

The Art of “Mathematics for Industry”

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This monograph presents the art of industrial mathematics through examples of talks at the 2009 SIAM Conference on “Mathematics for Industry” (MI09)¹. The reader should not expect that the distinctive industrial theme and mathematics in the MI09 conference will necessarily follow the neat ‘theorem-proof’ paradigm that dominates traditional mathematical texts. While industrial mathematics incorporates theorem and proofs, it works within a broad paradigm. Mathematics in industry includes

- innovative syntheses of known mathematics into new models,
- development of models to produce partial answers for problems that remain intractable by practical methods and
- continuous experimenting with and refinements of existing mathematical models in response to increasing computational power.

The formulation of these models, an art in itself, largely follows the scientific paradigm of hypothesis formulation, experimental design and analysis of data. This monograph captures *some* of the current and future directions of industrial mathematics, a field too broad and varied for this one volume to contain. Problems motivate mathematics in industry and their solutions provide economic advantages to companies.

This monograph contains papers solicited from all who participated in the conference. These published papers underwent rigorous peer and editorial review. Arguably, every paper presents a *mathematical model*. Some models are in their nascent stage of conjecturing what might be the appropriate formalisms; others

are more advanced with extensive computational experiments leading to further refinements of an initial model; all participate in a typical iterative improvement process. This central modeling theme is divided further into five sub-categories to emphasize differing industrial applications. Since the term ‘mathematical modeling’ applies to all the articles, an adjective has been chosen to identify the type of modeling within these subdivisions. The five modifiers further classify

systems, visual, bio-medical, fluid & financial

mathematical models.

Overall, the ‘systems’ section appears first because these models might, arguably, apply to all industries. Of the four papers in this section, the first considers scenarios for analyzing the resilience of a national petrochemical supply chain model. This methodology applied to the petrochemical sector introduces a broader generalization relevant to many industries. The second paper analyzes mobile communication, which pervades nearly all contemporary industries. The third paper focuses upon industrial organizations themselves. The fourth concentrates on manufacturing systems, which are central to any industry that creates physical products.

The ‘visual’ section applies widely to the visual arts. The first two papers treat the human eye, but in very different ways. The first provides new techniques to improve how surgeons view the human eye under surgery assisted by a 3D visualization system. The second synthesizes more realistic blur that occurs in human vision for use in computational photography and computer animation. The third paper develops tools for analyzing virtual environments, allowing them to be ‘seen’ for evaluation while using only parsimonious geometric data for improved computational efficiency. The last paper explores mathematics that can be invoked for improved video compression – so that files can be made smaller for faster transmission while having minimal discernible degradation for the human viewer.

The bio-medical section features three papers, ranging from a perturbation analysis for acquiring better knowledge of the behavior of hepatitis type C virus and supporting design of improved therapeutics, to numerical simulation of polymer flow and to a study of tumor growth and metastasis. This central third section

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¹The inaugural SIAM Mathematics for Industry conference was held in 2003. Since then, it has met biennially, with those historical details available at the SIAM web site. The monograph of invited papers, *Mathematics in Industry – Challenges and Frontiers*, SIAM, 2005, was produced after the first conference. Its preface contains a discussion of the origin and rationale for the MI conferences. To promote intellectual synergy between the MI09 and the SIAM/ACM Joint Conference on Geometric and Physical Modeling, the conferences were co-located, with MI09 immediately following the joint SIAM/ACM conference.

prompts two observations. First, the initial two papers rely heavily on classical numerical analysis, indicating a strong connection to that traditional mathematics. Second, the third paper relies heavily on partial differential equations and might naturally fall under the category of applied mathematics. This paper could also have appeared in the *fluid* section, leading to the perspective that many mathematical problems in industry do not fit neatly into specific traditional sub-specialties.

The fluid section has the most number of papers, six. These papers employ numerical analysis, differential-algebraic equations, vibrational analysis and integral equations, all tools found in traditional applied mathematics. Diverse applications, ranging from water flow in San Francisco Bay to numerical resolution of CO_2 , demonstrate the strong influence of PDEs prevalent in traditional and current applied mathematics, which is a trend that will continue in the foreseeable future.

The last section considers a topic of significant contemporary interest during current world-wide economic conditions. In this financial section, the papers invoke the common practice of probabilistic and stochastic analyses in this field. The first paper considers pricing sensitivity to errors in stochastic modeling. The second utilizes Markov trees and the third uses Bayesian analysis to propose strategies for maximizing revenue within an oligopoly service network.

While this MI09 volume represents the fourth MI conference, this is only the 2nd monograph produced. Industrial mathematicians and their academic collaborators hope that these books will serve as a catalyst for broader understanding and appreciation of the richness of mathematics practiced in industry and the vital contributions that can be made to complement more traditional mathematics.

These summarizing statements present a very rich pallet of mathematics, with a range of partially posed problems to highly refined models. Viewed in its entirety, the volume shows a vibrant and varied role of mathematics for industry. This attests further to the intent of the organizers “To put the ‘I’ back in SIAM” – meaning, of course, that industrial mathematics has very much to offer to enrich the professional community served by SIAM. As the first electronic volume for these conferences, SIAM anticipates that this mode of dissemination will facilitate more communication among mathematicians in industry and in academia.