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Predicting Acoustic Properties in Enclosure Using Neural Network

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Abstract: This study aims to predict the reverberation time in enclosed space using neural network. The predicting of reverberation time in an enclosed space is conducted by designing five different enclosed space model equipped with windows, walls, floor, and ceiling in which the design process is completed by using Google SketchUp. The Neural Network training dataset from 5 different models of enclosed space with reverberation time at 500Hz were computed from ODEON 12.10. The Neural Network was conducted for 500Hz as absorption coefficient, volume of each model, and number of windows used as the input variable. Mean square error and Regression values were obtained to examine the neural network efficiency. Overall, the neural network efficiency shows a good result with Mean Square Error below 0.005 and regression above 0.9.

Keywords: Reverberation Time, Enclosed Space, Neural Network,

1. Introduction

In an enclosed space, the propagation of sound wave can possibly behave in three different manner which it can be reflected, diffused or absorbed. Each of these reactions will depend entirely on the properties and composition of the material the sound wave contacted with. Reflection of sound is when a sound wave bounced off a surface. This usually occurs on flat, rigid surfaces with a lot of mass like concrete or brick walls. Because the sound wave unable penetrate very far into the surface, the wave bouncing back off the surface which will induce an echo [].

Sound reflected from walls generates a reverberant field that is time dependent. When the source suddenly ceases, a sound field persists for a finite interval as the result of multiple reflections and the low velocity of sound propagation. This residual acoustic energy constitutes the reverberant field. The sound that reaches a listener in a large enclosed space can be classified into two broad categories: the direct (free field) sound and indirect (reverberant) sound. Room acoustics / reverberation affects the way a space sound. A high reverberation time can make a room sound loud and noisy. Speech intelligibility is also a function of reverberation, a high reverberation time causes speech to sound muffled and muddy.). Rooms designed for speech therefore typically have a low reverberation time: ≤1 second. A high reverberation time can enhance a music hall by adding richness, depth and warmth to

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music. A higher level of reverberation within a concert hall is therefore critical. Reverberation time is a period, in seconds, taken for the sound to decay by 60dB after a sound source has been stopped. Verbal communication is deemed to be the most frequently used communication approach on human daily basis. It helps people on conveying and receiving information for various purposes which includes learning process. Since the education become more inclusive in early 1800s, the learning process is carried out in mass until today's modern world. Learning and teaching is widely conducted in enclosed space such as learning hall and classroom which considered as the most practical facility for learning purpose. Along with the current technology that is being used to aid learning process, one of the problems worth assess is the acoustic behavior in an enclosed space as it substantially influenced the learning process in many ways.

In enclosed space, the behavior of acoustic wave propagated with respect to the circumstance of the space which include the size and material of noise insulator implemented. Due to the variables that are altered in the enclosed space, it is crucial to study the acoustic wave behavior in terms of reverberation time (RT) to ensure the learning process takes place in the most optimal environment acoustically. An enclosed space with high tendency of sound reflection that conflicting with its source will interrupt concentration compromise the learning process hence resulting poor performance among students as the comprehension of the content of teachings are not received optimally. Therefore, the learning session will experience poor speech intelligibility. Having the latter circumstance will also generate poor learning condition that will hinder any progress on task completion that takes place in the particular enclosed space such as reading, writing and speaking.

This study aims to predict the reverberation time in enclosed space using neural network. neural network is applied to predict and study the reverberation time of an enclosed space particularly classroom given the geometry, classroom size and placement of sound source.

2. Materials and Methods

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

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2.2 Methodology

2.2.1 Data Collection

For this research, the three-dimension drawing of enclosed space, specifically enclosed space is design and constructed with Google SketchUp software. In the software, the most important part is to identify the dimension of the enclosed space for further progress which is to analyze the characteristics of sound and predicting the reverberation time given the geometry of enclosed space. The model that has been constructed earlier will be used as the enclosed space in the Odeon software with all the characteristics of sound such as frequency will be introduced. The aspect that is needed to be analyze is the behavior of sound when a source of sound wave is placed in the system which will bounce off the wall of the model and create a reverberant effect. The Matlab is used for the purpose of machine learning and to generate a system to predict the reverberation time in any enclosed space. From 100 data served from the simulation, 70% is used to application on machine learning, 15% for testing of the system and 15% for validation purpose.

