Knowledge Extraction from Aerodynamic Design Data and its Application to 3D Turbine Blade Geometries

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Applying numerical optimisation methods in the field of aerodynamic design optimisation normally leads to a huge amount of heterogeneous design data. While often only the most promising results are investigated and used to drive further optimisations, general methods for investigating the entire design data set are rare. It is our target to extract comprehensive knowledge from the design data concerning the interrelation between the shape and the performance of the design. The extracted knowledge is prepared in a way that it is usable for guiding further computational as well as manual design and optimisation processes.

For the design of complex aerodynamic shapes it is common to use different kinds of representations, what makes it difficult or even impossible to analyse the entire design data set. We suggest the transformation of the design data into discrete unstructured surface meshes and hence result in a homogeneous parametrisation of the designs. This makes it possible to analyse the design data independent of the representation used during the design and optimization process.

On the basis of discrete unstructured surface meshes we propose a displacement measure in order to analyse local differences between designs[1]. The measure provides information on the amount and the direction of surface modifications. We recently introduced a framework[2] that uses the displacement data in conjunction with statistical methods and techniques from machine learning to provide meaningful knowledge from the dataset at hand. The framework comprises a number of approaches for the displacement analysis, sensitivity analysis, dimensionality reduction and rule extraction.

In order to demonstrate the feasibility of the suggested framework, we applied the proposed methods to a data set of a ultra-low aspect ratio transonic turbine stator blade of a small Honda turbofan engine that resulted from a computational optimisation run[3]. Decision trees have been formulated to generate a set of design rules which refer to a pre-defined blade design.

The results have been verified by means of modifying the turbine blade geometry using direct manipulation of free form deformation (DMFFD)[4] techniques. The performance of the deformed blade design has been calculated by running computational fluid dynamic (CFD) simulations. It is shown that the suggested framework provides reasonable results which can directly be transformed into design modifications in order to guide the design process.

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