Physics with Ape100: first experiences

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Abstract

This paper resumes the APE100 parallel architecture, sketches out the dynamic problem adaptable APE programming environment, outlines results obtained in several areas of theoretical physics using the first prototypes of the machine and mentions other starting and promising areas of APE100 application. APE100 is a SIMD massively parallel tridimensional mesh of processing nodes based on custom VLSI building blocks. Modules with 128 nodes and performances of 6 Gigaflops are available, and a larger machine (2048 nodes and 100 Gigaflops) is foreseen for the first half of 1993. Big efforts have been spent to make APE100 a reliable and easily programmable computer. Programs are written in an innovative and problem-adaptable evolving language, which allows the definition of new syntaxes, data types and operators. The presently existing APE100 machines are mainly used in LGT simulations. Moreover we have started to use APE100 in other areas of physics, such as fluid dynamics and neural networks. Low temperature crystal simulation and conformational analysis of polymeric structure seem also promising areas of application.

APE100 Hardware and Operating System Architecture

Ape100 is a Single Instruction Multiple Data (SIMD) massive parallel computer with a tridimensional architecture based on a cubic mesh of nodes. The APE100 architecture [1] is scalable from 8 to 4096 nodes. Each node is composed of a floating point custom VLSI processor [2], a 4 to 16 Mbytes RAM bank and a custom chip containing the logic for node-to-node data communication. Each node has a peak performance of 50 Megaflops so that the 2048 nodes configuration reaches the speed of 100 Gigaflops, while a 128 node configuration has a peak performance of 6.4 Gigaflops.

Each group of 128 processing nodes is mastered by a controller and housed in a crate. The controller is presently based on a scalar processor named S-CPU which controls the program flow sending instruction microcode and data addresses to the processing nodes. The controller has its own data memory, program memory and registers. We have recently developed a custom VLSI chip (Z-CPU) to integrate the controller functionality on smaller boards.

The APE100 hardware architecture consist of a synchronous computing kernel (controllers and processing nodes) and an asynchronous interface serving the purpose of machine management and communication with the host computer. The crate asynchronous interface is located on the same board hosting the controller.

The APE100 Operating System [3] is composed of two sub-systems, the first running on the asynchronous part of the machine and the second running on the host computer APE100 is connected to.
The Problem Adaptable Programming Language of APE100

Some of us have defined a theoretical framework for "evolving grammars" and "dynamic compilers" [4]. Dynamic compilers are compilers able to follow the evolution of a grammar during source program compilation. Dynamic compilers and growing grammars allow the compilation of programs written in problem adaptable programming languages. Moreover dynamic compilers easily perform purely syntactic strong type checking and operator overloading. A dynamic parser ("Z₂ Parser") has been developed and has been successfully employed by the APE100 group to develop the APE100 compiler, the symbolic debugger and other system software tools.

Using the dynamic parser Z₂ we have built a number of modular language extension libraries. The QCD extension library ("qcd.hz"), for example, defines the compilation rules for QCD specific data structures (e.g. su3 and spinor data types) and makes available an appropriate set of QCD specific statements and operators (e.g. gamma operators, multiplications of su3 "variables", ...). Other problem specific language extension libraries have been defined for fluid dynamics, neural networks and for other promising areas of application of the APE100 machine. The starting language itself is defined in a language extension library ("std.hz"). This base language is very similar to a new generation fortran language with parallel support instructions, flow control instructions and integer, float and complex data types and operators.

The programmer may use the Z₂ dynamical compiling features to incrementally extend the APE language predefined packages, adding new syntaxes and features suitable for his/her application.

The APE100 software structure aims at an explicitly parallel environment. The underlying idea is that the end-user is the best candidate to parallelize any algorithm that must be ported on APE100. Last but not least, compiled codes are optimized. Efficiency of about 70-80% are achieved on computation intensive parts of LGT programs and several other programs.

First Results in LGT

The main target of the APE100 architecture project is to be adequate as a new generation LGT simulation engine. The first 128 node APE100 subsystem has been actively used for LGT simulations (quenched fermions approximation) since april. This subject is in fact most appropriate for the 128 nodes configuration, which has enough memory space for rather large lattices (up to about 32\(^4\) ) but still lacks the processing power needed for a reasonable treatment of full fermion dynamics.

Results have been obtained on a 18\(^3\) * 32 lattice, with emphasis on the fermionc sector. The standard Wilson action has been used, as well as the improved (so called 'clover') action for the fermion fields. About one hundred fermion configurations have been analyzed, and values of the decay constant of the scalar and pseudo-scalar mesons, as well as the lattice parameters relevant to the CP violating K-Kbar system have been measured.

For a detailed report of these first results, see ref [5]

Fluid Dynamics using APE100

The APE100 architecture is almost equally effective in other computation-intensive areas of theoretical physics, for example in the fields of Fluid Dynamics.
Two different areas in fluid dynamic are currently under investigation: the Lattice-Boltzmann approach to solve the Navier-Stokes equation [6] and the solution of flows of fluids described by Navier-Stokes equations around 3-D bodies (using grids of arbitrary shape) by means of an explicit Runge-Kutta time stepping scheme.

The Lattice-Boltzmann approach is an improvement on the cellular-automata techniques proposed in the past to mimick viscous flow. This style of computation is optimally suited for the APE100 architecture, since it shares all properties of locality and homogeneity typical of LGT system. Furthermore typical systems are very large in terms of lattice points (say 512*512) so inter-node communication bottlenecks are less important than in LGT.

Studies of thermally induced convective systems in two dimension (Benard cells) have been performed, and averages on the correlation functions of temperature and velocities in the limit of large Rayleigh numbers have been measured.

Neural Networks with APE100

The simulation of some models of neural networks is another example of efficient use of the APE100 architecture [7].

We were attracted by the the simulation of completely connected neural networks because these are models of systems having a total connectivity, while the APE100 architecture bases itself on a mesh of processing nodes that are only connected with the first neighbouring processors in a tridimensional mesh.

We found out an efficient way to execute the multiplication of big non sparse matrices and non sparse vectors on APE100 machines. Using this method we have developped efficient APE100 codes for Hopfield and Kohonen pattern recognition models.

Other Promising Areas of Application

There are some other areas in which coding activity is running. Low temperature crystal simulation [8] and conformational analysis of polymeric structure [9] seem two particularly promising areas of application of the APE100 machines. At low temperatures each crystal atom is moving around a fixed spatial position, subjected to Lennard-Jones interactions with neighbouring crystal atoms. The way to write an APE100 code simulating the dynamic of such a system is straightforward and can lead to efficiently running codes. The conformational analysis of polymeric structures aims to predict the 3-D structure of complex polymers. It needs the evaluation of a potential containing Coulombian and Lennard-Jones like contributes describing the interaction between all atom couples.

Machine availability schedule

A module that contains 128 nodes, with 512 MegaBytes of memory and a peak performance of 6.4 GigaFlops has completed all tests in december 1991 and is heavily used for physics programs since april 1992. Two smaller machines are intensively used for system and applicative software development since march 1992. Another 128 nodes 6.4 GigaFlops modules should be completed within september 1992, while the completion of two other 128 nodes modules is planned for november 1992. We plan to complete the first 512 nodes 25 GigaFlops machine during the first quarter of 1993, while the first 2048 nodes 100 GigaFlops machine is expected by the second quarter of 1993.
Bibliography

C. Battista, "The APE100 Supercomputer", proceedings of Computing in High Energy Physics (Tokyo, Japan, 1991);


[5] The APE collaboration, talk presented at LATTICE 92, Amsterdam


