MobiHicleNosis: A Mobile-based Application for Vehicle Fault Diagnosis using Fuzzy Logic

A Thesis Proposal
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CHAPTER 1

The Problem and Its Background

1.1 INTRODUCTION

At present vehicles are used in a variety of activities by different walks of life and as such are not considered a luxury but rather a necessity. Individuals use vehicles to go to work and firms use vehicles for their transport and logistic activities. But at the same time, each of those who owns a vehicle definitely do not want to have a problem on their vehicles as the troubleshooting of the vehicle can be a difficult to them.

More than 3,000 traffic accidents occur around the world every day, and this number is expected to climb along with population growth. Casualties are mainly caused by automobile component malfunctions and human negligence. It is thus important to ensure the healthy status of each component [Tse, Y. and Tse, P.]. In a situation where the vehicle owner or driver is not an auto-mechanic or not knowledgeable about vehicle troubleshooting, they may diagnose a problem wrongly and it may cause more severe problems to their vehicle. Also in uncertain situations, vehicle owners and drivers need to cope with the unexpected problems as fast as possible. Vehicle fault detection and identification is not easy for inexperienced mechanic or driver because it requires a lot of knowledge for finding the fault.

1.2 BACKGROUND OF THE STUDY

Most vehicle noises come from the engine, belts and pulleys, hoses, exhaust system, tires, suspension system, tire to pavement contact, braking and aerodynamic interference. A vehicle noise may be an early signal of an auto system or component failure [ClingClanger]. Even those with lots of experience in vehicle repairs can be fooled by the meaning of engine sounds.

Ignoring these engine noises could lead to a catastrophic situation where the component parts need to be replaced. In addition disregarding vehicles noises could threaten the safety of the driver and result in a breakdown at the worst possible moment. While a vehicle owner always have the option of taking the vehicle to a mechanic for a diagnostic test, one can often get a good idea of what's troubling the engine by listening to it. [The Advance Team, 2013].

The motivation of the study is to develop an expert system that will provide vehicle users with immediate diagnosis of their vehicle faults based from the unusual uncanny sound their vehicle emitted. It is aimed to substitute the traditional "by-ear" method, usage of additional tools such as automotive stethoscope which was used by a mechanic, stated in an article [The Benefits of Using an Automotive Stethoscope] and mobile-application [ClingClanger] which is dependent on the user's decision if sounds from the application's sound library and what the user heard from his vehicle matches.

1.3 CONCEPTUAL FRAMEWORK

1.3.1 Conceptual Framework of the System

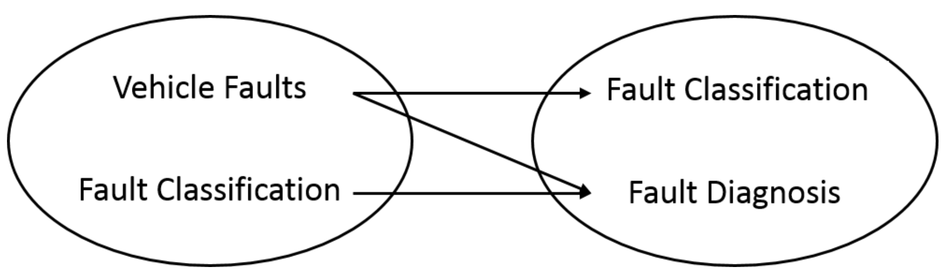

Figure 1. Conceptual Framework of the System

Figure 1 shows the conceptual framework of the MobiHicleNosis. The concept of the system is to develop a mobile-based application for classifying vehicle faults via sound analysis and using fuzzy logic approach for generating its diagnosis. 3 variables are presented by an independent-dependent variable notation. The number of vehicle faults or the combination of faulty sounds in the recorded audio file affects the fault classification. The ability of the system to generate a diagnosis is dependent from the identified vehicle faults based from the sound analysis.

1.3.2 Conceptual Framework of the Study

Figure 2 shows the concept of the study, to conduct a study to develop a fault diagnosis application, which is defined by 3 variables as threshold of its experimentation. The variables: accuracy, performance, correctness of diagnosing will tested.

