Newsletter

Simulation Based Engineering & Sciences

Year 11 n°2 Summer 2014

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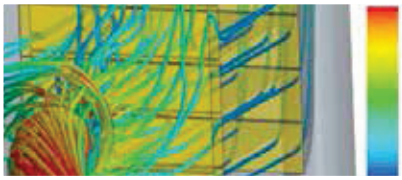
Interview with the Tuscany District President of **Railway Technology**

Saipem's further innovation in **Urea Technology**



HPE: Passion for **engines** and a great push towards innovation

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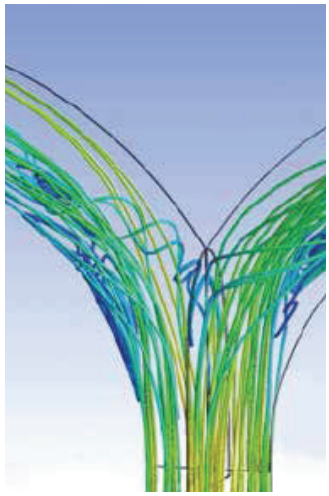
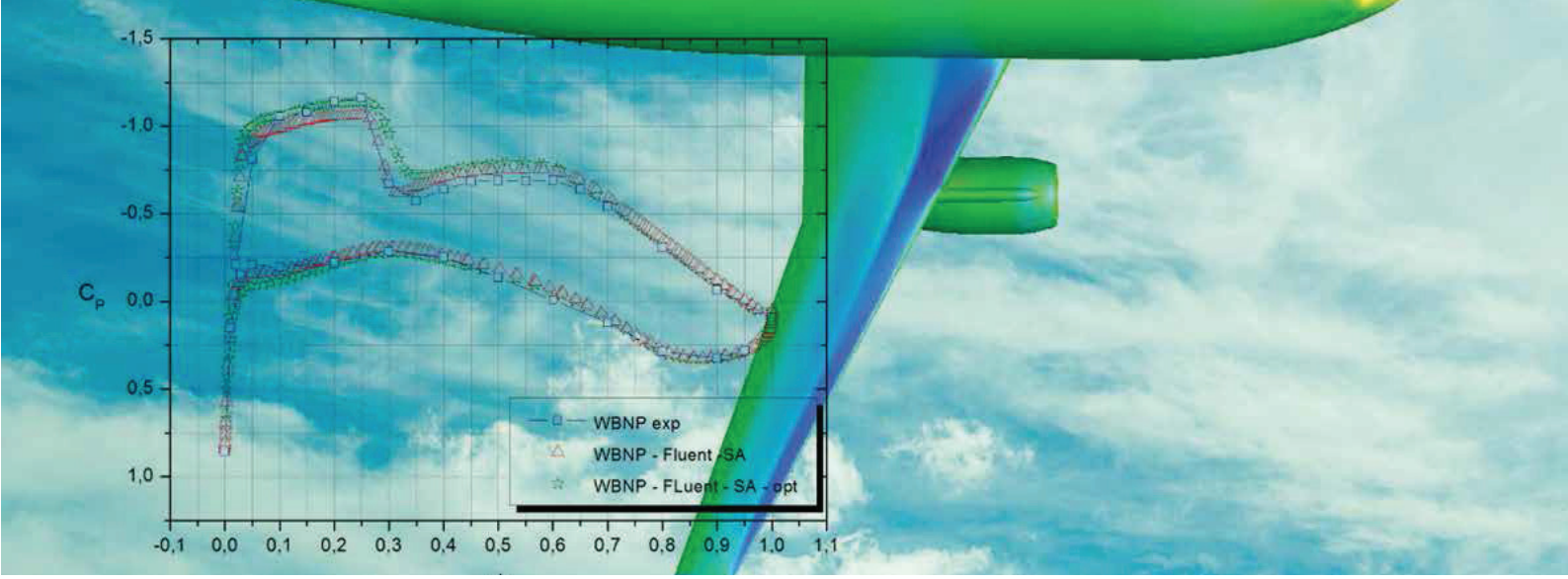




RBF Morph software – how to reshape the CAE workflow by Radial Basis Functions mesh morphing

The technological advancement and the continuous improvement of computational and numerical resources have unleashed, in the recent years, the adoption of innovative and powerful approaches to CAE problems that, in the past, seemed unbearable or even unapproachable. Together with a consistent increase in the simulation accuracy by means of an increasingly fine mesh size – in the range from tens to hundreds of millions of cells – CFD users have witnessed at the same time a shift of the analysis focus to a broader range of variants, allowing a deeper optimization that takes into account a greater number of different parameters. In this scenario – where DOE, RSM and adjoint methods are able to smoothly drive the simulation towards an optimal design – the mesh update process is often a bottleneck that cannot be underestimated. The analyst invests an important portion of his/her work to obtain, starting from the geometrical model, a validated numerical grid that reflects properly the trade-off between simulation accuracy and computational needs: creating new grids on the updated geometries is one of the most labour-intensive and time-consuming parts of the design, analysis and optimization workflow. Recent studies have proven that the time spent in the mesh generation process can take up to 70% of the total analysis effort. When dealing with a large number of design variations this process can become unbearable and, while for medium size models the mesh generation process can be partially automated, the remeshing noise should be also taken into account since its influence – even if small - could be mistaken for parameter sensitivity.

