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A Fuzzy Rule-Based Engine to Predict Noise

Ramin Zare*[a], Seyed Majid Alavi[b]

[a] *Department of Environment, Arak Branch, Islamic Azad University, Arak, Iran*
[b] *Department of Mathematics, Arak Branch, Islamic Azad University, Arak, Iran*

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ABSTRACT

Noise annoyance can result from interference with daily activities, feelings, thoughts, sleep, or rest, and may be accompanied by negative emotional responses, such as irritability, distress, exhaustion, a wish to escape the noise, and other stress-related symptoms. Hence, the main aim of the current study is to provide an expert system using the fuzzy approach to determine the effects of noise environment on annoyance. Speech annoyance is considered to be a function of noise levels, exposure duration, the noise level in habitat, and age. It is implemented on fuzzy logic employing the Mamdani techniques. The results are found to be annoyance reactions in old are stronger than in young relative to the noise exposure. Annoyance reactions can be somewhat stronger due to the combined effects of the noise level in habitat, noise level, and age. The study showed that the noise level should not exceed 75 dB(A) for 'young' and 'middle-aged' and 64 dB(A) for 'old' persons.

1 Introduction

Since 1972, the World Health Organization (WHO) classified noise as a pollutant [26]. Noise, or unwanted sound, is a major environmental problem in the world today. Environmental noise is defined as noise emitted from all sources except noise at the industrial workplace. The extent of the noise problem in an urban environment is large. In the European Union countries, about 40% of the population are exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) daytime and 20% are exposed to levels exceeding 65 dB(A) [5, 21, 29]. Main sources of Environmental noise include traffic; industries; construction: public work; and the neighborhood. Noise may adversely affect the well-being and health of individuals. The adverse effects of noise may include noise-induced hearing loss; sleep disruption, speech interference, annoyance, and reduction in human work efficiency.

Noise annoyance is defined as a feeling of displeasure, nuisance, disturbance, or irritation

*Corresponding author's E-mail: r-zare@iau-arak.ac.ir

caused by a specific sound. Noise annoyance is a form of psychological stress that triggers different personal resource. On the other hand in comparison to other pollutants, the control of environment noise has hampered by insufficient knowledge of its effects on human and of dose-response relationships as well as a lack of defined criteria. Since this relationship, in general, is quite complex and Nonlinear in nature, an accurate mathematical representation is rather difficult.

Moreover, the parameters involved in this relationship are imprecise and uncertain, which cannot be dealt by conventional techniques [4,9,10]. In order to deal with such situations, a fuzzy model approach based on fuzzy logic, is considered to be the most appropriate [11-15]. In this paper, an attempt has been made to develop a fuzzy model for determining the work efficiency of humans as a function of noise level, exposure time, and the type of task. The modeling 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.

2 Noise Annoyance

Nowadays noise pollution is an important environmental problem for man. For noise-induced effects, source-specific assessments reveal the importance of both traffic and noise from neighbors. Noise is an unwanted sound which may adversely affect the well-being and health of individuals. The adverse effects of noise may include noise induced hearing loss; sleep disruption, speech interference, annoyance, and reduction in human work efficiency. Noise annoyance is a form of psychological stress that triggers different personal resources. Noise annoyance can be explained by acoustical and nonacoustical factors. Noise sensitivity is a personality trait covering attitudes towards noise in general and a predictor of noise annoyance. In 2000, about 25 million residents in the European Union reported being highly annoyed by road traffic noise [2,3]. The follow-up estimations in 2007 were much higher, showing that up to 50 million citizens in different European countries (approximately 20–25% of the population) were highly annoyed by noise.

3 Fuzzy Expert System

Fuzzy sets were introduced by Zadeh as a means of representing and manipulating data that was not precise, but rather fuzzy [30-43]. The use of fuzzy sets provides a basis for the manipulation of vague and imprecise concepts. In particular, we can employ fuzzy sets to represent linguistic variables. A linguistic variable can be regarded either as a variable whose value is a fuzzy number or as a variable whose values are defined in linguistic terms. A linguistic variable is characterized by a quintuple (x,T(x),U,G,M) in which

- X is the name of the variable;
- T(x) is the term set of x, that is , the set of names of linguistic values of x with each value being a fuzzy number defined on U;
- G is a syntactic rule for generating the names of x;
- and M is a semantic rule for associating with each value its meaning,

