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European Study Groups with Industry in Portugal: importing a forty year old concept

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What do tyre recycling, the incubation of penguin eggs, LEGO and traffic monitoring have in common? If your answer includes any complicated multidisciplinary theory involving female penguins going down the Antarctic highway on LEGO vehicles with recycled tyres, you are way off the mark. These and other disparate problems such as consumers' behaviour, artificial heart pumps, flight simulators and a host of other seemingly unrelated problems are brought together by the fact that they have all been presented by industrial partners at European Study Groups with Industry (ESGI) in Denmark, the Netherlands, Portugal and the UK, within the last few years. In short, mathematics is the common denominator.

ESGIs originated in the UK in 1968 under the name Oxford Study Groups with Industry. The concept has, since then, been adopted by other countries such as those mentioned above, and study groups have become a well established institution and the leading workshop for interaction between mathematics and industry in Europe. Besides being a source for interesting new problems in mathematics, they also function as a privileged ground for the transfer of mathematical technology between the academic world and industry.

How does it work?

Study groups normally take up the best part of a week, starting on Monday morning with the presentation of the problems by industry and finishing on Thursday or Friday morning with the presentation of the results obtained in the meantime by the mathematicians involved. In between, a lot of brainstorming, modelling, experimenting and discussion goes on, from early in the morning till well after dinner everyday. Not to mention, of course, the usage of a wide range of mathematical techniques.

A typical study group will address between three to six problems, each being presented by a participant from industry appointed by the firm submitting the problem. The presentation will consist of a brief summary of the area of expertise of this particular sector of the company, and a full description of the problem, including solutions already attempted. The precise aim to be achieved should be specified as clearly as possible, together with all the relevant information available. A short written summary of the problem should have been sent to the organizers beforehand, so that there is enough time to contact experts in specific areas if necessary. Since it is not realistic to establish a confidentiality agreement, any sensitive data should not be given explicitly at this stage. However, if sensitive information is involved, firms should provide mock data to be used during the meeting. Written reports produced by some of the participants are sent to firms later on.

What can companies expect from a study group, and why should they participate?

Study groups are exploratory meetings. Except in very specific cases, it is too optimistic to expect a finished, ready to use and well wrapped up solution to result from a four or five day meeting. This will be particularly true when what is at stake is not a specific problem but how to start developing a project to achieve a certain goal, when the production of software is necessary to implement an algorithm, or sometimes even just because for technical reasons it is not physically possible to finish the work in the available time. As an illustration of this last situation take one of the problems presented by Biosafe at the 65^{th} ESGI in Porto in 2008. This required numerical simulations of Navier-Stokes equations which would, by themselves and with the means available, take more time to run than the duration of the meeting itself. However, these simulations could be carried out after the meeting and the results were included in the report sent to the firm afterwards.

In any case, enough information is available by the end of a study group for a company to decide whether this is enough and the company itself may pick up from here, or whether it will find it advantageous to establish a more lasting association with one or several mathematicians to pursue a particular goal.

An important point that should be stressed here is that in general most firms, particularly smaller ones, do not have neither the means nor the need to keep the necessary human resources to address specific problems which may arise. In this sense, study groups may be seen as a possibility for small and medium sized firms to have access to specialized know-how that they will otherwise lack.

What can mathematicians expect from a study group, and why should they participate?

The mathematics needed for problems arising in study groups varies a lot in type, depth, difficulty and novelty. It is, for instance, possible that once a problem has been translated into mathematical form the mathematics needed to solve the problem are trivial. However, this is normally not the case, and industrial problems have become more and more a source of challenging new situations which bring together many aspects of what are traditionally called pure and applied mathematics. In some areas such as statistics, this may also allow access to relevant data for testing methods and algorithms which would otherwise be difficult to come by.

Another important issue is that being in contact with industrial problems keeps mathematicians updated on the challenges facing engineers and other professionals who receive part of their university training in mathematics. If nothing else, this provides a wide range of fresh examples that can be used to motivate many of the fundamental concepts which are taught in first and second year linear algebra and calculus courses. Showing how checking the fuel level in an airplane tank gives rise to a natural example of a continuous, non differentiable, function, does not jeopardize mathematical rigour while at the same time it allows teachers to emphasize the fact that such objects do exist. Not to mention the fact that it is not obvious how to describe and deal with such functions in practical terms, the actual problem which was posed by Airbus at the 56^{th} ESGI in Bath, 2005. The report on this problem, together with a fairly comprehensive collection of ESGI reports, are available at the Study Groups web site [10].

