58th European Study Group
Mathematics with Industry

Monday January 29, 2007

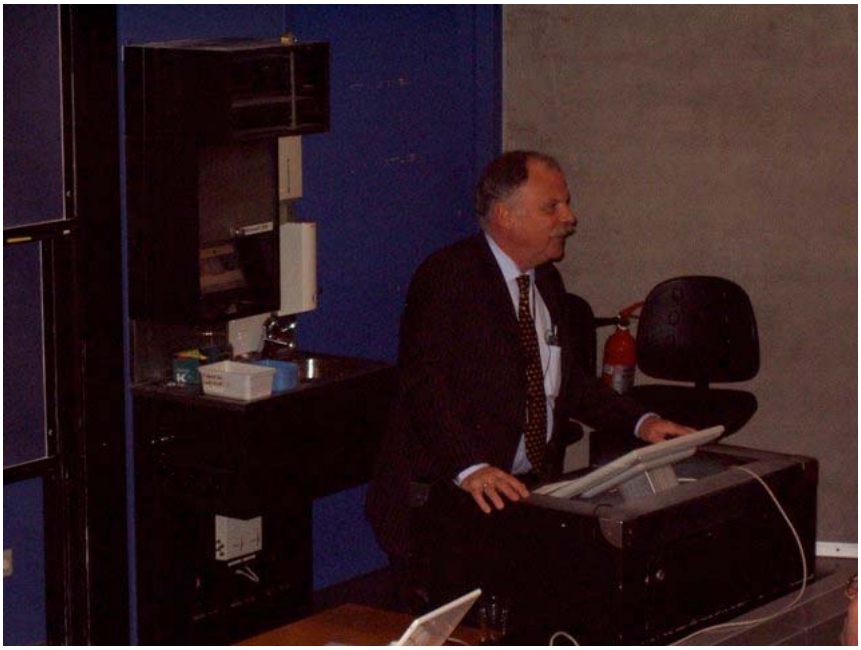
The feeling is different from last year, when I was part of the organisation, but as soon as I enter the relative small room within the Minnaert building the deja-vu is complete: the Study Group Mathematics with Industry is about to begin! With a large group of participants from academia, industry and research institutes, it is again an outstanding event, where challenging problems, full of jargon, are posed to professional mathematicians and students. Whether the problem is ill-posed or not – you have to face the fact that this week there is no escape!

The Minnaert building – the water from the basin is used to cool the building. Its origin is plain rainwater! The resemblance with the 'Gesloten Kas' problem cannot be a coincidence ☺

"Do we all fit in this room?!" The early birds have already found the best position. The rest of the group is still drinking coffee or testing the equipment.

