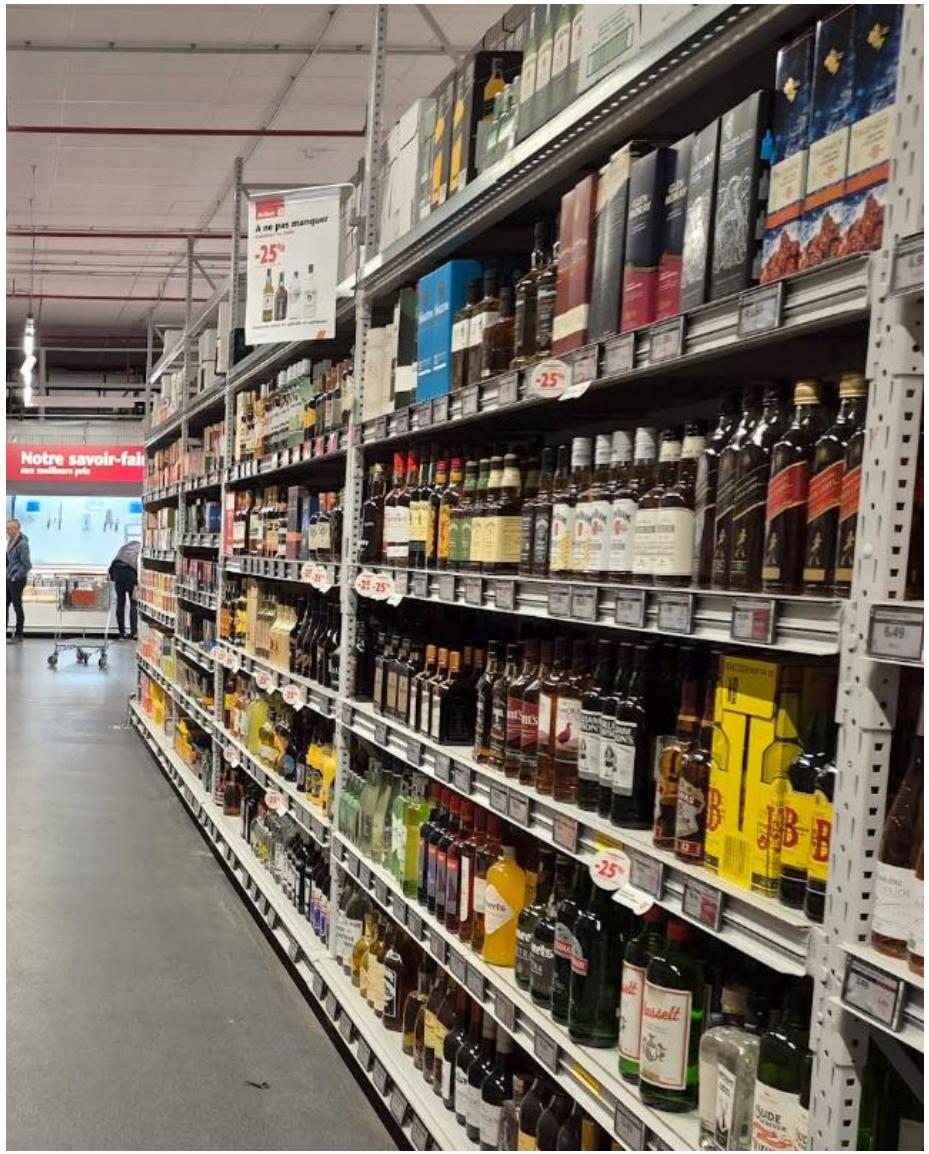
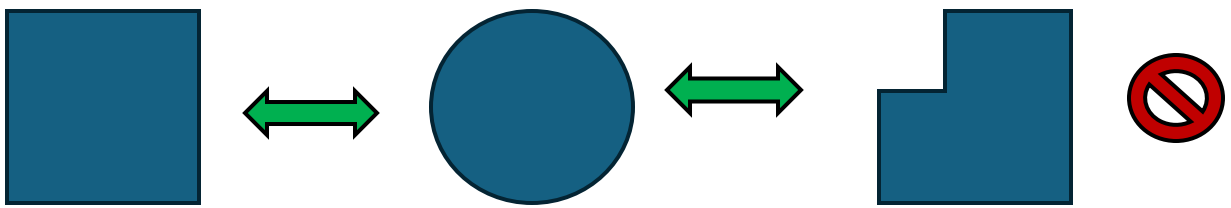
A guided tour of Topology Optimization with Morfeo software

