COMPUTATIONALLY DERIVED MASKING OF BACKGROUND SOUND WITH NOISE SIGNAL

by

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Abstract

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The use of sound masking systems has a history back into the 1960s when the first open-plan office was established. Even though the technique of electronic masking systems is old and encouraged by many design guidelines, it is not used very frequently. The purpose of this thesis is to find masking sounds that reach higher acceptability by the users and reach the higher masking of effects noises around us by evaluating different masking sounds in some effect sounds environments such as commercial offices, shopping malls, playground, neighborhood, animals, and more others. Two models are use to generate different colors' noises based on the generation of a uniform white noise: Spectrum resize exponential and filtering white noise models. The experiment includes a series of generated noises and different background noises around us. The loudness of noise and the components of its frequencies have measured by using power spectral density (PSD) technique and Fast Fourier Transform (FFT) Algorithm. The generated noises are tested by using scaling technique to find the optimal masking that fit any given background. The results show that pink and white noises are the best maskers for most of the backgrounds. In model 2, we found that the best masker when b has the negative values, and a has positive values.

Keywords: sound masking, masking sounds, colored noises, PSD, FFT.

HUMAN OR ANIMAL SUBJECTS REVIEW FORM

for

Wedyan Habeeb Hameed

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This research project has been reviewed by the Institutional Review Board and approved as follows (the appropriate block must be checked by either the Thesis chair or the Chair of the Institutional Review Board):

Neither humans nor animals will be used and this research is certified exempt from Institutional Review Board review by the thesis committee chair.

Human participants will be used and this research is certified exempt from Institutional Review Board review by the Chair of the Institutional Review Board.

Human participants will be used and this research was reviewed and is approved by the Institutional Review Board.

Animal participants will be used and this research was reviewed and is approved by the Animal Research Review Board.

Signature of Thesis Committee Chair Date

Signature of Chair of Institutional Review Board Date

INTRODUCTION

The term "mask" means simply to cover up something or disguise it. That something will not be changed in any way, but it just simply has hidden. For instance, the physical mask covers up the wearer's face but does not change their natural faces. Another good example is one-way windows that block the ability for a person to see persons on the other side so, they are not visible. Sound can mask some other effects sounds in our environment. In every case, the objective is to hide something that already exists, and we do not have any control of it, but we do not try to eliminate it. This chapter gives a basic idea about what is sound masking, where is used, and why people need this kind of sounds these days. It also explains the aim of this paper.

Sound Masking

Sound masking is the process of adding a low level of an inconspicuous background sound to an environment. It creates a noise floor, which is the level of constant sound existing in a space, high enough to hide annoying noises, and it is low enough for comfort. It works because the human ear cannot distinguish or separate sounds of a similar frequency and volume. Masking operates by covering up unwanted sounds such as human speech, helping mitigate the distraction of other sounds, making the environment more comfortable, workers be more productive, reducing distractions, and achieving privacy. This technique is in contrast with the others such as an active noise control technique which attempts to eliminate unwanted sounds.

There are two types of activity sounds around us ‘Steady’ and ‘Transient’. When the background sound in any environments are steady, continuous for a long term without any change and its level is somewhat low, people would generally accept it as a normal sound. Steady sound can be divided into two major types ‘Random’ and ‘Tonal’ as well. Random sounds will be less annoyance than the tonal sounds of the same level since the random convey no information to the listeners.

Transient sounds are short term, and they can vary considerably in level. They distract the attention of people when the level is high relative to the steady sound level such as conversation, machine sounds and any external sounds such as the road traffic. The distraction will be stronger when the sound has high information contents such as human speech. The main concern of relatively low levels sounds is the psychological effect of annoyance and distraction. The major benefit of sound masking is to diminish the distraction associated with the transient sounds, and in some cases, it reduces the intelligibility of those transient sounds especially in closed offices and secure facilities. Sound masking can play a great role in covering up the activity sounds or make them more acceptable by maintaining a low background sound level with no transient sounds; a state that requires a complete isolation from all activity sounds. In other words, it helps to hide some distracting sounds but not all sounds. The negative effects of transient sounds can be divided into three main groups based on their levels. At a high level, the noise causes some mechanical changes in a person such as hearing loss, heating of the skin, etc. At medium levels, the noise causes a variety of serious health problems on a person such as stress, elevation of blood pressure, interfere with auditory perception and reduce the capability of signal processing. At lower levels, the changes are psychological such as complaints and annoyance (Wikipedia, Sound Masking, 2016).

