Lagrange Prize awarded to Prof. Roger Fletcher

Our very own Prof. Fletcher and his colleagues, Dr. Leyffer and Prof. Toint were awarded the Lagrange prize for outstanding work in the area of optimization. The prize is only given every three years and further emphasizes the immense contribution that Prof. Fletcher has made in the field of Optimization.

Nonlinear Programming (NLP) refers to the optimization of complex nonlinear systems and has widespread applications in science and engineering. As an example, electricity generation companies have to decide which of the various power stations to use to generate power to satisfy demand. Different costs are associated with different types of generation (oil, coal, nuclear etc.). Also some power is lost in the transmission lines. The aim is to decide on a schedule which minimizes the overall cost of generation, whilst satisfying the demand. (continued on page 2)

Magnetic Mathematics

The newly appointed Dr. Gunnar Hornig will be working in the field Magnetic Hydrodynamics. This involves the mathematical study of magnetic fields and how they behave.

Magnetic fields are ubiquitous in the universe. We find them on planets like the Earth, in stars like the Sun and even in galaxies or black holes. Magnetic fields also play an important role for life on Earth as the magnetic field of the Earth shields us from the intense cosmic radiation. Most magnetic fields in the universe are not the result of a magnetised solid body, such as a bar magnet, but they are continuously generated by the motion of an electrically conducting matter. (continued on page 2)
Prize for Prof. Roger Fletcher

The equations underlying power generation, have to be satisfied, and there are limits as to how much power can be generated at each station and how much power can be tolerated on each transmission line. Conditions such as these are an integral part of any NLP problem.

Another example of topical interest is to find the optimum trajectory of a space vehicle fired from earth, to dock with the space laboratory. Here the aim is to find a trajectory which minimizes the amount of fuel needed. Complex conditions such as the differential equations of space flight, and the need to meet the target at zero velocity have to be satisfied.

Roger first described the "filter" approach in a talk at the SIAM Optimization Conference 1996 in Victoria, Canada, which attracted much interest. Sven Leyffer (who gained his PhD in Dundee in 1994 and stayed on as a postdoc) and Prof. Fletcher worked on the development of the basic idea, and implemented a production computer code. This was written up as a technical report in 1997 and documents evidence to show that their code significantly improves on the efficiency of other codes for NLP that were available at the time. Since that time many licences to use the code have been issued to researchers throughout the world, perhaps getting on for 100, and including such well known organizations as ICI, Schlumberger, AT&T, EXXON and the European Space Agency ESA.

The novelty of the filter approach is to treat the NLP problem as two separate optimization problems, namely the determination of the best schedule or design and the minimization of some measure of the extent to which the conditions underlying the design are satisfied. Roger says that NLP is still a very active research area, and developments in penalty and other types of method continue to be made. The competition to develop a method which meets with universal acceptance is still very fierce.

Magnetic Mathematics by Gunnar Hornig

Thus these fields are varying in time and the magnetic field of the Sun is a typical example in this respect. For us on the Earth this means that the solar radiation, which depends on the solar magnetic field, is also varying in time and hence our climate shows the same periodic modulation of about eleven years as does the solar magnetic field.

Despite the omnipresence of magnetic fields we have no sense to "see" them. We are thus forced to make measurements and use mathematical models to get an idea of the magnetic world around us. Only on rare occasions can we, in an indirect way, "see" magnetic fields. For instance the glowing curtain-like structures known as northern lights are caused by charged particles travelling in spirals along magnetic field lines. When they hit the upper atmosphere of the Earth radiation is emitted. These light curtains therefore trace out the magnetic field lines of the Earth & make them visible.

For the same reason we can observe magnetic structures on the surface of the Sun. The solar atmosphere is a hot ionised gas, called plasma, which consists of ions and electrons. These ions and electrons move in spirals along the magnetic field lines while emitting radiation. Therefore X-ray images of the solar atmosphere can sometimes show us the magnetic field lines (Figure below).
They often consist of magnetic loops emanating from the surface. Sometimes these loops erupt in huge explosions which set free magnetic energy of the equivalent of millions of hydrogen bombs (see Figure prominence).

