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TRENDS IN SYSTEMS AND SIGNALS

Status Report prepared by the IFAC Coordinating Committee on Systems and Signals

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Abstract: This report discusses problems and methodologies that lie in the broad scope of systems and signals, with special focus on modeling, identification and signal processing; adaptation and learning; discrete event and hybrid systems; and stochastic systems. A common theme underlying all these areas is that problems in control systems and signals are usually defined and best studied in the framework of stochastic approaches. Although there are common precepts among all these technologies, there are also many unique topics within each area. Therefore, the current key problems in each technology are explained, followed by a discussion of recent major accomplishments with trends, and finally some forecasts of likely developments are provided. The conclusion summarizes some general forecasts for the overall field of systems and signals. *Copyright©2005 IFAC*

Keywords: Systems and signals, Modeling, System identification, Adaptive control, Learning, Discre event systems, Hybrid systems, Stochastic systems.

1. INTRODUCTION

There are many diverse methodologies that concern systems and signals. This Milestone Report addresses the current status and likely future developments for the following theoretical control techniques and methodologies:

- Modeling, identification and signal processing,
- Adaptation and learning,
- Discrete event and hybrid systems,
- Stochastic systems.

There are also many common challenges that all of these control methodologies face, but each with its own unique perspective, e.g. need for improved performance, need for better models, better methods for handling uncertainty, complexity, stability, boundedness, reduction of restrictive assumptions within design methodologies, more applicability to nonlinear systems, overcoming random disturbances, improved verification, etc. and certainly the challenge of applying the techniques to real-world applications such as networked systems. However, in order to more clearly address the uniqueness of each of these methodologies, we will discuss the problems, accomplishments and forecasts of each individually in this report.

This paper is organized as follows. In Section 2, we discuss the present status, key problems, recent accomplishment and forecasts within Modeling, Identification, and Signal Processing. Sections 3, 4 and 5 are devoted to similar exposition of problems and methodologies in the areas of Adaptation and Learning, Discrete Event and Hybrid Systems, and Stochastic Systems, respectively. Finally, we conclude the paper in Section 6 with a summary of general forecasts for the overall area of systems and signals.

2. MODELING, IDENTIFICATION AND SIGNAL PROCESSING

The objective of modeling and identification technology is to develop efficient techniques which can be used to construct dynamic models based on physical insight and experimental data. The use of a plant model is crucial for model based control techniques, synthesis of servomechanisms, design of predictive control algorithms, and absolutely every simulation is based on a model of the event or process under consideration. Thus it is virtually impossible to consider the field of automation and control without including the discipline of modeling. In signal processing, dynamic models are essential in time-series analysis, adaptive filtering and fault/change detection, etc. Dynamic models and identification techniques are also critical in many other scientific areas such as econometrics and environmental engineering.

A model of a physical system for developing control solutions should include two main parts; a description of the dynamics from inputs to outputs and a description of the disturbances acting on the system. Fig. 1 shows a standard configuration for open-loop identification, where no feedback exists from y to u. The basic identification problem is to construct a dynamic model of the system based on measured input-output data (u, y). The identification process is satisfactorily solved when the measured data is used to formulate a dynamic model that, when subjected to an input, produces output that "matches" the output

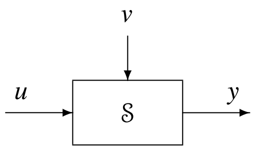

Fig. 1. A system with input u, output y, and unmeasured disturbance v.

of the system when excited by the same input. Most existing control systems are, however, operated in a closed-loop configuration as shown in Fig. 2; in this case we can employ measured input-output data (u, y) together with the reference input r for identifying the plant model. In some cases, the external input can also be measured; this additional information can then also play an important role in successful identification.

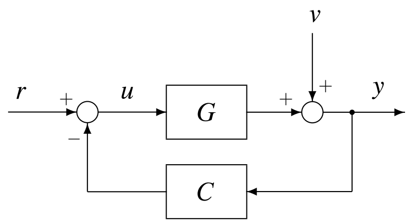

Fig. 2. A block diagram of closed-loop system with plant input u, output y and reference input r.

2.1 Current Key Problems

Modeling, identification and signal processing faces many interesting problems; among others, the following are some of the current key problems.

Disturbances in control applications are predominantly described by finite order rational spectral models; yet this type model is not totally compatible with several other formats used to model stochastic systems. Therefore, the unification of several methods for approximation of stochastic systems with rational spectral disturbance models is an important open problem.

Since an accurate dynamic model is essential for the design of most controllers, identification should always be seen as an integral part of control design. Therefore interplay between identification and the designed controller should be utilized when optimizing the design process. Continued development of methods and analysis tools for control oriented modeling is therefore another key problem within modeling and identification.

Development of computational Bayesian approaches for both estimation and quantification of modeling errors has emerged only quite recently. Techniques such as Markov Chain Monte Carlo methods have for example the ability to provide accurate probabilistic error descriptions for finite length identification data.

The success of many control applications when using linear controllers relies on the fact that the process being controlled behaves like a linear system around an appropriate working point. Clearly this is a limited approach; therefore identification of non-linear systems using non-linear model structures has been the subject of many studies during recent decades. Nevertheless, this is still a significant challenge for modeling and identification. Since estimation of general nonlinear structures from input-output data is quite difficult, we often consider simple combinations of linear dynamics G and a static nonlinearity f as shown in Fig. 3. The non-linear models can be used in several ways; examples are detecting the existence of nonlinearities or providing nonlinear models for use in subsequent