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Editorial

Special Issue on "Modelling, Monitoring, Control and Optimization for Complex Industrial Processes"

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Industrial automation systems, such as chemical processes, manufacturing processes, power networks, transportation systems, sustainable energy systems, wireless sensor networks, robotic systems, and biomedical systems, are becoming more complex [1–3], but more expensive, and have higher requirements for operation performance, quality of products, productiveness, and reliability. Stimulated by Industry 4.0, automation industries are keen to improve the reliability and operational performance of complex industrial processes using advanced modelling, monitoring, optimization, and control techniques. Recently, artificial intelligence, data-driven techniques, cyber–physical systems, digital-twin, and cloud computation have further stimulated research and applications of modelling, monitoring, optimization, and control techniques [4–6].

This Special Issue on "Modelling, Monitoring, Control and Optimization for Complex Industrial Processes" (https://www.mdpi.com/journal/processes/special_issues/Complex_Industrial_Processes) aims to provide a forum for researchers and engineers to report their recent results, exchange research ideas, and look over emerging research and application directions in modelling, monitoring, optimization, and advanced control for complex industrial processes. There are 22 papers included in this Special Issue, after a rigorous review process, which are categorised and presented in Table 1.

Table 1. Categories of the paper included in the Special Issue.

Categories	Modelling and Parameter Identification	Monitoring, Diagnosis, and Resilience	Control Applications	Optimisation Applications
Papers	[7–10]	[11–14]	[15–20]	[21–28]

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1. Modelling and Parameter Identification for Complex Industrial Processes

It is significant but challenging to identify system parameters of a mechanism system under on-line working conditions as uncertainties exist due to the differences between design requirements and real-time environment. In the paper co-authored by Zhang et al. [7], a reinforcement learning approach was applied to forging machines to attain real-time model parameters, where raw data were used directly, and an online parameter identification algorithm was implemented in a period without the aid of labelled samples as a training database. The addressed parameter identification technique proved to have a powerful capability to adapt a new process without historical data. The effectiveness was validated via a forging machine process.

It is difficult to model porous structures due to their irregular internal morphologies. Conventional CAD modelling approaches fail to represent internal structures and conformations in models, although they can effectively describe the external geometric and topological information of the models. In the work completed by Ren [8], an effective modelling method for 3D irregular porous structures was presented based on a finite element method and thermodynamic analysis, and the key idea was to solve isothermal issues in the modelling of the porosity of porous units. It was shown from experiments

that the proposed technique can achieve smooth and approximate porous structures from arbitrary irregular 3D surfaces.

The discrete element method has a capability to analyse interactions among particles themselves, and interconnections between particles and mechanical components, to reveal the influencing factors and operating mechanism of the mechanical components. In the work by Liu et al. [9], a discrete element method based modelling technique was used to represent pill particle population which was employed to optimise the anti-corrosion process of oil and gas wellbore casing annuli. A simulation model was built, and the theoretical foundation was established for the further investigation of the pill discharging process and the parameter optimisation of the pill discharging device.

Green growth is defined as a process for a manufacturing enterprise to grow stronger with green strategies and green behaviours to achieve less consumption of resources and energy, less pollution, and more environmentally friendly and healthy products. In the article by Li et al. [10], a conceptual model of the factors influencing the green growth of manufacturing enterprises was established and a method was addressed to further reveal the relevant dynamic mechanisms and essential influencing factors, determined using a decision-making trial and evaluation laboratory strategy. Six key influencing factors were finally verified using a wooden flooring manufacturing company as a case study.

2. Monitoring, Diagnosis, and Resilience for Complex Industrial Processes

Fault diagnosis approaches are categorized into a model-based diagnosis approach, signal-based diagnosis method, and knowledge-based diagnosis approach. A model-based approach is widely used if a model is available to the designer. Continuous stirring tank reactors are widely used in chemical production processes, where there is a nonlinear dynamic process disrupted by time delays and uncertainties. In the article contributed by Wang et al. [11], continuous stirring tank reactors were represented by a T-S fuzzy model with state delays and disturbances. A fuzzy fault detection filter was addressed to detect faults and the design gains were obtained to solve the convex optimization of linear matrix inequalities. The effectiveness of the proposed diagnosis method was demonstrated by simulation studies.

