Frontiers in Physics,
High Technology & Mathematics

Proceedings of the 25th Anniversary Conference

FRONTIERS IN PHYSICS, HIGH TECHNOLOGY AND MATHEMATICS

31 October – 3 November 1989

Miramare, Trieste, Italy

Editors

H.A. Cerdeira

Universidade Estadual de Campinas,
Campinas, Brazil
and
ICTP, Trieste, Italy

and

S.O. Lundqvist

Chalmers University,
Göteborg, Sweden
and
ICTP, Trieste, Italy

World Scientific

Singapore • New Jersey • London • Hong Kong

Published by

World Scientific Publishing Co. Pte. Ltd.
P O Box 128, Farrer Road, Singapore 9128
USA office: 687 Hartwell Street, Teaneck, NJ 07666
UK office: 73 Lynton Mead, Totteridge, London N20 8DH

FRONTIERS IN PHYSICS, HIGH TECHNOLOGY & MATHEMATICS

981-02-0172-9
981-02-0173-7 (pbk)

Printed in Singapore by JBW Printers & Binders Pte. Ltd.

FRONTIERS IN PHYSICS,
HIGH TECHNOLOGY AND MATHEMATICS

FOREWORD

This Conference which marks the 25th Anniversary of the International Centre for Theoretical Physics, has been planned as a gift to its founder: Prof. Abdus Salam, on the subject which he treasures most: science and technology of the highest quality.

During these twenty five years the Centre has seen and taken part in some of the important discoveries in physics. When the discovery was not immediately related to the research activities of the Centre, its directors took care that soon the news be spread on to the developing countries by means of schools, conferences, workshops, etc. Thus creating a friendly atmosphere where contact between the great physicists of the world became easy, with the aim of helping those from countries which resources were very limited.

The Conference was planned to present those subjects in physics, mathematics and high technology which have had the harder impact when projections into the future are thought today. In this way mathematics was represented by the theory of Minimal Surfaces, Direct Methods in the Calculus of Variations, and the Relation Between Physics and Mathematics, physics in its most basic areas by Spin Glass Theory, First Class and Second Class Difficulties in Quantum Mechanics, Quantum Phases and Angles, Tracing the Mechanism of Electroweak Symmetry Breaking, Fractional Quantum Numbers in Condensed Matter Physics, Neutrinos as a Unique Probe of Stellar Interiors, the Emergence of Structure in the Universe and the Dark Matter Problem, the Problem of High T_c Superconductors, Chaos and Turbulence, Adhesion and Fracture, and finally high technology by Engineering of Novel Semiconductors and Supercomputers.

This impressive representation of the science of today, which appears in this book, was particularly enriched by the work of the Chairmen who, specially chosen to match the speakers to ensure an interesting discussion, never deceived the audience. To them:

B. L. Altshuler
D. Amati
A. Aspect
J. S. Bell
E. Burstein
M. Cardona
J. Eells
A. Frova
E. Giusti
J. A. Krumhansl
A. K. Mann
K. A. Müller
M. J. Rees
D. P. Ruelle
D. W. Sciama

W. Thirring
A. Zichichi

and in particular to the late Prof. Edoardo Amaldi, we express our thanks.

We are very grateful to the Italian and International Authorities who participated in the event. To the other members of the Organizing Committee: L. Bertocchi, H. R. Dalafi, A. M. Hamende and E. Vidiz, as well as to Ms. A. M. Poropat who handled the secretarial work very efficiently. And last but not least, to the Staff of the Centre, without whose help this unforgettable event could not have taken place.

H. A. Cerdeira   S. O. Lundqvist

CONTENTS

SUPERCOMPUTING – POWERFUL TOOL FOR SCIENTIFIC DISCOVERY AND INDUSTRIAL COMPETITIVENESS

C. J. CONTI

It's a privilege to address this distinguished forum.

And I always enjoy returning to Italy.

As you may have gathered from my name, I am the descendant of Italians who emigrated to the U.S. two generations ago.