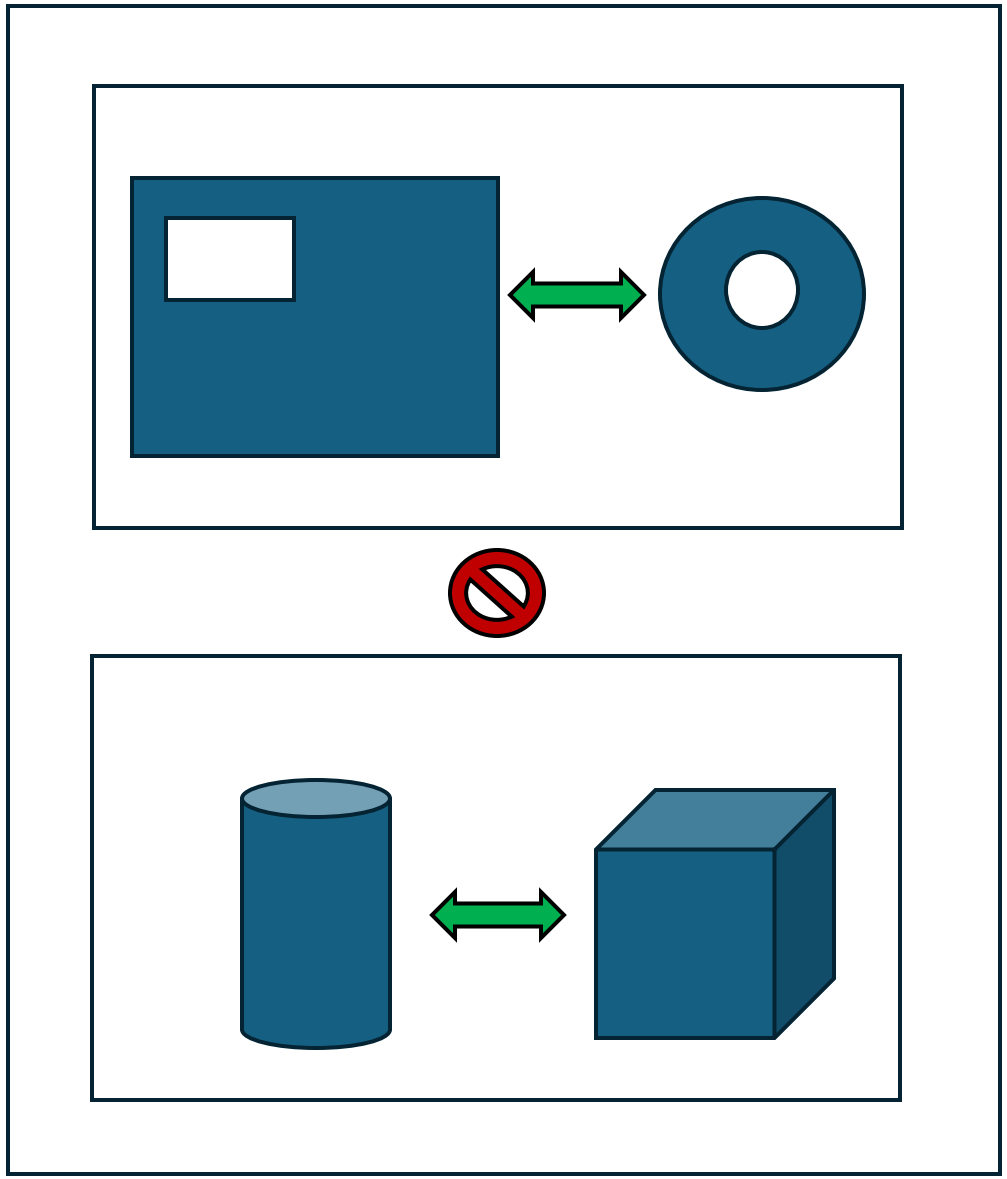
Pierre-Alexandre Beaufort

Topology is about Neighborhood Invariance

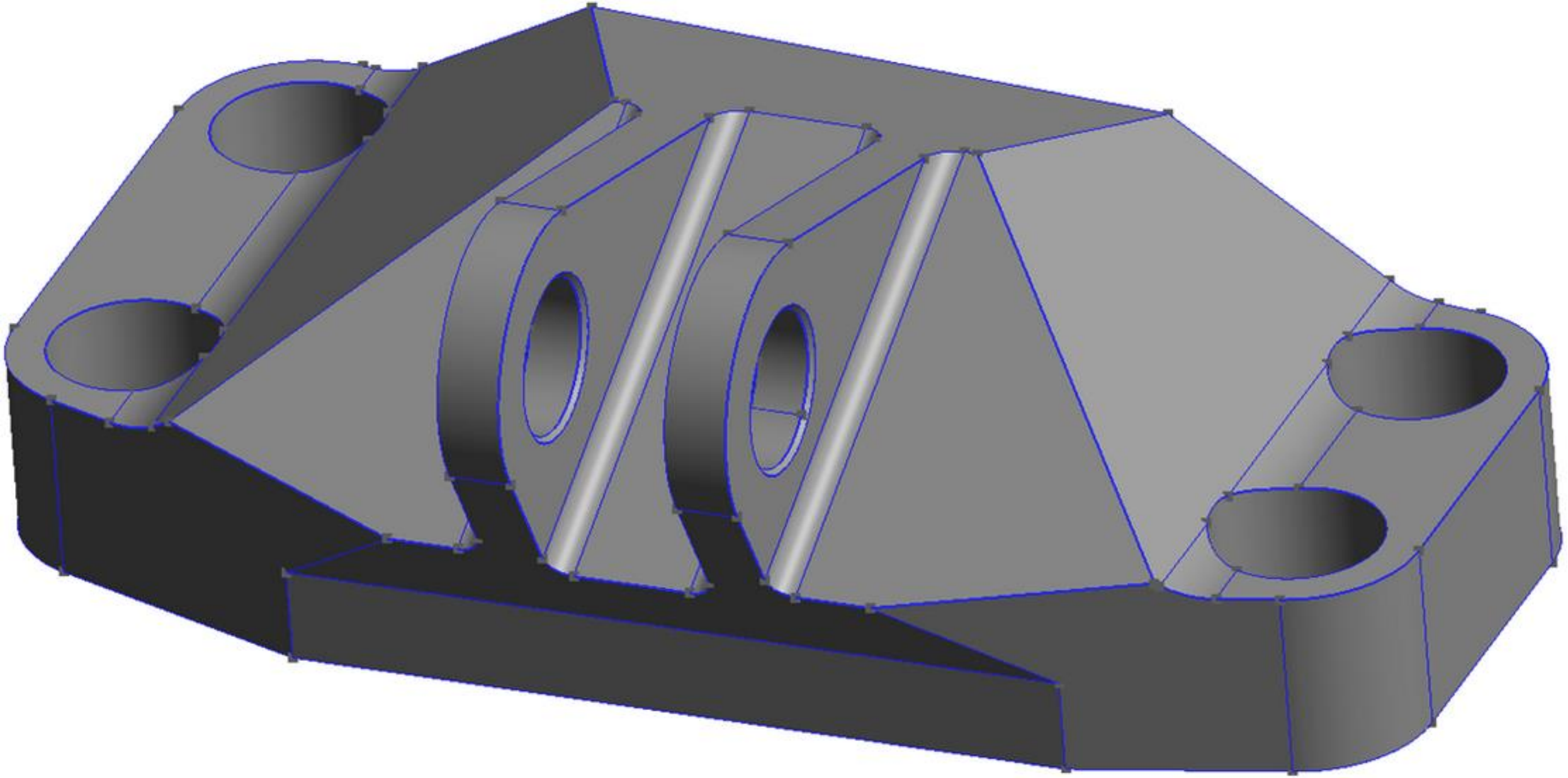


Inner Hole changes Topology

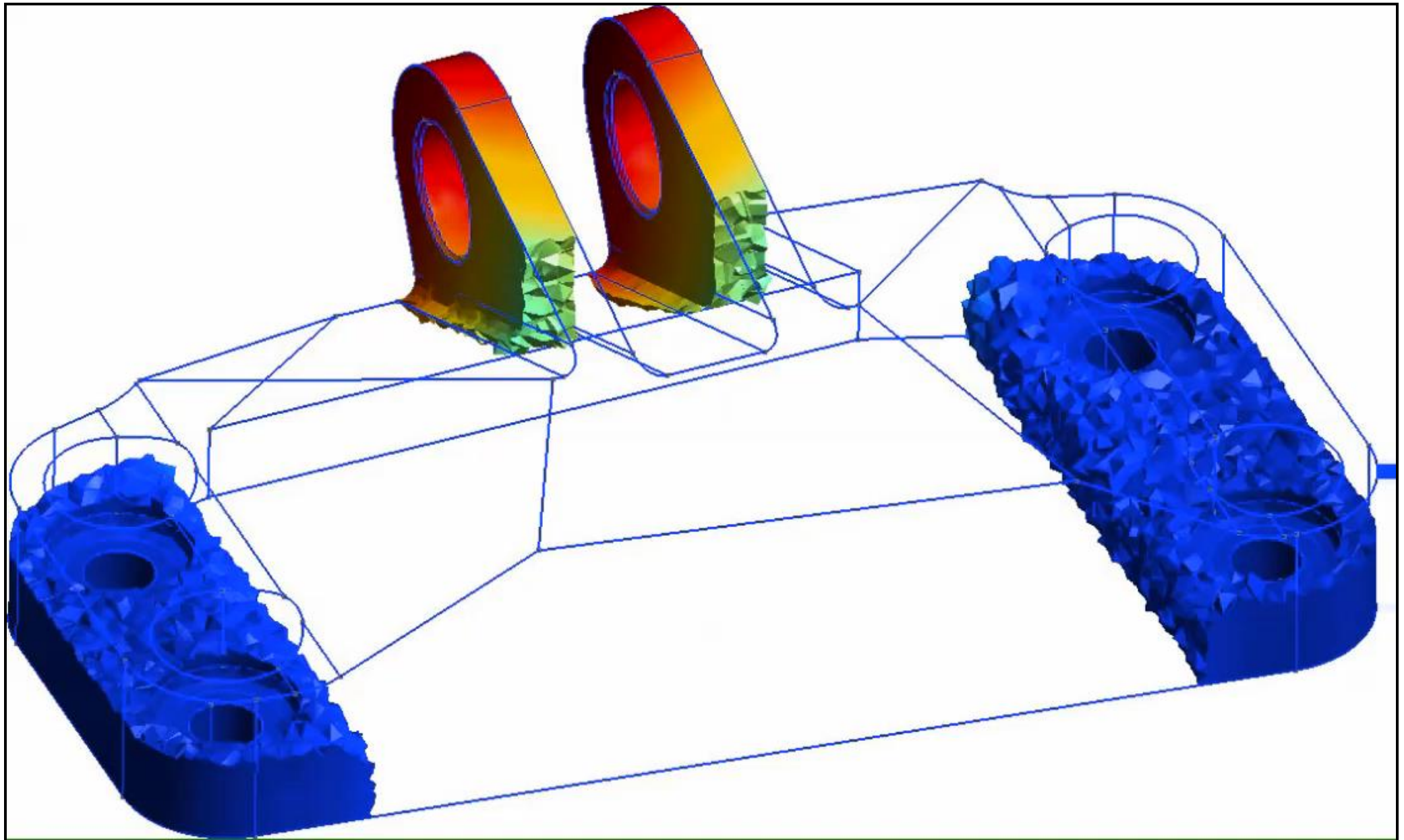




Topology Optimization: Drilling or Filling?



Topology Optimization in Action



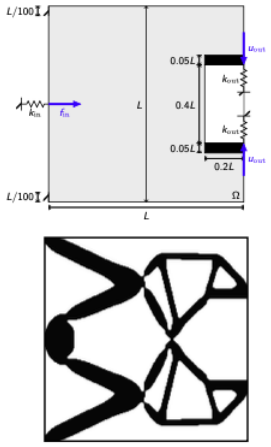
Multidisciplinary Design for Manufacturing

