IDENTIFICATION OF NOISE SOURCES USING PRINCIPAL COMPONENT ANALYSIS

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of
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ABSTRACT

Principal component analysis (PCA) can be used as a tool to rank the noise sources. Identification of noise sources in a room is rather difficult since the noise heard is a superposition from several noise sources. This becomes more difficult if the room is quite reverberant. A simple experiment using two loudspeaker were conducted in a room with reflective surface. It was found that as the microphones are away from the sources, identification becomes more difficult due to reflection from the walls and floors. Experiment was also conducted in a car on engine idle and on running. The results show that at the back seat of the noise is dominant from the exhaust and at the front seat, the dominant source is from the engine.

ABSTRAK

Analisis Komponen Utama (PCA) boleh digunakan sebagai alat untuk mengesan bunyi. Pengesanan sumber bising di bilik adalah agak sukar kerana mendengar bunyi yang dihasilkan adalah superposisi dari beberapa sumber bising. Ia menjadi lebih sukar jika dilakukan di bilik yang bergaung. Satu ekperimen dilakukan dengan menggunakan dua pembesar suara dan ia dilakukan di bilik dengan permukaan reflektif. Daripada keputusan yang diperolehi, didapati bahawa apabila mikrofon jauh dari sumber, pengesanan bunyi menjadi lebih sukar kerana ada refleksi dari dinding dan juga lantai. Eksperimen juga dilakukan di dalam kereta dengan enjin idle dan ketika kereta bergerak. Keputusan kajian menunjukkan bahawa di kerusi belakang kereta menerima lebih banyak bunyi bising daripada di kerusi depan. Hal ini disebabkan suara dari tayar kereta dan knalpot.

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CHAPTER 1

INTRODUCTION

1.1 Background

Noise is one of the scourges of the modern world. It is unwanted product of our technological civilization, and is becoming an increasingly dangerous environmental pollutant. There is a growing public awareness and even some progress in the fight against air and water pollution but noise pollution has already begun to gain attention.

In a building also in a car there a many working thing that making sound and some of them causing unpleasant noises which is so disturbing. Much more in car also have the same issue. Noise is defined as a loud outcry or commotion or unwanted sound to human. Noises are unwanted to human ear. Therefore noise should be controlled.

Noise can be control at its source, the path between the source and the listener, or at the listener. If noise can be controlled from the source, it is unnecessary to consider the path and the listener position. On the other hand, if we can control noise from the path and listener, it is unnecessary to consider the noise source location.

Sound is a travelling wave that is an oscillation of pressure transmitted through a solid, liquid, or gas, composed of frequencies within the range of hearing and of a level sufficiently strong to be heard, or the sensation stimulated in organs of hearing by such vibrations. Sound generation is a physical phenomenon meanwhile noise is subjective interpretation of sound.

In building, sound can be generated by machines, air handling unit system, chiller, amplifier, computers and many more. To human when they are working this kind of sound might become annoying to them. Also for some quite places such as library and hospital much noise can be a threat to people in those building. Even ringtone from hand phone can become a noise.

In car, noise is one of the big problems due to user discomfort from driving their car and controlling the noise is increasingly important. Noise from car can be contributed from the internal mechanism such as the engine, screeching steering, groan when breaking, clicking from wheels and many more.

Acoustics is the study of sound or the science of sound. Through our sense of hearing we interpret sound. A scientist who works in the field of acoustics is an acoustician while someone working in the field of acoustics technology may be called an acoustical or audio engineer. Acoustic studied can be applied in many fields such as noise control, psychoacoustic, physiological, bioacoustics and architectural acoustics.

In building environment and manufacturing cars, in many ways, especially with music the field of architectural acoustics is very controversial. This is because of the wide variation in personal taste of different people. Only within the past century, human have been able to scientifically understand and predict the behavior of sound for both indoors and outdoors. From the understanding of sound, study of acoustics has evolved into an established field of engineering.

1.2 Problems Statement

Controlling sound usually concerned about to the reduction of sound. The primary ways to reduce sound are through absorption and insulation. Absorption may eliminate unwanted reflection. Redirection and diffusion can have favorable acoustic results for even sound distribution in large rooms.

Many source of sound produces in a building and also in a car can be detect by human ears. There are some small sound and loud sound. To reduce sound, firstly is to find the source of the sound. With the finding the source of the sound, it can be controlled. Especially when we can control the loudest sound produced in the vehicles and building it's the better.