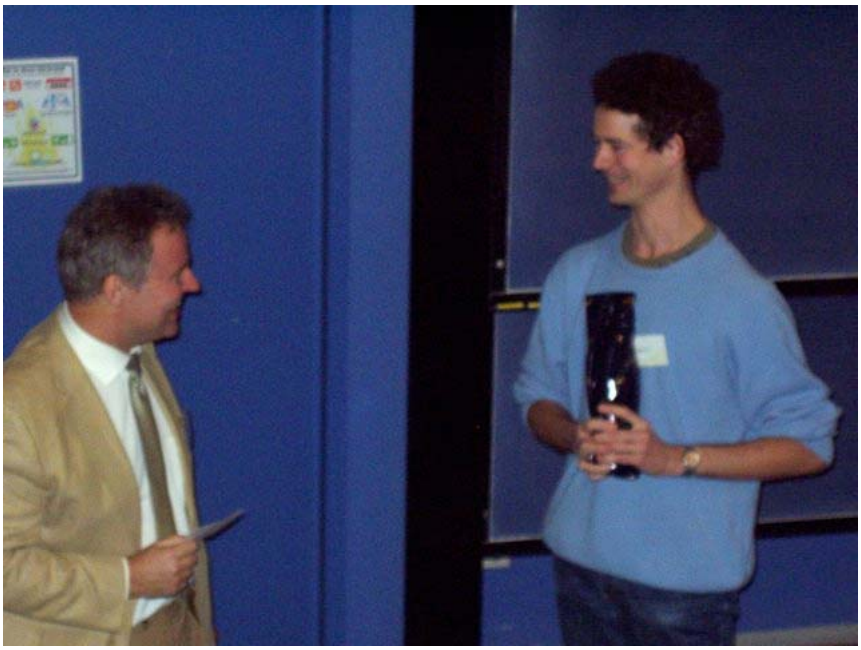
Inviting the rector for the opening speech has become some sort of a tradition, and also this year, prof. Willem H. Gispen was able to deliver a creative opening speech in which he browsed through the different problems. Although a biologist by training, he emphasised the importance of mathematics by highlighting the parallel of the current curriculum of the University of Utrecht with Plato's Academy: a broad bachelor, followed by a focused master. The inscription above Plato's Academy read "Let no one ignorant of geometry enter here" – proving the point of the importance of math. Prof. Gispen continued by mentioning a number of achievements of mathematics and its applications in daily life ('shorter queues in supermarkets") and industry ('MRI scans'), and finally he expressed the hope that this week would not only give solutions to the challenging problems, but also opportunities for new careers of mathematicians in industry.

Local organiser Rob Bisseling has a final chat and laugh before he 'kicks off' the week.



Rector Magnificus Willem Hendrik Gispen delivers his opening speech.

After the opening speech, it was the turn of dr. Rik Janssen from STW, the main sponsor of the Study Group. He started of with snowy scenery of last year – hard to imagine this year with temperatures up to 10 °C! But after that he had serious matters to discuss with us: will this be the last Study Group?! With an increasing percentage of participants that is attracted to this Week, it better be not. Rik had good news for us: some hardworking volunteers had drawn up and submitted a proposal to STW, to safeguard budget for the next years. The 'only' thing that was still required was the persuasion of STW's top management … With such a success every year this should not be too difficult!



Rik Janssen (STW) receives a bottle of wine for his speech – hopefully not his last on this occasion!

KLM – Optimising the reserve strategy of cabin crew

With 8000 flight attendants, a large variety of flights, airplanes, and the hectic of today's airline industry, scheduling at KLM is more than a challenge; the cabin crew of KLM receives a new roster every week, which shows their assignment for the next several weeks. A remark from the audience whether the knowledge of your schedule on such short notice isn't annoying was rebound by noticing that a schedule of four weeks ahead does only give a fake-stability – the number of 'disruptions' (unforeseen changes to the daily/weekly pattern) is large and causes short-term re-assignments.

The typical jargon for this problem was quickly introduced: crew pairings, flight assignments, duty policies, reserves, etc. – the audience had no time to sit back and relax, but had to grasp hard. An example how a disruption caused the assignment of a flight assignment to a reserve, causing a problem (secondary disruption) later on in the week that could be resolved by 'bringing in' another reserve, and so on.

Difficult problems are often simply stated: minimise the number of unused reserved days (cost, discomfort), minimise the number of "open" roster days (cost, discomfort), minimise the number of secondary disruptions (cost). A combined optimisation of discomfort and money: was there preference for one or the other? Teasing questions for the challengers from Airfrance / KLM, but they didn't flinch – personnel is of utmost importance, and so are the finances, so any balancing should be discussed later on in the week.


Heidi de Ridder en Marc Paelinck (Airfrance / KLM).

Innogrow – Optimising a closed greenhouse
Greenhouses in the Netherlands are 'big business'. But the investments that are required for heating, cooling and watering are also important topics on the "environmental" agenda; saving energy in this sector can be rewarding. This was one of the triggers of the development of a new type of greenhouse, called GeslotenKas®, developed by Innogrow. It all started with the idea of keeping the windows closed, to keep as much as possible CO_2 inside the greenhouse. But closed windows require a new solution for controlling the climate (temperature, humidity).

