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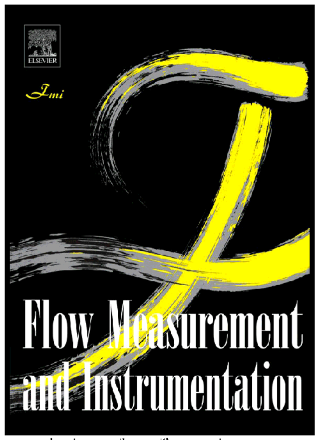

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Editorial for Special Issue on Process Tomography in Flow Measurement and Instrumentation

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Analysis and control of industrial processes is inseparably interlinked with appropriate process measurement techniques. Among such distributed sensing, imaging and tomography are emerging technologies, which gain more and more attention, as they have the capability to measure field quantities. The latter is an asset, since industrial processes are associated with complex flows and heat and mass transfer in e.g. reactors, distillation columns, mixers, separators, heat exchangers, pipeline systems and others, and process parameters do always vary in space and time. Process tomography is a generic term for all those imaging techniques, which provide field information, on e.g. phase and species distribution, flow rate, temperature and pressure, with sufficient spatial and temporal resolution and with no or minimal intrusion via spatially distributed measurements and subsequent image reconstruction.

Research and application in the field of process tomography is continuously intense and recently many innovative concepts and ideas have been born and demonstrated. Exchange of knowledge within the process tomography community and transfer of knowledge to research and industry is supported by the International Society for Industrial Process Tomography on the basis of regular expert meetings. The 7th International Symposium on Industrial Process Tomography ISPT7, held in Dresden, Germany, Sept. 1-4, 2015, was the latest symposium of that kind and offered a platform for specialists to present and discuss their most recent advancements in the development and application of process tomography techniques. The symposium was preceded by similar events held in Jurata (2000), Wroclaw (2002), Lodz (2004), Warsaw (2006), Zakopane (2008) and Cape Town (2011). It has been organized by the International Society for Industrial Process Tomography (ISIPT) together with the Helmholtz-Zentrum Dresden-Rossendorf.

This special issue is a compilation of the 21 most important contributions from this symposium. It covers a broad range of process tomography technologies but also a broad range of technology readiness levels from very fundamental aspects, such as raw data processing or new methods of analysis of tomographic images, new modalities, such as microwave tomography, up to important industrial applications, such as cyclone separators, bubble column reactors and waste water abatement.

Papers in this special issue have been organized in three categories. The first seven papers deal with **technological fundamentals of process tomography**, including hardware for sensing and data processing as well as multimodality approaches.

Paper 1 (Y. Yang et al., “A novel multi-electrode sensing strategy for electrical capacitance tomography with ultra-low dynamic range”) reports on a novel multi-electrode sensing strategy for electrical capacitance tomography with ultra-low dynamic range. For a 24-electrode ECT sensor it is demonstrated by numerical analysis that by simultaneous excitation of asymmetrically opposite electrodes the dynamic range of measurements is significantly decreased and the nonlinear effect is weaker compared with that of conventional sensing strategies for linearized-model-based image reconstruction.

Paper 2 (S. Langener et al., “A real-time ultrasound process tomography system using a reflection-mode reconstruction technique”) presents a real-time ultrasound process tomography system with a ring of 32 ultrasound transducers. Simulations and measurements were conducted and a reflection-mode reconstruction technique was used to obtain the system's point spread function and assess the system performance. Furthermore, the possibility of increasing the measurement rate by reducing the number of excitations and its effects on the quality of the reconstructed images was investigated.

Paper 3 (M. Mallach et al., “2D microwave tomography system for imaging of multiphase flows in metal pipes”) describes a new experimental eight-port microwave tomography system with broadband measurements in the frequency range from 0.7 GHz to 5.5 GHz. The hardware for data acquisition and the algorithm for image reconstruction are described and static dielectric phantoms mimicking oil/water-in-gas and gas/water-in-oil flow distributions were imaged at frequencies between 1.25 GHz and 2.5 GHz using the one-step Gauss-Newton reconstruction method.

