Guest Editorial
Special Section on Big Data Analytics in Intelligent Manufacturing

AN INTELLIGENT manufacturing system is a manufacturing system that can automatically adapt to changing environments and varying process requirements with minimal supervision and assistance from operators. It is essentially a cyber–physical production system that has enhanced intelligence due to learning, reasoning, adaptation, and decision making. The success of intelligent manufacturing relies on the timely acquisition, distribution, and utilization of various types of data from machines, manufacturing process, and products. These huge amounts of data, both numerical and structural, are fused and form the "big data" required for execution of intelligent manufacturing.

The efficient use of big data can enhance the intelligence and automation of manufacturing process, provide high quality products and just-in-time production, and increase productivity and reduce costs. For example, by analyzing the factory floor data, equipment monitored data, and the enterprise manufacturing database, it could help to store, explore, and make complex decisions for the manufacturing system. While these big data topics have been widely discussed in the public media and the theory has been rigorously treated by statisticians and computer scientists from academia, little has been explored in the manufacturing research community from an engineering point of view.

This special section aims to bridge the gap, and provides a platform for the communities to report recent findings and emerging research developments in the field. Nine papers have been selected for publication in this section from 48 submissions, following several rounds of reviews. They cover a wide range of subjects, from large-scale manufacturing data analytics, data-driven process monitoring, prognostics, and health management to machine learning applications, especially the fast developing deep learning techniques with applications to intelligent manufacturing.

Digital twin (DT) is one of the key technologies for realizing intelligent manufacturing. The DTs are seamless integration of the cyber and physical spaces, and have been successfully implemented in various aspects, including design, production, maintenance, and lifecycle management, etc. In an effort to understand the development and application of DTs in industry, Tao *et al*. investigate the DT research in the paper "Digital Twin in Industry: State-of-the-Art" concerning the key components, the current developments, and the major applications in industry. It outlines the key enabling technologies for the DT modeling, simulation, and verification, validation, and accreditation, etc. Based on the survey, it concludes that DTs are most popular in the prognostics and health management; the core of DTs is modeling, and the most pressing issue is cyber–physical fusion.

Deep learning, as the latest achievement of artificial intelligence, can effectively train and learn the multilevel characteristics of data in the deep network. It has the powerful complex data expression ability, and has been successfully applied in many fields. Deep learning has been one of the most studied and promising tools for big data analytics in intelligent manufacturing. There are four papers that present new results in this aspect.

The sequential decision-making problem with large-scale state spaces is an important and challenging topic for multitask reinforcement learning. Wang *et al.* propose a multitask policy adversarial learning method for learning a nonlinear feedback policy that generalizes across multiple tasks, making the cognizance ability of robots much closer to human-level decision making. The key idea is to construct a parameterized policy model directly from large high-dimensional observations by deep function approximations, and then train optimum of sequential decision policy for each new task by an adversarial process All the related human-level empirically derived are integrated into the sequential decision policy, transferring human-level policy at every layer in a deep policy network. The experimental results show that this approach can surpass human performance simultaneously from cart-pole to production assembly control.

With the rapid development of industrial Internet of Things, the category and quantity of industrial equipment are increasing. In order to attain accurate recognition performance of power equipment in intelligent manufacturing system, Lai *et al.* study the collected appliance data by adopting the long short-term memory recurrent neural network to build a nonintrusive load monitoring system, and combines edge computing to implement parallel computing to practice the effect of power equipment identification. According to the proposed optimal adjustment strategy of the parameter model, relatively high average recognition rates can be achieved.

Deep learning with the ability to feature learning and nonlinear function approximation has shown its effectiveness for machine fault prediction. While the question of how to transfer a deep network trained by historical failure data for prediction of a new object is rarely researched. Sun *et al.* present a deep transfer learning (DTL) network based on sparse autoencoder

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(SAE). In the DTL method, weight transfer, transfer learning of hidden feature, and weight update are used to transfer an SAE trained by historical failure data to a new object. By these strategies, prediction of the new object without supervised information for training is achieved. A case study on remaining useful life prediction of a cutting tool is performed to validate the effectiveness of the DTL method.