Topology Optimization s.t.
Manufacturing Constraints

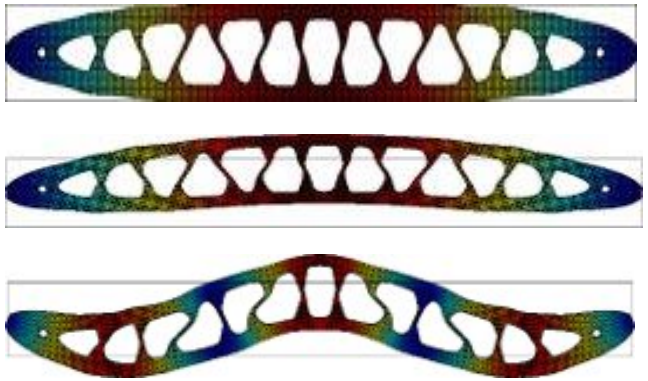
Morfeo Assets for Topology Optimization

Multidisciplinary Formulations

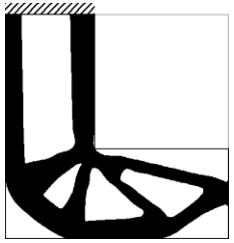
Compliant mechanism



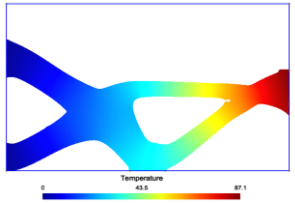
Eigenfrequencies



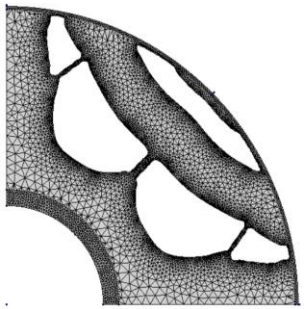
Stress constraints



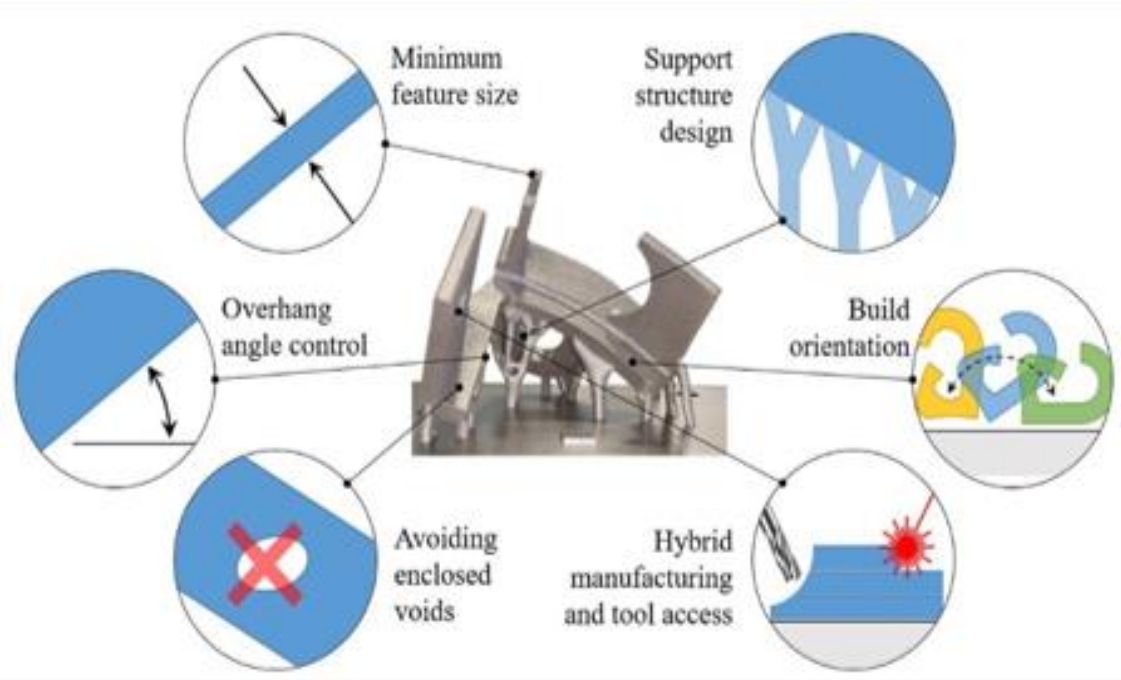
Thermo-mechanics



Electrical machines

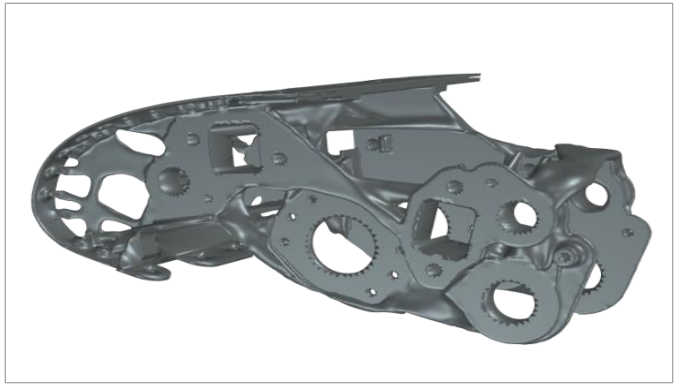


Manufacturibility Constraints

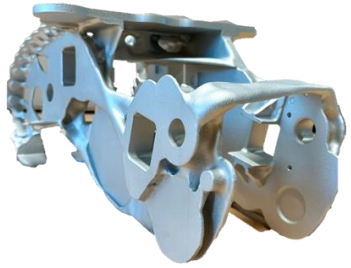


Some Industrial Achievements

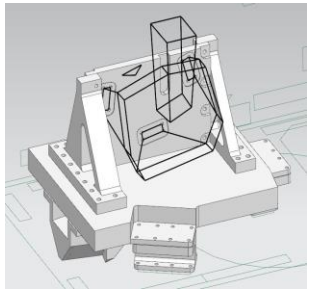
sonaca



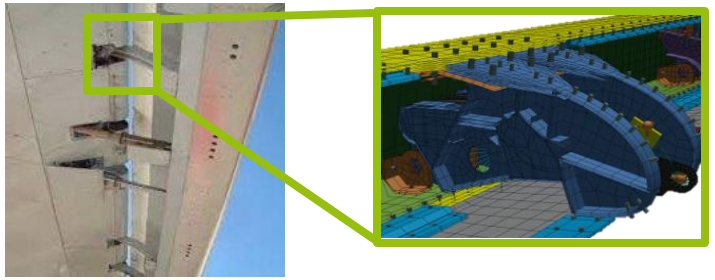
AnyShape



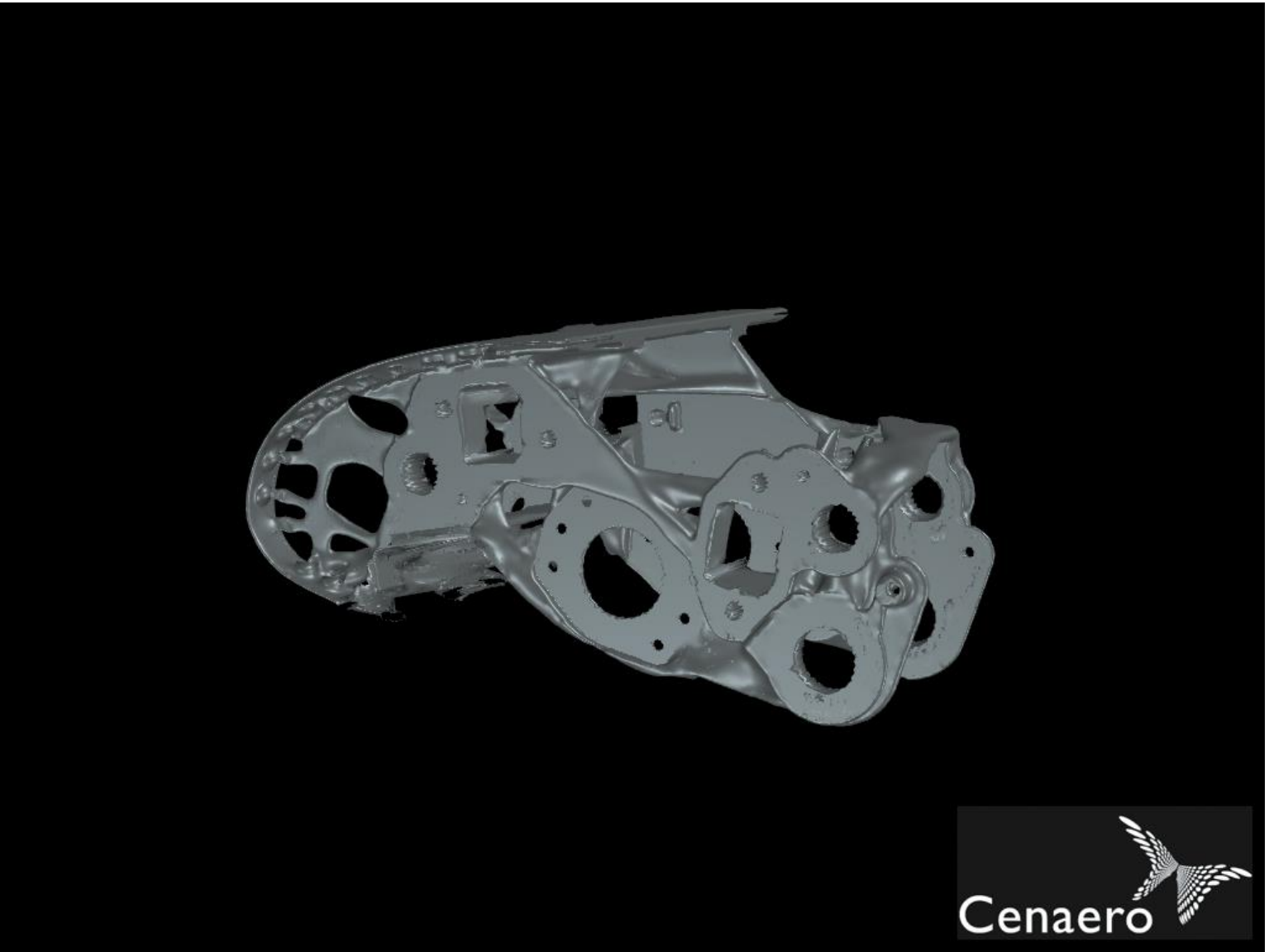
