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Editorial

The Fourth World Congress of Nonlinear Analysts: Modelling, control and analysis of coupled problems, processes and phenomena

This workshop took place from June 30 to July 3, 2004 and included 24 contributed talks and three one-hour invited talks. The most interesting aspect of the workshop was the very wide range of topics covered, from very theoretical mathematical approaches, to mathematical modelling, control, optimization, optimal numerical algorithms for systems, and numerical simulations including large-scale ones. This diversity of topics had a unifying focus on modelling, control and analysis of coupled systems, processes, and phenomena. It is known that in many cases coupling requires dealing with interacting components which could be structures, fluids or solid media, while in other cases such interacting components could be given by several different fields such as mechanical and thermal, or electrical and mechanical, invoking a unification of two or more physical theories that have been considered separately before. Many interesting and stimulating examples in this area were presented during the workshop.

The three invited talks discussed issues of optimization of multidisciplinary computer simulations, control and bifurcation of systems, and the applications of nonlinear analysis to cell biology. All three talks were very interesting and provided the audience with a broad overview of the subjects. In particular, it became very clear during the cell biology presentation that the potential for mathematical modelling, analysis, and simulations of the many fascinating and complicated processes which take place in a living cell is almost unlimited. And, it is very likely to lead to the development of new mathematics, since one has to deal with both continuous and discrete models simultaneously.

There were few talks, in addition to the invited one, on the modelling, simulations, and analysis of problems from biochemistry and biology. Examples presented at the workshop

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included a model for the sedimentation and saturation of adhering proteins on a container surface, as well as the analysis of the spatial distributions of the various components in the process of anaerobic digestion of solid waste. Other fascinating examples of the application of mathematics to life sciences were related to the use of the Poisson–Nernst–Planck equation for the description of active ion channels and to the analysis of the diffusion of wear particles in a hip transplant.

A few of the presentations dealt with the modelling of processes and phenomena on multi-scales, i.e., when coupled processes take place on different spatial and/or time scales. For the mathematical models to be useful, they need to capture the main characteristics of the system behavior, with predictive capabilities, but also they have to be as simple as possible (not more than that) so that they can be analyzed and simulated within reasonable resources and time allocation.

Applications of mathematical methodologies in aeronautics, fluid mechanics, as well as structure–fluid interaction problems were well represented at the workshop. One of the talks from this group of presentations dealt with a posteriori error estimates of the numerical solutions of the Navier–Stokes equations. Presenters provided the audience with a model and simulations of the acoustic levitation of a gas bubble, an analysis of a flow in a cavity, and a detailed discussion of the triple line dynamics, found when solids are immersed in a fluid. A series of talks on the development of efficient numerical procedures in these areas were also presented. This included a methodology for efficient parallel computations of multi-physics problems with applications to nonlinear aeroelasticity, as well as higher-order integration schemes for numerical solutions of fluid–structure interactions. Interesting computational examples of the coupling between hydrodynamic and thermal instabilities were also discussed in this group of talks. Another fascinating example was given in the area of the coupled multi-physics in supernova explosions where the authors presented an efficient numerical algorithm.

Some, more traditional, topics that were presented at the workshop included: controllability of a nonlinear thermoelastic plate; models for material damage of structures, strains in semiconductors, electrostatic coupling in MEMs; the development of mathematical models, the analysis, and control issues for smart materials; some examples of recent progress in contact processes; the stability of linked dynamic structures; a method to optimize the sound absorption of a viscoelastic coating; and combustion in periodic medium.

There was a considerable interest in the effective large-scale computational methods for partial differential equations, in particular when the processes and their models are of different dimensions. The ideas presented include: coupled interpolation–collocation for PDEs; reduced-order control based on an approximate inertial manifold, fast sweeping schemes for infinite horizon optimal control; and nonconforming computational methods for coupled problems. These presented approaches to computations of numerical solutions for coupled nonlinear problems are of considerable interest in applications, and the reported progress is impressive.

It was made clear from all the presentations in the workshop that considerable progress has been achieved in the topics discussed, but also that much remains to be done. Certainly, nonlinear analysis is expanding rapidly into all branches of science and engineering, as well as undergoing considerable mathematical extension and growth. The area of modelling, control, and analysis of coupled processes and phenomena is a fascinating interdisciplinary area of science to demonstrate this growth.

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