Gated Recurrent Units Based Neural Network For Tool Condition Monitoring

Introduction

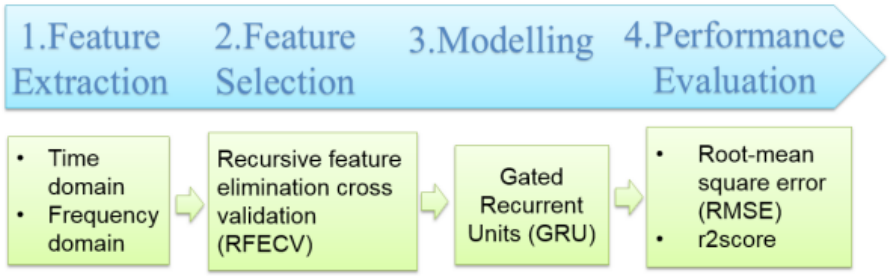
Tool condition monitoring (TCM) is a prerequisite to ensure high finishing quality of workpiece in manufacturing automation. One of the most important components in TCM system is tool wear estimation. Tool wear includes the gradual failure, chipping, broken of cutting tools due to regular operation. The tool wear increases as the cutting proceeds, which directly reduces the tool residual life. Subsequently, the friction between the worn tool and the workpiece increases, so as to the power consumption and vibration in the system. Eventually, the worn tool produces a rough surface of workpiece, distortions in dimension.

In the past few decades, recurrent neural network (RNN) has shown a great success in learning long-term dependence of the sequential data. However, traditional RNNs (e.g., vanilla RNN, etc.) suffer gradient vanishing or exploding problem as well as long computational training time when the model is trained through back propagation through time (BPTT). To address these issues, a gated recurrent units (GRU) based neural network is proposed to estimate the tool wear for tool condition monitoring. The GRU neural network can analyze time-series data on multiple time scales and can avoid gradient vanishing during training. A real-world gun drilling experimental dataset is used as a case study for tool condition monitoring in this paper. The performance of the proposed GRU based TCM approach is compared with other well-known models including support vector regression (SVR) and multi-layer perceptron (MLP). The experimental results show that the proposed GRU based TCM approach outperforms other competing models on this real-world gun drilling dataset.

GRU based TCM approach

The proposed GRU based TCM approach includes four parts. They are: 1) feature extraction; 2) feature selection; 3) GRU regression modeling; 4) evaluation. The flowchart of the proposed approach is shown in Figure below. Firstly, time-domain and frequency-domain features are extracted from the sensory data. Then the normalized features are selected via recursive feature elimination with cross validation (RFECV). Thirdly, the

selected features are used as the inputs of the GRU based neural network for tool wear estimation. Finally, the regression. The flowchart of the proposed GRU based TCM framework. performance is evaluated with two evaluation metrics (i.e. RMSE, r2score).



Conclusion

A GRU based TCM approach has been proposed for accurate tool wear estimation. The proposed approach has been compared with SVR and MLP on this dataset. The experimental results have shown that the proposed approach outperformed other competing methods in terms of RMSE and r2score. Based on the experimental results, the effectiveness and generalization ability of force signals and GRU based TCM approach in progressive tool wear estimation is proven to be practical. The limitations include the limited experimental conditions and small data size. In order to achieve a better generalization ability on new cutting conditions, further research needs to be done such as on other varying cutting conditions. In summary, GRU based TCM approach shows better performance in continuous tool condition monitoring system.