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Editorial

Special Issue: Neural Networks, Fuzzy Systems and Other Computational Intelligence Techniques for Advanced Process Control

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Computational intelligence (CI) techniques have developed very fast over the past two decades, with many new methods emerging. Novel machine learning techniques, such as deep learning, convolutional neural networks, deep belief networks, long short-term memory networks, and reinforcement learning, have been successfully applied to solve many complicated problems ranging from image processing to natural language processing. These novel CI techniques have also been applied to process systems engineering areas, with many successful applications reported, such as in the data-driven modelling of nonlinear processes, inferential estimation and soft sensors, intelligent process monitoring, and process optimisation. This Special Issue (https://www.mdpi.com/journal/processes/special_issues/advanced_process_control accessed on 17 July 2023) includes 17 papers on CI techniques applied to the areas related to advanced process control.

Liu et al. [1] present a reference-model-based neural network (NN) control method for a multi-input multi-output (MIMO) temperature system. A reference model is introduced to provide the teaching signal for the NN controller. The control inputs for the MIMO system are given by the sum of the outputs of the conventional integral-proportional-derivative (I-PD) controller and the outputs of the neural network controller. It is shown that the proposed NN control method can not only improve the transient response of the system, but also realize temperature uniformity in the MIMO temperature system. The proposed control system is demonstrated on simulations in the MATLAB/SIMULINK environment and a Digital-Signal-Processor-based experimental platform.

Hung [2] presents a memetic particle swarm optimization (MPSO) algorithm combined with a noise variance estimator to address the issue of performance decay in a direction of arrival (DOA) estimator under a non-uniform noise and low signal-to-noise ratio (SNR) environment. The proposed MPSO incorporates the re-estimation of noise variance and iterative local search algorithms into the particle swarm optimization (PSO) algorithm, resulting in higher efficiency and a reduction in non-uniform noise effects under a low SNR. In the proposed algorithm, PSO is initially utilized to evaluate the signal DOA using a subspace maximum-likelihood (SML) method. Then, the best position of the swarm to estimate the noise variance is determined and the iterative local search algorithm is built to reduce the non-uniform noise effect. The proposed method uses the SML criterion to rebuild the noise variance for the iterative local search algorithm to reduce non-uniform noise effects. The proposed method is demonstrated by simulation.

Xue et al. [3] propose a quality integrated fuzzy inference system (QFIS) to quantify the deviations of the operating variables and the product quality from their target values in order to overcome the measurement delay of the product quality and to estimate the reliability of the operation status, as well as the product quality, to enhance the performance of the safety monitoring system. A quality-weighted multivariate inverted normal loss function is proposed to quantify the deviation of the product quality from the target value

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in order to overcome the measurement delay. Vital process safety variables are identified according to the expert knowledge. Then, the quality loss and the vital variables are used as inputs for an elaborate fuzzy inference system to estimate the process reliability of the fluorochemical engineering processes. By integrating the abundant expert knowledge and a data-driven quality prediction model to design the fuzzy rules of QFIS, the operation reliability can be enhanced and the product quality can also be monitored on-line. The proposed method is applied to a real fluorochemical engineering process located in East China and the benchmark Tennessee Eastman process.

Zhang et al. [4] propose an improved finite control set model predictive torque control strategy for induction motor (IM) control. The proposed strategy is based on a novel fuzzy adaptive speed controller and an adaptive weighting factor for the tuning strategy to reduce the speed, torque, and flux ripples caused by different factors. Both simulation and hardware-in-loop tests are conducted on a 1.1 kW IM drive to verify the proposed ripple reduction algorithms.

Aguilar-López et al. [5] propose a two-input two-output control strategy for an exothermic continuous chemical reactor. The reactor temperature is regulated by a standard proportional-integral controller. An optimal controller is activated to increase the reactor productivity in terms of the mass of the product. The optimal control strategy is based on a Euler–Lagrange framework, where the Lagrangian is based on the model equations of the reactor and the optimal controller is coupled with an uncertainty estimator to infer the unknown terms required by the proposed controller. The proposed method is demonstrated on a simulated continuous stirred tank reactor with a Van de Vusse chemical reaction.

Almarashi et al. [6] study the group acceptance sampling plan in the case where (i) the lifetime of the items follows the Marshall–Olkin Kumaraswamy exponential distribution and (ii) a large number of items, considered as a group, can be tested at the same time. When the consumer's risk and the test termination period are defined, the key design parameters can be extracted. The minimum ratios of the true average life to the specified average life are calculated. The proposed technique is explained using real-world data on the breaking stress of carbon fibres.

Zhang et al. [7] propose double-layer back propagation neural networks for the learning of PID control parameters. One network is used to fit the relationship among the working parameters, the control parameters, and the control performance. Another network is used to fit the relationship between the working condition parameters and the selected control parameters, and to realize the adaptive adjustment of the PID control parameters according to the working condition parameters. The effectiveness of the proposed control method was verified by a simulation and experiment on the hydraulic drive unit of a legged robot.

Yang et al. [8] propose a self-organizing radial basis function neural network (RBFNN) based on network sensitivity to improve the generalization performance for nonlinear process modelling. In the proposed approach, a self-organizing structure optimization strategy is designed based on the sensitivity measurement to adjust the structure and parameters of RBFNN. The convergence of the proposed RBFNN-GP is analysed. The proposed method is applied to two numerical case studies and a membrane bio-reactor in a wastewater treatment plant.

