

Topology optimization of pressure-loaded structures and compliant mechanisms using the Darcy method



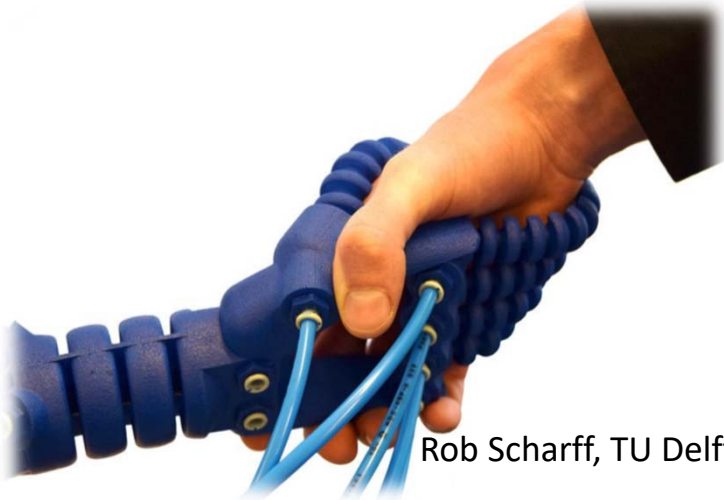
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Struct Multidisc Optim (2020) 61:1637
<https://doi.org/10.1007/s00158-019-02442-0>