Why is the magnetic field of the Sun so complicated? The reason for this can be found in the origin of these fields. Other than the simple dipole magnetic field of a bar magnet they are not the result of a single magnetisation of a solid body, but are constantly generated by a dynamo process. A dynamo in astrophysics is a process whereby a magnetic field is generated by the motion of an electrically conducting fluid - a plasma or the electrically conducting molten iron core of a planet. This is a complicated, and not yet fully understood, process in which the fluid (plasma) acts on the magnetic field but as well as the magnetic field acting back on the plasma and modifying its motion. This non-linear interaction is the reason of the wealth of magnetic structures which we observe on the Sun. It is believed that at the heart of a dynamo a process similar to the one sketched below it at work. A magnetic flux tube (a bundle of magnetic field lines) is first stretched by the motion of the fluid it is embedded in, then folded back onto itself such that both loops have the same orientation. Where the flux tubes cross a process called "magnetic reconnection" can cut and reconnect the field lines so that we end up with the initial configuration but with twice the magnetic flux.

The mathematical description of these phenomena uses equations from both fluid dynamics and electrodynamics to describe the magnetic fields embedded in an electrically conducting fluid. It has links to various other areas of mathematics, dynamical systems, differential geometry, differential equations and knot theory. An important problem for instance is to find an adequate description of the complexity we find in these magnetic fields. As a most primitive example consider an idealised magnetic field that is confined in a tube with the field lines exhibiting a twist. Such a twist can be measured by a quantity called magnetic helicity.

To find topological invariants of magnetic fields like magnetic helicity is of paramount importance for understanding the dynamics of magnetic fields in the universe. However, it is still an open question whether further integrals of the type of magnetic helicity exist which can measure more complicated forms of linkage or knottedness of magnetic fields.

These questions together with the modelling of reconnection processes in magnetic fields are the main area of activity of our new group in the Division of Mathematics in Dundee.
PhD Student awarded £20,000

Cancer Research UK have awarded £20,000 to final year mathematics PhD student, Heiko Enderling, for his joint research project with consultant surgeon, Dr Jayant S Vaidya, to develop mathematical models of tumours under radiation therapy. The research, which will focus on mathematical models of radiotherapy used to treat early breast cancer, will help to predict the outcomes of treatment and determine which types of therapy are most effective.

Heiko Enderling is currently in the final year of his PhD in the Division of Mathematics supervised by Dr Alexander Anderson and Professor Mark Chaplain. This project focuses on both the modelling and visualisation of various aspects of tumour growth and treatment. More recently, his research has focused on how exposure to radiation affects tumour cells & normal (uncancerous) tissue.

Already collaboration between Mr Enderling, Professor Chaplain and Dr Anderson in the Division of Mathematics, and Dr Vaidya and Professor Alastair Munro in Surgery and Molecular Oncology, has resulted in a joint publication which demonstrates the power of mathematical modelling in predicting the outcome of treatments with standard radiotherapy and the new Targit approach.

The £20,000 grant from Cancer Research UK will fund an eight month project to further develop the mathematical models - a useful tool for simulating different treatment scenarios on theoretical patients before applying them on actual patients. These models work by representing each piece of the biological system as a separate component, each of which can be expressed by a mathematical equation. For example, different equations describe the behaviour of both normal and cancer cells as well as their interaction.

By applying radiation to the cells mathematically, it is possible to predict what the likely impact on the cells will be - will they cease growing, or die, or will they continue to multiply? In this manner the researchers are able to analyse how effective different types of radiation therapy are likely to be.

ESMTB Meeting in Dresden 2005 by Ian Pierce

The annual meeting of the Society for Mathematical Biology (SMB) was held in conjunction with the sister European Society at the European Conference for Mathematical and Theoretical Biology (ECMTB) in Dresden, Germany from July 18th - 22nd, 2005. The conference was organised by the irrepressible Andreas Deutsch and colleagues and brought together more than 700 students and academics from around the globe. The main purposes: to discuss recent advances in mathematical biology, catch-up with collaborators and friends and, in short, have a great time. In suitably eccentric fashion Andreas wished us a fruitful and “interaction-rich time” and there is no question that these aims were achieved. On top of that, all involved appeared to hugely enjoy themselves.
Once again, as has been the case for the last few years, the Mathematical Biology research group from Dundee had a significant presence with nine of us making the trip including our intrepid group of six Ph.D. students, several of whom had arrived directly from a workshop in America. The conference venue was the impressive “Hoersaalzen” at the Dresden University of Technology, which proved to be ideal with state of the art facilities. The conference schedule was busy and organised into twelve key topics under which talks and posters were presented. These included cellular biophysics, evolution and ecology, biomedical applications and innovative mathematical methods, areas in which members of the Dundee group made a number of presentations. The programme included 15 invited talks, 150 mini-symposia talks and 275 contributed session talks, along with numerous poster presentations spread over two poster sessions. A special lecture was also held to present Professor James Murray with the Okubo prize. In all, the Dundee group gave eight oral presentations and one poster presentation. It was particularly notable that five of the Ph.D. student gave talks, all but one of us having taken posters to the previous year’s SMB conference in Michigan, USA. This highlighted the progress made by the Ph.D. students over a twelve month period. In many cases it was the most important talk we had given and in some cases our first and I think we all found it a hugely rewarding experience.

