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Integration of intelligent systems in development of smart adaptive systems

Esko K. Juuso

Control Engineering Laboratory, Department of Process and Environmental Engineering, University of Oulu, P.O. Box 4300, FIN-90014 Oulu, Finland

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Abstract

Different combinations of fuzzy logic and neural networks provide various ingredients for smart adaptive applications. Both expertise and data can be integrated in the development of intelligent systems. Evolutionary computation is also widely used in tuning of these systems. For small, specialised systems there is a large number of feasible solutions, but developing truly adaptive, and still understandable, systems for highly complex systems require more compact approaches in the basic level. Linguistic equation (LE) approach originating from fuzzy logic is an efficient technique for these problems. Insight to the process operation is maintained since all the modules can be assessed by expert knowledge and membership definitions relate measurements to appropriate operating areas. The LE approach increases the performance by combining various specialised models in a case-based approach: models can be generated automatically from data. The LE approach is also successfully extended to dynamic simulation and used in intelligent controller design. The integration of intelligent systems is based on understanding the different tasks of smart adaptive systems: modelling, intelligent analysers, detection of operating conditions, control and intelligent actuators. The system integration leads to a hybrid system: fuzzy set systems move gradually to higher levels, neural networks and evolutionary computing are used for tuning, and the whole system reinforced with efficient statistical analysis, signal processing and mechanistic modelling and simulation.

E-mail address: esko.juuso@oulu.fi (E.K. Juuso).
URL: http://www.ntsat.oulu.fi.

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1. Introduction

Development of smart adaptive systems for non-linear, complex, multivariable and highly interactive industrial processes is a challenging task. Usually, the important quality variables can be estimated only from other measured variables. Physical limitations of actuators must be taken into account. Significant interactions between process variables cause interactions between the controllers. Various time delays depend strongly on operating conditions and can dramatically limit the performance and even destabilise the closed-loop system. For overall production processes, control systems take care of several subprocesses. There are many and long time-varying delays, process feedbacks at several levels, closed control loops, factors that exist and cannot be measured and interactions between physical and chemical factors. Uncertainty is an unavoidable part of the process control in real-world applications since there always are some unknown factors affecting to the process conditions. Successful applications require integration of data-based methods and expertise, especially if fast reactions to changing operating conditions are needed.

Smart adaptive systems are based on intelligent methods, i.e. individual subsystems are intelligent systems. The smartness of the overall systems depends on integration of these intelligent systems. A smart system needs a decision making unit: in Fig. 1 this is the control block. Putting everything in this block would result too complicated systems. A better alternative is to make a generic and configurable control block whose inputs are (calculated) variables related system properties which really should be controlled. This can be done with software sensors type intelligent analysers. This part is especially important in connection to continuous on-line analysers. Intelligent analysers may also include trend analysers. If operating conditions are changing, intelligent analysers are also needed for detection of the operating conditions. Measurement should be handled with digital signal processing. Also operation of actuators can be improved with intelligent modelling. Dynamic modelling and simulation is needed for comparing alternatives in controller design.

On-line analysers facilitate new measurements which also need new calculation modules to be used in everyday process control. Intelligent analysers provide solutions for this, but part of the work could be done also in digital signal processing. Possibilities of using intelligent techniques are improving also in actuators. Moving close to the process brings new challenges for the implementation of the intelligent systems.