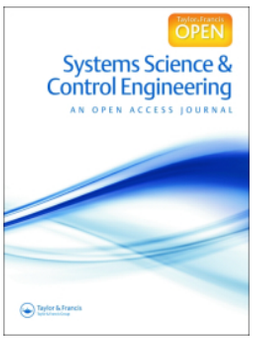

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GUEST EDITORIAL



# Recent developments on complexity science

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## 1. Introduction

Nowadays, there is a growing interest in understanding the theoretical aspects of complex systems that are highly dynamic. The study of dynamic systems is to understand the involved influence of nonlinear/stochastic behaviour and consequently to provide effective analysis/design ways to improve the system performance. Since the rapid developments in system science and mathematics, a great deal of research has been focused on the analysis and synthesis of dynamic systems. It has been found out that the recent technological advances can play a crucial role in the emergence of dynamic behaviours in various fields, such as biology, physics, technology, control engineering, computer science, economic and the life sciences.

Dynamic systems have already become an ideal research area to control engineers, mathematicians, computer scientists and biologists to analyse, design and interpret functional information from real-world networks. The main challenges, associated with the analysis and synthesis problems for such systems, are the computational complexity of solving the large-sized cooperative problems with coupled tasks, the executing tasks under limited communication channel, the performance requirements subject to incomplete information and obtaining scalable solutions, etc. This special issue aims to bring the latest approaches to understanding the dynamic systems from the systemic analysis perspective and the mathematical understanding viewpoint. Topics include, but are not limited to the following aspects of analysis for dynamic systems: stability analysis, robustness, fragility, controllability; synchronization, control, estimation; topology structure and dynamics, applications in real-world complex networks, sensor networks, neural networks, multi-agent systems; multi-scale analysis, operational research, dynamic programming and graph theory.

In this special issue, we have solicited submissions to this special issue from electrical engineers, control engineers, mathematicians and computer scientists. After a rigorous peer review process, 15 papers have been selected that provide overviews, solutions or early promises to manage, analyse and interpret dynamical behaviours of complex systems. These papers have covered both the theoretical and practical aspects of analysis and synthesis for complex systems in the broad areas of dynamical systems, mathematics, statistics, operational research and engineering.

## 2. The special issue papers

### 2.1. Networks theory

Distribution network reconfiguration (DNR) technique can significantly reduce power losses, improve the voltage profile and increase the power quality in power network. In recent years, a large number of distributed generation (DG) and electric vehicles (EV) have been connected to the distribution network, which gives rise to significant impact on the power quality and power system stability. In the paper entitled 'A distribution network reconstruction method with DG and EV based on improved gravitation algorithm' by Q. Sun et al., a multi-objective mathematical model for distribution network reconstruction is established. Then, a particle swarm algorithm-based algorithm is proposed to improve the global search capability of gravitational algorithm. Three coding rules are employed to simplify the network topology and two delooping rules are utilized to reduce the probability of occurrence of infeasible solutions and shorten the calculation time. The variability of load, DG output and EV charging load are considered to establish an equivalent daily load curve, which will decrease the number of switching operations in dynamic reconstruction.

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The effectiveness of the proposed optimization algorithm and refactoring strategy are demonstrated by some engineering examples.

The cooperative control problem of multi-agent systems is one of the mostly investigated issues due primarily to its extensive applications in various fields, such as the multivehicle systems, satellite clusters, mobile ad hoc networks and coupled oscillators. The consensus problem is one of the critical problems for cooperative control issues of multi-agent systems. In traditional consensus control schemes, agents would exchange information continuously with their neighbours through the local network, which leads to huge consumption of resources. Event-triggered mechanism is an effective way to reduce such a communication burden while guaranteeing required system performance. Furthermore, it should be noted that the results concerning the general second-order multi-agent systems are relatively few. In the paper entitled 'Event triggered consensus control for general second order multi agent systems' by F. Liu and Z. Ji, an event trigger control protocol is designed to tackle the consensus problem of multi-agent systems with fixed topology. Sufficient conditions are proposed to ensure that the system can achieve consistency under this control protocol and Zeno behaviour is strictly excluded. Finally, a simulation example is given to illustrate the effectiveness of the obtained results.

