Preface

Development of Real-Time Monitoring Using Soft Sensors

FUNATSU, Kimito*

The processes of chemical plants and various other production systems must be continuously monitored and controlled in order to assure their proper functioning. This operation requires accurate, low-cost measurement of process variables, such as temperature, pressure, and flow rate. Although measurements like temperature, pressure and flow rate can be obtained at low cost and in real time, data on the physical properties and concentrations of chemical products can only be obtained after a costly and time consuming chemical analysis. Real time monitoring of such physical properties and concentrations is usually required to control the processes rapidly, which, however, is difficult to be achieved with the conventional approaches. Against this background, soft sensors have been developed to estimate physical properties and concentrations, which are difficult to measure in real time, using process variables that are easy to measure in real time, such as temperature, pressure, and flow rate. Currently, soft sensors are used not only in chemical plants but also for quality control in various product manufacturing processes. A soft sensor, also explained in detail in this special issue, consists of a statistical model $y = f(x)$, which formulates the relationship between the process variables (x) that are easy to measure in real time and the process variable (y) that is difficult to measure in real time. With its application, soft sensors are expected to have both economic and environmental effects: reducing the number of chemical analyses; speeding up control; and, consequentially, reducing waste through the improved quality control of products.

To lead this coming era of soft sensors, the 143rd Committee of the Japan Society for the Promotion of Science and Process Systems Engineering established the workshop No. 32 "Soft Sensor Implementation" (chaired by Kimito Funatsu) in October 2016. In March 2020, the Committee oversaw the successful completion of tools to develop more accurate soft sensors for targeted processes easily and quickly and to deploy and use the soft sensors on-site. After that, to spread the use of this soft sensor tool and lay the foundation for its continuous maintenance, Fuji Electric, a member of the workshop, has started a service for supporting utilization of the tools and is preparing to offer them as products.

Soft sensors now serve as indispensable tools for real time monitoring and control of manufacturing processes, including semiconductor processes, small and large scale chemical processes, and continuous pharmaceutical processes. They have been also being introduced to monitor the internal state of combustion equipment and heat exchangers. As input process variables for soft sensors, in addition to the process variables measured by conventional hard sensors (e.g. temperature, pressure, and flow rate), near-infrared (NIR) spectroscopy and other spectral data have begun to be actively utilized as input variables to directly measure target chemical properties in the processes mentioned above, and its use is becoming widespread. Soft sensors using spectral data will also soon be used routinely for real-time monitoring and process control of raw materials and main- and by-products in flow reactors. It is important to note that using expensive spectral instruments for the inputs will hinder the widespread use of soft sensors. Fortunately, inexpensive and compact spectral instruments are now beginning to appear in the market.

Various efforts have been launched under the keyword of process informatics, whose fundamental roles are to know the present and to predict the future of the target processes. In this sense, soft sensor is a keyword inherently connected with process informatics. Innovative soft sensors beyond conventional concepts are expected to be developed to meet the distinctive features of individual target processes that need to be monitored and controlled. Soft sensors are mostly used for monitoring current process in real time, but they are also being increasingly used to predict process conditions in the near future. They are an important tool not only for the monitoring and controlling chemical plants, but also for the automatic optimization of high-yields, by-product-free reaction conditions through Bayesian optimization, and for design, development, and automatic operation of flow reactors, which stably produce target products. The time is just around the corner when soft sensors are commonly implemented in small to large scale manufacturing equipment as a new technology for continuous manufacturing of various products.

* Director, Data Science Center, Nara Institute of Science and Technology
Specially Appointed Professor
Professor Emeritus, University of Tokyo

Fuji Electric

Innovating Energy Technology