@hotmail.com

Department of Statistics
Bahauddin Zakariya University
Multan, Pakistan
e-mail: ahmad.shehzad@bzu.edu.pk

Received: September 28, 2023; Accepted: November 29, 2023

2020 Mathematics Subject Classification: 98K80.

Keywords and phrases: sensors, monitoring, robotic technology, statistics analysis, neutrosophic method, flexibility, robotic data.

*Corresponding author

How to cite this article: Usama Afzal, Muhammad Aslam, Muhammad Ahmed Shehzad and Florentin Smarandache, Analyzing imprecise data from wireless temperature sensor, Advances and Applications in Statistics 91(1) (2024), 111-123.

http://dx.doi.org/10.17654/0972361724009

Published Online: December 21, 2023

Mathematics, Physics, and Natural Science Division
University of New Mexico
Gallup, NM, U. S. A.
e-mail: fsmarandache@gmail.com

Abstract

Various sensors play an important role in the monitoring and development of robotic technology. We present a contemporary statistical analysis method for evaluating datasets generated by robotic systems. Specifically, this data set originates from the physical structure of the robot and is acquired by a wireless temperature sensor. The data collection process spans a temporal period of 1 to 10 hours during the operational period of the robot. The collected data is subjected to a rigorous analysis using neutrosophic methodology. To facilitate this, a modern neutrosophic formula has been devised, drawing on definitions established within the field. To benchmark the effectiveness of the proposed approach, a conventional formula is also used for comparison purposes. Our results clearly indicate that the proposed method achieves higher levels of information richness and adaptability compared to classical methods. This indicates the improved utility of the proposed approach in solving the complexities of robotic data analysis.

1. Introduction

The use of the robotic technology in every field of life got importance. One can easily observe that man has created a good interaction system between human and robots and both work in combination (de Graaf et al. [13] and Etemad-Sajadi et al. [14]). Robotics technology is an effective example of the internet of things (IoT). However, for monitoring the robot, different sensors are used (Hadi Hosseinabadi and Salcudean [17]) as shown in Figure 1.

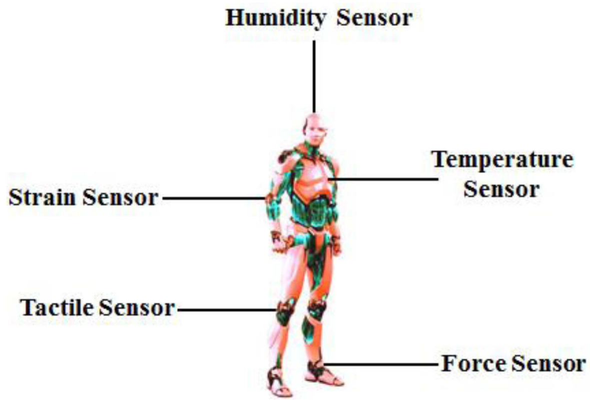

Figure 1. Use of different sensors to monitor.

The above figure is expressing the use of the sensors to monitor and measure different factors. Like temperature sensor is used for the detection of temperature of robotic body (Afzal et al. [1, 5]), humidity is used to measure the humidity effects (Afzal et al. [3]), strain sensor is used to measure strain effect (Liu et al. [20]), force sensor is used to measure applied force on robot body or by robot body (Ko et al. [19]) and tactile sensor is used for the detection of physical interaction (Afzal et al. [23]). If we talk about the communication medium, generally two types of medium are used for this purpose, i.e., wireless or non-wireless. However, nowadays wireless communication medium is widely used due to its high rate data transmission (Gu and Peng [16]). Figure 2 shows the wireless sensing data communication from robot body to the server. The sensors are responsible for the detection and then processors process sensing data. After, this communication unit transfers this data to the server.

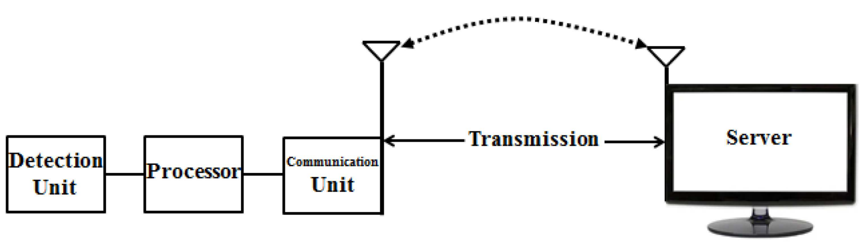

Figure 2. Communication setup.

