# PREFACE

The concept of long-range model-based predictive control has recently been acknowledged as a significant and useful approach to adaptive control design. The famous Minimum-Variance (MV) controller of Åström and Wittenmark as well as some extensions like the Generalized Minimum-Variance (GMV) approach by Peterka and by Clarke and Gawthrop, or the Generalized Pole-Placement (GPP) by Lelič and Zarrop represent certain original designs founded on the idea of the Emulator-Based Control (EBC). Fundamental relations between the EBC and the Internal Model Control (IMC) principle were established by Morari and Zafiriou, and investigated by Gawthrop *et al.* What is interesting, yet at most early stages of the theoretical development of the predictive *modus operandi* of Richalet, large manufacturing companies, permanently hunting for profitable industry control tactics, instantly adopted this easy-to-understand scheme. In particular, the Generalized Predictive Control (GPC) proposed by Clarke *et al.* as a discrete-time parametric polynomial-based design methodology taking advantage of a long horizon quadratic cost function has attracted a widely acclaimed interest, which is due to its general practicability as compared to other strategies. The GPC design approach, in which rational models of the controlled plant are used in an 'indirect' manner, is free from some key hindrances restricting the area of applicability of other control algorithms (as it is, for instance, in the case of the basic IMC method 'directly' employing a complete model of the plant that suffers from the limitation to stable plants). What is more, nominal guaranteed stability of predictive algorithms can be obtained by imposing input and output constraints that results in monotonically non-increasing receding-horizon costs.

The widespread interests as well as a plain gusto for tasting new trends in the predictive methodology entirely justify special attention paid nowadays to this approach by many control-systems related meetings and publications. One of such occasions took place during the Fourth International Symposium on *Methods and Models in Automation and Robotics MMAR*, held in Międzyzdroje on the Baltic Coast in the north part of Poland in August 1997. After the invited session on *Predictive Methods for Adaptive Control PMAC* organized by myself, I had a fruitful conversation with Professor Józef Korbicz about current directions in the development of automatic control, including 'classical' and 'soft computing' techniques. This discourse concluded with a proposal to compile up-to-date papers devoted to predictive control that could make a special issue of the International Journal of *Applied Mathematics and Computer Science.*

Several symposium proposals and many other offers, received by inviting active researchers from all of the world as well as gathered in response to a general call for the *PMAC* papers, underwent a multiple and thorough reviewing process. Due to a limited space of a single edition, only half of the submissions could be accepted for printing. Consequently, a bit more than one year later, I have the pleasure of finalizing the publication idea and offering the Reader the special issue of *AMCS*, entitled *Predictive Methods for Adaptive Control* and comprising an interesting collection of fine papers selected in the course of a 'hard constrained polyoptimization' procedure.

In the first paper, Magni, De Nicolao and Scattolini discuss a number of critical SISO design issues, including nominal and robust stability, nominal and robust performance, as well as the interplay between controller design and model identification. The stability issues are tackled with the use of the constrained receding-horizon predictive control and the frequency output weighting polynomial, respectively. Whereas the performance topics are addressed in a two-step design procedure exploiting the two-degrees-of-freedom control structure. Based on the above and a model uncertainty estimation scheme, an iterative model-identification and controller-design procedure are presented.

Nikolaou and Eker contest the basic idea behind the adaptive control paradigm composed of FIR-model-based predictive control and identification. Consequently, they propose two (stationary and nonstationary) adaptive variants using output constraints instead of the output setpoint tracking principle. Namely, process outputs are freed to move away from setpoints, as long as they remain within specified limits, while process inputs are forced to excite the process as much as possible, for the generation of persistent excitation in closed loop (to gain maximum parameter-estimation information).

The lack of tuning rules is often seen as a drawback of both GPC and CGPC. In particular, the interplay between the design parameters and the stability and performance indices has not yet been satisfactory explained. Taking this into account, Kowalczuk and Suchomski consider the continuous-time generalized predictive control and present an analytical stable control design procedure for both minimum-phase and non minimum-phase SISO systems that is based on a set of closed-loop prototype characteristics with definite time-domain specifications. Their work also attempts to fill the above stated gap by giving a closed-form procedure that assures both nominal stability and nominal performance requirements at the same time. It thus shows a direct way of guaranteeing stability and an indirect way of assuring a limited control signal as opposed to the constrained receding-horizon control conception.