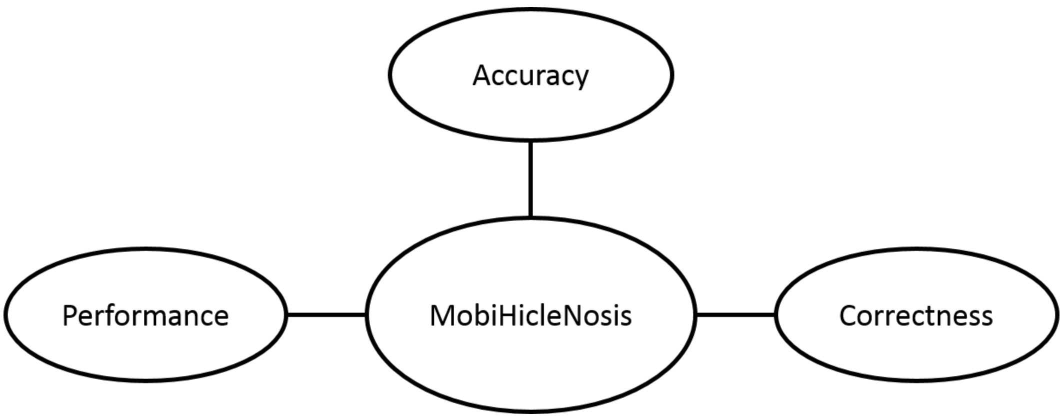

Figure 2. Conceptual Framework of the Study

1.4 STATEMENT OF THE PROBLEM

The study is aimed to develop a mobile-based application for classifying vehicle faults via the sound analysis and give its accurate diagnosis using fuzzy logic approach. Specifically, it wants to answer the following questions:

1. What is the accuracy of classification in terms number of vehicle faults present in the recorded sound?
2. What is the accuracy of fault diagnosis in terms of number of faults classified?
3. What is the performance advantage of the application in giving accurate diagnosis over expert's diagnosis?

1.5 HYPOTHESIS

The proponents hypothesized that there is a performance advantage of the application over the expert in terms of the accuracy and harmonic mean of giving diagnosis. Also, the number of faults present in the sound affects the accuracy of the application.

1.6 ASSUMPTIONS

The proponents of the study assumes the following:

- The age of the vehicle will affect the accuracy of the classification.
- All mobile-devices are of the same features.
- Ambient noises will affect the accuracy of the classification.

1.7 SCOPE AND LIMITATION

1.6.1 Scope and Limitation of the Study

The researchers of the study focuses in developing a mobile-application for vehicle diagnosis. The brand or model included will be Toyota Vios, Honda Civic, Mitsubishi L300, Isuzu Crosswind, Hyundai Starex, Toyota Corolla, Mitsubishi Lancer, Toyota Tamaraw FX and Jeep. The sounds from under the hood, under the vehicle, and outside the vehicle will be considered. Specifically the following vehicle noises are: Engine Clicking noises, Collapsed Lifter noise, Engine Valve noise, Engine Bearing noise, Engine pings or knocks when accelerating, Valvetrain Noise, Piston Pin Noise, Piston Ring Noise, Piston Slap, Crankshaft Knock, Connecting Rod Noise and Detonation. The application will only accept wav files formats of vehicle sound recordings of either moving vehicle or not. To implement the methodologies, MATLAB tools and Android Studio will be used in developing the application. The application is expected to be finished before January 2016.

1.6.2 Scope and Limitation of the System

The study will include established concepts and other developments of audio signal processing and fault diagnosis for automobile diagnosis. The users will use spectral analysis and pattern classification for identifying the faults present and Fuzzy logic approach for diagnosing how to help the user. It will be conducted during the academic year 2015-2016 and expected to be finished before the March 2016. A mechanic-expert will be invited to participate for testing and experimentation of the application.

1.8 SIGNIFICANCE OF THE STUDY

Other Researchers – The proposed study serves other researchers by providing an automotive fault diagnosis solution by utilizing the use of audio signal processing and expert system methodologies that could help them improve the range of their knowledge in applying sound analysis and fuzzy logic approach for providing reliable diagnosis by using the same ideas and concepts presented.

Users – The study helps users especially vehicle owners or drivers, who do not have prior knowledge about vehicle components and how each component works, to carry out immediate aide to possible vehicle defects. It can be used for diagnosing unknown and unseen vehicle problems immediately in the absence of mechanic-experts.

1.9 DEFINITION OF TERMS

Audio Signal Processing – a field that focuses on the computational methods for intentionally altering sounds or sound, often through an audio effect or effects unit.

Automotive Stethoscope – a tool used by mechanics to hear engine parts in need of adjustment or replacement.

Expert System – a computer application that performs a task that would otherwise be performed by a human expert.

Diagnosis – an answer or solution to a problematic situation, a determining or analysis of the cause or nature of a problem or situation.

Vehicle – a thing that is used for transportation.

Mobile-based – application that is installed on mobile devices.

Wavelet packets – a wavelet transform where the discrete-time (sampled) signal is passed through more filters than the discrete wavelet transform (DWT).

