Control and Cybernetics

vol. **29** (2000) No. 3

Book review:

Nonlinear Model Predictive Control

by

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In order to control effectively, we have to be able to predict the behaviour of the plant to be controlled. It is surprising that this basic fact has been fully appreciated by the control community only in the 1970s. Up to this period the need to predict has been — to the best knowledge of the reviewer — never ever stated explicitly — although it was implied by plant modelling, necessary for control system design. The prevalent methodology of the period before 1970, being an offspring of the late 19th century differential equation approach, developed by Tolle for the steam engine control stability analysis, was well hiding the fact that some prediction of plant behaviour was done in the feedback loop.

Therefore, the development and successful application of approaches advocating explicit prediction of plant behaviour for the sake of controller design must be regarded as a major revolution in control methodology. The various approaches developed are known under the all-embracing name *model predictive control.* Its basic idea is to use optimization at each sampling interval to solve for the control action over a future time horizon using a dynamic plant model. Its main advantage is to deal successfully with the constrained multi-input multi-output plants, widespread in the process industries. *Linear* model predictive control is by now an established tool in the control engineers' toolbox. Despite its name it proved rather successful in controlling plants with hard constraints on control and state variables. However, *nonlinear* model predictive control is still of an adolescent age with plenty of room for improvement, many interesting research topics and no textbooks providing assistance and advice. This is precisely where the reviewed book seems to fill an obvious gap.

Nonlinear Model Predictive Control, being the 26th volume of a well-known Birkhäuser series *Progress in Systems and Control Theory*, is a skilfully assembled and thoroughly reviewed collection of papers presented on the *Nonlinear Model Predictive Control Workshop* in Ascona, 1998. It contains some of the latest developments in a rapidly developing area.

The book (like Gallia) is divided into three parts.

Part I — *Theoretical Issues in Nonlinear Predictive Control* contains some survey papers which are simply *a must* for *anybody working on predictive control.*

on *Nonlinear Model Predictive Control: Challenges and Opportunities*, while G. De Nicolao with co-authors surveyed the field of stability and robustness for nonlinear model predictive control. Some particularly interesting contributions are dealing with predictive control of mixed logical dynamical systems, i.e. systems described by linear dynamic equations subject to constraint involving both continuous and logical variables (Bemporad-Morari and Lemos et al.).

Part II, entitled *Modelling and Computational Aspects in Nonlinear Predictive Control*, is of particular importance. At the root of predictive control is the idea to turn an intractable dynamic optimization problem into a sequence of tractable static optimization problems. This means for nonlinear predictive control (NPC) the need to solve (at least partially) a nonconvex nonlinear optimization problem at each sampling period, both for control and for identification. This is contrasted with *linear* predictive control, where the model linearity leads to convex linear or quadratic optimization problems. Therefore, it is not surprising that the important contributions to that part deal with efficiency of NPC optimization and identification problems. There are 8 papers on that subject, covering a wide range of techniques, from Successive Quadratic Programming for control optimization (*Efficient Solution of Dynamic Optimization and NMPC Problems* by L. T. Biegler) to wavelets for plant identification (*Efficient Nonlinear Modelling Using Wavelet Compression* by M. Nikolaou and D. Mantha).

Part III, *Applications of Nonlinear Predictive Control*, consists of seven papers, of which two (the papers on multivariable NPC of cement mills by V. Wertz, L. Magni and G. Bastin, and on NPC of a submarine by G.J. Sutton and R.R. Bitmead) are complete with plant model data, while two others (on NPC of a styrene polymerization reactor by M. Schley et al., and NPC of internal combustion engines by G.D. Nicolo et al.) refer to model data in the literature. However, an excellent application paper by A. Zheng (*Some Practical Issues and Possible Solutions for Nonlinear Model Predictive Control*) got lost in the *Theoretical Issues in Nonlinear Predictive Control*, Part 1 of the book, although it fits here very well.

When reading the application part of the book one cannot help thinking about *benchmarks*. For nonlinear predictive control — as well as for linear predictive control and virtually any other control — there are no established benchmarks against which new (and indeed also not so new) control algorithms may be tested. This is in strong contrast to developments in other control-related areas, like operational research, where, e.g., for the n-machines-m-jobs scheduling problems well established benchmarks are available and more of them are constantly being developed. Without benchmarks for testing the efficiency of new algorithms, the engineering relevance of control research is bound to decline and along with it the interest of potential users. Given the degrees of freedom available for modifying nonlinear predictive algorithms and the lack of benchmarks, the potential user is bound to react sooner or later like this: *A new*

To conclude, to anybody interested in nonlinear predictive control, the collection of papers edited by Frank Allgöwer and Alex Zheng is a good starting point. To anybody working on nonlinear predictive control, the collection is a source of inspiration and gold mine of problems.

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Frank Allgöwer and Alex Zheng (eds.): *Nonlinear Model Predictive Control*. Birkhäuser Verlag, Basel-Boston-Berlin, 488 pages, 2000. ISBN 3-7643-6297-9. Price: DEM 198.–