Development of the System to Predict the Absorption Coefficient of the Room Acoustic Using Zernike Moments and Radial Basic Function (RBF)

Mohamad Hafiz Abu Bakar[1, a *], Abd Kadir Mahamad[2,b], Sharifah Saon[3,c] Musli Nizam Yahya[4,d] and Fathin Liyana Zainudin[5,e]

[1~5] Embedded Computing System, Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia
86400 Parit Raja, Batu Pahat, Johor, Malaysia

[a] apiz_bakar_89@yahoo.com, [b] kadir, [c] sharifa, [d] musli@uthm.com.my,
[e] fathin.liyana.zainudin@gmail.com

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Abstract. The development of system to predict absorption coefficient using Zernike moments and Radial Basic Function (RBF) for classroom is a system based on the system developed using Matlab simulation. This project is designed to predict the absorption coefficient of the surface material and reverberation time in the classroom for wall concrete, floors and ceilings. In this project, the modified Zernike moments of image processing is applied to extract image features and RBF is used to identify the absorption coefficient of the material. For the reverberation time, Sabine equation is used to calculate the reverberation time for model dimension and reverberation time of the classroom at UTHM. In addition, Matlab GUI is employed in order to determine the effectiveness of this system. The proposed system has been trained with 200 samples of surface materials from 10 classrooms in UTHM. The system is tested with 30 samples of surface material images, which its surface has never seen before. The results of predicting the absorption coefficient shown it can predict almost 90% accurately. To sum up, the developed system can predict the absorption coefficient and the reverberation time of classroom at UTHM.

Introduction

Nowadays, various systems have been proposed to predict a room's acoustic properties, e.g. Reverberation Time (RT). Reverberation time is a fundamental quantity in architectural acoustics, which is defined as the time it takes for sound energy in an enclosed space to decay by a factor of 60 dB [1]. Reverberation time is dependent on the volume and amount of acoustical absorption in the space and related materials in classroom [2].

Generally, there are two essential factors that make the RT values within appropriate ranges which are absorption coefficients of the materials and dimension of the room. The absorption coefficient determines how far into a material light of a particular wavelength can penetrate before it is absorbed [2]. In a material with a low absorption coefficient, light is only poorly absorbed, and if the material is thin enough, it will appear transparent to that wavelength [2]. Absorption coefficient depends on the material and on the wavelength of light that is absorbed by the surface of the material.

Aiming for practical application, this project is to purposes efficient systems using photo images technique to predict the factor using two subsystems which are Image processing (Zernike moments) and Radial Basic Function. Using these combinations of the subsystem, involve Zernike moments and Radial Basic Function (RBF) is to determine absorption coefficient material surfaces in classroom. Zernike moments have mathematical properties, which make them to become ideal image features to be used as shape descriptors in shape classification problems [3]. A RBF network is neural network trained using a supervised training algorithm, which is typically configured with a single hidden layer of units whose output function is selected from a class of functions called basis functions [1].

Using these subsystems, it can design room parameters easily, rapidly and at a low cost compared using physical measurement. These systems are useful for researchers, practical engineer, and designers to estimate sound field of the existing room [4].

Methodology

As methodology, in this project there are 3 types of surface material capture using DSLR and Micro Nikkor lens such as the marble floor, wall concrete, and ceiling acoustic. MATLAB R2011b has been used as programming for Zernike Moments Modification and Radial Basic Function in order to predict the absorption coefficient. Each of the samples material was analyzed using Zernike Moments to extract surface features. Then, the information from the extraction process is used as input for the RBF to classify the surface of the material by it type and absorption coefficient. By knowing the value for absorption coefficient and the dimensions of the classroom, the reverberation time can be calculated by using Sabine equation. All steps to develop this system is shown as in Fig. 2.