2.2.2 Data Analysis

The data that needed to be recorded are the coefficient of absorption of the wall, floor, and ceiling at 500Hz, the reverberation time, and the volume of the model after assigning the material. The data set attained is loaded to the MatLab neural network with specific script to run with intention to produce the best testing result from the neural network training.

The generated data produced by the neural network is then compared with the input which is the reverberation time from the simulation. The separated parts which are training, testing, and validation will be assessed separately and regression is produced. The process is also known as the neural network train-validate-test which is a technique used with the purpose of reduce model overfitting.

3. Results and Discussion

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.1 Neural network training result

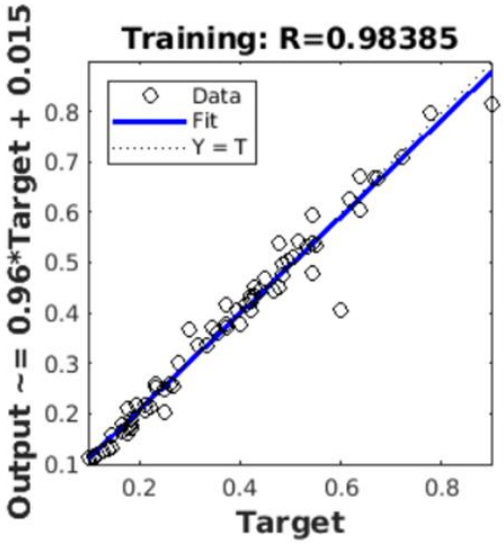

Figure 3.1: shows the best fit line from the data of neural network

The training of neural network part consists of 70 data which the mechanism of machine learning from multiple inputs to produce an output that has value nearest to the simulation value. The data from the simulation is gathered for the training to analyze the pattern for the purpose of practicing which then developing a set of algorithms that enable to perform on providing the most accurate and consistent value of output which is the reverberation time. The 70 inputs served to the neural network has proved to generate an equation for the pattern of data forming a regression (R) of 0.98385 in which it attains a high accuracy in term of input output ratio.

3.2 Neural network testing

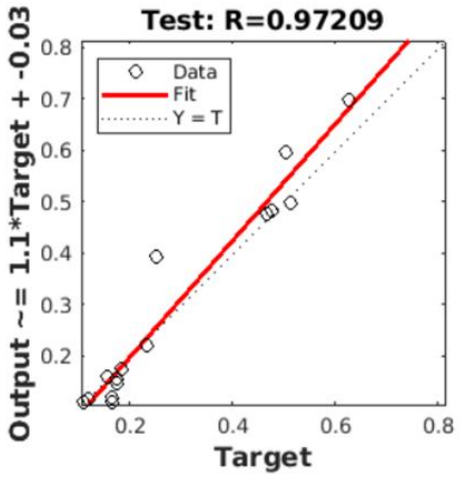

Figure 3.2: the best fit line for testing of output of neural network

The testing of the output is crucial as it analyze the performance of the machining learning that has been carried. The test data analyses the neural network wights and biases after the training complete which it informs the estimation of accuracy of the training data will be upon presenting the newly generated data. The test of the neural network data has generated an equating correspond to the test data and train data and regression which is the correlation coefficient or the regression is 0.97209 that indicate it is very close to 1. Therefore, the testing process of neural network output is considered acceptable.

