TopOpt.jl: Truss and Continuum Topology Optimization, Interactive Visualization, Automatic Differentiation and More

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In this paper, we present a major update on the status of TopOpt.jl[1], an open-source topology optimization software package written in the high-level and high-performance Julia programming language [Bez+17]. Despite the active developments in the field of topology optimization, the community nevertheless still lacks an open-source, efficient, and flexible software test-bed that is easily accessible and usable for developing new algorithms and solving practical problems in both academia and industry. To date, TopOpt.jl is the only open-source software that supports several popular topology optimization algorithms on unstructured 2D, 3D continuum meshes as well as truss domains, including (1) solid isotropic material with penalization (SIMP) [Ben89] with various penalty options (power and rational) [SS01] (2) evolutionary optimization algorithms (BESO and GESO) [HX10]. TopOpt.jl also includes wrappers for various mathematical optimization solvers, including the method of moving asymptotes [Sva87; Sva02]. All of these features work right out-of-the-box, achieving computational efficiency without bugging users with nuanced compilation and dependency management on various operating systems, thanks to the Julia language's portability and powerful package management system. Since the last presentation at WCSMO-13 [Moh19], TopOpt.jl has been developed significantly. Some of the major updates include:

- A new, interactive visualizer for displaying the optimized results as well as FEM deformation.
- 2D and 3D truss optimization support, complimenting previously supported 2D and 3D continuum topology optimization on unstructured meshes.
- Experimental support for local stress constrained optimization using the augmented Lagrangian algorithm.
- Support for differentiable programming and automatic differentiation in the nonlinear optimization solvers used.

Our benchmarks[2] show that we achieve comparable performance to well known open-source topology optimization codes with hard-coded local stiffness matrices for only rectilinear meshes, while TopOpt.jl supports arbitrary unstructured meshes and various standard element types, including reading problems from existing .inp files.

We hope that with the latest release of TopOpt.jl, its efficiency and flexibility can invite colleagues to join our development task force towards a more transparent and reproducible research environment in the field of topology optimization. With its business-friendly, open-source license and machine-agnostic nature, we believe TopOpt.jl can serve

[1] https://github.com/mohamed82008/TopOpt.jl

[2] https://github.com/yijiangh/TopOpt.jl_WCSMO21

as a bridge between academic research and a more user-friendly design and engineering practice. As of the writing of this abstract, we are also working on adding support for more nonlinear and mixed integer nonlinear optimization solvers as well as adding support for buckling constrained optimization.

References

[Sva87] Krister Svanberg. "The method of moving asymptotes—a new method for structural optimization". In: *International journal for numerical methods in engineering* 24.2 (1987), pp. 359–373.

[Ben89] Martin P Bendsøe. "Optimal shape design as a material distribution problem". In: *Structural optimization* 1.4 (1989), pp. 193–202.

[SS01] Mathias Stolpe and Krister Svanberg. "An alternative interpolation scheme for minimum compliance topology optimization". In: *Structural and Multidisciplinary Optimization* 22.2 (2001), pp. 116–124.

[Sva02] Krister Svanberg. "A class of globally convergent optimization methods based on conservative convex separable approximations". In: *SIAM journal on optimization* 12.2 (2002), pp. 555–573.

[HX10] Xiaodong Huang and Yi-Min Xie. "A further review of ESO type methods for topology optimization". In: *Structural and Multidisciplinary Optimization* 41.5 (2010), pp. 671–683.

[Bez+17] Jeff Bezanson et al. "Julia: A fresh approach to numerical computing". In: *SIAM review* 59.1 (2017), pp. 65–98.

[Moh19] Mohamed Tarek Mohamed. "TopOpt.jl: An efficient and high-performance topology optimization package in the Julia programming language". In: *13th World Congress of Structural and Multidisciplinary Optimisation, WCSMO 13*. 2019.