European Journal of Control 19 (2013) 358–368

Contents lists available at SciVerse ScienceDirect

European Journal of Control

journal homepage: www.elsevier.com/locate/ejcon

Successful industry/academia cooperation: From simple via complex to lucid solutions

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ARTICLE INFO

Article history:
Received 27 March 2013
Accepted 2 May 2013
Recommended by Alessandro Astolfi
Available online 7 June 2013

Keywords:
Industrial/academic cooperation
Industrial control
Control project management
Advanced control
Impact of control technology

ABSTRACT

The control literature is rich on impressive applications of advanced control, and within almost any industrial sector there are numerous examples of successful advanced control applications. Nevertheless, there is a widespread belief that there is still a wide potential for increased cooperation between academia and industry within this area.

In this position paper, it is advocated that one of the enablers for successful cooperation between industry and academia within the control area is a proper framework for cooperation projects between companies and universities. Some suggestions for such a framework based on elaborate experience are proposed. In particular, the paper points to the importance of designing projects with project time explicitly scheduled for a phase based on reflection of complex academic solutions. In this phase, the objective is to mimic the behavior of the complex controllers by less complex but industrially feasible solutions. The proposed approach is illustrated by three case studies of successful industrial/academic cooperation.

1. Introduction

The scientific area of control theory and control engineering can in many ways be said to be a mature area in the sense that it has a very long history, it has gone through several development phases and it is a technology that has become pervasive in our societies. An intuitive understanding of the behavior of closed loop systems can with some right be said to have been associated with the design of adobe houses for the right thermal behavior or with the design of fire places and smoke openings for maximal ventilation at the beginning of civilization. The conscious design of feedback mechanisms definitely predates Watt's steam engine, although it is difficult to put a precise date to the first real application of feedback design. An early example often mentioned is the water clock of Ktesibios from the third century BC, see Landels [12].

Ever since the antics, the history has been full of successful applications of control methods. Control technology is ubiquitous, and it has become virtually impossible to count the number of explicitly designed control loops in our surroundings, embedded in cars, indoor climate systems, refrigerators, cell phones, etc. Nonetheless, there is a persistent concern within the scientific control community that there are vast unexploited potentials of control theory within industry, and there is considerable frustration caused by these unexploited potentials. The analysis is probably correct to some extent, as several reports have analyzed the return-of-investment for advanced control projects within several industries and documented that compared to many other technologies, investments in control technology seems to be considerably under-emphasized, see e.g. Samad and Annaswamy [16] and Brisk [4].

To the extent where the potential for industrial/academic cooperation is not fully exploited, this can have several reasons. In many cases, such an endeavor is never pursued, either because such cooperation has never been discussed between the company and a potential academic partner, or because the parties could not agree on a contract. In other cases, an attempt has been made, but it has not been successful in the sense that no results of the cooperation has been implemented in a product (or in the production process, if that has been the scope).

The classical paper [5] challenges frequent statements given in the academic literature, leaving "[…] *the unmistakable impression that those who conceive the theory are in some sense leagues ahead of those who would use it*". Instead, it proceeds to support the thesis that theory "[…] *has some rugged terrain to traverse before it meets the needs of those who would apply it*. At the end, the paper concludes: "*The gap is present indeed, but contrary to the views of many, it is the theoretician who must close it*".

A very recent paper [17], which deserves significant attention, challenges the control community to consider how a novel control

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http://dx.doi.org/10.1016/j.ejcon.2013.06.001

technology fits into an industrial value chain. In particular, it argues that the customer and the end-user are usually distinct, and whereas the customer might be able to appreciate the virtues of a new control technology, the end-user might not demand the added value sufficiently to justify the added cost for the customer. If a new technology does not provide sufficient added value to each link in the value chain, it will not be implemented.

In this position paper, we shall discuss how a cooperation project between an industrial and an academic partner can be designed in such a way that the probability for a successful outcome is improved. There is clearly a high number of conditions that must be satisfied for such a successful cooperation, starting with agreeing on a contract, assigning the right team, etc., and this paper does not in any sense have the ambition to encompass all those complicated aspects. It just addresses a few aspects regarding the project phase plan that is possibly sometimes overlooked. The approach suggested is based on the experience of the author and his co-workers and a large number (100+) of industrial partners, and is probably applicable to a class of cooperation projects between industry and academia, but definitely not to all.