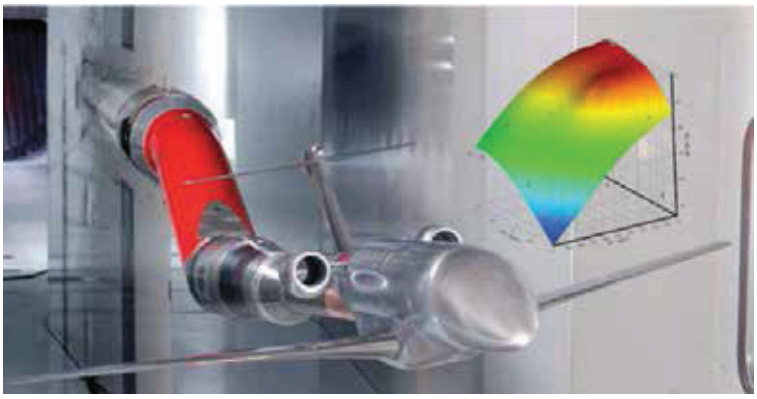


Fig. 1 - In research partnership with Piaggio Aero, an optimization study of a business class aircraft sweep angle was carried out. Lift and drag coefficients were exported to derive the efficiency as objective function using a MOGA algorithm for DOE and estimating the Kigring response surface. A 25% efficiency variation was observed in the design space and a 1% improvement was achieved.

Mesh-morphing has become an answer to this kind of requirement, allowing the rapid application of geometrical variations directly on the original baseline numerical models by changing the position of affected nodes and by propagating automatically such displacements within the surrounding domain. Numerical models can be modified without the need to create them from scratch, saving time and money. An award winning and well established approach to mesh morphing is exploited by RBF Morph, a morphing and shape optimization tool that, by using Radial Basis Functions (RBF), performs fast mesh morphing using a mesh-independent approach. RBFs are able to interpolate everywhere in the space of a function defined only at discrete points: nodal mesh positions can be calculated by imposing the displacements to a discrete number of points only. Since the method is mesh independent, a single RBF solution can be used to modify multiple meshes handling any kind of element, displacements can be amplified to obtain (at no significant cost) an amplified shape variation, and different solutions can be merged to obtain parametric and complex geometries.

Originally conceived as an ANSYS Fluent add-on, but now available also as a solver-free multi-platform standalone application with a dedicated

graphical user interface and as an add-on module fully integrated in ANSYS Mechanical, RBF Morph was born in 2007 in the challenging world of motorsports for an F1 top-team seeking a powerful tool able to quickly parameterize very large models with a high degree of control. With such a demanding application in mind, RBF Morph was first released as a commercial tool in 2009 and rapidly became a reference point in the CFD world, receiving the "Most Advanced Approach Using Integrated and Combined Simulation Methods" at that year's European Automotive Simulation Conference (EASC). Given their complexity, to this date RBF Morph is the unique industrial mesh morphing implementation of RBFs. The technology under the hood is indeed the result of a continuous development involving cutting-edge numerical algorithms and state-of-the-art research. This never ending evolution pushes a constant performance increase over time: the first software version, in 2008, was able to fit a 10000 point problem in 120 minutes while, two years later, the same problem required only 5 seconds. This massive firepower allows parameterizing a 100 million cell model in barely 15 minutes and, in the most recent GPU powered version, further raised the bar with a 40x speed up. Special efforts are in-hand to push parallelization and scalability even further: in fact, in 2013, RBF Morph received the Automotive Simulation World Congress (ASWC) award for the "Best Use of HPC".

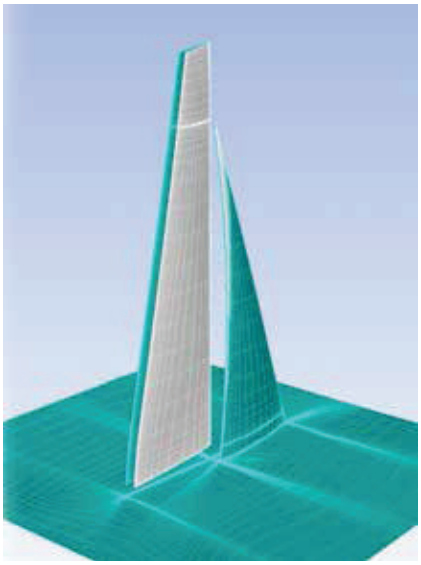


Fig. 2 - The study is focused on the use of mesh morphing to explore different trims of yachts sails, studying 16 configurations resulting from the parameterization of four trims of the fore and aft sail of a model-scale sailing yacht. The original full factorial map of 16 points was also replaced with a new reduced map of 9 points with an optimal space filling approach. In both cases optimal point was evaluated using a fine DOE with 41 levels for each parameter. The maximum thrust is achieved at the same trim for both metamodels.

