

# A Belgian view of Computational Science and Engineering

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Computational Science and Engineering (CS&E) education in Belgium is evolving favourably. Even though none of the Belgian universities has a complete interdisciplinary CS&E educational program, there is a growing trend to include more CS&E in the existing engineering, mathematics and computer science curricula. Before discussing this in more detail, we give a brief overview of the educational system in Belgium.

To obtain a university degree, students must successfully complete two cycles of courses in a discipline. The first cycle, *candidature*, is a two- or three-year program, depending on the discipline (it is two years for all exact sciences and for engineering, but three years for a medical degree). It is meant to give the students a broad basis of the chosen discipline and also includes some basic courses in closely related subjects. The second cycle, usually called *licence*, is a two-, three- or four-year program (two years for exact sciences and three years for engineering). In contrast to the first cycle, the second cycle is more specialized, with different options to choose from. In the last year of the second cycle, most disciplines require students to write a thesis showing that they can independently understand new material; no original work is required.

After successfully completing the first two cycles, many students leave university for the job market. Some others, who are motivated to do research, enter the doctoral program. Another option for graduating students is to go on to what is usually referred to as the third cycle. This is typically a one- or two-year program in a field that is in some sense related to, but different from, the discipline chosen by the student in the first two cycles. Hence the third cycle is, in the current context, the only framework for the organization of interdisciplinary CS&E programs. Students interested in CS&E can currently choose from a small range of advanced programs such as Computer Science and Industrial Mathematics, Biomedical and Clinical Engineering, Biostatistics and so on.

For the sake of completeness, we should mention that besides the university engineering degree, which is referred to as *civil engineering* degree, there is also an *industrial engineering* degree. The educational program for industrial engineers takes four years and is taught at non-university schools for higher education. However, in the sequel of the text we shall focus only on university curricula. May we remark that worldwide the Belgian educational system has a good reputation.

As was pointed out in [1], CS&E is a methodology rather than a discipline. More importantly, it is a methodology which requires that the borderlines between different disciplines be crossed. The different aspects of CS&E are

often characterized by 3 A's [2], [3]: Application, Algorithm and computer Architectures. It is therefore natural that the mainstream courses which cover one or more aspects of CS&E, are usually taught in the engineering, mathematics and computer science departments. It is also important to note that all exact-science curricula have in the first cycle at least one extensive mathematics or applied mathematics course and one introductory computer science course. Unfortunately, there is traditionally little interaction between the math/computer science and the respective science departments. Opportunities to develop these courses in an interdisciplinary fashion according to the CS&E problem-solving methodology, which is described in [1], are not exploited.

The fact that, as already mentioned, no true CS&E program exists in Belgium, can in part be ascribed to the fact that Belgium is a small country. Even if the need for such a program is acknowledged, the expense would be too great for several universities to offer a CS&E curriculum. Yet it is a politically delicate issue to promote one university over all others for the organization of a CS&E program without a global structural reform of the higher-education policy. A proposal to introduce university *gravitation points*, such that each university attracts all students in specific disciplines, rather than offering nearly all disciplines at nearly all universities as is the case now, may shed a new light on the CS&E situation and is the subject of an on-going political debate.

To meet current demands for CS&E education, cross-fertilization occurs between the engineering, mathematics and computer science curricula, in line with the cross-fertilization of Applications, Algorithms and Architectures. We refer the reader to the adjacent navigation bar for details on CSE-related programs at the different Belgian universities. As can be seen, several universities include in their engineering curricula applied mathematics and computer science as specialization, some offer a computer science specialization within the mathematics curriculum and a number of universities include numerical analysis as a main option within their computer science curriculum. An official evaluation of the mathematics curricula of the Flemish universities, carried out in 1995, confirms the need for this evolution: more emphasis should be given to actual computing in the mathematics curricula in general and in the applied mathematics curricula in particular. For the sake of completeness, we mention that the computer science curricula and the computer science specialization of the engineering curriculum will be evaluated in a similar way in 2001.