TOP Webinar 3
July 21, 2020

Motivation: soft robotics

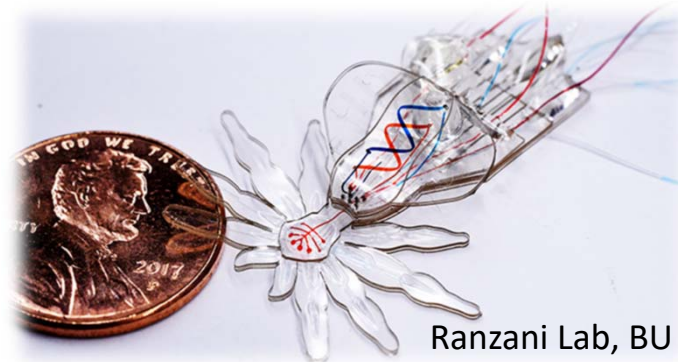


Rob Scharff, TU Delft



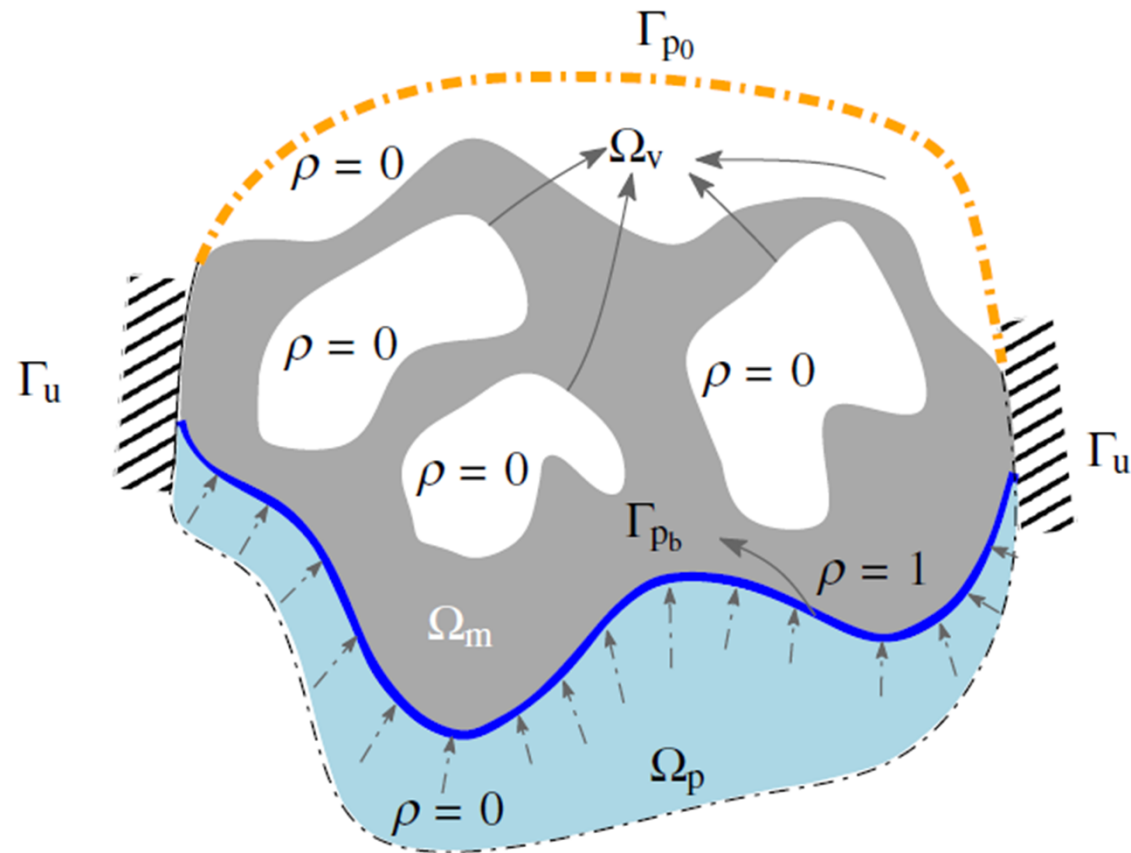
Whitesides Group, Harvard

- Compliant
- Often actuated by pressure
- Cheaper and safer than conventional robots



Ranzani Lab, BU

Aim: automate soft robot design



Challenges and previous approaches

Design-dependent pressure load:

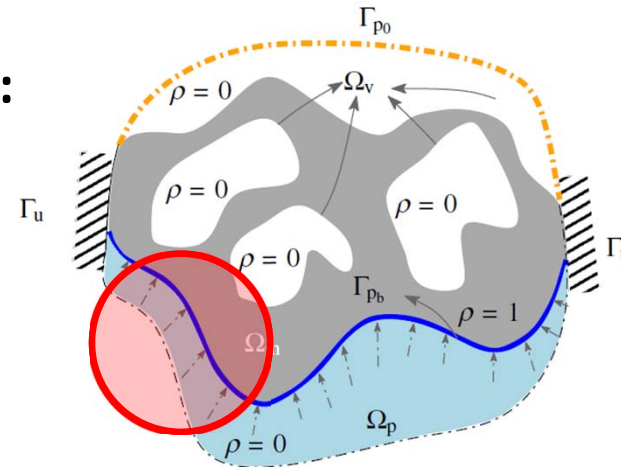
- Where to apply?
- Load sensitivity

Desired:

- Easy to implement
- Extensible to 3D
- Compatible with density approach

Prior art:

- Level set and evolutionary methods
- Discrete boundary-identification approaches
- 3-field approach with mixed finite elements



Our approach

Core idea:

Construct pressure field for a given density field through an **auxiliary problem based on Darcy's Law:**

$$\mathbf{q} = K \nabla p$$

Flow through
a porous medium

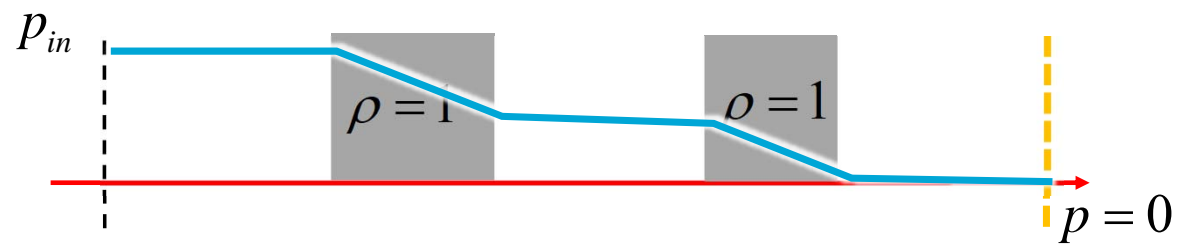
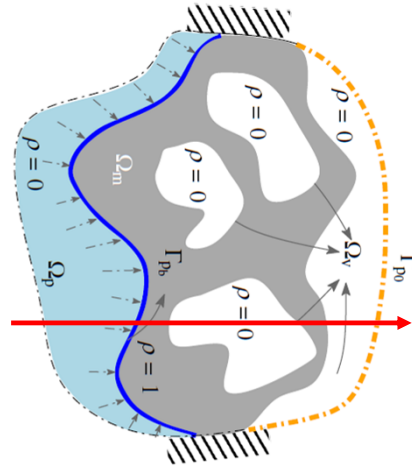
Pressure
gradient



