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Partnership for Advanced Computing in Europe

SHAPE Project Algo'Tech: A Successful Switch to HPC

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Abstract

Manufacturers increase the use of electrical and electronic components in all kinds of products to provide new functions, improve performance and reduce the operational and development costs. The counterpart is the introduction of new constraints such as the electromagnetic vulnerability where the equipment functioning can be disturbed by electromagnetic effect. The perturbation can happen in various conditions: (1) Inside an electrical harness between power supply wire and command wire; (2) Between electrical harnesses; (3) Or because of external sources (electrical equipment, engines, Wi-Fi etc.) or natural ones like lightening. This concerns machine design, robotic assembly lines, devices for commercial buildings and public facilities, embedded systems (aircraft, trains, boats, tramways, drones), and in general, all automatic devices and electrical systems. To reduce the time to market, manufacturers need tools able to: (1) Detect bad electromagnetic effects as soon as possible: before prototyping, during the design phase; (2) Avoid cable shielding when it is not necessary: lighter equipment, less manufacture operations (welding). An electromagnetic simulator, integrated into an electrical CAD software suite, used during the design phase, on a simple PC connected to HPC, would allow the manufacturers to adapt the design to electromagnetic constraints before building the first prototype. As of today, they generally identify the problems during testing phase, if not on the customer site during the installation with all consequences behind that.

1. Introduction

Electromagnetic effects have very serious consequences in electrical and automatic devices like robots and vehicles that use sensors and other electronic components. These problems are growing as total reliance on electrical devices becomes increasingly common in every area: automatic machines, vehicles design, commercial buildings and public facilities, aircraft, trains, drones, robots, etc. In all these fields, European SMEs are offering more and more solutions and are therefore confronted by the problems of electromagnetism.

Today, electric and electronic gadgets are everywhere. These devices require special wiring, which provides electrical power for sensors, motors, computers, multimedia equipment, and other accessories. An electrical harness is a wiring configuration designed for specific wiring devices. A harness groups wires together and, most of time, extremities of the harness are electrical connectors. An electrical harness can contain wires dedicated to transmit command signals but it can also contain wires that provide electrical power. Electricity transmitted into wires implies electromagnetic effects. Moreover, wires can be the targets of an external electromagnetic effect (example: coming from other electrical equipment or from a natural event like thunder).

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It is possible to model the electromagnetic effects on the cables, wires, strands and electrical harnesses that make up the connections of electrical systems: we can define a sparse linear system to solve. The use of PC-type computers by SMEs allows them to solve small-scale problems. For example, if we take an installation made up of 100 wires 100 metres long, to obtain a good simulation, the wires have to be cut into 1-metre sections – in other words that makes a total of 10,000 sections. Each of these sections involves about 100 equations to model the electromagnetic effects (depending on the number of contiguous wires), resulting in a system of 1,000,000 by 1,000,000, a sparse but quite voluminous system of linear equations that needs to be solved 1,000 times to generate a sweep frequency (50Hz to 2GHz).

Such a system cannot be solved within an acceptable time frame on a PC. The aim of the solution is to produce the whole installation on a PC-type computer (desktop or laptop) and be able to connect automatically with a computing centre to quickly perform the calculations and recover the results for modelling on the PC. A preliminary study carried out by the Inria HiePACS team has concluded it was necessary to transfer calculations to HPC. This has been the subject of the present project in the context of the PRACE 4IP SHAPE initiative.

Solving large sparse systems of linear equations is a crucial and time-consuming step, arising in many scientific and engineering applications. Consequently, many parallel techniques for sparse matrix factorization have been studied, designed and implemented. Solving a sparse linear system by a direct method is generally a highly irregular problem that induces some challenging algorithmic problems and requires a sophisticated implementation scheme in order to fully exploit the capabilities of modern hierarchical supercomputers. In this context, graph partitioning and nested dissection approaches have played a crucial role. The PaStiX[1][2] solver has been widely used by industrial partners of Inria. The present project was the opportunity to demonstrate the efficiency of such an approach for a SME that has assessed and realized the technological leap needed for developing accelerated software using HPC facilities.

2. Presentation of the SME Algo'Tech

Created in January 1999, Algo'Tech Informatique is a Public Limited Company with a share capital of 401,000€. It has a workforce of some 15 people. Algo'Tech Informatique develops a range of software dedicated to professionals in the industrial and service sectors that is marketed in Europe and North Africa and which will soon be available in India and Brazil. The company's agencies in Paris, Bidart and Marseilles guarantee it a major presence out in the field. The company is much more than just a simple CADD software editor and has gained renown on the electrical circuit diagram market due to its innovativeness and software upgrades allowing us to propose cutting edge solutions that are suited to the requirements of the market. The R&D division of the company works mainly on the recovery and computerization of electrical circuit diagrams and simulation.

