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Application of Fuzzy logic in Noise Pollution & Air Quality - Review

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Abstract— Fuzzy means blurred, indistinct in shape or outline. In modern mathematical society, fuzzy is defined as a branch of modern mathematics that was formulated by Zadeh 1965 to model vagueness intrinsic in human cognitive process and to solve ill-defined and complicated problems because of ambiguous, incomplete, vague, and imprecise information that characterize the real-world system.Fuzzy logic has become a common way of dealing with information in various fields, such as control theory, smart machines, and investment analysis.Fuzzy Logic applications have been used in field of environmnental engineering field as well. Various research works has been carried out on different aspects of environment engineering such as Air quality, Noise Pollution, Water Qualty, Environment Impact Assessment, Solid waste Management.In this paper an effort has been made to review such application of fuzzy logic in Air Quality assessment and Noise Pollution using case studies.

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Index Terms— Fuzzy logic, Air Quality, Noise PIlution, Fuzzy Rule Based System, Fuzzy set theory,Air Pollution, Speech Interference.

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1 INTRODUCTION

URBAN environmental quality evaluation is an important part of environmental planning & management. It can help to identify major issues, priority areas of environmental quality in urban area. Because of the constraint of discontinuous classification and constraint of dealing with imprecise information, it is difficult for the environmental evaluation (based on traditional set theory) to reflect actual phenomenon precisely.[6] Noise is one of the most important factors in producing deterioration of both well being and quality of life of people in urban areas. Noise produces a series of physiological, psychological, behavioural changes in responses [10]. Fuzzy set theory provides framework for urban planners to evaluate urban environmental quality more effectively than conventional method [6]. The ever increasing rate of industrialization and urbanization, especially in developing countries, has led to increased levels of air pollution as well as increased concern about air pollution impact on human health. This has brought about a variety of strategies for air quality management and pollution control. Air quality indices are widely used in air quality management schemes [5]. In the fuzzy sets and systems membership functions are used to handle uncertainty or express vague concepts. Numerous methods for constructing membership functions, in the most fundamental way, may be classified into direct and indirect approaches [8]. Direct approach is totally base on experts opinion and they are expected to give answers to questions of various kinds that explicitly pertain to the constructed membership function [8]. On the other hand, in indirect approach, experts are required to answer simpler questions. These questions are only implicitly related to the constructed membership function and their answers are subject to further processing based on various assumptions [8].

Fuzzy logic refers to all of the theories and technologies that employ fuzzy sets, which are classes with unsharp boundaries. The concept of fuzzy modeling was originally proposed by [30] and developed further by other researchers [26]. The model proposed by [16] is based on the collections of IF-THEN rules with both fuzzy antecedent and consequent predicates and functional consequent; essentially they are a combination of fuzzy and non-fuzzy models. The main benefit of this model is its computational efficiency [8], [1]. An important trait of fuzzy model is that it uses fuzzy algorithm which is a knowledge-based algorithm, the essential concepts of which are derived from fuzzy logic. The fuzzy expert system is a knowledge-based system that contains the fuzzy algorithm in a simple rule-base.

2 SCOPE OF STUDY

The study presents the review of fuzzy logic application in noise pollution and air quality index by using different case studies.The study starts with a background of fuzzy logic and literature review of application of fuzzy logic in environmental field.

3 CASE STUDIES: APPLICATION OF FUZZY LOGIC IN NOISE POLLUTION

Noise has many ill effects on living beings as well as non-living things. The adverse effects of noise may include noise induced hearing loss, sleep disruption, speech interference; reduction in human work efficiency and annoyance.Some case studies on applications of fuzzy logic has been discussed here.

3.1 Case Study – I: Annoyance Level Measurment due to Noise Pollution using Fuzzy Logic

The study of measurement of percentage of annoyance level caused by road traffic noise pollution, a survey based on Agaratala city, a relatively medium-large urban city, situated in the North Eastern region of India and located at 23.50°N and 91.5°E has been under taken and the data obtained have been analyzed.[2]

It is important to study noise pollution from a quantitative point of view as well as from the point of view of the annoyance that it produces in the population [13]. Annoyance is measured in the interval [0, 1]; '0' represents the lowest degree of annoyance and '1' represents the highest degree of annoyance.

The sampling area is the Agartala city. The noise level was recorded from road side residences, offices, organizations, banks, etc which are at variable distances depending on the location of the building from the center of the road. Motor vehicular traffic prone sites of the city are identified and selected during the survey.

For this, the study is conducted in three levels. The first level predicts the percentage of Highly Annoyance (%HA) among the individuals in terms of various noise indices like: Day–Night Noise Level (Ldn), Traffic Noise Index (TNI), Equivalent Noise Level (Leq) and Maximum Equivalent Noise Level (Lmax). The second level describes the percentage of Highly Annoyance (%HA) in terms of average traffic volume, % of two wheelers, % of heavy vehicles and mean traffic speed. In third level i.e., Quis model based on Ldn has been used to predict percentage of Highly Annoyance. A comparison among observed values of %HA and values calculated by above three levels have been furnished.

