Wish-List Items

Industry representatives were asked "What improvements in process control would permit next-level practicable applications?" The responses were distilled into 17 wish-list items, which are classified into five categories on this page. The AACC is now soliciting one-page descriptions from researchers proposing how they might provide enabling solutions – investigate methodology, reveal underlying concepts, test approaches, etc. Subject Matter Experts will select ten respondents to present their ideas at an invitation-only Workshop on Opportunity Matching.

Titles of the Wish-List items are here, details of the 17 wish-list items follow:

Category 1: Control

1) Reveal improvement possibilities for MPC
2) Goodness-of-control metrics
3) Industry credibility in simulations for research testing
4) One model for all applications

Category 2: Optimization

5) Batch end point
6) Control to functionality, not set point

Category 3: Data processing, interpretation, and analysis

7) Anomaly or abnormal condition detection, interpretation, and analysis
8) Detect when models need to be updated
9) Knowledge from data
10) Living PFD and P&ID
11) Data Cleaning
12) Automate vulnerability diagnostics
13) Models for equipment reliability

Category 4: Instrumentation

14) Improve measurements

Category 5: Education/Training

15) Provide reality in labs
16) Align course content with practice needs
17) Include standards in course material

Details of the 17 wish-list items follow:

Category 1: Control

1) **Reveal improvement possibilities for MPC**. These include the following:
    a. Make MPC easier to implement and maintain by in-plant personnel.
    b. Improve process safety models and action to permit greater confidence in operation closer to constraints.
    c. Forecast when the MPC model needs to be updated or recalibrated.
    d. Develop MPC models from simulations, or heuristics, not step upsets to plant operation.
    e. Make models have variable gain and delays that match process operating conditions.
    f. Use first-principles models in MPC.
    g. Develop guidelines to indicate when the model is good enough to stop plant tests.
    h. Expand MPC to plant-wide control (coordinate sequential units, overall plant optimization instead of local units).
    i. Automate the synthesis of control structure, hierarchy and strategies for what and how to control in a plant.
    j. Use process flow diagrams to automate the selection of what variables should be part of the conventional ARC and what should be inputs and outputs of the supervisory MPC.
    k. Should there be one supervisory MPC or does the plant isolation of effects indicate that several smaller MPCs, one for each section, would be better?
    l. Show how to coordinate control of several interacting MPCs.
    m. Explore methods to make MPC applicable to batch processes.
    n. What level of model fidelity to the process is really required for fully acceptable control?
    o. Which is better CV damping or MV damping? What are all the issues involved?
2) **Goodness-of-control metrics.** Which metrics for evaluating controllers are most aligned with industrial desirables? For continuous processes, classic CV metrics have been the basis for tuning methods, but usually lead to unacceptably aggressive MV action. Industry usually tunes controllers for operator comfort, which means an over-damped return to the set point. And many claim that tuning for regulatory performance is more relevant than setpoint following. Batch and semi-batch processes can experience huge load changes during the run, and they don't operate at steady state. Some PID loops in highly interactive service are purposely detuned for poorer control on less important loops. When evaluated one at a time, this would show poor scores for those loops.
3) **Industry credibility in simulations for research testing.** Present simulators and provide guidance to researchers for industry-relevant testing of innovative control and automation algorithms. There seem to be many independently developed process simulators. Present the best of them, covering a diversity of control issues, in a convenient form for data generation and data exchange. Research publications often use trivial simulation models to demonstrate one aspect of how well an innovation performs, but such illustration has too little industrial credibility to engender industrial interest. The simulators should have fidelity to the processes. They should be nonlinear and include noise, stochastic disturbances, stages in the instrument signal transmissions, disparate

sampling rates, calibration error, instrument dynamics, and varying input variables. The simulators should include associated hazardous conditions (excess O2 in flue gas, charring in process heaters, etc.).

4) **One model for all applications**. Use one model for all applications, such as supervisory set point optimization, process design, training, real-time process analysis, preserving process knowledge, and process control. Updating one model updates all. Staff only need to understand one modeling approach. Presently different kinds of models are used for diverse applications. Is this necessary, or an artifact of the legacy of development paths and computing power? What is a best structure for the one-model (adaptive first-principles, first principles trimmed with empirical corrections, AI)?

Category 2: Optimization

5) **Batch end point**. Explore ending a batch to optimize annual production in batches. For example, running a batch to completion will take longer than running to 80%. It may be that the shorter batch time at 80% produces more product year than fewer batches at 100% conversion. Use the concept of a "maturity variable", some key quality variable that should ultimately determine the duration of the batch. Include recycle and waste costs and cleaning to optimize the profitability metrics. Batch production is dependent on the vagaries of feed material. If each batch is monitored for on-line end-point optimization, then include issues with scheduling human operations and sequential processing in batch management, and the use of statistical techniques to temper recipe or model feedback changes.
6) **Control to functionality, not set point**. Functionality is a customer perceived property – a metric of the utility/price ratio for the customer. Product specifications, which determine set points, are related to product functionality, but do not guarantee that functionality is maximized. For example, the customer may be concerned about molecular weight distribution in polymer, not just the average that is implied by viscosity control. Explore the use of process data for a control strategy to shape product property distribution in real time, responding to vagaries of other influences, to maximize functionality. Could AI generate the models that relate process measurements to customer functionality, then the model inverse used to determine specifications? Examples may include polymer molecular weight distribution, product distribution in cat cracking, particle size distribution in crystallization, passable computer chips on a wafer after etching, maximum concentration in biological reactions, etc.