Knowledge-based approaches are based on data driven and machine-learning techniques. Therefore, quantitative knowledge-based approaches are also called data-driven approaches. In the paper co-authored by Zhang et al. [12], a novel fault–diagnosis–classification optimization method was proposed by fusing a sine cosine algorithm, support vector machine, and transfer learning. Intensive simulation studies were carried out, and the proposed algorithm outperformed five existing diagnosis algorithms with higher precision and a faster response time. In addition, the proposed algorithm can run effectively using transfer learning with less failure data.

Multi-agent systems have received attention where multiple agents communicate through a premeditated protocol to operate collectively. A fault in an agent may deteriorate the performance of its neighbouring agents and even the entire network. As a result, it is important to detect an agent fault as early as possible. In the paper co-authored by Lu et al. [13], a fault diagnosis problem was investigated for multi-agent systems, where a neural-network-based state prediction model was built via offline historical data training, and the residuals between the actual outputs and predicted outputs were checked to detect potential faults. The effectiveness of the presented diagnosis algorithm was finally demonstrated via a real experiment on a leader–follower inverted pendulum.

Networked dynamic systems would suffer potential security threats caused by malicious attacks, which would destabilize networked dynamic systems and disturb communications between networked systems. As a result, there is a motivation to discuss the resilience issue in networked systems subjected to cyber-attacks. In the article contributed by Tan et al. [14], a resilient control issue for networked nonlinear dynamic systems with dynamic trigger mechanisms and malicious aperiodic denial-of-service attacks was examined. A resilient dynamically triggering controller was designed to alleviate the effects of

cyber-attacks and reduce the usage of communication resources. The proposed approaches were validated by using the well-known nonlinear Chua circuit.

3. Control Applications for Complex Industrial Systems

Chaos is a complex nonlinear phenomenon in nature and chaotic systems have been widely applied to a variety of practical systems, such as secure communications, industrial processes, and ecosystems, etc. Some chaotic behaviours are harmful, which should be supressed. In the article contributed by Liang et al. [15], a tracking controller was designed for hyperchaotic complex systems, and the feasibility of the proposed design was verified from two perspectives, via both mathematical proofs and simulation experiments.

H8 transformer-less inverter can be used to eliminate an earth leakage current, and model predictive control has been a popular control technique in industrial applications. In the paper contributed by Zaid et al. [16], a model predictive control method was used to improve the performance of H8 transformer-less inverters supplied by a photovoltaic energy source. The Hardware-in-the-Loop was implemented using a DSP target LaunchPadXLTMS320F28379D kit to demonstrate the effectiveness of the proposed approach.

Temperature control has been widely used in the control of dividing-wall distillation columns, which has an advantage in dynamic characteristics, but cannot track the steady values well due to its limited accuracy in estimating controlled product purities. Motived by the above, in the paper contributed by Yuan et al. [17], an improved temperature control approach was addressed with the aid of product quality estimation and a genetic algorithm. It was demonstrated by the simulated studies that the proposed control scheme can reduce steady-state deviations in the maintained product purities as well as have better dynamic characteristics, which proved to be a useful tool for the temperature inferential control for dividing-wall distillation columns.

A permanent magnet synchronous motor has a wide industrial application. It is noticed that it is usually challenging to establish an accurate mathematical model for a permanent magnet synchronous motor, and an application of a complex algorithm may pose a challenge for embedded code development. Motived by the above, in the paper co-authored by Jiang et al. [18], a characteristic model for a permanent magnet synchronous motor was built, and a speed control scheme was proposed by integrating a linear golden-section adaptive control and integral compensation. It was shown by the simulation and experimental results that the speed control accuracy using the proposed control algorithm for a permanent magnet synchronous motor was improved by 3.8 times compared with traditional proportional-integral-derivative control algorithms.

Electric vehicles are green modes of transportation, which will replace fossil-fuelled vehicles soon. However, charging stations for electric vehicle batteries may impose a high energy demand on the utility grid. As a result, it is of interest to investigate standalone charging stations for electric vehicles using photovoltaic power sources to support the utility grid. In the paper contributed by Atawi. [19], an isolated electric vehicle charging station model based on a photovoltaic energy source was built, which was composed of a photovoltaic panel, boost converter, energy storage system batteries, DC/DC charging converters, and an electric vehicle battery. The control system was composed of a maximum power tracking controller, electric vehicle charging controller, and storage converter controller, which were, in essence, PI controllers, as well as a single-chip PIC18F4550 microcontroller utilized for control implementation. It was demonstrated by the simulations and experiments that the used controllers can provide good response speeds and satisfactory tracking abilities to their references.

