58th European Study Group
Mathematics with Industry

Friday February 2, 2007

The tiring week has come to an end; all the teams have finished their work and prepared a presentation, to report about their solution(s). The time they could spend on their challenge was, all in all, about three days, but these were long days!

The AMC team is discussing the last details – some last-minute computations?

The ASML team has fun – they must be confident on their results. But the presenter of the results is not present in the room – does he prefer some isolation, these last minutes?

Also the organisation has some last minute preparations – order of presentations, are all companies present, does everything work …?

And finally, also the representatives from the companies are somewhat nervous – what can they expect after a week hard work?

Before the coffee break, we will have UMC, Innogrow and ASML; Paul Zegeling will be our host for the pre-break programme.

Paul introduces the first speaker.

UMC – Rapid calculation of the radiofrequency pattern in MRI

Yves van Gennip (TU Eindhoven) will guide us through the solution of the UMC-team. The (size of the) team is quite extensive, and they have worked on a few different approaches, that have received titles like ‘confocal confusion’ and ‘circular reasoning’ …

Yves van Gennip is our enthousiastic guide for the solution to the UMC problem.

Yves starts with some familiar pictures from Monday’s presentation, but then he starts off with the mathematical basics: Maxwell’s equations with and without medium, a divergence free potential, leading to a wave equation, followed by an “Ansatz”, providing us with Helmholtz equation. This is still textbook mathematics, but now the relation with the actual domain of interest, the MRI-scan, is made.

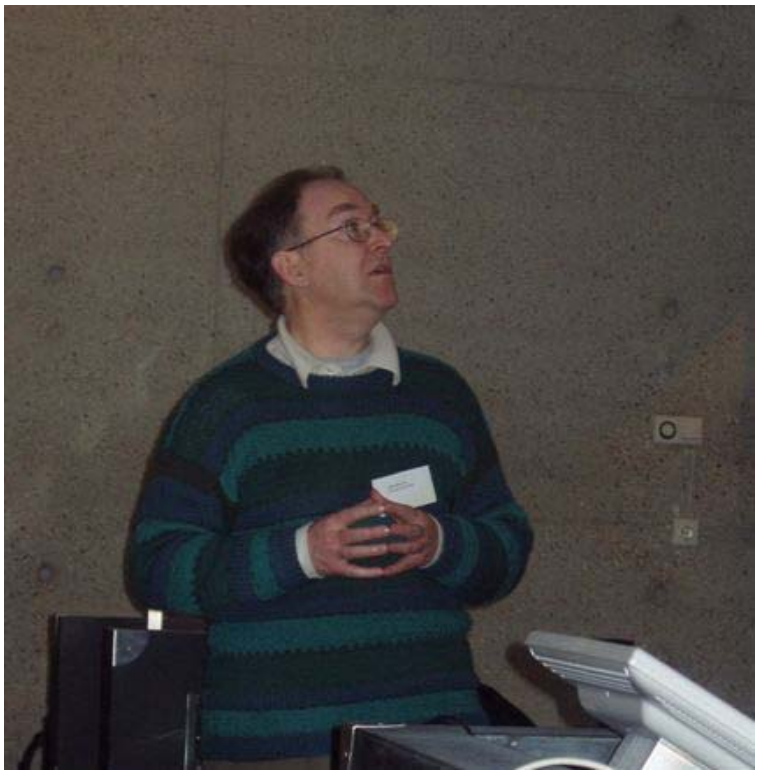
For each ring in the domain, a different solution is suggested, with matching boundary conditions. Assuming a near-elliptical boundary, the team first introduced elliptical coordinates, applied ‘separation of variables’, leading to Mathieu and modified Mathieu functions. The actual solution consists of a superposition of these functions; using some symmetry conditions Yves gets rid of some of the nasty terms, but he ends up with a difficult-looking set of equations that reflect the problem of matching

the solution to the boundary conditions and different material parameters … So much for the confocal confusion!
An alternative approach is the use of polar-coordinates, leading – after separation of variables – to (co)sines and Bessel functions. But solving the equation is only one tiny step in the complete story: the team had to optimise the antenna settings, in order to make a homogeneous magnetic field and prevention of hot spots in the body. Yves shows a few computations, but the optimisation has not been implemented completely.

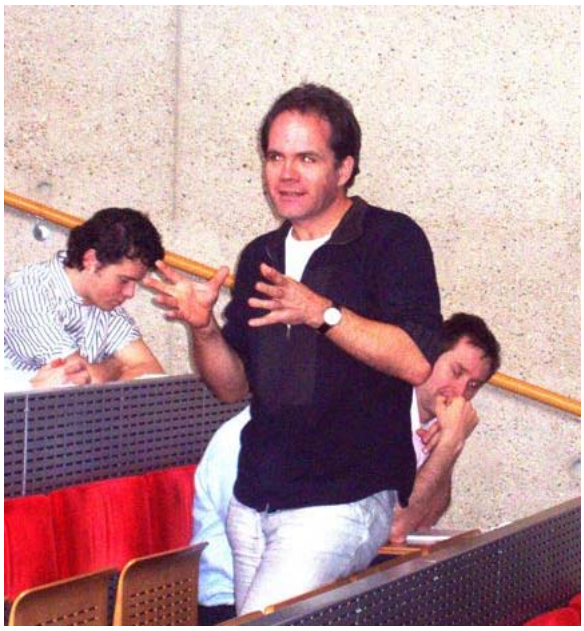
Nevertheless: *Nico van den Berg* (UMC) is very impressed! It was a pleasure for him to work with the team of mathematicians; using their impressive toolkit of mathematical theories and practical hands-on experience, the team not only managed to derive the proper equations, but was even able to start solving some of them. For him, the week has accelerated the forming of new ideas, and after some checks he will probably continue using the approach of the team. So much positive news, and we've only had one team – what will this bring for the rest of morning!