Balance equation leads to:

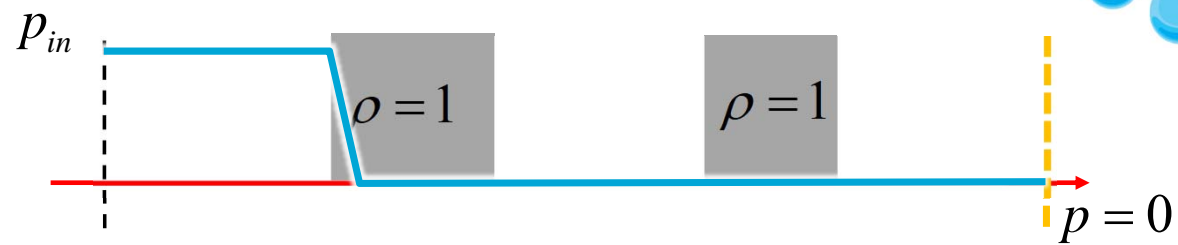
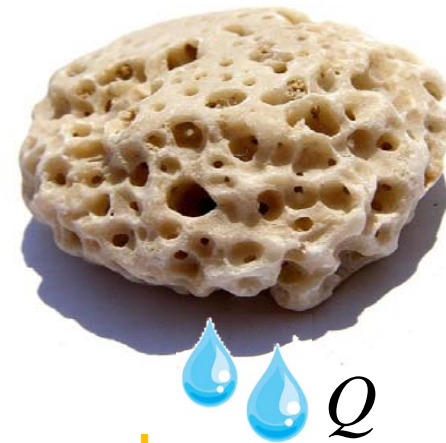
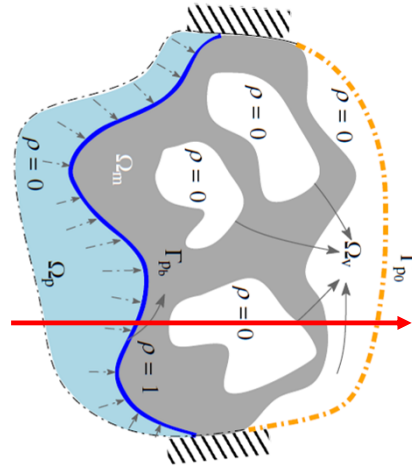
$$\nabla \cdot (K \nabla p) = 0$$

Constructing pressure field



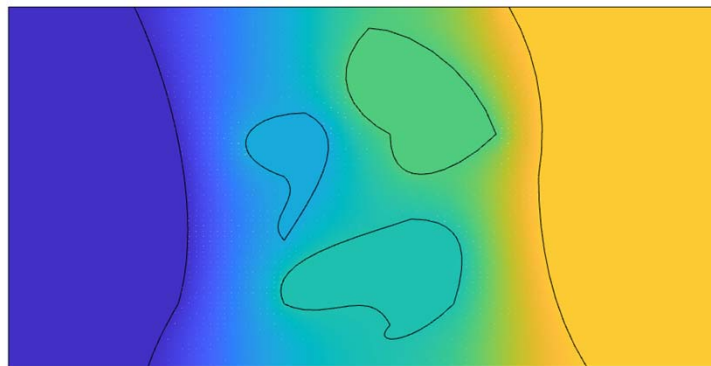
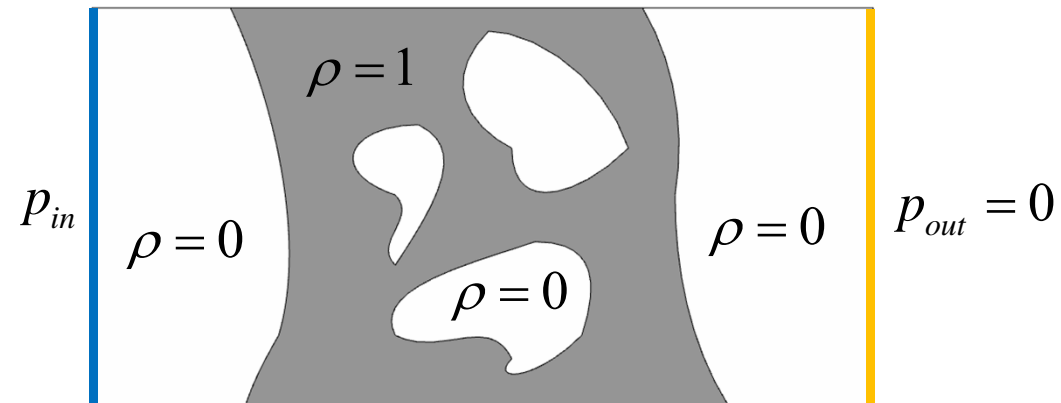
$$\nabla \cdot (K(\rho) \nabla p) = 0$$

