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CAD-BASED LARGE SCALE SHAPE OPTIMIZATION METHOD WITH INTENSIVE SIMULATIONS

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Abstract

Within the framework of mechanical product shape design with fluid mechanics considerations, designers aim at finding an optimal shape with regard to a set of multiphysics constraints.

The development process of CFD is based exclusively using CAD models. Current design loops involve considerable modeling, adjustment, and re-design. To cover a larger design space, this loop is repeated sequentially several times. Advanced methods try to use an optimization on the CAD parameters that allows enhancing the shape, with the exception that the design space should be confined enough in order to be explored within a reasonable computational time. This limitation makes it very difficult to design a generic CAD model that adheres to a large neighbourhood of solutions. Due to the computational cost of large-scale parametric optimization, combined with the lack of parameterization approaches, roll-out methods in CFD optimizations face difficulties. The aim of this paper is to present a cutting edge method that tackles the computational complexity and the amount of necessary evaluations.

The proposed workflow schedule is based on a CAD model. That model is first defined by physical parameters without any restriction regarding their numbers. A set of several thousand geometries is chosen by using Design of Experiments techniques and are generated. Many CAD failures occur due to the generation of inadmissible geometries. These failures are due to either direct geometric constraints and so on that are difficult to express mathematically or a software bug. Input geometries are classified by using a Support Vector Machine technique with a rate of 90% due to software bugs. New geometries for simulations are chosen in this novel design space by a D-optimal design that seeks to minimize the covariance of the parameter estimates. Next, they are simulated by an automated process with a simplified continuum that allows saving computing time.

The CAD parameters are used in an auto-associative feed-forward neural network to create a limited set of meta-parameters which represent a combination of parameters having a similar influence towards the variation of objective functions. In fact, the design space is reduced intelligently and rapidly, browsing an interesting subspace close to the optimum. A similar action to decrease the number of initial parameters is run parallel and still on going. A voxellisation is applied on the input geometries of the simulations. To achieve this, a cubic grid with a pre-determined resolution is fixed and geometries are thrust into this grid so as to generate a binary matrix. Each element of the grid intersected with the geometry has a value -1, otherwise +1. A Principal Component Analysis is then applied on these matrices.

These meta-parameters obtained are used in a loop kriging-based method. Interesting points are computed by using the confidence intervals of the kriging and simulated with the full continuum. At the end, the design team can make better and faster choices.

The workflow schedule method explained above has been applied on shape optimization of a car body. The objective was to optimize the drag coefficient. The starting point of the worfklow was an IGES file, without any attached specific information. The coachwork was first parameterized as an initial step, next the workflow schedule discussed above was executed. Finally, the results were compared with ones obtained by experiments in order to prove the efficiency and accuracy of the method.