Noise in the building can damage hearing. Hearing damage occurs when noise is higher than 85 decibels, which is about the loudness of heavy traffic. Damage can include tinnitus, hearing loss and other health problems such as headaches and fatigue. If people have to raise their voice or shout to be heard, or if people's ears ring or sounds seem muffled afterwards, then the noise level was too loud and harmful.

There many source of noise might be a problem because it will give multiple inputs of sound frequency and wave length such as model analysis testing.

1.3 Objective

The objective of this project is to identify the source of noises which is the dominant from the analysis. An experiment will be conducted for this purpose. A technique, principle component analysis, will be used to verify which sound is the dominant noise in a building and in car.

Also the objective of this experiment will show student how the technique can be used to detect dominant noises. Student also can understand the working operation of this method. This can expose student the application of numerical method to a real life problems.

Student can understand the principal component analysis used as a tool to explore correlation pattern between statically data sets. This numerical technique then will be used to estimate frequency response which is sound.

Studying sound can give understanding knowledge to student about designing a build which related with sound such as an orchestra stage, concert hall, library and many more. In car section, manufacture car with less noise sound will give commercial to business. This will enable for student to design a building and manufacture with regard to noise control.

1.4 Methodology

1.4.1 Principal Component Analysis

Principal component analysis (PCA) involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible.

PCA was invented in 1901 by Karl Pearson. Now it is mostly used as a tool in exploratory data analysis and for making predictive models. PCA involves the calculation of the eight envelope decomposition of a data covariance matrix or singular value decomposition of a data matrix, usually after mean centering the data for each attribute. The results of a PCA are usually discussed in terms of component scores and loadings (Shaw, 2003).

PCA is the simplest of the true eigenvector-based multivariate analyses. Often, its operation can be thought of as revealing the internal structure of the data in a way which best explains the variance in the data. If a multivariate dataset is visualized as a set of coordinates in a high-dimensional data space, PCA supplies the user with a lower-dimensional picture, a "shadow" of this object when viewed from its most informative viewpoint.

PCA is closely related to factor analysis; indeed, some statistical packages deliberately conflate the two techniques. True factor analysis makes different assumptions about the underlying structure and solves eigenvectors of a slightly different matrix.

1.4.2 Decibel

The decibel (dB) is a logarithmic unit for the ratio of a physical quantity, usually power or intensity, relative to a specified or implied reference level. A ratio in decibels is ten times the logarithm to base 10 of the ratio of two power quantities. Being a ratio of two measurements of a physical quantity in the same units, it is a dimensionless unit. A decibel is one tenth of a bel, a seldom-used unit.

The decibel is widely known as a measure of sound pressure level, but is also used for a wide variety of other measurements in science and engineering, most prominently in acoustics, electronics, and control theory. In electronics, the gain of amplifiers, attenuation of signals, and signal to noise ratios are often expressed in decibels. It confers a number of advantages, such as the ability to conveniently represent very large or small numbers, a logarithmic scaling that roughly corresponds to the human perception of sound and light, and the ability to carry out multiplication of ratios by simple addition and subtraction.

1.5 Scope of the Project

Measurement will be conducted in small room using two loud speakers for validation purpose. Measurement in room with real noise sources might also be conducted. For car sound measurement, an 80's car will be used where when it is in idle and moving.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Sound produces in a building by working mechanical. Working mechanical machine usually will produce vibration; from the vibration sound will exist. Different machine will produces different level of sound. This different level of sound contributes different potential noise sources which need to be estimate.

Previous study use of principal component analysis for dominant noise source identification showed it a new technique to reveal correlation pattern between many signal produces from a vehicle. Multivariable statistical technique in principal component analysis is used.

The ordinary analysis which is the correlation or coherence analysis can be performed on time or frequency data. This technique was used to identify frequency produced by vehicles. The partial technique related to correlated inputs and outputs. Coherences function between the remainder signals was calculated at each of the experiment process held.

From the implementation in both time and frequency which is domain possible using the principal component analysis and the classical coherences technique, the new technique is formulated in the frequency domain to enable both technique to be compared.

