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Esko Juuso received Doctor of Technology in Department of Process and Environmental Engineering at the University of Oulu. He is responsible on courses in intelligent systems and simulation and a project manager of several research projects on intelligent systems applications in various fields of industry, including energy, pulp and paper, steel and mining. He is the developer of the linguistic equation (LE) approach and the nonlinear scaling methodology, which is currently used in various applications. His research interests are in modelling and control of industrial processes with a special emphasis on combining intelligent control, fault diagnosis and performance monitoring. He has done research visits in the UK, Spain and Germany. He has been a conference chair, a chairman or member of several conference IPCs and NOCs giving plenary and invited talks in France, German, Italy, Sweden and UK. He has organised special sessions in several conferences. A list of more than 300 publications of which he is (co)author is available. He has been the president of SIMS, the Scandinavian Simulation Society, 2007-2013, and the secretary of EUROSIM, the Federation of European Simulation Societies, 2007-2010. From 2013 he is the president of EUROSIM, a member of the Editorial Board of The International Journal of Condition Monitoring (IJCM) and a member of the International Society for Condition Monitoring (ISCM) Management Committee.

Smart adaptive methods in modelling and simulation of complex systems

Keywords: Linguistic equations, Smart adaptive systems, Intelligent methods, Statistical analysis

Abstract

A multitude of methodologies is available for the modelling of complex systems. Small, specialised systems have a large number of feasible solutions, but developing truly adaptive, and still understandable, systems for highly complex systems require domain expertise and more compact approaches at the basic level. Linguistic equation (LE) approach originating from fuzzy logic is an efficient technique for these problems. The nonlinear scaling methodology based on advanced statistical analysis represents the variable meanings in a compact way, which facilitates recursive parameter estimation approaches for the adaptive scaling. Well-known linear methodologies are used for the steady state, dynamic and case-based modelling in connection with the cascade and interactive structures in building complex large scale applications. To achieve insight and robustness the parameters are defined separately for the scaling and the interactions. The linguistic representation becomes increasingly important when the human interaction is essential. Fuzzy set systems move gradually to higher levels, neural networks and evolutionary computing are used for tuning. The overall system is reinforced with advanced statistical analysis, signal processing, feature extraction, classification and mechanistic modelling and simulation.

Integrated modelling approaches produce smart adaptive models for forecasting and control design: the smoothly operating LE models are combined with fuzzy set systems in many ways to enhance the properties of the multivariate models. Fuzzy set systems or working point models facilitate smooth transitions between LE-based submodels, which are developed for different process phases and operating conditions. Linguistic Takagi-Sugeno models are special cases, where the modelling areas and the local models use the same variables. The nonlinear local models reduce the hedges and valleys and the risks of chattering. The system may contain phenomenological models whose parameter handling is based on discrete membership functions. Dynamic LE models have been combined with fuzzy set systems to handle special cases together with the smoothly operating LE model. Uncertainty of inputs and models is handled with fuzzy calculus based on the extension principle and interval analysis. Type-2 fuzzy numbers can be used for the centre point and the feasible area, i.e. the parameters are fuzzy. As the basic LE models are flexible in representing nonlinear behaviour, the linguistic neural networks have not been used so far. The LSOM is used for generating linguistic interpretation for SOM neurons. The recursive parameter estimation is the key to the adaptation in these applications.