# Editorial


## Dianhui Wang*

School of Engineering and Mathematical Science,
La Trobe University,
Melbourne, Victoria 3086, Australia
E-mail: dh.wang@latrobe.edu.au
*Corresponding author

## Wen Yu

Departamento de Control Automatico,
CINVESTAV-IPN,
Av. IPN #2508, Mexico D.F. 07360, Mexico
E-mail: yuw@ctrl.cinvestav.mx

## Tianyou Chai

Research Center of Automation,
Northeastern University,
P.O. Box 309,
Shenyang, Liaoning Province, 110004, China
E-mail: tychai@mail.neu.edu.cn


**Biographical notes:** Dianhui Wang received his PhD from Northeastern University, China in 1995. He had postdoctoral research working experience at Nanyang Technological University, Singapore, and The Hong Kong Polytechnic University. Since July 2001, he has been with the Department of Computer Science and Computer Engineering at La Trobe University, Australia, where he is currently working as a Reader and Associate Professor. His research interests include bioinformatics and intelligent systems for multimedia database management and control engineering. He is a Senior Member of IEEE and serving as an Associate Editor for *Information Science*, *Neurocomputing*, *International Journal of Applied Intelligence* and *International Journal of Modeling, Identification and Control*.

Wen Yu received his BS in Electrical Engineering from Tsinghua University, China in 1990 and his MS and PhD both in Electrical Engineering, from Northeastern University, China in 1992 and 1995, respectively. From 1995 to 1996, he served as a Lecturer at the Department of Automatic Control, Northeastern University. In 1996, he joined CINVESTAV-IPN, México, where he is currently a Professor at the Departamento de Control Automático. He also held a research position with the Instituto Mexicano del Petróleo, from December 2002 to November 2003. Since October 2006, he has been a Senior Visiting Research Fellow at Queen's University Belfast. He also held a visiting professorship at Northeastern University, China. He serves as an Associate Editor of *Neurocomputing* and the *International Journal of Modelling, Identification and Control*. He is a member of the Mexican Academy of Science.

Tianyou Chai received his PhD in Control Theory and Engineering from Northeastern University, China in 1985. Since then he has been with the Research Center of Automation at Northeastern University, China, where he became a Professor in 1988. His research interests include adaptive control, intelligent decoupling control, integrated plant control and system and the development of control technologies with applications to various industrial processes. He has published two monographs and over 150 publications including more than 50 peer reviewed international journal papers and about 100 international conference papers. He is the Editor-in-Chief of *Journal of Control Engineering* and on editorial board of a number of technical journals. He is a member of Chinese Academy of Engineering and a Fellow of IEEE, USA.

In process control practice, non-linearity and uncertainties often occur in dynamical systems, which make the modelling and control tasks quite difficult and may result in poor performance even failure when model-based approaches are applied. It is necessary and important to develop advanced techniques which can deal with these challenging problems. In the past decades, great efforts have been made to approach better solutions for complex systems modelling and control. Typically, intelligent approaches include adaptive control and robust control techniques, self-tuning PID controllers, adaptive fuzzy logic controllers, and neural networks based model predictive control and inverse dynamics modelling. It is known that intelligent control systems including the above-mentioned control techniques address learning or adaptation concept in system design. Therefore, further studies on data-driven control system design with performance analysis will be useful in control engineering.

Over the past decades artificial neural networks (ANN) have attracted many researchers and engineers due to its universal approximation capability to non-linear maps, learning and generalisation capability. ANN also has higher model reliability and tolerance due to massively parallel interconnections of simple computing elements. Due to its potential for modelling and controlling unknown or uncertain non-linear systems ANN has great interest to the control community. Pioneering contributions on this topic could be found in some publications in late 1980s and early 1990s. In particular, two special issues published in *IEEE Control Systems Magazine*, and a paper by Narendra and Parthasarathy published in *IEEE Transactions on Neural Networks* attracted many control engineers and academics to study neural modelling and control techniques. At earlier age, ANN was employed in modelling non-linear dynamics through learning input-output patterns. The main technical contributions were empirically demonstrated by simulation studies and very few publications presented either theoretical results or practical applications. Since the middle of 1990s, many researchers turned to address some theoretical issues on non-linear system identification and system performance analysis, such as model selection, learning convergence and closed-loop stability. In practice aspect, some promising results and commercial products were also reported in literature and market.

Neural networks have some essential characteristics needed for complex dynamical systems modelling and control. As a powerful modelling tool, it greatly contributes to the theoretic framework development of intelligent control theory. Many interesting theoretical questions have attracted researchers from well established areas of control theory, and helped in making the field more rigorous from a theoretical viewpoint. On the other hand, successful engineering applications, in return, give us more hope and confidence on such advanced technologies. We believe that the collection in this special issue provides a valuable reference for better understanding the adaptive neural control techniques and learning the latest trends of technical development. In total, 15 papers have been selected to reflect the call thematic vision. The contents of these studies are briefly described as follows.

