International Journal of Combinatorial Optimization Problems and Informatics, 14(2), May-Aug 2023, 43-48. ISSN: 2007-1558.

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Complexity on Fuzzy set and Fuzzy Logic for Air Quality

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Abstract. The Air quality measurement is reported as micrograms per cubic meter or parts per million. In this article, we proposed a survey of the complexity on Fuzzy Logic for air quality. The traditional air quality assessment is estimated using air quality indices as mean values of selected air pollutants, where the ambient environment has given limits without considering specific local conditions and synergic relations between air pollutants and other meteorological factors. Different models analyze the structure of data to find the characteristics of air quality similarities and to interpret the classification results by means of fuzzy logic.
Keywords: Air quality, Complexity, Fuzzy set, Fuzzy logic.

Article Info
Received Dec 26, 2022
Accepted Dec 11, 2022

1 Introduction

The concept of Fuzzy logic was introduced by Mr. L. A. Zadeh in 1965 in the article entitled "Fuzzy Sets" [3]. The formulation of the fuzzy logic yields the accuracy or inaccuracy of propositions in fuzzy problem is called the membership function where this function should be compatible with the nature of process. To identify the process before defining the membership function, the researchers can use different rules to infer fuzzy like fuzzy maximum-minimum rule. In this step the researcher needs to produce a sampled inferences and it need to have compared them with reality by selecting fuzzy inference rules [5]. The minimum rule used as connector is the conjunction 'and', where the minimum value of propositions (equation 1) is accepted as an inference [4], and the maximum rule is used when a separator is used when the maximum value of propositions is accepted as an inference [4, 5].

Fuzzy Minimum Rule = min (a, b, c, d, ...) (1)
Fuzzy Maximum Rule = max (a, b, c, d, ...) (2)

2 Air Quality Index

The guidance proposed by the U.S. Environmental Protection Agency is designed to aid local agencies in reporting the air quality using the Air Quality Index (AQI). In this report the authors need to consider the follow [7]:

- The reporting area(s),
- The reporting period,
- The critical pollutant,
- The AQI,
- The category descriptor and, if reported in a color format, the associated color. Use only the following names and colors for the six AQI categories (table 1).
- Statements cautioning sensitive groups for a ll pollutants with an index value over 100 (table 2).

Table 1. Descriptors and colors for the six AQI categories.

AQI	**Descriptor**	**Color**
0 – 50	Good	Green
51 – 100	Moderate	Yellow
101 – 150	Unhealthy for Sensitive Groups	Orange
151 – 200	Unhealthy	Red
201 – 250	Very Unhealthy	Purple
251 – 300	Hazardous	Maroon

Table 2. Pollutant Specific Sensitive Groups

When this pollutant has an index above 100	**Report these Sensitive Groups**
Ozone	People with lung disease, children, older adults, and people who are active outdoors are the groups most at risk
PM2.5	People with heart or lung disease, older adults and children are the groups most at risk
PM10	People with heart or lung disease, older adults, and children and the groups most at risk
CO	People with heart disease are the group most at risk
SO_2	People with asthma are the group most at risk

3 Air Pollutants Model

Harmful substances are measured to identify the parameters of air quality modelling. These substances are emitted by external sources or generated secondarily in the air which harmfully influents of the environment after a physical or chemical transformation. The parameters are presented by Hajek and Olej [6] on figure 1 and table 3.

$$
\mathbf{P} = \begin{array}{c|ccccc:c}
 & p_1^t & \cdots & p_k^t & \cdots & p_m^t & \\
\hline
o_1^t & p_{1,1}^t & \cdots & p_{1,k}^t & \cdots & p_{1,m}^t & \omega_{1,j}^t \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
o_i^t & p_{i,1}^t & \cdots & p_{i,k}^t & \cdots & p_{i,m}^t & \omega_{i,j}^t \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
o_n^t & p_{n,1}^t & \cdots & p_{n,k}^t & \cdots & p_{n,m}^t & \omega_{n,j}^t
\end{array}
$$

Figure 1. Matrix P [6].