In addition to the academic aspect of the conference there was also ample free time to enjoy the delights of Dresden an extremely beautiful and culturally rich city, which has been hugely revived since the tragic bombings towards the end of the Second World War. Dresden has a vibrant bar and café culture and the Dundee group, along with a number of friends took full advantage and were often to be found chatting over a beer well into the wee small hours. All of us also took an extremely enjoyable boat ride along the Elbe to the Pillnitz Castle where we were entertained with an organ and violin recital in the recently restored wooden church “Zum Heilligen Geist” (Church of the Holy Spirit). Of many highlights the greatest was a superb conference banquet in the Dresden treasury building. The hospitality was simply outstanding and a great time was had by all. All too soon it seemed, it was time to go, not before a significant honour was bestowed on a member of the Dundee team, with Professor Chaplain being elected as President of the SMB at their AGM. This, along with the significant contribution of the research group from Dundee, is testimony to the strength of the research being carried out at the University of Dundee. It is to be hoped that this will continue for many years to come. Ultimately, thanks must go to Andreas Deutsch and his team for providing the opportunity to participate in such a well organised and enjoyable conference and we look forward to returning to Dresden in the future.

Please visit the Mathematical Biology Group homepage for information on all of the groups activities, [http://www.maths.dundee.ac.uk/mbg](http://www.maths.dundee.ac.uk/mbg).
Scientists have always strived to describe the universe and all that surrounds us in as general terms as possible. They are not looking for rules or laws that only apply to a few objects of phenomena, but for laws that can be generalised to a large number of objects and that can explain a wide number of phenomena. The laws of physics are an excellent example of this as they apply to any atom or molecule in the universe independent of where, how and when it exists. Biology on the other hand has been more focused on explaining things within their context instead of trying to generalise them, but recent observations have lead biologists to view things in a broader perspective.

One such example is the law of allometric scaling between body weight and metabolism of animals. This law states that the metabolic rate $B$, measured in kcal/hour, scales as the weight $M$ in grams of the animal to the power 3/4, and can be written as

$$B = aM^{3/4}$$

The fascinating thing about this law is that it is true for any animal, from single cellular organisms like amoebas to elephants, the largest land-living animal in the world. The explanation of this law can therefore not be specific to a certain animal or not even to a group of animals like the mammals, but has to be something that is shared by all animals on the planet.

This intriguing mathematical relationship has of course caught the eye of mathematicians and physicists who are used to dealing with general laws and trying to explain them from basic principles. The phenomenon was first described in the 1930s by Kleiber, and although it has been around for more than 70 years no one has been able to give a good explanation as to why it is true. Many different explanations have been given, ranging from the mechanics of body movement to the general structure of a vascular system. Although some approaches have been more successful than others, none has been able to fully convince the scientific community and the law of allometric scaling therefore remains an unsolved problem to this day.
In August 2003 Dr. Fordyce Davidson, Dr. Sandy Anderson and myself organized a Mathematical Biology Conference which hosted the Annual Meeting of The Society for Mathematical Biology (SMB). The meeting was attended by around 230 participants. It was the first time the Society for Mathematical Biology’s Annual Meeting had taken place outside continental USA and it was a great success. The following year, July 2004, I was approached by Professor Lou Gross (then President of SMB) at the Annual SMB Meeting at the University of Michigan who asked if I would be willing to stand for election as the next President of the Society. In a moment of weakness, I said that I would be happy to stand for election. A few months later, after the elections had taken place, I was surprised to receive an email from Prof. Gross informing me that I had won the “Presidential Election”. For the next year, I was officially “President-elect”, formally becoming President during a joint SMB-ESMTB (European Society for Mathematical and theoretical Biology) Conference last summer in Dresden, July 2005. The Society for Mathematical Biology is the world’s largest such organization for mathematical biology and has been in existence since the early 1970s. It is a great honour and pleasure to serve in this role.

