Fuzzy Expert System for Noise Induced Sleep Disturbance and Health Effects

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Abstract - In this paper an effort has been made to develop a fuzzy based model to study the impact of various noise factors on Sleep disturbance and Health. We thoroughly survey the existing literature and identify the deficiencies in the existing models in this field. We then identify various noise factors which can have the significant impact on Sleep and health. The MIMO Expert system developed in this paper gives sleep disturbance, health condition in the morning and health as output variables and noise level, short noise duration, long noise duration, age and Type of noise as the input variables. Appropriate fuzzification and defuzzification strategies have been used and the implementation in MATLAB 7.0.1 has been done. It has been established from work of various researchers that effect of meaningful noise like songs and talks affect sleep and health-conditions badly than meaningless noise like railway noise, roadside noise. Similarly other input variables affect sleep & health condition. These factors have been studied in this paper. The noise level and duration of noise, which are also the prominent factors in deciding effect on hearing output factor have been discussed, for e.g. a noise of low level does not have prominent affect on human being as of high level of noises..

Index Terms - Noise, Expert system, Fuzzy logic

INTRODUCTION

Noise, which is often referred to as unwanted sound, is typically characterized by the intensity, frequency, periodicity (continuous or intermittent) and duration of sound. Sound is the result of pressure changes in the air caused by vibration [2]. Noise effects on people is more than stress. Noise affects millions of people worldwide on a daily basis. Highway noise alone affects more than 18 million people in the United States and 100 million people worldwide [3]. Noise cannot only degrade the living of a person but can also produce some permanent ill-effects like hearing loss[1]. So it is crucial to have a model which can predict the effect of noise on different age groups. There are several factors which can disturb sleep like age, noise duration, noise level, type of noise, physical health, mental health, etc. but the main factors are age, noise duration, noise level and type of noise. It has been found that type of noise disturbs people's sleep in a significant manner. As described in [12], noise-induced sleep disturbance in urban areas degrades the quality of life and therefore must be given a high priority from a public health point of view. World Health Organization (WHO) in this regard has stated "If through living in an area that is too noisy, a person fails to obtain sufficient sleep over long periods of time, the implications for health are obvious". Uninterrupted sleep is known to be a prerequisite for good physiological and mental functioning of healthy persons. During the last four decades, there has been an exponential growth in noise level due to reasons like increase in population, increase in traffic density (both road and air), increase in industrial establishments, and increase in the use of various noise producing devices on several occasions [12]. So making a model on this concept is very necessary and useful. The type of noise is basically a very important factor in deciding the sleep disturbance. As the karaoke songs, people's talk, the noises which get meaning, disturbs people more and in the morning they don't feel good. The effect of this is shown in different ways like headache in morning, tiredness etc. . On the other hand if the noise is meaningless then people get disturbed only when the noise level is high as is shown in the experiments of S. Kuwano and T. Mizunami [8]. So this factor is considered as very important in deciding sleep disturbance and health conditions in the morning. In this paper basically four different types of noises are considered like karaoke songs, people's talk, railway noise[15] and road traffic noise[9]. There are other types of noises also like ventilation noise, air conditioner noise but they are not included in this model as they do not affect people much in all the three output variables. There are also some factors like psychological conditions, physical health etc. which can affect all output variables. This will be focus of our next research.

The effect of noise duration and noise level on the health of human beings is very high, for e.g when the noise duration is very less but the noise level is 75db (A) then hearing loss is also possible, on the other hand if noise duration is long and noise level is room noise then there is no danger to human ears.

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2. FUZZY LOGIC

A. Introduction

Boole[5] introduced the beautiful notion of binary sets, which is the foundation of modern digital computer but boolean logic is unable to model the human cognition and thinking process. Because of its rigid boundaries, the two valued logic is not so efficient in mapping real world situations. For handling real world problems Zadeh [6] introduced the concept of 'mathematics of fuzzy or cloudy quantities' followed by his seminal paper 'Fuzzy sets' [7]. Generally, the term fuzzy logic is used in two different senses [13]. In a narrow sense, fuzzy logic refers to a logical system that generalizes classical two-valued logic for reasoning under uncertainty. In a broad sense, fuzzy logic refers to all of the theories and technologies that employ fuzzy sets, which are classes with unsharp boundaries.