Steam generators are critical devices in nuclear power plants, and their control performances are paramount to maintain normal operations. It is of interest to develop optimal control in a steam generator level process. In the article by Kong et al. [20], a systemic data-driven optimization methodology was proposed, which was used to optimise control system parameters by using control performance measurements directly. The effectiveness of the addressed method was demonstrated via simulations, concluding that the addressed

simplex search method was effective in controller parameter optimization to improve control system performance in steam generator level processes.

4. Optimization Applications for Complex Systems

Wind energy plays a leading role in renewable energy industries. To reduce workloads, improve efficiency, and provide better evaluation and judgment, inspection robots have been introduced into wind farms for inspection. It is a prerequisite to produce a path planning for intelligent inspection using robots. In the article by Chen et al. [21], a new path-planning algorithm was proposed based on a chaotic neural network and genetic algorithm. The proposed algorithm was verified via a path planned for patrol robot using the actual locations of 30 wind farms, showing the addressed algorithm can generate a shorter inspection path compared with some existing algorithms.

It is of significance to boost material removal rate and waste reuse rate in a rough processing stage of a three-dimensional stone product with an unusual shape. In the paper contributed by Shao et al. [22], circular saw disc cutting was inspected to cut a convex polyhedron out of a blank box, with reference to a targeted product. It is evident that this problem can be better solved by geometrical methods rather than mathematical methods. An automatic block cutting strategy was proposed by using a series of geometrical optimization approaches. The effectiveness of the proposed method was demonstrated via simulated studies using both MATLAB and the Vericut platform.

It is of importance to have precise process planning to produce an open-die-forged part with a desired final geometry as well as economic production. In the paper contributed by Reinisch et al. [23], a multi-objective optimization-based schedule design was addressed by combining fast process models with a double deep Q-learning algorithm. The produced pass schedules lead to a desired ingot geometry with a minimal number of passes. The addressed methods were validated via a forging experiment, showing the ability of the addressed double deep Q-learning algorithm to achieve an optimal pass schedule in real open-die forging processes.

New opportunities are provided to companies to gain competitiveness with a transformation to Supply Chain 4.0 with the aid of the lean value stream mapping tool. In the work by Kihel et al. [24], a new process design was presented by integrating 4.0 technologies, taking multinational supply chains in Automotive Wiring Equipment Morocco as case study. Using the lean value stream mapping 4.0 tool, all products and information flow in a value chain from suppliers to customers were optimized so that economic, social, and environmental performance were improved.

Real-time optimization is a strategy to maximize a cost function with constraints so that operation can be kept at its optimum point even under conditions subjected to nonlinear behaviours and disturbances. In the work by Delou et al. [25], a small-scale real-time optimisation was investigated for a real industrial case, that is, the Natural Gas Processing Unit. A novel approach was addressed for improving efficiency using a sequential-modular simulator within an optimization framework. It was shown, using the addressed method, that an improvement in stability and an increase in profit were achieved.

Process optimization aims to optimize a set of parameters with constraints to achieve an optimal processing time and production. In the article by Chen et al. [26], the process optimization for an automated yogurt and flavour-filling machine was discussed under two scenarios: multi-filling points (Case I) to filling point (Case II). Mathematical models under different cases were developed by considering optimisation objectives. The models were tested with real data, and it was revealed that Case II was faster than Case I in processing a set of customer orders.

Inter-channel advertising and service cooperation are important research areas in channel convergence, which is an important issue in the online to offline supply chain. In the paper co-authored by Zhang et al. [27], the impacts of time delay and bidirectional free riding on inter-channel service and advertising cooperation strategies were discussed. A differential game model between brands and retailers was established by encompassing

delay effect and bidirectional free-riding occurrence. Differential game theory was used to seek the optimal advertising and service decisions of the brand owners and retailers. It was shown that the service strategy, advertising strategy, and brand goodwill of the online to offline supply chain members were optimal under a centralized decision-making system.

Artificial-intelligence-based music generation has attracted much attention. In the work by Min et al. [28], a novel approach was proposed to develop a competitive music generation algorithm by blending a transformer deep-learning model with generative adversarial networks. It is shown that the model based on transformer and generative adversarial networks can reveal the relationship in the notes of long-sequence music samples, and the rules of music composition can be learned well. An optimized transformer and generative adversarial-networks-based model can improve the accuracy of the generated notes.

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