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TYRE PRESSURE MONITORING SYSTEM USING STATISTICAL ANALYSIS AND ROTATION FOREST ALGORITHM

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ABSTRACT

Tyre pressure monitoring systems (TPMS) are dedicated vehicle systems, which is to calculate the vehicle tyre pressure at any condition. Direct tyre pressure monitoring systems use normal pressure sensors to measure the pressure which is fitted within the tyre. These systems are accurate and they need batteries and wireless sensors. An indirect TPMS uses the sensor data from the wheel speed sensor of the anti-lock breaking system and compares them to determine a pressure difference. This paper suggests a new and reliable vehicle tyre pressure supervise hardware using rotation forest algorithm. Vertical wheel hub vibrations are extracted using an accelerometer. The statistical features are acquired from the accelerometer data and the features are classified using rotation forest algorithm. A reasonably good percentage (93.33%) of classification accuracy was attained from the experiment.

Key words: Fault diagnosis, structural health monitoring, machine learning, statistical features, J48 algorithm and Rotation forest (RF) algorithm.

INTRODUCTION

Pressurized air or nitrogen is used in pneumatic tyres to ensure proper maintenance of contact path. Tyres can be classified in to different types such as diagonal, radial and bias belt construction. A radial type tyre inflated with air or nitrogen was chosen for the current work. The Tyre pressure monitoring systems (TPMS) are active intelligent safety systems incorporated with the automobiles to supervise the tyre pressure on a real-time basis. TPMS can be classified in to two, direct TPMS and indirect TPMS according to the data acquisition. Direct TPMS data acquisition can be done using barometric sensors directly connected to the tyre. Indirect TMPS used some indirect methods for data collection from wheel speed sensor or vertical vibration.

Most of the tyre pressure monitoring systems consist of an arrangement with temperature sensor and integrated barometric sensors Velupillai and Güvenç, 2007). In other method of direct TPMS systems an accelerometer is exclusively for the detection of centrifugal acceleration due to the movement of tyre (Wei et al., 2012). Indirect TPMS rely on the signals taken from the wheel speed sensor connected to the wheel of automobile (NIRA Dynamics AB and Dunlop Tech GmbH 2012). While the vehicle is driven in a normal way the damper condition and wheel balance condition were measured using vibration monitoring (Craighead 1996). A piezo electric sensor is used to produce power along with the vibration extraction and that power was fed to the TPMS (Singh et al., 2012). Vertical vibrations are used to acquire for the study of relevance of suspension system and tyre pressure was already presented (Hamed et.al., 2013). In a survey processed by the UK tyre industry council, was found out that approximately 50 percentage of light vehicle accidents were due to the proper tyre conditions (Michael Paine et.al., 2007). All the tyre failures or defects are caused due to the improper tyre pressure also each tyre can drop a pressure (1 psi) due to natural diffusion during a month. (Joshua and Hanlon 2007).

EXPERIMENTAL SETUP

The data and experimental setup used in the present study are same as one used in previous study (Anoop et al., 2016). The experimental arrangement, conditions, procedure and fault simulation are thoroughly explained in previous work. In order to minimize the external electronics interference a shield wire was used to connect between the accelerometer and data acquisition device. According to Nyquist Shannon sampling theorem the sampling rate chosen for a study should be at least two times the high value of incoming frequency to avoid antialiasing (McLean et al., 2005). The minimum sampling rate required in the current study was calculated as 28.26 Hz and hence sampling rate was set at 66 Hz. The accelerometer module was fitted to the rear right wheel hub of the automobile by using some adhesive materials were shown in figure 1.

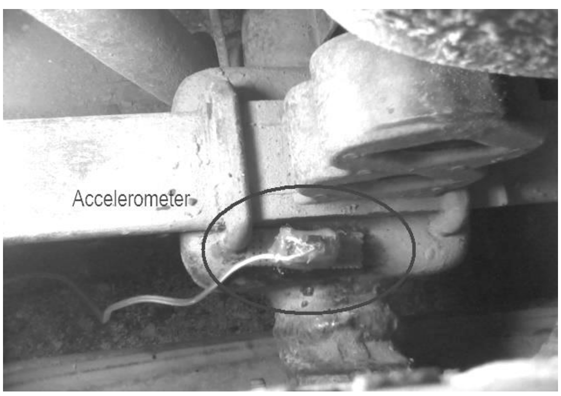

Figure 1. MEMS Accelerometer fixed on the axel

Feature Extraction: Feature extraction is the process of extracting all the statistical features associated with the input signal. Commonly spread sheet software is used to extract the features.

