Shape optimization tools for CFD analysis: ANSYS Fluent, RBF Morph and modeFRONTIER.

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Summary

Mesh morphing has emerged as a meaningful technology given its ability to accelerate the Simulation Driven Product Development process. An effective industrial implementation of this method has been tested coupling three commercial tools: the CFD solver Ansys Fluent, the embedded morphing tool RBF Morph and the multi objective and design environment modeFRONTIER. A real life problem, the optimization of a motorbike windshield varioutouring, has been successfully faced in a typical design scenario, where calculations required by Fluent and RBF Morph are conducted on a parallel Linux HPC server, whilst the controller modeFRONTIER run on a simple Windows desktop tailored for office automation requirements.

Keywords

Shape Optimisation, CFD, Mesh Morphing, DOE, RBF

Introduction

Product developers must quickly perform and test numerous design variations in an environment steeped in complex customer requirements and short development cycles. Faced with increasing competition, companies have to produce higher performing products and deliver in shorter time frames to remain competitive. The need to innovate has never been greater.

Fluid dynamic optimization is however a very crucial task, especially for problems where the motion of a fluid has an important impact on performances. In fact, a slight shape modification can dramatically affect the behavior of a component that interacts with the fluid. CFD can give an important aid to drive the design of such critical components but a lot of effort is required if several configurations have to be considered.

Mesh morphing has emerged as a meaningful technology given its ability to accelerate the Simulation Driven Product Development process. This approach consists in studying the effects of shape modifications acting directly on the CFD mesh. Required modifications can be introduced by morphing the surface mesh at the boundary of the fluid mesh and propagating such deformations inside the domain by means of a smoother. Original mesh topology is preserved but the final quality of the mesh depends on the action of the surface morpher and the fluid smoother [1,2].