2. Solutions to industrial problems: from simple via complex to lucid

No prudent industry is prepared to take risks that are unnecessary in the sense that they are not matched by extraordinarily high promises of benefits. Some of the risks associated with applications of advanced control can to some extent be captured by the notion of *complexity*. This does not mean that industry in general will shun complexity. In fact, most industrial systems have in themselves a huge complexity and sometimes the competitive edge is based on mastering complexity. In the advanced control context described here, however, the somewhat ambiguous notion of complexity will be understood in a more narrow sense, e.g. a control solution characterized by having one or more of the following properties:

A crucial dependency of a high fidelity model. Such a model is often difficult and/or expensive to obtain and to maintain. Moreover, as many systems are subject to frequent engineering or operational changes this dependency compromises robustness of the solution.

A large number of parameters in the algorithm. This is challenging in particular if the parameters need to be tailored to the application at hand. In addition to the challenges mentioned under the previous property, this can make the controller difficult to tune and expensive to adjust to new product versions.

A 'monolithic' or highly centralized structure of the algorithm. This makes the controller difficult to integrate with other SW components, e.g. exception handling or monitoring. It also makes debugging more challenging.

A large extent of SW code required for its implementation. This is not always relevant, but crucial if the controller is to be implemented on a strictly resource limited embedded platform.

In designing new control architectures and algorithms, a key (and time-consuming) aspect concerns the analysis of functional and operational requirements. As it is with software engineering, a successful requirements analysis is a key factor in a good controller design. Below, we shall argue that it is crucial that also elements of complexity as indicated by the examples in the above list are taken into consideration.

Using the existing actuators and sensors only is often a requirement for an advanced control project. However, investing in measuring additional physical entities in general may lead to a complete redesign of the control system providing, at the same time, a simplification and a performance improvement. In the example section of this paper, Section 3, we shall give two examples, where it was crucial to restrict the control solution to existing instrumentation, and one example where the key to the breakthrough was adding one additional low-cost sensor, which in that case was uncomplicated.

In the sequel, we shall discuss various approaches to projects targeted at improving the performance of industrial control loops. There are probably as many types of such projects as there projects themselves. However, in order to facilitate the discussion, we shall introduce a coarse taxonomy based on stereotypical project types, including the approach proposed in this paper. The exposition is deliberately kept at an abstract and non-comprehensive level as the purpose of this section is exclusively to facilitate the discussion of the specific project design aspects addressed in this paper.

2.1. Consultancy type control projects

There is no doubt that a huge unexploited potential across many industries throughout the world is constituted by improper tuning of millions of simple control loops. In Åström [1] it was argued that the largest economical potential for control engineering was constituted by tuning existing PID loops. One example is within Heating Ventilation & Air-Conditioning (HVAC) systems, where Komareji [8] summarizes a technological study based on a survey of a large number of actual HVAC installations in commercial buildings. Although such systems always are delivered with a detailed installation manual, the study mentioned nevertheless documents that a majority of actual HVAC systems are left untuned, i.e. with default settings.

The large potential of making fairly simple changes to existing control loops is mainly due to the large number of such loops worldwide. In many cases the improvement will be significant but perhaps not radical. For the discussion in this paper, the development in a 'consultancy' project is illustrated in Fig. 1 in a stereotypical embodiment. In this stereotype, a consultancy project is characterized by a moderate increase in complexity in the proposed solutions relative to the existing/original solution. In fact, if only tuning is performed, no complexity is added at all. If the control software is modified, a common type of change in this type of project could be to introduce handling of certain special types of operating conditions by conditional software clauses ('if' statements in the source code). In the stereotype consultancy project type illustrated in Fig. 1, the solution complexity grows slowly with time. As the solution complexity grows, also the performance grows, but at the same moderate pace. Typically,

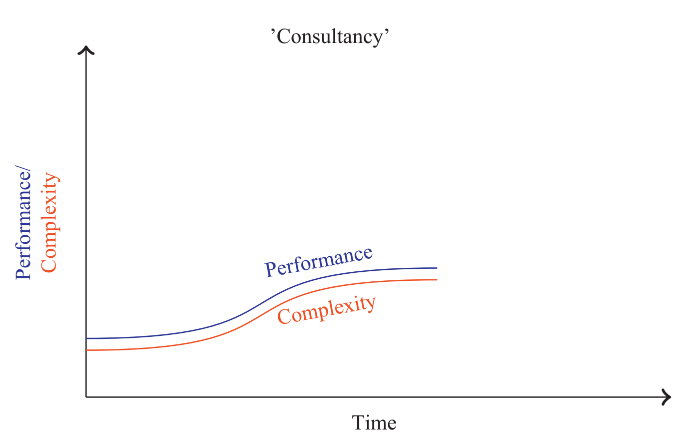

Fig. 1. Project of 'Consultancy' type. The solution only involves a moderate increase in complexity, but also has only a moderate increase in the performance.