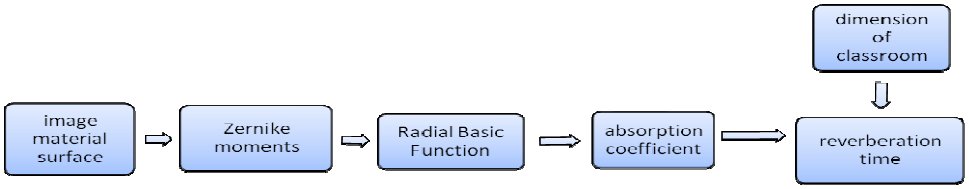

Figure 2. Block diagram of the system

1) Image Material surface

There are 3 types of material surface were taken in UTHM classroom at different locations which are marble floors, ceilings acoustic and walls concrete as shown in Figure 3. To conduct this stage, a DSLR with MICRO Nikkor lens is used. Besides that, the distance from camera to the surface material is set to 2 feet with the lens settings for aperture, ISO speed and shutter speed were f2.8, 400 and 1/80 with autofocus mode.

(a) (b) (c)

Figure 3. (a) Samples of material surface for marble floor (b) Samples of material surface for ceiling acoustic (c)Samples of material surface for wall concrete.

2) Zernike Moments modification

Zernike Moments, an image processing application which extracts image features based on the shape of the surface of the sample. Through this modification it is able to process the sample surface of the material based on texture. The outputs for this method are amplitude, mean and power spectrum (ac power). The mathematical equation for output of Zernike Moments modification is can be referred as in journal [5].

3) Radial basic function

The output from Zernike moments with modifications is used as input data for the RBF. There have four subroutines have been used in this process which are;

1. Data classification process
2. Learning and train process
3. Test the performance of neural network and
4. Validation of surface material.

In this process, RBF have been trained with 200 samples of surface material.

4) System to identify the absorption coefficient

After appropriate network have been determined, Zernike Moments modification and RBF is integrate to create a system that can predict and identify the absorption coefficient of the material surface. The standard absorption coefficient is shown as in Table 1 by Alan Truesdale [6].

Table 1: Type of surface material with absorption coefficient

Type of material surface	Absorption coefficient					
	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Wall concrete (painted)	0.1	0.05	0.06	0.07	0.09	0.08
Floor (marble)	0.01	0.01	0.01	0.01	0.02	0.02
Ceiling acoustic	0.5	0.7	0.6	0.7	0.7	0.5

5) Model calculation of reverberation time using The GUI Matlab

Reverberation is phenomena occur when the sound source stop, the sound energy still heard for some time until sound energy decays away to inaudibility. To compute reverberation, the RT (reverberation time) is defined as the time required for the average sound energy density to decay by 60dB after the sound source is stopped as illustrated as example in Fig. 4.

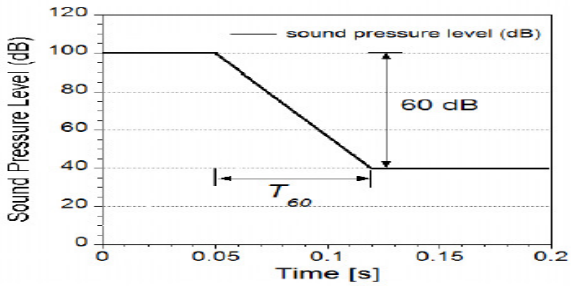

Figure 4 : Shown sound pressure level in room decay in time.

From the Sabine equation [7] was proposed to compute reverberation time, as Eq.(1)-(2).

$$T60[s] = \frac{0.161V}{A} \quad (1)$$

$$A[m^2] = \sum S\alpha \quad (2)$$

Result and analysis

1) Identify of surface material

RBF plays an important role in determine the success of the system developed in this project. The performance is depends on the mse (mean square error) of the system during trained and tested. Table 2 shows the result for training and testing process of RBF network to determine the lowest mse value for material surface at UTHM classroom.

