ParMA
(ITEA 2 06015)

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Exploiting the power of multicore architectures

The ITEA 2 ParMA project developed advanced technologies to exploit the power of multicore architectures and so deliver substantial performance improvements in high-performance computing applications. This greatly helps to achieve new goals in modelling and simulation and enables the development of innovative computer-intensive applications to accelerate research in many domains as well as speed the design of better products in industry. The ParMA technology makes it possible, for instance, to explore many more parameter combinations in the form of virtual prototypes, as demonstrated with the automatic 3D-combustion optimisation carried out by ParMA industrial partner RECOM.

Efficient computational power is a key differentiator in both research and industrial applications. It is instrumental for modelling, simulation and engineering design. For over 20 years, device manufacturers regularly increased processor performance by raising clock frequencies. When this was no longer possible because of problems with heat dissipation, power consumption and leakage, they decided to put several cores on the same die.

While such multicore architecture offers many benefits, it has forced software developers to parallelise their code. If this was not done, only one core would be used to run a sequential code and it would run slower since the frequency per core has been reduced. Moreover, simply parallelising the code is not sufficient. It is also necessary to balance the charge on each core and make the coding scalable so that it adapts automatically to the number of cores available.

Parallel programming is the key to taking full advantage of multicore architectures. However, existing parallel programming methods and tools were not able to cope with a high number of tasks or threads. The techniques available were diverse, could not be easily combined and only applied to main parallel programming techniques and on a limited number of platforms. Moreover, libraries were not optimised for the new multicore-based architectures.

In addition, most high-performance computing (HPC) applications had poor scalability and often existed in several variants – for example:

- One for shared memory systems with Open Multi-Processing (OpenMP);
- One for distributed memory systems with Message Passing Interface (MPI); and
- One for non-uniform memory access (NUMA) clusters with hybrid MPI and OpenMP.

HPC applications developers also had little experience of parallelisation in terms of how to restructure code and organise the data. At the same time, embedded software developers knew very little about multicore architectures – particularly in multiprocessor system-on-chip (MPSoC) devices.

CRUCIAL FOR RESEARCH AND INDUSTRIAL APPLICATIONS

A comprehensive, innovative, integrated and validated set of programming methods and tools was required to harness multicore architectures. Obtaining and maintaining such advanced technology was crucial for European research organisations and industry to improve competitiveness and independence. Indeed, it was essential to help the development of computing-intensive applications by providing advanced modelling and simulation capabilities. ParMA set out to meet this challenge.

Consortium members covered three categories:

1. *Simulation software* developers asked by customers to handle larger and more accurate models – they needed methods and tools to adapt and optimise their code to exploit fully the power of multicore architectures;
2. *Tools developers* who needed to extend, improve and integrate HPC development tools for debugging, performance analysis and code optimisation to help HPC software developers adapt and optimise their code to multicore architectures; and
3. *HPC platform and MPSoC-based embedded system providers* who needed to design and optimise multicore-based platforms to fit applications needs.

Partners included industrial HPC users, research organisations and supercomputing centres. HPC application developers focused on their own markets which included: 3D-combustion modelling; casting process simulation; metal forming and crashworthiness; avionics; and virtual reality in automotive and x-ray exposure dosimetry. Three partners targeted the MPSoC-based embedded systems market, including embedded network design and time-constrained applications.