The cross-fertilization of engineering, mathematics and

computer science at the curricular level can also be retraced at the research level. Indeed, Scientific Research Communities sponsored by the Science Foundation – Flanders (in Dutch FWO–Vlaanderen), such as the Scientific Research Community “Advanced numerical techniques for mathematical modelling” to which we belong, group researchers from engineering, applied mathematics and computer science. This brings us to research in CS&E in Belgium and its funding.

In the past, the opportunities provided by a computational approach to science were often underestimated. Funding agencies tended not to honour CS&E projects – for instance, in computational chemistry – because they were regarded as not truly chemistry by the chemists and not truly computer science by the computer science people. CS&E projects clearly seemed to suffer an image problem. Moreover, with the advent of computer science as a full-fledged discipline, interest in and funding for traditional numerical analysis research and, more generally, scientific computing research dwindled. All attention was drawn to other aspects of the rapidly evolving computer science discipline. In recent years, there has been a reversal of that trend. Scientific computing, which also greatly evolved because of the rapid changes in computer hardware, together with the advent of symbolic computation, has taken up a forefront position again. A new look is cast on this rather old (in computer science terms) discipline, and this slowly attracts students and researchers alike. Scientific computing is now considered to be an integral part of computer science by Belgian funding agencies and is appreciated accordingly. Nevertheless, all teams in Belgium involved in CS&E remain aware of the danger of neither being recognized within the discipline of the application nor within the computer science discipline and beware of too much optimism. As far as funding from the European Union is concerned, we have experienced in the last years a downward shift towards industry and a move from pro-active or more basic research to reactive research, which responds to industrial needs and has known and acceptable levels of risk. On the job market, a similar trend can be observed. Many large companies which did have a research center in a small country such as Belgium, have had to close down or severely cut back on their research activities here.

We conclude by giving an overview of the evolution of the student population at the Flemish universities in engineering, mathematics and computer science and indicate some consequences of this evolution. In Figure 1, we have plotted student population versus academic year [4]. The numbers reflect the student population in the second cycle for mathematics and for engineering, specialization computer science, and the student population in the first cycle for computer science. Since most Flemish universities did not organize computer science as a discipline until some years ago, figures for the second cycle student population in computer science are not representative. The most striking feature of Figure 1 is the rapidly increasing number of computer science students. This phenomenon is not only typical of Flanders or Belgium as a whole, but can be ob-

served in many European countries. The decrease in the proportion of mathematics students to computer science students has already led to the merging of mathematics and computer science departments at some universities in neighbouring countries.

Of the three curricula that are traditionally most relevant to CS&E education, the University of Antwerp, which does not have an engineering school, offers computer science and mathematics. It should be noted that, whereas on the average 1/8 of the total Flemish student population studies at our university, two disciplines stand out: all biology-related sciences and computer science. As far as computer science is concerned, the University of Antwerp delivers almost 1/4 of all Flemish computer science degrees. Hence we have, relatively speaking, the opportunity to address a large audience potentially interested in CS&E. This was reason enough to put effort in developing a scientific computing course with special attention for the computer science background of the students. That it takes more than classical numerical analysis courses to get students majoring in computer science interested in CS&E, can be read about in a separate contribution in this issue.

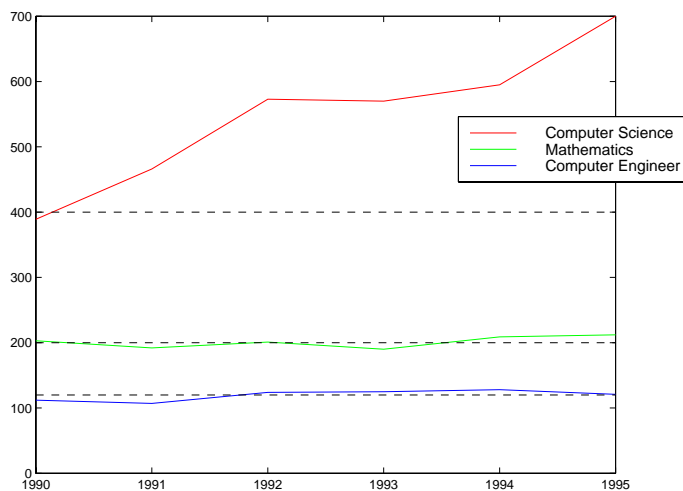


Figure 1: Evolution of student population at Flemish universities

#### ABOUT THE AUTHORS

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#### Belgian Universities with CSE-Related Programs