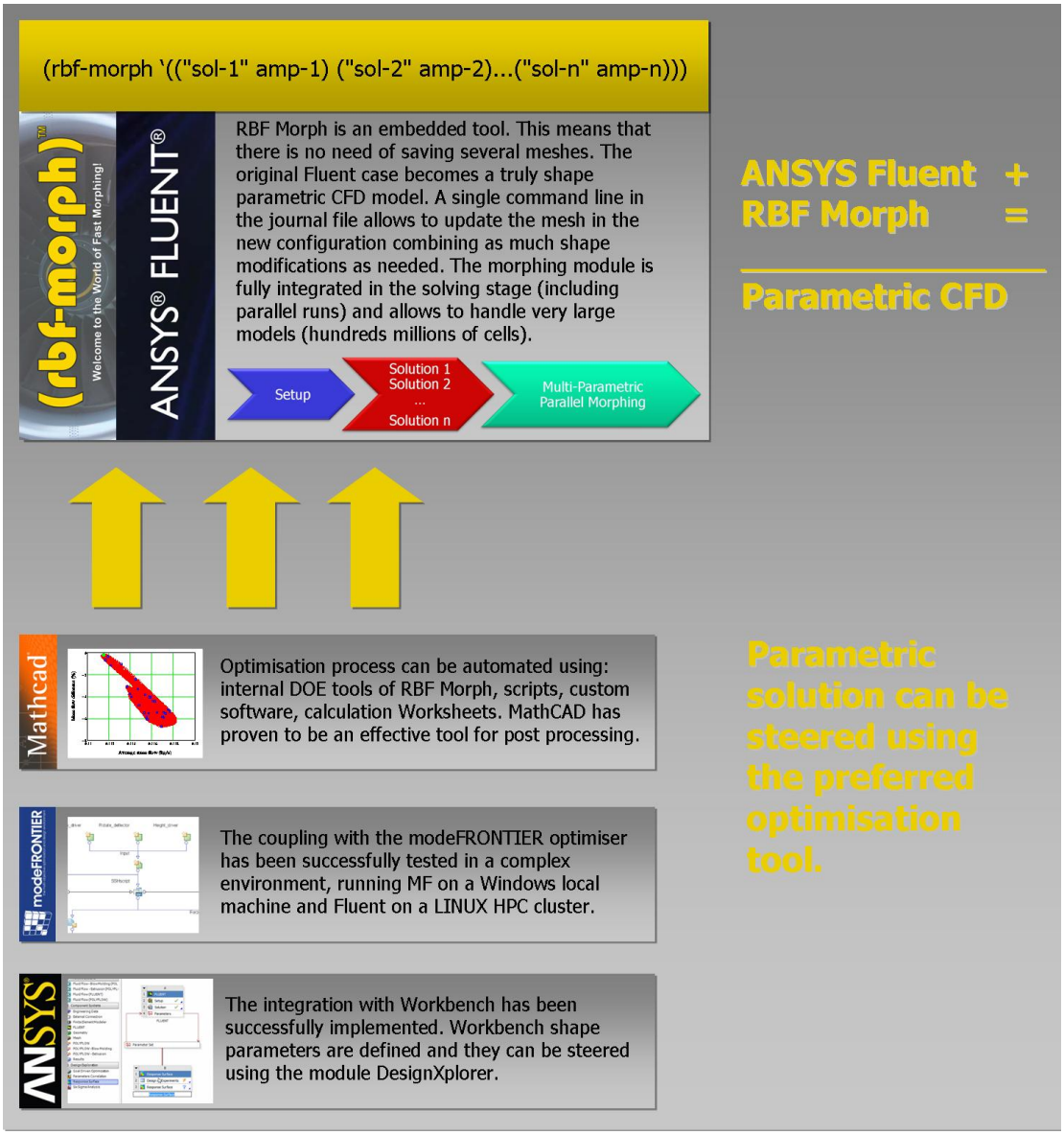

Figure 1: (left) ANSYS Fluent and RBF Morph combine to have a shape parametric CFD model that can be steered with any optimization tool; (right) RBF Morph Product features.

An effective industrial implementation of proposed approach has been tested coupling three commercial tools: the CFD solver ANSYS Fluent [3], the embedded morphing tool RBF Morph [4] and the multi objective and design environment modeFRONTIER [5].

RBF Morph

RBF Morph is a unique morpher that combines a very accurate control of the geometrical parameters with an extremely fast mesh deformation, fully integrated in the CFD solving process. The tool, initially released as RBF Morph 1.1 in July 2009, was presented at the European Automotive Simulation Conference [6] - where it has been awarded as the "Most Advanced Approach using integrated and combined simulation methods". The major benefit is the coupling with any optimization tool, including modeFRONTIER, that makes the optimization task effectively straightforward (Figure 1).

The RBF Morph add-on has been used to deform the original CFD model considering three deforming actions:

- changing of driver height;
- changing of driver position acting on the hunching angle (Figure 2);
- adjustment of the variotouring acting on the deflector angle.

