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Mathematics in Industry

A technological challenge and an opportunity for mathematicians

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Although the role of Mathematical Sciences in Civilization has been of central importance for centuries, the current trend to a global economy and a knowledge society has placed information and innovation technologies increasingly dependent on scientific research, which results and techniques are underpinned and driven by Mathematics.

Recognizing that Mathematics provides the context for communication and discovery in many other disciplines, the Global Science Forum (GSF) of the Organization for Economic Co-operation and Development (OECD) has promoted a report on "Mathematics and Industry", which was published in July 2008 and is openly accessible at the site: http://www.oecd.org/dataoecd/47/1/41019441.pdf.

This report is a consequence of an OECD workshop, held in Heidelberg under German initiative and the coordination of Willi Jäger, on March 22-24, 2007. That meeting had the participation of more than fifty experts from industry, academia, and government agencies, from fourteen European countries, Japan, Australia, Canada, USA and Russia. Companies like Airbus, Nokia, the Norwegian Statoil, the Nipon Steel Corporation, the Italian STMicroelectronics, the German BASF AG, Bayer and HEIDELBERG Print Media Industry where among the industries that have send participants from their research departments.

Mathematics (or the mathematical sciences, including statistics and computing) is considered in its broadest sense, as well as Industry, is interpreted "as any activity of economic or social value, including the service industry, regardless of whether it is in the public or private sector". The analysis of their current relationship, including significant trends in mathematical research in academia and industrial challenges that may create opportunities for interactions and partnership between both sides, as well as the formulation of recommendations was the aim of that workshop.

The report is addressed to the community of mathematical scientists, to the industry (large, medium and small size) and governments and it recommends the improvement of the infrastructure for increased interactions, both in academia and industry, the enhancement of the curriculum for students of mathematics and the reinforcement of coordination and cooperation at national and international levels.

Mathematics versus Industry

While Mathematics, as a scientific discipline, has seen an enormous development, mathematicians, that tend to classify themselves either "pure" or "applied", not often look at its applications to industrial problems. Academia structure, with known obstacles to the interdisciplinarity and cross-disciplinarity, as well as current cultural practices are facing new challenges and transformations.

Overcoming the traditional classification between "pure mathematicians", that exclusively dedicate to inquiry new concepts, new theorems and new theories within the discipline, and "applied mathematicians" that limit themselves to the use of known techniques to address problems outside the discipline, more than ever the future of Mathematics depends in a critical way on a strong connection and interaction between the creators and the users of this discipline.

Without loosing their freedom in academic research, "mathematics and mathematicians must recognize the importance of industrial problems for the development of their discipline and should adjust the academic curriculum to the new environment". Problems from Chemical and Pharmaceutics Industry, Oil Exploration, Medical Imaging and Biotechnology, Microelectronics and Nanotechnology, Logistics and Finance, Information Security and Communications or Entertainment, are good examples that can nourish new and exciting progress in the mathematical sciences.

The following mathematical areas are basic for the applications: dynamical systems (asymptotics, stability, time-space patterns,...); multi-scale analysis, transitions between models in different scales; systems reduction, algorithms for high dimensional problems; flow,

transport and reactions on the micro-scale level; multiphysics problems, reactive laminar and turbulent flow, diffusion and transport; analytical and numerical treatment of processes in random media; inverse modelling and parameter identification;. continuous and discrete optimization, shape optimization; design of experiments and control of technological processes; multidimensional image processing, model based image analysis, visualization; advanced statistical methods for data processing.

On the other hand, Mathematics is a key and enabling technology for the industry, as it "provides a logically coherent framework and a universal language for the analysis, optimization, and control of industrial processes", even if its contributions are, in most cases, invisible in the industrial products. While industry is facing tremendous local and global challenges, innovative companies that are able to exploit properly that enabling technology can rapidly gain a clear advantage over their competitors.

The OECD reports highlights a paragraph from an article published in February 2006 in the newspaper Financial Times on "Mathematics offers business a formula for success": [Mathematicians] have come up with an impressive multiplication formula for British commerce and industry: spend a few million pounds promoting the use of maths as a strategic tool, and add billions of pounds of value to businesses. That is the thinking about a new government-industry consortium, the Mathematics Knowledge Transfer Network. The network aims to boost the use of maths throughout the economy from grocery distribution to banking, telecoms to manufacturing.

Mathematics as a partner to the Industry

Recognizing that "the interface between mathematics and industry is much more than a medium for technology transfer", the Report supports the vision of a synergetic partnership between mathematics and industry where information is exchanged freely at the precompetitive stage, and knowledge is shared profitably by the mathematical and industrial communities.

Referring to existing examples of mechanisms of partnership, like Interdisciplinary Research Centres, faculty positions for industrial mathematics, research internships, special interest groups sponsored by professional societies or government agencies, Study Groups and direct research collaborations, students activities, "technology translation" agents, consultancy and transnational cooperation, diverse experiences and large differences have been recognized among the OECD countries, according to their state of development and economic structure.

