SOUND CHARACTERIZING USING AI TECHNIQUE

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Abstract -This study concentrated on how to characterize sound signal using AI (Artificial Intelligence) technique. The software implemented was MATLAB Fuzzy Toolbox and MATLAB Simulink based on MATLAB 6.5 version. The sound or signal generated by the signal generator will be classified using simulation model developed in the MATLAB Simulink. The output result will be displayed in numerical form represented the frequency division e.g. VLF, LF, and MF etc.

Keyword: MATLAB Fuzzy Toolbox, MATLAB Simulink, Simulation model, classified.

1.0 INTRODUCTION

In our daily life, sound is essential to us. As to our hearing sense, it has the limitation. In our environments there are a lot of sounds or signals that are invisible to us but there are actually present. This is because there are located above of human hearing capability in different frequency ranges call ultrasound [4]. The classification of this frequency can be detail as below:

Frequency range	Frequency spectrum	Symbol
3kHz - 30kHz	Very Low Frequency	VLF
30kHz - 300kHz	Low Frequency	LF
300kHz - 3MHz	Medium Frequency	MF
3MHz - 30MHz	High Frequency	HF
30MHz - 300MHz	Very High Frequency	VHF
300MHz - 3GHz	Ultra High Frequency	UHF
3GHz -30GHz	Super High Frequency	SHF
30GHz - 300GHz	Extremely High Frequency	EHF

Table 1: General division of frequency spectrum (Ultrasound Level)

Fuzzy modeling is another new modeling for nonlinear system. Compare with conventional modeling technique it only utilized numerical data. The fuzzy approach is unique in the application of quantitative and qualitative information. Qualitative information is human modeling expertise and knowledge, which are capture and utilized in the form of fuzzy set, fuzzy logic and fuzzy rules. This expertise and knowledge are the nonlinear structure of physical system and this structure are represented in linguistic form rather than analytical form, as being used in the conventional system [1].

2.0 PROJECT OVERVIEW

In this paper, it is aim to classify the input signal based on the frequency generated as shown in Table 1. The process involved the used of AI technique. Software based on MATLAB Fuzzy Toolbox will be used to develop the fuzzy logic and simulate using MATLAB Simulink. The simulation will be done using generated signal obtained in Simulink library. The input based on the specify frequency will be insert to the fuzzy logic controller and the output will be given in numerical form based on the classification of the frequency signal set in the membership function.

The type of signal at Table 1, basically are frequency spectrum used in communication system. The lowest range is classify as Very Low Frequency (VLF) which start at 3kHz and the highest range is up to 300GHz which is call as Extremely High Frequency (EHF). Practically this signal used as transmitter and receiver medium in mobile communication, satellite communication, radar system, medical applications and many others [4]. Most of this signal propagates using air as a medium of transmission.

3.0 METHODOLOGY

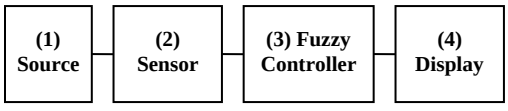


Figure 1: Classification of Sound using AI Technique

The classification of sound using fuzzy logic technique can be describe in Figure 1, the source

used are generated using signal generator provide in MATLAB Simulink library. Only discrete signals with variable sampling time are used as they are more stable in giving high input frequency. The frequency value will be detected by the counter which act like a sensor and give this value to the Fuzzy Controller. The value from the counter will be classified by fuzzy logic controller. Through defuzzification process, the output will be display in numeric form as they are set to specific value depend on frequency type.

4.0 CLASSCIFICATION DESIGN

The design actually based on the human way of logic thinking. From Table 1, the frequency classifications is the output depend on certain ranges of frequency given as an input. The membership function will be one input and one output.

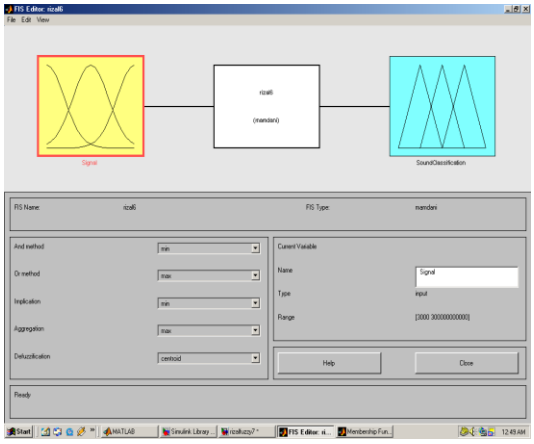


Figure 2: Sound Classification using Fuzzy Logic Toolbox

For the sound classification, there are eight membership functions for each of the input and output fuzzy variable of the system. Table 2 shows the input fuzzy variable for classification of frequency signal.

