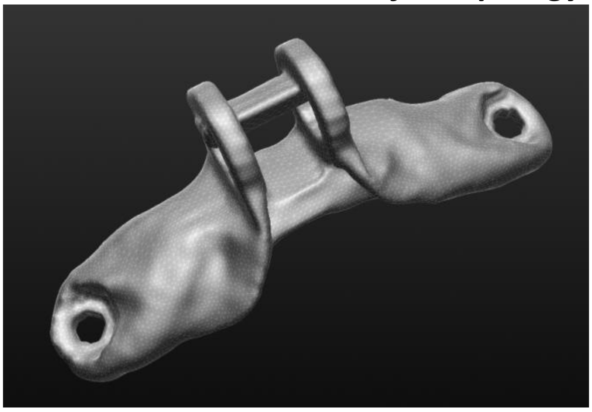
High-performance Computing for Topology Optimization

Tailored iterative solvers for topology optimization



A topology optimized aerospace engine bracket, optimized for static performance.

Designing parts with fine resolutions, for instance for 3D printing, requires solving very large finite element models repeatedly.

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Location: EEMCS, Numerical Analysis Group; may be carried out in part at Precision and Microsystems Engineering, 3mE, in which case this is eligible as a “non-mathematical internship”

Setting

Topology optimization is a powerful method to find optimal designs. To achieve a design with a fine resolution requires the use of fine meshes, resulting in very large finite element models (millions of DOFs). In topology optimization we start with a solid block of material and remove or add some material in each iteration, requiring the finite element model to be solved again to evaluate its performance. This computational effort determines how fast designs can be completed.

Potential applications

If the project is successful, the developed algorithms could become the workhorse for several problems in topology optimization, for instance:

- Design of stiff and lightweight parts such as the example in the picture above; this requires solving large FE models repeatedly;
- Design of photonic components; while the design of photonic components leads to comparatively small FE problems, these need to be solved a very large number of times to lead to designs that are robust against manufacturing defects.

Aims

The aim of this project is to explore the possibilities of using the special properties of the topology optimization problems to develop solvers that are significantly faster than general purpose techniques, thereby allowing significant reductions in optimization time. One of the challenges is that the optimized part at some point will include areas with and without material, leading to ill-conditioned FE problems. It is a well-known fact that this is detrimental to the performance of generic iterative solvers.

Aspects of the research

We envision the following aspects to play a prominent role in this research:

- Investigating state-of-the art iterative solvers such as the *deflated* preconditioned conjugate gradient (DPCG) method;
- Developing a preconditioner that is well-suited to topology optimization problems; Implementation on parallel hardware;
- Evaluating the (improved) performance on a number of test cases

Since these projects involve a significant amount of programming we expect candidates to have affinity with programming in C or a similar language.