After, collecting the data through server, it is analyzed through different statistics methods and approaches. Generally, classical statistics is widely used for analysis. It analyzes the single value or fixed value in well manner. But for interval values, it is not enough to analysis and explains the flexibility and complexity of data. That is why for proper analysis, we have to move other statistical methods and approaches like neutrosophic statistics. Neutrosophic is a method which is used to visualize the data and proposed by Smarandache [21]. Nowadays, the use of this technique has been enhanced to analyze the data in various fields, i.e., in medicine for diagnoses data analysis (Ye [24]), in applied sciences to analysis the conductor data (Afzal et al. [4]), in astrophysics for earth speed analysis (Aslam [8]) and others. Usama Afzal and his company have developed many applications of material statistics under the neutrosophic statistics for the analysis of sensors data (Afzal et al. [1-3, 5, 6]). The neutrosophic approach is based on the interval data with its indeterminacy to explain the difference of data (Aslam [9]). But the ancient method follows to deal with single value data and unable to explain the indefiniteness or difference of data (Afzal et al. [3], Chen et al. [11, 12] and Smarandache [22]).

1.1. Aim of the study

We develop an application framework to use neutrosophic statistical techniques in the analysis of interval-based temperature data. The temperature data set under consideration is acquired by wireless sensors integrated into the robotic structure. Notably, our initiative marks an important application of neutrosophic analysis in the realm of temperature data, particularly in describing the temporal variability exhibited by a robotic entity. A comparative aspect is realized through the inclusion of traditional methods, thus facilitating a comprehensive evaluation of the results.

2. Methodology

2.1. Neutrosophic approach

Let 'A_{iN}' be the neutrosophic numbers having A_{iL} lower values and A_{iU} upper values. Hence, the neutrosophic expression for the ith interval is as follows:

$$A_{iL} + A_{iU} I_{iN}; \quad I_{iN} \in [I_{iL}, I_{iU}]. \tag{1}$$

Here, $I_{iN} \in [I_{iL}, I_{iU}]$ is an indeterminacy interval and $A_{iN} \in [A_{iL}, A_{iU}]$ is an unsystematically neutrosophic variable having size $n_{iN} \in [n_{iL}, n_{iU}]$. The lower part/value of $A_{iN} \in [A_{iL}, A_{iU}]$ is the classical part/value and the upper part/value is the indeterminate part/value.

Similarly, neutrosophic mean $\overline{A}_N \in [\overline{A}_L, \overline{A}_U]$ is defined as follows:

$$\overline{A}_N = \overline{A}_L + \overline{A}_U I_N; \quad I_N \in [I_L, I_U]. \tag{2}$$

Here

$$\overline{A}_L = \sum_{i=1}^{nL} (A_{iL}/n_L) \quad \text{and} \quad \overline{A}_U = \sum_{i=1}^{nU} (A_{iU}/n_U).$$

The computational algorithm of the neutrosophic statistics is stated as follows:

- Start program.
- Select the interval $[A_L, A_U]$ and let $A_N \in [A_L, A_U]$.
- Run a loop for indeterminacy $I_N = I_L$ to $I_N = I_U$.
- Execute formula $A_{iN} = A_{iL} + A_{iU} I_{iN}$; calculate values.
- Draw graph.
- End program.

2.2. Classical approach

In classical statistical approach, we use the fixed point values. The data is in the interval form. So, we use the mean formula to convert interval point values into fix point values which is as follows:

$$A = (A_L + A_U)/2. \tag{3}$$

Here, 'A' is the interval with 'A_L' lower value and 'A_U' upper/higher value.

The computational algorithm of the classical statistics is stated as follows:

- Start program.
- Select the interval $[A_L,\ A_U]$ and let $A_N \in [A_L,\ A_U]$.
- Execute formula $A = (A_L + A_U)/2;$ calculate values.
- Draw point/graph.
- End program.

3. Data Collection

The data through the wireless temperature sensor of robot body can be seen in Table 1. These values are not measured from experiment but by concerning with different already published works (Gong et al. [15], Husain et al. [18] and Zukowski et al. [25]) and also using some consumptions. Because, in this work, we only want to explain the data analysis through modern statistics approach.

Table 1. Collection of data

Working time (hour)	**Temperature** (^{o}C)
1	[23.5, 24.8]
2	[24.2, 25.1]
3	[25.8, 26.4]
4	[27.2, 29.3]
5	[28.8, 29.9]
6	[32.1, 33.1]
7	[32.9, 34.6]
8	[34.9, 36.2]
9	[35.1, 35.9]
10	[35.7, 37.4]

The above table is expressing the interval data of temperature of robot with respect to working hours. With increase in working time, the temperature of the robot body has been also increased. However, our main concern is with the analysis of the above data.