Using an ingenious system of heat and cold storage, in combination with high-performance pumps, Innogrow has obtained impressive reductions of energy usage while increasing the crop production.

To control the different elements in the Geslotenkas®, a combination of models is used and optimized: a *climate model*, yielding temperature and humidity based on the different energy supplies, a *crop growth model*, yielding e.g. the production of plants on the basis of a certain climate, a *cost model*, yielding the cost of investments, energy and the revenues based on market conditions, and a *utility model*, determining the components that will produce the necessary energy, how much energy is stored, and how much is saved.

The level of detail of all models is varying, and it is difficult to perform some sort of optimization. The main challenge for this week is to obtain an optimal control of the different elements in the greenhouse, while aiming at highest profit at lowest costs and energy usage.

Lou Ramaekers (Innogrow).

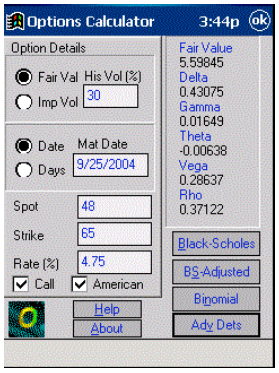
ASML – Rasterising a chip layout

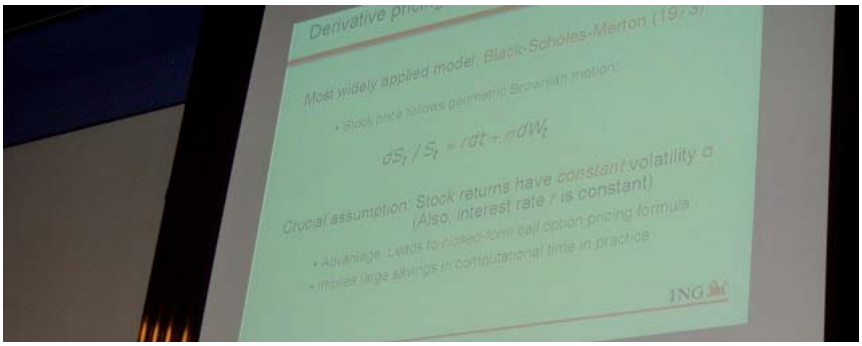
After a quick break with coffee, tea and cookies, ASML continued with the presentations. Last year they were in on the Study Group as well, but ASML has a large variety of challenges, as it turned out. The quite technical process required some explanation; the use of masks is employed to obtain the right structure on chips, but making a mask is expensive, and ASML tries to find ways to work with a more generic approach with which they can emulate a large variety of masks. This approach is called the *optical maskless lithography*, where a vast amount of small mirrors are turned under different angles in order to produce the actual structure. To compute the angles based on a prescribed structure requires an astronomic amount of computational power. Hence the challenge: given a grid geometry and a list with simple polygons, calculate the sample value of each grid pixel, resulting in a position for the corresponding mirror, such that the error residual in a certain norm is sufficiently small, with a minimal amount of computational operations.

Wouter Mulckhuyse (ASML).

ING – Improving an option pricing model

In 2006, the organisation could not reach agreement with a company on providing a financial problem for the Study Group, but this year, the local organisers have been able to attract ING. Again, jargon was quickly introduced: stocks, bonds, commodities, and – the topic of the challenge – derivatives. Not just 'derivatives', but financial derivatives. The well-known example of a call-option was explained, including the notion of *option price.* ING is often approached with other, more exotic, types of financial derivatives, and asked for an offer. In that case, ING wants to able to quickly evaluate the price of such a derivative. To that end, different models are in use, that all have the characteristic of being solvable in ("nearly") closed form. However, they should also be realistic! The most well-known formula that is on everyone's calculator at the stock-exchange is based on the Black-Scholes-Merton model.

