Karlsruhe Institute of Technology

Seminar series of the Graduate School GRK 2078

Referee:	**Prof. Jan Zeman** Czech Technical University in Prague
Date:	Thursday, February 23, 2023
Time:	10:00-11:00h
Location:	Building 10.23, 3rd floor, seminar room 308.1 Please note that you can also participate in the event online
Title:	**Wang tiles for modular-topology optimization of compliant structures and mechanisms**

Abstract

Two contemporary research challenges are relevant to structural design: automation and sustainability. In this contribution, we address both by considering the optimal design of structures containing a limited number of repeating patterns (modules). The proposed *modular-topology optimization* framework, introduced in the talk, involves:

1. The design of module topologies.
2. Encoding admissible module connections.
3. The placement of modules at the structural scale.

In our initial work on this topic [1], we optimized compliance of modular trusses via a concurrent method based on meta-heuristics (operating at the module scale) and a conic program (generating optimal module topologies). Following [2], we present a computationally more attractive sequential strategy applicable to non-convex module design problems, including continuum topology optimization of reusable structures and compliant mechanisms.

Our strategy starts with a solution to the free-material optimization problem at the product scale, which we enhance to suppress emerging checkerboard patterns. Subsequently, we develop a novel deterministic clustering algorithm to partition the optimized elasticity tensors into a specified number of clusters while maintaining symmetries in the dataset. Utilizing the Wang tiling formalism [3], we subsequently convert the clusters to efficient assembly plans with a tunable number of module interfaces. Finally, we optimize the modules with single-scale topology optimization, reducing design space due to modularity.

We demonstrate the efficacy of the proposed method with three two-dimensional benchmarks of topology optimization. Besides the classical Messerschmitt-Bölkow-Blohm beam, we present, for the first time to the best of our knowledge, optimized modular designs of an inverter and a gripper. We complement these examples with the fourth one, which combines a gripper and an inverter, illustrating the reusability of the optimized modules. We compare the

performance of the optimized modular structures against uni-modular and non-modular designs, thereby quantifying performance gains and losses induced by modularity.

These results follow from joint work with Marek Tyburec, Martin Doškář, and Martin Kružík.

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References

[1] Tyburec, M., Zeman, J., Doškář, M., Kružík, M., & Lepš, M. (2021). Modular-topology optimization with Wang tilings: an application to truss structures. Structural and Multidisciplinary Optimization, 63(3), 1099–1117. http://doi.org/10.1007/S00158-020-02744-8

[2] Tyburec, M., Doškář, M., Zeman, J., & Kružík, M. (2021). *Modular-topology optimization of structures and mechanisms with free material design and clustering*, Computer Methods in Applied Mechanics and Engineering 395 (2022), 114977. http://dx.doi.org/10.1016/j.cma.2022.114977

[3] Wang, H. (1961). Proving Theorems by Pattern Recognition - II. Bell System Technical Journal, 40(1), 1–41. http://doi.org/10.1002/j.1538-7305.1961.tb03975.x

You are cordially invited to take part in the event.

Prof. Dr.-Ing. Thomas Böhlke
(Spokesperson of GRK 2078)

Jun.-Prof. Dr. Matti Schneider