

# NI Optimization in Process Control

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## PROBLEM STATEMENT

Depending on case, different criteria are set to the performance of process control:

- Accuracy: The controller must reach and keep the set point in spite of disturbances.
- Speed: Set point changes must be carried out in preset time or fast enough to avoid quality impairment or other disturbances in the controlled variable.
- Robustness: The control system should behave in a similar fashion in spite of moderate changes in the system operation or environment.
- Adaptation: The control system should change its operation when the system operation or environment markedly changes, while keeping the above mentioned criteria.
- Transparency: The operation of the control system should be easily understandable to the user and make the interaction with the operator as easy as possible.
- Safety: In case of severe disturbances and emergency situations, safe operation is guaranteed as automatically as possible, and operator interactions are easy to design and inform.

In process control, 90% of cases are solved with conventional PID controllers. The cases that require different solutions are usually characterized by the following:

- Difficulties in measurements: The noise behaviour of measurements change with time – aging or faults. Direct measurement of the controlled variable is not possible. Software sensors need a special care. In multi-sensor systems, the weight of different sensors vary with time; e.g. different wavelengths in spectral measurements become important, when the raw material changes. Self-configuring and self-healing features are needed.
- Adaptation requirements largely exceed the capabilities of conventional controllers: The operation point changes often and inside a large range. Most processes are also planned to operate at maximum production and operation with, e.g. 50% or 30%, capacity is difficult to manage. Changes in the control strategy require self-configuring features.
- Interactions are difficult to handle with conventional controllers: Interactions may change with varying operating points or changing quality requirements. Multivariable control is sensitive to faulty sensors or actuators. There is a need to re-organize the control in these cases or when product grades or raw materials change. Processing routes may also change and change the interactions. Actually, they may change the whole target setting of the controllers.

This list does not even aim to be complete – the problems in process optimization, mill optimization and production scheduling are not touched at all.

## SOFTWARE SENSORS

Software sensor has been defined as the association of a sensor (hardware), which allows on-line measurements of some process variables, with an estimation algorithm (software) in order to provide on-line estimates of the non-measurable variables, model parameters or to overcome measurement delays. There are several estimation techniques: estimation via balance equations and statistical approaches, observers, filtering (Kalman filter, extended Kalman filter) and AI methods. Concerning with AI methods, neural networks are, by far, the most popular. Fuzzy logic, especially classical Takagi-Sugeno method has also found a lot of use. There are also

reports on using support vector machines and genetic algorithms, usually in combination with neural networks and fuzzy logic.

When process conditions change, software sensors must be manually adapted to the new situation – they must be re-tuned as also other control algorithms. The problem is that the tuning of software sensors is necessarily not so straight forward as with PID-algorithm. There are no “tuning rules” or easy ways to change the model parameters, but the modelling must be done again, sometimes even from scratch. NI methods may find room in these new self healing applications (term coined in NISSPI Task Force). This requires methods for performance evaluation and fast methods to learn new models on-line. In addition to accuracy and repeatability, robustness is the main criterion in this connection.

## ADAPTATION

Adaptive intelligent control usually identifies with fuzzy adaptive control or neuro-fuzzy (Anfis-type) systems. Hybrid systems combining neural networks and genetic algorithms with fuzzy logic have been tested. In fuzzy logic control, adaptation can consider changing scaling factors, membership functions and the rule-base.

These algorithms and controllers work usually well, when the need for adaptation stays inside the preset needs. Problems come when bigger changes in process operation occur: e.g. production lines are changing or the product follows an exceptional route through the existing lines. Then there is a need to change also the requirements for control. This requires self-configuration features that convert the new set of requirements to a new control strategy. Here the use of the term “self-organizing” is intentionally avoided.

There seems to be two alternatives to do this: learning the new situation and adapting to it or evolving from the existing situation to the new one. The first one needs tools for state recognition and data, and the second needs models and methods for selecting the way of evolution. Both need optimization methods, be them nature-inspired or not. The second strategy might use the ways the nature adapts to bigger changes or evolve to changing targets.

## CONTROLLER TUNING

Problems with controller tuning exist mostly in dealing with interactions. For instance, doing multivariable control with fuzzy logic brings in many new tuning factors in comparison with the conventional PID controller. This has been the main obstacle keeping the number of applications of fuzzy logic control small. Implementing new control systems and re-tuning the existing ones is tedious and difficult, if the configuration of the controller is complex.

Here NI methods could help especially in the design stage and in off-line tuning. Swarm optimizers, ant algorithms or Chemotaxis algorithms can work in optimal tuning of controllers with several tuning parameters. Also here the curse of dimensionality might be a problem, and the ways how to solve it with modularization and hierarchies must be considered. In the case of faulty sensors and actuators immune programming combined with NI optimization may help in locating the fault and recovering from the situation.

## FUTURE TOPICS

The presentation before started from the existing control systems and the use of NI methods was mainly in their advanced ability to learn and evolve in the existing control structures, and in this way lead to improved system performance. More challenging is to apply nature’s principles directly in control. This means that modular or hierarchical controllers can follow their counter-examples in nature; how the signalling and control proceed e.g. in metabolic or gene regulator networks, or how interactions are taken into account in nature systems. One has, however, to remember that feedback is a strong principle in nature, and more detailed research may lead to surprisingly similar results as the existing feedback controllers. What is, inevitably, worth learning is how these feedback systems adapt, evolve and change their operation in different situations and the stage of living..