MRCCS/NSF Summer School

Graham Carey

Director, CFDLab, Institute for Computational Engineering and Sciences (ICES), The University of Texas at Austin

During the week of September 1-5, 2003 Manchester Research Centre for Computational Science (MRCCS) hosted a summer school/workshop entitled "High Performance Computing in Finite Element Analysis". The goal was to bring faculty researchers experienced in parallel computing, algorithms finite element methodology and applications together with graduate students in this topical area. The workshop was comprised of three main components: (i) formal lectures by experts on several inter-linked topics covering both fundamental and state-of-the-art developments; (ii) demonstrations and application studies to provide "hands on" experience with tutorials where applicable, and (iii) informal discussion to encourage exchange of ideas among faculty and students.

This proved to be an excellent format since it provided an 'accelerated entry' for beginning graduate students whereas students further along in their research could discuss deeper technical issues with experienced faculty researchers. It also facilitated an interchange between faculty carrying out research and supervising graduate students in this topical area. This interaction at Manchester will no doubt lead to further contact, exchange of papers and possible collaborations between individuals at the various research groups represented.

It seems especially appropriate that this meeting was convened at the University of Manchester. The era of modern computing machines began in the middle of the last century with the development of the first generation of scientific computers in several countries. One of the earliest machines was designed and built at the University of Manchester. The small-scale experimental machine SSEM, or "Baby" as it was known, made its first successful run on June 21st 1948. In the intervening half century, the University of Manchester has maintained a prominent position in scientific computing. This position was formalized in 1969 with the opening of Manchester Computing (MC), and a succession of supercomputer generations have been in use at MC since that time. The September summer school program, mentioned in the opening paragraph, followed in the steps of this tradition.

First, one may reasonably comment that there are only a handful of truly major scientific developments in the past century and the development of electronic digital computers must stand with these few. The continuing revolution in microelectronics and the ability to mass produce the associated products as a commodity has reaped unimagined price-performance benefits so that computing is now pervasive throughout most areas of society. In particular, it has enhanced our simulation and problem solving capability. Previously, experiment and theory were regarded as the two pillars of science but today computer modeling stands as an equal partner in this endeavor.

The term "supercomputers" has been applied to refer to the leading high performance computers in any given 'technology generation'. Generally, supercomputers may be defined as current generation machines that are capable of solving, in a timely manner, problems that were significantly beyond the scope of previous computing technology. Since a computer generation here implies only a few years, this is a "rapidly moving target," and it has certainly been the case that the supercomputer a decade ago is surpassed by the desktop computer today. Consequently, the term supercomputing has recently been replaced by High-Performance Computing or Advanced Computing to better reflect the current state of the art.

Most high-performance computing today relies on parallel systems comprised of inexpensive commodity-off-the-shelf (COTS) processors with very fast communication hardware. However, high-performance computing is much more than the hardware alone. Amongst many other items it requires, in particular: (i) algorithms and software for partitioning very complex problems across parallel architectures containing many networked processors; (ii) methods, algorithms and software for scientific problem solving via numerical analysis, and related tasks; (iii) parallel software infrastructure, libraries and toolkits; (iv) storage for extreme volumes of data with data mining/ manipulation and (v) advanced visualization capability.

These key topics and other related issues were the subject of the summer school program. However, they were specifically framed in the context of Finite Element Analysis, so a few comments on the finite element method are also relevant. In a practical sense, finite elements also began in the engineering community approximately 50 years ago. The method was initially developed for structural analysis using the natural idea of combining contributions of structural members or "elements" into an "assembled" structure. Later, the relation to variational principles, partial differential equations and extension to more general applications was gradually realized. Above all else, it is the integral formulation that allows the use of unstructured and graded meshes of general elements that underlies the applications power of the finite element method. The idea of partitioning the mesh and parallel processing over collections of elements has led to an easy transition of finite element analysis into the parallel high performance computing arena while losing none of the generality of the method. The MC summer school workshop was designed to explore high performance computing in this context. The program of lectures on the subject was (in alphabetic order):

Professor Jacobo Bielak, Carnegie Mellon University, USA - *Parallel FEA*
Professor Graham Carey, University of Texas, USA - *Parallel FEA Algorithms*
Professor Mark Cross - University of Greenwich, UK - *Techniques and Tools for Parallel FEA*
Dr Jon Gibson, University of Manchester, UK - *Introduction to HPC*
Professor Boris Jeremic, University of California, Davis, USA - *Parallel FEA in Geomechanics*
Ms Jo Leng, University of Manchester, UK - *Introduction to Visualisation*
Dr Lee Margetts, University of Manchester, UK - *Parallelisation*
Dr Kengo Nakajima - GEOFEM/Earth Simulator Project, Japan - *GEOFEM / Earth Simulator Project*
Dr Mike Pettipher, University of Manchester, UK - *Performance Measurement and Optimisation*
Professor Olivier Pironneau - University of Paris, France - *Schwarz and Schur Algorithms*
Professor Mark Shephard - Rensslaer P I, New York, USA - *Parallel Automated Adaptive Analysis*
Professor Ian Smith - University of Manchester, UK - *HPC in FEA, Parallel EBE, Practicals*
Professor Nigel Weatherill - University of Wales Swansea, UK - *Parallel Mesh Generation*

The lectures were followed by organized software and applications demonstrations/tutorials/discussions. Details of the lectures and these sessions are available on a DVD. (Please contact Fiona Cook by email - fiona.cook@man.ac.uk - if you would like a copy of the DVD).

The technical exchanges continued into the coffee breaks and after hours: extra-curricular highlights of the meeting were (not necessarily in order of importance): the after- house social hour and discussions; the conference dinner at "The Ox" pub (one recalls that the algebraist Sylvester worked all night on binary forms with the aid of a decanter of port to sustain flagging spirits); and, last but not least, the surprise wake up "discussion session" on the college courtyard before early morning due to an errant fire alarm.

Figure 1: Enjoying the Conference Dinner at "The Ox".

Special thanks are due to the organizers, Professor Ian Smith, Dr Mike Pettipher, Dr Lee Margetts, Dr Jon Gibson, Jo Leng and Fiona Cook at Manchester Computing and to Boris Jeremic at UC Irvine, USA for planning and carrying out an excellent summer school program. Organizers, lecturers and students also thank the US National Science Foundation for providing financial support for the workshop.