Van der Vorst, H.A.

Computational Science Curriculum in Utrecht

Abstract

In 1993 Utrecht University has started a curriculum in Computational Science, starting at the undergraduate level and leading to the Dutch 'Doctorandus' degree (wich is more or less comparable to the Master's degree). The curriculum has been st up as a joint collaboration between the Departments of Mathematics & Computer Science, and Physics. It aims at a complete and self-contained educational program that should fulfill society's growing demand for scientific computing, and it does so by trying to make students familiar with computational models (physics), applied mathematics (with emphasis on numerical analysis), and computer possibilities (computer science).

In our presentation we will discuss the ideas behind this new study, the perspectives for students with respect to carreer, and we will report on our experiences during the first two years of existence of the new curriculum.

1. The Dutch Educational System

In order to understand how the CS-curriculum fits in the educational system we will first briefly sketch the Dutch educational system in relation with scientific education. From age 4 to 12 everyone attends the same type of primary school. At age 12 the education splits in essentially three streams:
1. MAVO (low to medium level)
2. HAVO (medium to high level), and
3. VWO (high level).

At each level the student can take a selection of courses, and typically such a selection (the selection has to follow certain rules to make it a proper one) contains Mathematics (Calculus), Physics, Biology, Dutch, two foreign languages, history, and economics. For the higher levels (VWO and HAVO) Mathematics comes in two flavours: Mathematics A and B. Type A deals with statistics, type B has calculus and simple linear algebra. The VWO type can be regarded as preparation for further education at a University. Several combinations of courses can be taken and the choice determines for what study the student qualifies. If one finishes the VWO successfully then one is allowed to enter University without further requirements than having followed the proper courses.
The education at the University consists of two phases:
4. The first phase takes in theory 4 years, but in practice often more than 5, and ends with a so-called 'Doctorandus (drs)' degree. This degree can be compared to the American Masters Degree.
5. The second phase takes again 4 years and ends with a PhD (Dr)-degree.
The Computational Science Curriculum starts right at the beginning of phase 1, so when the students are at an age of about 18 years old.

2. The Circumstances in Utrecht

The main departments that are involved in Computational Science at Utrecht University are:

- Department of Mathematics, with chairs in Algebra, Analysis, Numerical Analysis, Statistics & Probability, and Mathematical Pysics. For Computational Science the chairs in Numerical Analysis and Statistics & Probability are the most relevant ones. The chair in Mathematical Physics became vacant in the last year and it is to be expected that the new professor will also be involved at least partly in the Computational Science curriculum. The Numerical Analysis section consists at this moment of one full professor, three associate professors, four postdocs, and a small number of PhD-students. This section played a key role in the start of Computational Science, warmly supported by the other mathematicians (including the pure mathematicians; in Utrecht there is no clear separation between pure and applied).

- Department of Informatics. Although this Department played an active role in getting Computational Science started in Utrecht, it became more deeply involved only very recently. At this moment, July 1995, it is very active in the participation as well as in the design of new courses. The Department of Informatics is currently active in Algorithms and Algorithmic design, Information Technology, Programming, and Software Technology.

- Department of Physics. This department has different subgroups, among which we see Theoretical Physics, Experimental Physics, Astronomy, Oceanography, and Informatics of Physics. The last one was most actively involved in Computational Science, but the courses in Physics for the new curriculum are not restricted to this group.

Apart from these three Departments, computational activities take also place in the Departments of Medicine, Chemistry, Biology, Pharmacy, and Earth Sciences.
In 1990 a contact group was established, which acted as a forum for discussions on Computational Science matters and for mutual help with large scale computational work. This group has organized Symposiums and it has also made a list of all those courses that have strong emphasis on Computational aspects. Students in various Departments are encouraged to select courses from this list.

3. Promotion of exact sciences

The number of students who enroll for exact sciences has decreased dramatically over the last years, and this is seen as an alarming fact by the Dutch Government. The State Department of Education and Science has taken steps in order to help improve the situation, and together with the encouraging attention and stimulances of the Board of Utrecht University this has created an atmosphere in which the establishment of a new Computational Science curriculum was facilitated. The University Board has played a very active role in this by making money available, partly for Physics and partly for Mathematics & Informatics, under the condition that these Departments agreed to start the new curriculum by September 1, 1993. This deadline was made known only one year earlier, September 1992.
Furthermore, we received also warm support, in writing, from key industries and large research laboratories. Some of these groups were willing to help finance PhD positions (in fact, Philips Electronics is participating in a program for financing PhD positions in Utrecht, as per September 1995).
This has culminated in the official approvement by the State Department of the Computational Science curriculum as an independent study, of which the name is privileged. This status becomes effective as per September 1995, and from then on we are allowed to grant a Doctorandus title in Computational Science.