AEROSPACELAB



Roller Box Story



WINGS
sonaca



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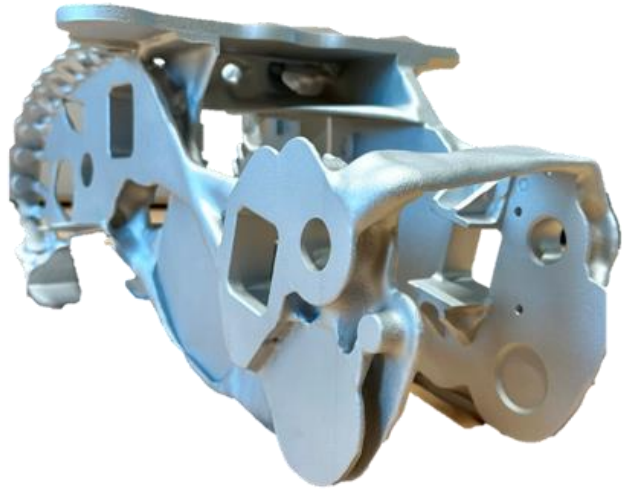
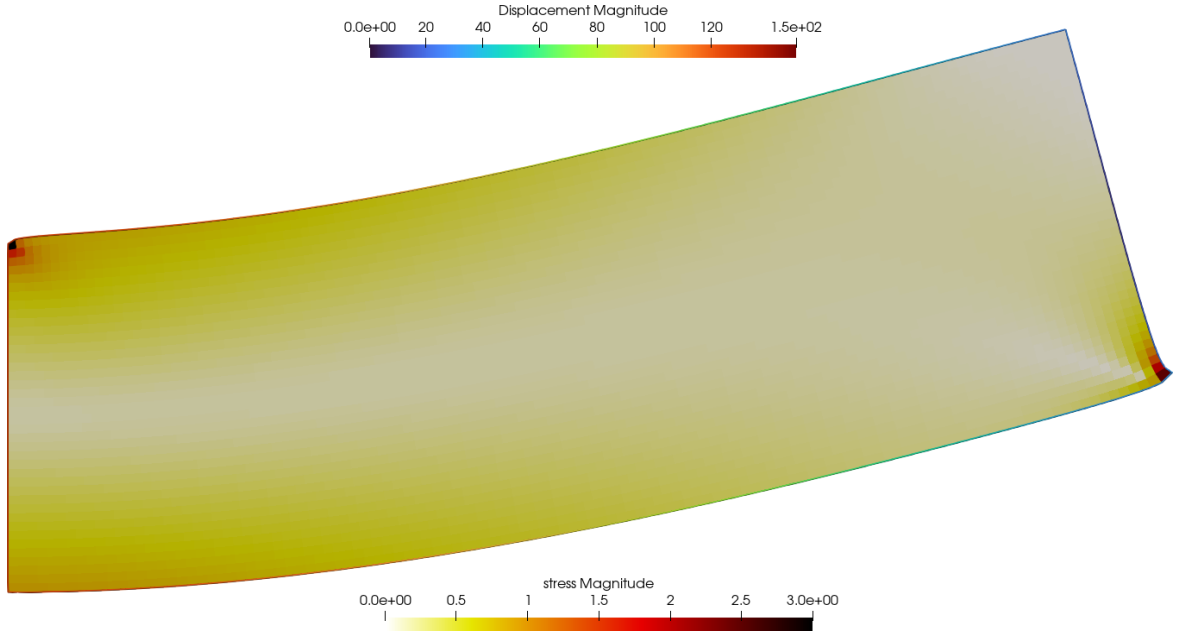
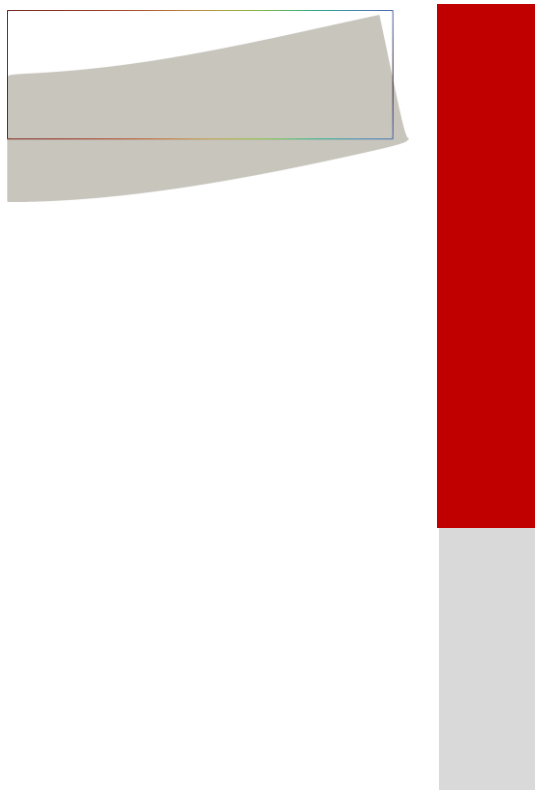


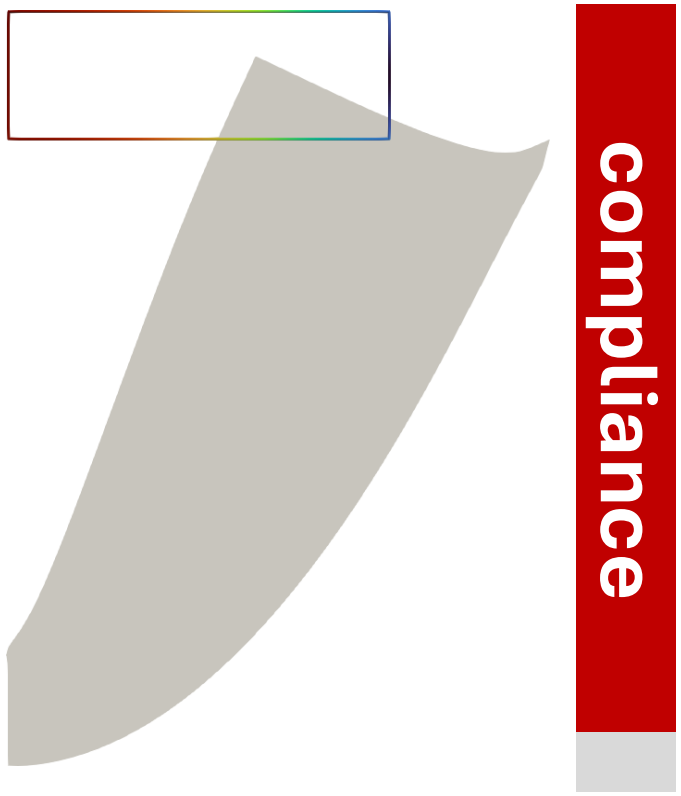
Topology Optimization 101 – MBB Beam



Least Compliant Beam Design

$$\text{compliance} := \sigma(u)^{ij}\,\varepsilon(u)_{ij}$$



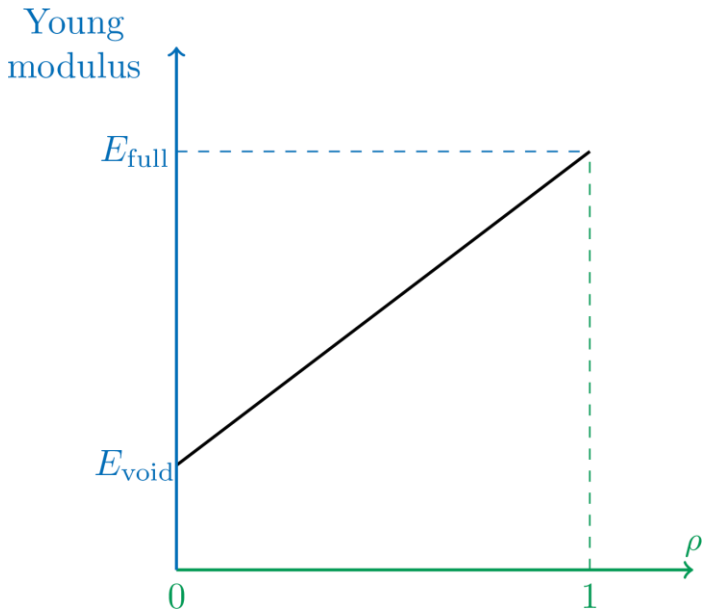


Density-based Topology Optimization

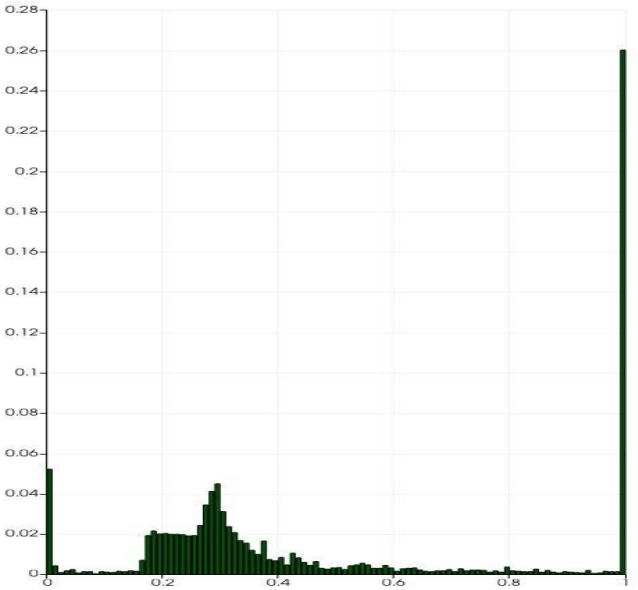
$$\min_{\rho} \int_{\Omega} \text{compliance}(\rho)\, d\Omega$$

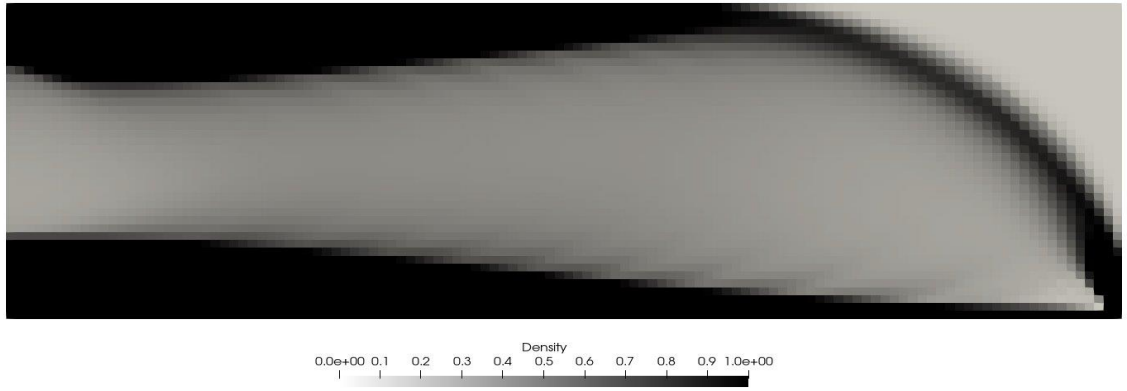
$$\text{subject to } \frac{\int_{\Omega} \rho\, d\Omega}{\int_{\Omega} d\Omega} = f$$