Frequency (Membership Range)	Symbol (Membership Function)
3kHz-30kHz	VLF
30kHz-300kHz	LF
300kHz-3MHz	MF
3MHz-30MHz	HF
30MHz-300MHz	VHF
300MHz-3GHz	UHF
3GHz-30GHz	SHF
30GHz-300GHz	EHF

Table 2: Input Fuzzy variables value for Signal

The output fuzzy variable would be the normalization process of frequency types set from 0 to 1. This is shown at Table 3

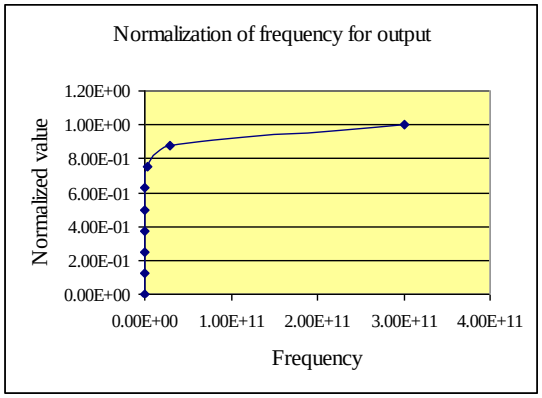


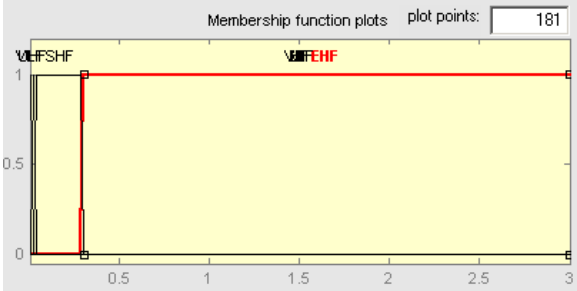
Figure 3: Normalization of frequency for output fuzzy variable

Frequency (Actual Value)	Symbol (Membership Function)	(Y) Normalized Membership Range
3kHz-30kHz	VLF	0.000 - 0.125
30kHz-300kHz	LF	0.125 - 0.250
300kHz-3MHz	MF	0.250 - 0.375
3MHz-30MHz	HF	0.375 - 0.500
30MHz-300MHz	VHF	0.500 - 0.625
300MHz-3GHz	UHF	0.625 - 0.750
3GHz-30GHz	SHF	0.750 -0.875
30GHz-300GHz	EHF	0.875 - 1.000

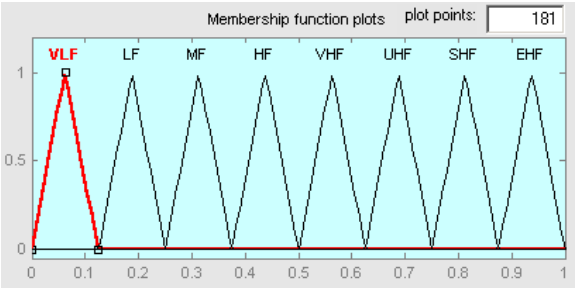
Table 3: Output Fuzzy Variable Value, **Y**

The graphical representation of the membership functions is presented in Figure 4. It can be observed that the y- axis is the degree of the membership of each of fuzzy variable. The input fuzzy variable (x-axis) is the frequency value. Note that the range is large that, it only able to display clearly at the end of frequency class

(EHF). The output (x-axis) is normalized value corresponding to the types of frequency.



Input Fuzzy Variable: Frequency Signal



Output Fuzzy Variable: Sound Classification

Figure 4: Graphical representation of membership functions.

The inference mechanism in the fuzzy logic controller resembles that of the human reasoning process. The fuzzy logic technology is associated with artificial intelligence [2]. In the development of fuzzy logic controller the similar rules of human thinking were used. This can be shown at Figure 5.

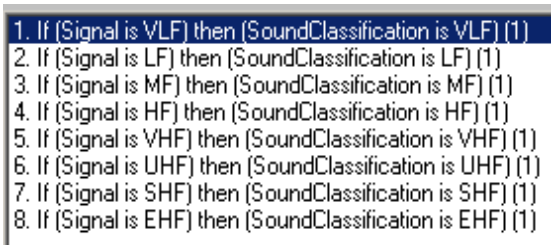


Figure 5: Fuzzy Rules

The rules are developed in such a way that if the fuzzy inputs recognize the signal (frequency), then it would give the appropriate sound classification. There are eight rules all together and each of them is dedicate to each sound classification.

In the fuzzy logic controller once the appropriate rules are fired, the degree of membership of the output fuzzy variable i.e. Sound Classification is determined by encoding the antecedent fuzzy subset, in this case Frequency Signal. Mamdani's fuzzy inference method is the most commonly used for fuzzy methodology. The defuzzification method is centroid of a two-dimensional function [3]. In sound classification technique the max-min implication technique is used [2]. Using this technique, the final output membership function for each rule is the fuzzy set assigned to that output by degree of truth values from the associated membership function. Once membership degree of the output fuzzy variable is determined then the actual crisp output is obtain through defuzzfication method.