3.3 Neural network validation

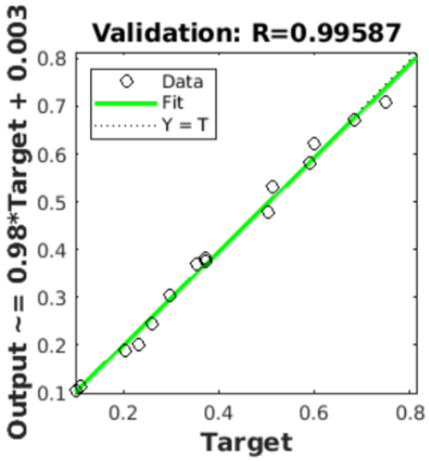

Figure 3.3: shows the validation of output testing

The validation comprises of 15 data generated from the neural network training and testing to anticipate the level of validation accuracy of the data tested from the neural network training. From the validation, a mathematical model is constructed with the correlation coefficient or the regression value of 0.99587 which considered as a highly accurate and acceptable value of output to input ratio.

3.4 Mean square error.

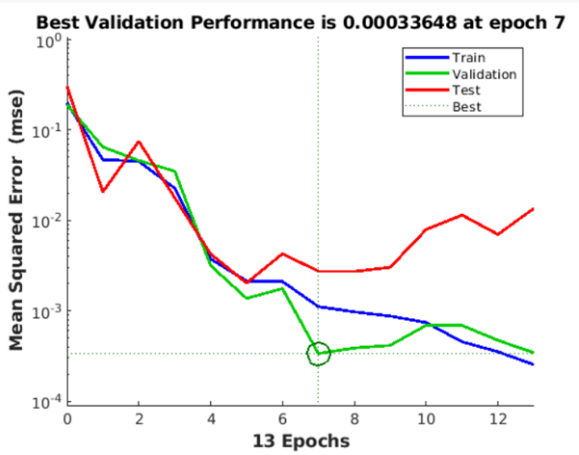

Figure 3.4: shows the mean square error of the train, validation, test data set

experiment to evaluate the models of the neural network. The objective that is to observe is the value of mean square error of the validation at its lowest and the number of its iteration or epoch. The epoch is a term used in machine learning and the number of passes of the entire training dataset the machine learning algorithm has completed. The best validation performance is 0.00033648 at the epoch 7.

4. Conclusion

In conclusion, the study of predicting the reverberation time in enclosure using neural network is conducted by designing five different enclosed space model equipped with windows, walls, floor, and ceiling in which the design process is completed by using Google SketchUp. From the different model of enclosed space, the materials with different value of coefficient of absorptions are assigned to each component of the model which is 10mm smooth brickwork, 60mm bricks with 19 holes, 6mm wood fibre board, and 50mm mineral wool. The latter materials' coefficient of absorptions is 0.12, 0.45, 0.2, and 0.65 respectively whilst the windows in each model is kept constant in dimension and the material which is the ordinary glass with the absorption coefficient of 0.19. The process of assigning the materials is done in Odeon Software.

All of the models are implemented with a sound point source and a receiver with respective coordinate according to the dimension and suitability of each model. The reverberation time is attained via 3D investigation ray where the 2 rays is propagated throughout inside the enclosed space and hit the receiver. The reverberation time is recorded in 500Hz and T30, the time taken for sound decay to 30 db after the sound source is switched off. The crucial parameters to be extracted as inputs from the simulation is the arrangement of material assigned to each of component of the model, volume of the model after the material is assigned, and the number of windows. The expected output from the Odeon simulation is the reverberation time.

The progress of experiment proceeds at the MatLab software where the data will be saved in the .txt file and loaded in the script provided in the Appendices. The data gathered from the MatLab is in the form of neural network training, the testing of result and the validation of the neural network result. 70% data gathered from the Odeon software for the purpose of the training of neural network has high accuracy in prediction of reverberation time. The coefficient of correlation or the regression 0.98385. The 15% of the data is served for the purpose of the testing of the prediction of reverberation time produced by the neural network. The coefficient of correlation or the regression is high as the value is 0.97209. 15% of the data gathered is used to validate the reverberation time prediction from the neural network. The coefficient of correlation is near perfect as the regression value is 0.99587.

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