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MATHEON: An Application-oriented Research Center in Berlin

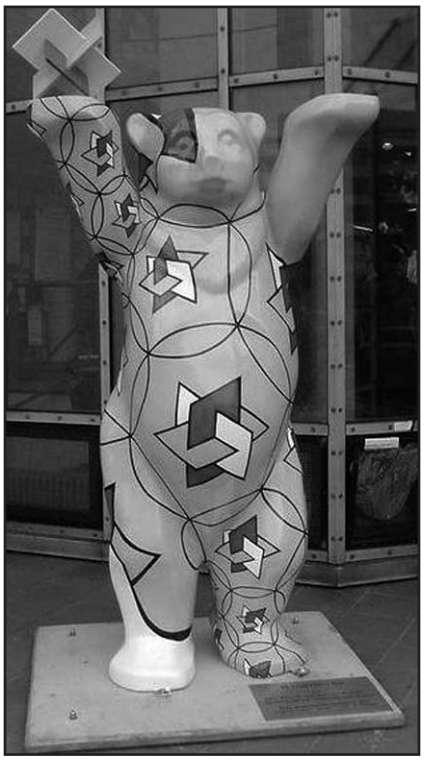
By Martin Grötschel

In 2000, endowed with a share in the proceeds from the German UMTS frequency auction, Deutsche Forschungsgemeinschaft (DFG), the German equivalent of the U.S. National Science Foundation, set out to create several new national research centers. The idea was to concentrate scientific research competence in particularly innovative fields and to create temporary, internationally visible research efforts at selected universities.

After a nationwide, very competitive application process, six DFG Research Centers were established between 2002 and 2006, in the following fields: Marine Geosciences, Functional Nanostructures, Experimental Biomedicine, Molecular Physiology of the Brain, Regenerative Therapies, and Mathematics. DFG provides about €5.5 million annually to each center; local participating institutions contribute additional resources, usually in the range of €3.5 million annually. DFG Research Centers have a maximum lifetime of three four-year terms.

One of the broadly defined areas in which DFG solicited proposals was "modeling and simulation in engineering and the natural and social sciences." A total of 14 groups of universities and research institutions responded. The successful proposal was a joint effort by Freie (FU), Humboldt (HU), and Technische Universität (TU) Berlin, together with two Berlin-based mathematical research institutes, Weierstrass-Institut für Angewandte Analysis und Stochastik (WIAS) and Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB).

The official name of the center—Mathematics for Key Technologies: Modelling, Simulation, and Optimization of Real-world Processes—is a bit difficult to remember. Two years after its founding (in June 2002), the center adopted its new (artificial) name: MATHEON. The center passed its first major evaluation with distinction in January 2006 and began its second term in June 2006.



Mathematics made visible: Gracing the entrance of the mathematics building at TU Berlin is the MATHEON bear, a creation of the center's visualization group.

Application Areas, Mathematical Fields, and Industry Connections

In a choice unusual for mathematics, MATHEON organizes its research by application areas rather than by mathematical fields. The current application areas (and the scientists in charge) are:

- life sciences (Alexander Bockmayr, Peter Deuflhard, Hans Jürgen Prömel, Christof Schütte),
- logistics, traffic, and telecommunication networks (Martin Grötschel, Volker Kaibel, Rolf Möhring),
- production (Carsten Carstensen, Jürgen Sprekels, Fredi Tröltzsch),
- circuit simulation and opto-electronic components (Volker Mehrmann, Frank Schmidt),
- finance (Anton Bovier, Peter Imkeller, Alexander Schied),
- visualization (Konrad Polthier, John M. Sullivan, Günter M. Ziegler), and
- education (Jürg Kramer).

Of course, research is also under way in traditional areas (each under specified leadership): optimization and discrete mathematics (Andreas Griewank, Martin Grötschel, Günter M. Ziegler), numerical analysis and scientific computing (Peter Deuflhard, Volker Mehrmann, Harry Yserentant), and applied and stochastic analysis (Anton Bovier, Alexander Mielke, Barbara Niethammer).

MATHEON has created six new research chairs, two at each of the participating universities. Filling those positions are Alexander Bockmayr and Konrad Polthier at FU, Carsten Carstensen and Andreas Griewank at HU, and John Sullivan and Harry Yserentant at TU. Seven independent junior research groups, led by young scientists, were also established. About eighty research positions are financed from the DFG grants.

Application areas and mathematical fields interact in various ways. MATHEON conducts frequent workshops that bring together mathematicians with different backgrounds and related application interests; partners from industry or other sciences are often involved. Challenging questions from companies or scientists in the key technologies addressed trigger many of the MATHEON research activities.