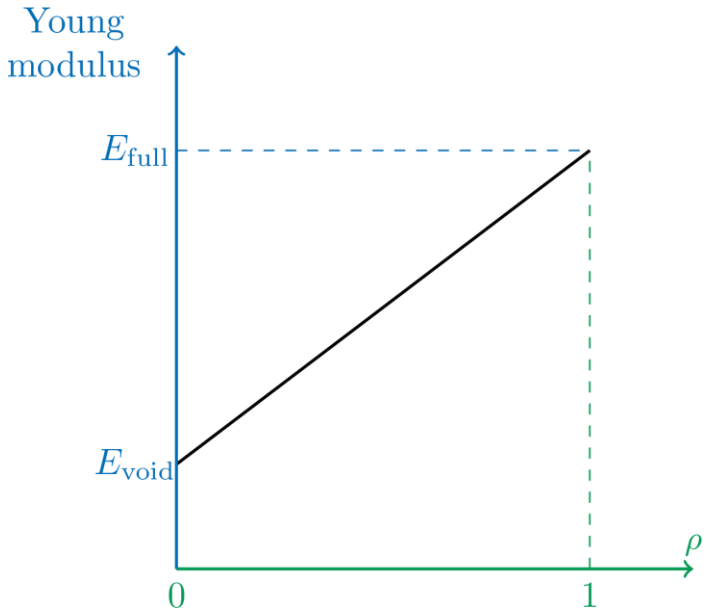
$$\int_{\Omega} \varepsilon(u)_{ij}\, C^{ijkl}(\rho)\, \varepsilon(v)_{kl}\, d\Omega = \int_{\partial\Omega_N} T^i\, v_i\, d\partial\Omega_N$$



Density-based Topology Optimization





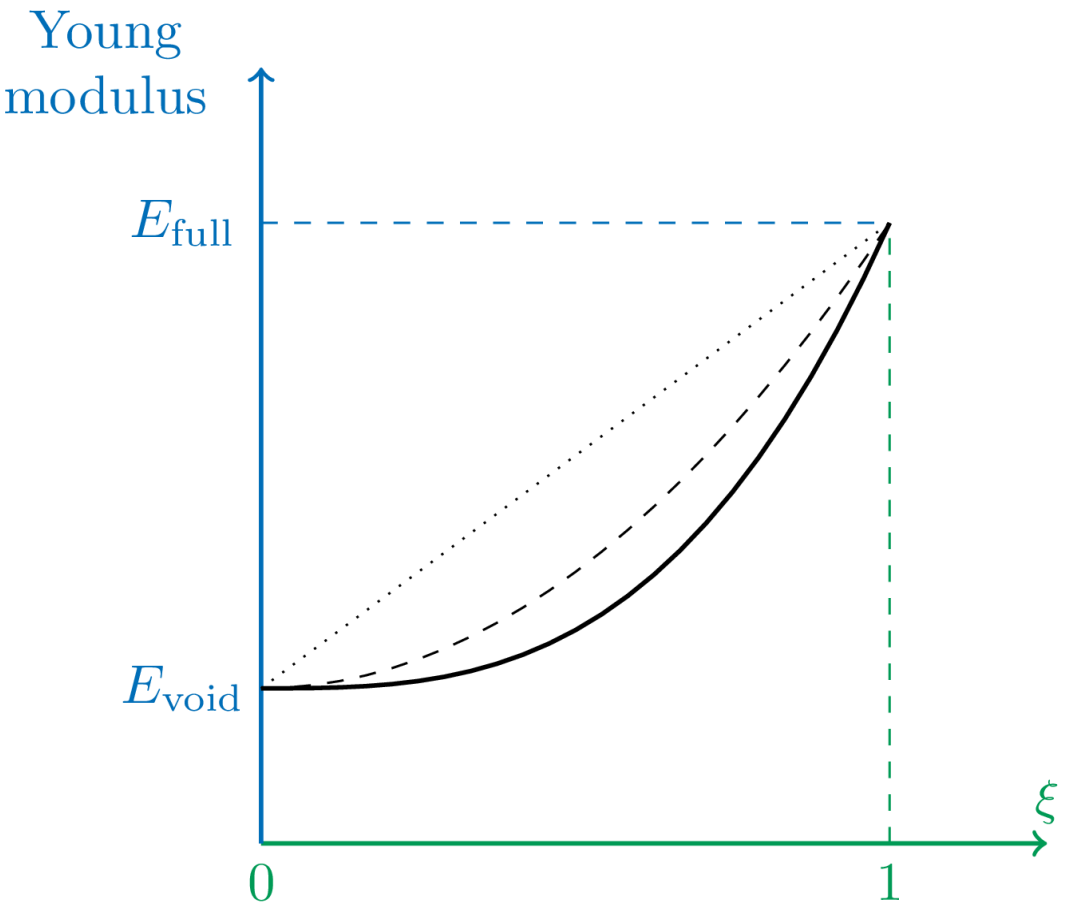


Solid Isotropic Material Penalty – SIMP

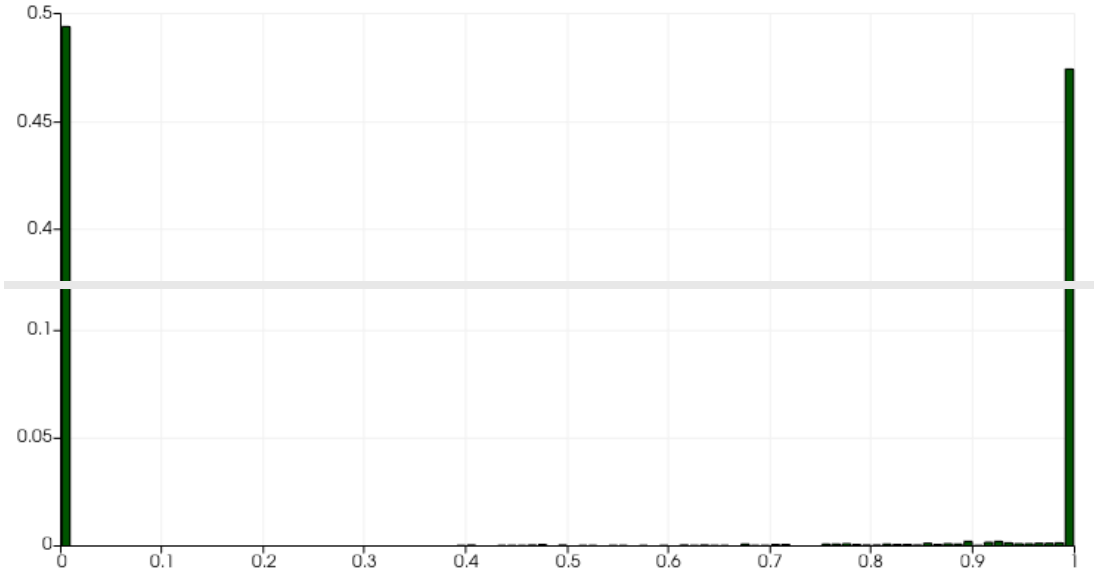
$$\min_{\rho} \int_{\Omega} \text{compliance}(\rho)\, d\Omega$$

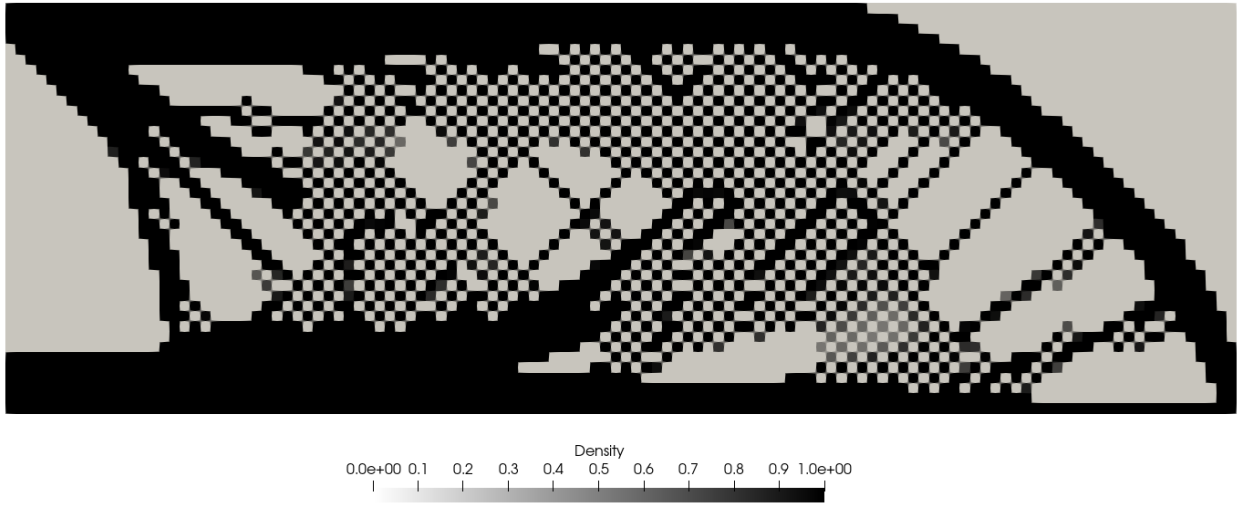
$$\text{subject to } \frac{\int_{\Omega} \rho\, d\Omega}{\int_{\Omega} d\Omega} = f$$

