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Special Issue on Continuous-time Model Identification

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Editorial

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General background and motivation for the special issue

The use of system models in different aspects of control engineering and in different application areas has been increasing in recent years. This growth in the use of models to accomplish different objectives in the design of industrial control systems has been accompanied by a similar growth in the science of system identification. A mainstay of the control system modelling paradigm are continuous-time models because they arise naturally when describing the physical phenomena of systems and processes. These models of physical systems usually involve differential equations that stem from the application of physical and chemical laws. However, the best known system identification schemes have been based on discrete-time models, without much concern for the merits of natural continuous-time model descriptions and their associated identification methods. In fact, early research on system identification focused on identification of continuous-time models from continuous-time data. Subsequently however, developments in digital data acquisition and computing technology and the concomitant sampled data led to an emphasis on the use of discrete-time system models, discrete-time control designs and discrete-time-based system identification algorithms from the mid 1960s onward. The last decade has, however, witnessed a renewed interest in the techniques for the identification of continuous-time models from sampled data. This approach to the modelling of deterministic/stochastic dynamic systems from discrete-time data has many advantages in scientific terms. It provides differential equation models that conform with models used in most scientific research. Continuous-time models are defined by a unique set of parameter values that do not depend on the sampling interval. As a consequence, there is no need for conversion from discrete to continuous-time domain, which is an essential element of indirect approaches to estimation based on discrete-time models. These continuous-time model identification methods have proven to be particularly well suited in a number of cases. As examples we can mention the case of mildly non-uniformly sampled data, dominant system modes with widely different natural frequencies (stiff systems), fast sampled data, or when the input does not respect the usual zero-order hold assumption.

The first significant survey in the field of continuous-time model identification appeared in 1981 [8]. Subsequently, further developments in the field were tracked by Unbehauen and Rao [6, 7] and Garnier *et al.* [2] while the latest survey was published only a few years ago in *IET CTA* [3]. Several books have also been dedicated to the subject of continuous-time model identification from sampled data [4, 5]. In fact, the lastest book on this topic appeared very recently in 2008 [1]. Continuous-time model has clearly now matured and several of the methods are now incorporated in the continuous-time system identification CONTSID (www.cran.uhp-nancy.fr/contsid) toolbox for use with Matlab. Clearly, continuous-time model identification has been one of the dominant directions in system identification over the last decade, as shown by the numerous special sessions organised for the IFAC world congresses in Barcelona (2002), Prague (2005) and Seoul (2008), but also for the IFAC Symposia on System Identification (SYSID) in Rotterdam (2003), Newcastle (2006) and Saint-Malo (2009). The large number of publications in this research area reflects the intensive effort devoted to the developments of the theory and applications of these techniques.

The aim of this special issue is to give a broad perspective of the state-of-the-art on the subject and to provide the community with an up-to-date account of recent advances in the continuous-time model identification field, such as for identification from non-uniformly fast sampled data, identification in closed loop, linear parameter varying (LPV) system identification, fractional order modelling, time-delay estimation and time-varying system identification.

The first two papers consider the identification of state-space models. The paper by Juan Yuz, Jared Alfaro, Juan Carlos Agüero and Graham Goodwin investigates the use of the Expectation-Maximization (EM) algorithm to identify δ-operator state-space models from non-uniformly fast sampled data.

Then, Marco Bergamasco and Marco Lovera present two subspace-based methods for the identification of continuous-time state-space models. The time-derivative problem is handled by using Laguerre filters and the methods are shown to be useful to systems operating in closed loop.

The next two papers aim at filling up gaps and focus on new developments for the refined optimal instrumental variable (RIVC) method, which has been used successfully for years in many application areas. The first contribution by Xian'en Liu, Jiandong Wang and Wei Xing Zheng establishes the convergence property of the RIVC estimates. The paper by Vincent Laurain, Roland Toth, Marion Gilson and Hugues Garnier presents the use of the RIVC method to identify input/output LPV continuous-time models when the additive measurement noise is assumed to be coloured.

Fractional order models are the main subject of the next two papers. Jean-Denis Ga-bano, Thierry Poinot and Houcem Kanoun consider the identification of LPV fractional order models. The proposed approach is successfully applied to the modelling of nonlinear diffusion systems. Then, the time-delay estimation issue of fractional order models is investigated in the paper by Anuj Narang, Sirish Shah and Tongwen Chen. Their method simultaneously estimates time-delays along with other model parameters in an iterative manner by solving simple linear regression equations. The proposed approach is successfully applied to identify a simulated thermal diffusion in a wall.

Identification in the frequency domain can constitute an elegant alternative to time-domain identification. The next two papers provide some new results for identifying linear continuous-time time-varying dynamical systems. First, Ai Hui Tan and Chin Leei Cham describe a frequency-domain identification technique combined with an adaptive estimation of the variable time-delay through a simple gridding method. The proposed method is successfully applied to a cooling system. Then John Lataire and Rik Pintelon present a frequency-domain least squares-based estimator for identifying linear ordinary differential equations whose coefficients vary as polynomials in time. Several consistent parameter estimation methods based on the total least squares, generalised total least squares, and weighted nonlinear least squares estimators are constructed.