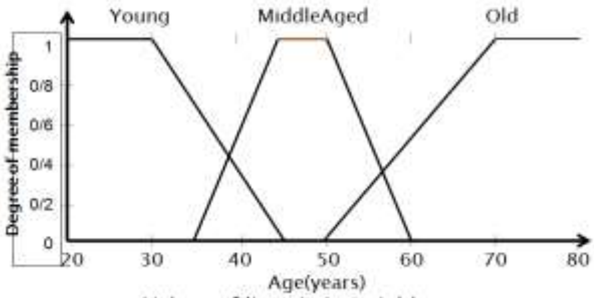
  for example, if the annoyance is interpreted as a linguistic variable, then its term set T (annoyance) could be:

T = { Young, MiddleAged, Old }

Where each term in T is characterized by a fuzzy set in a universe of discourse U =[0,100].
It might be interpreted

- Young as " 30–45years"
- MiddleAged as " 35–60 years"
- Old as " 50–70 years"

These terms can be characterized as fuzzy sets whose membership functions are shown the figure below:



Values of linguistic variable age.

It shoud be noted that the correct choice of the membership functions of a linguistic term set plays an essential role in the success of an application. Fuzzy logic control systems usually consist from four major parts: Fuzzification interface, Fuzzy rule-base, Fuzzy inference machine and Defuzzification interface.

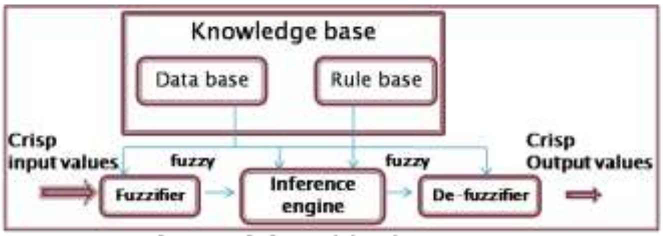


Fig. 1. Basic configuration of a fuzzy rule based system.

A fuzzy system is characterized by a set of linguistic statements based on expert knowledge. The expert knowledge is usually in the form of "IF-THEN" rules, which are easily implemented by fuzzy conditional statements in fuzzy logic.

the fuzzy implication is modeled by Mamdani minimum operator and the sentence connective also is interpreted as oring the propositions and defined by max operator. The output of the inference process so far is a fuzzy set, specifying a possibility distribution of the fuzzy output action. One must defuzzify the fuzzy control action (output)inferred from the fuzzy control algorithm. Defuzzification is a process to select a representative element from the fuzzy algorithm. The used defuzzification operator in this study is center-of-Area/Gravity.

4 Methodology

The methodology employed for developing the present fuzzy system is the following:

- Identify inputs and outputs and ranges.
- Define a primary membership function for each input output parameter.
- Construction a rule base.
- Selection of the appropriate reasoning mechanism for the formalization of the fuzzy model
- Verify that rule base output within its range for some sample inputs, and further validate that this output is correct and proper according to the rule base for the given set of inputs.

4.1 Inputs and outputs and ranges

in the present model the input variables are noise levels, exposure duration, noise level in habitat and age. The output variable is annoyance. Other factors such as gender, types of task, race, etc., which may influence the annoyance, have not been included.

4.2 Fuzzy partition of the input and output spaces

In this research we deal with four input and one output fuzzy systems. The input variables are "noise level" , "exposure duration" , "age" , "?". that domains are respectively [30,80] , [2,80] , [0,9] , [30,80]. The output variable is "Noise annoyance" with domain [0,100].

The fuzzy partition of the inputs are as follow:

- "Noise Level" can take 6 different value as "Low","medium",... . For each of this values we define a triangular fuzzy number as figure 3 that is fuzzy partition of the noise level.

-Exposure duration" take 5 different value as "few" , "medium","medium many ","many",numerius" that are difined respectively by fuzzy numbers as figure 5 that is fuzzy partition of the "exposure duration".

Table. 1: The input and output variables and renges.

