

Special Section on Process Imaging for Automatic Control

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Industry has traditionally relied upon point sensors such as thermocouples and pressure gauges to control its operations, but as manufacturing processes become increasingly complex, additional types of information are required. For example, typical process measurement needs now include contamination detection, particulate size and shape, concentration/density profile (in pipes and tanks), and thermal profile. In many cases, imaging systems are the only sensors that can provide the required information.

Process imaging is the art of visualizing events inside industrial processes. These events could be the mixing between two component materials, for example, or the completion of a chemical reaction. The image formation can be direct (e.g., acquired with a charge coupled device camera), reconstructed (e.g., tomographic imaging), or abstract (sensor data represented as an image). In advanced applications, data extracted from such images are fed back to the process control system to maintain optimum production.

Process imaging encompasses well-established fields such as flow visualization and machine vision, so it can hardly be considered to be a new area. However, ongoing advances in camera and computer technology have made it feasible to apply imaging and image processing techniques to a wider range of process measurements. Of particular note is the versatility of the tomographic technology developed over the past decade.

The papers in this special section highlight the current work in this area and span a wide range of technologies and applications. They were selected from the 32 papers presented at the November 2000 SPIE conference on Process Imaging for Automatic Control (*Proceedings of SPIE* Vol. 4188), and then underwent peer review and revision before publication in JEL.

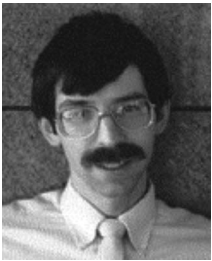
The first two papers address applications in the development of internal combustion engines. Winklhofer describes several types of applications, ranging from mapping of the flame front to monitoring air-fuel mixing behavior. Hindle *et al.* introduce near-infrared absorption tomography as a means of mapping the hydrocarbon distribution in the engine cylinder. In the third paper, Hall *et al.* demonstrate a variety of industrial uses for nuclear magnetic resonance imaging, which generates three-dimensional images.

The next five papers are on the subject of electrical tomography, i.e., tomographic systems based on electrical sensing. One of the first industrial applications of such a system was in a fluidized bed at the U.S. DoE Morgantown Energy Technology Center in the mid-1980s, but during the 1990s most of the subsequent development of this technology occurred in the U.K. York presents an overview of recent industrial applications of this technology, and Mann *et al.* describe its application to stirred tanks. Seppanen *et al.* assess the ability to make more accurate estimates of multiphase flow by incorporating the prior knowledge available from

fluid dynamical models; Figueroa and Selegheim evaluate two alternative sensing protocols for measuring two-phase flows with electrical tomography. Mohamad-Saleh *et al.* show that artificial neural networks can estimate the process state directly (without first reconstructing the tomogram).

The last four papers address the problem of control using multidimensional data. Deloughry *et al.* discuss the use of electrical capacitance tomography to control a pneumatic conveyor, and Duncan addresses the control of a general two-dimensional manufacturing operation (e.g., paper making). Sharif *et al.* then describe an imaging technique in which they use an array of magnetic sensors to map the transformation of the austenite phase of hot steel. Finally, Hjertaker *et al.* describe the control of an underwater oil/gas separator with a linear sensor that provides a one-dimensional "image" of the interfaces.

In making the above selections, many interesting papers from the conference have necessarily been excluded (e.g., radioactive particle tracking, microwave tomography, and principal component analysis), but they may be found in *Proceedings of SPIE* Volume 4188. We hope the reader will agree that process imaging does indeed provide a wide variety of tools for analyzing and controlling industrial processes. The next step is up to industry....



David M. Scott is a senior research physicist in the DuPont Company's Central Research and Development organization. He joined DuPont in 1986

after completing his PhD in physics at William & Mary; he also received his BA from Earlham in 1981 and his MS from William & Mary in 1984, both in physics. He initially worked on nondestructive evaluation of composites and process instrumentation, and in 1996 he was appointed group leader of Characterization within the particle science & technology (PARSAT) group. His primary research interest is on-line characterization of particulate systems, and his research activities have included

tomography and in-line ultrasonic measurement of particle size. He has authored over 30 technical papers in refereed journals, has been an invited or keynote speaker at nine international conferences, and holds two patents. He co-chaired the first two international conferences on process tomography (San Luis Obispo '95 and Delft '97).



Hugh McCann was appointed professor of industrial tomography at the University of Manchester Institute of Science and Technology in 1996, and is head of the Department of Electrical Engineering & Electronics (1999–2002). He gradu-

ated from the University of Glasgow with his BSc in physics (1976) and a PhD (1980). After ten years' experience in high-energy particle physics (Glasgow, Manchester, CERN, and DESY), McCann worked in industrial R&D for ten years at the Royal Dutch/Shell Group's Thornton Research Center, where his research topics included explosion hazards and turbulent combustion, *in situ* engine measurement technology, and lubricant product formulation. His work was recognized by the SAE Arch T. Colwell Award in 1995. Throughout his career, McCann has been deeply involved in measurement technique development, with heavy emphasis on multidimensional techniques. A member of the Institute of Physics since 1987, he was elected fellow of the IEE in 2000. He is author/co-author of over 70 publications in international refereed journals.

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