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MANAGEMENT OF UNCERTAINTIES AT THE LEVEL OF PRELIMINARY DESIGN

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ABSTRACT

This work is dedicated to a study of uncertainties related to Computational Fluid Dynamics (CFD) computations. This is carried out in the European project NODESIM-CFD[1], starting in November 2006.
It is necessary to define what we call “uncertainties”. Following the classification generally agreed upon (see [1] for example), “error” and “uncertainty” can be defined as follows:

- *Error* is a deterministic concept and is defined as the difference between the true answer to a problem and the answer observed through a computation or a measurement.
- *Uncertainty* indicates that the result can be only known with a limited amount of confidence for a given level of precision. This uncertainty is an inherent property of the measurement technique or model description and is due to lack of knowledge

Since error is a recognizable deficiency, all errors are in principle at least, correctable and therefore deterministic. Since uncertainty is caused by a fundamental lack of knowledge, it cannot be eliminated. If a higher confidence level of the prediction is required, the result can only be given with less precision and hence there is a fundamental trade-off between confidence and precision. The distinction between the deterministic and stochastic nature is important when determining how each should be represented mathematically and propagated through the mathematical model, and hence dictates the methodologies to be developed.
Some inputs of the computation can be viewed as true aleatoric variables. Among the possible variations we have the actual shape of the geometry (tolerance of the manufacturing process, …). The first part of this work is devoted to shape uncertainty study using moment methods.
The First-Order Second Moment (FOSM) method, very popular in uncertainty analysis, uses a linearization of the function that relates the input variables and parameters to the output variables. This approximation occasionally leads to problems when the mean

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value of the input variables is close to a local / global extremal value of the function. In this case, the FOSM computes artificially a zero uncertainty because the first derivative of the function is close to zero. To overcome this, we have to use a quadratic reconstruction, instead of a linear one : second derivatives of the observation function are required (SOSM: Second-Order Second Moment method). In CFD this can be done by automatic differentiation tools (cf [3]). In [2] a general formulation for efficient Hessian calculation using automatic differentiation has been given but the formulation for fluid dynamics do not use grid adjoint solution. In order to study uncertainties modelized by CAD-features variations, we have developed a formulation involving both flow solver and grid adjoints.

One of the major sources of error is the discretization error. The second part of this work is devoted to anisotropic mesh adaptation.

With the adjoint linearization it is possible, for any given scalar output quantity, to identify those regions of the field which contribute the most to the error in that quantity. This information may be used to refine the mesh in a way that minimizes error in this output functional. In the following, we extend the isotropic formulation introduced in [4]-[10] to the anisotropic case.

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