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Smart Sensor Data to Predict Machine Performance with IoT-Based Machine Learning and Artificial Intelligence

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Abstract : The global manufacturing industry is utilizing the internet and cloud-based services to further explore the anatomy and optimize manufacturing processes in support of the movement into the Fourth Industrial Revolution (4IR). The 4IR from a third world and African perspective is hindered by the fact that many manufacturing systems that were developed in the third industrial revolution are not inherently equipped to utilize the internet and services of the 4IR, hindering the progression of third world manufacturing industries into the 4IR. This research focuses on the development of a non-invasive and cost-effective cyber-physical IoT system that will exploit a machine's vibration to expose semantic characteristics in the manufacturing process and utilize these results through a real-time cloud-based machine condition monitoring system with the intention to optimize the system. A microcontroller-based IoT sensor was designed to acquire a machine's mechanical vibration data, process it in real-time, and transmit it to a cloud-based platform via Wi-Fi and the internet. Time-frequency Fourier analysis was applied to the vibration data to form an image representation of the machine's behaviour. This data was used to train a Convolutional Neural Network (CNN) to learn semantic characteristics in the machine's behaviour and relate them to a state of operation. The same data was also used to train a Convolutional Autoencoder (CAE) to detect anomalies in the data. Real-time edge-based artificial intelligence was achieved by deploying the CNN and CAE on the sensor to analyse the vibration. A cloud platform was deployed to visualize the vibration data and the results of the CNN and CAE in real-time. The cyber-physical IoT system was deployed on a semi-automated metal granulation machine with a set of trained machine learning models. Using a single sensor, the system was able to accurately visualize three states of the machine's operation in real-time. The system was also able to detect a variance in the material being granulated. The research demonstrates how non-IoT manufacturing systems can be equipped with edge-based artificial intelligence to establish a remote machine condition monitoring system.

Keywords : IoT, cyber-physical systems, artificial intelligence, manufacturing, vibration analytics, continuous machine condition monitoring
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