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# Topology Optimization of an Aircraft Component as a Fluid-Structure System with Unstructured Mesh

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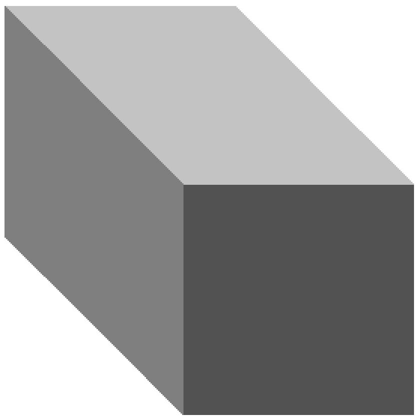
# Contents

# 1 - Introduction

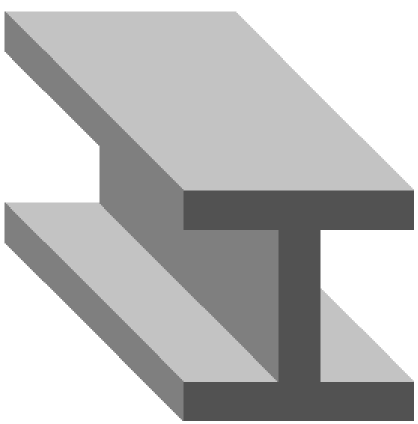
TOPOLOGY OPTIMIZATION
FLUID-STRUCTURE SYSTEM
WITH UNSTRUCTURED MESH

# TOPOLOGY OPTIMIZATION

# TOPOLOGY OPTIMIZATION



Solid structure, with too much unnecessary material



Less loaded material removed: structure optimized

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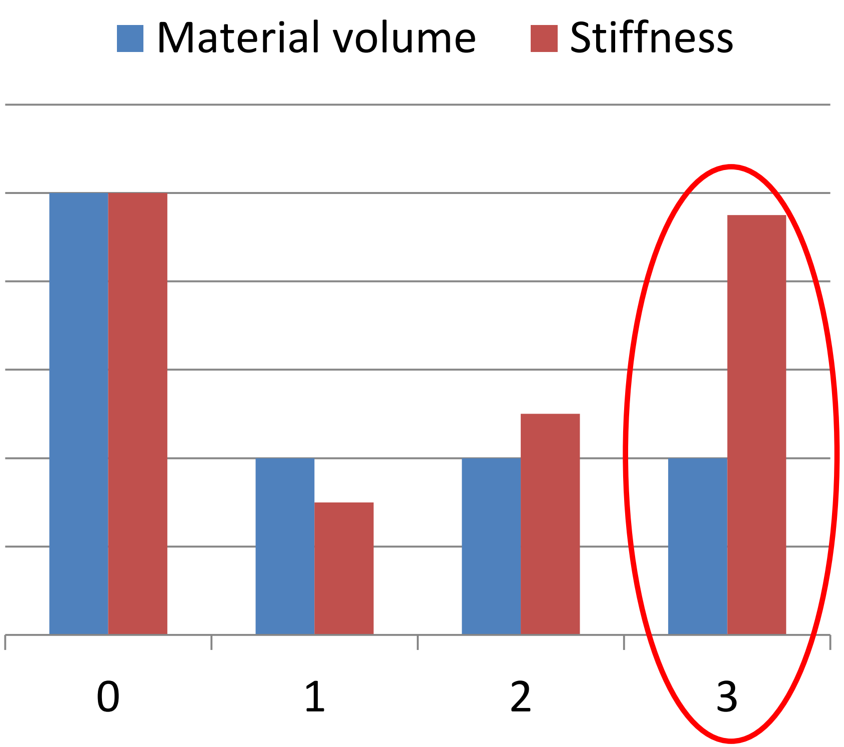
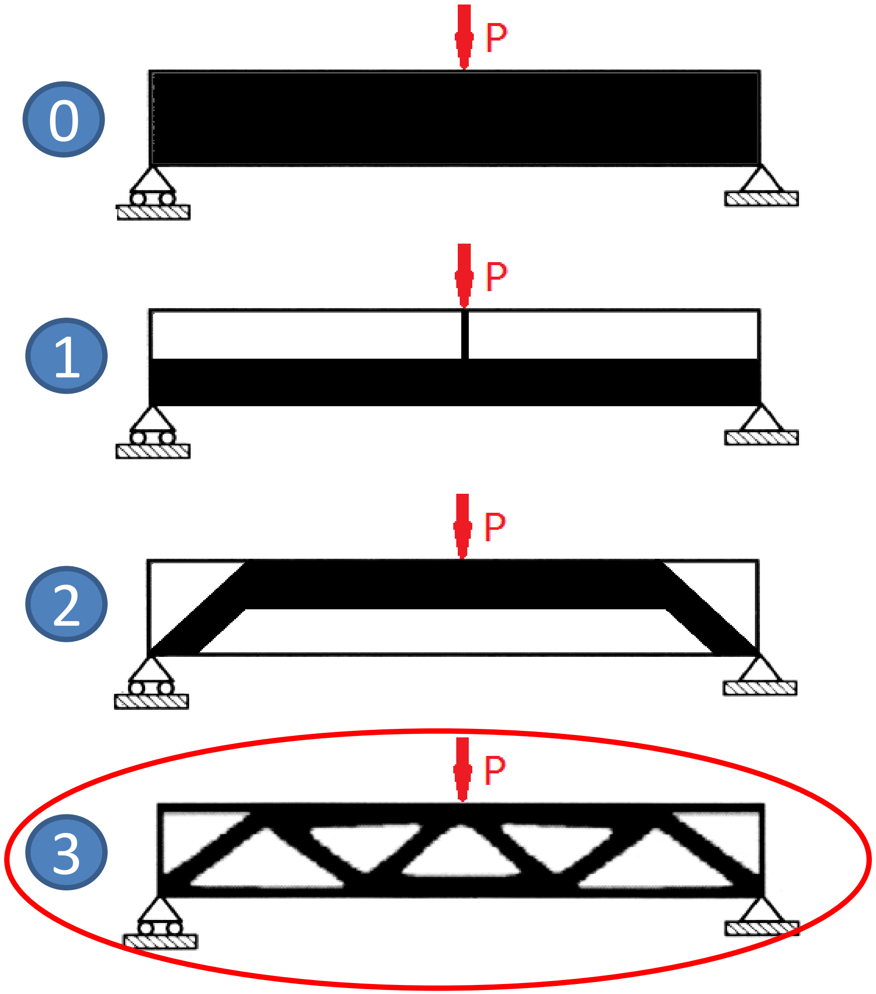
# TOPOLOGY OPTIMIZATION