Constructing pressure field

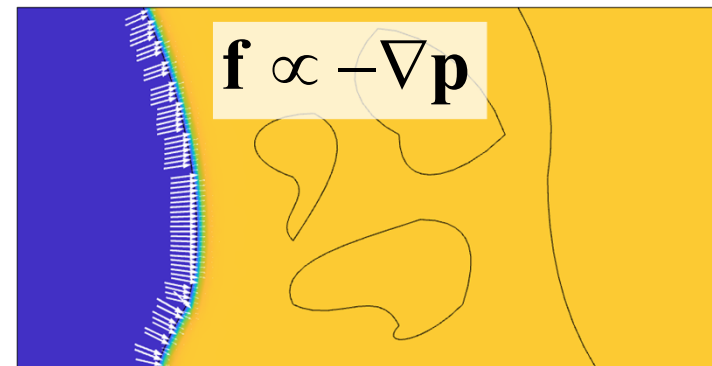


$$\nabla \cdot (K(\rho) \nabla p) + Q(\rho)(p - p_{out}) = 0$$

Constructing pressure field

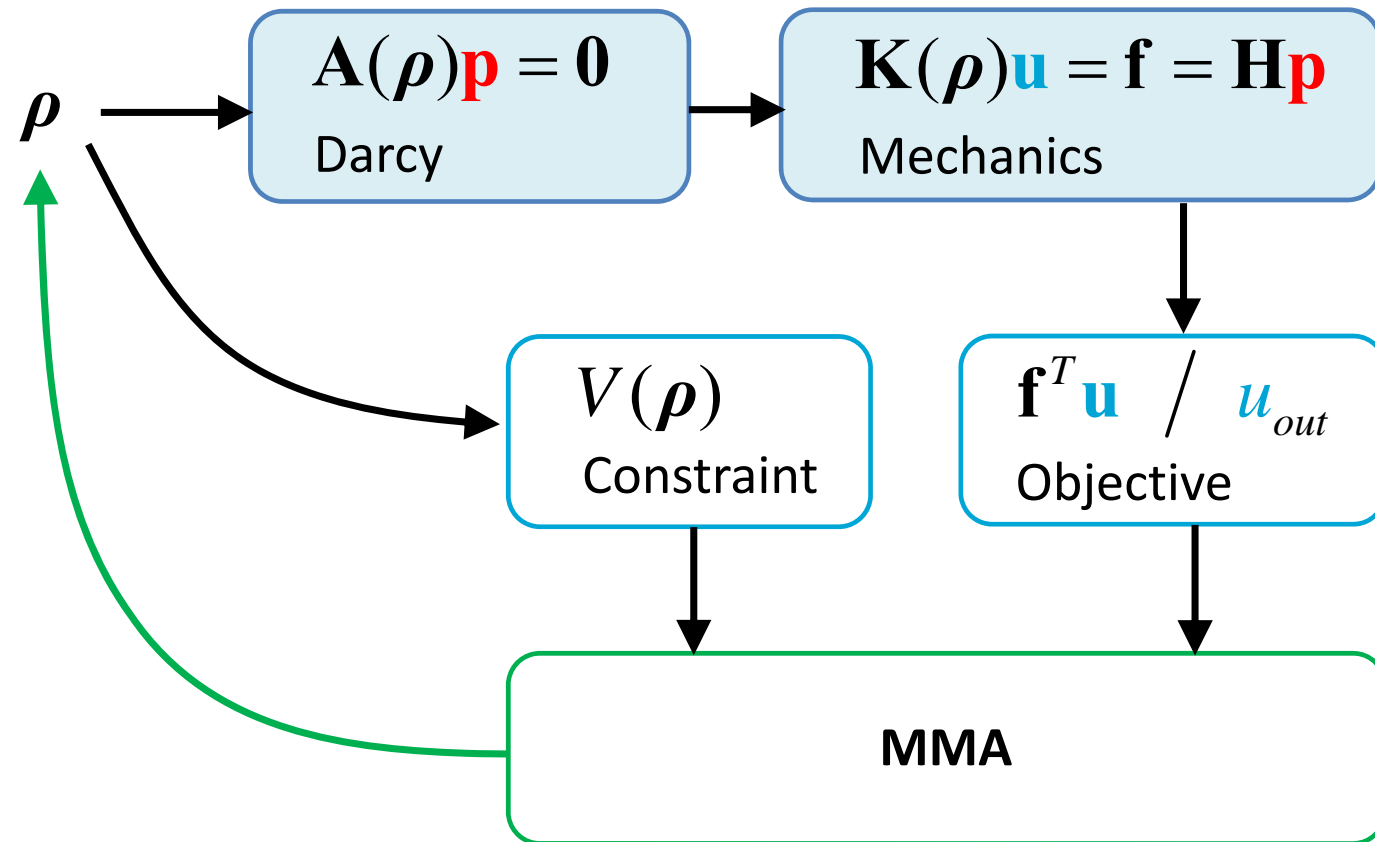


