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MCDM APPLICATION FOR BACTERIA MEASUREMENT DEVICES

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Abstract: This study explores the innovative use of gas sensors to detect bacterial infections. The fundamental reliance of this technique is on monitoring fluctuations in the quantities of biogenic gases produced by bacteria during their growth. Through analysis, these sensors can accurately identify the kind and severity of a disease by detecting chemicals such as ammonia and hydrogen sulphide. Preliminary studies indicate that gas sensors provide a rapid and non-intrusive method for diagnosing bacterial infections. Additionally, they possess a notable level of sensitivity and precision. This technology improves clinical results and reduces the transmission of infections, enabling healthcare personnel to administer the appropriate medications promptly

Keywords: Sensors, Diagnosis, Treatment, Analysis, Bacterial infection, Gases

Introduction

This study explores the innovative use of gas sensors to detect bacterial infections. The fundamental reliance of this technique is on monitoring fluctuations in the quantities of biogenic gases produced by bacteria during their growth. Through analysis, these sensors can accurately identify the kind and severity of a disease by detecting chemicals such as ammonia and hydrogen sulphide. Preliminary studies indicate that gas sensors provide a rapid and non-intrusive method for diagnosing bacterial infections. Additionally, they possess a notable level of sensitivity and precision. This technology improves clinical results and reduces the transmission of infections, enabling healthcare personnel to administer the appropriate medications promptly. This project aims to create a specialized Bacteria Measurement Devices (BMDs) application utilizing the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. The application will be designed for Multi-Criteria Decision Making (MCDM) purposes.

The proposed application will be an efficient tool for the evaluation and selection of BMDs by taking into account various traits. Yet, it tries to improve the provided knowledge and make it possible to make better decision in the sphere microbiological analysis. In this decision-making process, the TOPSIS technique will consider numerous BMDs from the standpoint of a variety of factors such as accuracy, economic feasibility, simplicity and reliability. The aim of the project is to design an easy to use instrument that aids in enhancing the decision-making criteria of the researchers, microbiologists, and healthcare practitioners regarding the selection of suitable BMDs according to a specific vital parameter.

Methods

Many electronic noses are now existent in the market and widely applied in several fields and industries. These electronic noses are applied in food industries, manufacturing industries, quality assurance, environmental sector, security, safety, and defence, and products industries, pharmaceutical, medical, microbiological and diagnostic sectors (1).

zNose

The Model zNose is specially a GC/SAW instrument which is highly portable designed for quick determination and identification of various forms of vapours as well as the traces of organic and chemical specimens. The device contains a built-in helium tank that may be refilled, and also it could be used in combination with disposable helium tanks. Lithium-ion battery is rechargeable, and its average working life span as estimated to be 6 hours. The 4300 and 7100 versions provide percent-value determinations with higher quantitative values than the 4600 model but require an additional PC. Nevertheless, the 7100 model has one major drawback, namely, it cannot be considered portable.

PEN3 Portable Electronic Nose

Depending on the multi-sensor system that is based on the gas-sensing material in the form of metal oxide.

There is also the offer to provide quick solutions to complicated decontamination situations, as well as from being overwhelmed by floods of contaminants that are beyond the dilution capability of the system in question. This contributes towards extending the life of the sensors and as well reducing the cycling period. This allows the modulation of gas flow and aids in the establishment of stability of the pattern based on the concentration and events of the analytical structure.

HERACLES NEO E-Nose

HERACLES NEO is an apparatus that can recognize smells and aromas in particular, by making use of the dual flash gas chromatography method to do analysis.

An example is that it can be manually injected and utilized with an autosampler. The system consists of a dual, fast gas chromatography electronic nose unit necessary to identify and analyze the volatility of substances in the sample. It also comprises a computer that is used in monitoring of the system, data acquisitions and processing within the Alpha Soft software.

In certain applications, the HERACLES NEO may integrate an autosampler into the design. This aspect undertakes the work of managing the samples and injecting them to reduce the workload of the analysis process.