Paper 4 (A. F. Velo et al., “A portable tomography system with seventy detectors and five gamma-ray sources in fan beam geometry simulated by Monte Carlo method”) introduces a conceptual non-scanning gamma ray tomography system containing five radioactive sources and seventy NaI(Tl) detectors along with an iterative image reconstruction by SIRT. The system performance was analyzed by MCNP4C Monte-Carlo simulations.

Paper 5 (R. Hoffmann, “An ATEX-proof gamma tomography for measuring liquid distribution in process equipment”) is paper on a scanning gamma ray tomography setup with a Cs-137 source, particularly adapted to industrial measurements under explosion hazards. Its capabilities have been demonstrated in an experimental study on the liquid distribution in a 440 mm column filled with structured packing.

Paper 6 (A. Bieberle et al., "Data processing performance analysis for ultrafast electron beam X-ray CT using parallel processing hardware architectures") describes how data pre-processing and data reconstruction algorithms for an ultrafast X-ray tomography scanner have been ported to multi-core central processing units (CPUs) and many-core graphics processing units (GPUs). With that a performance improvement of factor 137 in the data processing chain could be demonstrated.

Paper 7 (M. Banowski et al., "Comparative study of ultrafast X-ray tomography and wire-mesh sensors for vertical gas-liquid pipe flows") presents a comparative study of gas-liquid two-phase flow in a pipe using ultrafast X-ray tomography and wire-mesh tomography simultaneously. Comparisons were made for gas hold up, velocity and bubble size profiles.

The following six papers deal with **algorithms and methods for data processing, image reconstruction and image analysis.**

Paper 8 (S. I. Kang, "EIT image reconstruction for two-phase flow monitoring using a sub-domain based regularization method") describes a sub-domain based regularization method with adaptive thresholding for electrical impedance tomography. In the proposed regularization method a part of the whole computational domain is considered as a sub-domain and this is incorporated into the regularization method as prior information. The regularization matrix is asymmetrically modified to include the sub-domain and the regularization parameter is set to different weights for the sub-domain. The performance of the proposed regularization method was evaluated with numerical simulations and phantom experiments.

Paper 9 (Y. Xu et al., "An adaptive Tikhonov regularization parameter choice method for electrical resistance tomography") proposes a spatially adaptive regularization parameter choice method for electrical resistance tomography, which was tested on simulated data. The proposed method adaptively updates the regularization parameters during the iteration process and provides spatially varying parameters for each pixel of the reconstructed image. When the iteration is stopped, large regularization parameters for the smooth background region and small regularization parameters for the object region can be obtained.

Paper 10 (B. S. Kim et al., "Resistivity imaging of binary mixture using weighted Landweber method in electrical impedance tomography") proposes and investigated a weighted iterative Landweber method for two-phase flow imaging with electrical impedance tomography to enhance the resolution of the reconstructed images. Numerical simulations and experiments were carried out to evaluate the performance of the proposed method.

Paper 11 (J. Polansky et al., "Proper Orthogonal Decomposition as a technique for identifying two-phase flow pattern based on Electrical Impedance Tomography") deals with POD as a data analysis technique to identify flow structure in horizontal pipeline, specially, for slag, plug and wavy stratified air-water flow regimes.

Paper 12 (A. Saoud et al., "Measurement of velocity of gas/solid swirl flow using Electrical Capacitance Tomography and cross correlation technique") describes, how dual-plane electrical capacitance tomography can be used to measure the particle velocity in a gas/solid swirl flow using a physical model for the swirl flow and cross-correlation of the signals from the two ECT planes.

Paper 13 (M. Wagner et al., "Dynamic bias error correction in gamma-ray computed tomography") introduces a dynamic bias error correction method and its application to correct cross-sectional images of gamma ray tomography from a centrifugal pump. The method was investigated both with simulated tomography data set as well as real measured data.

The last seven papers describe diverse **applications of process tomography**, both in fundamental engineering research as well as for well-known process engineering applications.