Backstepping technique is an effective tool dealing with the control problem of nonlinear systems. The backstepping-based adaptive neural control is particularly suitable to handle the nonlinear systems with unknown dynamics (e.g. unknown nonlinearities). On the other hand, it should be noted that delays commonly occur in many dynamical systems and are usually the source of system instability or performance degradation. The control problem subject to input delays has gained increasing research attention in the past decades. Some initial results have been reported in the literature concerning the control problem of nonlinear systems with input delays by using the backstepping-based adaptive neural control methods. However, the existing results on such a topic are mainly presented for strict-feedback systems. In the paper entitled 'Adaptive neural network control for nonlinear non strict feedback time delay systems' by Y. Xu and B. Chen, a backstepping-based adaptive neural controller is developed for a class of non-strict-feedback nonlinear systems with state delays and input delays. The proposed control strategy is capable of guaranteeing that the tracking error converges to a small neighbourhood of the origin, meanwhile, all the closed-loop signals remain bounded. Finally, two examples are used to illustrate the effectiveness of the developed control strategy and give a comparison to the existing results.

As an important tool in the machine learning method, deep neural network (DNN) has been successfully utilized in a variety of tasks, such as character recognition, image recognition and speech recognition. In human face recognition issue, the convolutional neural network (CNN) (which is one of the architectures of DNN) has proved to be very effective and various results have been reported in the literature in this topic. Nevertheless, it is worth noting that most of the existing DNNs that face recognition methods are usually developed based on a large original dataset, which is sometimes quite difficult to achieve in some practical applications. In fact, some of the existing successful methods could lead to poor performance on a small original dataset. In the paper entitled 'Human face recognition based on convolutional neural network and augmented dataset' by P. Lu et al., a new approach combining CNN with augmented dataset is developed to handle the issue of human face recognition on a small original dataset. The original small dataset is augmented to be a large dataset via several transformations of the face images. Based on such augmented human face dataset, the face recognition is implemented via an ingenious CNN, which will be robust to the image transformations. The effectiveness and superiority of the proposed approach are verified by several experiments and comparisons with some frequently used face recognition methods. Finally, concluding remarks are drawn and several possible future research directions are pointed out.

Adaptive event-triggered (AET) is an improved event-triggered mechanism which can further save communication resources. On the other hand, the well-known Takagi–Sugeno (T-S) fuzzy model is a powerful tool to approximate the nonlinear systems through linear subsystems described by IF-THEN fuzzy rules. By now, the event-triggered control problem of T-S fuzzy systems has received some initial research interest and some interesting results have been reported in the literature. It is worth mentioning that the utilization of event-triggered mechanism would change the membership functions of the fuzzy system as well as the fuzzy controller. In the paper entitled 'Adaptive event triggered dynamic output feedback H-infinity control for networked T-S fuzzy systems' by Y. Hu and C. Lin, a dynamic output feedback H-infinity controller is designed for networked T-S fuzzy system under AET mechanism. Considering the impact of AET and mismatched membership functional, a model of fuzzy control system is proposed. Based on the Lyapunov–Krasovskii functional method, the stability and stabilization conditions of the control system are obtained. Then, the desired controller parameters and AET weight matrix are derived by solving a set of linear matrix inequalities. Finally, an

example is used to verify the feasibility of the design method.