GDA

It was developed to detect and monitor known hazardous substances such as chemical warfare agents, Gas masks, and to protect the respiratory systems of individuals. The first and main detector is the ion-mobility spectrometer which in turn detects ammonia, inorganic acidic gases, low molecular weight chlorinated compounds, and any other positively or negatively charged particles. It is also used in the CWA detection mode, in the IMS. The IMS works as a part of a whole system that comprises a photo ionization detector, an electrochemical cell, and two types of metal oxide sensors. The extension of supplementary detectors allows the GDA to monitor more toxic materials for instance benzene, phosgene, vinyl chloride, and chlorobenzene among others.

TOPSIS METHOD

The foundational principle of the TOPSIS approach was introduced for the first time by Hwang and Yoon in 1981. The alternate answer was selected based on a compromise between being the farthest from the ideal method (non-optimal solution) and being closer to a positive ideal solution (perfect solution) (2).

The TOPSIS method is based on the principle that the best option is the one that is farthest from the perfect answer and closest to the perfect great option. This concept is commonly utilized in certain models to address practical decision-making problems. The reason for this is that the notion is simple and easy to understand, computation is useful, and a basic mathematical formula can assess the comparative effectiveness of several decision options. The TOPSIS technique is based on the idea that the best choice is characterized by the greatest distance from the perfect answer and the shortest distance.

Key steps:

This approach's speed and ease of computation have contributed to its growing popularity. The decision-maker decides the weighting of the decision criteria, and no expert is involved in any further computations. For this reason, choosing the appropriate weights for this method is crucial. The following thoroughly explains the TOPSIS algorithm, which is based on (3).

Assuming that X = (xi j) m×n represents n criteria, the decision matrix with m alternatives is considered.

Step 1. Perform the normalized decision matrix calculation. The normalized values (rij) for profit and cost criteria were computed using the normalization equation.

$$(a_{ij})_{M \times N}$$

Step 2. Utilizing the equation, compute the weighted normalized decision matrix vi j.

$$v_{ij} = w_i r_{ij}$$

Step 3. Determine the vectors for the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS). PIS and NIS are the maximum and minimum values, respectively, for each condition (3) and (4). Since normalization is used in step 1 to convert cost criteria into profit criteria, there is no need to separate the criteria into profit and cost categories.

$$A^+ = (R_1^+, R_2^+, , R_m^+)$$

$$A^- = (R_1^-, R_2^-, , R_m^-)$$

Step 4. Calculate the distance between the alternative to the best and worst solution:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} (R_{ij} - R_j^+)^2}$$

$$D_i^- = \sqrt{\sum_{j=1}^{m} (R_{ij} - R_j^-)^2}$$

Step 5. proximity degree calculation:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

APPLICATION & RESULTS

The following table shows the alternatives and criteria. We have extracted it from the devices.

alternatives	Weight	Unit Cost	Maintenance Cost	Start-Up Time	Response Time	Sensitivity ppm	accuracy
zNose Series	14.6	$30,000.00	$4,300	15	5	10	78.8%
PEN3 Portable Electronic Nose	2.1	$26,693.00	$1000	20	4	1	99.27%
2 HERACLES NEO E-Nose	16	$11,000	$1500	20	120	10	90%
GDA	7.7	$50,000.00	$400	5	60	10	96.7%
Max/min	2.1 min	$11,000 min	$1000 min	5 min	5 min	10 max	99.27% max

To evaluate the provided options using the **TOPSIS methodology**, adhere to the following instructions:

Matrix for Decision Making:

Construct a choice matrix comprising five criteria: The criteria built and used to compare the contenders were: accuracy, throughput rate per hour, cost, the number of sensors, and the number of bacterial samples detected. The experts proposed a number of criteria to evaluate Coursework concepts, and they should define the relative importance of the criteria by assigning weights to them. For this example, let us assume that the weights are distributed as follows: For this example, let us assume that the weights are distributed as follows:

- Weight ($w1$) = 0.2
- Unit Cost ($w2$) = 0.2
- Maintenance Cost ($w3$) = 0.1
- Start Up Time ($w4$) = 0.15
- Response Time ($w5$) = 0.15
- Sensitivity ($w6$) = 0.1
- Accuracy ($w7$) = 0.1

