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Editorial

Editorial: Advances in Stochastic System Modeling, Control, Optimization, and Their Applications

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Abstract: Stochastic systems can be widely adopted for describing practical complex systems, such as meteorology. Recently, there have been many advances in the design of stochastic systems, including system modeling, control, estimation, performance enhancement, and industrial applications. Motivated by these results, this Special Issue encourages researchers to publish their latest contributions in the study of stochastic systems. In summary, we first introduce the current technical challenges in stochastic systems. Then, a current prevalent problem is provided to demonstrate the challenges in these systems, while the developing trends for stochastic system research are summarised. In particular, data-driven non-Gaussian system analyses will be the one of the significant research focal points in future.

Keywords: stochastic system modeling; stochastic system control; stochastic system optimization; stochastic system application

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1. Introduction

Stochastic systems theory and its applications are significant research themes in system science. Stochastic systems describe the randomness and uncertainties in a system's design, and analyses are conducted using statistics and probability theory. Recently, complex dynamical systems have been investigated for many existing scientific problems. At the same time, a number of technical challenges have been observed: for example, the scale of a system increased dramatically and the computing complexity is another problem when extending the algorithms to complex stochastic systems.

As an example of complex dynamical stochastic systems, networked systems [1] have been investigated, where randomness widely exists in systems, and the stochastic properties are affected by the nonlinearities of a system. Moreover, the distributed structure of a networked system will increase the difficulty of the analysis.

All these aforementioned complexities will result in a non-Gaussian stochastic process. With features different from the traditional stochastic system analysis, Gaussian assumptions cannot meet the conditions introduced by new challenges. In particular, the probability density function (PDF) of a system's variable can possess multi-peak shapes. Thus, a mean-variance analysis cannot fully reflect the characteristics of a system's dynamics. To deal with the non-Gaussian stochastic system design problem, recent contributions have been summarised in [2] regarding modelling, controlling, filtering, and applying a system.

Recently, some new solutions for stochastic systems have been published using a data-driven approach [3]. Motivated by the new framework, this Special Issue is designed to develop new results in stochastic systems and to explore new features in system designs.

2. The Present Issue

This Special Issue includes five research articles. In summary, modeling, optimization, estimation, control, and fault diagnosis problems are covered in these contributions:

Ref. [4] A simulation-based policy improvement (SBPI) scheme was proposed to obtain the optimal policies using Markov decision processes (MDPs), where the state transition probabilities are unknown. In particular, a new method was introduced for improving the overall efficiency of SBPI by using optimal computing budget allocation (OCBA) methods based on accumulated samples. In contrast to existing methods, the proposed method improves the overall efficiency until an optimal policy can be found in the consideration of the state traversal property of the SBPI. The estimation for the mean and variance of the Q-value for each action was obtained, and then the optimal policy was obtained with a lower budget.

Ref. [5] The improved artificial bee colony algorithm was proposed for power systems. In particular, heat storage devices and electric boilers were added to the cogeneration system to alleviate the wind curtailment phenomenon. In this paper, the main reasons for wind curtailment were analyzed according to the structural characteristics of the power supply in the northern part of China. Moreover, a scheduling model of a cogeneration system is constructed.

Ref. [6] A robust controller was designed to deal with transient dynamics of distributed generator (DG)-based power electronic devices. In this study, a nonlinear control strategy for VSG with uncertain disturbance was proposed to enhance the system's stability in the islanded, grid-connected, and transition modes. Firstly, the model for a VSG's rotor considering virtual inertia and damping coefficients was presented.Then, the nonlinear backstepping controller (BSC) method combined with the extended state observer (ESO) was constructed to compensate for the uncertainty. To deal with the uncertain items, a second-order ESO was built to estimate uncertainties and external disruptions.

Ref. [7] A dynamic model of Chinese solar greenhouses was developed based on energy conservation laws, and a nonlinear adaptive control strategy combined with a radial basis function neural network was presented to control temperatures. Note that the greenhouse system is described with complex dynamic characteristics, such as multi-disturbance, parameter uncertainty, and strong nonlinearity. Therefore, directly adopting a traditional conventional control method is difficult. In this paper, nonlinear adaptive controller parameters were determined by using generalized minimum variance laws, while unmodeled dynamics were estimated by using a radial basis function neural network. The experimental results show that the new control scheme enhanced the control performance.

Ref. [8] A long short-term memory (LSTM) model with discrete wavelet transformations (DWTs) was presented for multi-sensor fault diagnoses. As the core component of the rotating machinery, the failure of rolling bearings may lead to serious accidents during industrial production operations. This study uses a DWT-LSTM model to diagnose the health of rolling bearings. In particular, the DWT was used first to obtain detailed fault information with respect to both different frequency and time scales. Secondly, the LSTM network was employed to characterize the long-term dependencies hidden in the time series of the fault's information. The proposed DWT-LSTM method makes full use of the advantages of feature extraction based on expert experience and deep network learning in order to discover complex patterns from a large amount of data.

3. Future Trends

Following all these contributions, it has been shown that stochastic systems research is popular, and potentially, it will be the next focal point in systems science. In particular, analytical and data-driven approaches are both important in the theoretical sense and in practical applications, especially for non-Gaussian systems. Once a system's model can be obtained, a full stochastic description can be formulated analytically, which leads to stochastic-based designs: for instance, the state-estimation for non-Gaussian continuous-time stochastic systems [9]. In contrast, data-driven approaches are adopted for complex stochastic systems using kernel density estimation [10]. Since the complexity of a system's dynamics increases, a data-driven design would be beneficial for all the mentioned research topics.

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