Study groups in Portugal

The first study group to be hosted in Portugal was the 60^{th} in the ESGI series [1]. It came about as a result of the chance encounter of several people at the meeting of the Portuguese Mathematical Society that took place at the Instituto Superior de Engenharia de Lisboa (ISEL) in 2006. The study group itself took place approximately one year later, also at ISEL, and counted with the collaboration of several British specialists including John Ockendon FRS, the Research Director of the Oxford Centre for Industrial and Applied Mathematics [9] and one of the mathematicians with more study groups experience. Two problems were presented, one on traffic flow monitoring (BRISA) and another on a Stewart platform simulator (FunZone Villages). The former provided an example where the firm has a project in mind which they want to embark on (in this case, providing customer information on the A5 motorway connecting Lisbon to Cascais), and wants to know how they should go about merging all the data available, which models to use, etc.

The second problem provided a classical example of a specific situation where there is already a working model in place, but where things are not functioning as expected. Understanding the problem and proposing solutions required techniques from algebra, analysis and geometry.

The 65^{th} ESGI took place in Porto in April 2008 [2] and had four problems, proposed by three firms:

> Biosafe (cooling of a rotor and material separation in tyre recycling);
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> Forever (task assignment in a factory);
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> GROHE (warehouse logistics).

Except for the second of Biosafe's problems which was similar in nature to that of BRISA mentioned above in the sense that Biosafe wanted some input before embarking on a project, all other problems fell into the category of specific situations. They involved techniques from partial differential equations and numerical analysis (the first of Biosafe's problems) and combinatorial optimization (GROHE and Forever problems).

After the Porto meeting, the three participating companies were asked to comment upon different aspects of the process. In general, they all agreed that the meeting had been fruitful and at least for two of the problems the results provided were going to be used by the firms.

The 69^{th} ESGI will take place in Coimbra between the 20^{th} and the 24^{th} of April 2009 [3], and will be preceded by a three day workshop in Porto (April $16^{\text{th}} - 18^{\text{th}}$) [4].

Industrial Mathematics in Portugal: bringing it all together

Anyone who has ever participated in a study group knows that these can be great intellectual fun. However, in order for this to be a sustainable activity and have a lasting positive effect on the relation between

mathematics and industry, study groups should not be seen in isolation from other academic activities. Although they are mentioned in the 2008 OECD report on Mathematics in Industry [8], study groups are just one of several possible mechanisms recommended to enable the partnership between these two forces to flourish. In fact, irrespectively of how successful study groups are point wise, it is only if coupled to other initiatives that their outcome will have a lasting positive influence on both mathematics and industry.

In particular, there should exist a structure at the national level bringing together centres and departments involved in industrial mathematics. This would then integrate the organization of study groups and other activities to be developed in parallel. Some examples of these are the following:

1. Integration of student activities: 2^{nd} cycles in Applied Mathematics at Portuguese Universities. Some of these already include a period during which the student spends some time at a firm working on a specific problem. In the future, these courses could be organized in such a way that during one week students would attend the study group, thus obtaining some important hands on experience. In the Danish study group system this type of practice already provides some ECTS count for students. Apart from putting students in contact with real world problems, study groups themselves would then also function as an aggregating factor, allowing researchers and students working in these areas to be in contact with each other and giving outside visibility to the university community working in industrial mathematics. Such a connection between a degree in mathematics and prospective employers might also help strengthen the number of students applying for these courses, at a point in time when this might become critical for the existence of sustained 2^{nd} and 3^{rd} cycles in these and related areas.

2. Invited chairs in Industrial Mathematics: It would allow for a great qualitative leap to be able to bring to this country specialists in this field taking advantage, for instance, of the Ciência 2008 program sponsored by the Foundation for Science and Technology (FCT).

3. Knowledge transfer networks: To systematically reach industrial partners who might be interested in collaborating with academia is a nontrivial task requiring a lot of time and experience. Without the existence of full-time technology translators, promoting these initiatives within industry will be very difficult. Such a system is already in place in countries like the UK [7].

4. Research institutes: At a much more ambitious level, the Portuguese mathematical community should aim at the creation of an institute similar in nature to the Oxford Centre for Industrial and Applied Mathematics [9] in the UK, or the Fraunhofer-Chalmers Research Centre in Industrial Mathematics [5] at Chalmers University in Sweden, for instance. Apart from the obvious advantages of having a successful institute of this type, it would dramatically increase the visibility of the usefulness of mathematics in today's world, not only to industry but also to the general public.

The existence of a national structure of this type would greatly benefit the Portuguese mathematical community in general and also help the development of certain aspects of industry with emphasis on small and medium sized firms as mentioned above.

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