Shao *et al.* develop a deep learning framework to achieve highly accurate machine fault diagnosis using transfer learning to enable and accelerate the training of deep neural networks. This study creates a machine fault diagnosis pipeline and experiments are carried out to verify the effectiveness and generalization of the pipeline on three main mechanical datasets including induction motors, gear boxes, and bearings with sizes of 6000, 9000, and 5000 time series samples, respectively. Compared with existing methods, the proposed method is faster to train and more accurate. The associated benchmark datasets are freely accessible through a public repository.

In the following three papers of this special section, challenges in data-driven modeling and monitoring of intelligent manufacturing equipment are addressed.

As the monitoring manufacturing big data are typically measured from different machines and under different working regimes, prior information and domain knowledge are preferred to properly analyze and utilize these data. To meet this requirement, a data-driven self-comparison approach is proposed by Zhao *et al.* for the monitoring of rotating machinery. In this approach, comb filtering is introduced to extract the concerned signals from multisource background noise. A modified singular value decomposition is applied to enhance local anomalies. Finally, an iterative Mahalanobis distance is constructed to measure the statistical deviation of the monitored component from normal states. With this self-comparison framework, the health condition of rotating machinery can be carried out without historical data, domain knowledge, or human intervention.

Induction motor-planetary gearbox drivetrains are widely used for industrial productions, including machine tools in manufacturing systems. Planetary gearbox faults generate load torque oscillations, leading to both amplitude modulation and frequency modulation (AM-FM) effects on induction motor current signals. Feng *et al.* derive an AM-FM current signal model through mechanical–magnetic–electric interaction analysis to study the current signals. To avoid an intricate sideband analysis, amplitude and frequency demodulation analyses are proposed, explicit equations of corresponding demodulated spectra are derived, and gear fault features are summarized. The theoretical derivations are validated through lab experiments. Localized faults on the sun, planet, and ring gears are all successfully diagnosed using the proposed method.

Large skin parts play an important role in the aerospace industry. The wall thickness of the machined pocket in the skin part needs to be strictly controlled to ensure transport capacity and structural strength. To ensure the wall-thickness accuracy, Bi *et al.* have proposed a fuzzy v-support vector machine based wall-thickness error decomposition method. The wall-thickness errors, which are monitored in the cutting process, are decomposed into spatial-related errors and time-related errors. The spatial-related wall-thickness error is compensated offline, and the time-related wall-thickness error is compensated by using a real-time strategy. The developed approach can be applied to complex tool paths.

In the final article, Tian *et al.* discuss the modeling and planning for dual-objective selective disassembly with intelligent optimization approaches. Disassembly sequencing is important for remanufacturing and recycling used or discarded products. AND/OR graphs have been applied to describe the practical disassembly problem, which is a challenging NP-hard combinatorial optimization problem. This study develops a novel dual-objective optimization model such that disassembly profit is maximized and disassembly energy consumption is minimized. An improved artificial bee colony algorithm is developed for this dual-objective disassembly optimization problem. This methodology is employed to practical disassembly processes of two products to verify its feasibility and effectiveness.

In this special section, the selected articles provide interesting approaches and promising views regarding the modeling and data analytical issues of intelligent manufacturing. We hope that the readers benefit from the different perspectives in this special section and that it will contribute to this frontier but fundamental research area.

The Guest Editors would like to thank the authors for their contributions and the reviewers for their valuable time. We are grateful to the Editor-In-Chief, Prof. Ren C. Luo for the acceptance of the Special Section proposal. Warm thanks are extended to the Administrators of the journal, for their professional support of the full stages leading to publication.

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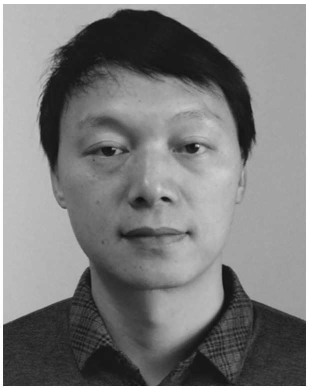

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