These universities offer a degree in one or more of the disciplines of engineering, mathematics and computer science:

- Katholieke Universiteit Leuven (KUL), <http://www.kuleuven.ac.be/kuleuven>
- Universiteit Gent (RUG), <http://www.rug.ac.be>
- Universiteit Antwerpen (UA), <http://www.ua.ac.be>
- Vrije Universiteit Brussel (VUB), <http://www.vub.ac.be>
- Limburgs Universitair Centrum (LUC), <http://www.luc.ac.be>
- Université Catholique de Louvain (UCL), <http://www.ucl.ac.be>
- Université Libre de Bruxelles (ULB), <http://www.ulb.ac.be>
- Université de Liège (ULg), <http://www.ulg.ac.be>
- Facultés Universitaires Notre-Dame de la Paix in Namur (FUNDP), <http://www.fundp.ac.be>
- Université de Mons-Hainaut (UMH), <http://www.umh.ac.be>
- Faculté Polytechnique de Mons (FPMs), <http://www.fpms.ac.be>, an independent academic institute offering only the civil engineering degree.

**Engineering** is offered at the following Flemish universities:

- Katholieke Universiteit Leuven
  - Universiteit Gent
  - Vrije Universiteit Brussel
- and at the following French-speaking universities:
- Université Catholique de Louvain
  - Université de Liège
  - Université Libre de Bruxelles
  - Faculté Polytechnique de Mons

Within their respective curricula, both Ghent and Leuven offer, among others, a specialization "Computer Science". This specialization is further split into options. In particular, the option "Applied Mathematics" at the KUL centers on algorithmic and numerical problems and their implementation on different computer architectures.

As for the French-speaking engineering schools, the UCL offers the "Applied Mathematics" and "Computer Science" specializations, and the ULB offers a "Computer Science" specialization. These specializations, in turn, have several options covering different aspects of CS&E.

For **Computer Science**, the degree of "Licentiaat (Toegepaste Informatica)" is offered by the following universities:

- Katholieke Universiteit Leuven
- Universiteit Gent
- Universiteit Antwerpen
- Vrije Universiteit Brussel
- Limburgs Universitair Centrum

while the degree of "Licencié en Informatique" is offered by

- Université Libre de Bruxelles
- Université de Liège
- Université de Mons-Hainaut

in both cases after two cycles of two years each. Furthermore, the FUNDP organizes a five-year computer science program leading to a "Maîtrise en Informatique".

The universities of Ghent and of Leuven offer the option "Numerical Computer Science", respectively "Numerical Analysis". From a CS&E perspective, it is important to note that the degree of "Licentiaat Informatica" in Ghent is organised jointly by the Faculty of Applied Sciences and the Faculty of Sciences.

At the French-speaking side, the degree of "Licencié en Informatique" at the ULg, although not an engineering degree, is completely organised by the Faculty of Applied Sciences, and has "Mathematics" as a main option.

We conclude with a review of the **Mathematics** curricula. All Flemish and all French-speaking universities offer the degree of "Licentiaat Wiskunde" (wiskunde is the Dutch word for Mathematics), respectively "Licencié en Mathématique".

The main difference between the curricula of the Flemish universities is to be found in the different specializations that they offer in the second cycle. All Flemish universities offer the specialization "Applied Mathematics", but only Brussels and Antwerp also have a "Computer Science" specialization within the mathematics curriculum. Evaluating the contribution to CS&E of the "Applied Mathematics" specialization is very difficult, because its content varies greatly between universities.

Regarding the French-speaking mathematics curricula, they too are very diverse with respect to the different specializations offered. We mention here that a "Computer Science" specialization is offered within the mathematics curriculum at the UCL, the UMH and, in the first cycle, at the FUNDP. All the specializations in the second cycle of the mathematics curriculum at the FUNDP are applied mathematics specializations: "Numerical Analysis", "Optimisation", "Mechanics and Differential Equations" and so on.