B. Fuzzy Expert System

Expert systems solve problems that are normally solved by human "experts" [17]. The problems that expert systems deal with are highly diverse. As specified in [19], the main paradigm of fuzzy expert-system (fuzzy rule based system) is the fuzzy algorithm, the essential concepts of which are derived from fuzzy logic. It is basically an expert knowledge-based system that contains the fuzzy algorithm in a simple rule base. As depicted in Fig. 1, a fuzzy rule based system is composed of four parts: fuzzifier, knowledge base, inference engine, and defuzzifier [11].

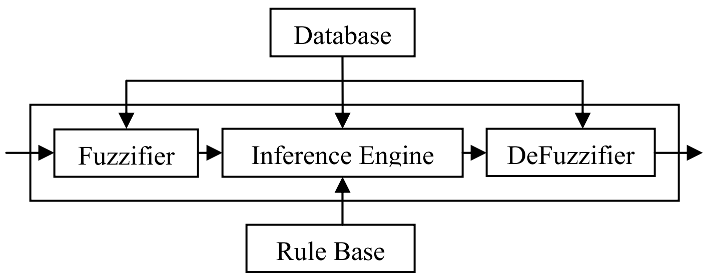

Figure1. The structure of Fuzzy Expert system[11].

In general, a fuzzy rule based system with multi-inputs multiple-output (MIMO) can be represented in the following manner:

IF X1 is A1 AND X2 is A2 AND
.. . AND Xr is Ar
THEN Y1 is C1 AND Y2 is C2 AND
… AND Ys is Cs

Where X1, X2,., Xr are the input variables and Y1, Y2,., Ys are the output variables, Ai (i=1,., m) and Ci (i=1,., s) are fuzzy subsets of the universes of discourse U1, U2,., Ur, and V1, V2,., Vs of X1, X2,., Xr and Y1, Y2,., Ys respectively.

3. PROPOSED FUZZY SYSTEM

In 1975 Mamdani and Assilian proposed MIMO model. Using this model, a new type of Fuzzy Expert System is implemented, the following equations define this system:

V1=F(U1,U2,U3,U5);
V2=F(U1,U4);
V3=F(U1,U3,U5).

Where V1, V2, V3 are output variables sleep disturbance, health effects, health condition in morning res. and U1, U2, U3, U4, U5 are input variables noise level, age, type of noise, long noise duration, short noise duration res. .

For the development of this fuzzy expert system the following steps are followed:

1. System's variables are identified;
2. Ranges of input and output variables are determined.
3. Membership functions for system's variable is selected.
4. Linguistic rules are formed.

The various input and output variables can be considered for this system like stage of sleep, psychological health condition, physical health condition, duration of noise, status of a person and so on but for the sake of simplicity only five input variables viz. long noise duration, short noise duration, noise level, age and type of noise are considered. Similarly only three output variables are considered viz. sleep disturbance, health effects, health condition in morning. The MIMO model of fuzzy system is shown in Fig.2, depicting its various input and output variables. These variables in fuzzy modelling are defined as linguistic variables whose linguistic values are words or sentences in a natural or synthetic language (Zadeh, 1994) [18]. Then in the next step table 1 is formed which shows linguistic variables, their linguistic values and associated fuzzy intervals. For instance corresponding to the linguistic variable Noise-Level, linguistic values are Extremely Extremely Low (EEL) to Very Very High Extremely High (VVHEH), fuzzy interval from 25 dB(A)to145Db(A) is assigned. In third step all linguistic values are expressed in the form of fuzzy sets, which are represented by its membership functions. The Triangular membership function is used as it is simple and computationally efficient. Membership functions for this system are shown in Fig 3 a-h. Finally, through IF-THEN rules, the relationship between input and output variables are formed. A set of rules are illustrated in Table 2. This model is implemented in MATLAB 7.0.1.

4. RESULTS AND DISSCUSSION

In this Mamdani & Sugeno fuzzy model, Sleep disturbance, health effects, health condition in morning are considered to be a function of long noise duration, short noise duration, noise level, age and type of noise. The results are plotted using MATLAB 7.0.1 and are shown in Fig. 4a-I, Fig. 4(a) shows output variable Sleep Disturbance as function of age and noise level and other input variables at their default value. Fig. 4(a) shows output variable Sleep Disturbance as function of age and noise level and other input variables at their default value. Fig. 4(b) shows output variable Sleep Disturbance as function of short noise duration and noise level and other input variables at their default value. Fig. 4(c) shows output variable Sleep Disturbance as function of long noise duration and noise level and other input variables at their default value. Fig. 4(d) shows output variable Sleep Disturbance as function of Type of noise and noise level and other input variables at their default value. Fig. 4(e) shows output variable Health effects as function of age and noise level and other input variables at their default value. Fig. 4(f) shows output variable Health effects as function of short noise duration and noise level and other input variables at their default value. Fig. 4(g) shows output variable Health effects as function of Type of Noise and noise level and other input variables at their default value. Fig. 4(h) shows output variable Health effects as function of Long noise duration and noise level and other input variables at their default value. Fig. 4(i) shows output variable Health condition in morning as function of Long noise duration and noise level and other input variables at their default value.

