Sound Recognition of Four Stroke Manual Transmission Motorcycle Engine’s Damage

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Abstract. Sound recognition that learns about the source of a sound, which is then used as a reference in learning. Sound recognition referred to in this study is the sound produced from the sound of a motorcycle engine. From the sound of the engine, the sound is then studied more and the results of the recorded sound are then used as objects of research. The management of motorcycle engine sound is carried out using Matlab and assisted by using the HMM (Hidden Markov Model) method with GMM (Gaussian Mixture Model) where HMM is used as chain pattern formation and GMM is used as a sound matching pattern. In this study indeed really learns from every sound of a motorcycle engine that will be used as a sample in the laboratory. From the sound of a motorcycle engine that is heard by the human ear can already indicate the conditions and eligibility limits of the motorcycle. Therefore, from this study trying to find answers to each condition and type of damage from a motorcycle through the sound of a motorcycle engine. With this research, it can help the vehicle owner, because the results of this study warn the vehicle owner to immediately conduct a scale check at the nearest official workshop and from this study also provide benefits and benefits for researchers and motorcycle vehicle owners to find out the condition of the damage early vehicles and help prevent them so as not to cause severe damage which can add air pollution in the city of Dili, East Timor. And the results of existing research are very helpful both for researchers, mechanics and motorcycle vehicle owners.

1. Introduction

In the case of learning being faced that is how to tell or explain to users of motorcycle vehicles to find out the condition of their vehicles. In the automotive world, especially in the current mode of transportation which is becoming popular and much favoured by the people in the City of Dili, East Timor, especially motorcycle vehicles, because of their simple and elegant models and shapes. The motorcycle itself has a classification of engine capacity starting from 50cc (Centimeter Cubic) and there are even more than 1000cc (Centimeter Cubic) with the type of engine there are some that use Two-Stroke and there are Four-Stroke [1], with manual and automatic transmission types that are often found along the city highway of Dili, East Timor [2] - [4]. Why is it necessary to recognize the type of damage to a motorcycle because of the sound of a motorcycle engine we can find out the conditions of eligibility and the type of damage. Because every sound of a motorcycle engine can show the presence status of each engine component or engine part. Therefore, the purpose of this study is to create a system that can recognize signals from the sound of machines that are processed using Matlab and supported by using the Hidden Markov Model (HMM) [5], [6] with the Gaussian Mixture Model (GMM) [7] - [9] and how to analyze system performance in providing accuracy to engine damage according to the symptoms caused by the engine sound signal.
2. Four-Stroke

Sound recognition engine damage motorcycles are learning to know and identify the eligibility conditions of the motorcycle, which learned through the sound of the engine noise when turned on. Before the machine can be switched on a motorbike motorcycle engine has a bunch of components or parts that are formed and arranged in order to switch on the machine and run it. In the structure of the component or part-own motorcycle, engines have different roles and functions [10] – [12]. The condition of the sound of a motorcycle engine noise, there are two conditions at the time of normal or standard and condition at the time of damage to components or parts. Conditions at the time, the damaged component or part is divided into four as to the condition of the engines suffered damage at the components of the Cylinder Head which consists of Camshaft and Valve, engine noise conditions suffered damage on the components of Cam Chain, engine noise conditions suffered damage at the components of the Clutch and engine noise conditions suffered damage at the components of the Crank Shaft/Piston.

![Figure 1. Four Stroke Process](image1)

**Figure 1.** Four Stroke Process [11]

In Figure 1. Above shows the workings of the crankshaft and piston in the position up and down.

![Figure 2. Camshaft and Valve Part](image2)

**Figure 2.** Camshaft and Valve Part [10]

In Figure 2. Above is the engine camshaft from the group with the valve and the arrangement of the parts of the engine group.
In Figure 3. Above is the engine cam chain part of the group and the arrangement of the parts of the engine group.

In Figure 4. Above is a group from the engine clutch and the arrangement of the parts of the engine group.