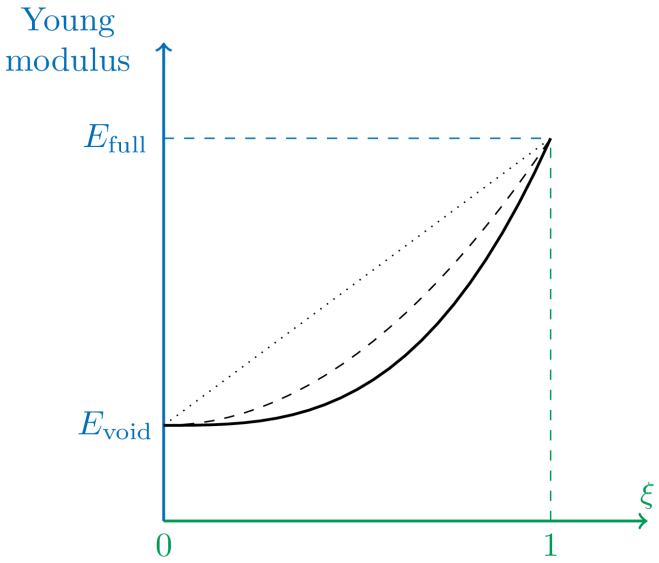
$$\int_{\Omega} \varepsilon(u)_{ij}\, C^{ijkl}(\rho)\, \varepsilon(v)_{kl}\, d\Omega = \int_{\partial\Omega_N} T^i\, v_i\, d\partial\Omega_N$$



Solid Isotropic Material Penalty – SIMP







Helmholtz Filter for Density

$$\min_{\xi} \int_{\Omega} \text{compliance}(\rho)\, d\Omega$$

$$\text{subject to } \frac{\int_{\Omega} \rho\, d\Omega}{\int_{\Omega} d\Omega} = f$$

$$\int_{\Omega} \varepsilon(u)_{ij}\, C^{ijkl}(\rho)\, \varepsilon(v)_{kl}\, d\Omega = \int_{\partial\Omega_N} T^i\, v_i\, d\partial\Omega_N$$

$$-r^2 \,\text{div grad}\, \rho + \rho = \xi, \text{ in } \Omega$$

$$\partial_n \rho = 0, \text{ over } \partial\Omega$$

Helmholtz Filter – Radius Impact

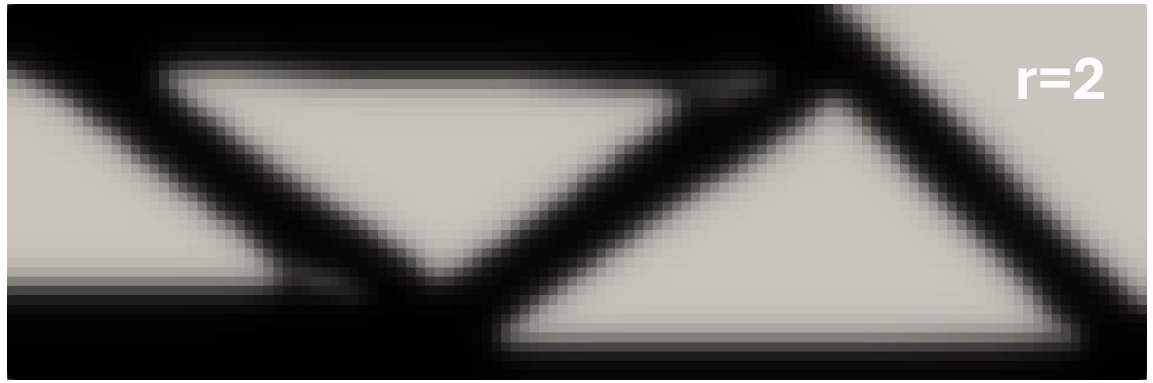
$$\min_{\xi} \int_{\Omega} \text{compliance}(\rho)\, d\Omega$$

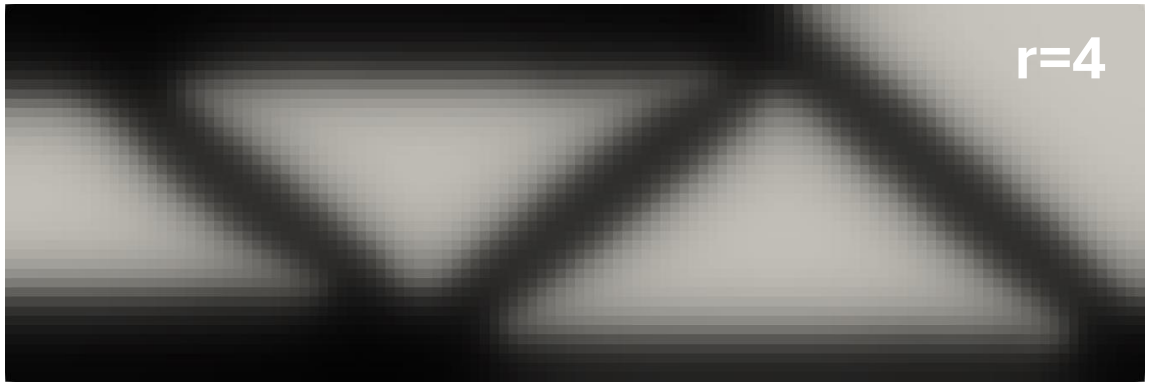
$$\text{subject to } \frac{\int_{\Omega} \rho\, d\Omega}{\int_{\Omega} d\Omega} = f$$

$$\int_{\Omega} \varepsilon(u)_{ij}\, C^{ijkl}(\rho)\, \varepsilon(v)_{kl}\, d\Omega = \int_{\partial\Omega_N} T^i\, v_i\, d\partial\Omega_N$$

$$-r^2 \,\text{div grad}\, \rho + \rho = \xi, \text{ in } \Omega$$

$$\partial_n \rho = 0, \text{ over } \partial\Omega$$





Helmholtz Filter – Mesh Impact

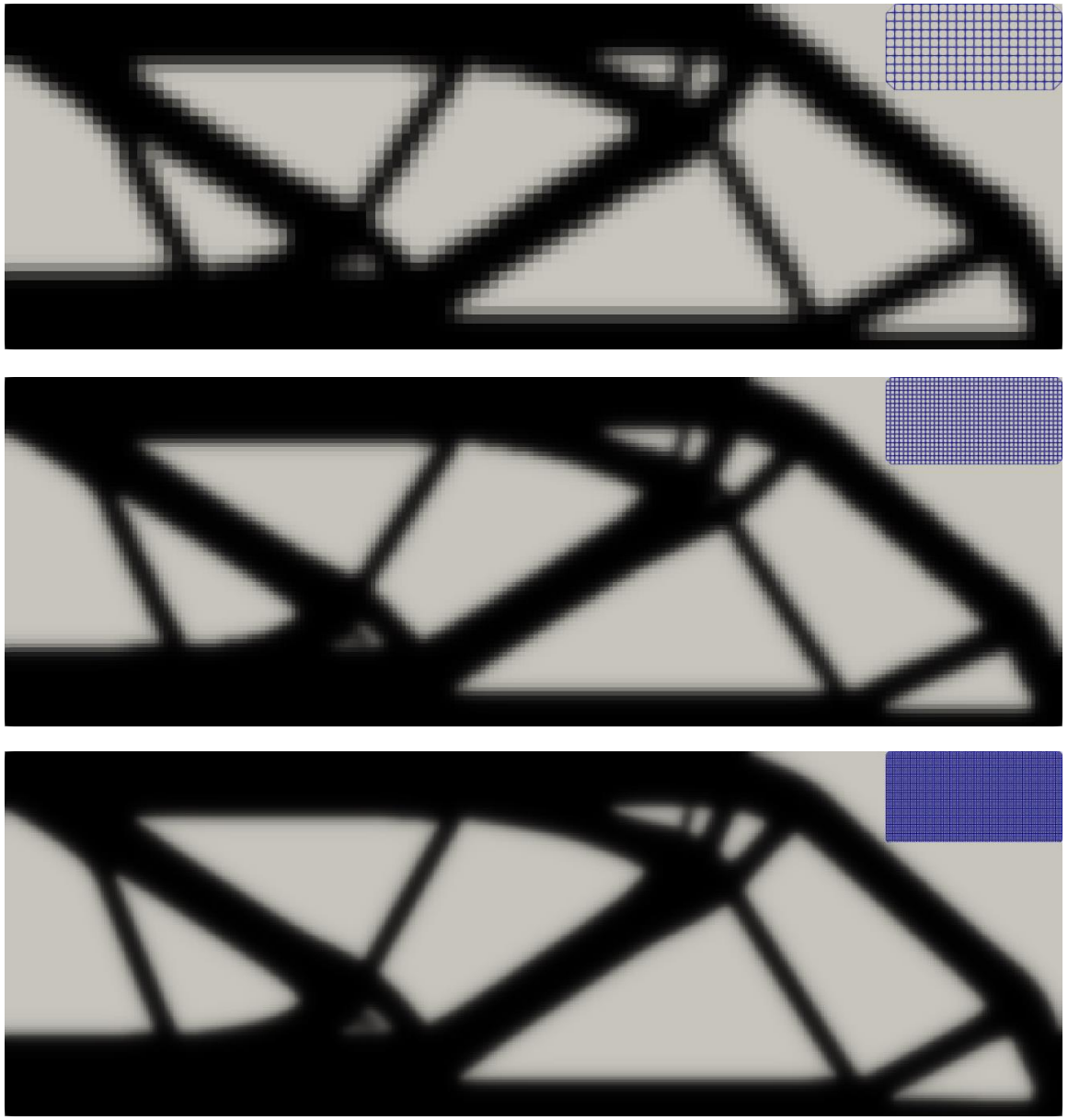
$$\min_{\xi} \int_{\Omega} \text{compliance}(\rho)\, d\Omega$$