5. CONCLUSION

A new type of Fuzzy MIMO Expert system has been successfully implemented using Matlab 7.0.1. This MIMO system predicts the health effect, health condition in the morning and sleep disturbance, taking five different types of input variables viz. type of noise, age, short noise duration, long noise duration, and noise level. This fuzzy expert system can be used for knowing health effects in noisy region. This fuzzy expert system will prove to be a guideline for making new expert systems in future and can be effectively used in medical engineering.

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TABLE 2 SET OF RULES.

1. If (Noise_level is EL) and (Age is Young) and (Short_Noise_Duration is Short) then (Sleep_Disturbance is ES)(Health_effects is Comfortable) (1)

2. If (Noise_level is EL) and (Age is Young) and (Short_Noise_Duration is Medium) then (Sleep_Disturbance is VVS)(Health_effects is Comfortable) (1)

………

308. If (Noise_level is VVHEH) and (Age is Old) and (Short_Noise_Duration is Long) and (Type_of_noise is Road_traffic) then (Health_effects is beyond_Thershold_of_pain) (1)

309. If (Noise_level is VVHEH) and (Age is Old) and (Short_Noise_Duration is Long) and (Type_of_noise is Karoke_songs) then (Health_effects is beyond_Thershold_of_pain) (1)

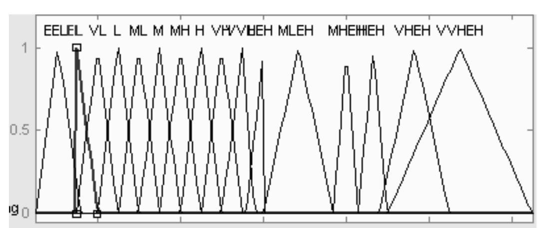

Figure 3a: Noise Level

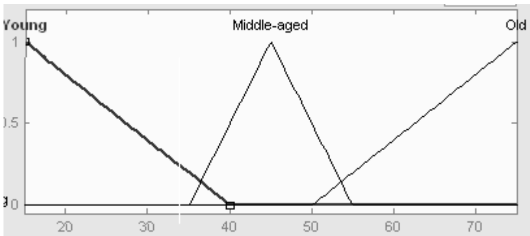

Figure 3b: Age

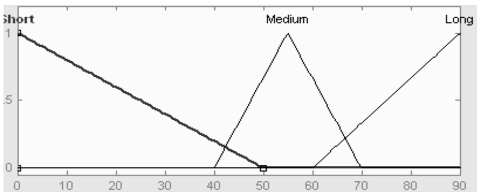

Figure 3c: Short Noise Duration

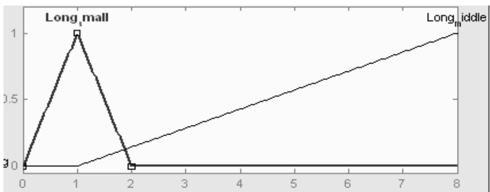

Figure 3d: Long Noise Duration

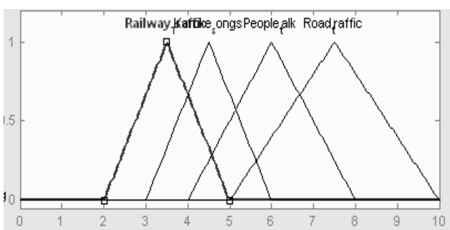

Figure 3e: Type of Noise

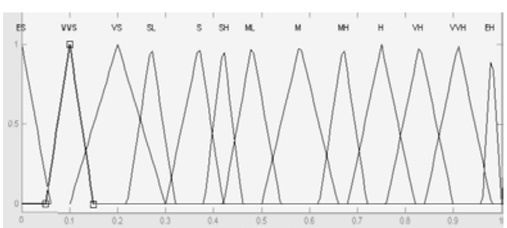

Figure 3f: Sleep Disturbance

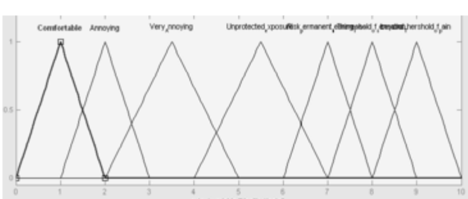

Figure 3g: Health Effects fig

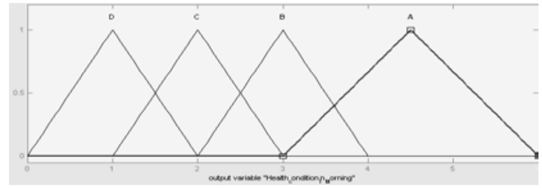

Figure 3h: Health_condition_in_morning

Figure 3: Showing membership functions for all input and output variables

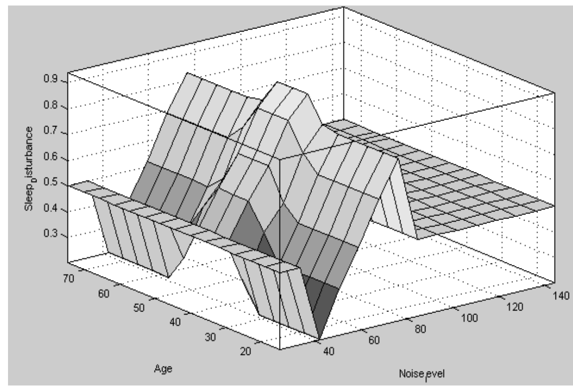

Figure.4a: Output (Sleep Disturbance), inputs noise level and age.

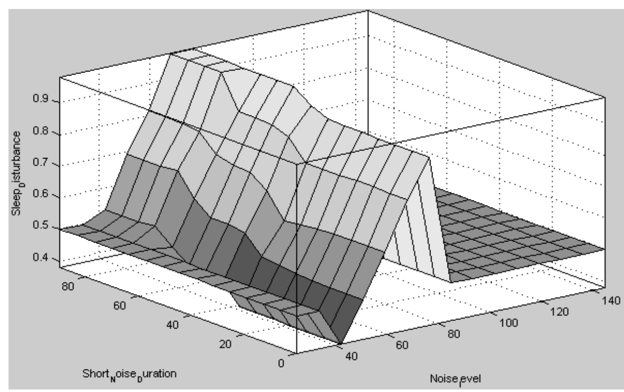

Figure.4b: Output (Sleep Disturbance), inputs noise level and short noise duration.

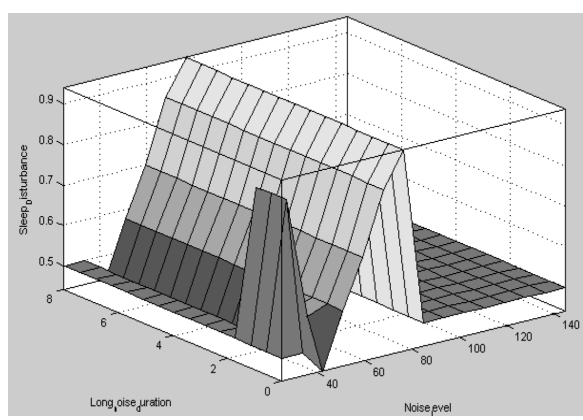

Figure.4c: Output (Sleep Disturbance), inputs noise level and Long noise duration

