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INTELLIGENT DIAGNOSTICS AND PROGNOSTICS FOR INDUSTRIAL MACHINES USING AN OPTIMIZATION APPROACH

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ABSTRACT

The complexity and high-value of many industrial machines coupled with the ever-increasing demands on manufacturers to offer ensured operational availability means that effective ways of monitoring their health must be adopted. One way to achieve more accurate diagnostic capabilities is to use pattern matching and classification techniques which allow the identification of novel machine behavior. This paper proposes a new data discretization algorithm based on the Piecewise Aggregate Approximation (PAA) algorithm called Optimum-PAA, in order to facilitate more accurate matching of operational data and also allow identification of fault initiation. The paper also demonstrates how the performance of the Symbolic Aggregate Approximation (SAX) pattern matching algorithm is increased through the use of the Optimum-PAA parameters. This has numerous applications in machine health monitoring as well as in ECG analysis and financial data mining.

Keywords: condition monitoring, pattern recognition, piecewise aggregate approximation (PAA), symbolic aggregate approximation (SAX), pattern matching.

INTRODUCTION

The purpose of a condition based monitoring system is to identify abnormal machine behavior as early as possible and assess machine health in order to reduce the risk of component failure. Traditional condition monitoring systems operate by comparing machine operating characteristics with set limits, and triggering an alarm if the limit is reached. In some cases, however, the alarm is triggered very close to, or at the point of component failure with no prior indication of fault initiation. More advanced systems can offer more reliable indication of the onset of failure, although their increased sensitivity means that there is a greater risk of false alarms. These systems, however, offer little opportunity to identify the initiation point of a particular fault meaning that the system merely indicates that a fault has occurred but lack any prognostic capabilities. The ability to identify a fault along with its failure mode is profound in terms of allowing users and manufacturers to make informed decisions on the future running of the equipment, identifying required parts and optimizing service time.

Piecewise Aggregate Approximation (PAA) is one of the more recent methods for dimensionality reduction which uses the mean values of equal sized frames (Keogh, 2000). This discretized version of the signal can then be used to generate a symbolic representation through the Symbolic Aggregate Approximation (SAX) algorithm allowing for fast similarity searching (Lin, 2003). This approach has been widely used in the analysis of ECG signals (for example, Kulahcioglu 2008). The Optimum-PAA algorithm proposed in this paper has been developed using a combination of the Differential Evolution and Particle Swarm Optimization algorithms which are able to select the most efficient PAA parameters to give the best separation of operational data and thus achieve more accurate and reliable pattern matching and classification. The paper uses a series of rundown vibration data from an industrial gas turbine as a way of validating the approach.

RESULTS AND CONCLUSIONS

The optimum PAA parameters (for 4 clusters) in terms of the number of frames (count left and right thresholds) and their distribution (left and right form factors) are shown in table 1 along with the associated cluster separation and density. This is also shown for the non-optimized PAA.

Table 1 - PAA parameters and associated cluster separation and cluster sizes

	Count Left Threshold	Left Form Factor	Count Right Threshold	Right Form Factor	Separation (Required Large)	Cluster Size (Required Small)
Optimum-PAA	4	1.1648	2	0.3903	0.674	202.26
Non-optimised	3	0.1667	3	0.1667	0.426	394.5

The parameters identified by Optimum-PAA are then used to provide an improved SAX representation. Comparisons are shown for two rundowns in different clusters; rundown 1 in cluster 2 and rundown 2 in cluster 3. The similarity between rundowns is measured using a Euclidean distance measure and by the number of matches.

Optimized SAX

Rundown 1 - CFFFFFFFAA

Rundown 2 - FBBBBBBBCD

Matches = 0, Distance = 11.58

Non-optimized SAX

Rundown 1 - ACFCAAAAAA

Rundown 2 - ECFFBAABDE

Matches = 4, Distance = 7.21

The results show that through application of the new optimization methodology, vibration signatures in different clusters show less matches and a greater distance measure. Similarly, the full paper shows that vibration signatures in the same clusters show greater matches and a smaller distance measure when compared to the non-optimized approach. It is also shown that the model is able to separate out the two rundowns associated with a fault condition into an individual cluster thus enabling prognostic capabilities.

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REFERENCES

[1]-Keogh E, Chakrabarti K, Pazzani M, Mehrotra S, Dimensionality reduction for fast similarity search in large time series databases, Journal of Knowledge and Information Systems (2000).

[2]-Lin J, Keogh E, Lonardi S, Chiu B, A Symbolic Representation of Time Series, with Implications for Streaming Algorithms, In proceedings of the 8th ACM SIGMOD Workshop on Research Issues in Data Mining and Knowledge Discovery (2003).

[3]-Kulahcioglu B, Ozdemir S, Kumova B, Application of Symbolic Piecewise Aggregate Approximation (PAA) Analysis to ECG Signals, Journal of Applied Simulation and Modelling, Issue 609 (2008).