$$\nabla \cdot (K(\rho) \nabla p) = 0$$

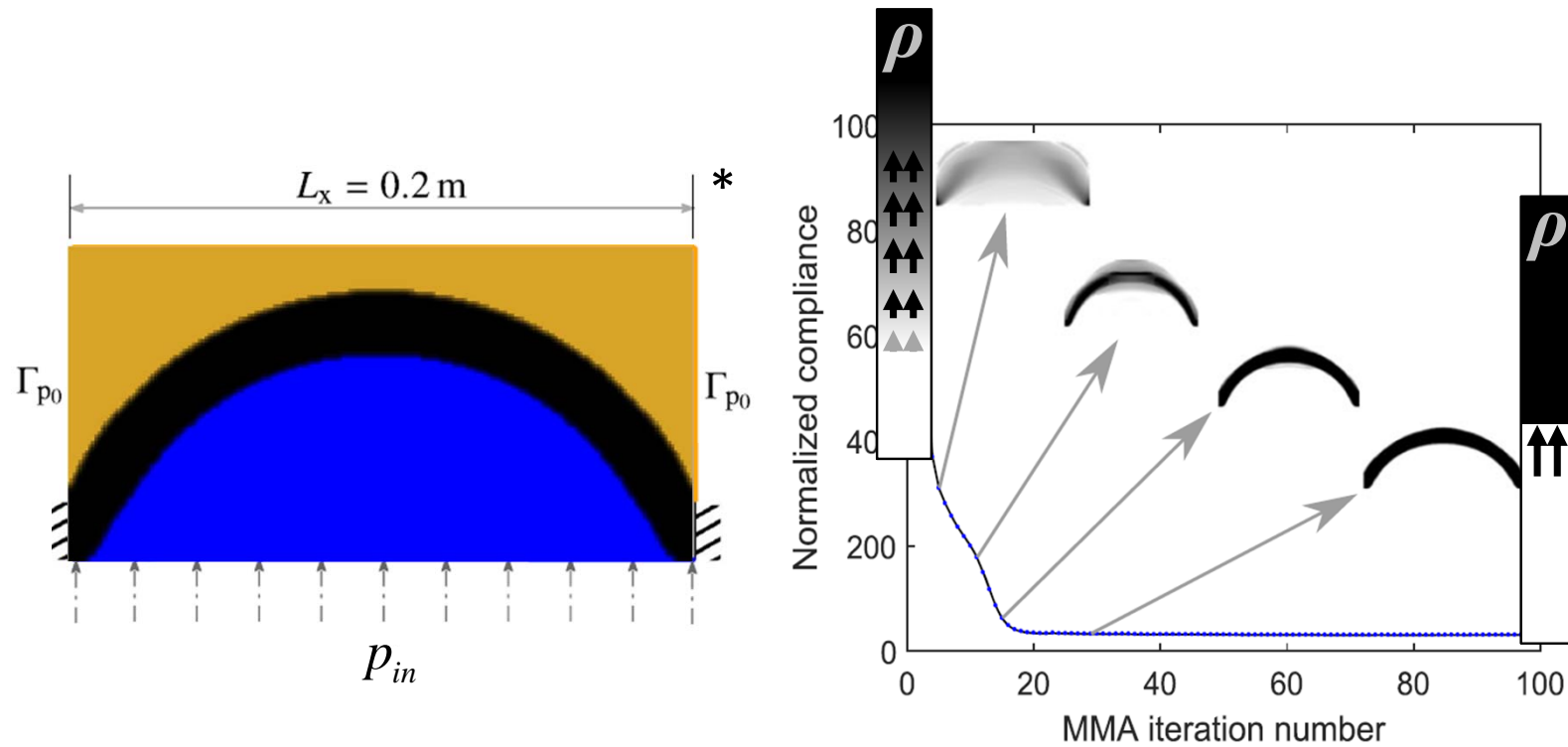


$$\nabla \cdot (K(\rho) \nabla p) + Q(\rho)(p - p_{out}) = 0$$

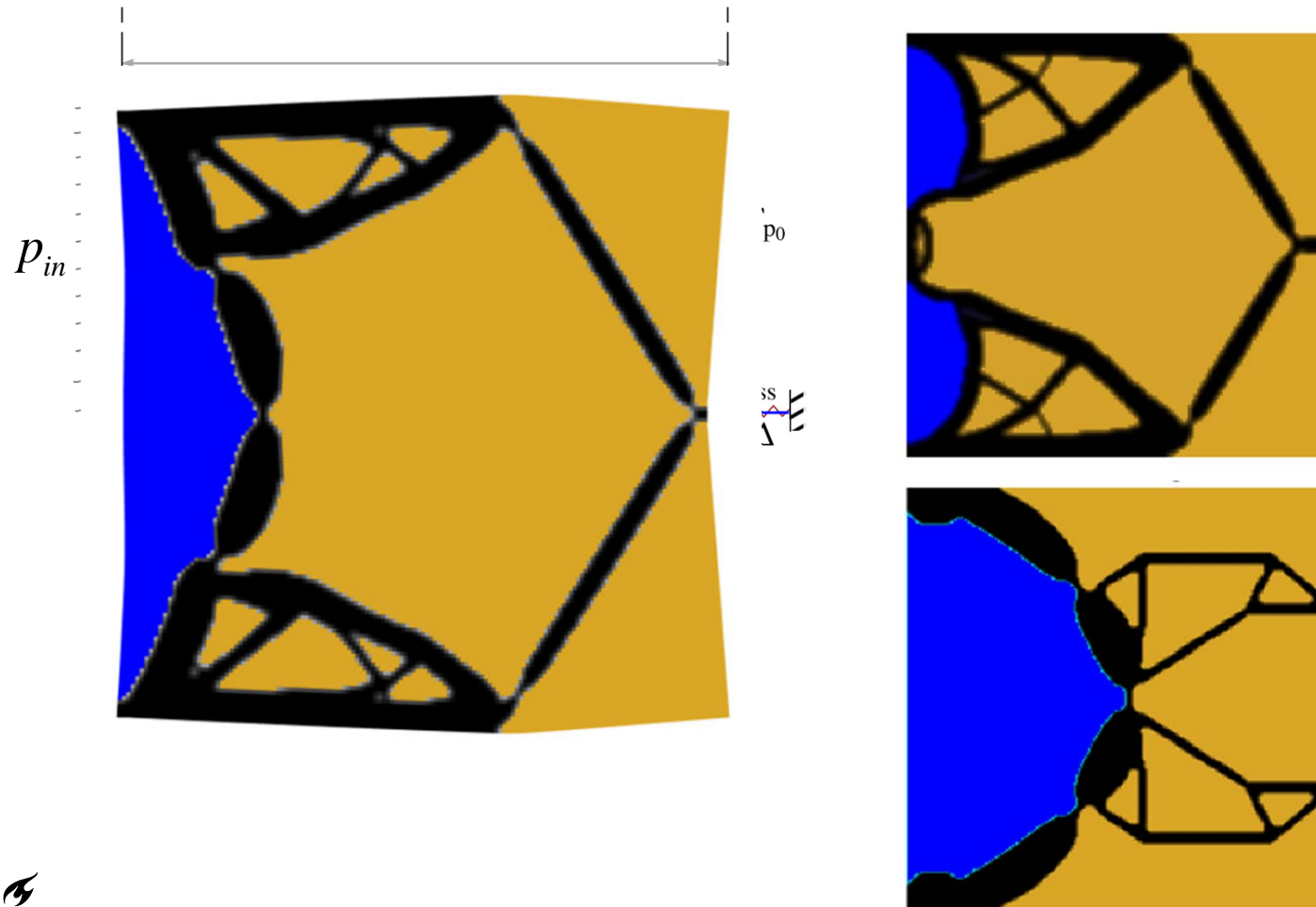
Process



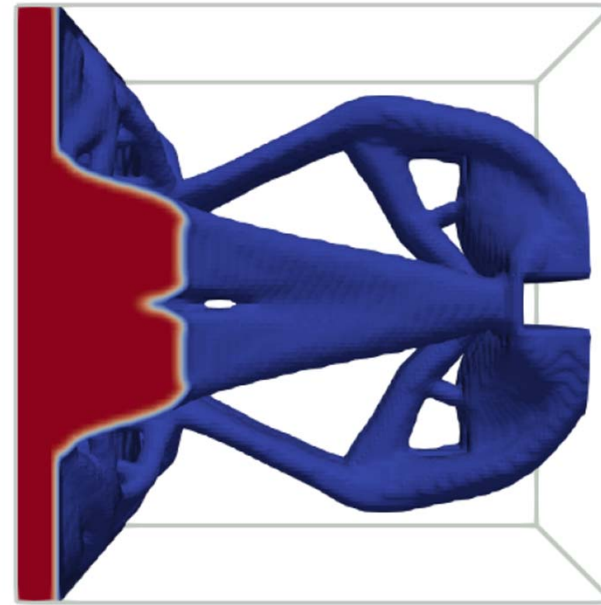