The main tasks of the President are in communicating with the Board of Directors and “running” the business of the Society throughout the term of “Presidential Office” (2 years). Details of the Society’s history, governance, conferences and activities can be found at the web-pages of the Society: http://www.smb.org/

Reading through the pages devoted to its history, one is very aware of the history of the Society, how it came into being, how it has developed, where it is now and where it is heading in the near future. With the future in mind, it is perhaps useful to consider the words of wisdom of a past mathematical master D. Hilbert: "Who of us would not be glad to lift the veil behind which the future lies hidden; to cast a glance at the next advances of our science and at the secrets of its development during future centuries? What particular goals will there be toward which the leading mathematical spirits of coming generations will strive? What new methods and new facts in the wide and rich field of mathematical thought will the new centuries disclose?"

These words perhaps have particular resonance after the excellent meeting in July 2005 in Dresden (joint with our sister society, ESMTB). Having spent a week in the company of over 700 mathematical biology colleagues, listening to and watching wonderful talks it should be clear to all that mathematical biology as a discipline stands on the threshold of truly exciting, challenging and interdisciplinary times. The Life and Biomedical Sciences are throwing up many beautiful, challenging problems for mathematicians, statisticians, and computer scientists. The foreseeable future for the subject offers many new methods and new facts to be discovered, as yet unsuspected relations between mathematics and biology to be uncovered.

In signing off this "Presidential letter", I leave you with further inspirational words of wisdom from a fellow Scot and “Honorary Dundonian”: "I know that in the study of material things, number, order and position are the threefold clues to exact knowledge; that these three, in the mathematician’s hands, furnish the ‘first outlines for a sketch of the Universe’. "

D’Arcy Thompson

While sketching the outlines for the Universe may take a little longer, mathematical, statistical and computational sciences are already furnishing outlines for sketches for the deeper understanding of and solution to significant biological problems. The Society and its members will continue to work to be at the forefront of such exciting scientific developments.
Letter From the Head of Division

I am pleased to contribute an article for this Newsletter as I come to the end of my spell as Head of Division. It was suggested to me that I look back over this period, and also look forward. It is easier to look back than to look forward, although I have in mind Albert Schweitzer's words: “Happiness is nothing more than good health and a poor memory”.

Anyway here goes. As I look back, it would be foolish to pretend that there were not some trying times. An appropriate response to my wife’s question “Have you had a good day?” was sometimes “Yes, I’ve had a good day, but this wasn’t it”. There have certainly been disappointments, although this has never bothered me much because I’m a Hibs supporter, and so accustomed to disappointments.

However, overwhelmingly my experience has been a positive one, with much having happened that I can look back on with some satisfaction. The Division has made what I believe to be some very good appointments, with the potential, in particular, to develop and build a very strong group in Magneto hydrodynamics. The Mathematical Biology group has been very successful in generating research income, and postgraduate numbers over the last few years have been at a record high. It was good to see Professor Roger Fletcher honoured once again, winning the prestigious Lagrange prize for two of his recent research papers in Optimization. Staying with numerical analysis, we had another successful conference (the 21st in the biennial series) in 2005.

On the teaching front, there was a very up-beat review of our teaching provision in November 2005. In particular, the Review Board judged that Mathematics students were very positive with regard to their learning experience, expressing confidence in the staff and supporting the teaching methods used. We continue to have some excellent students, and we consistently produce Faculty and University prizewinners among our undergraduates (and postgraduates). We have a record number of students in Level 3 this year, and so expect to have a record number in Level 4 from this September.

My responsibility for Mathematics will be taken over by Professor Mark Chaplain on August 1, and I wish him well. I recommend to him the words of Paul Getty: “My formula for success is rise early, work late, and strike oil.”

Final Word from the Editor

It’s been a hectic year, with new appointments, promotions, conferences and awards. I’d like to personally thank Prof. Watson for a successful term as head of division and look forward to seeing what new plans Prof. Chaplain will bring as his successor. I would also very much like to thank the respective authors (both staff and students) for their contributions to the newsletter as they give a real flavour of what’s happening in Dundee. This issue has again highlighted the strength of Mathematics at Dundee, with two prizes and a president I think we can safely say we’re doing pretty well. I wish you all as much success in the rest of 2006 and look forward to a long hot summer.

Sandy Anderson (Editor)

Contact Information

Division of Mathematics
University of Dundee
Dundee DD1 4HN
Phone: 01382 344471
Fax: 01382 5345516
E-mail: anderson@maths.dundee.ac.uk

Details on any courses run by the Mathematics Division at Dundee University as well as many other aspects of the Mathematics Division can be found at our webpage:

http://www.maths.dundee.ac.uk