Feature Selection Using J48 Algorithm: The decision tree generated by the J48 algorithm, the detailed accuracy by class for the untrained J48 classifier and the confusion matrix generated by the untrained J48 classifier was obtained from the previous work (Anoop et al., 2016).

Feature Classification – Rotation Forest Algorithm: Rotation Forest (Rodriguez et al., 2006) is a new proposed strategy for building classifier ensembles utilizing individually prepared decision trees. It was observed to be more exact than bagging, Ada Boost and random forest. Rotation forest attracted upon the random forest views. As the tree learning algorithm formulates the classification areas utilizing hyper planes parallel to the feature axes, a slight pivot of the axes might lead to an altered tree. The impact of turning the axes is that classification areas of high accuracy can be developed with fewer trees than in bagging and Ada Boost (Kuncheva and Rodríguez, 2007). The base classifiers are similar to individually made decision trees, yet in rotation forest every tree is trained on the full data set in a rotated feature space. Random forest and bagging gives remarkable outcomes with very bulky ensembles having a huge number of estimator results in the enhancement of the accuracy of these approaches (Patricia, et al., 2015)

Principal Component Analysis (Koen and Dirk, 2011) is an unsupervised technique. In multivariate statistical problems, PCA is used to decrease the dimension of the data with nominal data loss or, in other words, keep determined variation in the information.

RESULTS AND DISCUSSION

Totally 360 samples were collected; out of which 120 samples were from normal condition. 120 from puncture and 120 from idle were collected. Different statistical features were extracted. To predict the different tyre conditions the collected data at different conditions are processed using machine learning technique. 10-fold cross validation is used for measuring the performance of the classifier. Diagonal elements in the confusion matrix shows the correctly classified instances (Table 1) and the others are misclassified once. Table 2 represents the class wise accuracy of rotation forest algorithm. The obtained classification accuracy percentage using rotation forest algorithm was 93.33%. From this classifier, the kappa statistic, mean absolute error and the root mean square error value was found to be 0.9, 0.094 and 0.2053 respectively.

Table 1.Confusion matrix of rotation forest algorithm

Classified as	Normal	Puncture	Idle
Normal	106	12	2
Puncture	9	110	1
Idle	0	0	120

Table 2.Classwise accuracy of rotation forest algorithm

Class	TP Rate	FP Rate	Precision	Recall	F-Measure	ROC area
Normal	0.883	0.038	0.922	0.883	0.902	0.959
Puncture	0.917	0.05	0.902	0.917	0.909	0.973
Idle	1	0.013	0.976	1	0.988	0.993

True Positive (TP) and False Positive (FP) are very important in the classification accuracy of different experiment. Prediction of the performance of the classifier based on the TP and FP values. If a classifier having good performance in classification then the TP rate should be near to one and FP rate should be near to zero. In this experiment the classifier satisfies this condition. So the classifier used in this paper is a better one for solving fault diagnosis problems. Classification accuracy rely on many factors. Figure 2, Figure 3, Figure 4 and Figure 5 shows the variation of classification accuracy with different parameters like varience covered, number of iterations, confidence factor and minimum number of objects respectively.