As well as designing CADD tools, Algo'Tech Informatique has designed a range of software solutions that are suited to all technical documentation and diagram-related requirements. Algo'Tech Informatique thereby provides specific and adapted solutions in three major areas: on-board wiring, industrial electricity, and service sector.

The customers of the company are at the heart of our software range. Its consulting business and the close relationship shared with its partners has allowed us to build tools that transcend standard electrical CAD solutions. Algo'Tech Informatique is the only software editor on the market providing the user with comprehensive solutions that cover the creation, consulting, updating and archiving of an electric diagram. Furthermore, with increased compatibility of formats and data, these solutions can be integrated into any existing system thereby increasing its value and durability. Elec'View, the most recent, adaptable and powerful graphic core on the market is the pivotal product of our range. The module-centered architecture allows us to design tools that are specifically suited to each business line and profession. All components in the range have been designed and developed based on three major strategies: simplicity, productivity, communication and integration. Algo'Tech Informatique is also developing tools to apply electromagnetic simulations on electrical harness in order to find the best position of the wires. As a result, no bad electromagnetic effects will require to change the design of the product and no additional weight will be incur due to non-essential shielding and armor of cables. This is a central topic to the present project.

3. Work performed

Manufacturers increase the use of electrical and electronic components in all kinds of products to provide new functions, improve performance and reduce costs. But it creates new constraints of which electromagnetic vulnerability. In fact equipment operations can be disturbed by electromagnetic effect. The perturbation can happen in various conditions:

- Inside an electrical harness between power supply wire and command wire;
- Between electrical harnesses;
- Or because of external sources (electrical equipment, engines, Wi-Fi, etc.) or natural ones like lightening.

Then there are different ways to deal with that: changing position and/or routing of the wires and cables, cable shielding with problems of costs, weight, etc.

This concerns machine design, robotic assembly lines, devices for commercial buildings and public facilities, embedded systems (aircraft, trains, boats, tramways, drones), and in general, all automatic devices and electrical systems.

To save time and money, manufacturers need tools able to

- Detect bad electromagnetic effects as soon as possible: before prototyping, during the design phase
- Avoid cable shielding when it is not necessary: lighter equipment, less manufacture operations (welding).

An electromagnetic simulator, integrated to an electrical CAD software suite, used during the design phase, on a simple PC connected to HPC, would allow the manufacturers to adapt the design to electromagnetic constraints before building the first prototype. As of today they generally identify the problems during testing phase when not worst on customer site during the installation with all consequences behind that.

For the purpose of conducting electromagnetic vulnerability studies, AlgoTech has developed such a numerical simulator, for which a major computational bottleneck is the solution of a large sparse system of linear equations. To overcome this problem, the aim of this SHAPE project was to use a state-of-the art parallel sparse direct solver, namely PaStiX, which has been developed at Inria Bordeaux-Sud Ouest for several years, into the Algo'Tech simulator. The features of the PaStiX solver should reduce both the memory footprint and the time to solution on computers ranging from multicore desktop up-to large-scale platforms.

In short, the Algo'Tech software provides an electrical model for the wire harness, which is translated into a sparse system of linear equations written in a matrix format, $Ax = b$, where the matrix size depends on:

- The number of wires into the electrical harness;
- The length of the wires combined to the frequency range selected for the simulation.

Representative data for different problems are given in Table 1 below.

Number of Wires	Length (meters)	Matrix [A]	Number of non zero terms into [A]	Memory (GB/Core)
200	1 m	[40 209 x 40 209]	164 568	0,130
	10 m	[398 409 x 398 409]	1 636 368	1,300
	20 m	[796 608 x 796 608]	3 272 519	2,700
	50 m	[1 990 608 x 1 990 608]	8 178 519	> 4,000
500	1 m	[101 038 x 101 038]	417 434	0,330
	10 m	[1 001 038 x 1 001 038]	4 150 634	3,300
	12 m	[1 101 538 x 1 101 538]	4 567 508	3,500
	20 m	[2 220 076 x 2 220 076]	8 301 268	> 4,000
1000	1 m	[202 153 x 202 153]	835 133	0,800
	10 m	[2 220 300 x 2 220 300]	8 351 330	> 4,000
1500	1 m	[303 440 x 303 440]	1 252 850	1,100
	10 m	[3 344 000 x 3 344 000]	12 530 000	> 4,000
2000	1 m	[404 434 x 404 434]	1 670 213	1,400
	10 m	[4 443 400 x 4 443 400]	16 702 130	> 4,000

