PRIN2015 METAMATERIALS WEBINARS
Friday, June 25, 17:00 (CET)

WANG TILES FOR MODULAR (META)MATERIALS

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Abstract

Proposed as a visual alternative to proving theorems in mathematical logic in 1961, Wang tilings have found applications ranging from computer graphics to DNA-based self-assembly and computing. In this contribution, we discuss the use of Wang tilings to design and optimize architectured non-periodic (meta)materials and structures.

The talk splits into four parts. The first part addresses the tiling concept in its most straightforward installment, employing a single tile, possibly rotated by 90 degrees, that allows assembling auxetic or non-auxetic structures.

In the second part, we show that the elementary scenario naturally extends to the framework of vertex-based Wang tilings and demonstrate its use in the design of a soft porous metamaterial with a non-periodic structure. Here, the emphasis is on the inherent modularity of this concept and its potential for scalable robot-assisted manufacturing.

The third part of the talk is devoted to developing a two-level optimization tool to simultaneously optimize the geometry of tiles and their placement in the structure. In particular, we focus on the problem of the minimum-compliance design of modular truss structures, for which we demonstrate the performance gains and losses relative to uniform and non-modular designs, respectively. Moreover, we outline how these procedures extend to the optimal design of continuum bodies.

The concluding part introduces pilot experiments on magneto-mechanical tiles capable of centimeter-scale self-assembly of checkerboard patterns. We demonstrate that the platform allows for error-less assembly of the target pattern with robust error recovery while employing purely mechanical excitation and passive tiles.

Acknowledgment. This work was supported by the Czech Science Foundation project No. 19-26143X.

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Short bio

Dr. Jan Zeman is a Full Professor in the Theory of Materials and Structures at the Department of Mechanics, Faculty of Civil Engineering, Czech Technical University (CTU) in Prague. Currently a core member of the CTU's Open Mechanics Group, Jan Zeman earned his Ing. (MSc. equivalent) degree in 2000 and his Ph.D. in 2003 from CTU in Civil Engineering with a specialization in Structural Mechanics. He received the 2000 Hlavka Talent Foundation prize (top CTU student) and the Ivo Babuška Award for the best Ph.D. thesis in Applied and Computational Mathematics and Mechanics in 2003. Jan's research interests lie at the interface between applied mechanics and mathematics, with an emphasis on modeling and simulation of deterministic and stochastic microstructured materials, variational techniques for modeling inelastic materials, and mathematical analysis of engineering models and algorithms in general. His early work was supported in the context of a Marie-Curie Intra-European Fellowship (2005) and, in addition to leading 5 projects funded by the Czech Science Foundation (CSF) from 2004 to 2019, he is currently the principal investigator of a highly-selective five-year EXPRO project, a CSF initiative established in 2019, aiming at the design of modular architectured materials. In addition to research, he is committed to mentoring talented future researchers and has (co-)supervised 6 doctoral students (3 ongoing).