System's variables	Linguistic variables	Linguistic values	Fuzzy intervals
Inputs	noise level	low	40–55 dB(A)
		Mediom	50–60 dB(A)
		Partly high	55–65 dB(A)
		High	60–70 dB(A)
		Very High	65–75 dB(A)
		High extremely	70–80 dB(A)
	age	Young	30–45years
		MiddleAged	35–60 years
		Old	50–70 years
	Exposure duration	Few	1-3 Hours
		Medium	1.5-5.5 Hours
		Medium-Many	3-6 Hours
		Many	5.5- 7.5 Hours
		Numerous	6.5-8 Hours
	noise level in habitat		40–55 dB(A)
		Quiet	40–55 dB(A)
		Quiet-Noisy	40–65 dB(A)
		Noisy	55–73dB(A)
		Very Noisy	63–78dB(A)
		Extremely Noisy	73–80 dB(A)
Output		not at all annoyed	10–30%
		moderately annoyed	20–50%
		annoyed	30–60%
		High annoyed	50–80%
		Extrmely annoyed	60–90%
			90–100%

-"age" take 3 different value "young","middleage", and "old" that we affer that by fuzzy numbers. As figure 4 that is fuzzy partition of "age".
- “noise level in habitant" take 5 different value as "Quit", Quit-noise","noisy","very noisy" and extra noisy" that represented by triangular fuzzy number as fig. 6 that is fuzzy partition.
Fuzzy partition of the output is as fallow:
The output variable is "noisy annoance" that take 6 different value as "not at all annoiance","moderately annoyed","high annoyed" and "exterely annoyed" that are represented by triangular fuzzy number as fig 7.
Note the support of fuzzy value of input and output linguistic variable is represented in Table 2.

4.3 Membership Function

It should be noted that the correct choice of the membership functions of a linguistic term set plays an essential role in the success of an application.

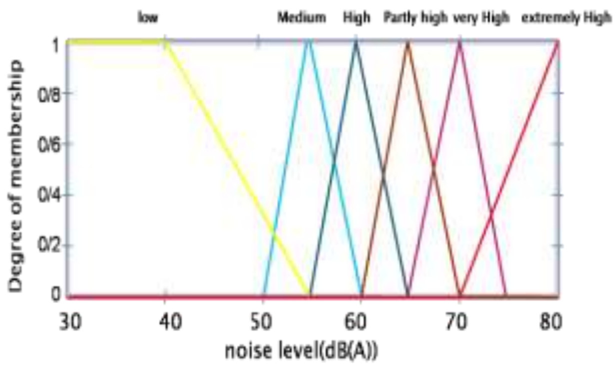


Fig.3.Membership functions for noise level.

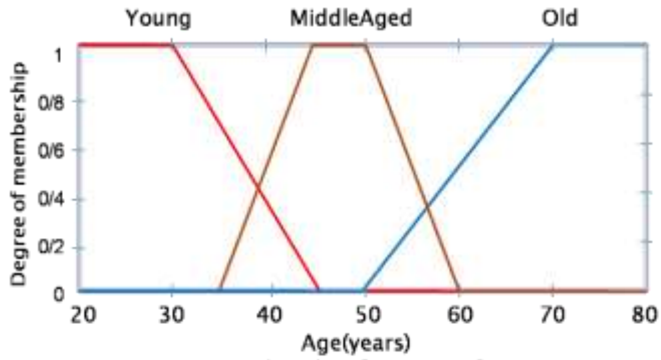


Fig.4.Membership functions for age

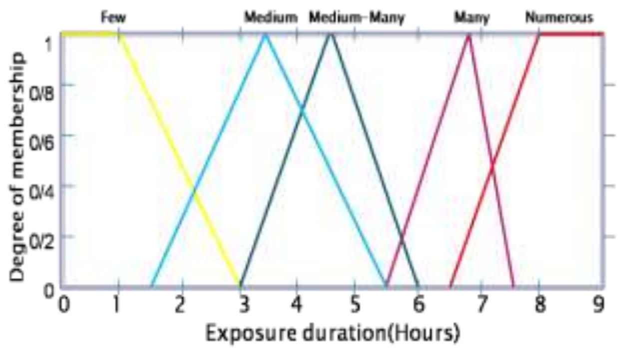


Fig.5.Membership functions for exposure duration.

