Large-scale three-dimensional topology optimization considering stress constraints for lightweight printable structures with Kratos Multiphysics

Semester thesis

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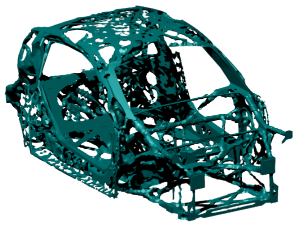

1 Motivation

Topology optimization is an efficient tool for the design of innovative structures, based on finite-element analysis and is especially applicable with the advances in additive manufacturing methods. This study project encompasses the further development of topology optimization in open-source mutliphysics and finite-element code Kratos Multiphysics. The topology optimization in this project can also include vibrational behavior, complaint mechanisms or printing on the in-house 3D printer, if time allows. This work builds on the previous work on topology optimization in Kratos Multiphysics by Gonzalez (2015); Malfavon (2016) and the work in the TUM–unibz group of the advisors Reinisch (2017, 2019); Wehrle et al. (2019); Reinisch et al. (subm).

Kratos Multiphysics is a powerful open-source multiphysical solver developed by a team of researchers led by the International Center for Numerical Methods in Engineering and Chair of

Structural Analysis Technical University of Munich. This code has toolboxes for computational structural analysis via the finite-element method and shape optimization. A previous toolbox for topology optimization developed by Gonzalez (2015); Malfavon (2016) with a dependency on the obsolete Solid Mechanics Application has not been further developed and therefore is no longer able to be used with the current version of Kratos Multiphysics. The objective of this semester thesis is the reactivation of the Topology Optimization Application, linking it with the Structural Analysis Toolbox and considering the insights from the work of Reinisch (2017, 2019); Wehrle et al. (2019); Reinisch et al. (subm). This work will also extend the previous mentioned work from the two-dimensional finite-element code to three-dimensional volume elements. Specifically, the work of Gonzalez (2015); Malfavon (2016) shall be built upon to include stress constraints as described by the TUM-unibz team to ensure the structural integrity of the optimized structures.

2 Contents

1. Getting started
    a) Theory
        i. Previous work at unibz and TUM: Reinisch (2017, 2019); Wehrle et al. (2019); Reinisch et al. (subm); Wehrle et al. (2012); Sauerer et al. (2014); Schmid (2011)
        ii. Introduction to topology optimization: Michell (1904); Bendsøe and Sigmund (2003); Aage et al. (2017); Zhang and Zhu (2018)
        iii. Topology optimization with stress constraints Cheng and Jiang (1992); Duysinx and Sigmund (1998); De Leon et al. (2015); Verbart et al. (2017); de Assis Pereira and Cardoso (2018); da Silva et al. (2019)
    b) Software
        i. Finite-element analysis: Kratos Multiphysics github.com/KratosMultiphysics/Kratos
        ii. Programming languages
            A. Python python.org
            B. C++
        iii. Finite-element pre- and post-processing, either:
            A. GiD gidhome.com
            B. Salome salome-platform.org
        iv. Documentation of thesis (recommended):
            A. LyX lyx.org
            B. Literature with JabRef jabref.org
    c) Documentation and writing of thesis:
        i. Documentation throughout process to avoid "mad dash" at end
        ii. English is recommended
2. Benchmark cases
    a) Development example: Three-dimensional MBB beam
        i. Optimization formulation

            A. Unconstrained, e.g. minimum compliance
            B. Constrained, e.g. minimum compliance under stress constraints, minimum mass under stress constraints
        ii. Optimization algorithm
            A. Optimality criterion
            B. MMA
    b) Large-scale engineering example: to be agreed upon

3. Evaluation and interpretation of results

3 Time table

The following milestones are foreseen:

1.12.2020 Compilable Topology Optimization Application

23.12.2020 First results – unconstrained minimum compliance

1.2.2021 Implemented stress constraints with first results

1.3.2021 Begin of large-scale engineering case

15.5.2021 Final submission

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