An important issue raised at the OECD report is the intellectual property one, since it is a delicate issue and may present difficulties. Clearly mathematics is not a tangible product, and mathematical equations, with their expression in algorithmic form cannot be patented. However, when mathematical algorithms are implemented in computer software, intellectual properties rights issues may arise and are fraught with difficulties, as the Report observes. But since these practices and processes "vary greatly according to country, industry, and even academic institution, the workshop participants refrained from making any specific recommendations about the management of intellectual property, except to point to the need to share best practices in the management of mathematical intellectual property and to learn from successes and failures of scientists and organizations working at the interface of mathematics and industry".

Among the conclusions and recommendations to stimulate the interaction of Mathematics and Industrial Innovation, it is important to refer the need of Interdisciplinary Research Centres, special positions of Industrial Mathematics, Workshops, specific actions in Education and Training, the creation of initiatives at their interface (joint teams, translators, networks of experts, information sites, etc.), as well as national and international collaboration and coordination.

The European Mathematical Society response

The European mathematical community has a relevant experience and non negligible cooperation record in industrial mathematics. For instance, the 6th International Congress on Industrial and Applied Mathematics was held in July 2007 in Zurich and was the fourth organized in Europe. It hosted, in particular, a Panel Discussion on the OECD Global Science Forum report, where the recommendations to improve the transfer of mathematics to industry were presented and where the requirement of the education of students to be more interdisciplinary was debated.

In order to promote the interaction between universities and research groups in industry, since 1986, the European Consortium for Mathematics in Industry (ECMI) established a network of expertise, nowadays with about twenty academic members. ECMI organizes a regular series of conferences and common activities, including a joint educational programme on Mathematics for Industry operating on a European scale.

The European Mathematical Society (EMS), through its Applied Mathematics Committee chaired by Mario Primicerio
(http://ems.math.uni-bremen.de/comm-applied.html), has proposed to the European Science Foundation (ESF) the creation of a pilot project directed towards the enhancement of the European mathemat-

ics/industry interface. The aim of the project is two-fold: on one side, to focus on "in house" industrial mathematics, i.e. on mathematicians working in industry and services; to gather information on their educational curricula, their recruitment and the possible need of continuing education, in particular, to question if the professional career of "technomathematician" does (or should) exist; on the other hand, to consider the cooperation between academic research and industry, to analyse the different forms of partnership between university and research centres on one side and industry and services on the other; and to stimulate a coordinate program of research.

The ESF has expressed a preliminary agreement to finance a Forward Look project "Maths & Industry" and has sponsored a "Scoping workshop" aimed to define its topics, the timetable and the prospected outputs of the project. The workshop took place in Pisa, Italia, on 20-21 December 2008, and was hosted by the Centro De Giorgi. With nineteen participants from ten European countries, the meeting contributed to the elaboration of the project that aims an ESF Forward Look Report, with three directions: academia-industry interface; training and careers and opportunities and challenges.

The activities that ESF may promote will take place during 2009 and 2010, and they should produce the state-of-the-art revue in the area, highlighting of the major advances in the last years, present the scientific challenges, including the identification of European strength and weakness, and present a vision with major goals that could provide directions for research in the medium and long term time frame and contribute to the implementation plan (in terms of infrastructure, institutional innovation, human resources, governance).

This is a timely and very important project. The situation differs from one European country to another and this should be properly taken into account. Such an initiative should enhance the European cooperation and activity in the area of mathematics in industry, in particular through a series of special Workshops. The European Mathematical Society, through its permanent special committee on Applied Mathematics, is the natural candidate to act as the reference institution for the project and the ERCOM centres the natural hosts of "Maths & Industry" events in Europe.

Coming Events

April, 17-19, 2009: 1st Porto Meeting on Mathematics for Industry,

Department of Mathematics, University of Porto.

Organizers

Pedro Freitas (UTL/GFM).

Diogo Pinheiro (CEMAPRE/CMUP).

Carla Pinto (ISEP/CMUP).

João Nuno Tavares (CMUP).

José Miguel Urbano (CMUC).

Aims

The purpose of this meeting is to focus the attention on the many and varied opportunities to promote applications of mathematics to industrial problems. Its major objectives are:

- Development and encouragement of industrial and academic collaboration, facilitating contacts between academic, industrial, business and finance users of mathematics.
- Through "bridging the industrial/academic barrier" these meetings will provide opportunities to present successful collaborations and to elaborate elements such as technology transfer, differing vocabularies and goals, nurturing of contacts and resolution of issues.
- To attract undergraduate students to distinctive and relevant formation profiles, motivate them during their study, and advance their personal training in Mathematics and its Applications to Industry, Finance, etc.

The meeting will be focused on short courses, of three one-hour lectures each, given by invited distinguished researchers, which are supplemented by contributed short talks by other participants and posters of case studies.