While RBF Morph is a strong tool to perform optimization studies taking advantage of its best-in-class capabilities (complex shape optimization scenarios have been explored with some of the leading industries across diverse fields) this powerful mesh morphing tool can also be considered as a joining link between CAD and CAE, since it is able to parameterize the mesh directly in the solving stage and to update the shape both ways, reimporting back to CAD the modified shapes and imposing very specific shape variations via CAD with a high degree of control. RBF Morph can further be conceived as a missing link between different fields of physics, given its meshless ability to update numerical grids with various levels of refinement and element combinations. From this point of view RBF Morph can be seen as a glue that permits the linking of different solvers and results in multi-physics workflows.

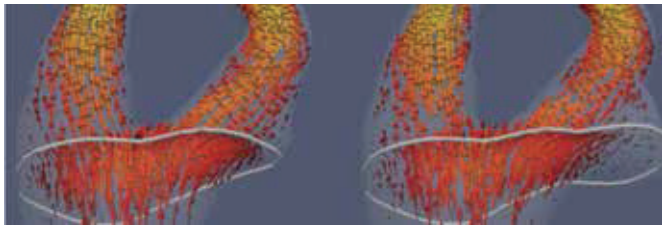


Fig. 3 - The CFD model of a carotid artery bifurcation was parameterized to simulate a carotid sinus aneurysm. The two images refer to a wealthy patient and a patient affected by the aneurysm, highlighting the hemodynamic flow differences introduced by the abnormal carotid shape.

Such features during the years have been exploited in various fields, with applications ranging from motorsport to marine, from aeronautical to medical. An interesting optimization study, leveraging morphing, advanced CFD simulations, high performance computing, and process automation was carried out by ANSYS in the 50:50:50 project supported by RBF Morph, Volvo and Intel, involving a 50 design point 50 million cell mesh DOE in 50 hours. Shape optimizations were also carried using shape parameters suggested by the flow through the use of adjoint solvers both in internal and external applications. RBF Morph has been used for the hemodynamic simulation of an atherosclerotic plaque evolution in a carotid sinus.

The FSI capabilities of RBF Morph were demonstrated to require only a 2% overhead despite the single CFD analysis. Recently, the steady aero-elastic method has been successfully implemented by Dallara on a GP2 and an Indy car. RBF Morph has been used for aeroelastic response studies of wing/store separation under both with steady and unsteady conditions. Unsteady FSI problems have also been successfully faced in complex rototranslating systems in helicopter rotor studies.

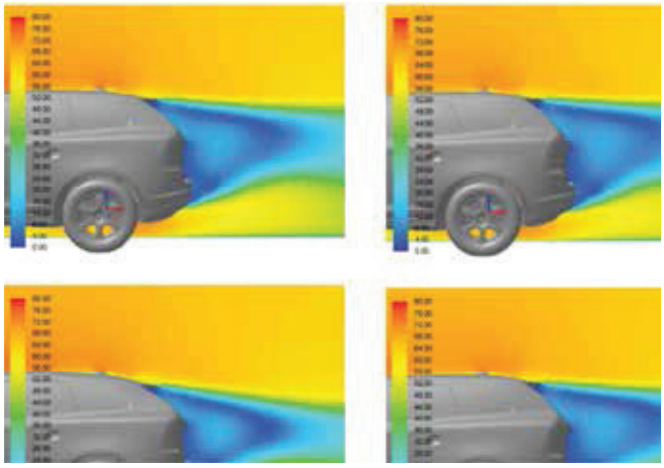


Fig. 4 - In collaboration with ANSYS, Intel and Volvo, a parametric optimization study involving 50 different design points, on a 50 million cells mesh in 50 hours was carried using 240 compute cores. The morphing task for each design point required only 69 seconds.

