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A prognosis method using age-dependent hidden semi-Markov model for equipment health prediction

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ABSTRACT

Health monitoring and prognostics of equipment is a basic requirement for condition-based maintenance (CBM) in many application domains. This paper presents an age-dependent hidden semi-Markov model (HSMM) based prognosis method to predict equipment health. By using hazard function (h.f.), CBM is based on a failure rate which is a function of both the equipment age and the equipment conditions. The state values of the equipment condition considered in CBM, however, are limited to those stochastically increasing over time and those having non-decreasing effect on the hazard rate. The previous HSMM based prognosis algorithm assumed that the transition probabilities are only state-dependent, which means that the probability of making transition to a less healthy state does not increase with the age. In the proposed method, in order to characterize the deterioration of equipment, three types of aging factors that discount the probabilities of staying at current state while increasing the probabilities of transitions to less healthy states are integrated into the HSMM. With an iteration algorithm, the original transition matrix obtained from the HSMM can be renewed with aging factors. To predict the remaining useful life (RUL) of the equipment, hazard rate is introduced to combine with the health-state transition matrix. With the classification information obtained from the HSMM, which provides the current health state of the equipment, the new RUL computation algorithm could be applied for the equipment prognostics. The performances of the HSMMs with aging factors are compared by using historical data colleted from hydraulic pumps through a case study.

1. Introduction

The manufacturing industry of modern economy systems increasingly needs to produce at high reliability, low environmental risks and human safety while operating their processes at maximum yield. Technological development has resulted in increased complexity in both industrial machinery and production systems. It is difficult or almost impossible to identify and predict failure conditions in a timely manner. In manufacture systems, machine breakdowns usually limit uptime in critical situations. Equipment health diagnostics and prognostics implementing CBM becomes a basic and desirable requirement in many application domains where safety, reliability, and availability of systems are considered mission critical.

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