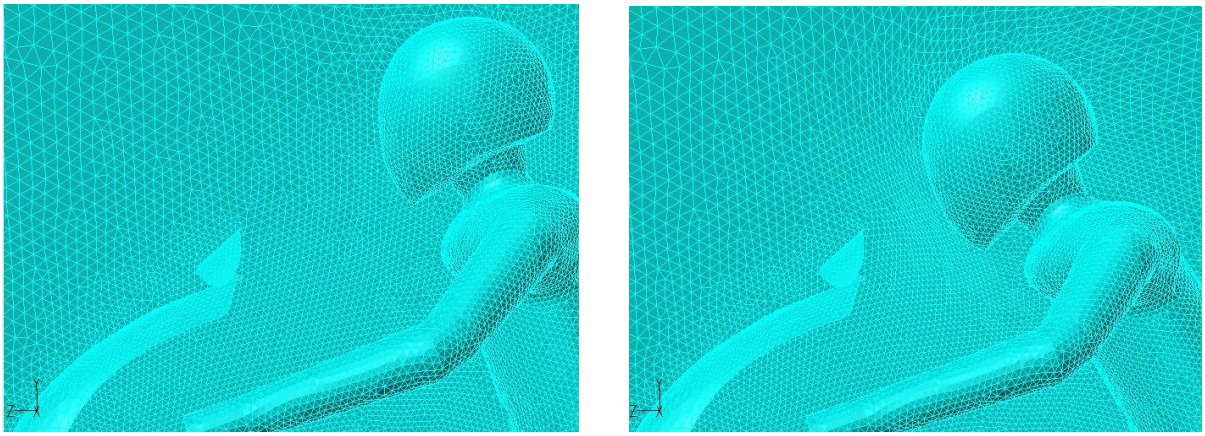

Figure 2:The mesh is morphed to change the driver angle of 15 degrees with respect to vertical axis.

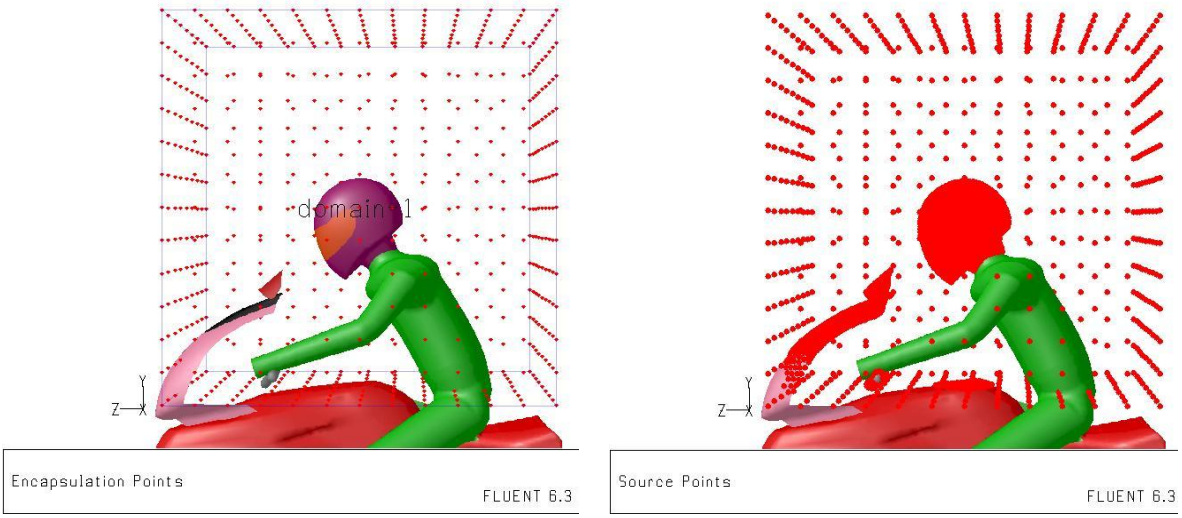

Figure 3:Set up step of RBF Morph. The morphed action is limited in the box region "domain 1" (left). The motion of the surfaces inside the encapsulation domain (right) is imposed to the points on the windshield (fixed), the fairing (fixed) and the helmet (moving).

The setup of each modifier has been performed using the GUI of RBF Morph; several tools are available for the definition of source points distribution and their movement (Figure 3). Thanks to RBF Morph the Fluent model becomes parametric. Of course this is not a new feature. Several parameters are available for standard Fluent analysis and usually they can be controlled by means of journal files and scripts. The new feature is that shape parameters become available and can be controlled basically in two ways:

- using the interactive Multi-Sol panel the user can set-up desired modifiers and amplifications (Figure 4);
- using the TUI command that is also available in batch and parallel mode.

For instance, considering the same modifiers of the example reported in Figure 4, the RBF-Morph batch command line is:

(rbf-morph '(("rotate-driver" 0.45)("rotate-deflector" -0.2)))

Industrial application: optimization of a motorbike windshield

A real life problem, the optimization of a motorbike windshield varioutouring [7,8], has been faced in a typical design scenario, where calculations required by Fluent and RBF Morph are conducted on a parallel Linux HPC server, whilst the controller modeFRONTIER run on a simple Windows desktop tailored for office automation requirements.