You are the scientific descendants of a long line of men and women who helped build the foundations for our knowledge of the physical universe today.

Torricelli, Volta, Galvani, Avogadro, Marconi, Fermi. It is a long and distinguished list of scientists and inventors.

Foremost, of course, was Galileo, the physicist and astronomer whose observations helped overthrow the medieval concept of the physical world.

I'm certainly not the genius that Galileo was. But my message has some similarities with his.

It is this: The supercomputer, like Galileo's telescope, is a powerful tool for scientific discovery, enabling us to see phenomena in new ways and to challenge old assumptions.

Between January 14 and 25 in 1611, not far from here, Galileo trained his telescope on the heavens and discovered four of Jupiter's moons.

His observations constituted the first clear proof that all heavenly bodies do not revolve around the earth.

ut Galileo never saw Jupiter as we can see it today with the aid of supercomputer-generated graphics.

In the video simulation we just viewed, we saw a day in the life of Jupiter.

The simulation was created on an IBM 3090-Model 600 mainframe with Vector Facility, a system with supercomputer capabilities in many scientific and engineering applications.

It required the analysis of 5,000 separate images of Jupiter returned to the earth by the space craft Voyager, and involved more than 4 trillion floating point operations on the 3090.

The resolution is about 100 times greater than Galileo achieved with his telescope.

Galileo could see the red spot in Jupiter's southern hemisphere only dimly.

What we now know to be a giant storm center roughly three times larger than the earth, Galileo believed to be a massive mountain.

The tape represents the highest resolution global coverage that exists for Jupiter and its cloud cover.

Still higher resolution may have to wait until the mid-'90s, when we receive data from the next space probe, launched earlier this month -- a space craft most appropriately named Galileo.

Viewing the tape, we see much more than a pretty picture.

We see images that give us clues to the physical and chemical properties of Jupiter's atmosphere -- clues that may ultimately be useful in understanding and predicting climatic conditions on earth.

With the aid of supercomputer simulation, we can investigate entities as tiny as sub-atomic particles or as immense as galaxies.

What thoughts might have been triggered in the mind of a genius like Galileo had he been able to view this galactic collision?

In 20 seconds, with the aid of supercomputer simulation, we have just witnessed a drama played out in space over 3 billion years.

Plotting the positions of the thousands of stars in the swirling galaxy involved 10,000 time steps, the manipulation of 1 billion bits of data, and calculations that would take up to two years on a minicomputer.

Like the image of the revolving Jupiter, this simulation was constructed by a vectorized 3090 at the Cornell University Supercomputer Facility in Ithaca, New York.

So today's supercomputers give us tools for scientific discovery undreamed of in Galileo's time.

First, they enable numerically intensive computing that was simply not possible then.

Calculations that would have required centuries for teams of mathematicians in Galileo's day, can be accomplished on supercomputers in days, hours, even seconds.

In fact, it has been estimated that a large supercomputer installation today -- such as the Los Alamos National Laboratory in the U.S., or CERN in Switzerland -- can perform more calculations in a single day than all of mankind accomplished before the 1960s.

That's all of the calculations by all the world's people, using the abacus, pencil and paper, calculators, early computers -- and all 10 fingers and toes.

Put another way, a complicated fluid flow problem might take a modern supercomputer a matter of hours.

By contrast, an early vacuum-tube computer would have had to have run continuously since the early 1960s. And it still would not have completed the solution.

Second, and of transcending importance, supercomputers enable a new dimension to scientific investigation -- visualization, simulation, and animation.

They allow us to transform vast amounts of abstract data concisely and dramatically into images, enabling us to "see the unseeable," and think the previously unthinkable.

And they enable us to predict the future with a higher degree of certainty than ever before.

Satellite modeling of Mount Etna, for example, is being used by the Italian government to predict eruptions and the direction of lava flows.

However, as much as 90 percent of the numerical data beamed to earth from orbiting weather satellites is never analyzed. Pouring through the reams of numbers and trying to see patterns and relationships in the atmospheric data is tedious business.