CHAPTER 2
Review of Related Literature

2.1 RELATED LITERATURE

2.1.1 Vehicle Faults

From Transmission Repair Cost Guide Blog, it is important to keep up a regular maintenance schedule for your car. Many times major expensive repairs can be avoided if the vehicle is properly maintained. The car should be taken in immediately for service. Determining what problem(s) your car has may seem like an impossible task, especially to the untrained eyes and ears of the average driver. Automotive problems are diagnosed in a similar manner. Problems that involve mechanical systems typically exhibit distinct sensations and sounds that act as indicators that a certain process isn't working the way it is intended to. As soon as you recognize that something seems a bit "off" with your vehicle's functionality, it is time to assess the issue and look for a way to fix it. A car's transmission is a complex mechanical system that controls the application of power from the engine to the driveshaft. It experiences more wear and tear over time than most other parts of your vehicle due to the heat and friction produced by their many moving and interacting components. Major issues are bound to arise if the transmission is not well maintained and/or symptoms of a problem are not checked by a professional soon after they develop [Transmission Repair Cost Guide, 2014].

According to a Citizens Advice Bureau, it is a good idea to approach a mechanic who is a member of the Motor Trade Association (MTA). The MTA expects its members to perform to a high standard of service and honesty, and can provide a free mediation service should a dispute arise between you and your mechanic. Be aware that it is often difficult to estimate how much repairs will cost, as damage may not be obvious and some mechanical faults can lead to other problems. Many mechanics have specialist areas of knowledge, and because of this, it's worth taking the time to find one who has specialist knowledge about your particular make of car and problem area. It is also good to get more than one estimate of the cost of repairs, to ensure the price you will pay is reasonable. When you get the vehicle's condition assessed by the mechanic, you should ask for a quote. The quote is a statement of how much it will cost to fix the car, and also a record of your agreement with the mechanic [Citizens Advice Bureau, 2014].

Based from the AA1Car blog, Engine noise is usually a symptom that something may be wrong with your motor. All engines make some operating noise, but when you hear an unusual noise or excessive noise coming from under the hood, it usually means trouble. The following are some common engine noises: Engine Clicking noises, Collapsed Lifter noise, Engine Valve noise, Engine Bearing noise and Engine pings or knocks when accelerating [AA1Car].

David Fuller said even the manliest of mills can have problems, and the sounds they make can help us track down the troubles. Sometimes it’s nothing; sometimes it’s serious. On his blog, he gave a diagnosis to the common engine noises to avoid potential damage. In the event of strange or unusual engine sounds, remain calm, grab an automotive stethoscope, and be on the lookout for Valvetrain Noise, Piston Pin Noise, Piston Ring Noise, Piston Slap, Crankshaft Knock, Connecting Rod Noise and Detonation [Fuller, 2014].

Brain, M. said that you know how an engine works, you can understand the basic things that can keep an engine from running. Three fundamental things can happen: a bad fuel mix, lack of compression or lack of spark. Beyond that, thousands of minor things can create problems, but these are the "big three." He stated a quick rundown on how these problems affect engine and how does it occur [Brain, 2015].

2.1.2 Fault Diagnosis

According to an article, for the true car fan, nothing beats the roar of an engine or the sounds of a turbo firing up. For the more casual driver, silence is the normally preferred sound as this means nothing is wrong with the car. Next to a visual diagnosis, listening to your car is one of the easiest ways to spot something wrong. Unfortunately, listening to sounds isn’t an exact science, so saying you hear a clunking coming from your vehicle can mean a number of different issues. An engine is loud. There are sounds and noises that will naturally come from the vehicle as it operates. An engine is essentially thousands of contained explosions, so there is some sound to be expected. Some sounds are not to be expected, and can be signs of a greater problem [Hughes, 2015].

An android application, [ClingClanger: When Your Car Makes Noise], is aimed to solve such problem. It turns the smart phone into a library of car noises library then the user is tasked to find a match with those noise coming from the car. Once the user decides that the sounds are matching, the necessary information like the problem and how to repair is presented.

Patrascu, D. said on an article that pretty sure there is no single driver out there who hasn't experienced, at one point in his driving career, strange or eerie noises coming from the car. Regardless of the type of noise, a sudden screech, knock, rattle or whistle is enough to send the driver into a not so pleasant state: What happened? What's wrong? Will my car be OK? Depending on the car you are driving, some of the noises can point to a different fault. What is important to know is that most likely, not being trained, you will miss entirely what the noise means. At that point, you have two options: you either go online and google your problem, or you take the car to a mechanic. Usually, the second course of action is faster and more reliable [Patrascu, 2010].