Table 3. Air Quality Modelling [6]

Parameters	
Harmful substances	$p_1^t = SO_2$, SO_2 is sulphur dioxide.
	$p_2^t = O_3$, O_3 is ozone.
	$p_3^t = NO$, NO_2 (NO_x) are nitrogen oxides.
	$p_4^t = CO$, CO is carbon monoxide.
	$p_5^t = PM_{10}$, PM_{10} is particulate matter (dust).
Meteorological	$p_6^t = SW$, SW is the speed of wind.
	$p_7^t = DW$, DW is the direction of wind.
	$p_8^t = T_3$, T_3 is the temperature 3 meters
	$p_9^t = RH$, RH is relative air humidity.
	$p_{10}^t = AP$, AP is air pressure.
	$p_{11}^t =$ SR is solar radiation.

Where:

$$o_i^t \in O, O = \{o_1^t, o_2^t, \dots, o_i^t, \dots, o_n^t\} \quad (3)$$

$$p_i^t \in P, P = \{p_1^t, p_2^t, \dots, p_i^t, \dots, p_n^t\} \quad (4)$$

O Set of objects

P Set of parameters

4 Industrial Pollutants

Vahdat and Nakhaee [2] proposed three sets to monitor pollutants:

1. Select the type of metallurgical process m from M = {iron and steel production, aluminum production, copper production, zinc production, etc.} (equation 5).
2. Set the area a that provokes pollution from A Where A_1[set of world factories] = {Khuzestan Steel, Isfahan Iron Melt, Bohler, Myhanaite, so on}, A_2 [world states or provinces] = {Mazandaran, Gilan, Florida, Texas, so on} or A_3 [world countries] {Iran, Japan, México, so on} (equation 6).
3. This step consists of set the typeof pollutant p from P = {carbon dioxide, carbon monoxide, sulfur dioxide, lead, nitrogen oxides, evaporative organic compounds, arsenic, lead and copper in water, so on} (equations 7, 8, 9, 10, 11).

$$M = \{i \in N, i \in [1, m], m_i\} = \{m_i\} \quad (5)$$

$$A = \{j \in N, j \in [1, a], a_{i,j}\} = \{a_{i,j}\} \quad (6)$$

$$P = \{k \in N, k \in [1, p], P_{i,j,k}\} = \{m_{i,j,k}\} \quad (7)$$

$$M = \{1,2, \dots m\} \quad (8)$$

$$A = \sum_1^n m \quad (9)$$

$$P = \sum_1^p m \quad (10)$$

$$P_{i,j,k\ Normalized} = (total\ k\ pollution\ in\ the\ a_{i,j})/(total\ mass\ production\ of\ a_{i,j}) \quad (11)$$

Where:
m_i can be described as the process i to be studied.
$a_{i,j}$ is the representation of the process i in area j to be studied
$P_{i,j,k}$ is the resultant amount of pollutant k in process i that is in area j.
$P_{i,j,k\ Normalized}$ is the amount of pollutant produced in area j for each unit of product of process i.

5 Models and algorithms

Upadhyaya and Dashore [1] proposed a fuzzy logic-based monitoring system able to calculate Air Quality Index (AQI). The authors mention the Air Quality Index as a simple and generalized way to describe the air quality in some countries like U.S, China, Hong Kong, Malaysia and India. The health-related index is proposed as: "Good (0-50)", "Moderate (51- 100)", "Unhealthy for sensitive groups (101-150)", "Unhealthy (151-200)", "Very Unhealthy (201-300)", "Hazardous (301-400)", "Hazardous (401-500)". For this research, the base of AQI is based on the level of 5 atmospheric pollutants: sulferdioxide (SO2), nitrogen dioxide (NO2), suspended particulates (PM), carbon monoxide (CO), and ozone (O3). The Air quality measurement is reported as micrograms per cubic meter (μgm/m3) or parts per million (ppm). In this article, the authors applied a real time Fuzzy Logic System with Simulink to calculate AQI.