The paper entitled 'DSC approach to robust adaptive NN tracking control for a class of MIMO systems' by T.S. Li, W. Li, and W.L. Luo studies a problem of robust adaptive neural tracking control for a class of MIMO non-linear systems with strongly coupled interconnections. A unified and systematic procedure is developed by fusion of dynamic surface control (DSC) with minimal learning parameters algorithm. The proposed solution avoids a possible controller singularity problem and guarantees the stability of the closed-loop system.

The paper entitled 'Observer-based stabilisation of some non-linear non-minimum phase systems using neural network' by S.M. Hoseini and M. Farrokhi presents a neuro-adaptive output-feedback stabilisation method for non-linear non-minimum phase systems with partially known Lipschitz continuous functions in their arguments. Updating rules of the neural network weights are obtained using the Lyapunov's direct method, where a suitable output of a linear state observer is employed. Also, an error bound of system output is established through analytical analysis based on Lyapunov stability theory. Simulations demonstrate the effectiveness of the proposed techniques.

The paper entitled 'RBF networks based approximate decoupling controller' by Q. He, X.F. Yuan and Y. Wang discusses a problem of decoupling controller design using RBF neural networks. Based on a direct linearisation method from the input-output model of this coupled plant, the decoupling control law was derived using Taylor expansion approach and was implemented using RBF networks. The robustness of the stability and the performance of a closed-loop system were established using Lyapunov method. Simulations demonstrate the effectiveness of the proposed decoupling controller.

The paper entitled 'Robust stabilising controller synthesis for discrete-time recurrent neural networks via state feedback' by J.H. Zhang, H.X. Zhang, G.J. Dai, S.L. Zhang and M.Q. Liu addresses the robust stabilisation problem of discrete-time recurrent neural networks (RNNs) with norm-bounded uncertainties. By Lyapunov stability theory and the S-procedure technique, state feedback controllers are designed to guarantee the global asymptotical stability of closed-loop dynamic discrete-time systems. The controller gains are obtained by solving a set of linear matrix inequalities.

The paper entitled 'State feedback linearisation based neural network adaptive controller for a class of uncertain SISO non-linear systems' by M. Chemachema and K. Belarbi presents a neural network direct adaptive control algorithm for a class of uncertain SISO non-linear systems. In the proposed approach there is no sign constraint on the system control gain and/or on its derivative as done in the literature. The neural network approximates an ideal controller in feedback linearisation form based on an estimate of the control error signal used in the adaptive laws derivation. An estimated value of the control error is provided by a fuzzy inference system composed of a set of rules determined heuristically from information related to the history of the output tracking error. Lyapunov direct method is then used to prove the global exponential boundedness of all the signals involved in the closed loop and hence the stability of the system. Simulation results demonstrate the effectiveness of the proposed approach.

The paper entitled 'System identification using the neural-extended Kalman filter for state-estimation and controller modification' by S.C. Stubberud and K.A. Kramer develops a neural extended Kalman filter (NEKF) for adaptive state estimation that can be used in target tracking and directly in a feedback loop. It improves state estimates by learning the difference between the a priori model and the actual system dynamics. The neural network training occurs while the system is in operation.

The paper entitled 'Inferential control with the aid of modified QPLS-Based soft sensor for an industrial FCCU fractionators' by X.M. Tian, L. Tu, M.H. Yang and S. Chen proposes a modified quadratic partial least squares (MQPLS) algorithm based on non-linear constrained programming techniques, in which sequential unconstrained minimisation technique is employed to calculate the outer input weights and the parameters of inner relationship. It is shown that the MQPLS not only can explain better the underlying variability of the data but also achieves improved modelling and predictive performance over the existing QPLS algorithms. An inferential control system is implemented on the distributed control system for an industrial FCCU main fractionator, in which the soft-sensor was built based on the MQPLS algorithm to estimate the diesel oil solidifying point online, and the controller is established via a constrained dynamic matrix control algorithm. Experimental results obtained demonstrate that the inferential control system with the aid of the MQPLS soft sensor works much better than the original tray temperature control system, and it realises well the bounder control of diesel oil solidifying point.

The paper entitled 'Use of a neural-network-based approach for a reliable modelling of a distillation column' by Y. Chetouani considers a problem of building reliable neural networks to model process behaviour for both the steady-state and unsteady-state regimes. The proposed techniques are used to predict the product quality of a distillation column. An analysis of the inputs choice, time delay, hidden neurons and their influence on the behaviour of the neural estimator is carried out. Three statistical criteria are used for the validation of the experimental data.