TABLE 1
DESCRIPTION OF VARIOUS PARAMETERS COLLECTED AT EACH SELECTED LOCATION

Site	Traffic Condition	Sample Size	% High Annoyance	Noise Indices,dB(A)			
				L_{eq}	L_{dn}	L_{max}	TNI
L1	Medium, Congested	35	27.06	62.25	76.22	83.56	88.74
L2	Heavy, Congested	35	30.64	65.11	77.34	86.22	87.42
L3	Heavy, Congested	35	28.52	63.23	72.34	86.06	88.17
L4	Medium, Congested	35	26.15	60.56	74.52	82.12	87.64
L5	Medium, Congested	35	27.28	63.78	75.14	86.71	89.35
L6	Heavy, Congested	35	30.32	64.82	74.16	85.96	85.46
L7	Heavy, Congested	35	30.23	66.54	77.06	90.24	86.08
L8	Heavy, Congested	35	29.46	65.37	72.82	88..24	87.67

A relationship has been developed between different traffic noise parameters and its harmful impact on daily life of individuals using multiple regression analysis. In addition, statistical analysis was also carried out between measured and predictive values and a good agreement was noticed between observed and predicted value of noise based level.

3.2 Case Study – II: Predicting the Effects of Speech Interference due to Noise Pollution on Humans using Fuzzy Approach

An attempt has been made to develop an expert system using fuzzy approach to investigate the effects of noise pollution on speech interference.The speech interference measured in terms of speech intelligibility is considered to be a function of noise level, distance between speaker and listener, and the age of the listener. The main source of model development is the reports of World Health Organization (WHO) and field surveys conducted by various researchers. It is implemented on Fuzzy Logic Toolbox of MATLAB using both Mamdani and Sugeno techniques.[3]

The present fuzzy model has been developed to investigate the effects of noise pollution on speech interference.

The speech interference measured in terms of sentence intelligibility has been modelled as a function of noise levels, distance between the speaker and the listener, and the age of the person concerned. The model has been implemented on Fuzzy Logic Toolbox of MATLAB.

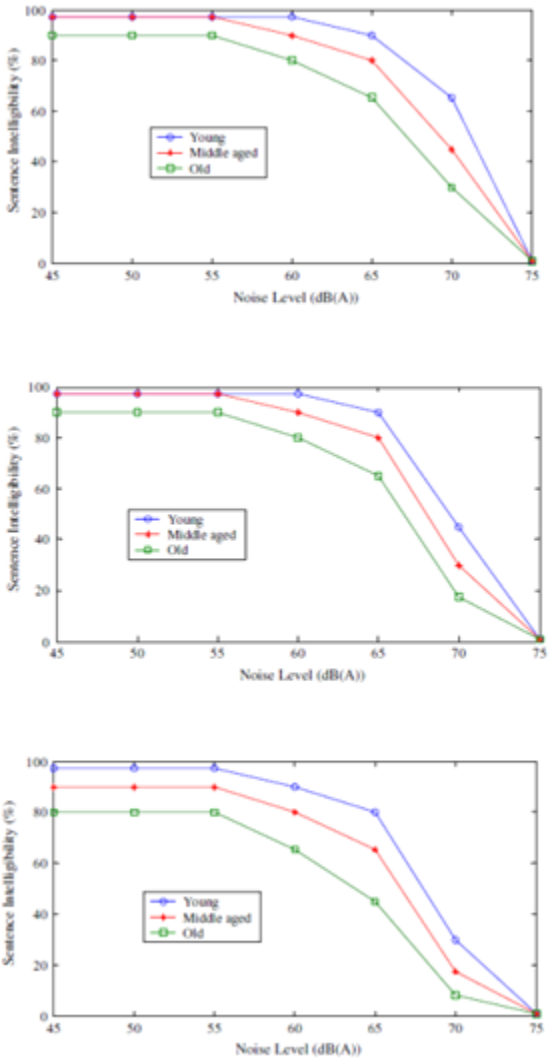

Fig. 1 Sentence intelligibility as a function of noise level forshort, medium, long distance with age as parameter

The results obtained from the proposed model are in good agreement with the findings of field surveys conducted in different parts of the world.

