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Introduction

The purpose of this issue is to illustrate the concept of *Industrial Mathematics*. This branch of applied mathematics is concerned with the mathematical modeling and analysis of problems arising in an industrial setting. Industry plays a dominant, ever-increasing role in modern society. Its playing field is rich and almost unbounded. This is why there is no limit to the kind of mathematics that can be brought to bear *vis-à-vis* the technical and organizational problems it generates.

Any sophisticated product or system made by today's industry has a history of extensive mathematical modeling. The Wright Brothers may have been able to fly their planes from first mechanical principles, possibly aided by some crude slide-rule calculations. It is unthinkable that a modern aeroplane could be developed without the use of extremely refined and massive computing based on the best available mathematical models. Long before a prototype sets off on its maiden flight, its theoretical image has undergone extensive testing in the virtual environment of a computer. Whereas in the past test flights were watched with a certain measure of trepidation, modern engineers know for a fact that the actual aeroplane will perform perfectly, simply because its virtual predecessor did so in their computers.

Some mathematicians in academia still believe that mathematics in industry entails a routine and pedestrian application of antiquated, mostly simple, mathematics. It was G.H. Hardy who wrote that he would be utterly disappointed if anything he had done would be applied later on. He probably meant to say that the sophistication of his art put it beyond the capabilities of a lower kind of mathematician, unfortunate enough to earn his/her livelihood by applying mathematics in a rather mundane environment, such as an industrial research laboratory. This point of view seems to overlook the fact that mathematics in industry is concerned first and foremost with mathematical modeling. The application of mathematical methods comes in only as a tool. These tools, however, are often insufficiently developed, so that new mathematical ideas and methods need to be found in order to analyze the model. Thus, rather than trailing far behind modern practices in mathematics, industrial mathematics often acts as a generator of fresh ideas and initiator of new developments.

Industrial institutions for research and development are rich sources of novel applications of mathematics, affording opportunities for deep thought. Whereas new developments in pure mathematics emanate mainly from human curiosity, it is the non-mathematical industrial environment that drives industrial mathematics in all its forms and in directions that are often quite unexpected. As such, it is much the same as the mathematics of the early days. Infinitesimal theory was prompted by questions that arose in mechanics in the seventeenth century. Bessel functions came up quite naturally in the context of new theories to explain astronomical phenomena. No one ever sat down to devise these functions all by him/herself, simply because he/she felt a mathematical urge to do so. Even further back in time, geometry, that is measuring the earth, is said to have originated in ancient Egypt to help those who dwelt in the Nile delta to locate again their own plots of land after the annual inundations. A very practical motivation indeed!

Although the larger industrial companies employ highly qualified mathematicians in their research-and-development laboratories, most of the mathematical modeling is done by the physicists, engineers, chemists, biologists, etc., they employ. The reason for this is clear: the non-mathematical problems that require modeling are posed by these specialists themselves or by colleagues with whom they are in day-to-day contact, for instance, experimentalists and product managers. Clearly, the sophistication of their modeling is restricted by the mathematical knowledge they possess. Since they are specialist engineers, etc., their knowledge of mathematics may be insufficient, which explains why the larger companies do hire specialized mathematicians. Even so, this pool of in-house mathematicians is mostly fairly small, their combined mathematical knowledge and working power being too limited to deal effectively with every problem that comes their way. This is why many industries, both large and medium-sized, or even small, turn to the academic world for assistance. Many successful collaborations between industry and academia have been established over the years, resulting in fine publications covering virtually every branch of mathematics.