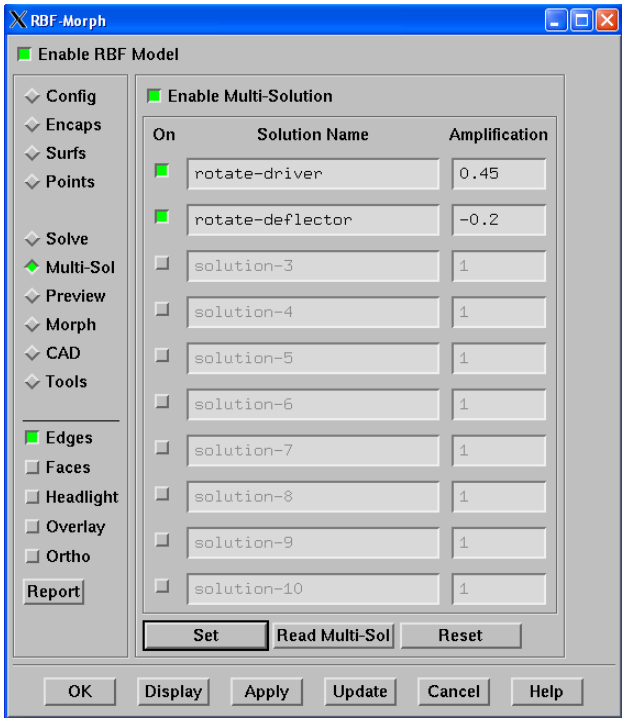

Figure 4: GUI of RBF Morph, Multi-Sol Panel. Up to ten modifiers can be combined using the GUI. The effect of the combination can be previewed on a particular area or can be imposed to the mesh (parameters can be tweaked several times thanks to the undo capability).

The design space has been explored according to the workflow of modeFRONTIER (Figure 5). A wise set-up of SSH node allowed to manage calculation resources. Thanks to the parametric mesh available within Fluent powered by the RBF Morph add-on, only one case file is stored on the server, together with configuration (.rbf) and solution (.sol) files for each modifier. A symbolic link to such input files is created for each simulation, removing the bottle necks experienced when input files are directly provided by modeFRONTIER as support files.

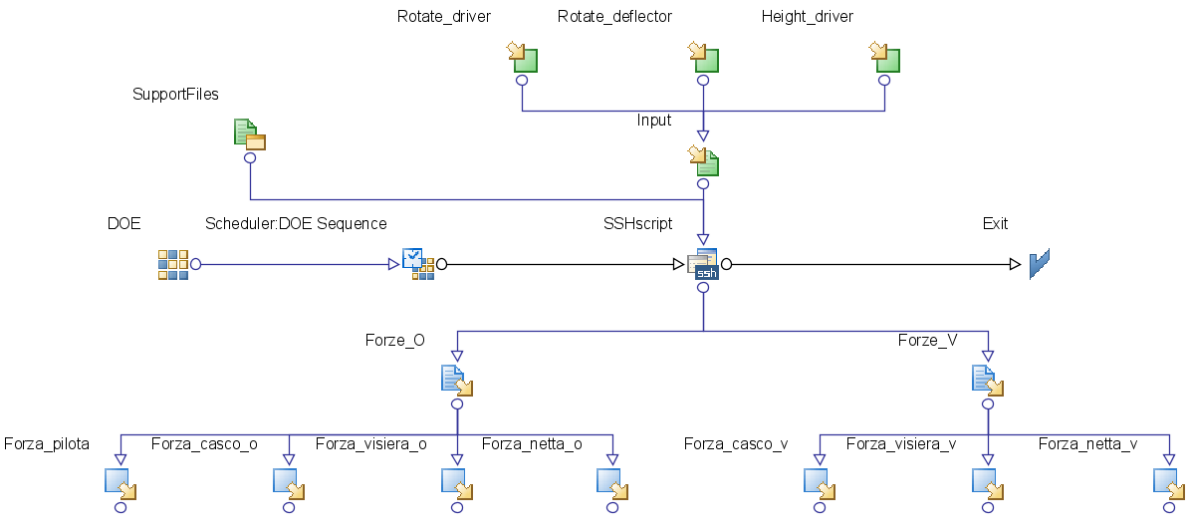

Figure 5: The optimization is controlled by modeFRONTIER workflow.