As a special network, the so-called complex network is usually adopted to model the dynamical behaviour of certain systems composed of a series of nodes (which are connected with each other through certain topology). Since the node information of a complex network is always not fully available, state estimation technique becomes an important tool to estimate the desired node information through the received measurement outputs. Among the existing state estimation schemes, the well-known H-infinity state estimation is the most investigated one due to its capacity of guaranteeing a bound for the worst situation estimation error without statistical information of noise. In the paper entitled 'Finite horizon H-infinity state estimation for time varying complex networks based on the outputs of partial nodes' by W. Zhang et al., a partial-nodes-based resilient state estimator is designed for a class of discrete time-varying complex network. The so-called resilient method is introduced to deal with the harmful influence caused by inaccurate estimator parameters. By means of the recursive Riccati difference equations approach, the estimation error can satisfy the required finite-horizon H-infinity performance constraint. Finally, a numerical simulation example is given to demonstrate the effectiveness of the proposed state estimation method.

### 2.2. Estimation theory

In the past few decades, the filtering or state estimation problems were extensively investigated. Accordingly, the filter theory was successfully applied in many branches of practical domains, such as computer vision, communications, navigation and tracking systems, econometrics and finance, etc.

In the work entitled 'Fault estimation for nonlinear systems with sensor gain degradation and stochastic protocol based on strong tracking filtering' by J. Xu et al., the fault estimation problem for a class of nonlinear systems with sensor gain degradation and stochastic protocol is considered based on strong tracking filtering (STF). The phenomenon of the sensor gain degradation is described by a sequence of stochastic variables. The stochastic protocol is used to deal with possible data conflicts in multi-signal transmission. New state vectors are formed by augmenting the original system state vectors and the faults. The STF is designed for the system with burst faults by introducing a fading factor into the filter structure to estimate the burst states more quickly. The experimental results of three tanks show the effectiveness and applicability of the proposed algorithm.

In the paper entitled 'Secure state estimation for cyber physical systems with state delay and sparse sensor attacks' by M. Zhang et al., a secure state observer is designed for cyber physical systems with state delay and sparse sensor attacks. By combining a set cover approach and an adaptive switching operator, the attacked sensors can be found quickly and the computational complexity can be reduced. This algorithm can greatly reduce the search space, eliminate the impact of attacks on state estimation, improve the estimation speed and ensure the real-time performance of state estimation under the premise of effective estimation. Based on the generalization of the Krasovskii classical stability theorem for stability analysis of time-delay systems, the sufficient condition for the existence of the observer can be determined, and the observation error can converge within a certain range in the case of sparse attacks and bounded noises. Two examples are given to verify the effectiveness and practicability of the designed observer.

### 2.3. Control theory

The control problem has been gaining an ever-increasing research interest because of the merits of satisfactory control effects and clear engineering insights. So far, the control theory has been successfully applied to a wide range of fields, such as aviation, spaceflight, measuring equipment, power system and robotics.

In recent years, a lot of adaptive neural control schemes based on backstepping technology emerge and are applied to control nonlinear systems. In addition, the systems usually contain a variety of nonlinear factors in practical engineering applications. Moreover, input delay and input saturation are two very common cases. In the work entitled 'Adaptive neural tracking control for a class of nonlinear systems with input delay and saturation' by Y.-D. Li and B. Chen, the tracking control problem is addressed for a class of non-strict-feedback nonlinear systems with input delay and saturation. The considered nonlinear systems have the non-strict-feedback form, which takes the strict-feedback form and pure-feedback form as the special cases. So, the systems considered are more general. A novel auxiliary system method is developed, which not only compensates the effects of input delay in theory but also successfully overcomes the difficulty of controller design caused by input delay. The unknown nonlinear functions generated in backstepping control design are approximated by radial basis function neural networks. And then, an adaptive neural control scheme is proposed. It is proved by Lyapunov stability theory that the tracking errors converge to a small neighbourhood of the origin and the other closed-loop signals are bounded.