Sound Masking Uses

Originally used only in offices and call centers, sound masking now benefits visitors and employees alike in hospitals, medical and dental clinics, bank branches, military facilities, libraries, hotels, and a whole host of other applications. In offices, there are many things that cause a noise such as people conversations, phones ringing, printer machines, keyboards clicking, people walking, and cars traffic outside the window, elevators dinging, and much more. These noises cause bad distractions that lead to reducing employees' productivity and increase their stress, raise data entry errors, mental fatigue, and so on. Another example, masking uses in doctor's office when doctor does not want people in the waiting room to overhear their private conversations with their patients. Students also get some benefit from sound masking technique. Masking provides a good environment for reading and studying. For instance, some students have difficulty focusing on their studies when there are different types of sounds/noises around them; in contrast, others cannot study when the area is too quiet. In homes, sound masking helps parents too, it is a great way to overcome snoring sounds from other family members and neighborhood noises. It provides soothing sleep sounds for babies and makes daytime naps are more comfortable. By playing some low-level noise in a bedroom will help all sleep peacefully. Masking also provides a discreet and personalized environment for some confidential conversations. These examples and more can give us a brief introduction about the importance of using sound masking in these days.

Sound masking is a very useful technique for people, but there still two groups of people that should not be exposed to sound masking: people with significant hearing loss and people with very limited vision. The first group does not need sound masking; they already have considerable privacy. The second group uses acoustical cues to navigate; sound masking can remove those cues.

The Effectiveness of Sound Masking

Many numbers of researches have been done on sound masking to show the effectiveness of it. In a study between 2006 and 2008, researchers worked with a group of students to try the effect of adding sound masking on their study, and they found that the addition of sound masking led to increasing the privacy of speech from (35% to 90%), and the participants of that study had gotten approximately an 8.7% increase in the participants' ability to recollect a series of numbers and a (7.8%) rise in recollection of words in the environment with sound masking.

In a 2008 survey, researchers added sound masking in an office. The survey found that the employees on average wasted approximately (21.5) minutes per day due to conversational distractions. In addition, a (48%) of participants' survey reported that speech as the most disturbing source of noise, and it causes of workplace discomfort (Wikipedia, Sound Masking, 2016).

How does Sound Masking Work?

Many people incorrectly think that sound masking system gobbles up unwanted sounds. In fact, sound masking systems do just the opposite, and they do not gobble up the sounds at all. Sound masking essentially adds an ambient noise to the area. Increasing that noise will effectively cover the spoken word because it makes it more difficult for speech to be understood or heard.

The most important factors in sound masking are the level and frequency composition of the masked sound and the masker. In case the masked sound is a pure tone, and the masker has a constant power spectral density(PSD) at all audible frequencies (i.e. white noise), then any increase of masking produced by the masker will be equal to the increase in the level of the masker. However, masking by using a white noise depends on the frequencies of the masked sound, so that at frequencies higher than (500 Hz), a 10-fold increase in frequency leads to a 10-dB stronger masking. A special type of noise with attenuated high frequencies (called pink noise) is used when an unchanging masking across all masked frequencies is required. The masking of a pure tone by a narrowband noise increases as the bandwidth of the noise increases until its bandwidth reaches the critical band for this specific frequency, and with a more widening of the band upwards, the noise has the masking properties of a wide-band noise (Novitski, 2006, pp. 17–18). The critical band is around 100 Hz wide at frequencies lower than 500 Hz and around $0.2 * f$ at higher frequencies. At levels, higher than 40 dB, the narrow-band noise masks the tones with frequencies higher than its central frequency more than lower-frequency tones. Pure tone as a masker acts in a similar way to the narrow-band noise, and the combination of 5 or more pure tones within a critical band totally mimics the masking by narrow-band noise at those frequencies.

Aim of study

This study aims to simulate sound masking system by generating different kinds of noises such as colored noise or noise floor by using two different models that are built based on white noise characteristics. The main part of this study is to evaluate what kinds of noise signals can be used as masking sounds by comparing the working performance.

Research Question

After this study the following question will be answered.

1. How can we automatically find the optimal masking sound for any giving background?

The rest of this thesis is organized as follows: Chapter 2 briefly reviews the signal processing. Chapter 3 includes a brief introduction about the noise, the types of colored noise, and noise generation. Chapter 4 introduces the idea of frequency masking. Chapter 5 illustrates the MATLAB environment. Chapter 6 presents our experimental methodology, results discussing, conclusion, and future work.

Conclusion

The aim of this study was to simulate the frequency masking system by generating different noises. We have analyzed the complex categories for background to produce the best noise model for each category. We are working on developing data mining approach to produce the best noise for any given background. The results show that some backgrounds are very loud and need to scale them to find the perfect masking sound. The plotting and the listening experiment show that the best two colors that can mask any given background are pink and white noise. They have high values of frequencies which can mask any background. It also shows that when the frequencies of generated noises are higher than the background noise, they can cover up almost 80% from unwanted noise, but with the respect to the background loudness; they may not be the perfect maskers, and they are not acceptable from the listeners. Listeners need quiet and perfect masker that can cover up the environment around them without getting noisier from the masker itself. As a simulation case, it was better to scale the background noises and make them quitter than to rise the loudness of the generated noises.

Future Work

This paper shows that how can find the best masking sound by using the plotting graph and the listening experiment. In future, we want to investigate the computational technique for choosing the noise signal without the need to plot and listen to that masker previously.