4. The Computational Science Curriculum

The goal of our Computational Science curriculum is to provide a complete program for professional simulation of scientific processes. The ingredients of this program are Mathematics, Numerical Analysis, Physics, and Informatics. The students have, in the last two years, also a choice from courses in Chemistry, Economics, etc.
The program of the first year leads to a 'Propedeuse'-degree. Without this degree students are formally not allowed to take 3-rd and 4-th year courses. This first year program consists of the following elements:

- Calculus ($\approx 20\%$)
- Linear Algebra ($\approx 16\%$)
- Introduction to Statistics ($\approx 8\%$)
- Principles of Programming ($\approx 10\%$)
- Algorithms & Datastructures ($\approx 10\%$)
- Mechanics ($\approx 10\%$)
- Electrodynamics ($\approx 10\%$)
- CS Practical Work ($\approx 16\%$)

After this first year the student has still the possibillity to switch from Computational Science to a program in Mathematics or Physics with no delay in the total program. We anticipated that this switch possibility might make it easier for the student to select our new program, in the sense of a reduced risk.

The program of the second year includes

- Advanced Calculus (differential equations, partial differential equations) ($\approx 22\%$)
- Introduction Numerical Analysis, and
- Numerical Linear Algebra (together ($\approx 18\%$)
- Introduction to Probability theory ($\approx 8\%$)
- Knowledge Technology ($\approx 8\%$)
- Parallel Programming ($\approx 8\%$)
- Quantum Mechanics, and
- Waves + Optics (together $\approx 16\%$)
- Coputational Science Practical Work ($\approx 20\%$)

The practical work includes sessions in which the students becom familiar with computer simulations of increasing complexity. The simplified versions of the models are introduced in the first year. In these sessions students use C, Matlab, Mathematica, and they make their reports with LaTeX.

The 3-rd and 4-th year are rather diverse and we give here only an impression of the most important elements:

- Numerical Algorithms for super and parallel computers
- Nonlinear PDE's and Dynamical Systems
- Theory of Programming
- Decision Theory
- Artificial Intelligence
- A Project (in which the students work in small teams)
- Computer practice
- A seminar, in which the students have to give at least two presentations of two times 45 minutes each.
- A selection upon choice from a list of courses in Physics, Chemistry, Earth Sciences, Hydrodynamics, etc.
- Thesis work (6 months)

5. Promotional Activities

Of course we have undertaken actions to make sure that students at secondary schools, as well as their teachers in mathematics and physics, became aware of our program in Computational Sciences. Among our activities in this direction we mention

- special brochures with information on the program, the purpose of the program, career perspectives, and telephone numbers for further information.
- Utrecht University organizes each year in November two special days, during which students in the final year of secondary school, get all sorts of information on the various programs. Example lectures are given, computer demonstrations, special introductions, and students have an opportunity for contacts with staff. These days are usually very lively events that are rather popular for young students and their parents. Free lunches are provided. Of course, also Computational Sciences presents itself at these occasions with introductions, example courses, and videos.
- Our postdocs and some of our younger students present introductions at schools (or at meetings where students of several schools attend). It turns out that it is often more efficient to let younger persons do this kind of propaganda.

- Since 1993 we have prepared, with professional help of editors of a popular scientific journal, special inlays in full color for this magazine. A significant number of the students in our program became aware of the program through these inlays.
- Occasionally we give special lectures for secondary school teachers.
- We are in the process of providing information through WWW.

6. Early Experiences

Our early experiences are quite encouraging. In the first year of existence, '93-'94, we had 18 students enrolled in our program, and the same number in the second year. We have no definitive numbers for this year but there are indications that the number will be higher this time.
It is our impression that the best students are those with an interest in physics.
After two years we are now building up the necessary courses for the third year and the involved Departments are willing to adjust their courses, or to develop special variants for the Computational Science students. This leads to further improvements in the program and it also leads to a better identification of the curriculum.

7. Related Research Projects

We are convinced that the researchers who are involved in the new program, should also be involved in related research projects, because of the stimulating effect of this on students. This creates also positions for students to participate for their thesis work and later on for their PhD work.
The Dutch Organization for Scientific Research (NWO) has started a program in Massively Parallel Computing and Networking. We got a fairly large proposal granted, and this includes research in Plasma Physics (Tokamak modeling), Earth Mantle convection, and studying the influence of the Oceans on the long term climate.
Cray Research has also set up a grant program in the Netherlands from which we received a grant for research on BSP-models for linear algebra.
Other projects, amongst others with Philips Eelctronics, are anticipated, and this includes simulation studies for circuits and integrated circuits.

Addresses: PROF. DR. HENK VAN DER VORST, Mathematical Institute, University of Utrecht, P.O. Box 80010, 3508 TA Utrecht, the Netherlands. `email: vorst@math.ruu.nl`