Table 1. Evolution of need of memory according to number of wires and length of wires

In the context of this SHAPE project, Algo'Tech has modified its electromagnetic simulator in order to interface to the PaStiX solver and include the associated libraries. Some parallelization work has also been performed in the source code of the electromagnetic simulator in order to take advantage of multi-processors and multi-core architecture. The parallelization is applied twice:

1) To solve the large sparse matrix systems;
2) To run the solver on different data sources (frequencies) in order to obtain a wide scale of results (curves).

The new version of the electromagnetic simulator allows obtaining results of the electromagnetic simulation in a few seconds on a HPC system instead of a run that takes minutes or hours on a simple PC.

Moreover, in order to develop a cloud-based service to solve large scale electromagnetic problems that will be accessible simply and directly from the end user's computer, the matrix assembly and the solver steps have been embedded in a dedicated driver that can be easily deployed on a dedicated machine of the HPC center. This driver is in charge to build the different systems that have to be solved in the frequency range. Several strategies can be selected to solve these systems depending on the properties of the matrix, on the target architectures and on the features proposed by the PaStiX library.

However, PaStiX interactive usage is not optimal for most Algo'Tech customers who need to run hundreds or thousands of small jobs. Algo'Tech provided very valuable feedback during this beta program, which helped fixing a few minor bugs and finalize the final release.

Bull (Atos technologies) has provided to Algo'Tech Informatique an access to high performance center in order to improve calculation time of electromagnetic simulations. The test configuration is made of 26 nodes B510 SandyBridge 16 cores @ 2.60GHz + RAM 4GB/core, for a total of 416 cores linked by an InfiniBand switch. In order to measure time and assess performance, this configuration was available during 10 days. Figure 1 shows how the calculation time changes as a function of the number of cores. From these results, we can see that the best gain is obtained from 100 cores: the calculation with 100 cores is 5.6 times faster than the calculation with 16 cores, taking into account that the theoretical maximum gain is 6.25 (100/16). Table 2 and Table 3 detail some performance figures. The average of the real gain toward theoretical gain is 90% (Table 3).

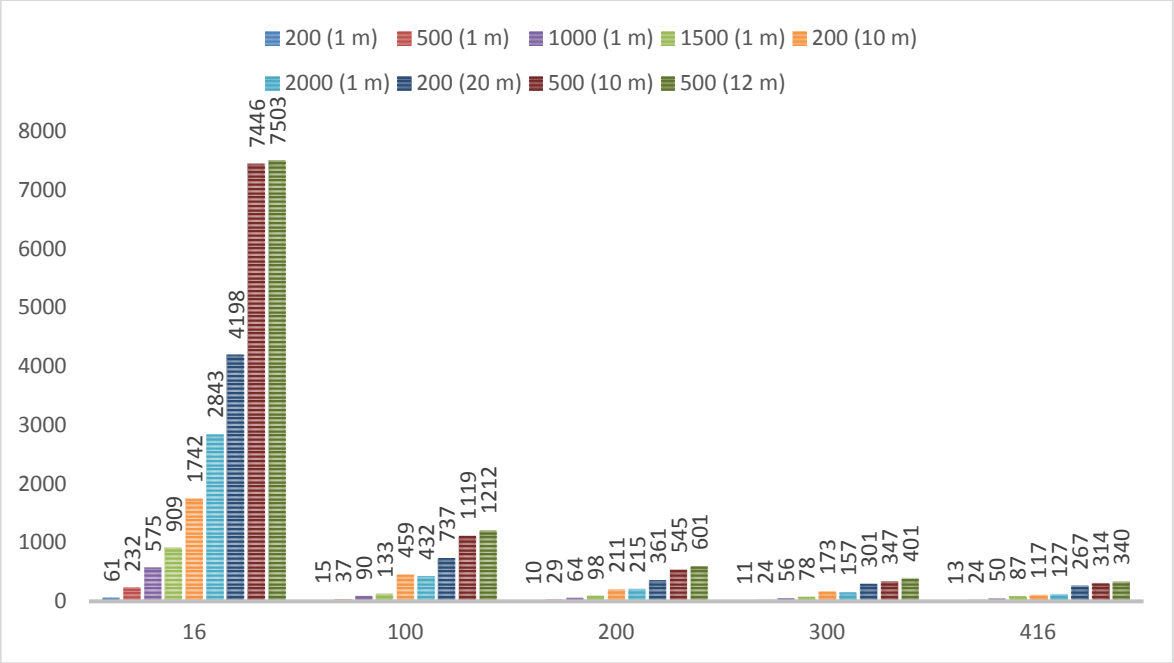

Figure 1. Runtime in seconds according to the number of cores for different test cases