4. Analysis of Data

As it is mentioned above, two types of statistical approaches have been used for the analysis of the electricity production data, i.e., classical and neutrosophic approaches.

Table 2. Classical and neutrosophic analyses of electricity production

Working time (hour)	**Temperature** (^{o}C)	
	Classical	**Neutrosophic**
1	24.15 ± 0.65	$24.8 + 23.5\, I_N;\; I_N \in [0, 0.052]$
2	24.65 ± 0.45	$25.1 + 25.1\, I_N;\; I_N \in [0, 0.036]$
3	26.1 ± 0.3	$25.8 + 26.4\, I_N;\; I_N \in [0, 0.023]$
4	28.25 ± 1.05	$27.2 + 29.3\, I_N;\; I_N \in [0, 0.072]$
5	29.35 ± 0.55	$28.8 + 29.9\, I_N;\; I_N \in [0, 0.037]$
6	32.6 ± 0.5	$32.1 + 33.1\, I_N;\; I_N \in [0, 0.030]$
7	33.75 ± 0.85	$32.9 + 34.6\, I_N;\; I_N \in [0, 0.049]$
8	35.55 ± 0.65	$34.9 + 36.2\, I_N;\; I_N \in [0, 0.036]$
9	35.3 ± 0.4	$35.1 + 35.9\, I_N;\; I_N \in [0, 0.022]$
10	36.55 ± 0.85	$35.7 + 37.4\, I_N;\; I_N \in [0, 0.045]$

Table 2 highlights the classical and neutrosophic analyses of electricity production. From the above table, it is seen that for classical approach, all the interval data have lost their indeterminacy as classical formula converts intervals into single value. However, there is some uncertainty is present for each interval due to some error. If we talk about the data variation, uncertainty does not accurately explain it. Because, error only expresses the specific addition or deduction in the value, for example 24.15 ± 0.65 means one can get either only 23.5 or 24.8. That is why, the classical analysis is not efficient in order to explain the difference of data interval by its maximum and minimum values and one cannot fully depend on it in other to making some decision or concluding a problem. The classical graph of the temperature with respect to working time can be seen in Figure 3. Similarly, if we see the neutrosophic formula, it provides much flexible as it gives an equation for each interval with indeterminacy interval (AlAita and Aslam [7]). It means intervals do not loss their indeterminacy (Aslam and Albassam [10]). Moreover, it is more efficient in explaining the variation of data interval with its maximum and minimum values. The neutrosophic graph of the temperature with respect to working time can be seen in Figure 4.

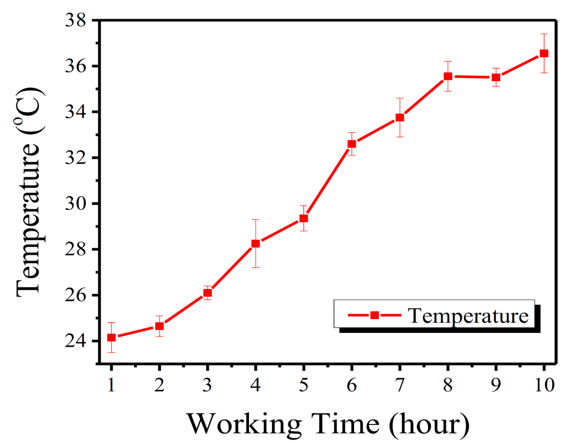

Figure 3. Classical graph of the temperature data.

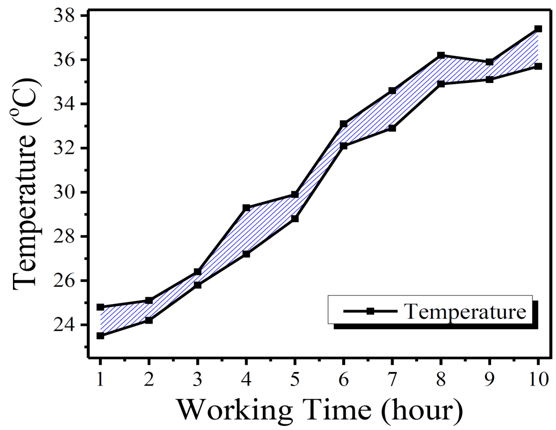

Figure 4. Classical graph of the temperature data.