Projects with industry partners not only drive MATHEON's areas of concentration, but are also an increasingly important source of income, leading to additional projects and employment of additional researchers. MATHEON cooperates with many major companies (among them Daimler-Chrysler, Volkswagen, Siemens, NEC, Infineon, Deutsche Bank, Deutsche Telekom, Schering, BASF, Bayer, Lufthansa) as well as with a number of small and medium-sized firms. Several spin-off companies extend the industrial reach of the mathematics produced in MATHEON. "Quantitative Products Laboratory," a research spin-off institute concentrating on financial mathematics, was founded in the summer of 2006; it is fully sponsored by Deutsche Bank.

MATHEON's research activities cannot even be outlined in the space available here. Readers are invited to visit http://www.matheon.de/research/research.asp and explore the more than 80 projects that have been carried out to date.

Vision and Mission

One of MATHEON's aims is to make mathematics come to the fore as an indispensable ingredient in technological progress and to support mathematical research that contributes directly to high tech. To guide our future development and to convince the DFG evaluation team, we included the following (very general) vision statement in our application:

> Key technologies become more complex, innovation cycles get shorter. Flexible mathematical models open new possibilities to master complexity, to react quickly, and to explore new smart options. Such models can only be obtained via abstraction. This line of thought provides our global vision: innovation needs flexibility, flexibility needs abstraction, the language of abstraction is mathematics. But mathematics is not only a language, it adds value: theoretical insight, efficient algorithms, optimal solutions. Thus, key technologies and mathematics interact in a joint innovation process. The center is to give a strong push to the role of mathematics in this interactive process. The center's research program is application-driven. Its implementation will have a strong impact on the development of mathematics itself and will define a new stage of inter- and transdisciplinary cooperation.

This statement reflects MATHEON members' shared general view of the role of mathematics and its relations to application areas. Mathematics is clearly a field of basic research in its own right. But it also has tremendous potential to contribute to progress in other sciences and industry, and neither mathematicians nor users of mathematics have taken sufficient advantage of that potential. MATHEON is determined to help change this situation by supporting mathematical contributions to scientific and industrial development, especially in key technologies.

Here, in slightly more depth, is MATHEON's view of the important role played by mathematics in a modern production environment: A high-tech company may have made an excellent invention and may manufacture an outstanding product. But because of the very high speed of international information networks and global knowledge transfer, the company may quickly lose its competitive advantage. Understanding the invention fully, perfecting the product and its manufacture, fabricating and distributing it at minimum cost, estimating the risks involved, avoiding environmental hazards, and so forth, often require very specific mathematical models and appropriate model simulations. And only mathematical models that have stood the test of simulation runs and critical reviews by experienced practitioners are utilizable for optimization.

Many steps in this development process cannot be made without adequate mathematics, tuned to the particular application. The mathematics required is often not available "off the shelf" or from software vendors. Meeting these challenges depends on the development of mathematics in collaboration with users and requires the design of algorithms and their implementation in such a way that the users' needs are supported. MATHEON tries to participate in these processes and to make the important role of mathematics more apparent.

Outreach and Education

One small example of our efforts to make mathematics more visible is the MATHEON "buddy bear," shown on page 1, which stands in front of the TU mathematics building. Designed by the MATHEON visualization group, the bear holds in one paw the three-dimensional version of the MATHEON logo. The body painting represents a conformal mapping of a cylindrical surface around which the logo has been wrapped several times.

MATHEON projects include the development of concepts for teaching high school students in a more application- and problem-driven way. MATHEON is working in close cooperation with a network of schools in Berlin for the mathematically talented.

Further bridging the gap between mathematicians and the public at large are the Urania lectures—a lecture series directed toward high school students and teachers. Given in the morning, three to four times a year in the Berlin Urania center, the lectures often attract several hundred people.

But it is probably through the Mathematischer Adventskalender (http://www.mathekalender.de/) that MATHEON has achieved its greatest public visibility. In this annual competition participants solve mathematical problems (related to MATHEON research and applications), one a day, each day from December 1 to 24; prizes are awarded in different categories. Close to 10,000 people participated in Adventskalender 2005. Major newspapers, magazines, and radio stations ran frequent reports on the event, which even made an appearance on ZDF Heute Journal, one of the most popular TV evening news shows.

Details about MATHEON's work can be found at http://www.matheon.de/. A comprehensive paper by the author ("Matheon: Introducing the DFG Research Center 'Mathematics for key technologies' in Berlin") appeared in Jahresbericht der DMV *(Vol. 107 (4), 2005, pages 173–196) and can also be downloaded from the author's Web site.*

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