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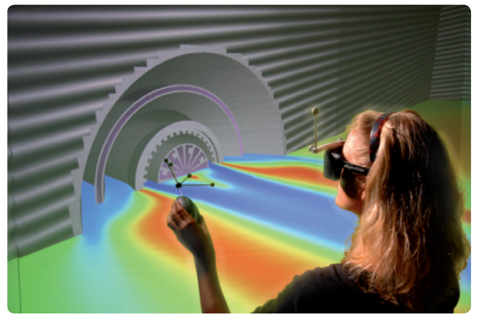
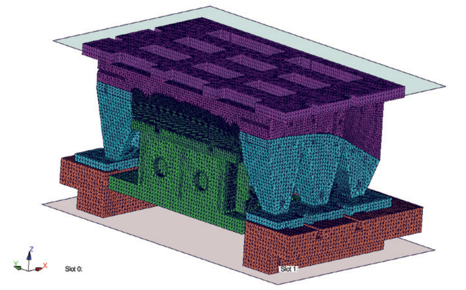
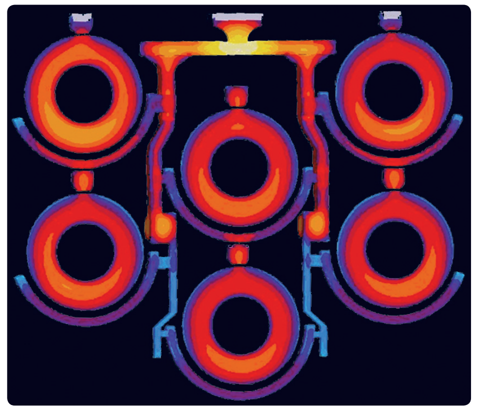
Simulation of a 3D-Boiler with RECOM-AIOLOS (Visualization of computational results)



3D - Model of entire molding press with several millions elements (GNS-INDEED)



Simulation of the solidification of a break disc pattern (MAGMA)



Bull provided the partners with a powerful common HPC platform – a cluster on which all tools were installed and where application developers could experiment with these tools. Thanks to the confidence gained among partners, industrial partners did not hesitate to give the research organisations access to some of their code, enabling them to understand industrial needs better and so help improve and optimise this code.

DRAMATIC PERFORMANCE IMPROVEMENTS

A series of advanced/new technologies/methodologies were developed. These included mature debugging and performance-analysis tools that have been integrated in a single package that is freely available at http://apps.fz-juelich.de/unite/.

At the same time, project partners dramatically improved the performances of more than a dozen industrial HPC applications. In addition, superior platforms emerged – such as bullx, partly optimised by ParMA, which was named as the world best supercomputer by HPCWire in November 2009.

The benefits of ParMA are manifold:

- HPC research organisations worked closely and unified their tools in a single package that has been presented at major HPC conferences. They are continuing to co-operate in new projects so that tools users are guaranteed continued support and evolutions;
- Developers learnt how to restructure and optimise code for multicore applications and obtained new contracts because of superior performance with their applications. Such applications are also much more versatile, able to run efficiently in various environments where before it had been necessary to maintain a variant per type of environment;
- Platform developers are able to stay competitive in their markets; and
- Research laboratories have gained industrial experience which they will put to work in various ways. This includes: creation of a two-year Master's course for simulation sciences and HPC development; and participation in Exascale Labs, recently created by Intel in France with Ex@tec, and in Exascale initiatives, such as the International Exascale Software Programme.

COMMERCIAL EXPLOITATION STARTING

The impact on the business of the partners has already been observed: The main one is customer satisfaction for simulation software tools. An important contract has been signed for instance by RECOM because work with ParMA resulted in a generic algorithm for an automatic 3D-combustion optimisation in a plant that involves several billion possible combinations of parameters. As a result, it is possible for instance to reduce fuel consumption, thus saving around €125,000 a year while reducing CO_2 production by 16,000 tonnes a year.

Other simulation software tool providers are also able to provide their customers with superior capabilities, resulting in better performance, refined simulations and more accurate models, and automatic automation.

A key outcome was the establishment of a closer relationship between the partners. As an example, before the project, the German tool developers operated separately, so their tools – MARMOT, KOJAK and VAMPIR – could not work together. For instance, they were using different trace formats so that the user who faced a difficult problem had to run each tool separately. As a result of ParMA, all these tools use the same trace format and interoperate. In fact, the UNITE package developed in ParMA makes it possible to install and use the tools as a powerful, comprehensive and integrated set of functions.

ParMA also benefited from simultaneous projects or initiatives such as VI-HPS and POPS which were working on some aspects that complemented and thus enriched the ParMA results. Several new projects have been set up subsequently that will continue this work in the framework of ITEA – such as 'hybrid parallel programming for heterogeneous architectures' (H4H), at national level with SILC and eeClust in Germany and at EU level with the Seventh Framework Programme (FP7) TEXT project.

More information: www.parma-itea2.org