In Figure 5. Above are the engine crankshaft of the group (piston) and the arrangement of the parts of the engine group. Sound recognition is a sound signal or longitudinal waves caused or resulting vibration from an object in the form of solid, liquid and gas as an intermediary. The voice that can be heard by the human ear is limited, and humans can only hear the sound with a frequency of 20 Hz to 20 kHz or less [13].
On any conditions, the engine noise that has been collected starting from normal conditions until the turn of the spare parts can be view as shown in Table 1.

| Engine Group         | Information | Conditions (%) | Solution for Item Repair                      |
|----------------------|-------------|----------------|-----------------------------------------------|
| Cylinder Head        | Smooth      | 50-70          | Normal Part                                   |
|                      | Noisy       | 71-80          | Setting Valve (Intake and Exhaust)            |
|                      |             |                | Valve IN and EX Guide Replacement Includes Seal, Valve Stem |
|                      | Very Noisy  | 80-90          |                                               |
| Cam Chain            | Smooth      | 50-70          | Normal Part                                   |
|                      | Noisy       | 71-80          | Setting Cam Chain                             |
|                      |             |                | Cam Chain Replacement Include Tensioner(1set)  |
|                      | Very Noisy  | 80-90          |                                               |
| Clutch               | Smooth      | 50-70          | Normal Part                                   |
|                      | Noisy       | 71-80          | Replacement Include Outer Clutch              |
|                      |             |                | Bearing, Radial Ball Replacement              |
|                      | Very Noisy  | 80-90          |                                               |
| Crank Shaft /Piston  | Smooth      | 50-60          | Normal Part                                   |
|                      | Noisy       | 61-70          | Ring Set Piston                               |
|                      |             |                | Replacement Include                           |
|                      | Noisy and Smoky | 71-80      | Replacement Include Piston Replacement Include  |
|                      |             |                | Ring Set Piston and Cylinder                  |
|                      |             |                | Rod Kit Connecting                            |
|                      |             |                | Replacement include                           |
|                      |             |                | Bearing Crankshaft                            |
|                      | Very Noisy  | 81-90          |                                               |

The sound that is used in processing and introduction is the sound of a motorcycle engine the sound with decent conditions of use and the condition of the voice can be recognized, which covers the mechanical condition of the spare part Cylinder Head, Valve, Cam Chain Tensioner, and Crank Shafts Piston [10].
In Figure 6. above is a workflow system developed originally in the form of a sound record of damage to motorcycle engines after recording results in conversions and conversion results in a pattern and use it as a result of the pattern formed is collected data matching used as the information is a result of the program.

In Figure 7. Above is the process of pattern recognition results from the sound extract needed by the HMM, if the recorded sound results that have been patterned by the HMM are then grouped by GMM to determine the results of information that determine the solution of the recorded sound condition of the engine sound that has been processed.
In Figure 8. Above is the process of extracting recorded sound from recorded machine sound so that it can be processed as needed from step by step here the role of MFCC [14] is needed because MFCC is used to extract recorded sound that has normalized noise so that it is easy to use to form the HMM chain to find the patterns needed by GMM.

3. Hidden Markov Model (HMM)
HMM is the model class statistics are frequently used in voice recognition [14], [15]. HMM, that helps model the occurrence is hidden and cannot be observed, but the result can be seen [16], [17]. Although the order of the State cannot be observed directly can only be estimated from the observations resulting from the sequence of the temptation of possibilities. HMM should build a probabilistic model to be able to explain the sequence of observations, in HMM for the probability to use parameters:

In Figure 9. Above are parameters of the HMM in existing presenting State probability in accordance with condition X, which causes the transition state of the possibility of $a_{ij}$, with the possible results of the $b_j$, so the observation might happen Y.
From the HMM parameter with the flow of each Markov chain addressing the transition state and the possibility that will occur in a way that is if the condition [15]:

\[ P[q_t = X_j | q_{t-1} = X_{i-1}, q_{t-1} = X_{i}, \ldots ] \]

\[ = P[q_t = X_j | q_{t-1} = X_j] \] (1)

\[ a_{ij} = P[q_t = X_j | q_{t-1} = X_i], 1 \leq i, j \leq X \] (2)

\[ a_{ij} \geq 0 \] (3)

\[ \sum_{j=1}^{N} a_{ij} = 1 \] (4)

