Advances in Modelling, System Identification and Parameter Estimation

Foreword

The field of system modelling and identification has advanced at a rapid rate since the time of Gauss. As early as in 1795, Gauss made pioneering contributions to parameter estimation of dynamical systems. This century has seen applications of Kalman filtering (in 1960s) to the present-day neural networks and genetic algorithms. With a view to keeping in tune with this fascinating area, it was decided to invite researchers and engineers working in the field to contribute to this special issue of *Sādhanā*. The response has been very good. These ten contributory papers span a wide range of techniques and applications of mathematical modelling.

The paper by N K Sinha gives a brief overview of system identification methods for continuous-time systems from samples of input-output data. The paper describes direct and indirect methods. The subject matter of the paper is relevant to the modelling of many industrial plants, determination of transfer function between motion responses and control inputs of an aircraft or helicopter, and many other electromechanical systems, most of which are inherently continuous-time in nature.

P V S Giridhar and S V Narasimhan present a method for blind system identification. The method is based on properties of group delay and second-order cyclic statistics. Authors show, using numerical simulation for two system functions, the improvement in percentage normalized mean square error in the range of 20% to 50%. The method presented in this paper would find application in modelling and analysis of cyclostationary time series arising in communications systems, rotary machinery, astronomical and weather-related processes.

Yun Li and K C Tan present a linear approximation model (LAM) network for modelling of nonlinear systems. The approach is to use multiple linearizing models fitted along the operating trajectories. These individual models are networked through output or parameter interpolation. This LAM can be obtained from sampled step responses and retains a linear time-invariant model. The evolutionary computation approach is used for global search for an optimal LAM and some examples are presented. The approach would serve as a simple multivariable nonlinear modelling technique. As a good exercise in mathematics, the present approach further opens up a scope for investigation of online model adaptation and the design of a local control network.

The paper by R N Singh and A Manglik describes a variational approach for identification of radiogenic heat source distribution in the crust (rocks/earth). A two-layered model of the crust is considered and a variational principle is used to determine the nature of the radiogenic source distribution in both the layers. The analysis presented in the paper suggests that the distribution is more complicated in nature and depends on the magnitude of the advective velocity. The variational approach has found application in physical, engineering and biological problems.

The paper by R V Jategaonkar and F Thielecke dwells concretely on the explicit determination of parameters of an aircraft and modelling of elastoviscoplastic deformation of metallic materials – seemingly the two different dynamical systems. Major issues and aspects discussed are the handling of nonlinear systems, gradient computation, choice of optimization and integration method, aerodynamic data base requirement, identification of unstable aircraft dynamics, and handling of atmospheric turbulence. The mathematical models determined from flight test data by using parameter estimation methods find extensive use in design/modification of flight control systems, high fidelity flight simulators and evaluation of handling qualitites of aircraft and rotorcraft. R K Mehra *et al* present new algorithms and results for flutter tests and adaptive notching of structural models in tilt-rotor aircraft. Their deterministic stochastic realization algorith (DSRA) accurately identifies multiple modes and the two adaptive notching techniques effectively suppress the structural modes. Very convincing results using simulated and flight test data are presented. The Kalman filter is advantageously used for this important engineering application. The work of this paper is a significant milestone in the area of design of integrated flight structural control systems – a crucial constituent of many aerospace vehicle control systems. The importance of the work of the above two papers need not be over emphasized in the light of present day high level of research activity in the field of aerospace engineering all over the world.

Girija *et al* present a different application of Kalman filter-target tracking and sensor data fusion. A factorization filter is used for tracking and a fusion filter is used to fuse (estimated) state vectors from different sensor channels for which a hierarchical architecture is presented. Fusion philosophy and implementation aspects are presented with some results.

K Warwick *et al* present a hyperstable neural network for modelling and control of nonlinear system. Description of neural network modelling procedure and mathematical formulation of the controller structure are presented. Authors state that their new controller is open for comparison with other neural network-based adaptive controllers – which is still an active area of research with potential applications in control of industrial systems and aerospace vehicles.

The paper by S C Raisinghani and A K Ghosh describes an interesting application of feedforward neural network for estimation of stability and control derivatives of an aeroelastic aircraft using the so-called delta and zero methods. Features of the methods are highlighted. This work opens up novel possibilities in the area of system identification using neural networks for aeroelastic aerospace structures and systems.

M Sinha *et al* present a compensatory neural network architecture (CNNA) to determine the orbit of a satellite. A set of governing equations associated with the presented architecture is given. For the specific example considered, the performance of the CNNA is compared with the Kalman filter in terms of computation time and the amount of data needed for a desired accuracy in orbit determination.

Although extensive further theoretical and practical work is needed to establish the superiority of neural network based approaches over the well-established and proven conventional methods for parameter/state estimation for a large class of problems and systems, the papers related to neural networks in this special issue take an intriguing and yet bold approach to advance the application of neural network techniques to the challenging problem of estimation and control.

On the whole, this special issue provides a wide spectrum of interesting research papers on various aspects of modelling, system identification and parameter estimation with good mathematical theories, techniques and applications to real-life practical problems. It is hoped that the volume will be useful to many researchers and practicing engineers, as well as postgraduate students working in this field.

The authors must be commended for their valuable contributions. The referees of these papers have done justice to the entire review process and have helped in improving the quality and clarity of presentation of all the papers. Thanks are also due to Dr. Gangan Prathap, Editor of *Sādhanā*, for giving us this opportunity to serve as guest editors for this special issue.

April 2000

JITENDRA R RAOL, Bangalore
NARESH K SINHA, Hamilton, Ontario
Guest Editors