Table 2. Value of mse trained and tested with the percentage error of tested

sc1 (spread)	mse trained	mse tested	Percentage error of tested (%)
1.0	0.0410	0.1753	18
2.0	0.0709	0.1369	13
3.0	0.0838	0.0988	13
4.0	0.0877	0.0886	9
5.0	0.1002	0.0768	9
6.0	0.0921	0.1112	14
7.0	0.0925	0.1357	16
8.0	0.1048	0.1078	13
9.0	0.1048	0.1073	13
10.0	0.1000	0.1356	18

Through this assessment it can be can be interpreted that the sc1 (the spread of neurons) gave good performance at sc1 = 4 where the mse trained and tested is low and the percentage of error is less that 9%. Moreover, the selection of the correct sc1 also helps the system to predict more accurately and efficiently on the surface of classroom material.

To test the system in this project a total of 30 samples of surface images captured randomly by the system at a fixed standard in this study where the distance is 2 feet from DSLR camera. Fig. 5 shows the testing done on the system developed in predicting the absorption coefficient.

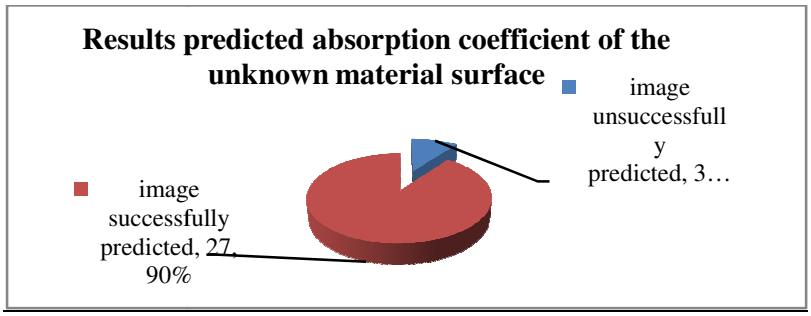

Figure 5: Results predicted absorption coefficient images that unknown it material surface

2) Development model of the reverberation time

In order to compare the developed system works is going well, the proposed system is compare with mathematical calculations with the system is developed using Matlab GUI. Figure 6 shows the Matlab GUI in order to calculate reverberation time.

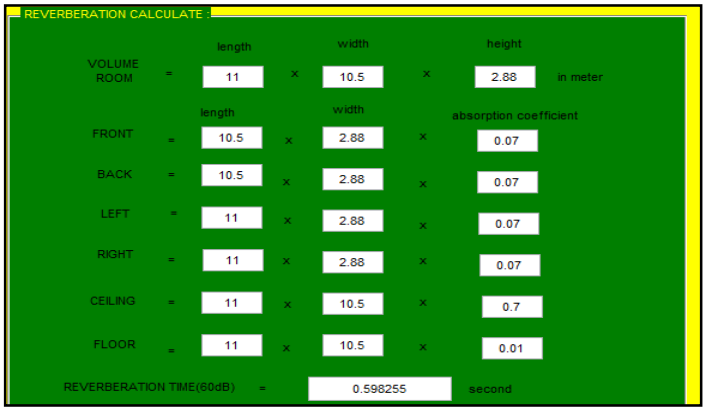

Figure 6. Results of the GUI system developed to calculate reverberation time

Conclusion

To sum up, the image processor systems of Zernike Moments modifications is developed to assist the system in identifying the surface material in the UTHM classroom. RBF network is used for the classification process and validation data for absorption coefficient of the surface material. To make the system complete and successful, an experiment has been conducted involving a sample of the unknown surface to predict its effectiveness in predicting absorption coefficient. Results from experiments shows the proposed system can predict 90% accurately. This project will not only focus on the absorption coefficient, but also involves the reverberation time as the main criteria in a study room acoustics. In calculating the reverberation time for classrooms, Sabine equation model was used to predict the reverberation time in classroom using Matlab GUI. The proposed system can be used to ease the other user to predict the absorption coefficient and reverberation time of classroom.

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