A SCALABLE HPC FE SOLVER FOR STRUCTURAL ANALYSIS.

DEVELOPMENT OF A FREE-SOFTWARE FOR THE PORTUGUESE INDUSTRY

Thesis Proposal MAP-i 2010/2011

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Research Units

CCTC – Computer Science and Technology Center

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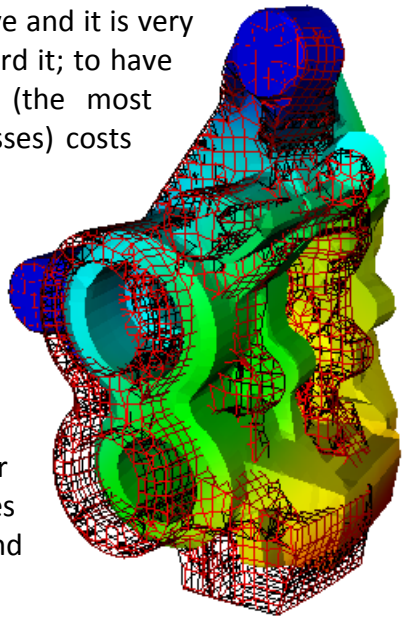
Framework

Structural Analysis in an activity of Computer Aided Engineering (CAE) in which, by using computers and Finite Element (FE) software tools, mechanical engineering tasks are carried out, beforehand any other activity of manufacturing or experimental try-out. From an engineering point of view, the use of finite elements in the structural analysis of mechanical parts and manufacturing processes can drive very important savings in all design process. As an example, automotive industry uses massively CAE software for the design of the automotive panels. A recent study shown that the cost savings obtained from the most advanced CAE tools can reach around 80%!

However, such numerical tools are very expensive and it is very difficult to the small sized Portuguese Industries to afford it; to have an order of magnitude, one licence of AutoForm (the most worldwide used FE solver to simulate stamping processes) costs around **80k€** per year.



DD3IMP (acronym of Deep Drawing 3D IMPlicit code) is a non-linear FE solver **already** developed as a sequential algorithm by one of the supervisors of this proposal; it was implemented in Fortran 90/95 comprising around 41k lines and 320 subroutines. DD3IMP is one of the most important world academic players in the field of non-linear structural analysis and sheet forming processes simulation, very up-to-date in terms of algorithms and constitutive description of metallic materials.

The potential industrial usage of DD3IMP is huge. However, the current sequential algorithm and its implementation is slow thus limiting its application to more realistic and larger problems.

Objectives & Strategies

The main goal of this proposal is to develop a high performance parallel scalable version of the DD3IMP FE solver, that enlarge its potential, both in terms of speed and size of the problems to be simulated, and consequently its industrial applicability.
The main expected tasks and achievements of the present proposal are:

1) A methodological study and evaluation of the current DD3IMP sequential code implementation:
    - to be aware of the importance of concurrency, scalability, locality, and modularity;
    - to evaluate scalability, and to identify bottlenecks and other inefficiencies;
    - use profiling and performance models costs to study the efficiency of the different algorithms;
    - to maximize the range of options considered, and try to reduce the cost of backtracking from bad choices.
2) In parallel as in sequential programming, there are many different languages and programming tools, each suitable for different classes of problems and algorithms. As so, we ponder the possibility to evaluate the following alternatives:
    - Fortran vs C vs hybrid programming
    - OpenMP vs MPI vs hybrid parallelization
    - Clustering /SMP/ GPUs vs hybrid architecture

3) The study and implementation of several speed-up algorithms, such as:
    - dynamically Hybrid FE meshes, which combines in the same mesh and dynamically interchangeable different FE such as membrane, shell, thick-shell and solid, in combination with re-meshing and re-mapping techniques,
    - new contact strategies
    - a modified Newton-Raphson algorithm
    - small ‘tricks’ to overcome the not so unusual problems of convergence of the implicit algorithms

In order to obtain, at the end of the project, a FE solver for non-linear structural analysis, which will be freely used by the Portuguese industrial companies, hoping to contribute to improve their competitiveness.