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Intelligent Chatter Detection in Turning Operations with Imbalanced Data Using Conditional Generative Adversarial Networks

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ABSTRACT

Turning is one of history's oldest and most frequently used machining methods. Chatter is an undesirable vibration caused by the forces between the cutting tool and the workpiece, reducing cutting efficiency in machining processes. Chatter vibrations, the most destructive vibration type for machines, can damage the workpiece, cutting tool, and machines during the machining process. Despite recent advances in intelligent data-driven chatter detection methods, most studies assume balanced training datasets for different class conditions. However, chatter signals are often difficult and expensive to collect, resulting in unstable training datasets. In addition to real training data, this study proposes a deep learning-based chatter detection method to eliminate data imbalance issues. For the first time, one-dimensional conditional generative adversarial network (CGAN)s are used in chatter detection to alleviate the lack of data in the datasets, especially the data manifesting chatter. Turning data is obtained with the help of a low-cost sensor that can be easily integrated into the system. The complete ensemble empirical mode decomposition with adaptive noise (CEEMDAN) decomposition algorithm is used for the first time within the scope of chatter detection studies to eliminate the noise effects in the data collected within the scope of the experiments. Furthermore, the reliability of synthetic data produced in different scenarios is investigated. The results of the scenarios in which synthetic data produced with CGAN are also compared with the test results obtained with synthetic data produced with variational auto encoder (VAE). While aiming to increase the chatter detection percentages with synthetic data, the detection model trained with unreal data is tested with real-life scenarios collected from another tool position, and the capability of the synthetic data produced is demonstrated. The contributions of the synthetic data and the CEEMDAN algorithm to detecting chatter are presented in light of the results. All experimentally obtained and synthetically generated data will be available on open platforms.

Keywords Regenerative Chatter · Turning · Deep Learning · CGAN · CEEMDAN · VAE

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