# TOPOLOGY OPTIMIZATION

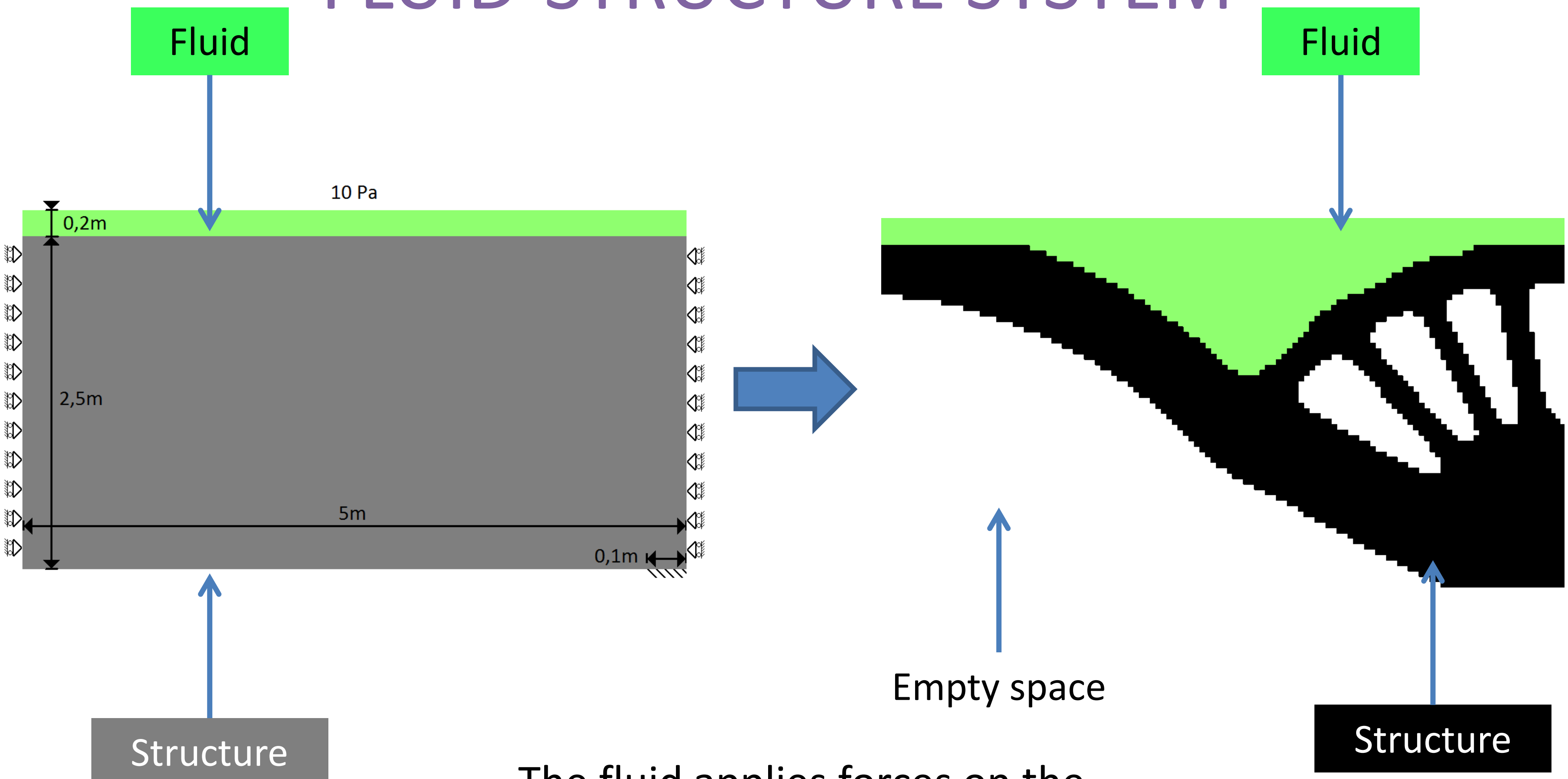
- Part of the design of a structure
  - Generation of an optimized concept
  - Then it needs to be converted to CAD
- Depends on the problem definition
  - Domain that can be occupied by the structure
  - Loads and boundary conditions
- Seeks the best possible characteristics of a structure that uses less material
  - Reduces weight and potentially costs
  - Final characteristics may be worse than the ones found in the original structure