Van den Boom and De Vries address the state-space problem of robust predictive control with signal constraints handling, where robust stability is achieved via on-line selection of a time-varying Youla parameter. With known stability and feasibility results, a feedforward part of the controller is tuned for optimal signal tracking by using nominal plant model in an unperturbed case. A feedback division of the controller is implemented by the Youla parameter, which is, at every sample time in a receding horizon setting, optimized to reject state disturbances and the effects due to model uncertainty, and which becomes time varying by handling signal inequality constrains. Based on the small-gain theorem, bounds on this parameter give robust stability against 1-norm bounded model error.

Declercq and De Keyser argue applicability of simplified nonlinear state-space predictors, which, without resorting to Diophantine equations, can be built with the aid of black or white box modelling concepts. In such a predictor, a nonlinear archetype is utilized to calculate a 'free' plant response, while an incremental linearized model is used to calculate a 'forced' response. Instead of linearizing the model around a certain state of the process, or near the current state of it, the system is linearized about the predicted 'free' trajectory of the process. This strategy can be interpreted as a (single- or) multi-iteration (Levenberg-Marquardt) procedure for solving the nonlinear non-convex constrained optimization problem using gradient-based minimization techniques.

Błachuta talks about a state-space solution to a predictive control problem, obtained by using a receding-horizon quadratic performance index and an innovation-type explicit-delay state-space process realization. The proposed detailed twofold solution refers to an optimal controller gain linked with an associated LQG control design and an optimal Kalman filter (KF) gain of the complementary state estimation task. The resulting two Riccati equations, concerning both the LQ and KF problems, can, under certain stationarity and rank assumptions, be replaced by computationally more efficient (fast) Chandrasekhar equations, known from the filtering context.

Haber, Bars, and Lengyel debate using predictive control for nonlinear dynamical plants of SISO type. By taking a quadratic cost function with the output signal in future points beyond the dead time, they develop extended horizon (one-step-ahead and long-range) suboptimal predictive control algorithms for noise-free parametric Volterra models with quadratic-polynomial steady-state characteristics (and linear in the parameters). Even if the models have no separate linear dynamical part, by assuming a constant value of the control signal, or its increment, within the control horizon and by prediction based on a basic Diophantine equation the optimization problem is reduced to a one-dimensional minimization task, where the optimal current control increment is computed by a suitable roots-handling procedure.

Oliveira, Amaral, and Favier have a conference on the indirect-adaptive receding-horizon-predictive control methodology for discrete-time stable processes with (Lebesgue) impulse responses (that can also be extended with integral action), based on their unstructured truncated representations. An overview of both the modelling conception of orthonormal basis functions, including Laguerre and Kautz functions, and the signal-constrained predictive control using the 2-norm (quadratic, with control weighting) and the infinite-norm (of output-prediction-error) cost functions, based on these orthonormal series functions and an approximate plant time constant, is presented. In such a way, fewer parameters are identified than in the case of impulse response models, and both the plant order and time delay do not need to be known exactly.

Yoon, Yang, Lee, and Kwon deal with a difficult problem of designing a high performance control system for a destillation column, characterized by an involved multivariable nonlinear dynamics. They consider an adaptive control scheme composed of a multivariable receding-horizon predictive controller using suitable transfer function models and a recursive least-squares adaptive parameter estimator with covariance regularization. Even for uncertain nonlinear plant characteristics, with only few tuning parameters a consistent multivariable closed-loop system performance can be obtained.

Hilgert and Vila deliberate prediction of controlled autoregressive processes with additive white Gaussian noise and random coefficients adjusted to an observation process. They extend the optimal Kalman filter result for conditionally Gaussian systems with random matrix coefficients to a $k$-step ahead prediction, under almost sure finiteness assumptions and measurability assumptions for these coefficients. This approach to process modelling and optimal standard Kalman filtering can be applied to nonlinear systems, in place of the approximate and computationally more complex extended Kalman procedure, which is based on implicit linearisation.

Finally, I would like to express my gratitude to all the authors, who submitted their works to this special issue, for their cooperation, and to the 44 referees of all the 75 prime professionals, who have been called in, for their inestimable help, readiness and promptness in evaluating these papers. I am also grateful to the organizers of the *MMAR'97* Symposium, in particular, to Z. Emirsajłow, S. Bańka, and S. Domek, for stimulating my hosting the PMAC invited session. Exceptional thanks are due to Prof. J. Korbicz for inviting me to guest-edit this special issue, as well as for his enthusiasm for this publication idea and participation in the final editing management.

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