Paper 14 (S. Boden et al., "Measurement of Taylor bubble shape in square channel by microfocus X-ray computed tomography for investigation of mass transfer") demonstrates, how microfocus X-ray tomography is being used to generate highly accurate 3D images of Taylor bubbles in a small channel and use these data to determine gas-liquid mass transfer rates by measuring the shrinkage of CO_2 bubbles dissolving in counter-current water flow over a longer time.

Paper 15 (O. Adetunji et al., "Estimation of bubble column hydrodynamics: Image-based measurement method") discusses the use of electrical resistance tomography together with the Dynamic Gas Disengagement (DGD) technique to study the hydrodynamics of a bubble column reactor of 1.5 m height and 0.29 m diameter. ERT data from four rings of electrodes was used to analyze the local disengaging gas volume. The Dynamic Gas Disengagement (DGD) approach was used to induce transient gas holdup fractions, which were captured by ERT and then converted into bubble size distributions.

Paper 16 (A. Sommer et al., "Analysis of activated sludge aerated by membrane and monolithic spargers with ultrafast X-ray tomography") deals with the measurement of gas phase parameters (bubble size distribution, equivalent Sauter mean diameter, bubble rise velocity and local gas hold-up) in a column with aerated activated sludge and different gas injector devices using ultrafast X-ray tomography. The experimental results shall be used to develop CFD models for simulating aeration units in waste water abatement.

Paper 17 (A. Lomtscher et al., "Scale-up of mixing processes of highly concentrated suspensions using electrical resistance tomography) describes, how electrical resistance tomography was successfully used to study mixing in lab-scale biogas fermenters of 0.1 m³ and 1 m³ volume. Therewith a scale-up methodology was validated with the objective to predict flow profiles and mixing of the non-Newtonian fluid in larger vessels.

Paper 18 (S. Kanshio, "Study of phase distribution in pipe cyclonic compact separator using Wire Mesh Sensor") discusses the use of a 24x24 wire mesh sensor for the study of the unsteady swirling flow in the gas discharge section of a cyclone separator. Area average liquid holdup and images were analyzed to discriminate between partial separation and critical separation conditions in the device. The liquid holdup as a function of separator inlet superficial velocity was quantified.

Paper 19 (S. Lakshmanan et al. "Measurement of an oil-water flow using magnetic resonance imaging") introduces fast magnetic resonance imaging and its application to the study of oil/water two-phase flow in a 2.5" diameter Perspex pipe at stream velocities between 0.2 m/s and 1.47 m/s. Chemical shift selective (CHESS) MR was used to quantify the water-cut between 2.5% and 25% for static samples and for a flow of 0.2 m/s and for water cuts between 1% and 7.5%.

Paper 20 (S.-A. Tsekenis et al., "Towards in-cylinder Chemical Species Tomography on large-bore IC engines with pre-chamber") presents a feasibility study on chemical species tomography by near-IR absorption on a heavy duty, large-bore marine engine to visualize relative mixture strength for combustion of LNG with > 88.9 % methane content at in-cylinder conditions of 170 bar and 850 K. From the results an 31-laser beam tomographic imaging array is proposed utilizing standard fibre-optics and collimators.

Paper 21 (N. H. Huu et al., "Cole-Cole analysis of thrombus formation in an extracorporeal blood flow circulation using electrical measurement") introduces a biomedical application of electrical impedance tomography. Cole-Cole analysis was applied to measure local red blood cell concentration and with that monitor thrombus formation in extracorporeal blood circulation. Thrombus formation experiments were conducted in both static and flowing conditions by changing the coagulability of bovine and swine blood.

The different contributions being compiled in this special issue shall provide the unexperienced reader with a good overview on the potentials and capabilities of process tomography techniques and the experienced reader with an update on the state-of-the-art in the field. Eventually I shall express my hope, that this special issue may foster transfer of new and exciting scientific results and engineering solutions into industrial applications. I would like to thank all authors of the special issue for their hard and excellent publishing work.