started in CERN – the European Centre for Nuclear Research in Geneva, Switzerland – in 1989 to serve the needs of international collaborations in high energy physics. As WWW pioneer Tim Berners-Lee said at a recent meeting in CERN to see what lies ahead: "*The Web could have been invented anywhere, but there was nowhere better than CERN.*" Just see where it has reached today! With computers entering every aspect of life, children may start learning the alphabet reciting "*A is for Apple, B for Babbage (better, Boole?), C is for Cray, D for Digital…*".

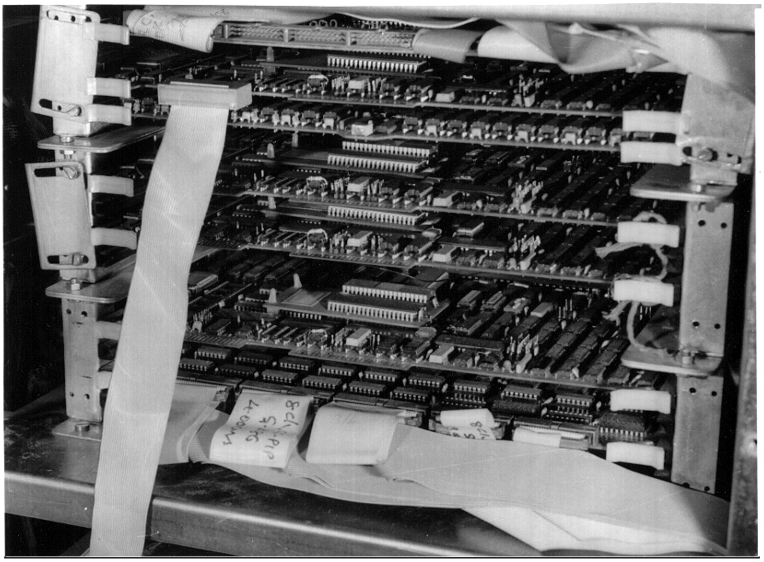
Amit Roy's series on Great Experiments in Physics turns to the Josephson effects in superconductors. Subhashis Nag in an easy humorous style uses college level vector algebra, calculus and mechanics to connect Archimedes and Gauss. Renee Borges tells us how and why plants change sex to follow changes in wind and weather, soil and sun.

On Parallel Computing – Indian Trends

Parallel computing is an excellent illustration of the power of team work. When processors act in unison, the symphony of computations make intractable problems computationally tractable. The distinguishing features are that these processors communicate and synchronize in addition to doing their own part. This, in essence, summarizes the spirit of parallel computing.

A large variety of computational problems arising in fluid dynamics, meteorology, electromagnetism, more generally all fields governed by partial differential equations, lend themselves naturally to parallel computing via domain decomposition techniques. The underlying idea is not new but its success has been made possible due to today's revolutionary microprocessor technology. Other techniques of computation (for example, spectral methods) are also amenable to parallel computing, but techniques are different and demands on the interconnection network more stringent.

By 1985, parallel computing had been recognized as a strategic discipline in US and Europe and many research projects (over 20) had already made substantial progress. In India parallel computing started in 1986 at the National Aerospace Laboratories, Bangalore when R Narasimha, then its Director, set up the Flosolver project with the specific objective to "design, develop, fabricate and use a suitable parallel processing computer for applications to fluid dynamical and aerodynamical problems." The first milestone was reached when the four processor Flosolver Mk1 became operational in December 1986 with all the system and application software developed in-house. By 1988, based on the recommendations of the Science Advisory Council to the Prime Minister, Government of India decided



FLOSLOVER Mk 1 (1986)

to promote this field, and since then CDAC's PARAM series has symbolized the Government's will to nurture this area of strategic importance, DRDO's PACE has been used for carrying out aerodynamic computations for missile configurations through the parallel route and BARC's parallel computer ANUPAM has served to meet the Centre's computational demands. The arrival of IBM's SP2 around 1994 provided a much sought yardstick in the calibration of system software, in scalability and in the benchmarking environment for Indian parallel machines.

It is interesting to note that parallel computing meant different things in different parts of the world. In India it meant acquiring computing power that was routinely accessible in the US, while in the US it meant acquiring computing power well beyond the reach of the technology used in designing a sequential central processing unit. Therefore, while the US has continued to pursue petaflop computing at an unprecedented rate, the availability of middle level sequential machines (comparable in power to existing Indian parallel machines) in the post 1990 era, following the initial successes of the Indian efforts, effectively dampened the further growth of parallel computing in India.