More and more attention has been paid to the research and application of agricultural technology, especially the study of greenhouse. Among the greenhouse environmental factors, temperature is an important factor affecting the growth of crops. How to control the greenhouse temperature more effectively is still one important topic. In the paper entitled 'Event-triggered control for greenhouse temperature under natural ventilation based on computational fluid dynamics' by X. Y. Sun et al., the event-triggered control for greenhouse temperature based on Computational Fluid Dynamics (CFD) is investigated. When the greenhouse temperature meets the event-triggered condition, the simulated data are transmitted to the controller. To overcome the deficiency of sensor which can only represent the temperature value of some points inside the greenhouse, CFD technology is used to simulate and output the temperature field data of the entire greenhouse. A new control scheme, including CFD technology, event-triggered strategy and MOPSO (multi-objective particle swarm optimization) algorithm, is proposed. MOPSO algorithm is adopted to design the controller. It solves the contradiction between control accuracy and energy consumption and has an effective combination of three technologies in greenhouse control field. The event-triggered control scheme-based CFD is designed for greenhouse. It is adopted in CFD simulation output-controller channel to save the resource of the communication network.

In the high performance surface permanent magnet synchronous motor (SPMSM) control system, the rotor speed needs to be accurately measured. The high precision mechanical sensors are used to install on the rotating shaft in the traditional methods, occupied the space and increased system cost and the mechanical sensors are easily affected by the environment, reduced the measurement accuracy and system stability. As a result, a series of control algorithms were used to accurately estimate the rotor position and speed of the motor by detecting related electrical signals in sensorless control, eliminating the use of the mechanical sensors. In the paper entitled 'SPMSM sensorless control of a new non-singular fast terminal sliding mode speed controller' by Y. Zhu et al., a new non-singular fast Terminal-SMC speed controller is designed. A new type of non-singular fast Terminal-SMC is designed, and the Lyapunov stability criterion is used to prove the stability of the designed SMC. The simulation results show that the new NSFT-SMC has faster responded speed, stronger system robustness and less chattering during stable operation. Compared with traditional SMC speed control and hyperbolic tangent function SMC speed control, it has better control performance.

Due to the rapid development of power electronics technology, Photovoltaic (PV) energy is more and more widely used in power systems. How to make the PV system work at the maximum power point (MPP) becomes a research hotspot. In the paper entitled 'Sliding mode control of SEPIC converter based photovoltaic system' by M. Zhang et al., the sliding mode controller based on single-ended primary inductor converter (SEPIC) is proposed to improve the tracking speed and reduce the oscillation. In the ripple control environment, the SEPIC converter can avoid the ripple content in the solar cell array (SCA) current. Moreover, compared to Boost converter, the buck-boost feature of the SEPIC widens the applicable PV voltage and thus increases the adopted PV module flexibility. First, the PV array is modelled and the simulation results are analysed, and then a sliding mode control strategy based on this circuit is derived. Finally, the results obtained in MATLAB/Simulink are compared with the conventional algorithms. The results show that the sliding mode controller proposed in this paper has faster speed and less oscillation when tracking the MPP.

### 2.4. Diagnosis and encryption theory

The past few decades witnessed great demands on system reliability due to the ever-increasing complexity of modern industrial processes. To guarantee the safety/reliability of the underlying systems, much rese arch attention has been paid to the fault diagnosis (FD) problem with the aim to detect, isolate and estimate the component faults as early as possible, thereby preventing the system performance from deteriorations. So far, the FD issue has been investigated in a number of practical scenarios, such as power systems, wind turbines, transcriptional circuits, induction motors and permanent magnet drives. In the paper entitled 'Diagnosability of composite automata based on semi-tensor product' by Z. Chen et al., the problem of diagnosability for composite Moore automata based on semi-tensor product of matrices is studied. Different from the existing methods, the faults are transformed into changes of state transition and an overall algebraic structure of the given system is established, based on which the matrix-based definitions of diagnosability for a fault and the system are proposed. Following that matrix observers are constructed and corresponding theorems and an algorithm are presented to determine whether a fault (respectively, the system) is diagnosable.

In conclusion, it is proved that the matrix approach to the analysis of diagnosability for discrete event systems is feasible and novel.