Hajek and Olej [6] exposed the traditional air quality assessment is estimated using air quality indices as mean values of selected air pollutants, where the ambient environment has given limits without taking into account specific local conditions and synergic relations between air pollutants and other meteorological factors. the authors present a design of a model for air quality assessment based on a combination of Kohonen's self-organizing feature maps and fuzzy logic neural networks. The model analyzes the structure of data to find localities with similar air quality and to interpret the classification results by means of fuzzy logic.

Dunea, Pohoata, and Lungu [8] proposed a method in assessing the Air Quality Index (AQI) by employing a Mamdani fuzzy inference system (FIS) obtaining the AQI output. The authors defined rules structured by level of air pollutants concentration, the triangular and trapezoidal membership functions fitted to the intended purpose of computational efficiency. The fuzzyfication process is described by the authors at equations 12 – 16.

Maji et al. [9] determined the optimum number of ambient air quality monitoring stations. This proposal is a combination of fuzzy similarity measures (to classify or regroup monitoring stations for the most critical air pollutant PM and NO_2 for the defined possibility a-cut levels) and fuzzy c-mean (FCM) clustering (to average values of PM_{10}, NO_2, SO_2, CO and SPM for the winter months).

Upadhyaya and Dashore [10] applied a real time Fuzzy Logic System with Simulink to calculate AQI individual score assigning a level of each pollutant and the final AQI is the Highest of those scores.

Yadav et al. [11] applied Fuzzy C mean (FCM) clustering method to estimate the pollution status. The authors have also investigated the efficacy of fuzzy set theoretic approach in combination with genetic algorithm in straightway describing air quality in linguistic terms with linguistic degree of certainty attached to each description using Zadeh-Deshpande (ZD) approach.

Upadhyay et al. [12] presented a new methodology for air quality assessment using an AHP coupled fuzzy pattern recognition model. An approach was developed in this study to determine fuzzy air quality based on the observed air pollution concentration. This will help to identify the air pollution control measures that are required in a certain area. The proposed method is a multi-pollutant aggregation method with varying weighting, and has the capability to consider subjective factors like sensitivity and population density. The concentrations of the five air pollutant parameters (O3, CO, SO2, NO2, and PM10) were used to develop the model for air quality assessment.

Deshpande et al. [13] classified the environmental quality like air (Air Quality Index) and water (Water Quality Index). The proposal is based on fuzzy air quality description monitoring locations, and linguistic classification of water quality with degree of certainty.

Dashore et al. [14] proposed a fuzzy approach to calculate the air quality index of atmosphere. The fuzzy metagraph model suggest the outdoor activity based on AQI to protect human body.

Authors	**Research**	**Methods**
Upadhyaya and Dashore [1]	Air Quality Index	Real Time Fuzzy Logic System with Simulink
Hajek and Olej [6]	Air Quality Assessment	Kohonen's Self - Organizing Feature Maps and Fuzzy Logic Neural Networks
Dunea, D., Pohoata, A. A., and Lungu [8]	Air Quality Index	Fuzzy Inference Systems
Maji et al. [9]	Determine the Optimum Number of Ambient Air Quality	Fuzzy Similarity Measures and Fuzzy C-Mean Clustering
Upadhyaya and Dashore [10]	Air Quality Index	Fuzzy Logic based Monitoring System
Yadav et al. [11]	The air pollution status	Fuzzy C mean (FCM) clustering method and fuzzy set theoretic with genetic algorithm in straightway describing air quality.
Upadhyay et al. [12]	air quality assessment	AHP coupled fuzzy pattern recognition model
Deshpande et al. [13]	Air Quality Index	Fuzzy Air Quality Description
Dashore et al. [14]	Air Quality Index of Atmosphere	Fuzzy Metagraph model

Acknowledgements

The authors are grateful to CONACYT (National Council of Science and Technology) for its support. We thank Laboratorio Nacional en Vehículos Autónomos y Exoesqueletos (LANAVEX). Authors also express their gratitude to the Applied Computational Intelligence Network (RedICA).

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