Test case	Rte (16/100)	Test case	Rte (16/100)
200 (1 m)	4,1	2000 (1 m)	6,2
500 (1 m)	6,2	200 (20 m)	5,7
1000 (1 m)	6,2	500 (10 m)	6,2
1500 (1 m)	6,2	500 (12 m)	6,2
200 (10 m)	3,8	Average	5,6
Rte (16/100): Ratio of runtime of the calculations on 16 and 100 cores			

Table 2. Evolution of runtime according to number of wires and length of wires

Test case	%gr/gt	Test case	%gr/gt
200 (1 m)	65%	2000 (1 m)	99%
500 (1 m)	99%	200 (20 m)	91%
1000 (1 m)	99%	500 (10 m)	99%
1500 (1 m)	99%	500 (12 m)	99%
200 (10 m)	60%	Average	90%
gr : real gain gt : theoretical gain			

Table 3. Evolution of gain according to number of wires and length of wires

4. Benefits for the SME

Today, the simulator of Algo'Tech is able to use the sparse solver libraries of Inria and can run on HPC clusters. Thanks to the present SHAPE project, the company has access to HPC and can simulate real industrial cases, much larger than those usually considered and that cannot be treated on a simple PC. It leads to detect memory need, especially in order to process cases with wires longer than 12 meters. That is why some cases have no result. We are looking for solutions; a student is leading a thesis about electromagnetic models for simulation into Algo'Tech premises.

Discussions were held in order to find the best way to beneficiate from HPC for an application that needs an immediate connection to run a very short process (some seconds or minutes). Electromagnetic simulation is a step that does not exist today in the design process of electrical systems. If the simulator is commercialized, it adds a step in the design process but it must not increase the design time: we can suppose that customers will accept to pay only if the service is immediately available and provides results in a reasonable delay because if the simulation detects conflicts, the design has to be modified and tested again. Employees of SMEs used to work in a hurry and will not accept a new step in their design model that makes them waiting for days. HPC allows saving hours of runtime but this gain must not be lost waiting for days the schedule of the job. However, the simulator does not need high security transmission because data transmitted is only numbers into matrix and cannot be interpreted by an unwanted observer. The HPC offer is an important point for the success of the electromagnetic simulator: delay, charge and price must be convenient.

In terms of business plan this project has allowed Algo'Tech to reach 2 main objectives:

- Consolidate Algo'Tech's business case and the feasibility of its preferred business model (SaaS);
- Understand better what kind of issues the company will face to propose this solution operationally on the market – meaning by that how to be able to propose at reasonable price a "on demand" HPC.

Algo'Tech ambitions to have 10% of its business driven directly by the simulation in mid-term future and considers it will help them significantly on 15 to 20% of their current business (CAD software) by creating an important competitive advantage. Algo'Tech also expects to get business with large group out of current "arm reach", thanks of this simulation capability.

5. Conclusions

The electromagnetic simulator of Algo'Tech Informatique needs an HPC offer able to provide resources (at least 200 cores) quite instantaneously for a short job (some seconds to minutes). By mutualizing resources, a dedicated cluster for SMEs could provide the relevant HPC support for the simulator requirements and Algo'Tech Informatique already has customers who are interested in this simulation service.

That's why Algo'Tech and Inria worked together with the PaStiX software, developed by the HIEPACS team. Thanks to this transfer of skills funded and the help of the SHAPE project, this French SME has assessed and realized the technological leap needed for developing accelerated software using HPC facilities. As a medium-term objective, all the other software of Algo'Tech will also take advantage of supercomputing by progressively being ported to HPC systems.

"HPC represents a very promising way for resolving complex problems such as the simulation of sensibility of the equipment to electromagnetic effects. It also increases our range of skills and enhances our research and innovation policy, which is a cornerstone for Algo'Tech. Moreover, we strongly believe that "cloud computing" based services will benefit to SMEs having the same kind of problems to resolve and will contribute to the dissemination of HPC among SMEs, with direct positive effects". Jean-Michel Petolat, CEO of Algo'Tech said.

References

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