# TOPOLOGY OPTIMIZATION

# FLUID-STRUCTURE SYSTEM

# TOPOLOGY OPTIMIZATION

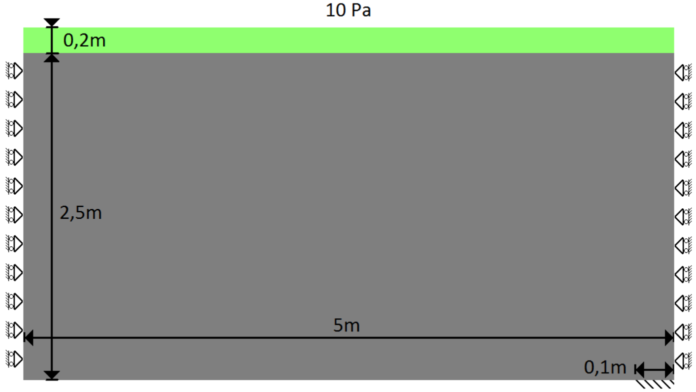
# FLUID-STRUCTURE SYSTEM



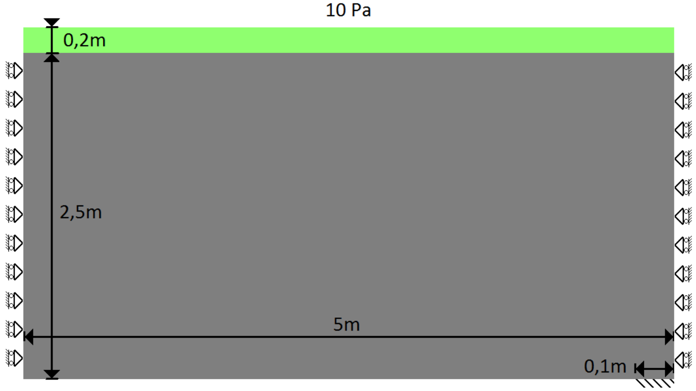

The fluid applies forces on the structure due to its pressure

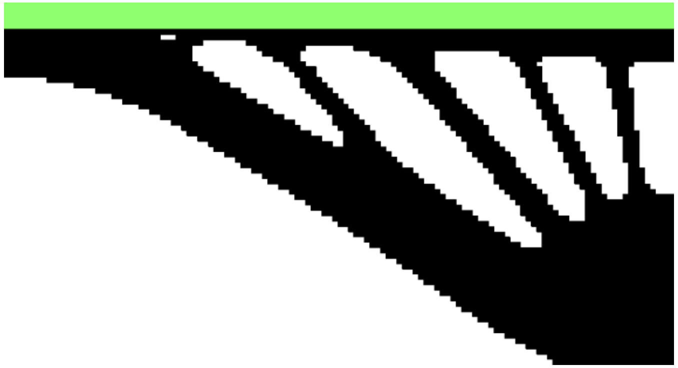
