Willi Schönauer
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The Efficient Use of Vector Computers with Emphasis on Computational Fluid Dynamics

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Volume 12

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The Efficient Use of Vector Computers with Emphasis on Computational Fluid Dynamics

A GAMM-Workshop

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PREFACE

The GAMM Committee for Numerical Methods in Fluid Mechanics organizes workshops which should bring together experts of a narrow field of computational fluid dynamics (CFD) to exchange ideas and experiences in order to speed-up the development in this field. In this sense it was suggested that a workshop should treat the solution of CFD problems on vector computers. Thus we organized a workshop with the title "The efficient use of vector computers with emphasis on computational fluid dynamics". The workshop took place at the Computing Centre of the University of Karlsruhe, March 13-15,1985. The participation had been restricted to 22 people of 7 countries. 18 papers have been presented.

In the announcement of the workshop we wrote: "Fluid mechanics has actively stimulated the development of superfast vector computers like the CRAY's or CYBER 205. Now these computers on their turn stimulate the development of new algorithms which result in a high degree of vectorization (scalar/vectorized execution-time). But with 3-D problems we quickly reach the limit of present vector computers. If we want e.g. to solve a system of 6 partial differential equations (e.g. for u, v, w, p, k, ε or for the vectors $\underline{u}$, $\underline{\text{curl } u}$) on a 50x50x50 grid we have 750.000 unknowns and for a 4th order difference method we have circa 60 million nonzero coefficients in the highly sparse matrix. This characterizes the type of problems which we want to discuss in the workshop".

When the first CRAY-1 (12,5 nsec cycle time) was delivered in 1976, it was an "exotic", a "supercomputer". It seemed that only a very few large research establishments would be able to afford such a computer. Now, roughly 9 years later, the CRAY-1 is history, it has been replaced by the CRAY X-MP (9,5 nsec cycle time) and the CRAY-2 is now on the market (4 nsec cycle time). But the most unexpected thing in this development is, that circa 70 CRAY-1's have been delivered. From the other "early" vector computer which reached commercial significance, the CYBER 205 of CDC (20 nsec cycle time), circa 30 units have been delivered. In Germany in the field of research there are presently installed 4 vector computers at universities and 3 vector computers in research establishments. In the USA a program has been initiated to give access to all universities to vector computing centres. In the commercial sector all large industrial companies in the field of aircraft, automobile or oil will have one or several vector computers if they do not have already.

Ultimately the extreme computational speed of the vector computers results from the parallelism which is inherent in most largescale computations (mostly this is some form of matrix manipulation). But the programmer has to write his programs in such a form that the vector computer is able to transform the language instructions into vector operations, otherwise it will compute only in scalar mode, i.e. like a usual general purpose computer. But we are still on the way to learn this "parallel computing". In this sense the goal of the workshop was to put together the experiences of the participants that they might present their own experiences to the other participants and, on the other hand, learn themselves from the experiences of the others.

We have mentioned above that a 3-D grid of 50x50x50 is the limit for the present generation of vector computers. But for the description of the flow around an automobile or a whole aircroft in sufficient details a grid of 500x500x500 would be needed. This requires the 1000-fold computational speed of the present generation of vector computers. If we denote the first generation by the "100 MFLOPSgeneration" (MFLOPS=million floating point operations per second), we have now by the recently announced CRAY-2 the 1 GFLOPS (GFLOPS= 1000 MFLOPS), around 1988 10 GFLOPS and perhaps 1992 the 100 GFLOPS. This will be possible only by a new type of parallelism: the multiprocessor vector computers. But these speeds can be achieved only if the main memories are large enough or if there are fast and large enough secondary storages to store the immense data sets of such large problems. The development of superfast computers will surely never end. Neil Lincoln who has designed the CYBER 205 and who is now designing the successor, the ETA[10], gave the following definition of a supercomputer: "A supercomputer is a computer which is only one generation behind the requirements of the large scale users". These remarks may conclude the definition of the background of the workshop.

The papers of the workshop are not presented in these proceedings as usual in alphabetic order of the authors. We had composed the program of the workshop by grouping the papers according to the subjects which were treated, to the vector computers and type of solution methods which were applied. And in the same sequence the papers are presented in these proceedings. We decided also that the participants should write their papers immediately after the workshop and that they should include suggestions which were obtained from the discussions. In this way, most recent results have been included.

In an introductory paper the hard- and software of the most relevant vector computers with their typical properties and deficiencies are presented. Then a group of 6 papers deals with the full potential and Euler equations. It is very informative to see how these problems are treated on the different types of vector computers by different types of discretization methods. Then follows a paper which treats the shallow water equations. The solution of the 2-D and 3-D Navier Stoker equations is presented in a group of 6 papers. Then follow two papers of the field of meteorology and climate modelling. A further paper reports on experiences with the testing of different linear algebra algorithms on vector computers in the frame of CFD problems.

In the final paper which was ultimately worked out during the workshop a summary and a conclusion of the workshop are presented. This paper tries to classify the problems which were treated on the different vector computers and the methods which were used, states the problems and points out the direction which further developments should take. We hope that these proceedings of the workshop will enable the reader to profit in the same way as we did from the cumulated experience which was gathered at the workshop.

June 1985 Willi Schönauer Wolfgang Gentzsch

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