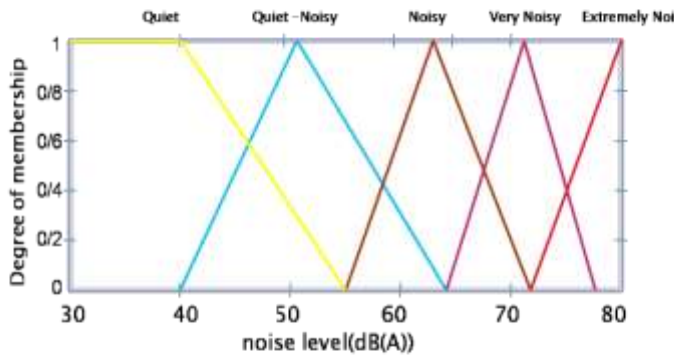


Fig.6.Membership functions for noise level in habitat.

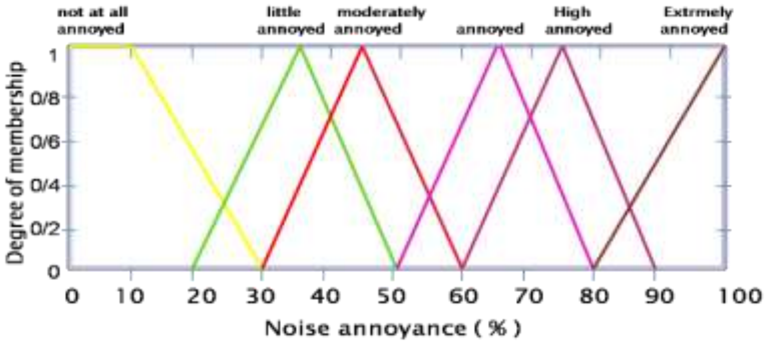


Fig.7. Membership functions for Noise annoyance.

4.4 Tule Bases of System

The construction of rule bases of the fuzzy system in this study is represented in table 2.

Table 2: Rule bases of fuzzy system

Rule's No.	noise level	age	exposure duration	noise level in habitat	Noise annoyance
1	low	Old	Numerous	Quiet-Noisy	Not at all annoyed
2	Mediom	MiddleAged	Numerous	Quiet-Noisy	not at all annoyed
3	Mediom	Old	Few	Quiet-Noisy	not at all annoyed
4	Mediom	Young	Numerous	Quiet-Noisy	not at all annoyed
5	Medium	MiddleAged	Numerous	Very Noisy	little annoyed
6	Medium	Old	Medium	Very Noisy	little annoyed
7	Partly high	MiddleAged	Medium	Very Noisy	little annoyed
8	Partly high	Young	Numerous	Very Noisy	little annoyed
9	High	Young	Numerous	Noisy	moderately annoyed
10	High	MiddleAged	Medium-Many	Noisy	moderately annoyed
11	High	Old	Medium	Very Noisy	moderately annoyed
12	Very High	Old	Medium	Noisy	annoyed
13	Very High	MiddleAged	Numerous	Noisy	annoyed
14	Very High	MiddleAged	Medium	Very Noisy	annoyed
15	Very High	Young	Numerous	Very Noisy	annoyed
16	Very High	MiddleAged	Medium-Many	Extremely Noisy	annoyed
17	Very High	Old	Numerous	Quiet	annoyed
18	Very High	MiddleAged	Numerous	Noisy	High annoyed
19	Very High	Old	Numerous	Noisy	High annoyed
20	Very High	MiddleAged	Numerous	Very Noisy	High annoyed

Table 2: Rule bases of fuzzy system

Rule's No.	noise level	age	exposure duration	noise level in habitat	Noise annoyance
21	Very High	Young	Numerous	Extremely Noisy	High annoyed
22	High extremely	Old	Medium	Very Noisy	High annoyed
23	High extremely	MiddleAged	Medium-Many	Noisy	High annoyed
24	High extremely	Young	Numerous	Noisy	High annoyed
25	High extremely				
26	High extremely	MiddleAged	Medium-Many	Extremely Noisy	Extrmely annoyed
27	High extremely	Old	Medium	Quiet-Noisy	Extrmely annoyed
28	High extremely	MiddleAged	Medium-Many	Very Noisy	Extrmely annoyed
29	High extremely	Young	Numerous	Very Noisy	Extrmely annoyed

4.5 Inference Mechanism

In this study the fuzzy implication is modeled by Mamdani minimum operator and the sentence connective also is interpreted as oring the propositions and defined by max operator. In this study Evaluation of the model adequacy implemented with Maple 12