# TOPOLOGY OPTIMIZATION
# FLUID-STRUCTURE SYSTEM

Movable boundaries




Fixed boundaries



# TOPOLOGY OPTIMIZATION
# FLUID-STRUCTURE SYSTEM

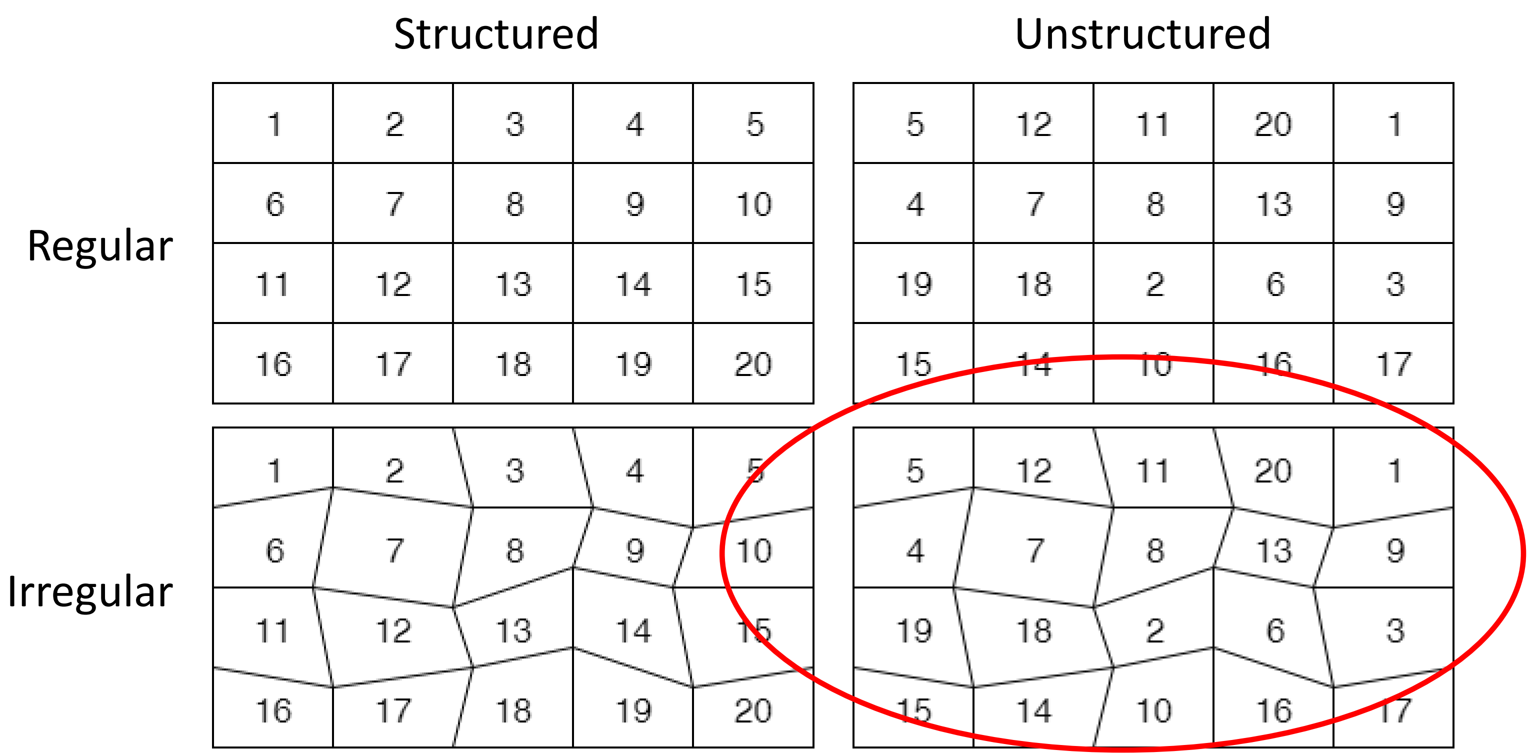
- Optimization method described in the literature: BEFSO
  - *Bi-directional Evolutionary Fluid-Structure Optimization*