AutoMD blog has a Q&A Diagnostic Tool for vehicle. It suggested to try AutoMD.com’s easy-to-use, Q & A diagnostic tool. You answer a series of simple questions (What does it sound like? Smell like? What area of vehicle is the problem located in?), and with each answer you narrow down the problem to a few likely diagnoses. When the possible diagnoses are returned, print them out. On that same page, you can click “Inspecting Further.” This sends you to a step-by-step Visual Inspection Guide (with helpful photos, etc.), so you can gather physical proof to hone in further on the right diagnosis. AutoMD.com’s unique “Visual Inspection Guide” explains which tools you may need and exactly what you’ll need to do (i.e., jack the car up, get in under the hood) [AutoMD].

According to James and Tracy blog, when your car develops a clunk or rattle when going over bumps in the road or starts to make an odd sound when driving, often the biggest issue is identifying which drive or suspension component is causing the noise so you can replace it. They said that in the past they have spent some considerable time and money gradually testing and replacing parts until they eventually found the "bad" one and fixed it. Many years on, they've found that there is an easier way. This guide will help track down the failed part using the 'LIT' process, which has three simple steps - Listen, Inspect, Test. If you have ever heard an engineer ask whether the cause of a problem has been "lit up", it is this test he is talking about. Although there are only a few types of suspension and final drive out there in cars, there are many different implementations of each type. While this guide will show you how to identify which part has failed, it does not tell you how to replace the broken part as the approach will be dependant on the make and model of your car. They gave a Component & Suspension Noise Identification Table which has the Listen, Inspect and Test column [James and Tracy].

2.1.3 Vehicle Types and Brands

According to Adrian Ladaga from Carmudi blog, the Philippines has the potential of becoming the “Detroit of Southeast Asia” given its long automotive history and local assembly plants. As a tribute to the rich car culture in the country, he look back at eight popular cars in the Philippines which have been household names and most common on our streets. Toyota Vios, Honda Civic, Mitsubishi L300, Isuzu Crosswind, Hyundai Starex, Toyota Corolla, Mitsubishi Lancer and Toyota Tamaraw FX are the Eight Most Popular Cars in the Philippines for the Past Two Decades [Ladaga, 2014].

2.1.4 Fuzzy Logic

A type of logic that recognizes more than simple true and false values. With fuzzy logic, propositions can be represented with degrees of truthfulness and falsehood. For example, the statement, *today is sunny,* might be 100% true if there are no clouds, 80% true if there are a few clouds, 50% true if it's hazy and 0% true if it rains all day. Fuzzy logic has proved to be particularly useful in expert system and other artificial intelligence applications. It is also used in some spell checkers to suggest a list of probable words to replace a misspelled one [Beal, V.].

2.2 RELATED STUDIES

2.2.1 Fault Diagnosis

Fault diagnosis in rotating machinery has always been a popular focus of researchers in terms of the application of sound and vibration signals instead of pressure signals. For instance, the use of a symmetrized dot pattern (SDP) has been proposed to visualize the sound signals collected from a motor bearing. A faulty SDP can be differentiable from a normal SDP if they are evaluated by well-trained personnel. Shibata showed that an SDP can be used to achieve a higher signal-to-noise ratio [Shibata K et. al., 2000]. Wu and Chuang extended Shibata's work by applying an SDP to both sound and vibration signals [Wu and Chuang, 2005]. They demonstrated the usefulness of this approach in detecting faults in different components such as combustion engines and cooling fans. However, the dot patterns are only interpretable by a trained person. The matching system Wu and Chuang proposed can only be accomplished with a huge number of history templates. On the other hand, Yadav proposed a correlation approach to differentiate between healthy and faulty engines [Yadav et al., 2011]. Their proposed method detects artificially induced defects with high accuracy after the collected sound signals are analyzed. However, they did not include defects associated with the combustion process in their study, perhaps because sound signals cannot provide a satisfactory localization source.

With the aim of minimizing the casualties caused by traffic accidents due to automobile component malfunction and to reduce the wastage of expensive fuel, an IAS method was adopted to monitor the health conditions of automobile engines. Expensive pressure sensors can be replaced with affordable encoders so that a low-cost, effective IAS method can be used for automobiles. The results obtained from the experiments conducted on two passenger cars show that the IAS method is capable of detecting abnormal engine conditions. To achieve real-time fault diagnosis capability, the methods cannot be too computationally intensive, given that they may eventually be used to provide fast diagnosis when an automobile is running on the road. Hence, a simple vibration analysis and simplified IAS method are implemented and reported on in this study. More engine faults must be investigated to provide quantitative analysis for the further verification of the IAS method's effectiveness [Tse, Y. L., 2012].