The value of \( a_{ij} \), is the transition probability that does not depend on the circumstances of the time \( t \) as the \( q_t \), and \( a_{ij} \), values amount \( \geq 0 \). If it is assumed according to Prior and Likelihood probability estimation with hidden state is the value \( X \), with a condition where \( X = B, X = R \) and probability for the observation of the circumstances is the value of \( Y \), for the observations of the State of the components of \( Y = H, Y = T, Y = C, Y = P \ldots \) (5) the probability of the possibility:

\[ P(X | Y) \] (5)

\[ P(X = B | Y = H) \] (6)

\[ P(X = R | Y = H) \] (7)

Where the value of \( X = B \) is condition part good, \( X = R \) is the condition of the damaged part, \( Y = H \) for the observation part of the Cylinder Head, \( Y = T \) to observation part Cam Chain Tensioner/, \( Y = C \) for observation part Clutch, \( Y = P \) for Crank Shaft part observation/Piston.

4. Gaussian Mixture Model (GMM)

GMM is a model of the algorithm classifies the data from a dataset to form groups of data not previously defined [9] in a Gaussian distribution with Mean parameter is the centre point Gaussian distribution (\( \mu \)), and Variance is a measure of the spread of the values of the data set (\( \sigma^2 \)):

\[ P(X | \theta) = \sum_{z} \rho(x, z | \theta) \] (8)

\[ P(X | \mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \] (9)

On a standard normal distribution when \( \mu = 0 \) and \( \sigma = 1 \), with probability density functions such as:

\[ \varphi(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2} \] (10)

5. Experiments Result

Simulation for testing the results of voting already as expected and indicates the alignment of a sound physical condition with damage to the motorcycle engines such as in the following image:
In Figure 10. Above displays, the main screen display from application development of this research was used as sound recognition performed on motorcycles.

In Figure 11. Above displays, the results of the recordings made by using Matlab GUI, then processed by a series of HMM from each transition probability already in assume according to Prior and Likelihood probability with estimation of the State of the hidden which is the value of X against the probability of observing the State of the value of Y to find out the percentage of probability the chances of that happening on the machine and the recorded sound will then be stored for use as sample data on further testing and the sound recognition results were done using Matlab GUI, indicate that collaboration between HMM with GMM can display the result of the vote has been recorded so that owners of vehicles, mechanical and researchers can know of any damage to the motorcycle's engine sound be heard.

The results of the motorcycle engine sound recorded can be recognized in accordance with the pattern that has been created. With the results of testing and recognition of the level of accuracy, the damage system is in accordance with the damage conditions of the motorcycle engine used as in Table 2.
Table 2. Recognition Level of Accuracy

| Record Sound | Human Expert (Mechanic) | Program (HMM and GMM) |
|--------------|-------------------------|-----------------------|
| Record 1     | 85                      | 84                    |
| Record 2     | 75                      | 73                    |
| Record 3     | 80                      | 78                    |
| Record 4     | 90                      | 89                    |
| Record 5     | 70                      | 69                    |
| Record 6     | 85                      | 84                    |
| Record 7     | 86                      | 85                    |
| Record 8     | 80                      | 76                    |
| Record 9     | 87                      | 86                    |
| Record 10    | 65                      | 60                    |

From the results of the comparison of the accuracy, level shows that the pattern that is built can recognize the sound produced from the recorded sound of a motorcycle engine with an average error value of 3% and at worst 5%, probably due to the not yet maximum noise normalization. But the results show that the system being built works well.

6. Conclusion

From the results of research that we do and can recognize the sound of a motorcycle engine in accordance with the conditions of any motorcycle engines are used. From the results of pattern recognition give 5%, a recording that has not been recognized by the system being developed, however, 95% of the recordings can be easily recognized and known conditions damage. But from our research did not cover the possibility that the program we develop can be worked perfectly on a type of motorcycle engines are different, therefore needed further research can apply other methods are more competent about voice recognition and can be developed further in the platform.

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