In partnership (UTV/RBF) with the University of Rome "Tor Vergata" RBF Morph started in 2013, a project, MorphLab, dedicated to the research in the field of mesh morphing where people, companies and developers can work together and share knowledge working on industrial applications. Moreover RBF Morph is involved in a number of research activities and co funded projects. UTV/RBF Morph is currently involved in the EU FP7 RBF4AERO project "Innovative benchmark technology for aircraft engineering design and efficient design phase optimisation" as a WP leader and technical coordinator. The RBF4AERO (www.rbf4aero.eu) project aims at developing the RBF4AERO Benchmark Technology, an integrated numerical platform and methodology to efficiently face the

Fig. 5 - In partnership with Dallara Automobili, and in the MorphLab framework, steady aerolastic response studies were carried on GP2 and Indy car models exploiting the modal superposition method. The first modal shapes were directly imported in the solving stage using RBF Morph and its integrated FSI module.

most demanding challenges of aircraft design and optimization.
Together with CINECA and HSL, UTV/RBF is participating in the EU FP7 FORTISSIMO project with "Virtual Automatic Rapid Prototyping Based on Fast Morphing on HPC Platforms", with the aim of developing a web-based environment and workflow in the field of shape optimization for virtual prototyping using adjoint solvers and morphing on HPC platforms. Moreover UTV/RBF Morph ranked first and is in the negotiation stage for the WP JTI-CS-2013-GRA-01-052 "Development and validation of methodologies and software tools for the implementation of accurate transfer of loads between numerical models" (RIBES) of the Clean Sky - Green Regional Aircraft EU Project.

Marco Evangelos Biancolini, Corrado Groth
University of Rome "Tor Vergata"

Header image - The study, performed in partnership with D'Appolonia, was carried on with the aim to improve the efficiency of a DLR F6 in a typical aeronautical shape optimization scenario. 8 different wing shape parameters were considered and 81 design points were studied by means of DOE methods obtaining an 1.67% efficiency increase for the best configuration.

EnginSoft, University of Rome Tor Vergata and RBF Morph commitment for the exploitation of mesh morphing technologies

We are very pleased to announce to our users, customers, partners and followers that in 2014 EnginSoft entered into a technical partnership with the existing relationship between RBF Morph and University of Rome "Tor Vergata" (UTV). This affiliation will enhance the integration of the RBF Morph tool with commercial software products provided by EnginSoft with a twofold objective. On the one hand, the aim is to reinforce the scientific research on RBF mesh morphing solutions for CAE applications and, on the other hand, to continuously generate and guarantee value-added offerings to each company's worldwide customers. RBF Morph and EnginSoft arranged the terms of this collaboration through an innovative Technical Agreement in which dissemination and technology initiatives will be jointly implemented by companies that are identified according to a proactive vision of the future needs of the scientific and CAE community.

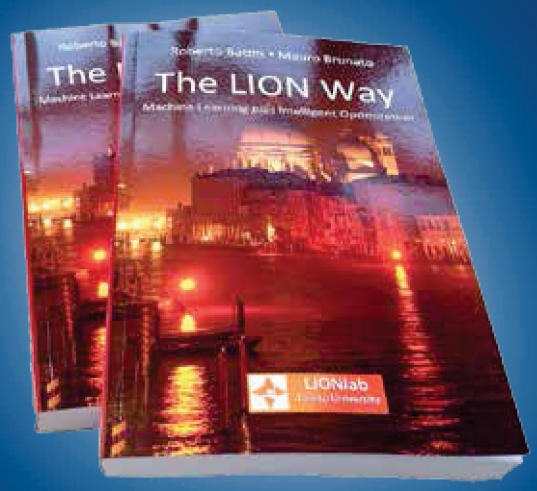
RBF MORPH at TechNet Alliance

Prof. Marco Evangelos Biancolini was invited to present RBF Morph at the "TechNet Alliance Spring Meeting 2014" that will be held in Malta on April 11th and 12th. This is the first important step of the new cooperation between RBF Morph/ University of Rome Tor Vergata and Enginsoft. The TechNet Alliance was founded in 1998 by a group of independent engineering companies and has grown into a worldwide network that allows its members, specialized in consulting, marketing, support and distribution of CAE software, to act as strong partners discovering new technologies and developing business contacts within the global CAE community. TechNet Alliance represents the very best in the CAE world and, to guarantee an enduring and strong collaboration, offers membership only by invitation to well-respected and successful selected companies.

The LION way

Machine Learning plus Intelligent Optimization
Roberto Battiti and Mauro Brunato
LIONlab, University of Trento, Italy, Feb 2014

This freshly printed book presents two topics which are in most cases separated: machine learning (the design of flexible models from data) and intelligent optimization (the automated creation and selection of improving solutions). Both topics are considered technical and we do not expect our book to be for the masses. But for sure, more and more innovative and bold people (lionhearted?) can now master the source of power arising from LION techniques to solve problems, improve businesses, create new applications.
Powerful tools are not only for cognoscenti and this book does a serious effort to distinguish the paradigm shift brought about by machine learning and intelligent optimization methods from the fine details, and it does not refrain from presenting concrete examples and vivid images.



For more information:
http://intelligent-optimization.org/LIONbook/