The service experts assess the condition of the vehicles based on the produced sound. To benefit both, the riders and the experts, the fault diagnosis process needs to be automated. Anami, B.et.al presents a methodology for fault detection of motorcycles, which uses the slopes of the eight pseudospectral segments as features, it employs the MUSIC (Multiple Signal Classification) algorithm to estimate the pseudospectrum. The computed features are classified into healthy and faulty using artificial neural network (ANN) classifier. The presented work classifies the motorcycles into healthy and faulty based on the slopes of the estimated pseudospectral regions. The samples are drawn from sound signals of healthy and faulty motorcycles of different makes and models. Since it takes considerable time for estimating the pseudospectrum and training the ANN, the methodology is not appropriate for on-ride fault diagnosis. The work finds many applications including fault diagnosis of machinery, electronic gadgets, musical instruments and vehicles based on the sound. The work leaves scope for further investigation of localization of faults in vehicles [Anami 2013].

An engine timing gear and valve clearance fault diagnosis method based on discrete wavelet transform (DWT) and a support vector machine (SVM) using engine vibration and sound signals is proposed in the study. The use of mechanical vibration and sound signals for fault analysis in rotating machinery has grown significantly due to the progress of digital signal processing algorithms and implementation techniques. The diagnosis system consists of feature extraction using the discrete wavelet transform and fault classification using the artificial neural network technique with the support vector machine method. In the experimental work, an electronic fuel injection scooter engine is used for simulating six working conditions in the faults of timing gear and intake-exhaust valves. The experimental results show the proposed system can achieve effective fault diagnosis for an expert system [Wu, 2012].

When motorcycle developed fault, the rider will have to call for the service of an Automobile engineers or a roadside mechanic simply because he/she has no technical skill and knowledge required to diagnose such faults. Even when the faults is not a major type, the attention of an engineer or expert is still required otherwise in an attempt to diagnose such fault, a faulty diagnosis may be carried out which further aggravate the problem an ground. Dependence on the expert can be minimized if its expertise can be documented into computer system [Deepa, 2012].

2.2.2 Expert System

Just like any other engine, a motorcycle engine can also develop one fault or the other. The type of fault developed might not be a serious type and hence can be handled by the rider or the owner. An expert system for diagnosing motorcycle fault has been presented in this research work to serve as a guiding tool to the owner or the rider especially when the automobile or mechanical engineer is not readily available. The automobile or mechanical engineer will also find the system useful. Though, the cost of maintaining a motorcycle is cheaper compared to a 4-wheeled vehicle, the developed system will further reduce the maintenance cost since the rider or the owner can carry out some of these activities with the assistance of the developed system. From the information collected, different rules were generated using forward chaining to form the knowledge base of the system. The system was implemented using CLIPS (C Language Integrated Production System) [Olanloye, 2014].

A Mobile Expert System for the Automobile Industry was done by Asabere and Sarpong. The research focus involved in the paper are broadly divided into two classes: (i) how to deal with an issue of a vehicle that is giving problems of sparking/starting the engine and (ii) how to deal with the problems of cooling systems of vehicles. The knowledge-base collected for the mVES proposed in this paper consists of a collection of knowledge from automobile/mechanical engineer experts and a website and constitutes a 15 RuleBased procedure/strategy. At any location and at any time, the proposed mVES in this paper will help vehicle owners or drivers as well as automobile/mechanical engineers improve and solve vehicular problems through the fault diagnosis and consequent advice of the expert system. This research paper recommends that the global automobile industry should develop Mobile Vehicle Expert Systems to help and advice vehicle owners or drivers with vehicular faults and problems when they occur at any time and at any location [Asabere and Kusi-Sarpong, 2012].

Knowledge-Based Expert System for Car Failure Diagnosis was presented from [Jindal, 2010], [Al-Taani, 2007] and [Mostafa, 2012]. The prototype of the system was developed in a limited time and resources and thus it is not that compatible and useful enough to be implemented in the real world yet. There must be so many other works to be taken in refining the errors and rules before it can really be used in the real situation. When this is done, the Expert System for Car failure diagnosis is ready to be used to assist all the car owners out there in situation where they are having problem with their cars and they can do it by themselves. Time and distance is no more a constraints to them [Jindal et.al, 2010]. The system has about 150 rules for different types of failures and causes. It can detect over 100 types of failures. The system has been tested and gave promising results. During the test phase of system it never gave wrong diagnosis according to the rules used. The system indicated that a full expert system will be practical and can be extremely useful in providing consistent car failure detection. Further work is needed to improve the system by adding sufficient domain knowledge that represents domain knowledge thoroughly [Al-Taani, 2007]. Mostafa et.al presents the imperatives for an ES in developing car failure detection model and the requirements of constructing successful

Knowledge-Based Systems (KBS) for such model. In addition, it exhibits the adaptation of the ES in the development of Car Failure and Malfunction Diagnosis Assistance System (CFMDAS). However, CFMDAS development faces many challenges such as collecting the required data for building the knowledge base and performing the inferencing. Furthermore, diagnosis of car faults requires high technical skills and experienced mechanics who are typically scarce and expensive to get. Thus, systems such as CFMDAS can be highly useful in assisting mechanics for failure detection and training purposes. Moreover, capturing and retaining valuable knowledge on such domain yield more accurate and less time consuming models. Adopting another AI technique to work in system rules revision to add more effectiveness to the diagnosis process will be considered [Mostafa et.al, 2012].