5.0 DESIGN OF SIMULATION MODEL

The MATLAB Simulink software enables user to simulate the effectiveness of the fuzzy logic controller in classifying the sound signal. The Fuzzy Logic Toolbox can be integrated with MATLAB Simulink in the MATLAB environment.

The simulations designs model were developed many times until the fuzzy controller able to pick up the frequency generated by the signal generator and thus giving the decision on type of frequency. The simulation time is 1 second. This will give the number of cycle in one period for the counter to count the frequency generated. The signal must be desecrate signal with sampling time in order to give better frequency oscillation. Brief description about MATLAB Simulink facilities used is given in this section.
The software has a number of facilities especially the Simulink Library, which help the user to do the simulation model. The Simulink provide user friendly environment for the user.

Simulink is a software package for modeling, simulating, and analyzing dynamic systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multirate, i.e., have different parts that are sampled or updated at different rates. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations [3]. For advance user, Simulink provide platform for user to create their own function by using C-programming, M-files and S-function.

During designing the simulation model several functions have been used. Source can be obtain from the signal generator in the Digital Signal Processing (DSP) is used to generate sine wave. This function enables to give stable output frequency with respect to the sampling time. In order to use sample time, the signal must be in discrete signal. The other alternative would be Pulse Generator. The signal would be in square wave. This function block generates a time base signal. A stable signal is generate by setting the cycle period.

Sensor is important element in detecting the frequency input. To make the fuzzy controller recognize the frequency value, a counter is used in this model. The counter will act like a sensor which will count number of falling edge signal in period of one second. This counter value is equivalent to frequency of the generated signal.

Controller is another element used in the simulation model. Fuzzy Logic Controller with Ruleviewer will link to the Fuzzy Logic Toolbox and the user must load the FIS (fuzzy inference system) file to the workspace in order for this controller to work. The refresh rate will be set to 0.1 sec to cooperate with the simulation time. Fuzzy Ruleviewer will display the defuzzification output in graphical form.

The simulation model in Simulink has to be modified to compensate with the generated signal generate by the signal generator. The Fuzzy Logic Controller link mask has to equip with Data Type Conversion block. The signal from Boolean will converted to Double. Figure 6 shown the modification been made at Fuzzy Link Mask.

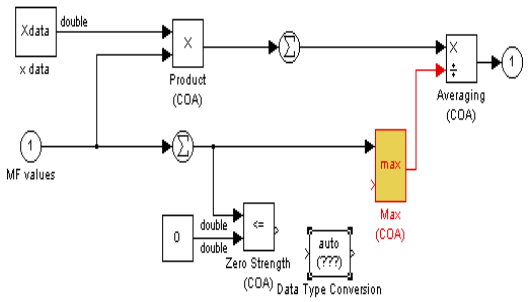


Figure 6: Modification made at Fuzzy Link Mask using Data Type Conversion

Display is used as to monitor during and after simulation. Beside the Ruleviewer, two type of display used are Scope and Numeric Display.

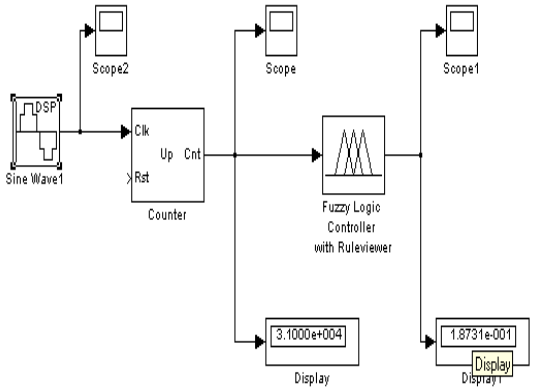


Figure 7: Simulation Model in Simulink

6.0 RESULT

The performance of the fuzzy logic controller can be evaluated by comparing the output value from Fuzzy Logic Toolbox set as a reference (Table 4) and the output result in the Simulink based on the simulation model (Table 5).