For example, consider the temperature interval [23.5, 24.8] for the first working hour. The classical approach yields a point value of 24.15, while the neutrosophic approach straddles the range between 23.5 and 24.8. This neutrosophic value can be calculated using the neutrosophic formula using its indefinite interval.

To further evaluate the effectiveness of the proposed approach compared to the established classical method, a combined graph is constructed showing both classical and neutrosophic analyses. This assessment is summarized in Figure 5.

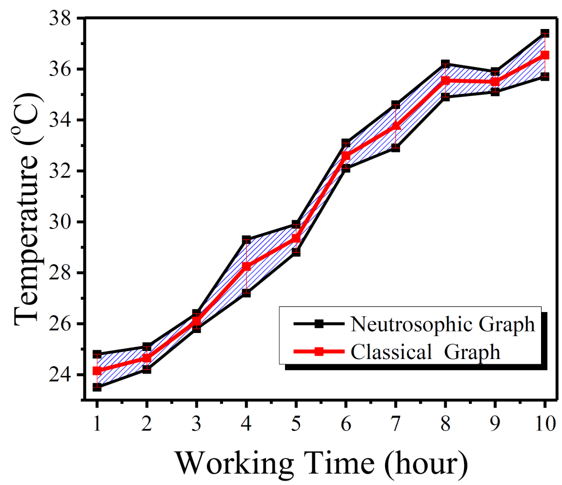

Figure 5. Combined graphs of classical and neutrosophic analyses.

The visual representation presented above provides meaningful insight. Graphs showing the results of classical analysis show that their adaptability is limited because their representation is limited to discrete single points. In contrast, graphs resulting from neutrosophic analysis exhibit the highest degree of adjustability, affording a more comprehensive and nuanced depiction of underlying trends. This observation confirms the notion that neutrosophic statistics offer a more efficient analytical framework.

Table 3. Comparison between classical and neutrosophic methods

Classical method	Neutrosophic method
The classical method relies on deterministic values adjusting for a degree of inherent uncertainty.	The neutrosophic method works based on interval values that are characterized by inherent uncertainty.
The classical method treats intervals as single values.	The neutrosophic method encompasses interval variations.
It exhibits relatively low flexibility and information content.	It exhibits high flexibility and information richness, which is attributed to the generalization status of the classical method.
It lacks a comprehensive treatment of probabilities, being characteristic of the classical method of assigning properties to true or false at any given time.	This addresses potential concerns well. This skill arises from the neutrosophic method's ability to simultaneously accommodate truth and falsehood for a statement within an indefinite interval.

This leads to the final conclusion that neutrosophic statistics inherently embody the properties of informativeness, flexibility and sufficiency that are postulated by classical statistical approaches. This deduction is strengthened by a comparative examination of the two methods, summarized in Table 3.

5. Conclusion

This investigation deals with the comprehensive analysis of data obtained from robotic systems using wireless temperature sensors with specific reference to temporal parameters. In particular, discernible trends emerge in which robotic body temperature shows a direct correlation with the operational duration range increasing from 23.5 to 37.4 degrees Celsius.

This dataset, captured in interval format, undergoes complex evaluation using both classical and neutrosophic statistical methods.

The resulting results clearly illustrate the limitations of the classical approach, which fails to adequately accommodate the multidimensional variability and complexity inherent to robotic temperature datasets. In stark contrast, the neutrosophic statistical approach emerges as distinctly more flexible and informative, better illustrating the relative variability and complexity within the data. Consequently, this investigation advocates the adoption of neutrosophic statistical techniques as the preferred method for interpreting interval-based robotic temperature data.

References

[1] U. Afzal, F. Afzal, K. Maryam and M. Aslam, Fabrication of flexible temperature sensors to explore indeterministic data analysis for robots as an application of Internet of Things, RSC Advances 12 (2022), 17138-17145. doi: 10.1039/D2RA03015B.

[2] U. Afzal, J. Afzal and M. Aslam, Analyzing the imprecise capacitance and resistance data of humidity sensors, Sensors and Actuators B: Chemical 367 (2022), 132092.

[3] U. Afzal, N. Ahmad, Q. Zafar and M. Aslam, Fabrication of a surface type humidity sensor based on methyl green thin film, with the analysis of capacitance and resistance through neutrosophic statistics, RSC Advances 11(61) (2021), 38674-38682.

[4] U. Afzal, H. Alrweili, N. Ahmad and M. Aslam, Neutrosophic statistical analysis of resistance depending on the temperature variance of conducting material, Scientific Reports 11(1) (2021), 1-6.