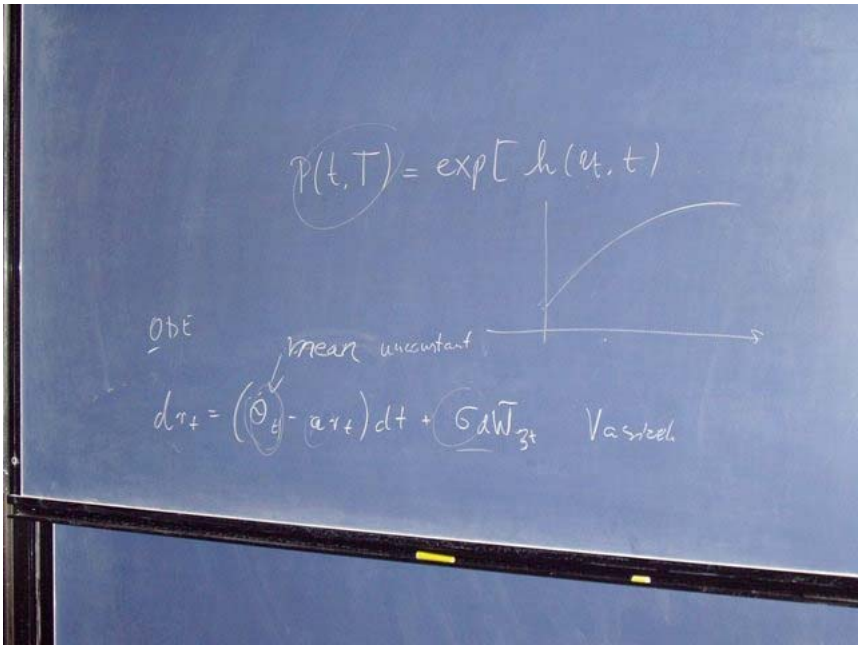




The Black-Scholes-Merton model – too simple for this challenge.

This model has two disadvantages: the volatility is constant, as well as the interest rate. Removing these two assumptions leads to the "Hybrid Heston – Hull-White" model – but is this model, though more realistic, still solvable in 'no-time'?

Antoine van der Ploeg (ING).



Some people could not wait till the groups were formed …

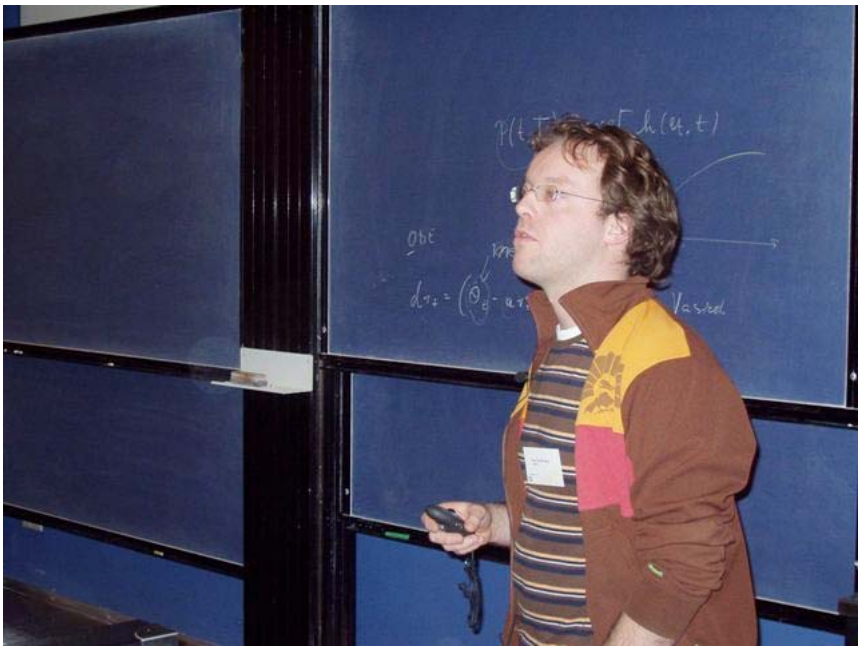
After the lunch break, the series continued with two more (medical) problems.