3.3 CASE STUDY – III: A FUZZY EXPERT SYSTEM FOR NOISE-INDUCED SLEEP DISTURBANCE

In this study, an attempt has been made to develop a fuzzy expert system for predicting the effects of sleep disturbance by noise on humans as a function of noise level, age, and duration of its occurrence. The modelling technique is based on the concept of fuzzy logic, which offers a convenient way of representing the relationships between the inputs and outputs of a system in the form of IF-THEN rules.[7]

Among them the intensity of the noise is considered to be the most important factor. It is related to sleep disturbance, with more intense stimuli awakening people more often (Bugliarello, Alexandre, Barnes, & Wakstein, 1976). For a good sleep, it is believed that the indoor sound pressure levels should not exceed approximately 30 dB(A) for continuous noise (Vallet & Vernet, 1991). Some studies show even an increase in the percentage of awakenings at 30 dB(A) (Passchier-Vermeer, 1993; Finegold, Harris, & von Gierke, 1994; Pearsons, Barber, Tabachnick, & Fidell, 1995). Noise events exceeding 45 dB(A) should be limited if possible. Most of the more recent field research on sleep disturbance has been conducted for aircraft noise (Fidell et al., 1995; Fidell, Howe, Tabachnick, Perason, & Sneddon, 1995; Fidell et al., 1998; Horne, Pankhurst, Reyner, Humer & Diamond, 1994; Passchier-Vermeer, 1994).

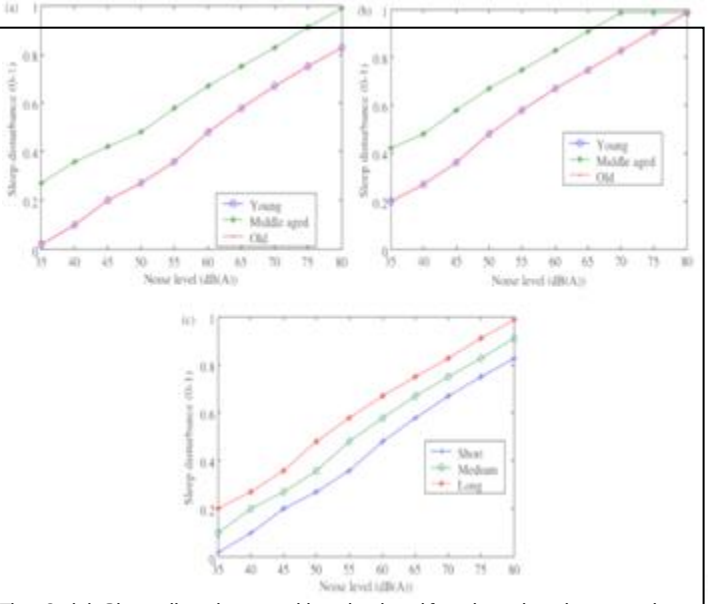

Fig. 2 (a) Sleep disturbance with noise level for short duration at various ages; (b) sleep disturbance with noise level for medium duration at various ages; (c) sleep disturbance with noise level for long duration at various ages.

It has been established on the basis of findings of various researchers that the effect of noise on sleep disturbance depends to a large extent on age. The middle-aged people have more probability of sleep disruption than the young people at the same noise levels. However, very little difference is found in sleep disturbance due to noise between young and old people. In addition, the duration of occurrence of noise is an important factor in determining the sleep disturbance over the limited range from few seconds to few minutes.

4 CASE STUDIES : APPLICATION OF FUZZY LOGIC IN AIR POLLUTION

Air pollution monitoring program aims to monitor pollutants concentrations and its possible adverse effects at various locations over concerned area on the basis of air quality. Traditional air quality assessment is realized using air quality indices which are determined as mean values of selected air pollutants. Thus, air quality assessment depends on strictly prescribed limits without taking into account specific local conditions (like time of exposure and sensitivity of the people) and synergic relations between air pollutants. Some case studies on applications of fuzzy logic has been discussed here.

4.1CASE STUDY – I: A NOVEL, FUZZY-BASED AIR QUALITY INDEX (FAQI) FOR AIR QUALITY ASSESSMENT

The ever increasing level of air pollution in most areas of the world has led to development of a variety of air quality indices for estimation of health effects of air pollution, though the indices have their own limitationssuch as high levels of subjectivity. Present study, therefore, aimed at developing a novel, fuzzy-based air quality index (FAQI1) to handle such limitations. The index developed by present study is based on fuzzy logic that is considered as one of the most common computational methods of artificial intelligence. In addition to criteria air pollutants (i.e. CO, SO2, PM10, O3, NO2), benzene, toluene, ethylbenzene, xylene, and 1,3-butadiene were also taken into account in the index proposed, because of their considerable health.[5]

Different weighting factors were then assigned to each pollutant according to its priority. Trapezoidal membership functions were employed for classifications and the final index consisted of 72 inference rules.

