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Implementation and testing of a soft computing based model predictive control on an industrial controller

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ABSTRACT

This work presents a real time testing approach of an Intelligent Multiobjective Nonlinear-Model Predictive Control Strategy (iMO-NMPC). The goal is the testing and analysis of the feasibility and reliability of some Soft Computing (SC) techniques running on a real time industrial controller. In this predictive control strategy, a Multiobjective Genetic Algorithm is used together with a Recurrent Artificial Neural Network in order to obtain the control action at each sampling time. The entire development process, from the numeric simulation of the control scheme to its implementation and testing on a PC-based industrial controller, is also presented in this paper. The computational time requirements are discussed as well. The obtained results show that the SC techniques can be considered also to tackle highly nonlinear and coupled complex control problems in real time, thus optimising and enhancing the response of the control loop. Therefore this work is a contribution to spread the SC techniques in on-line control applications, where currently they are relegated mainly to be used off-line, as is the case of optimal tuning of control strategies.

1. Introduction

The study and design of efficient, optimised and accurate control strategies for complex plants or systems in the Industry is a remaining challenge. The characterisation of real plants includes complex features such as highly nonlinear and coupled dynamics, several competing objectives, chaotic disturbances, randomness and uncertainties among others [22,34]. These features increase the complexity of the design of control systems (especially when the plant also must work in different and continuously variable operating points), making it difficult to obtain satisfactory results when the control problem is addressed through classical control theories and hard computing techniques.

As Rudas and Fodor described in their work [25], Intelligent Systems (IS) "provide a standardised methodological approach to solve important and fairly complex problems obtaining consistent and reliable results

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over time". In Computational Sciences the intelligence of a system can be characterised by its flexibility, adaptability, capacity for learning, reasoning, dealing with complex dynamics, as well as its capacity for managing uncertain and imprecise information. An overview of the IS and the different approaches based on intelligence is provided in [25]. The Computational Intelligence [6,7], the SC [2,14,20] and the Hybrid Systems [10,26] are examples of such approaches. In the last years, techniques coming from these paradigms have provided opportunities in engineering design, control and research in industrial applications, as is pointed out in [27].

Nowadays it is possible to find control applications and research works addressed using IS, offering advanced solutions for many complex industrial control problems. Some of these solutions are based on Artificial Neural Networks (ANN), such as in [3] where an introduction and perspective of using ANN in motor drives control is given, or in [19] where a new approach of a "brain-emotional-learning-based intelligent controller" is studied. Another widely spread technique in industrial applications is the Fuzzy Logic (FL) where some of the latest applications are listed in a recent review [24].

In the searching process context of a complex nonlinear multiobjective optimisation problem, it is possible to select different methods to obtain the set of non-inferior (Pareto) solutions. Nowadays, methods based on evolutionary algorithms (EA) are probably the most popular alternative, the high computational cost being their main drawback, especially when fast convergence time and real time characteristics are required. Several works dealing with this task can be found in [12,18,31]. Efficient EAs such as Nondominated Sorting Genetic Algorithm (NSGA), Micro-Genetic Algorithm, and Adaptive Genetic Algorithm are contributions presented in [1,29,30] respectively. Other relevant drawbacks appear when system stability and robustness analysis are pursued. The analysis of these aspects implies a very high complexity due to the requirement of a convergence analysis of the heuristic searching methods.

In recent years the Evolutionary Computing (where GAs are included) is progressively being introduced into industrial process control applications [22]. Most of the works in this area are related to project scheduling of industrial processes [13,28], or to obtain an optimised set-up or configuration of the processes which can include the calculation of the control systems' parameters [5,11,31,33]. Nevertheless there is a relatively low number of GAs as the core of real time control strategies. A recent approach in which a Multiobjective Genetic Algorithm is the core component of a hybrid predictive control strategy can be found in [32]. Most of this kind of studies have shown promising results over highly complex dynamic systems in numerical simulation frameworks.

The lack of real time implementation, analysis and validation of previously mentioned developments for their introduction in real industrial processes is an important drawback. This could be addressed by pursuing more realistic simulation frameworks (with a better approach to the real control systems). The problem is the development and testing laboratory equipment, which usually differs from the industrial equipment such as the PC-based industrial computers (PCIC), real time embedded systems, programmable logic controllers or programmable automation controllers (PAC). Furthermore, real conditions such as uncertainties, noisy or imprecise measurements, disturbances and complex nonlinear dynamics, among others, are usually not considered in the early simulation stages.

The work presented in [16] provided the first steps towards the implementation of a SC based control strategy in real industrial controllers such a PCIC and a PAC. The early real time implementation of a GA as a core of a Nonlinear Model Predictive Control (NMPC) strategy showed the real capabilities of some real time industrial platforms to cope with such complex control problems. In this first approach a single objective control strategy was implemented and characterised in two hardware platforms, despite the adapted Nondominated Sorting Genetic Algorithm (NSGA-II) being a multiobjctive GA. The main goal of the work was the evaluation of the computational cost, including the analysis of the computational time requirements for such kind of hardware controllers running the GA-based single objective predictive control strategy. Therefore, a 'Hardware in the Loop' (HiL) setup and the testing of simple control strategy based on a GA were the most important topics addressed in [16].