Zhai et al. [9] propose an adaptive depth-wise separable dilated convolution and multigrained cascade forest (ADSD-gcForest) fault diagnosis model for fault diagnosis in bearings. The multiscale convolution, combined with the convolutional attention mechanism, concentrates on effectively extracting fault information under strong noise, and the Meta-Activate or Not (Meta-ACON) activation function is integrated to adaptively optimize the model structure according to the characteristics of input samples. Then, gcForest, as the classifier, outputs the final diagnosis result. The proposed method is applied to bearings failure diagnoses under various noise and load conditions.

Wang et al. [10] present a new fault detection scheme using the mutual *k*-nearest neighbour (MkNN) method to solve the problem of pseudo neighbour caused by outliers or large noises in the dataset. In the proposed method, the distance statistics for process monitoring are calculated using the MkNN rule instead of kNN, so that the influence of outliers in the training data is eliminated. The effectiveness of the proposed method is demonstrated through numerical examples and the benchmark Tennessee Eastman process.

Wu et al. [11] present a parameter identification method based on the hybrid genetic algorithm for the control system of double-fed induction generator converters. A strategy of "individual identification, elite retention, and overall identification" is proposed in the improved genetic algorithm, which adopts the generation gap value and immune strategy. The proposed parameter identification method is applied to a wind farm in North China for maximum power point tracking, constant speed, and the constant power operation conditions of the wind turbine.

Chen et al. [12] present an event-triggered H_∞ asynchronous filtering for Markov jump nonlinear systems with varying delay and unknown probabilities. The devised filter is mode dependent and asynchronous compared with the original system, which is represented by a hidden Markov model. Both the probability information involved in the original system and the filter are assumed to be only partly available. Under this framework, via employing the Lyapunov–Krasovskii functional and matrix inequality transformation techniques, a sufficient condition is given and the filter is further devised to ensure that the resulting filtering error dynamic system is stochastically stable, with a desired H_∞ disturbance attenuation performance. The proposed filter design method is demonstrated through a numerical example.

Muhsin and Zhang [13] present the multi-objective optimization of a crude oil hydrotreating (HDT) process with a crude atmospheric distillation unit using data-driven models based on bootstrap-aggregated neural networks. The HDT of the whole crude oil has economic benefit compared to the conventional HDT of individual oil products. Reliable data-driven models for this process are developed using bootstrap-aggregated neural networks to overcome the difficulty in developing accurate mechanistic models and the computational burden of utilizing such models in optimization. Reliable optimal process operating conditions are derived by solving a multi-objective optimization problem, incorporating the minimization of the widths of model prediction confidence bounds as additional objectives. The multi-objective optimization problem is solved using the goal-attainment method. The proposed method is demonstrated on the HDT of crude oil, with a crude distillation unit simulated using Aspen HYSYS.

Gao et al. [14] propose using the extended Kalman filter algorithm and backpropagation neural network to build a state of charge (SOC) estimation model of the electric vehicle battery (E-cell) to improve the estimation accuracy. Three working conditions, constant current discharge, pulse discharge, and urban dynamometer driving schedule, were considered. The enhanced estimation and tracking of the SOC of the E-cell can provide a data reference for vehicle battery management, and is of great significance for improving the battery performance and energy utilization in electric vehicles.

Berard et al. [15] present a range of rate of error change–fuzzy logic controller designs to demonstrate the tunability of the controller for different haemorrhage scenarios. Five different controller setups are configured with different membership functions to create more- and less-aggressive controller designs. It is shown that the proposed controllers are well-suited for haemorrhagic shock resuscitation and can be tuned to meet the response rates set by clinical practice guidelines for this application.

Wang et al. [16] propose a traffic light timing optimization method based on a double duelling deep Q-network, MaxPressure, and self-organizing traffic lights, which control traffic flows by dynamically adjusting the duration of traffic lights in a cycle, and the phase can be switched depending on the rules set in advance and the pressure of the lane. In the proposed method, each intersection corresponds to an agent, and the road entering the intersection is divided into grids, with each grid storing the speed and position of a car, thus forming the vehicle information matrix and acting as the state of the agent. Experimental results show that the proposed method has superior performance in light and heavy traffic flow scenarios, and can reduce the waiting time and travel time of vehicles and improve the traffic efficiency of an intersection.

Ang et al. [17] propose a modified particle swarm optimization (PSO) variant with two-level learning phases to train an artificial neural network (ANN) for image classification. A multi-swarm approach and a social learning scheme are designed in the primary learning phase to enhance the population diversity and the solution quality, respectively. Two modified search operators with different search characteristics are incorporated into the secondary learning phase to improve the algorithm's robustness in handling various optimization problems. The proposed algorithm is used to train ANN, by optimizing its weights, biases, and the selection of activation function for the given classification dataset. It is shown that ANN models trained by the proposed algorithm outperform those trained by existing PSO variants in terms of classification accuracy.

The above papers in this Special Issue demonstrate that CI techniques can significantly improve the performance of process control systems. As more advanced CI techniques have emerged in recent years, more CI-based advanced process control techniques will be reported in the near future.

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