The craters distributed on the surface of Mars are the main obstacles for the spacecraft to avoid when landing. In order to avoid the probe falling into the crater during landing, effective methods are needed to detect and

identify the crater areas during the landing process. In the paper entitled 'A combined method of crater detection and recognition based on deep learning' by H. Li et al., the detection of craters is mainly divided into three parts: crater edge extraction, candidate area determination and crater recognition. In the edge extraction part of the crater, the method based on structure random forest is used to extract the edge of the crater. Based on edge detection, a candidate region extraction method is studied by morphological methods. For the recognition of candidate regions, the recognition method is studied based on the deep learning AlexNet model. Experimental results show that the edge detection method of the crater proposed in this paper is better than other edge detection methods; compared with other crater detection methods, the proposed method has higher detection accuracy and more correct detection rate.

Image information, as a kind of special data, is transmitted through the Internet in the form of plaintext, and its security needs to be solved urgently. In order to prevent the image information from being stolen, tampered and intercepted during transmission, it is necessary to encrypt it to a certain extent. In the paper entitled 'A novel color image encryption based on fractional order Lorenz system' by S. Li et al., we have a novel colour image encryption algorithm is proposed based on the fractional order Lorenz system. In the algorithm, the colour image is divided into three layers and scrambled, and the three scrambled images are not repeated by selecting clear pixels. The Tent map is used to control the initial iteration values of the fractional Lorenz system, which greatly improves the algorithm's ability to resist plaintext attack and known plaintext attack. Simulation results and analyses show that the key space of our algorithm is large enough, ciphertext correlation and plaintext sensitivity are close to theoretical values, and they can effectively resist various common attack methods.

***Papers on Topic of Networks theory***

1. A distribution network reconstruction method with DG and EV based on improved gravitation algorithm, Qi Sun, Yongjin Yu (Contact), Debing Li & Xiangqian Hu
2. Event triggered consensus control for general second order multi agent systems, Fan Liu & Zhijian Ji (Contact)
3. Adaptive neural network control for nonlinear non strict feedback time delay systems, Yuanyuan Xu & Bing Chen (Contact)
4. Human face recognition based on convolutional neural network and augmented dataset, Peng Lu, Baoye Song (Contact) & Lin Xu
5. Adaptive event triggered dynamic output feedback H-infinity control for networked T-S fuzzy systems, Yameng Hu & Chong Lin (Contact)
6. Finite horizon H-infinity state estimation for time varying complex networks based on the outputs of partial nodes, Wenhua Zhang, Li Sheng (Contact) & Ming Gao

***Papers on Topic of Estimation Theory***

7. Event-triggered consensus control for general second-order multi-agent systems, Jie Xu, Li Sheng (Contact) & Ming Gao
8. Secure state estimation for cyber physical systems with state delay and sparse sensor attacks, Man Zhang & Chong Lin (Contact)

***Papers on Topic of Control Theory***

9. Adaptive neural tracking control for a class of nonlinear systems with input delay and saturation, Ya-Dong Li & Bing Chen (Contact)
10. Event-triggered control for greenhouse temperature under natural ventilation based on computational fluid dynamics, XinYi Sun, Hua Yang (Contact), Qi-Fang Liu & Yan-Hong Liu
11. SPMSM sensorless control of a new non-singular fast terminal sliding mode speed controller, Yuhao Zhu, Yongjin Yu (Contact), Chi Xiao & Boyang Wang
12. Sliding mode control of SEPIC converter based photovoltaic system, Meng Zhang, Ningfan Zhong (Contact) & Mingyuan Ma

***Papers on Topic of Diagnosis and Encryption Theory***

13. Diagnosability of composite automata based on semi-tensor product, Zengqiang Chen (Contact), Yingrui Zhou, Zhipeng Zhang & Yongyi Yan
14. A combined method of crater detection and recognition based on deep learning, Haibo Li (Contact), Bei Jiang, Yuyuan Li & Le Cao
15. A novel color image encryption based on fractional order Lorenz system, Shixu Li, Yongjin Yu (Contact), Xingquan Ji & Qi Sun