2.2.3 Fuzzy Logic

The lack of an accurate model that describes a fault motor is difficult. The main objectives of this paper are to perform fault analysis on an induction motor using both Simulation and Real-time study, devise a failure identification technique to be applied for condition monitoring of the motor and help design an On-line condition monitoring system with fuzzy logic controller using Matlab. A Fuzzy Logic approach help diagnose induction motor faults under such jittery situations. In fact, Fuzzy Logic is reminiscent of human thinking process and natural language enabling decisions to be made based on vague information. Therefore, fuzzy logic technique can adequately be extended to the Induction Motor Fault Detection and Diagnosis. Thus health interpretation of induction motor turns out to be a Fuzzy Concepts [Patil, 2012].

Wu, J. D. presented a fault diagnosis system using acoustic emission with an adaptive order tracking technique and fuzzy-logic interference for a scooter platform. A fuzzy-logic inference is proposed to develop the diagnostic rules of the data base in the present fault diagnosis system. Fuzzy logic is a useful approach to simplify a complex system in engineering application. In their study, a fuzzy-logic inference is used to calculate complex numerical analysis with a membership value easily interpreted by humans. After extracting the features of the proposed adaptive order tracking amplitude figures, fuzzy logic is used to automatically diagnose the faults in the designed scooter experimental platform. The fuzzy-logic inference is proposed to establish the diagnostic rules of the data bank in this fault diagnosis system. The fault diagnosis system consists of the signal analysis and the fault inference. In the signal analysis, the adaptive order tracking with Kalman filter for extracting the order feature of acoustic emission signal is used, and fault inference utilizes a fuzzy logic approach to classify faults under different operating conditions. The experimental results indicated that the proposed expert system is effective for increasing accuracy in fault diagnosis of scooters [Wu J.D. et.al., 2007].

2.3 SYNTHESIS OF THE STUDY

Aside from "by-ear" method on diagnosing the problem of a vehicle or usage of additional tools such as stethoscope, applications which only depends on the matching sounds, and online diagnosis, there were researches that uses different methods in order to diagnose the sound of a vehicle. Some researchers uses ANC which refers to an electromechanical or electroacoustic technique of cancelling acoustic disturbance, symmetrized dot pattern (SDP), correlation approach, Instantaneous Angular Speed (IAS), spectral analysis with classifiers and generates diagnosis from a database, expert system in which users must provide adequate inputs before the system provides a diagnosis and there also exists knowledge-based expert system but further work is needed to improve the system by adding sufficient domain knowledge that represents domain knowledge thoroughly. Almost all existing methodologies mentioned used database for the diagnosis after identifying the faults present, fuzzy inferences alone, or fuzzy logic as classifiers.

The proposed methodology will consist of both audio processing for classifying the faults and fuzzy logic approach for the diagnosis. Specifically, spectral analysis, feature pattern extraction, pattern classification, and fuzzy logic approach for diagnosis which will also help in considering the fact that certain vehicle parts are faulty due to other damaged parts are the breakdown of the proposed methodology. A mobile-based application implementing the methodology is a unique way for vehicle fault diagnosis.

CHAPTER 3
Research Methodology

3.1 RESEARCH METHOD USED

The proponents of the study will make use of experimental research design. Experimental method is a systematic and scientific approach to research in which the researcher manipulates one or more variables, and controls and measures any change in other variables. The use of the experimental method in research makes us more confident about the validity of any cause-effect relationship established between an independent and dependent variable.

In the experiment method used in which the proponents have full control, they will consider the control variable which is the defects of the vehicle resulting to unwanted noises. The number of faults will be manipulated in order to determine its effects in the dependent variable which are the fault classification and diagnosis.

3.2 RESEARCH PARADIGM

Fuzzy Logic is the algorithm that will be used in the study. Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. Fuzzy Logic's approach to control problems mimics how a person would make decisions, only much faster. Fuzzy logic has proved to be particularly useful in expert system and other artificial intelligence applications [Beal, V.].

In this research, Fuzzy Logic will be used in diagnosing the classified fault of the vehicle. Vehicle fault will be classified as either one or more fault types classified by the system which are Engine Clicking noises, Collapsed Lifter noise, Engine Valve noise, Engine Bearing noise etc. Each classified fault will be diagnose using Fuzzy logic to give a solution on it.

