Frontiers in Industrial Process Automation – A Personal Perspective

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Extended Abstract: Over the last two decades, the environment of industrial process automation has changed significantly. Many process industries markets have matured, leading to increased competitive pressures driving consolidation and globalization of the industry. During the same period, available base technologies for process automation have also changed dramatically. Computing, communication, and storage capacities have all not only grown by a factor of more than one thousand during this period, but are also broadly available at a cost that typically corresponds to only a small fraction of overall investment into a plant and expected advanced control and optimization benefits.

Building on these advances, process automation systems have also evolved. Early digital automation systems were monolithic and algorithms of any sophistication resided in central and completely proprietary computers. The move to distributed control systems brought functionality residing in controllers closer to the field, and digital communication between controllers, but still only simple single-variable analog communication with sensors and actuators. Computing, memory, and communications capacities remained major bottlenecks that limited industrial deployment of advanced control and optimization, and automation given these limited resources demanded a significant part of engineering skills and efforts. Today, almost any sensor and actuator is at least available in a digital version with digital fieldbus connectivity and its own microprocessor. This broadens communications beyond the exchange of single analog measurement or control information and has opened new possibilities, e.g., self-supervision and diagnosis, fast local control loops very close to the process, and both local and distributed identification and adaptation.

Furthermore, modern automation systems are increasingly built using open communication standards and broadly available commercial-off-the-shelf hardware and software components, thus opening information integration possibilities far beyond classical process automation scope. While it previously could take several person-months to industrially implement modern control techniques after they had been designed conceptually, direct interfaces for automatic code generation and download from scientific computing tools directly into controllers allow fast deployment of new algorithms, or what-if analysis based on actual process states with any sophistication supported by such tools. Information integration with a company's production scheduling, maintenance optimization, logistics, and enterprise resource planning systems finally broadens the scope to a point where it becomes possible to view the operation of industrial processes as an integrated optimization problem that uses assets, labor, material, and energy to optimize direct economic measures such as profitability of a single or even multiple plants, subject to environmental, regulatory, health, and safety constraints.

This possibility emerges at a time when the competitive pressures described above call for an increasingly coordinated approach between different functions and disciplines in an organization, and when increasing productivity of existing assets is often chosen over investment into new plants. While research regarding combination of, e.g., the integrated optimization of process design and control, fairly few industrial applications of such a more integral view have been reported. At the same time as computational and programming limitations of the automation system have ceased to be the primary bottleneck for the implementation of advanced control and optimization techniques, new barriers to the extensive deployment of advanced methods and new frontiers for further research emerge. Availability of high-quality models for complex processes, especially during transients, abnormal situations, or over the life cycle of a process, is probably today's primary limitation to broader industrial use. Also, the resulting aggregated control problems tend to have mathematical properties that are "not nice", i.e., neither linear, quadratic, smooth, or convex. A further important area for research thus remains the conception of concentrated or distributed control and optimization schemes that can either transform, with sufficient fidelity and affordable transformation effort, real-world problem statements into formulations that can be addressed with existing algorithms, or to find new algorithms that can reliably and efficiently solve such problems in the way they are stated.