Soup, fruit, bread – lunch was well taken care of!

UMC – Rapid calculation of the radiofrequency pattern in MRI

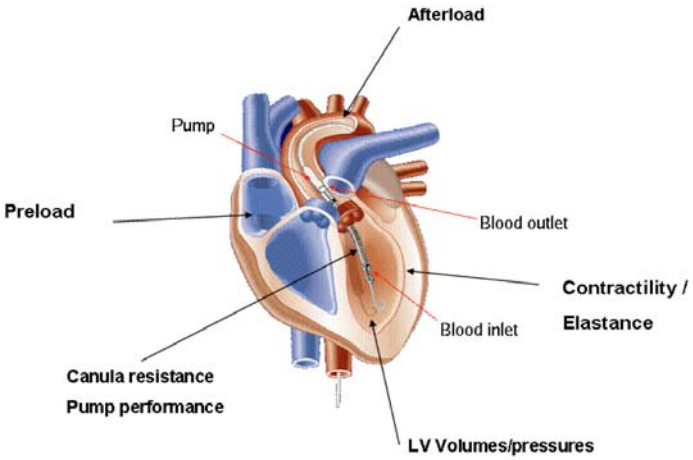
The rector had already mentioned the achievements of mathematics in the case of MRI – but somehow there was a problem left ☺ The UMC was invited to discuss the principles of MRI scans with us: a magnetic field ('orders of magnitude stronger than the Earth magnetic field') is applied to a patient; the magnetic spin of the hydrogen nuclei get aligned with this field, but make a small precession with a clearly defined frequency – the so-called Larmor frequency. By applying radio waves at this same

frequency, the spins start to rotate, and when switched off, they fall back to their original position, thereby emitting a radio wave themselves which is caught and 'displayed' – so far, so good. Now radio waves have the habit of stirring molecules, i.e., heating. This effect is strongly related to the magnitude of the applied field and the frequency: we do not get excited by TV-waves, at least not thermally, but radar waves on marine ships are a different matter. With the applied radio waves increasing in frequency – required because of higher Larmor frequencies, on their turn caused by higher applied magnetic fields – the problem of too much (local) heat is present. At the same time, the radio field inside the body is not uniform, leading to a decrease in quality of the scans.
The main way of improving the situation is by 'playing' around with the antennas around the body that emit the radio waves with a certain phase and amplitude. In radio communication this set-up is called a 'smart antenna', and e.g. the goal-keeper on marine ships is based on this principle, but now the challenge is of a slightly different nature: the computing power of an MRI is different from a marine ship, so the Study Group is asked to formulate an applied EM field that can be used quite generic, that is as uniform as possible across the body, and provides minimum warming-up.



Nico van den Berg (UMC) is 'heating up' the audience with his MRI-story.

AMC – Optimising the function of artificial heart pumps in humans
Finally, it was the turn of the AMC with another medical challenge in the area of heart pumps. It proved to be a hard 30 minutes for those who do not like the sight of blood and patients on the surgery table, even though most of it was rather decent and still image. The AMC works with a new type of heart pump that can be brought in the body with minimum surgical insertion. The performance of the heart pump and its effect on the patient is related to a.o. the wall stress at the heart chamber, and the systolic / diastolic volume. To that end, both



the heart and the pump need to be modelled. The understanding of these matters is quite important, since the mortality rate of the patients that enter the hospital in an acute situation is still rather high.

Krischan Sjauw (AMC).

After a quick coffee and tea, the people moved to the different rooms that were reserved for the problems. As it turned out, the presentations had merely teased our brains, but were not meant for a clean-cut problem-posing. Defining what the problem is in mathematical terms is one of the key challenges of the first day(s), and the presence of the problem-posers was very important for that step.

Erik Fledderus