Available online at www.sciencedirect.com
ScienceDirect
Mechanical Systems and Signal Processing 22 (2008) 1179–1193
Mechanical Systems and Signal Processing
www.elsevier.com/locate/jnlabr/ymssp

Machine condition prognosis based on regression trees and one-step-ahead prediction

Van Tung Tran[a], Bo-Suk Yang[a,*], Myung-Suck Oh[a], Andy Chit Chiow Tan[b]

[a]*School of Mechanical Engineering, Pukyong National University, San 100, Yongdang-dong, Nam-gu, Busan 608-739, South Korea*
[b]*School of Mechanical, Manufacturing and Medical Engineering, Queensland University of Technology, G.P.O. Box 2343, Brisbane, Qld 4001, Australia*

Received 2 August 2007; received in revised form 11 November 2007; accepted 13 November 2007
Available online 19 November 2007

Abstract

Predicting the degradation of working conditions of machinery and trending of fault propagation before they reach the alarm or failure threshold is extremely important in industry to fully utilize the machine production capacity. This paper proposes a method to predict the future conditions of machines based on one-step-ahead prediction of time-series forecasting techniques and regression trees. In this study, the embedding dimension is firstly estimated in order to determine the necessarily available observations for predicting the next value in the future. This value is subsequently utilized for the predictor which is generated by using regression tree technique. Real trending data of low methane compressor acquired from condition monitoring routine are employed for evaluating the proposed method. The results indicate that the proposed method offers a potential for machine condition prognosis.

Keywords: Embedding dimension; Regression trees; Prognosis; Time-series forecasting

1. Introduction

Unexpected catastrophic failures of machine that lead to a costly maintenance or even human casualties can be avoided with the proviso that the machine is appropriately maintained. Traditional maintenance strategies commonly used in industry consist of corrective maintenance and preventive maintenance. The former means "fix it when it breaks," i.e., maintenance is carried out after a breakdown or when an obvious fault has occurred, whilst the latter is carried out in order to prevent equipment breakdown by performing repair, service, or replacing components at a fixed schedule. Even though preventive maintenance plans increase the reliability of machine, they are costly due to the frequent replacements of the expensive components before the end of their lives and the reduction of the availability of the machine's productive capability. Therefore, the strategies of traditional maintenance are not adequate to fulfill the needs of expensive and high availability of industrial systems.

*Corresponding author. Tel.: +82 51 620 1604; fax: +82 51 620 1405.
E-mail address: bsyang@pknu.ac.kr (B.-S. Yang).

0888-3270/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ymssp.2007.11.012

Condition-based maintenance (CBM) which involves prognostic module is an alternative maintenance strategy that allows the machine to operate continuously until symptoms of a failure are detected. Prognosis is the ability to access the current state, forecast the future state, and predict the time-to-failure or the remaining useful life (RUL) of a failing components or subsystems. The RUL is the time left for the normal operation of machine before the breakdown occurs or machine condition reaches the critical failure value. Prognosis is also used to produce warning when the machine condition reaches the predetermined setup alarm or critical failure threshold. Furthermore, it can be used for running repairs periodically in manufacturing facilities and fault-tolerant control [1]. Due to the benefits mentioned above, prognosis has been extensively researched with focus on CBM in the recent time.

Nevertheless, prognosis is a relatively new area and becomes a significant part of CBM of systems [2]. Currently, numerous approaches to prognosis that range in reliability from simple historical failure rate models to physics-based models have been developed. According to Ref. [3], the hierarchy of potential prognostic approaches related to their applicability and relative accuracy as well as their complexity is performed in Fig. 1. Out of the experience-based prognostic technique that requires the component failure history data, the remaining techniques use the models for the purposes of predicting the future conditions of the monitored system.

Model-based prognosis techniques require an accurate mathematical model of the failure modes to be used to predict the RUL of critical components. Some of the published researches in prognosis include predicting RUL of high power clutch systems, estimating the time-to-failure of mobile robot and forecasting the remaining utility of bearings [4–6]. However, those techniques are merely applied for some specific components and each of them needs a different mathematical model. Furthermore, a suitable model is also difficult to establish to mimic the real life.

The data-driven approaches are directly derived from the routinely monitored system operating data and associated with either statistical or learning techniques based on the theory of pattern recognition. Artificial intelligent techniques which belong to learning techniques are regularly considered by researchers due to their flexibility in generating appropriate models. The salient researches based on data-driven approaches have been proposed, such as Vachtsevanos and Wang [7] who used dynamic wavelet neural network to predict the failure growth based on the vibration signals to estimate the RUL of bearings. Huang et al. [8] predicted the RUL of ball bearing by self-organizing map and back propagation neural networks methods using vibration signals. Wang et al. [9] utilized and compared the results of two predictors, which were recurrent neural networks and adaptive neuro-fuzzy inference systems, to forecast the damage propagation trend of rotating machinery.

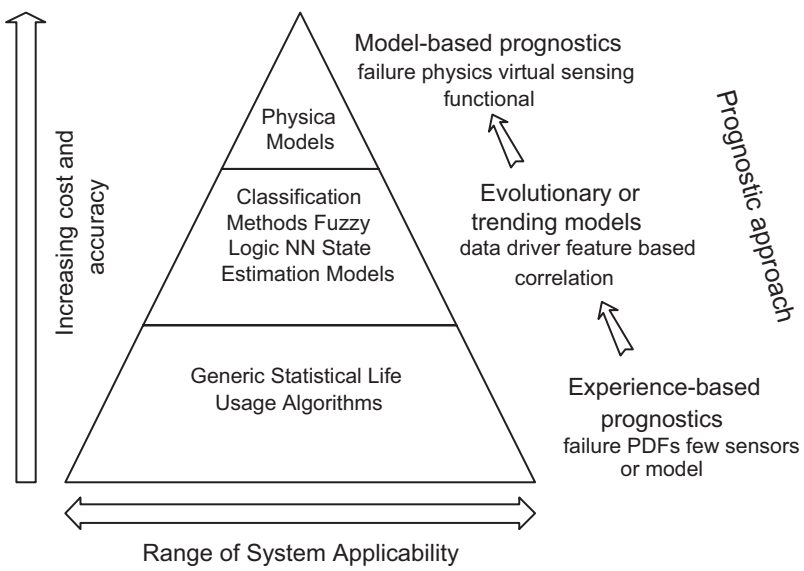

Fig. 1. Hierarchy of prognostic approaches.