As can be observed in the results (Figure 6 and Figure 7) the proposed approach has proven to be very useful for the presented industrial application. An optimal deflector angle can be found for a prescribed height and position of the driver. Nevertheless, the windshield optimization project is still open and ongoing activities include the study of the effect of screen and deflector shape and the definition of comfort parameters (turbulence intensity, transitory analysis). A more challenging scenario will be faced because design parameter (affecting shape) will be optimized as a compromise for good comfort for a wide range of drivers heights and posture.

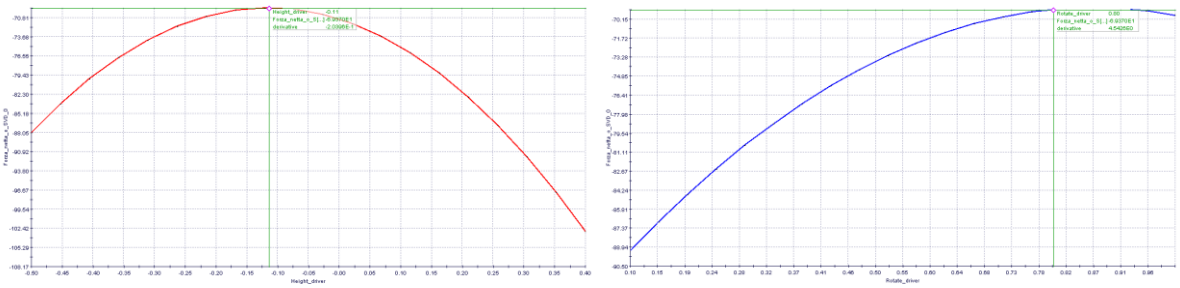

Figure 6: Design space has been explored investigating the response produced by a single parameter.

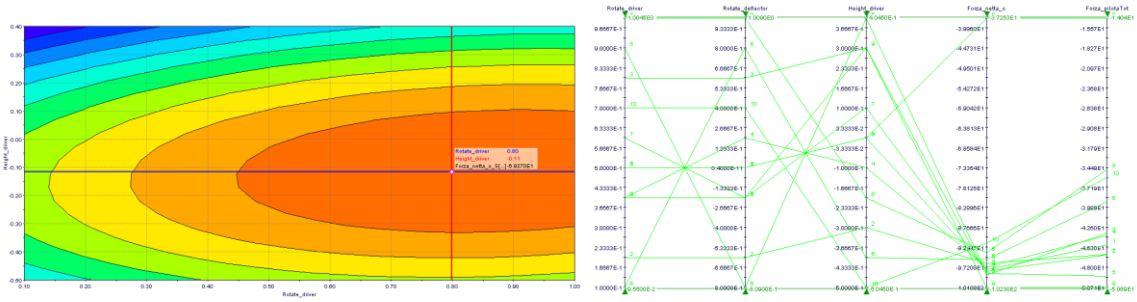

Figure 7: Design space has been explored investigating the cross effect of parameters by means of contour plot and parallel plots.

Conclusions

A shape optimization procedure for CFD problems has been successfully defined. The CFD solver ANSYS Fluent powered by the mesh morphing add-on RBF Morph allows to get a truly shape parametric CFD model; such parametric CFD model can be steered using the optimization tool modeFRONTIER. The approach has proven to be very useful for the presented industrial application demonstrating that a parametric motorbike model allows to define optimal configurations for driver position and windshield deflector angle.

The approach can be easily extended to a wide range of CFD applications considering that is based on general purpose commercial tools (modeFRONTIER, ANSYS Fluent, RBF Morph); furthermore the mesh-less nature of RBF Morph allows to further extend the integration to multi-objective multi-physics problems (for instance the shape of FEM and CFD can be synchronized right now)

References

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