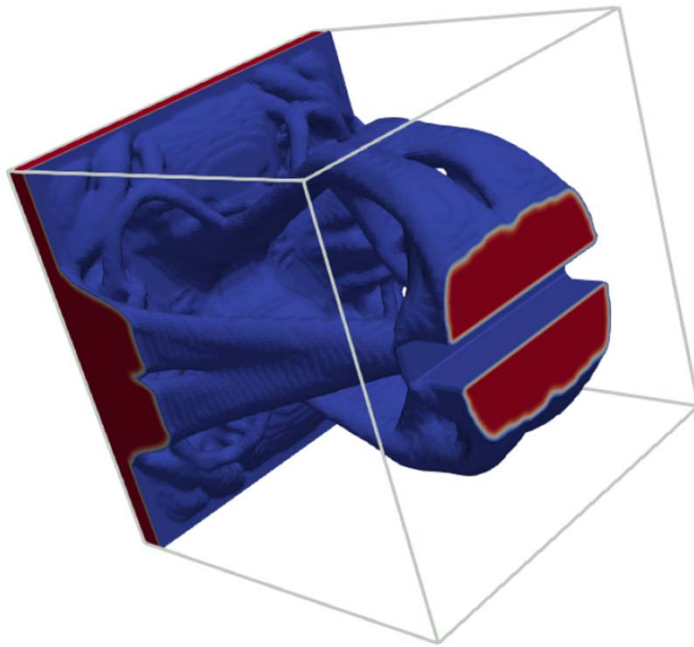
Optimizing pressure-loaded structures



Generating pressure-driven mechanisms



Preview: 3D



In preparation, with Prabhat Kumar

Summary and open challenges

- New approach for density-based topology optimization of pressure-loaded structures and mechanisms
 - ✓ Modest computational cost
 - ✓ Consistent load sensitivities
 - ✓ Extensible to 3D
- Challenges:
 - Large deflections
 - Self-contact