subject to $\dfrac{\int_{\Omega} \rho\, d\Omega}{\int_{\Omega} d\Omega} = f$

$$\int_{\Omega} \varepsilon(u)_{ij}\, C^{ijkl}(\rho)\, \varepsilon(v)_{kl}\, d\Omega = \int_{\partial\Omega_N} T^i\, v_i\, d\partial\Omega_N$$

$$-r^2 \,\text{div grad}\, \rho + \rho = \xi, \text{ in } \Omega$$

$$\partial_n \rho = 0, \text{ over } \partial\Omega$$

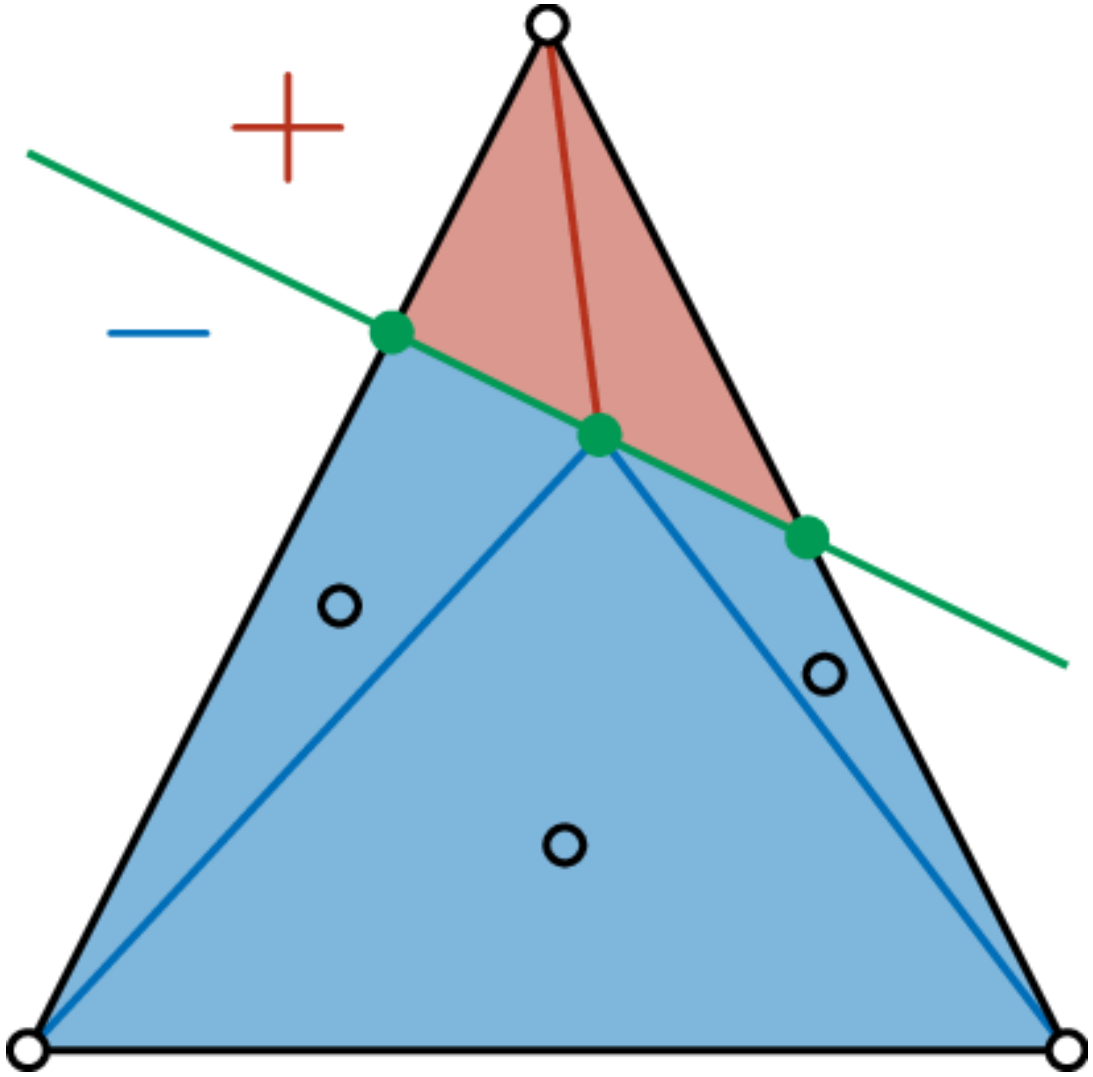


Levelset-based Topology Optimization

$$\min_{X} \int_{\Omega} \text{compliance } X \, d\Omega$$

$$\text{subject to } \frac{\int_{\Omega} X d\Omega}{\int_{\Omega} d\Omega} = f$$

$$\int_{\Omega} \varepsilon(u)_{ij} \, C^{ijkl} \, \varepsilon(v)_{kl} \, X \, d\Omega = \int_{\partial\Omega_N} T^i \, v_i \, d\partial\Omega_N$$

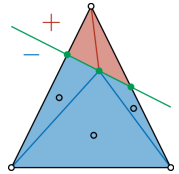


Levelset Cannot Nucleate

$$\min_{X} \int_{\Omega} \text{compliance } X \, d\Omega$$

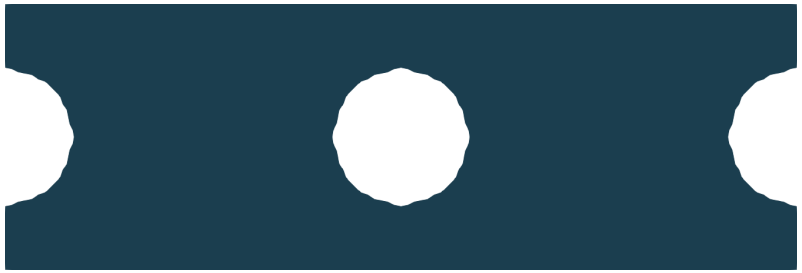
$$\text{subject to } \frac{\int_{\Omega} X d\Omega}{\int_{\Omega} d\Omega} = f$$

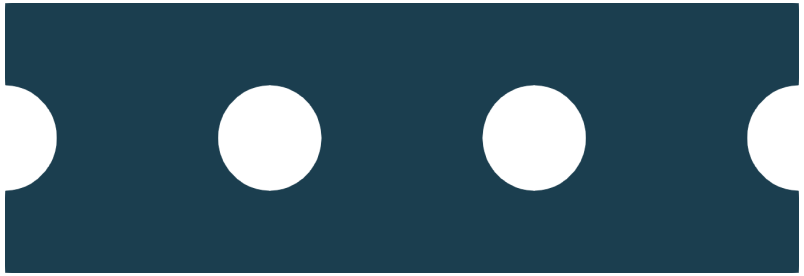
$$\int_{\Omega} \varepsilon(u)_{ij} \, C^{ijkl} \, \varepsilon(v)_{kl} \, X \, d\Omega = \int_{\partial\Omega_N} T^i \, v_i \, d\partial\Omega_N$$



Initial Designs

Optimization



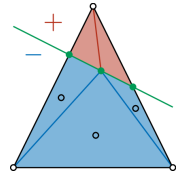


Levelset with Many Holes

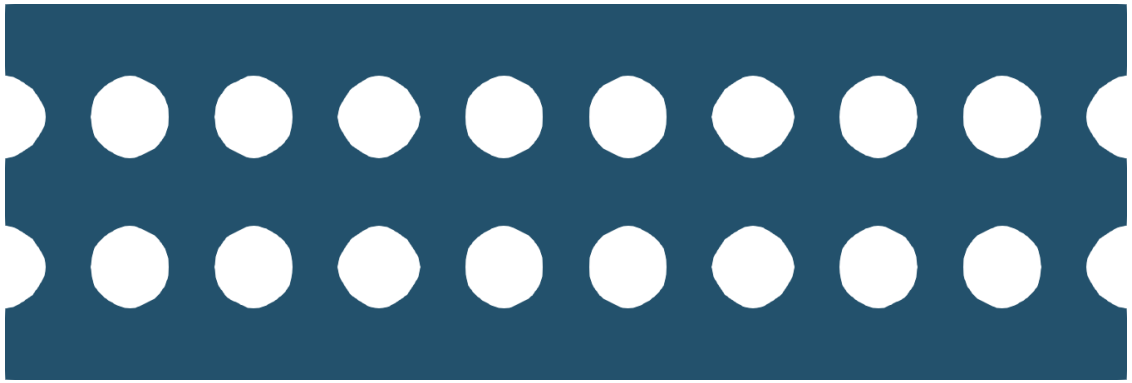
$$\min_{X} \int_{\Omega} \text{compliance } X \, d\Omega$$

$$\text{subject to } \frac{\int_{\Omega} X d\Omega}{\int_{\Omega} d\Omega} = f$$

$$\int_{\Omega} \varepsilon(u)_{ij} \, C^{ijkl} \, \varepsilon(v)_{kl} \, X \, d\Omega = \int_{\partial\Omega_N} T^i \, v_i \, d\partial\Omega_N$$