According to the basis of fuzzy logic and Mamdani inference system, weighting factors were assigned to the groups and the parameters included in accordance with the experts' knowledge based on the medical evidence available for the health effects of the air pollutants. In criteria group, PM10 and CO were given the highest priority, because they both have significant effects on human health which have been well established. For example, cardiovascular, cardiopulmonary, respiratory, pulmonary and systemic inflammatory, and recently carcinogenic effects of PM10 have been well documented in the literature (de Kok et al., 2006; Donaldson et al., 2005; Polichetti et al., 2009; Trasande and Thurston, 2005).

To assess the performance of the index, a case study was carried out employing air quality data at five different sampling stations in Tehran, Iran, fromJanuary 2008 to December 2009, results of whichwere then compared to the results obtained from USEPA air quality index (AQI).

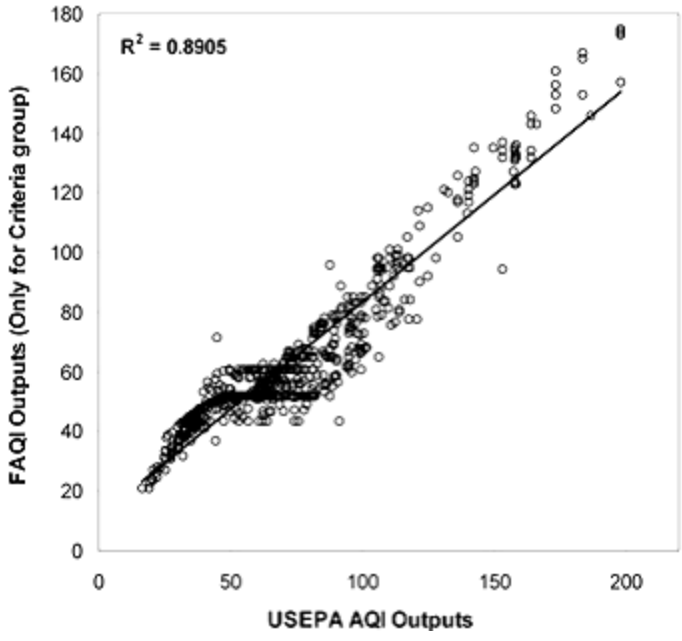

Fig. 3 Corelation betw een USEPA AQI & FAQI

According to the results from present study, fuzzy-based air quality index is a comprehensive tool for classification of air quality and tends to produce accurate results. Therefore, it can be considered useful, reliable, and suitable for consideration by local authorities in air quality assessment and management schemes.

4.2 Case Study – II: Application of Fuzzy Pattern Recognition Optimisation Model for Air Quality Assessment

This study includes, the use of fuzzy pattern recognition technique in air quality risk assessment for a number of artificial dataset prepared for the present study. To demonstrate the application, common air pollutants like PM10, PM2.5, SO2, NOx, CO, and O3 are used as air pollutant parameters. Different air pollutants have varying in health impact and hence in air quality, the weightage of each pollutant are different. Thus, the weightage of air pollutant parameter are determined using analytical hierarchical process (AHP).

The air quality values in fuzzy pattern recognition method is reflected by the relative membership degree of the sample; membership degree of 1 represents that the sample is having worst air quality, while the membership degree of 0 is having clean air. Thus the scale of air quality in fuzzy method is 0-1. Similarly, the scale in deterministic method is 0-4; 4 represents worst air quality (maximum air pollution) and 0 represents clean air (minimum or no air pollution). The air quality values are determined using both the method (fuzzy pattern recognition method and deterministic method).

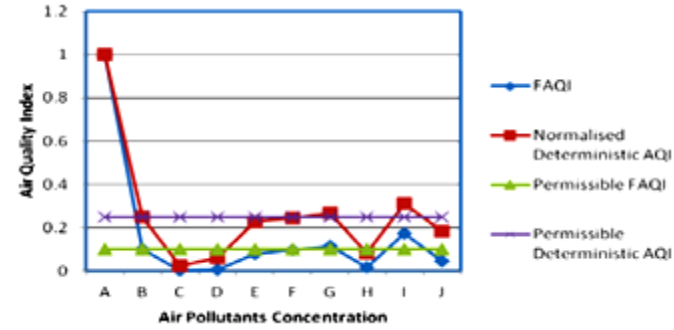

Fig. 4 Comparative Values Of Deterministic AQI And Fuzzy Method AQI

The result shows that the ranking in air quality for all the samples are same in both the method. The additional advantage of fuzzy method is that it can accommodate the other subjective parameters like time of exposure and sensitivity of the people in health impact assessment.

5 Conclusion

The main thrust of the present review work has been to study fuzzy logic application for the noise pollution and air pollution because the parameters involved in the environmental fields are inherently imprecise, vague, uncertain, and ill-defined. Fuzzy logic is the most convenient framework to convert these natural language descriptions into a fuzzy rule based systems using simple if-then rules. This study highlights the usefulness of fuzzy logic in environmental problems by syudying various case studies. Further development can be achived for solution of environmental engineering problems using fuzzy logic.

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