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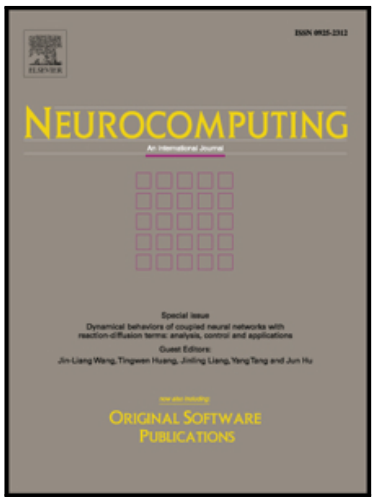

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Hierarchical multi-class classification in multimodal spacecraft data using DNN and weighted support vector machine

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Abstract

Prognostics and health management (PHM) is widely applied to assess the reliability, safety and operation of systems particularly in spacecraft systems. However, spacecraft systems are very complex with intangibility and uncertainty, and it is difficult to model and analyse the complex degradation process, and thus there is no single prognostic method for solving the critical and complicated problem. This paper presents a novel hierarchical multi-class classification method using deep neural networks (DNN) and weighted support vector machine (WSVM) in order to achieve a highly discriminative feature representation for classifying the multimodal spacecraft data. First, the stack auto-Encoder (SAE) or deep belief network is adopted to initialize the initial weights and offsets of the hierarchical multi-layer neural network in order to reduce the dimension of the original multimodal data, and the optimal depth of multi-layer neural network and the discriminative features are also obtained. Second, in order to make the high dimensional spacecraft data more separable, the initialization parameters are online monitored by using a gradient descent method. Finally, a flexible hierarchical estimation method of a multi-class weighted support vector machines (MCWSVM) is applied to classify the multimodal spacecraft data. The performance of the proposed work is evaluated by the classification accuracy, sensitivity, specificity and execution time, respectively. The results demonstrate that the proposed DNN with MCWSVM is efficient in terms of better classification accuracy at a lesser execution time when compared to K-nearest neighbors (KNN), SVM and naive Bayes method (NBM).

Index Terms—Prognostics and health management (PHM), deep neural network (DNN), multi-modal spacecraft data, weighted support vector machine (WSVM), deep belief network.

1. Introduction

Prognostics and health management (PHM) plays a vital role for the safety, reliability, launch and operation of the spacecraft. In the spacecraft systems, PHM monitoring capability is becoming desirable increasingly. Thus, the precise PHM can improve the safety and reliability of the spacecraft [1, 2]. Recently, some feature extraction algorithms and expert systems were commonly applied to assess both the spacecraft health and decision support in order to predict fault signals from the complex spacecraft systems [2, 3]. For example, a principal component analysis (PCA) approach clustered by the fuzzy *c*-means (FCM) was introduced to extract the discriminative features from the spacecraft multimodal data such as images, videos and digital heterogeneous data, and further a weighed proximal support vector machine (WPSVM) algorithm was used to improve the classification accuracy of electrical characteristics spacecraft based on the spacecraft multimodal data [4].Their results were shown that a highly classification accuracy was obtained, compared to the classical classification techniques like support vector machines (SVM) [5, 6]. However, their method did not consider the case of solution to the

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