3.3 SYSTEM ARCHITECTURE

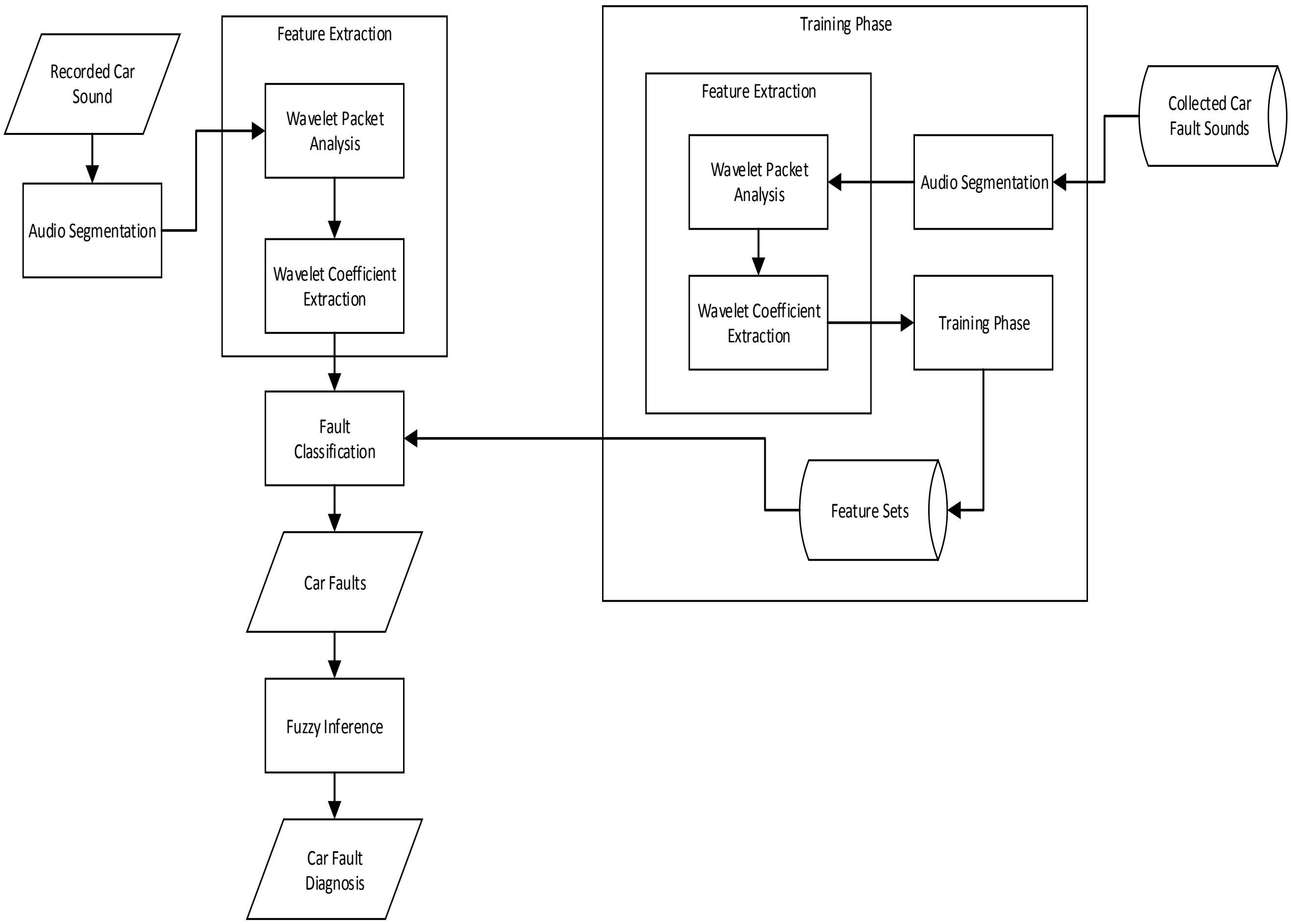

Figure 3. System Architecture

The processed of the system is divided into: Pre-Processing, Feature Pattern Extraction, Feature Pattern Classifier, and Fuzzy Inference. The input for the application is an audio file recorded using the application's recording function or via upload audio function. The acquired sound samples are segmented of one second each. Using DWT or Discrete Wavelet Transform, the combined fault signature in the time domain is transformed to time-frequency domain. The wavelet packet decomposition for feature extraction, both decomposes the details and the approximation coefficients. Wavelet packets form bases which retain the properties of their parent wavelets. A recursive algorithm is used to compute the coefficients. The energy in the approximation coefficients of the wavelet packet decomposition exhibits good separation of different vehicle faults. The extracted coefficients from sampled sounds are input for the training phase using Artificial Neural Networks. The Feature sets grained from training the data sets are used for comparing the input for classifying the faults present in the sound. For the diagnosis process, fuzzy logic will be used. It is because the proponents have taken into consideration the occurrence of chained faults, a component fault resulted to another component fault. Each output of the classifier will be subject to fuzzy logic which will determine what faults are the "real faults" and determine its appropriate diagnosis based from the percentages of each classified faults and the threshold set. Finally, the output of the system is a vehicle fault diagnosis.