Standardize the data:

Standardize the data for every alternative and criterion. Below is the standardized data for the provided options:

alternatives	Weight	Unit Cost	Maintenance Cost	Start-Up Time	Response Time	Sensitivity parts per million	accuracy
zNose Series	0.63	0.50	0.91	0.46	0.03	0.57	0.43
PEN3 Portable	0.09	0.0	0.21	0.61	0.02	0.05	0.54

Electronic Nose							
2 HERACLES NEO E-Nose	0.69	0.18	0.32	0.61	0.89	0.57	0.49
GDA	0.33	0.84	0.08	0.15	0.44	0.57	0.52

Determine the optimal and non-optimal solutions:

The maximum value in the weighted normalized matrix for each criterion in the Positive-Ideal Solution (PIS)

PIS = (0.139, 0.169, 0.092, 0.093, 0.134, 0.057, 0.054)

the smallest value in the weighted normalized matrix for each criterion in the Negative-Ideal Solution (NIS)

NIS = (0.018, 0.00009, 0.0085, 0.0231, 0.0044, 0.0057, 0.0430)

Calculate the separation measures:

Znose:

PIS Distance =

$$\sqrt{(0.63-0.139)^2+(0.50-0.169)^2+(0.91-0.092)^2+(0.46-0.093)^2+(0.03-0.134)^2 \\ (0.57-0.057)^2+(0.43-0.054)^2}$$

NIS Distance =

$$\sqrt{(0.63-0.018)^2+(0.50-0.00009)^2+(0.91-0.0085)^2+(0.46-0.0231)^2+(0.03-0.0044)^2 \\ (0.57-0.0057)^2+(0.43-0.0430)^2}$$

Pen3 portable electronic nose:

PIS Distance =

$$\sqrt{(0.09-0.139)^2+(0.0-0.169)^2+(0.21-0.092)^2+(0.61-0.093)^2+(0.02-0.134)^2 \\ (0.05-0.057)^2+(0.54-0.054)^2}$$

NIS Distance =

$$\sqrt{(0.09-0.018)^2+(0.0-0.00009)^2+(0.21-0.0085)^2+(0.61-0.0231)^2+(0.02-0.0044)^2 \\ (0.05-0.0057)^2+(0.54-0.0430)^2}$$

2 HERACLES NEO E-Nose:
PIS Distance =

$$\sqrt{(0.69-0.139)^2+(0.18-0.169)^2+(0.32-0.092)^2+(0.61-0.093)^2+(0.89-0.134)^2 \\ (0.57-0.057)^2+(0.52-0.49)^2}$$

NIS Distance =

$$\sqrt{(0.69-0.018)^2+(0.18-0.00009)^2+(0.32-0.0085)^2+(0.61-0.0231)^2+(0.89-0.0044)^2 \\ (0.57-0.0057)^2+(0.52-0.0430)^2}$$

GDA:

PIS Distance =

$$\sqrt{(0.33-0.139)^2+(0.84-0.169)^2+(0.08-0.092)^2+(0.15-0.093)^2+(0.44-0.134)^2 \\ (0.57-0.057)^2+(0.52-0.054)^2}$$

NIS Distance =

$$\sqrt{(0.33-0.018)^2+(0.84-0.00009)^2+(0.08-0.0085)^2+(0.15-0.0231)^2+(0.44-0.0044)^2 \\ (0.57-0.0057)^2+(0.52-0.0430)^2}$$

	S∗	S−	C∗
Znose	0.147	0.183	0.554
Pen3	0.259	0.071	0.216
Heracles	0.144	0.201	0.582
GDA	0.146	0.193	0.569

Assign A Numerical Ranking to Each of The Available Options: Since lesser distance implies that the evaluated alternative is better than other available alternatives, we may proceed to the ranking of the evaluated alternatives based on their C∗.

Heracles **(0.582)**

1- GDA **(0.569)**
2- Znose **(0.554)**
3- Pen3 **(0.216)**

Analyze and Explain the Findings:

Based on the decision-making criteria and using TOPSIS technique, the most appropriate candidate/alternative, which would come on top in ranking is Heracles. The first one is Heracles which is preferred the most, and the last one is Pen3 which is preferred the least. Ranking decision matrix is made by totaling up all aspects of the decision and comparing it with all aspects of the other options.