If we consider the Indian scenario, it is fair to say that twelve years is a sufficiently long period to look at the trends, at least from my individual perspective, and that is what I propose to do in the next few paragraphs.

The early years were spent in building parallel computing technology; the primary objectives, then, were to build the machine, get the system software in place and have demonstration codes run on these parallel machines. These codes were capable of being run on the then available sequential machines, albeit at a slower speed. Languages and operating systems specially suited for parallel computing are still evolving. In the Indian context, it is the applications that have found larger attention. The Indian expertise in the field of parallelization of large application software has been recognized by international giants like IBM, SGI and Hitachi and the Indian software industry. The collaborative projects have been rewarding both intellectually and financially.

Typical snapshot examples of challenging problems, solved using parallel computing, which otherwise would have remained intractable, have been chosen to summarize the Indian trends in parallel computing in the last 12 years.

Example 1: Panel code. C L Narayana. National Aerospace Laboratories. Circa 1989–92.
Platform: Flosolver Mk2, Mk3 [1],
The panel code, a design tool for computing aerodynamic load on aircraft configurations is difficult to parallelize on account of the global coupling of the data. The existing capability of 500 panels was increased to 5000 panels for handling realistic aircraft configurations.

Example 2 : Direct simulation of Navier-Stokes. A J Basu and others. National Aerospace Laboratories. Circa 1991–92.
Platform: Flosolver Mk3, [2]
Direct simulation of Navier-Stokes equations (DNS), the latest numerical tool for understanding turbulence, was not possible in the country. Flosolver Mk3 provided this class of computing power and the interesting problem of an axisymmetric turbulent wake was solved using the spectral method.

Example 3: Weather code. Organizations: NAL, CDAC and BARC. Circa 1994–96.
Platforms : NAL – Flosolver Mk3, Mk4, CDAC –PARAM series, BARC – ANUPAM [3].
The only super-computer India could ever import was the 2 processor CRAY XMP - 216 for weather forecasting and it was appropriate that the GCM code running on CRAY should have been run on Indian parallel machines. It was a long exercise. But in the end, a one-day forecast could be computed in 60 minutes, not unreasonable from the forecasting point of view. In 1994 when the project started, it was thought impossible to run this code on any sequential machine available in the country.

Example 4: BHEEMA. Organization DRDO Circa 1994. Nagarathinam and others.
Platform : ANURAG [4]
BHEEMA (Boltzmann Hypersonic Euler Equation Solver for Missile Aerodynamics) is a hypersonic Euler solver of DRDO based on the kinetic flux splitting technique and used for aerodynamic calculations on missile configurations. Grid points of the order of millions were used.

Example 5: AMES (Aircraft Multiblock Euler code) and VASBI (Viscous Analysis Symmetric Bifurcated Intake Duct),Organization ADA. Circa 1994–96. K P Singh and others.
Platform: ANUPAM and PACE [5].
The calculations are related to the design of combat aircraft. The indigeneous parallel machines were the only options for making these calculations as imported sequential computers, even if available, would have plenty of preconditions attached and would be a great deterrent for the exercise.

Example 6: EURANIUM, Organization NAL. Circa 1996–98. S K Saxena and others.
Platform : Flosolver Mk3, Mk4 [6].
EURANIUM is a state of the art 3D Reynolds Averaged Navier Stokes (RANS) code capable of simulating hypersonic flow past complex configurations. On the available sequential machines, development of such a code would not have been possible.

Example 7: Climate Modelling. Circa 1996–98. Ravi Nanjundiah. Organization CAOS, IISc [7]
Using the available IBM SP2 parallel machine, climate modelling has been done at higher resolutions than those achieved elsewhere in the world. Such calculations are beyond the reach of sequential machines.

Finally, let us note a few trends:

- Microprocessor technology is still progressing at a rapid rate, e.g. the GCM-T80 code mentioned in example 3 can in 1998 be run on a single Pentium II processor [8].
- Parallel computing had a strong peak in the late 1980's and early 1990's but with the availability of powerful workstations, there was a sharp decline in the civilian sector as most of the problems were within the reach of these workstations. In contrast, USA kept working toward petaflop computing unhindered. Large scale computing is yet to take firm root in our country.

No society can afford to fritter away its gains in a strategic area. Therefore, corrective measures are being taken. Post-Pokhran restrictions have once again exposed our vulnerability in high-performance computing. Whenever sequential computing could not meet the demands, parallel computing flourished. Parallel computing holds the potential, for example, in transforming an Euler solver into a routine design tool. The RANS solver for practical applications and DNS for design of turbine blades are possible only through the parallel route. Such problems have to be addressed if parallel computing is to be put back on its old glorious track.

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Suggested Reading

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