In the last contribution, Céline Casenave and Gérard Montseny presents the use of the so-called diffusive representation to identify non-rational input-output convolution models.

A special issue is the result of hard work by many people. We are first very grateful to the authors who have worked hard to take into account the comments from the reviewers and to respect the time schedule. We would also like to thank the reviewers who have provided careful and detailed reviews of the submitted papers. We are convinced that all these efforts have resulted in a special issue which will constitute a useful presentation of the current trends in continuous-time model identification, and will be helpful to delineate new challenging research directions in the whole area of system identification. We wish you a pleasant and interesting reading.

References

1 Garnier, H., Wang, L. (Eds.) 'Identification of continuous-time models from sampled Data' (Springer-Verlag, London, 2008)
2 Garnier, H., Mensler, M., Richard, A.: 'Continuous-time model identification from sampled data: implementation issues and performance evaluation', *Int. J. Control*, 2003, **76**, (13), pp. 1337–1357
3 Rao, G.P., Unbehauen, H.: 'Identification of continuous-time systems', *IEE Proc Control Theory Appl.*, 2006, **153**, (2), pp. 185–220
4 Sinha, N.K., Rao, G.P.: 'Identification of continuous-time systems. methodology and computer implementation' (Kluwer Academic Publishers, 1991)
5 Unbehauen, H., Rao, G.P.: 'Identification of Continuous Systems', in 'Systems and control series' (North-Holland, Amsterdam, 1987)
6 Unbehauen, H., Rao, G.P.: 'Continuous-time approaches to system identification - a survey', *Automatica*, 1990, **26**, (1), pp. 23–35
7 Unbehauen, H., Rao, G.P.: 'A review of identification in continuous-time systems', *Ann Rev Control*, 1998, **22**, pp. 145–171
8 Young, P.C.: 'Parameter estimation for continuous-time models - a survey', *Automatica*, 1981, **17**, (1), pp. 23–39

Editors' biographies

Hugues Garnier received the Ph.D. degree in 1995 from Université Henri Poincaré, Nancy 1, France, where he is a professor in automatic control. From Sept. 2003 to Aug. 2004, he visited the Centre for Complex Dynamic Systems and Control, University of Newcastle, Australia. In 2006 and 2007, he held visiting positions at different universities in Australia including the University of Newcastle, the Royal Melbourne Institute of Technology and the University of Technology in Sydney. He is a member of the IFAC Technical Committee "Modelling, Identification and Signal Processing" and of the IEEE Technical Committee "System Identification and Adaptive Control". He has also been a member of the International Program Committee for the IFAC Symposia on System Identification (SYSID) since 2005. Hugues Garnier's main research interest is related to the modelling of stochastic dynamical systems. This includes time series analysis and prediction, parameter estimation and system identification. He has been very active in the last decade to promote and develop new techniques for continuous-time model identification. He is also behind CONTSID, a Matlab toolbox for direct continuous-time model identification from sampled data. He is a member of the Editorial Board of *International Journal of Control*. He is the (co)editor of two books (with L. Wang): 'Identification of Continuous-time Models from Sampled Data', Springer Verlag, 2008 and 'System Identification, Environmetric Modelling and Control System Design', Springer Verlag, 2011.

Torsten Söderström received the MSc degree ('civilingenjör') in engineering physics in 1969 and the PhD degree in automatic control in 1973, both from Lund Institute of Technology, Lund, Sweden. He is a Life Fellow of IEEE, and an IFAC Fellow. During 1967–1974 he held various teaching positions at the Lund Institute of Technology. Since 1974, he has been with the Department of Systems and Control, Uppsala University, Uppsala, Sweden, where he is a professor of automatic control. Dr Söderström is the author or coauthor of many technical papers. His main research interests are in the fields of system identification, signal processing, and control. He is the (co)author of four books: 'Theory and Practice of Recursive Identification', MIT Press, 1983 (with L Ljung), 'The Instrumental Variable Methods for System Identification', Springer-Verlag, 1983 (with P. Stoica), 'System Identification', Prentice-Hall, 1989 (with P. Stoica) and 'Discrete-Time Stochastic Systems', Prentice-Hall, 1994; second edition, Springer-Verlag, 2002. In 1981 he was, with coauthors, given an Automatica Paper Prize Award. Within IFAC (International Federation of Control) he has served in several capacities including Council member, Executive Board member and Awards Committee

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Chair. He has been the Automatica editor for the area of System Parameter Estimation since 1992.

Juan I. Yuz received his professional title of Ingeniero Civil Electronico and Master degree in Electronics Engineering from Universidad Tecnica Federico Santa Maria (UTFSM), Chile, in 2001, obtaining the Best Electronic Engineering Student Award. He received his Ph.D. in Electrical Engineering from The University of Newcastle, Australia, in 2006. He currently holds a research position at the Department of Electronic Engineering, UTFSM where he is also involved in teaching at undergraduate and postgraduate levels. His main research areas include control and identification of linear and nonlinear sampled-data systems. He is (co)author of the book 'Linear System Analysis' (in Spanish), Pearson, Spain, and several book chapters on systems theory, robust identification, and sampled-data models.