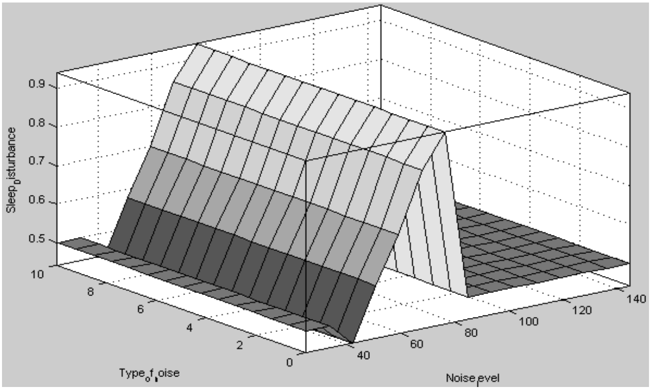

Figure.4d: Output (Sleep Disturbance), inputs noise level and Type of Noise

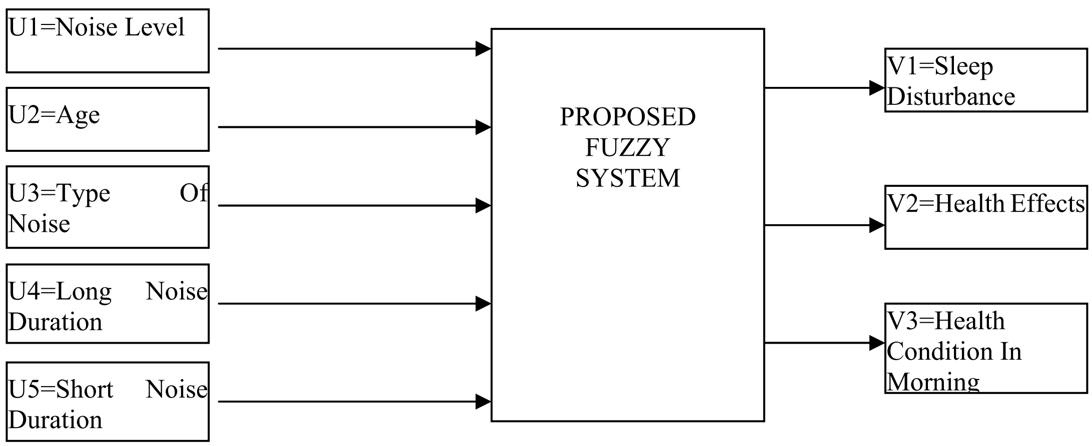

Figure 2: Fuzzy model for this system.

S.NO.	System's variables	Linguistic variables	Linguistic values	Fuzzy intervals
1.	Inputs	Noise level	EEL-Extremely Extremely Low	25 -36 dB(A)
			EL - Extremely Low	35 – 40 dB(A)
			VL - Very Low	35 – 45 dB(A)
			L - Low	40 -50 dB(A)
			ML - Medium Low	45 – 55 dB(A)
			M – Medium	50 – 60 dB(A)
			MH – Medium High	55 – 65 dB(A)
			H – High	60 – 70 dB(A)
			VH – Very High	65 – 75 v
			VVH - Very Very High	70 – 78 dB(A)
			LEH – Low Extremely High	76 – 80 dB(A)
			MLEH – Medium Low Extremely High	80 – 97 dB(A)
			MHEH - Medium High Extremely High	96.8 – 103 dB(A)
			HEH - Medium Extremely High	103 – 110 dB(A)
			VHEH- Very High Extremely High	108 – 125 dB(A)
			VVHEH – Very Very High Extremely High	110 – 145 dB(A)
2.		AGE	YOUNG	15 – 40 years
			MIDDLED-AGED	35 – 55 years

S.NO.	System's variables	Linguistic variables	Linguistic values	Fuzzy intervals
			OLD	50 – 75 years
3.		SHORT NOISE DURATION	SHORT	0 – 50 sec.
			MEDIUM	40 – 70 sec.
			LONG	60 – 90 sec.
4.		LONG NOISE DURATION	LONG-SMALL	0 – 2 Hrs.
			LONG-MIDDLE	1 -8 Hrs.
5.		TYPE OF NOISE	RAILWAY_TRAFFIC	2 – 5
			KAROKE_SONGS	3 – 6
			PEOPLE_TALK	4 – 8
			ROAD_TRAFFIC	5 – 10
6.	OUTPUT	SLEEP_ DISTURBANCE	ES – Extremely Small	0 - 0.06
			VVS – Very Very Small	0.05 - 0.15
			VS - Very Small	0.1 - 0.3
			SL –Small Low	0.22 - 0.32
			S - Small	0.3 - 0.42
			SH - Small	0.38 - 0.46
			ML – Medium Low	0.42 - 0.54
			M - Medium	0.5 - 0.66
			MH - Medium High	0.62 - 0.72
			H - High	0.68 - 0.82
			VH - Very High	0.76 - 0.9
			VVH - Very Very High	0.84 - 0.98
			EH - Extremely High	0.96 – 1
7.		HEALTH_EFFEC TS	COMFORTABLE	0 – 2
			ANNOYING	1 – 3
			VERY_ANNOYING	2 – 5
			UNPROTECTED_EXPOSURE	4 – 7
			RISK_PERMANENT_HEARING_LOSS	6 – 8
			THERESHOLD_OF_SENSATION	7 – 9
			BEYOND_THERSHOLD_OF_PAIN	8 – 10
8.		Health_condition_ in_morning	D - could not sleep and have headache	0 – 2
			C - could not sleep well, but do not feel bad	1 – 3
			B - slept well, but feel bad	2 – 4
			A - could not sleep and have headache	3 – 6

Table 1: Inputs and output with their associated fuzzy values.