Innogrow – Optimising a closed greenhouse
The Innogrow-team has found two people that will present the solution: a very enthusiastic *Claude Archer* from Haute école Francisco Ferrer (Brussels), and an expert from the UK (Coventry University), *Colin Reeves*. The success of the previous team leads to the speculation of free tomatoes for this team, but after some good laughs, Claude and Colin start off seriously with introducing us to their solution. Although the original problem consists of four coupled models, the team has concentrated on the energy-model; using this model, the aim is to minimize the costs of

energy, given a number of sources (pumps, buffers, aquifer, boiler), heat-and-cold demand during the year, and the possibility to sell electricity to the grid during e.g. the summer.
Using a free version of Lindo ("20 minutes typing, 2 hours of debugging"☺), a program that is capable of solving LP-problems, the team is able to show some actual graphs that clearly illustrate what is going on during the different seasons. It appears that the solutions are sensitive to the value of the parameter λ, denoting the hourly rate of extracting heat or cold from the aquiver; this value is difficult to measure, but now the team has exposed its large influence on the solution, it is of utmost importance to find ways to determine it.
The team has thought of a number of extensions: differentiate between summer and winter day, make the different elements in the model temperature dependent (make it all nonlinear!), and extend the time horizon. This last aspect seemed computationally a challenge, but some experts in the room indicate that more powerful programs will have no problem with the quoted number of variables.



Colin Reeves discusses some the solutions with the public.

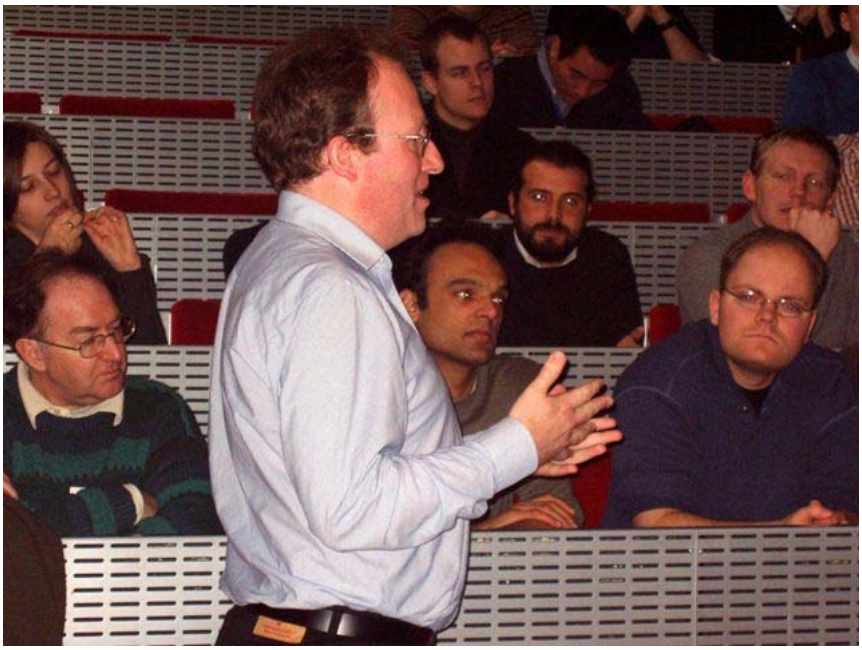


Lou Ramaekers from Innogrow is also asked about his opinion. He cannot promise free tomatoes, but he is quite pleased with the new approaches taken by the team. He also indicates that with these new approaches also new questions arose, but he will definitely, using some powerful LP-solvers, continue experimenting using the model developed by the team.

ASML – Rastering a chip layout

The last team before the break is the ASML-team. *Eric Cator* (TU Delft) first underlines that the team has had a lot of fun during the week. His vivid and detailed exposé took us from indicator functions, representing the actual mask, a Fourier transform and a low-pass filter to a sampler. The intricate relation between space and Fourier-space gave some nasty problems, and prevented straightforward solutions, like the use of triangles (~10^{13} flops) and fast-Fourier (~10^{11} flops). ASML itself had also studied quite long on the problem, and provided some additional insights during the week. A kernel that is used for 'pre-processing' could be tuned in such a way that it was both concise in Fourier-space and tractable for fast numerical manipulation. Using some smart tabulation and thereby use of memory, the team could indicate that their approach might lead to a speed-up of the current process active at ASML.

