DETECTING RISK OF FAILURE IN A POWERED WHEELCHAIR SENSOR SYSTEM USING ARTIFICIAL NEURAL NETWORKS

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Abstract

The Systems Engineering Research Group at the University of Portsmouth has been loading more and more complicated systems onto powered wheelchairs. It is important that these mixes of various complex wheelchair systems are fault tolerant. This paper presents a simple method that normalizes the electronic control sensor data of the modified powered wheelchairs to reflect their fault thresholds, and then uses the normalized data as inputs for a neural network. The network automatically analyses mixed correlations of data about the wheelchair and detects potential risks. Simulation suggests that faults in the powered wheelchair systems can be detected within the data sets.

Keywords: ANN, sensor, wheelchair, fault.

Introduction

The Systems Engineering Research Group at the University of Portsmouth has been experimenting with electronic control systems to improve the performance of some powered wheelchairs [1]. That has included mounting sensors and control devices onto the wheelchairs. The measured electronic data from each of the sensors can be analyzed to diagnose system faults. A wheelchair maintenance center can manage information about the control of the wheelchair and examine faults remotely when wireless network terminals are installed. If the data is analysed accurately and consistently then efficiency can be improved, for example: maintenance, and fault prediction.

Previous techniques for detecting vehicle faults [2, 3] have been limited to estimating specific equipment performance, for example battery life-times [2] or vehicle full-state estimations [3]. Although previous work [4] demonstrated a remote fault prognostic approach, it was designed to monitor the failure of each separate component. These approaches cannot forecast faults such as a "turned-off-during-driving" state that may occur even when no electronic equipment has malfunctioned. In addition, they cannot estimate the likely-hood of faults occurring from correlations of electronic vehicle data.

Method

This proposed method first normalizes the electronic data from the powered wheelchair systems through a data pre-processor, and then inputs the data into an artificial neural network to estimate whether wheelchair system failures may occur. Subsequently, the networks output the current risk for each sub-system. Finally, the system determines whether any problems with sub systems are dangerous through a probabilistic analysis. If a predicted result is distinguished as a sign of danger, then the system provides a warning to the user and any carers.

Data pre-processor*:* Expert knowledge was used with research data to identify relationships between powered wheelchair data and failures. Ten types of data were used with four types of sub-system for monitoring for faults. The normalization method was determined based on the median between the minimum and maximum thresholds.

Neural networks: A perceptron architecture [5] was used to map sets of input data onto a set of appropriate outputs. After wheelchair system data had been preprocessed, the neural networks learnt using a training data that consisted of varied fault data. A set of normalized wheelchair system data can be represented by:

$$\tau = \{v_{\varphi 1}, v_{\varphi 2}, v_{\varphi 3}, \ldots, v_{\varphi n}\}$$

where τ is a set of vehicle data and φ is normalized vehicle data range considering each vehicle data threshold.

A set of wheelchair sub systems is represented as Γ.

$$\Gamma = \{o_1, o_2, o_3, \ldots, o_m\}$$

Network learning is accomplished by calculating the link couplings among each node of the networks. The couplings are weights between input and output nodes. The approach is based on a detecting formula that considers multiple data inputs from the wheelchair sub systems, as follows:

$$f(\tau) = \{f_1, f_2, f_3, \ldots, f_m\}$$

$$f_k = \mathrm{NET}\left(\frac{\sum_{j=1}^{n} w_k \cdot v_{\varphi j}}{n}\right)$$

where $f(\tau)$ is a set of probabilistic risk values, τ is the normalized wheelchair data input into the networks, and *NET* is an activation function of the networks. Of these, the optimal value of w_k is determined by learning about the wheelchair sub systems.

$$w_k = \frac{\sum_{a=1}^{n} NET\left(\left(v_{\varphi a} \cdot P(v_{\varphi a}, o_k)\right) + \left(\frac{\sum_{b=1}^{n-1} \lambda_b \cdot P(\lambda_b, o_k)}{n-1}\right)\right)}{n}$$

Here, the relational degree between data and wheelchair subsystem is denoted as $P(v\varphi a, ok)$, and the link coupling between data as input nodes and failure / breakdown data as output nodes.

Let α be the number of vehicle data related to an outlier. Note that the formula to get w_k considers not only the relation of $v\varphi a$ and o_k but also the relation of λ_b and o_k. A sigmoid function [5] was adopted as the activation function of vehicle outlier predictions since this function was suitable for converting nonlinear values such as steering wheel angle voltage into linear values within the networks.

Performance tests were conducted on datasets with aged devices and sudden breakdowns. Prediction times and precision achieved between real sub systems and estimated failures were noted. The main purpose of detecting problems with the sub-systems was to give users, carers and rehabilitation engineers sufficient time to take proper action by detecting faults before they occurred or predicting problems in advance. The precision becomes more accurate as times increase. Therefore, potential problems should be detected before real problems occur.

Discussion and conclusion

A simple method for detecting problems is presented based on artificial neural networks monitoring wheelchair sub systems. The networks are capable of forecasting some wheelchair failures efficiently.

Theoretical outlier detection for time series data has been studied for some time. Advances in hardware and software technology has accelerated the growth of real data sets being considered, all generated by a multitude of applications. This paper provided a suggestion for use with systems now being loaded onto powered wheelchairs. The technique attempts to improve fault tolerance by normalizing electronic control sensor data and using that normalized data as inputs for a neural network. The network automatically analyses mixed correlations of the data and detects potential risks.

Simulation suggests that faults in powered wheelchair systems can be detected within the data sets. Experimental results showed that the system detected not only faults in aged equipment but also some critical breakdowns. The method can be used as an important module within a powered wheelchair management system for improving efficiency and safety.

References

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