Grid-computing in Multi-disciplinary CFD Optimization Problems: the Challenge of Multi-physics Industrial Applications

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The advent of grid-computing technology fosters essential breakthroughs in current problem solving environments. While compute and data intensive applications requirements put severe demands on current computing systems, it is clear that the future of affordable computing resources lies in networked clusters of smaller, cheaper and cost saving computers. They have altogether the power of highly specialized mainframes for only a fraction of their cost. Examples of such systems, currently connecting thousands of powerful but smaller computers abound. They are supporting highly demanding applications, in the fields of simulation for powerplant systems, meteorological, biomedical and climate modelling, as well as complex engineering in the aerospace and automotive industries.

So far, these simulation applications were at best formed by complex sequences of simulation codes in particular domains of expertise. A nuclear plant would be modelled by a structural mechanics simulator, loosely coupled with thermal, fluid mechanics, chemical and electromagnetic simulators. This would entail long-lasting simulation runs on powerful mainframes.

While adequate parallelisation of part of these simulator codes improves performance significantly, tight coupling remains an open issue in such simulations due to the large number of variables implied in the various simulation models and the implied model updates it requires.

Besides, while innovative methods have proved relevant to simulation and optimization, e.g. evolutionary methods such as genetic algorithms and game theory, their impact is still limited by the huge amount of computing power required by some more traditional fields, e.g. mesh adjustment algorithms, although these also benefit from advances like domain decomposition.

In parallel with these technological breakthroughs concerning the methods and mathematical models used in simulation and optimization, several quantum leaps have also occurred in the last decade concerning the computer science arena.

The most recent are grid-computing and cluster-computing environments. It has been well publicized that they allow CPU intensive applications to run in fractions of the time required previously by super-computers formed by specialized hardware and software. And indeed, large production simulation environments include today tens of PC-clusters, each one in turn made of thousands of casual PCs, all connected by high-speed gigabits/sec networks.

This will undoubtedly change the future of simulation in the industry, because even SME are now potential clients of this affordable technology.

This talk is mainly oriented towards the cross-fertilization between the applied maths, simulation and optimization communities on the one hand, and the computer science community, on the other hand, in particular the grid-computing community.

In the first part, we put some recent advances in the computer science field in perspective, relative to the new era opened by PC-clusters, high-speed networks and grid-computing. We emphasize on the benefits of this technology in simulation and optimization

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applications, when parallel programming techniques are used to implement the core application codes.

In the second part, we detail some applications related to CFD optimization that can benefit from the grid-computing technology. We stress the need for an adequate use of innovative technologies to design and implement new methodologies in the area of CFD optimization. Examples such as multidisciplinary multi-airfoil optimization are mentioned to illustrate the challenges of current industrial needs : for example the optimization of multi-criteria (i.e., high lift and low-drag) devices made of leading edge slats, main airfoil element, and trailing edge flaps in landing and cruise configurations, coupled to noise reduction criteria in aircraft design.

We also emphasize on the user requirements, stressing the need for simple interfaces that alleviate the idiosyncracies of distributed computing to the application experts. It is clear indeed that defining, configuring, deploying, monitoring and maintaining distributed applications is not the expertise of the application engineers, therefore the interfaces should be automated and user-friendly to their best.

In the third part, we describe some potential multidiscipline optimization applications that require this technology to be practical in the industry, focusing on demanding industry needs for large scale, real-time and responsive dynamic simulation environments, e.g. digital aircraft mock-ups. Their impact on the organization of concurrent, hierarchically organized and overlapping projects is also mentioned, stressing the need for sophisticated project management approaches and tools, e.g. virtual organizations.

In conclusion we draw future research lines for the grid-computing technology and the multidiscipline optimization fields that promise to enlarge significantly their impact in complex engineering applications, such as aerospace design.