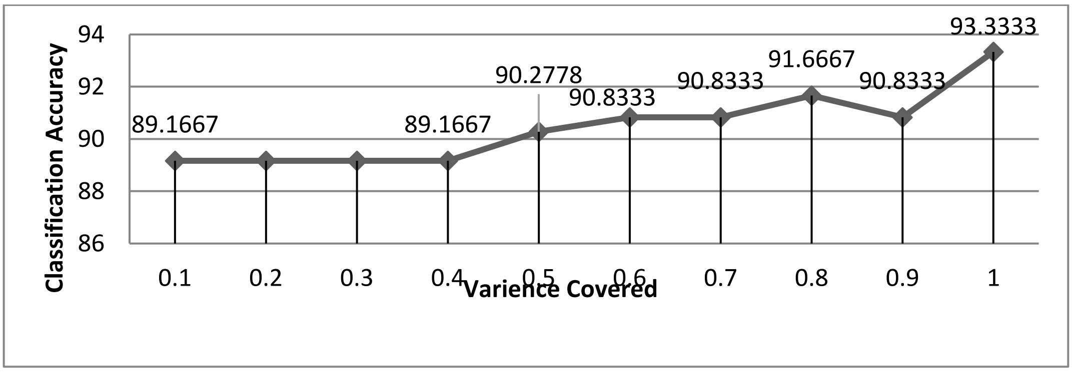

Figure 2: Classification accuracy vs varience covered

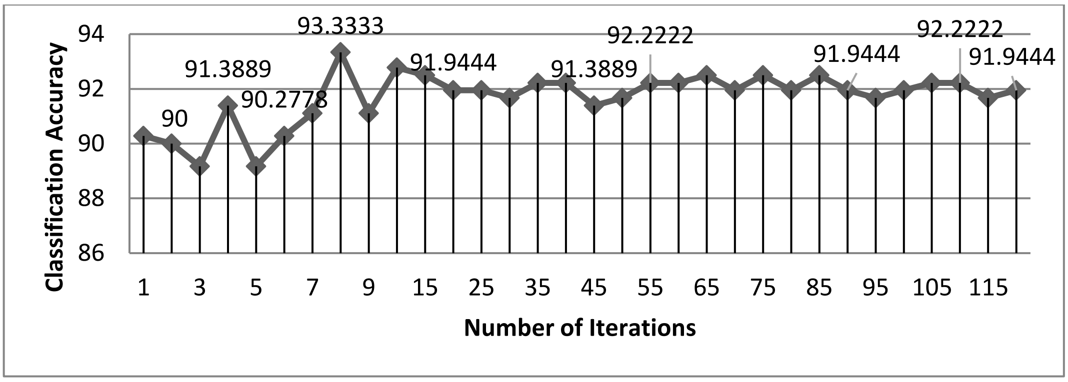

Figure 3: Classification accuracy vs number of iterations

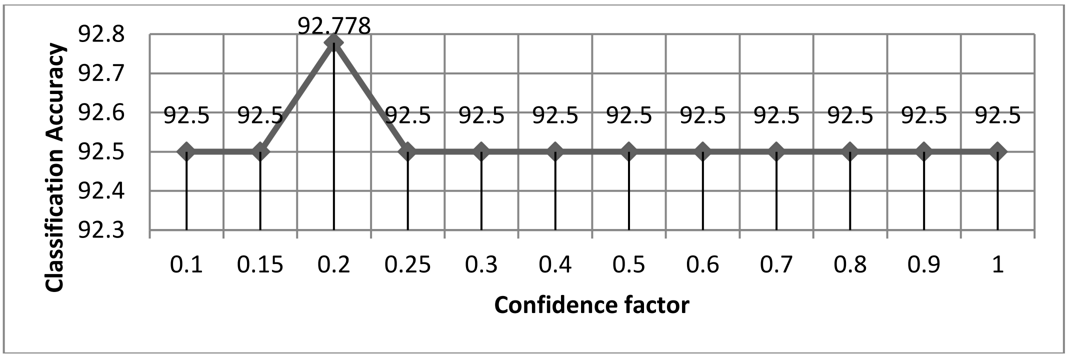

Figure 4: Classification accuracy vs confidence factor.

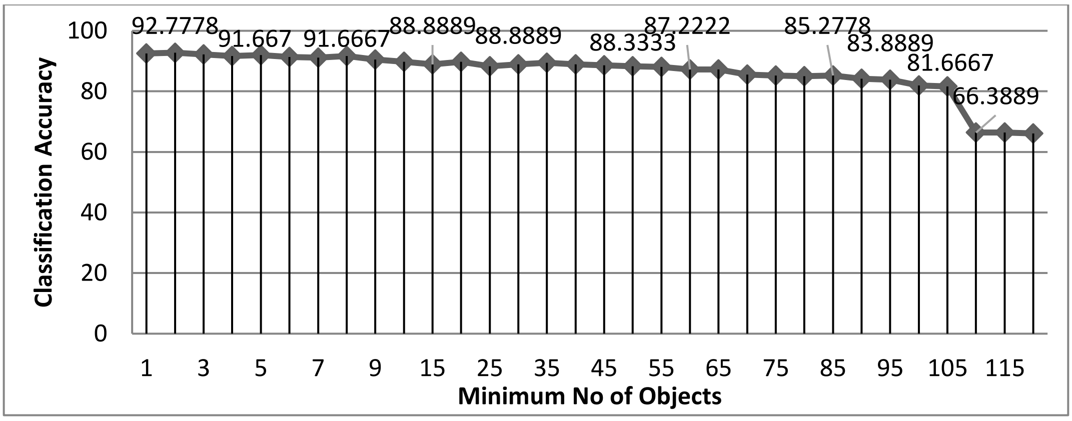

Figure 5: Classification accuracy vs minimum number of objects.

CONCLUSION

Tyre pressure monitoring system is very useful and unavoidable system for automobiles. This paper presents fault diagnosis in vehicle tyres using machine learning approaches. Statistical model was formulated using the extracted data. Rotation forest algorithm was used here classify various fault conditions of the tyre like normal, pucture and idle. Using 10- fold cross validation the model was tested succesfully. The classification accuracy obtained was 93.33%, which is reasonably high. Hence the rotation forest can be used for the condition monitoring of vehicle tyres to avoid the unexpected breakdown.

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