2.2 Theory

2.2.1 Principal Component Analysis

The basics of PCA are introduced by the works of Hotelling. In the concept is described and discussed extensively. This concept is discussed here briefly to demonstrate the origins of PCA. The main goal of Hotelling is to find a selection of data, which would represent a minimal representation of the entire data set. Consequently a significantly smaller data set is used to describe the original data set.[2]

Now suppose that x is a vector of p random variables. If the number of variables is large, it is time-consuming to look at all p variances and 1 2p (p − 1) covariances to analyze the properties of the data set. Hotelling therefore introduced a method with which a large data set could be qualitatively described by using a lot less variables. The first step in this method is to look for a linear function T 1 x of the elements of x which has maximum variance.[4]

$$\propto_1^T = \propto_{11} + \propto_{12} x_2 + \ldots \propto_{1p} x_p = \sum_{j=1}^{p} \propto_{1j} x_j \qquad (2.1)$$

Here 1 is a vector of p constants 11, 12... 1p the second step is to find a function T 2 x, uncorrelated to T 1 x, which has maximum variance. And so the iteration goes on until the pthtime. T p x, defined as the pth principal component, has maximum variance, but is uncorrelated with T i x for i = 1, 2. . . P, i 6= p. Up to p principal components are found, but in general most of the information in x will be accounted for by less principal components.

In principle, the first few principal components will account for most of the variation in the original variables and the last few principal components add very little information about the data set. Now consider the case where the vector x has a known covariance matrix.

This matrix has the variances of the variables on the diagonal and the covariance's between the variables outside the diagonal. Mathematically it is proven that for the principal components T k x (k = 1, 2... p), k is the eigenvector of the covariance matrix, which corresponds with the kth largest eigenvalue k. This idea forms the foundation for PCA. Hotelling considered PCA predominantly as a method to reduce the complexity of a data set. However, the next passages show that PCA is also used for other purposes.

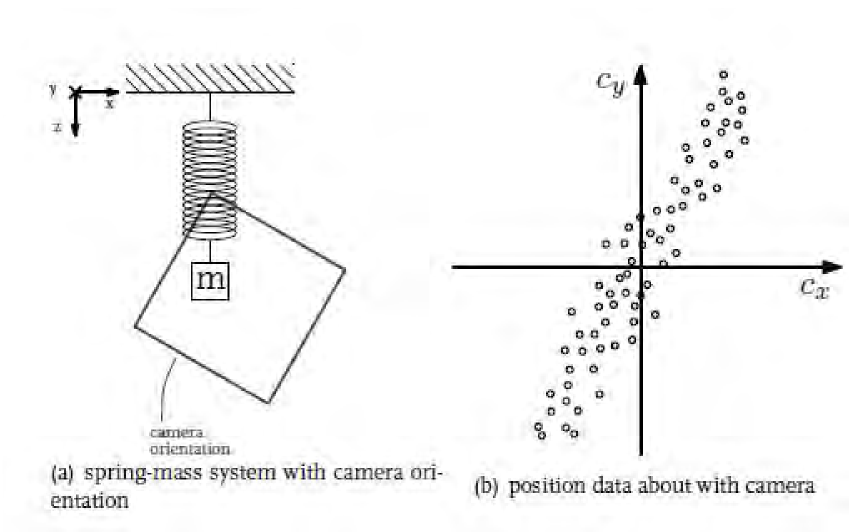

Figure 2.1.1 Example of PCA uses

To illustrate the basic ideas of PCA, an example of a spring-mass system shown in figure is used throughout this section. By moving the mass down, outside its equilibrium position and letting go, the mass should translate continuously up and down assuming no friction forces. The movement of the mass is our main interest and we try to analyze this by capturing its movement using a camera.

Of course we know that the line of action is along the z-axis, but we pretend we do not have any information about the system a priori. Therefore we position the camera arbitrarily in a plane parallel to the mass. The slightly tilted camera captures the position of the mass with a certain sampling frequency and a possible data set of a measurement with this configuration is shown in figure 2.1.1(b). Here the circles represent the position of the mass during the measurement.

Basically the goal of PCA is to clarify the data by re-expressing the data by means of a new coordinate basis. Now consider an $[e \times t]$ original data matrix E, where e is the number of dimensions measured and t represents the number of time samples taken. The matrix E can be converted to a new representation of the data, C, by an $[e \times e]$ transformation matrix T;

$$C = TE \tag{2.2}$$

The goal is now to find a transformation matrix T such that C becomes the most clear coordinate basis. Evidently from figure 2.1.1, the directions with most variances contain the most valuable information about the movement of the spring-mass system. We consequently assume that the directions with largest variances in our data set contain the dynamics of interest.