[5] U. Afzal, M. Aslam, F. Afzal, K. Maryam, N. Ahmad, Q. Zafar and Z. Farooq, Fabrication of a graphene-based sensor to detect the humidity and the temperature of a metal body with imprecise data analysis, RSC Advances 12(33) (2022), 21297-21308.

[6] Usama Afzal, Muhammad Aslam and Ali Hussein AL-Marshadi, Analyzing imprecise graphene foam resistance data, Materials Research Express 9(4) (2022), 045007.

[7] A. AlAita and M. Aslam, Analysis of covariance under neutrosophic statistics, J. Stat. Comput. Simul. 93 (2023), 397-415.

[8] M. Aslam, Enhanced statistical tests under indeterminacy with application to earth speed data, Earth Science Informatics 14 (2021a), 1261-1267.

[9] M. Aslam, A study on skewness and kurtosis estimators of wind speed distribution under indeterminacy, Theoretical and Applied Climatology 143(3) (2021b), 1227-1234.

[10] M. Aslam and M. Albassam, Forecasting of wind speed using an interval-based least square method, Frontiers in Energy Research 10 (2022), 469.

[11] J. Chen, J. Ye and S. Du, Scale effect and anisotropy analyzed for neutrosophic numbers of rock joint roughness coefficient based on neutrosophic statistics, Symmetry 9(10) (2017), 208.

[12] J. Chen, J. Ye, S. Du and R. Yong, Expressions of rock joint roughness coefficient using neutrosophic interval statistical numbers, Symmetry 9(7) (2017), 123.

[13] M. M. de Graaf, S. Ben Allouch and J. A. Van Dijk, Why would I use this in my home? A model of domestic social robot acceptance, Human-Computer Interaction 34(2) (2019), 115-173.

[14] R. Etemad-Sajadi, A. Soussan and T. Schöpfer, How ethical issues raised by human-robot interaction can impact the intention to use the robot? International Journal of Social Robotics 14 (2022), 1103-1115.

[15] Z. Gong, S. Jiang, Q. Meng, Y. Ye, P. Li, F. Xie and X. Liu, SHUYU robot: an automatic rapid temperature screening system, Chinese Journal of Mechanical Engineering 33(1) (2020), 1-4.

[16] G. Gu and G. Peng, The survey of GSM wireless communication system, Paper Presented at the 2010 International Conference on Computer and Information Application, 2010.

[17] A. H. Hadi Hosseinabadi and S. E. Salcudean, Force sensing in robot-assisted keyhole endoscopy: a systematic survey, The International Journal of Robotics Research 41(2) (2022), 136-162.

[18] M. D. Husain, S. Naqvi, O. Atalay, S. T. A. Hamdani and R. Kennon, Measuring human body temperature through temperature sensing fabric, AATCC Journal of Research 3(4) (2016), 1-12.

[19] D.-K. Ko, K.-W. Lee, D. H. Lee and S.-C. Lim, Vision-based interaction force estimation for robot grip motion without tactile/force sensor, Expert Systems with Applications 211 (2022), 118441.

[20] Z. Liu, C. Li, X. Zhang, B. Zhou, S. Wen, Y. Zhou and F. Zhou, Biodegradable polyurethane fiber-based strain sensor with a broad sensing range and high sensitivity for human motion monitoring, ACS Sustainable Chemistry and Engineering 10(27) (2022), 8788-8798.

[21] F. Smarandache, A unifying field in logics: neutrosophic logic, Neutrosophy, Neutrosophic Set, Neutrosophic Probability and Statistics, Infinite Study, 2005.

[22] F. Smarandache, Introduction to neutrosophic statistics, Infinite Study, Romania-Educational Publisher, Columbus, OH, USA, 2014.

[23] Usama Afzal, M. Aslam, Kanza Maryam, Ali Hussein AL-Marshadi and Fatima Afzal, Fabrication and characterization of a highly sensitive and flexible tactile sensor based on Indium Zinc Oxide (IZO) with imprecise data analysis, ASC Omega 7 (2022), 32569-32576. doi: https://doi.org/10.1021/acsomega.2c04156.

[24] J. Ye, Improved cosine similarity measures of simplified neutrosophic sets for medical diagnoses, Artificial Intelligence in Medicine 63(3) (2015), 171-179.

[25] M. Zukowski, K. Matus, E. Pawluczuk, M. Kondratiuk and L. Ambroziak, Patients temperature measurement system for medical robotic assistant, Paper Presented at the AIP Conference Proceedings, 2018.