Freq. Value	**Fuzzy Output**
3.1kHz (VLF)	**0.0627**
31kHz (LF)	**0.187**
301kHz (MF)	**0.313**
3.1MHz (HF)	**0.437**
31 MHz (VHF)	**0.563**
301 MHz (UHF)	**0.687**
3.1 GHz (SHF)	**0.813**
31GHz (EHF)	**0.937**

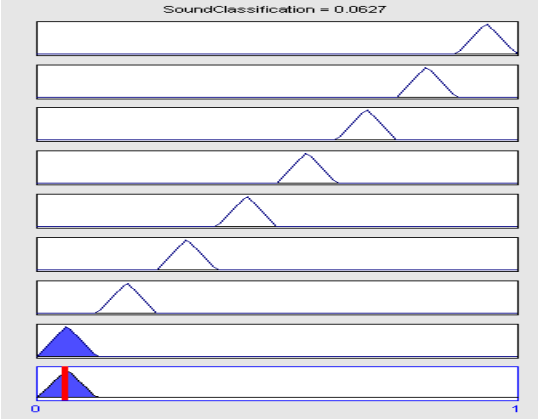
Table 4: Reference Value

The outputs from the Fuzzy Logic Controller in Simulink are given with certain frequency input due to large time consumption. The results are shown at Table 5.

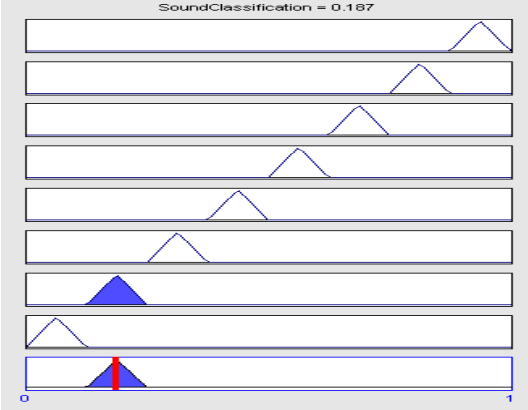
Input Freq.	Sample Time (1/f)	Period	**Fuzzy o/p**
3.1k Hz(VLF)	1/10000=100e-6 sec	16sec	**0.0627**
31 kHz(LF)	1/100000= 10e-6 sec	2m 32sec	**0.187**
301kHz(MF)	1/1000000= 1e-6 sec	31m 54sec	**0.313**
301kHz(MF)	1/700000=1.429e-6 sec	29m 40sec	**0.313**

Table 5: Result from simulation

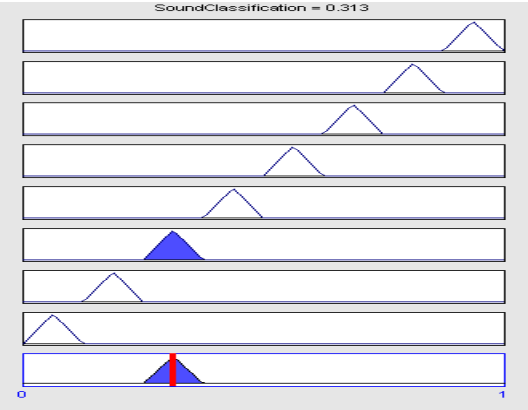
The output in graphical forms are shown in Figure 8



Fuzzy output value when input freq. 3.1 kHz



Fuzzy output value when input freq. 31 kHz



Fuzzy output value when input freq. 301 kHz

Figure 8: Fuzzy Output Value at Rule Viewer

7.0 DICUSSION AND CONCLUSION

Several matters will be discuss and conclude on the Sound Classification Using AI Technique. From the result obtain in simulations, the fuzzy controller can recognize the frequency value and give the output of sound classification in numeric form. The result at Table 5 shown that the fuzzy output values are same compared to the Reference Value at Table 4.

The sampling time must at least twice or higher then the discrete signal being generated, these obey the Nyquist sampling theorem [5].

Due to long period of simulation time the result have been limited up to 301 kHz. The amount of time it takes to run a simulation depends on many factors, including the model's complexity, the solver's step sizes, and the computer's speed [3].

The simulation time was reduced from 10 second to 1second in order for the counter to detect number of cycle in one period of time. This is will give the correct frequency value to the fuzzy controller. The reduction of time can be done at Real-Time Workshop toolbar.

From the discussions, it can be conclude that, the AI approach which means the Fuzzy Logic System can recognize the frequency given and able to give decision correctly in numeric form.

The usage of signal generator will give a long period of simulation time as it depends on sample time to generate discrete signal.

FUTURE DEVELOPMENT

This project can proceed for future development such, to make fuzzy controller work with dynamic signal which taken from real word and process using Signal Processing technique. This might be done using Filter Design Toolbox.

The simulation model can be potentially more user friendly by linking the simulation model with the MATLAB GUI Builder. This facility can be used to build the input menu such as **ENTER THE FREQUENCY VALUE** and output menu which will display the result from fuzzy output in letter form such as **LF**, **VLF**, **MF**, etc.

For further advancement, this Sound Classification Using AI Technique can be implementing to hardware development in near future.

ACKNOWLEDGEMENTS

Appreciation and sincere gratitude would like to express to Project Supervisor, Puan Zuriati Janin. This is for her good advice, support and supervision in the period in doing this project.

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