Mathematical modeling, simulation, optimization and control in science and technology

Brief description

Our group develops mathematical models, simulation methods, optimization techniques, and computational tools for the analysis, design, and control of processes in science, technology, and engineering. We combine modeling based on physical laws, numerical methods, mathematical analysis, artificial intelligence, and machine learning to address complex problems and support decision-making.

Our research lines include, among others, the modeling of epidemics, oil spills, and energy systems such as lithium-ion batteries and solar energy; the analysis of partial differential equations; the development of artificial intelligence and machine learning models; image processing; optimization; multiphysics simulation; and the development of scientific software.

How does it work?

The interested party explains the process, system, or prototype they want to model. Based on this information, a mathematical model is developed based on physical laws, mathematical principles, and, where appropriate, experimental or computational data. The resulting model is analyzed and discretized to obtain its numerical solution. A solution algorithm is developed and implemented in an appropriate language to obtain a computational simulation or prediction tool.

The numerical results are validated with experimental or real data, when available, and subsequently, optimization, control, sensitivity analysis, parameter calibration, or decision-support studies can be carried out on the simulated processes or the prototype to be designed.

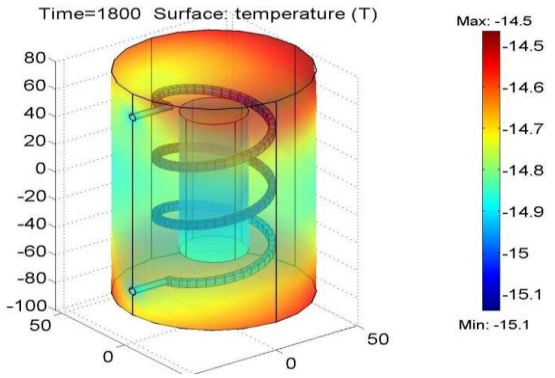

Figure 1. *Simulation of a prototype of high pressure equipment*

What problem does it solve?

It allows costs and time to be reduced in the design of prototypes and in decision-making related to complex scientific, technological, and industrial processes.

• Cost savings are due to the fact that having a mathematical model and computational simulation tools allows prototypes and processes to be studied on the computer, avoiding or reducing the need to carry out numerous experimental trials, which usually have a high cost.

• Time savings are due to the fact that, once the model and simulation software have been developed, obtaining results is usually fast, while carrying out experiments, collecting data, and analyzing them can require a considerable amount of time.

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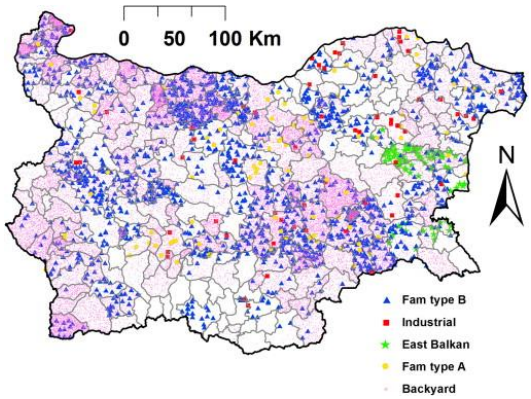

Figure 2. *Simulation of the development of a Classical Swine Fever epidemic in Bulgaria*

The use of computational simulation tools allows different options to be quickly compared in the design of a prototype or in the analysis of a process of interest. It is, therefore, a very helpful tool for decision-making, which complements the experience, intuition, and available data of the responsible team, and allows scenarios to be evaluated, risks to be anticipated, and solutions to be optimized before their real implementation.

Where has it been developed?

Development takes place in the MOMAT Research Group (Mathematical Models in Science and Technology).

Among its main activities are the development of research projects and scientific software, collaboration with companies, institutions and government entities, and the transfer of knowledge in applied problems of science, technology and engineering.

Researcher in charge

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