But now supercomputer technology can convert the masses of data into digital images. Scientists can then manipulate the images to learn how a hurricane forms, for example, or where the ozone layer may be weakening.

Many scientific investigations and challenging engineering tasks, simply cannot be performed without visualization.

This 3090-generated image depicts the airflow over the surface of an F-15 airplane.

Such visualization is indispensable to engineers working on a new hypersonic plane that will fly at very high altitudes at speeds as high as Mach 25, or 24,800 kilometers an hour.

No wind tunnel can reproduce those conditions. So design and testing are done with computer simulation and graphics, which enable us to see the mathematics.

Visualization can also significantly reduce design time and result in safer structures.

This (showing slide) is a model of the bridge that will carry cars and trains 3.5 kilometers across the Messina Straits. It was generated by a vectorized 3090 at IBM's European Center for Engineering and Scientific Computing in Rome.

Because the area is swept by strong winds and has a high earthquake potential, the design allows for structural oscillations of 8 meters at mid-span.

An estimated one-third of the human brain is devoted to vision and visual memory. So engaging those senses can help scientists and engineers better understand complex phenomena.

And that can mean increasing the chances for inspiration and insight, and a significant acceleration of the rate of discovery.

I have a university degree in physics, and I'm involved on a daily basis with computer science.

I'm responsible for the development and manufacturing of IBM's large computer systems. At the same time, I'm also accountable for the revenue and profit of my line of business.

So along with my discussion of the impact of high performance computing systems on science, I hope you'll indulge me, as a businessman, in an occasional commercial for IBM.

I'm still sometimes asked when IBM will enter the supercomputer arena.

The answer is we're already there. We HAVE been for more than three years. And we expect to have an even larger supercomputer presence in the '90s.

IBM's largest computing system today is the 3090 with Vector Facility, which generated the videotapes and slide images used in my presentation today.

The Vector Facility, in effect, supercharges the speed of the 3090 by seamlessly integrating vector processing power with the superb scalar speed and parallel processing abilities that have made the 3090 the world standard for mainframes.

The 3090 with Vector Facility differs from most other supercomputers in that it can use all three types of processing power on a single problem.

This machine does not always deliver the highest megaflop numbers in the supercomputer industry.

It is, however, the most successful parallel machine in the world with supercomputing capability in a rapidly growing number of scientific, engineering, and industrial applications.

And it offers some considerable advantages over other systems -- very large memory, large input/output bandwidths; and the ability to efficiently manage entire supercomputing configurations, consisting of host processor, data storage devices, high performance workstations, and peripherals.

Having said that, we're well aware that a system like the 3090, for which the requirements are so demanding, must be continually enhanced.

In partnership with our customers, we're working particularly hard to improve the vectorized 3090's ease of use and its ability to interconnect with other systems. At the same time, we're making a major effort to expand our applications base.

And we've made substantial progress.

When we shipped our first vectorized 3090 in 1985, we had about a half dozen applications. By the end of this year, we will have more than 150.

In Europe alone, we have well over 100-3090 vector customers.

The list of industrial and commercial customers includes such well-known companies as Fiat and Banca D'Italia, here in Italy; Volkswagen of Germany; Electricite du France; Philips of the Netherlands, and Rolls Royce of England.

Our equipment is being used in Europe and around the world in a range of industrial supercomputing applications:

o By auto makers to design more fuel-efficient and safer cars.

o In the aircraft industry for aerodynamic stress analysis.

o By pharmaceutical firms, synthesizing new drugs by predicting, through supercomputer simulations, how molecules will interact.

o In petroleum companies for oil exploration using seismic analysis and 3-D models of underground oil and water movements.

o By manufacturers, for adjusting just-in-time production, analyzing inventories, and controlling quality.

o And in a range of other applications requiring the numerically-intensive, large memory, and graphics capabilities of supercomputers.

Just over half of our total worldwide supercomputing installations are in industry.