Eric Cator uses hands and black board to explain the details of the solution of the ASML-team.



Wouter Mulckhuyse from ASML marks the week as a very fruitful experience; ASML had already good experience with SWI, and this has continued. He indicates that ASML will take the clever ideas from the team further.

Immediately after

the coffee break it is time for an announcement – irrespective of STW-financing, next year's Study Group will be in Twente. Onno Bokhove, from the local organizing committee, presented in a marvellous, mathematical poem SWI2008 – we only need 80 participants and 6 problems, and we will have another fantastic week!

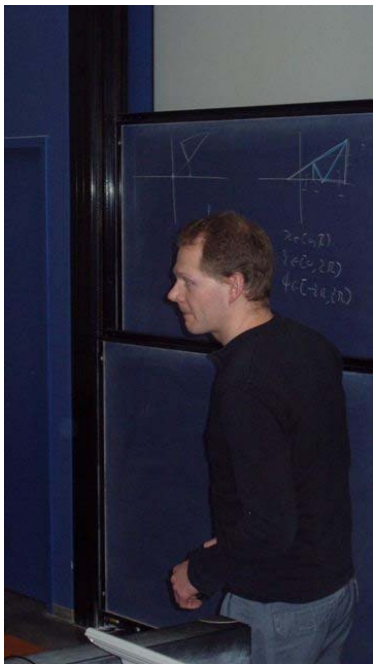
Then the last three problems got their turn: AMC, ING and KLM.

AMC – Optimising the function of artificial heart pumps in humans
Our guide through the AMC-solution was *Michel Vellekoop* (University of Twente). He started out by explaining in some more detail the analogy between the blood system and heart, and electric circuitry. In this way, (blood) flow was replaced by current, pressure by potential, blood mass by a coil, buffering by a capacity, friction by a resistor, the heart contraction by a battery, the valves by diodes, and finally, the subject under study – the pump – by an artificial battery. For people who do not like the sight of blood, this was a relieving analogy! For mathematicians, this gave at least some grip on the matter, but – conservation of problems – they of course needed to tune the values of the respective elements in their model. Using 'pressure-volume' diagrams as a result from the model and measurements, the team was able to calibrate their approach. It turned out that they needed the pump to act also as a *resistor*, in order to get the so-called systolic part of the diagram right. The exact value of the resistance was even a sensitive parameter.

Krischan Sjauw from the AMC explained that he had learned a lot in solving theses problems; the use of the computer model, even though it was not completely comprehensible, gave some insights - "the model came alive". Interesting quote within the context ☺. The results needed more discussion and interpretation, but after this week, there will be some time for that.

ING – Improving an option pricing model





The team that had worked on the ING-challenge had put its solution in a challenge for the audience; three(!) speakers all provided their way of looking at the problem and how to 'attack' it; needless to say that – because of their enthusiasm – time management was not on their list of priorities ☺.
Fang Fang (TU Delft) first presented a more-or-less camera-ready paper – and rushed us through a number of lemmas, corollaries, and proofs. A few experts in the audience were actually able to grasp some of it, and even managed to pose some intelligent questions – your reporter was not one of them ☹.
After that, *Joris Bierkens* (Leiden University) presented a number of modeling steps, calculations and results using Mathematica, whereas *Michael Muskulus* (Leiden University) concluded the series by following yet another route, arriving for the case of no correlation between the different stochastics entering the problem.

Antoine van der Ploeg from ING was quite enthusiastic – he indicated that the team had come very close to a solution, something a number of experts with PhD projects had not succeeded in during a number of years!

KLM – Optimising the reserve strategy of cabin crew

Being the last in a row, the KLM-team faces another challenge – keep the audience afresh, after a long morning, and just before the lunch break! The vivid exposé of *Peter van Heijster* (CWI Amsterdam) and *Marco Bijvank* (VU Amsterdam) cannot hide that the team has had a difficult week.

After an introduction, based on Monday's presentation, Peter mentions that the team has enjoyed an excursion to Schiphol, in order to get some more grip on the problem, and to get acquainted with the current solutions employed by KLM. In order to tackle the problem, a series of drastic assumptions is made, that may be relaxed later on; all people work full time, there are no different ranks, the reserve duties are for the full 24 hours, and the team concentrates only on long-haul flights.

Two novel approaches are explained and studied: the so-called *soft flight*, that aims at minimizing domino effects and the *mirror flight*. A numerical example is put on the board to make these concepts easier to digest.

Marc Paelinck from Air France / KLM indicates that it turned out the problem has shown to be a very tough problem. Some important aspects could not be resolved this week, but nevertheless, he has some very nice presents for the team!

With this last presentation, the 58th Study Group Mathematics with Industry has come to its end. The final words are for the organizers, that is, Rob Bisseling; he recalls that this week is not possible without the work of large number of volunteers – a big hand for all of them is very well in place!

Santa Claus is early this year; Marc Paelinck has presents for all team members.

Rob Bisseling thanks all the volunteers, and closes this exciting week.

Erik Fledderus