It should be clear that, with this issue, we cannot even begin to offer a complete overview of what industrial mathematics is. Ours is a journal with a well-defined Aims and Scope. For this issue we have solicited papers that are more or less in line with this definition, although there may be some borderline cases, but these make the collection interesting. Yet, even within this restricted range of disciplines, the present issue only touches upon this enormously rich field of human endeavor. We have simply collected fourteen papers that will give the interested reader an idea of the industrial-mathematical approach. We have grouped these contributions in three categories. First, there is a group of four papers written solely by mathematicians working in industry. The research reported in these papers is of direct use for an industrial methodology or product and has helped these industries to better understand the workings of these. The second group of five papers each involve one or more academics as co-authors. Apparently, the industrial authors felt that highly qualified help was needed to make their projects succeed. The purpose of the research reported in these papers is more or less the same as that of the first group. The third group of five papers involves academic mathematicians only. Often, this type of research results from consulting. Its main purpose is to afford background information that is shared with the company that posed the problem in the first place.

Collaborations between industry and universities have grown over the years. More than fifty years ago the already existing contacts in the U.S.A. were recognized as being important, which led to the foundation of the Society for Industrial and Applied Mathematics (SIAM). A very interesting intiative was taken in the early seventies in Oxford when Alan Tayler and John Ockendon began their now-famous Study Groups with Industry. This initiative has spead since to many parts of the globe and study groups are now being organized on a regular basis in the U.S.A., Europe, Australia and elsewhere. The basic idea of a study group is that representatives from selected industries bring a number of *unsolved* problems to a group of, say, fifty academics and their graduate students. The presentation of these problems takes place on a Monday, when the industrialists deliver half-hour presentations of *non-mathematical* situations that they believe will benefit from mathematical modeling. The problems are adopted by subgroups among the academics who will work, or rather brainstorm, on these for the next three days under the guidance of a chosen leader. The following Friday is reserved for oral presentations when the rapporteurs will report on the progress each group has made. Many a contact of this kind has led to doctoral theses and journal publications. In fact, among the present collection there is one such paper.

Another interesting initiative are the Mathematical Clinics of Claremont College in California. Meanwhile this arrangement has been emulated elsewhere. Again, the purpose of these clinics is that groups of students adopt problems coming from industry, and here too mathematical modeling plays a central role. The European Consortium for Mathematics in Industry

(ECMI) runs an extensive program of (undergraduate) student-placements in industry. This program is funded by the European Commission who, by doing so, recognize the importance of arousing the interest of young mathematicians in industrial problems.

The Institute for Mathematics and its Applications at the University of Minnesota has been running an Industrial Problem Seminar since 1987. The speakers are researchers from industry; they make presentations on problems that arise in their company. These talks have been described and expounded for a mathematical audience [1], including partial solutions and open problems.

The editors of the present issue hope that the readers of this journal and others will renew, or perhaps open up their interest in problems that arise in industry. It is true that certain difficulties have to be overcome. For instance, some industries are keen to safeguard all the know-how they have acquired, even that obtained through outside collaboration, and this may be at variance with the urge to publish that most academics have. Clearly, total secrecy is completely contrary to the academic spirit. A carefully drawn contract, defining publication and patent rights sometimes need to be written at the outset. An academic should not step in when work of a routine nature is offered by a company that does not want to hire qualified personnel of its own. As a rule, academics should go for the intellectual challenge, where they can make the difference.

Over the years much has been written about the nature of industrial mathematics. For those who wish to read more about it, we refer to some work of our own [2,3]. The best way to learn more is, of course, to contact an industrial establishment in your own neighborhood and talk to some people there in an attempt to find interesting problems to work on. For this, one must learn how to converse with people who are not mathematicians per se. More often than not they will be fairly hesitant themselves about the possibilities of mathematical modeling, but so were probably the Wright Brothers and see what we can do now in the field they pioneered!

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1. A. Friedman, *Mathematics in Industrial Problems*. IMA Series in Mathematics and its Applications. Ten Volumes. New York: Springer Verlag (1988–2000).

2. A. Friedman and J. Lavery, *How to Start an Industrial Mathematics Program in the University*. Philadelphia: SIAM (1993) 37 pp.

3. H.K. Kuiken, Mathematical modelling of industrial processes. In: V. Capasso and A. Fasano (eds.), *Mathematical Modelling of Industrial Processes*. Lecture Notes in Mathematics 1521. Berlin: Springer (1992) pp. 2–63.