Sensitivity Analysis of MCDA Method Information

Multiple Criteria Decision Analysis (MCDA), which is a framework of several approaches, contemplates the ways to sort out alternative strings of actions through defined criteria (5). These instruments are very critical because they help in Decision Support Systems (DSS), which aid decision-makers in basing their ideas on data facts availed (6).

The theoretical base of MCDA is built on the use of input data that specifies evaluation criteria, they apply ability, and the range of alternatives undergoing the assessment process. By definition, preferences follow a series of procedures, and statistical adjustments result in each choice value (yes, this value characterizes their attractiveness compared to the other options). The complex decisions which entail a few considering factors and choices are the situations where this process becomes effective as an aiding factor to the decision-makers (7).

For such conditions when decision- making abilities of the bureaucrats are less reliable, MCDA-based systems facilitate quick and precise results' calculation. Two other advantages of such systems are the possibility of doing repeat computations by others and the immunity of the obtained results to influence which, as one can know, may be exercised when relying only on the experts' experience (8). Like it was emphasized earlier, every strategy developed in the MCDA group is characterized by a distinct approach to make the intended change (9), (10).

As such, their computations are based on distinct metrics that are generally applicable, irrespective of the approach (11). Several data normalization techniques (12), (13), subjective and objective criteria weighing methods (14), (15), (16), distance metrics (17), or data defuzzification in a fuzzy environment (18), (19), (20) are examples of popular approaches.

Sensitivity analysis is a commonly utilized method in multi-criteria calculations (21). It makes it possible to examine how resilient the findings are to particular modifications (22). Sensitivity analysis also investigates the connection between the process's input and output (23).

It should be kept in mind while creating DSSs based only on MCDA methodologies that an expert utilizing such a system would not have a thorough awareness of potential changes in the input data and their effect on the outcomes. The choice variations that are reviewed often have slightly different preference values (11), (24).

This suggest that the two types are equally appealing. Therefore, it would be reasonable to invest more efforts into outlining how the change of inputs that define the model affects rankings. That is the very spot where sensitivity analysis comes in handy. It then means that the decision-support models based on the decision-maker assumption are complete with, of course, full knowledge, and active contribution from the decision-maker (25).

Another fact that should be mentioned is that sensitivity analysis is defined as a research methodology used in many areas (22). It is an approach that can be applied to search for answers since it remains somewhat open-ended, which makes it useful in all types of research.

Sensitivity analysis is becoming increasingly common in many engineering and scientific domains, including almost all experimental data processing tasks, as well as many computer modeling and process simulation tasks (26), (27).

Sensitivity is described by (30) as "to ascertain how a given model (numerical or otherwise) depends on its input factors." Sensitivity may be quantitatively represented as (31):

$$S_i = \frac{\partial F}{\partial x_i}$$

The variable is xi, and the function F is a preset multivariable function defined as $F= (x1, x2, x3... xn)$. The sensitivity of F to xi is Si. It indicates the output's sensitivity to an input disturbance. The concepts used in this definition are absolute.

A different concept of sensitivity based on relative words was put forward and Sensitivity was described as:

$$S_i = \left(\frac{\partial F}{\partial x_i}\right)\frac{x_i}{F}$$

When the independent variable displays one unit of relative variation, it means the dependent variable's relative variation. F is considered sensitive to the variation of xi when |Si| > 1, and insensitive to the variation of xi when |Si| < 1 Compared to the definition given in terms of absolute terms (32), this one is far more relevant.

sensitivity analysis of MCDA method information in Biomedical Engineering

Assessing the effects of changes in criteria and inputs on the decision-making process and results is the aim of sensitivity analysis in Multi-Criteria Decision Analysis (MCDA) in Biomedical Engineering. Sensitivity analysis specifically seeks to:

1. Assess robustness: It also help to detect how much different the overall conclusions are as a function of the one or the other inputs or criteria. Focusing on this aspect, one can identify how sensitive a given decision, identifying whether it is sound or not depending on the stakeholders' assessment.