Category 3: Data processing, interpretation, and analysis

7) **Anomaly or abnormal condition detection, interpretation, and analysis.** Instead of confusing operators by an inundation of alarms, provide likely cause and corrective action. Make use of all data - operator logs, process history, alarms, reliability, and lab data. Evaluate previous failures/trips and learn from them. Develop predictive analytics for process anomalies. Explore methods for detecting how oscillations and variability propagate through a process area to identify the control loop or influence responsible for the disturbance. Demonstrate how the enterprise data can be used to update probability of events, and also determine confidence intervals on event probabilities in risk analysis.

8) **Detect when models need to be updated.** Use plant data to automatically identify when controller, inferential on-line analysis, or supervisory optimization models need to be recalibrated. Goodness of control is somewhat model dependent, but processes change in time for many reasons (production rate, rerouting flows, fouling, deactivating, process throughput, tank levels, tray efficiency, changing suppliers of complex raw materials, changing strain of microorganism in bioprocesses, etc.). Model deviation from process data might also signal a process fault. Include nonidealities in data (noise, autocorrelation, discretization) and minimize false positives and negatives. Seek to make it simple to code with low data storage.
9) **Knowledge from data.** Reveal how to extract knowledge and models from historical data. Not just correlations, but models that represent process mechanisms which can be used for process understanding, abnormal operation detection, controller design, process optimization. This may be hybrid modeling where data-driven techniques and human linguistic descriptions enhance phenomenological models. A system that knows the underlying process could help decouple the highly correlated plant data, and provide clarity for operators.
10) **Living PFD and P&ID**. Use process data to automatically update process flow and piping & instrument diagrams – both the models and the flow paths. Issues include: process data comes with disparate sampling intervals, spurious or missed signals, from past periods that are inconsistent with new data (because of recalibration, new equipment, product distribution, etc.), extended periods of missing data, data compression in historians, and data that may need reconciliation or imputation. Relevant data also resides in operator and maintenance logs.
11) **Data Cleaning.** Data cleaning in the process industries transforms raw, real-time sensor and operational data into reliable inputs for analytics. It includes: missing data imputation, outlier detection, noise removal, time alignment and delay estimation, steady state identification, spurious signals, disparate sampling intervals, recalibrated instruments, process changes that make prior and current data inconsistent, and integration of diverse sources.
12) **Automate vulnerability diagnostics.** Explore a plain language, user-configurable diagnostic system to evaluate plant operating vulnerabilities based on equipment availability and operating conditions, and to recommend operator action for risk reduction and upset recovery. The implementation of such systems has been disappointingly limited, possibly due to the burden of the programming involved, which a new approach might alleviate.
13) **Models for equipment reliability.** Analysis of fault modes is fundamental to design choices and maintenance management. Explore methods to correlate equipment reliability to process history using maintenance, process, and equipment records for an entire corporation. Evaluate the effects of equipment cycles, variability, startup/shutdowns, operator interventions, etc. Off-line FMEA methods exist. Focus on on-line fault detection and root cause determination.

Category 4: Instrumentation

14) **Improve measurements.** Improve sensors, measurement devices, or inferential sensors to provide on-line results, with reliability, longer calibrated life, sensitivity, etc. Some pulp examples include consistency, freeness, kappa number, and viscosity. Paper examples include tensile, burst, tear, ring crush, and others. Water treatment BOD is also important in many industries. As are impending flooding, clinker formation, color, foaming, froth, agglomeration, and taste, which may be best diagnosed with data diagnosis from visual sensors. Leaks, two-phase flow, boiling, and cavitation may be detected by acoustic sensors. Bioprocess applications include viable biomass, various nutrients and metabolites. Many of these detections are based on human interpretation of visual and sound clues. Maybe AI models based on measurements of variation in color, motion, tension, sound, visual patterns, etc. could be useful.

Category 5: Education/Training

15) **Provide reality in labs**. Include comprehensive simulators and pilot-scale equipment (not FOPDT models or toys) for labs, so that students get experience with real process devices (i/p, valve characteristics, measurement lags, noise, steam traps, vents, approach to steady state, start-up and shut-down protocol, etc.), understand delay and noise and calibration, understand the reality of tuning and (heuristics, and good enough), and get experience in programming/configuring a digital system in controlling a unit operation. Lean more toward the object configuration option versus programming, because many new hires are used to writing programs from scratch rather than using commercial control systems.
16) **Align the course content with practice needs**. Reduce its dominance on linear continuous processes operating at steady state. Include content on alarms and abnormal situation management, and some content on on-line analytical systems. Focus on digital systems in process control, and associated non-continuum quirks (numerical methods, digital discrimination, Δt influence in calculations). Include ARC techniques (cascade, ratio, feedforward, override). Many processes are batch, most of which are non-linear, non-continuous, and do not operate at steady state. And with the proliferation of robotics, camera-based vision systems, parts manufacturing, etc. some content should exist on discrete control systems. Safety and specification violations are critical. By contrast, Laplace transforms, Bode diagrams, Routh and Nyquist stability criterion, and Root Locus analysis, are not practiced by process control engineers in industry.
17) **Include standards in course material**. Practice-relevant standards include ISA/ANSI 5.1 (symbols used in P&ID drawings), 18.2 (alarm Management), 84 (safety instrumented systems), 88 (batch control), 95 (IT- plant floor system integration), 101 (HMIs), 106 (procedural control), 75 (control valve response), 106 (procedure automation), and IEC 62443 (Cybersecurity). These are very important in industrial practice.