Table 3: Specifications of the inference system

System type	Membership functions' type	Fuzzy operator	Implication method	Aggregation method	Deffuzification method	software
Mamdani	Trapezoidal	AND	Minimum	Maximum	Centroid	Maple 12

5 Results and Conclusions

This paper presents a model that uses a fuzzy rule-based engine to predict noise annoyance reported by individuals in Arak city. The rules are proposed by the human expert and are based on linguistic variables. The annoyance in the present model is considered to be a function of noise levels, exposure duration, noise level in habitat and age. The model has been implemented using Mamdani inference. The results are presented in figure 8 and figure 9, shows annoyance as a function of noise levels,exposure duration, noise level in habitat and age. The result shows that the annoyance remains unaffected up to the noise level of 55 dB(A) if the person is 'young' or 'middle-aged' and exposure duration is numerous and noise level in habitat is quiet-noisy. However, it is affected as the noise level increases and approaches to 100 (Ex-trmely annoyed)' at 80dB(A).

It is 'Extrmely annoyed (96%)', 'High annoyed (77%)', and 'annoyed (63%)' at 75 dB(A) for 'old', 'middle aged', and 'young' persons respectively and exposure duration " Many" and noise level in habitat " noisy". There is a systematic relationship between exposure duration, noise level and age. Similarly, Annoyance reactions in old are stronger than in young relative to the noise exposure. annoyance reactions can be somewhat stronger due to the combined effects of noise level in habitat, noise level and age.

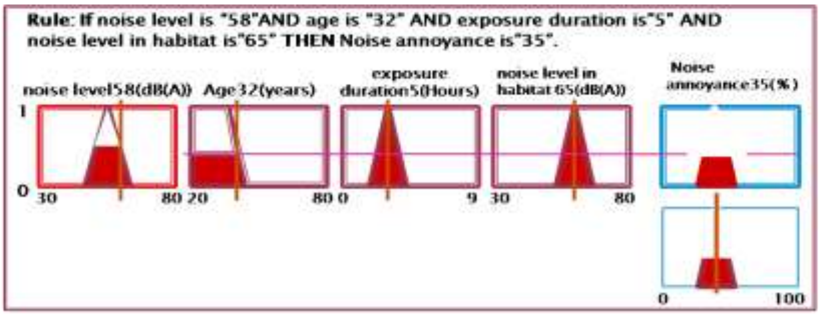


Fig. 8. Typical rule and their graphic representations in Mamdani approach

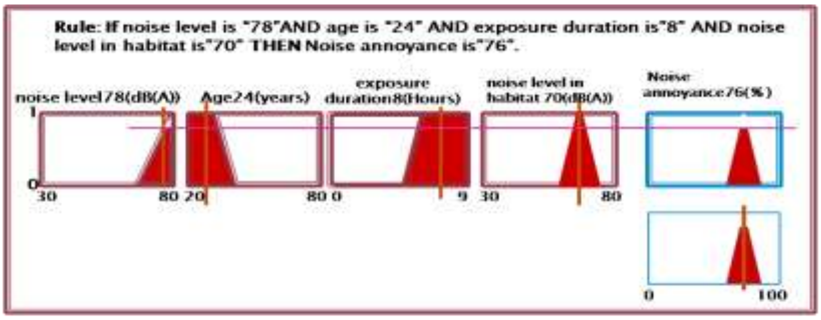
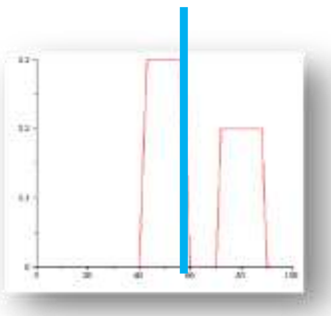
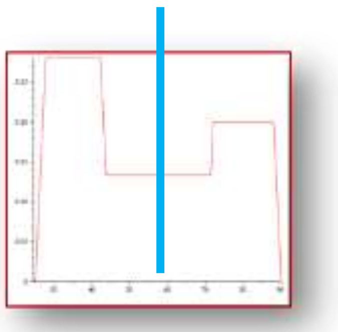


Fig. 9. Typical rule and their graphic representations in Mamdani approach





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