2. Determine crucial factors: Sensitivity analysis establishes the input variables or evaluation criteria within Biomedical Engineering that has the largest influence over the decisions made. This way, important aspects for such decision-making are given highest priority when it comes to identifying effort and resources to be directed.

3. Enhance decision-making: MCDA in Biomedical Engineering aims to determine weightage of inputs/attributes or criteria that have a relative importance by establishing sensitivity. For this reason, decision makers can be in a position to have made informed decisions which can lead to the best results by considering the likely consequences that can arise due to occurring specific situations.

In summary, by evaluating the sensitivity of results to changes in the criteria and inputs, sensitivity analysis in MCDA in Biomedical Engineering contributes to improving the robustness, efficacy, and dependability of decision-making processes. It helps decision makers to make well-informed choices that complement the objectives and specifications of Biomedical Engineering projects.

The Advantages and Disadvantages of Sensitivity Analysis in (MCDA) in The Field of Biomedical Engineering:

Advantages:

1. Better decision-making procedures: MCDA's sensitivity analysis is important in helping decision-makers who run or analyze medical data make informed decisions through establishing how adjustments to the criteria or inputs will result in changes in the analysis outcomes.
2. Giving precise insights: Sensitivity analysis is useful when used in medical data analysis for identifying the main factors and variables that produce great effects to lighten variables that have major impacts on the effects.

3. Improved planning and management: This can make it easier for one to determine threats that can be looming and the likelihood of how such threats can affect biomedical engineering projects in order that care and control mechanism can be instituted.

Disadvantages:

1. **Complexity of analysis:** the use of MCDA is flexible and often used when dealing with large and complex biological data; Nevertheless, sensitivity analysis may often be time-consuming and challenging.

2. Sensitivity to limited data: Thus, in case of inadequate or limited availability of data, there can be confusions in the outcomes of sensitivity analysis, as it would affect the accuracy of judgments.

3. Variability in interpretation: it is clear that the several different parties, involved in the given context might interpret the results of sensitivity analyses in a various way and might come to the various conclusions and, thus, make the various choices.

It is important to remember that the unique circumstances and difficulties of any project or application determine how well sensitivity analysis in MCDA may be applied in Biomedical Engineering.

Result and Discussion

We used excel to extract the results, and we get 4 cases by changing weight data

Case 1: using equal weight data.

		Si	Ki	Rank
1	Znose	**0.2102**	**0.6367**	**1**
2	Pen3	**0.1897**	**0.5747**	**2**
3	GDA	**0.1168**	**0.354**	**4**
4	Heracles	**0.1529**	**0.4632**	**3**

Case 2: using 50% beneficial and 50%non-benefical weight data.

		Si	Ki	Rank
1	Znose	0.217805312	0.662484711	**1**
2	Pen3	0.177845529	0.540941554	**2**
3	GDA	0.122276553	0.371920896	**4**
4	Heracles	0.153402284	0.466594072	**3**

Case 3: using 60% beneficial and 40%non-benefical weight data.

		Si	Ki	Rank
1	Znose	0.228334381	0.698893445	**1**
2	Pen3	0.16116009	0.493284149	**2**
3	GDA	0.129789702	0.397264625	**4**
4	Heracles	0.154007397	0.471390948	**3**

Case 4: using 70% beneficial and 30%non-benefical weight data.

		Si	Ki	Rank
1	Znose	0.236184916	0.734651371	1
2	Pen3	0.143539535	0.446478624	3
3	GDA	0.135719779	0.422155333	4
4	Heracles	0.153063255	0.47610208	2

Conclusion

The technique of using the gas-sensing devices in the case of bacterial infection is a major and appreciated development in the medical field. This methodology helps to minimize costs of medical treatment and finance, and at the same time improve the quality of services in the sphere of public health. In order to ensure that these advanced technologies help to monitor and minimize bacterial infections and enhance the standard of health care in the future the government and other players in the market must embrace partnership with different stake holders, cooperation in research and development of technologies.

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