3.4 DESCRIPTION OF RESPONDENTS

The respondents of the study are composed of expert and non-expert auto-mechanics. An expert mechanic will be part in testing the accuracy of the application both in terms of classifying vehicle faults and giving diagnosis. In repairing cars, the main role of auto-mechanic is to diagnose the problem accurately and quickly. They often have to quote prices for their customers before commencing work or after partial dis-assembly for inspection. Their job may involve the repair of a specific part or the replacement of one or more parts as assemblies.

3.5 SAMPLING TECHNIQUE

For this study, a purposive sampling will be used. Purposive sampling is a type of non-probability sampling technique - units investigated are based from the judgment researchers. The main goal of purposive sampling is to focus on particular characteristics of a population that are of interest, which will best enable you to answer your research questions. The proponents of the study will make use of a type of purposive sampling called expert sampling. Expert sampling is used when the research needs to glean knowledge from individuals which have particular expertise – automotive mechanics**.** Expert sampling is particularly useful where there is a lack of empirical evidence in an area and high levels of uncertainty. The proponents planned to test the accuracy of the application by considering the evaluation of the expert.

3.6 INSTRUMENTATION

The researchers will use the following tools to gather data:

- Android Phone – this will be used as mobile devices for testing the installed application

  Experiment Paper – (see appendix page) will be used for to record test results during the experimentation.

- Recorded vehicle sounds – this will be used for testing the independent variables to determine the effect to the stated dependent variables.

3.7 DATA GATHERING PROCEDURE

The following are the step-by-step process for collecting data needed for the study:

1. The proponents will prepare an experiment paper mainly based from the scope and limitations of the study.
2. With the guidance of a mechanic, vehicle sounds will be recorded both with and without fault present.
3. An expert, auto-mechanic, will be consulted for testing the accuracy of the system.
4. During experimentation, the expert will be asked to provide answers, such as diagnosis for vehicle faults, classification of vehicle faults, of recorded vehicle sounds with or

without faults. The recorded sounds are subject to different vehicle conditions which is randomly selected and based from what is stated in the scope and limitations of the study.

5. The proponents will also use the same vehicle sounds as input to the application to generate diagnosis and classification of vehicle faults.
6. The gathered data will be tabulated and analyzed.

3.8 STATISTICAL TREATMENT

To test the accuracy of classifying in terms of the number of fault present in the sound, the researchers will use Nominal Data Error Analysis.

$$error(\%) = \frac{n}{N}$$

$$Accuracy = 100\% - error(\%)$$

Where:

n = Total number of faults wrongly classified

N = Total number of faults present

To test the accuracy of diagnosis in terms of classified faults present in the recorded sound, the researches will use F1 Score. The F1 score can be interpreted as a weighted average of the precision and recall, where an F1 score reaches its best value at 1 and worst score at 0.

$$F_1 = 2 \cdot \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}}.$$

Where:

P (precision) = is the number of correct diagnosis divided by the number of all returned diagnosis.

R (recall) = is the number of correct diagnosis divided by the number of correct diagnosis that should have been returned.

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APPENDIX A

Experiment Paper

MobiHicleNosis: A Mobile-Based Application for Car Fault Diagnostics via Car Sound Analysis
Polytechnic University of the Philippines
College of Computer and Information Science
Questionnaire

Name: ____ Date: __________________
(Optional)

I. Test of accuracy of the application per fault. Directions: if fault is present, please put a check mark on the detected column and indicate the appropriate diagnosis.

	Detected	Not Detected	Diagnosis
1. Engine Clicking noises			
2. Collapsed Lifter noise			
3. Engine Valve noise			
4. Engine Bearing noise			
5. Engine pings or knocks			
6. Valvetrain Noise			
7. Piston Pin Noise			
8. Piston Ring Noise			
9. Piston Slap			
10. Crankshaft Knock			
11. Connecting Rod Noise			
12. Detonation			

II. Test of accuracy in terms of number of sounds. Directions: if fault is present, please put a check mark on the detected column and indicate the appropriate diagnosis.

No of Car Faults Present	Classified Car Fault/s	Diagnosis
1		
2		
3		
4		
5		
6		
7		
8		
9		

10		
11		
12		

APPENDIX B

System Template

Figure 4. Main User Interface of the Application

Figure 5. Choice of how input sounds will be provided

Figure 6. Diagnosis