The paper entitled 'Neural networks modelling and generalised predictive control for an autonomous underwater vehicle' by J.A. Xu, M.J. Zhang and Y.J. Wang investigates an application of neural networks based generalised predictive control techniques for an autonomous underwater vehicle (AUV). Modified Elman neural networks (MENNs) are used as the multi-step predictive model, and a fused identification model is proposed to improve the predictive and control precision. The MENNs online learning improves the control system adaptability to the unpredicted operating environment for AUV. Simulations on AUV yaw velocity control are concluded to illustrate the effectiveness of the proposed control scheme.

The paper entitled 'Neural network-based robust control for hypersonic flight vehicle with uncertainty modelling' by Y.N. Hu, F.C. Sun and H.P. Liu considers a robust control problem for hypersonic flight vehicles where the model uncertainties vary in a large scope. Neural network control techniques are employed to eliminate the large variations of the model parameters, and a neural network-based robust controller is designed to realise the tracking control task. The simulation results demonstrate the validity of the proposed approach.

The paper entitled 'Robust design of bipolar wave cellular neural network with applications' by J.Z. Liu and L.Q. Min discusses a problem of robust design for bipolar wave cellular neural network (BW CNN). This paper has two aims: establishing a theorem for designing the robust templates for BW CNN, which provides a group of parameter inequalities to determine the template parameter intervals within which the templates can implement corresponding functions; setting up an optimal model for searching the template with maximum robustness for BW CNN. Simulation results illustrate the effectiveness of the proposed approach.

The paper entitled 'Neural network based iterative learning control for product qualities in batch processes' by Z.H. Xiong, Y.X. Xu, J. Dong and J. Zhang presents a neural network based iterative learning control (NN-ILC) strategy to improve the product qualities in batch processes. The learning gain in the ILC is usually determined according to a linearisation model. Instead of building a model for the system dynamics, a feed-forward neural network (FNN) is used as a non-linear learning gain in the ILC law. The tracking error profile of the previous batch is used as the input of the FNN, while the output of the network is the control change profile for the next batch run. It has been proved that if the network is trained properly based on the historical operation data, the tracking error under the proposed NN-ILC can converge to zero gradually with respect to the batch number. The proposed control strategy is illustrated on a typical batch reactor.

The paper entitled 'Building neural network-based behaviour systems for emotion-based pet robots' by W.P. Lee, T.H. Yang and B.C. Jeng considers a problem of intelligent autonomous robot design for home entertainment. This paper develops a framework of robot configuration so that the user can always change the characteristics of his pet robot easily. They present a user-centred interactive framework that employs a neural network-based approach to construct behaviour primitives and behaviour arbitrators for robots. Experimental results show the efficiency of the proposed approach.

The paper entitled 'Neural network PID control for a water level system' by X.L. Li, L.H. Shi and J. Li proposes a neural PID control scheme for water level systems, where different PID strategies (empirical method and Ziegler-Nichols method) are studied for improving the control performances. Gradient descent method is employed to adjust a PID controller based on a radial based function (RBF) neural network. An actual A3000 three-tank water level system was tested and the obtained experimental results demonstrate the effectiveness of their proposed method.

The paper entitled 'Tracking control of robot manipulators based on orthogonal neural network' by H.W. Wang and S.H. Yu presents a robust adaptive control algorithm based on orthogonal neural network (ONN) for controlling robot manipulators. The adaptive controller constructed by Legendre orthogonal function neural network has some advantages such as simple structure and fast convergence speed. The adaptive learning law of orthogonal neural network is derived to guarantee that the adaptive weight errors and tracking errors are bounded by using Lyapunov stability theory. Simulation results on a two-link robot manipulator validate the control scheme.

The papers published in this special issue cover both theoretical advances and practical applications of neural networks in control engineering. As one of the key components in intelligent control systems, neural networks have demonstrated good potential in dynamics modelling, state estimation, fault diagnosis and adaptive control for complex systems where non-linearity and uncertainties presence. Doubtlessly, further studies and understandings on such advanced techniques will be significant to improve system performance. Whilst these neural networks based modelling and control techniques are applied for real world problem solving, some important issues remain open, such as applicability scope of various neural control schemes, reliability of the neural control systems, smart integration of traditional controller (PID or FLC) with learning and failure interpretation mechanisms, real-time state estimation, and predictive cost function optimisation. Although this special issue cannot fully cover all aspects in adaptive neural control theory and applications, it indicates the present state of the topic and shows domain workers a picture for future research.

Finally, we take the opportunity to express our sincere appreciation and congratulations to all authors for your contributions to this special issue.