Initial Design



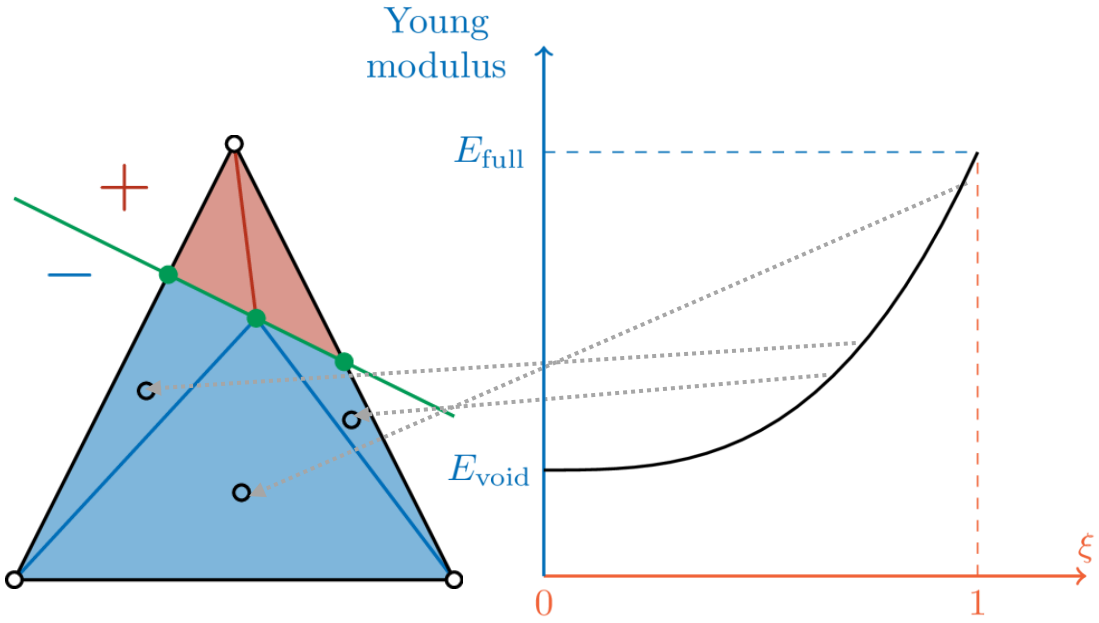
Optimization

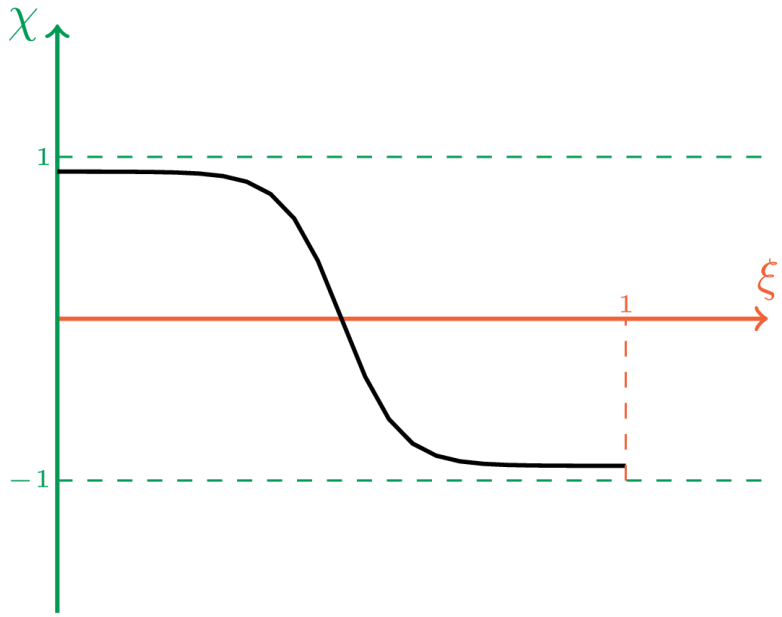
Nucleation for Levelset

$$\min_{\xi} \int_{\Omega} \text{compliance}(\xi)\, \chi(\xi)\, d\Omega$$

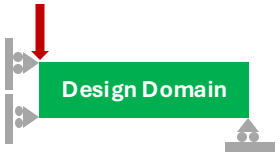
$$\text{subject to } \frac{\int_{\Omega} \chi(\xi) d\Omega}{\int_{\Omega} d\Omega} = f$$

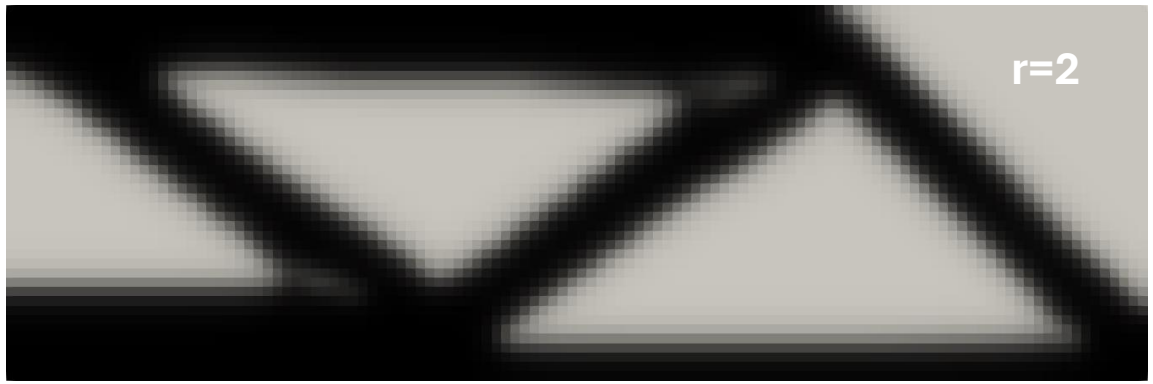
$$\int_{\Omega} \varepsilon(u)_{ij}\, C^{ijkl}(\xi)\, \varepsilon(v)_{kl}\, \chi(\xi)\, d\Omega = \int_{\partial\Omega_N} T^i\, v_i\, d\partial\Omega_N$$

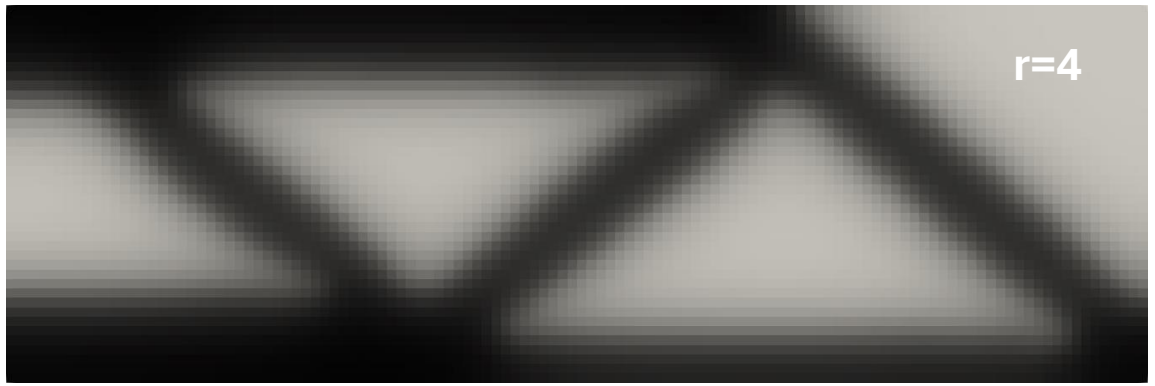


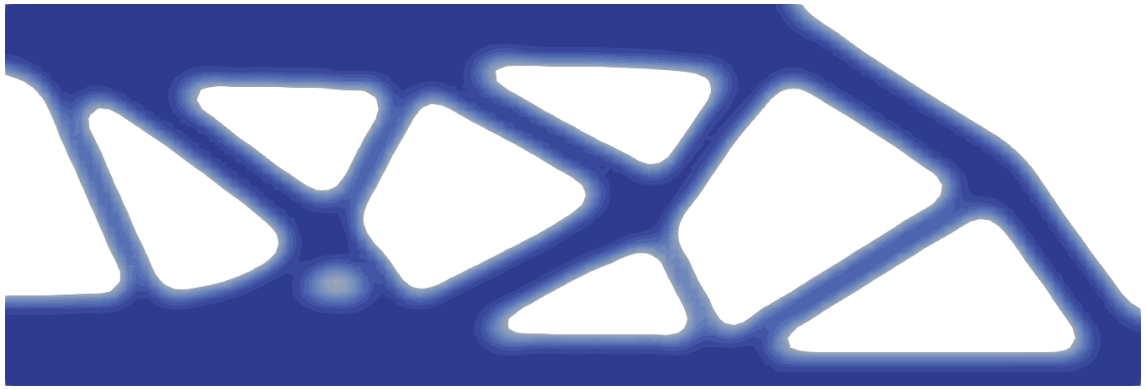


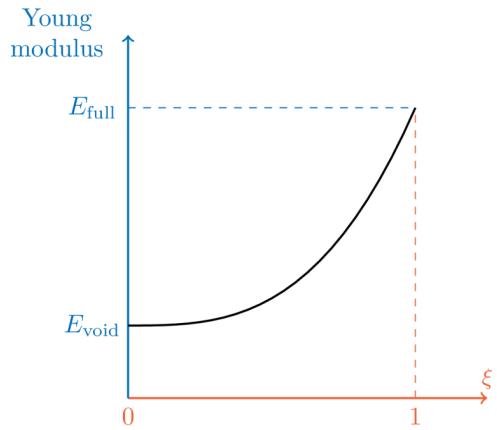
Conclusion

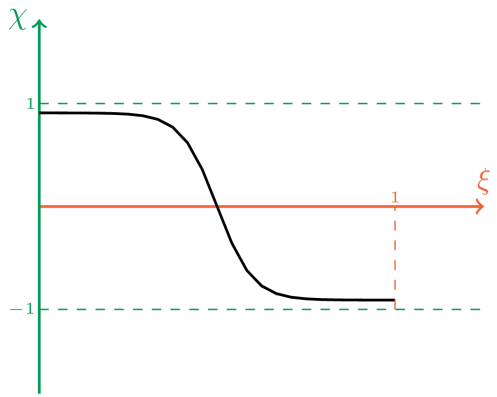












Thank You for Your Attention!

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