# TOPOLOGY OPTIMIZATION FLUID-STRUCTURE SYSTEM WITH UNSTRUCTURED MESH

(also irregular)

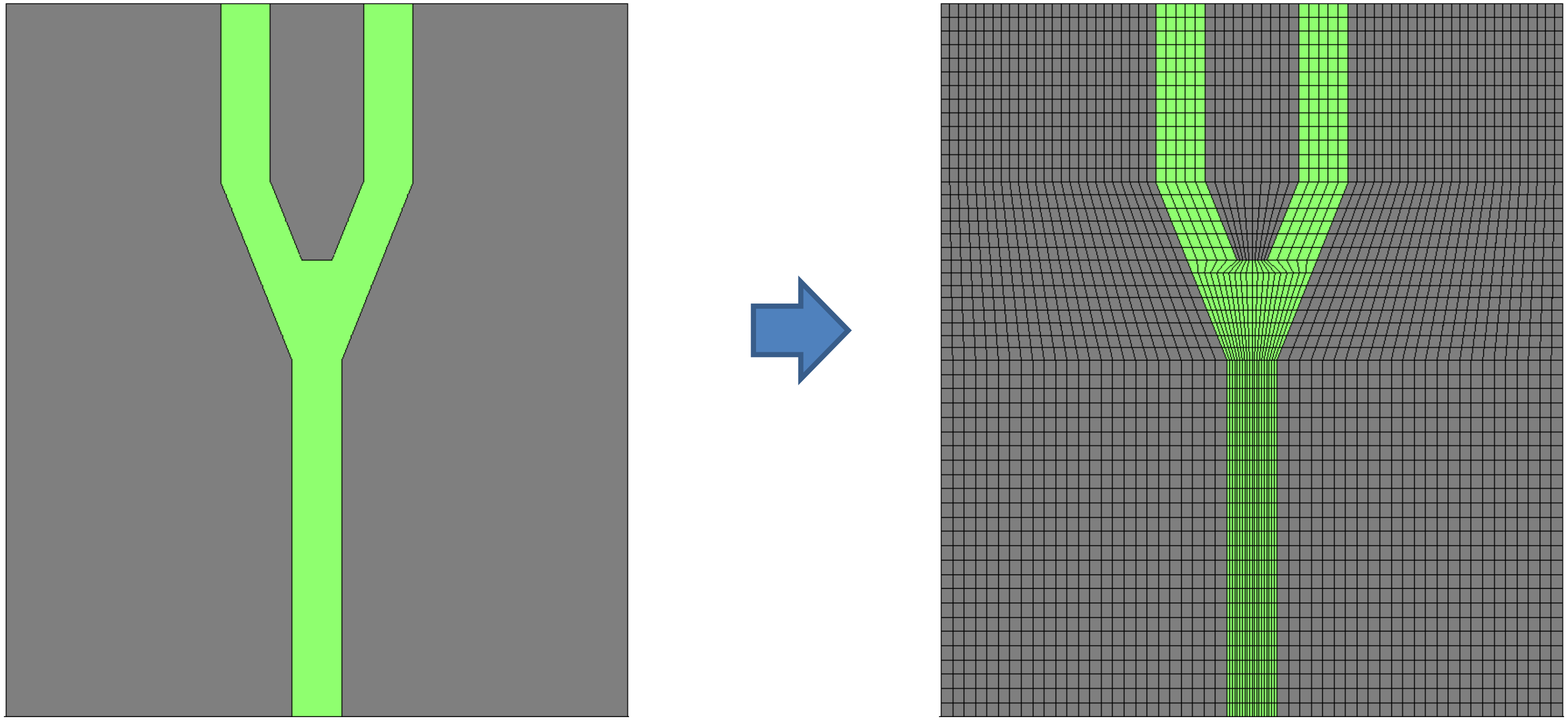
# TOPOLOGY OPTIMIZATION
# FLUID-STRUCTURE SYSTEM
# WITH UNSTRUCTED MESH

(also irregular)



# TOPOLOGY OPTIMIZATION
# FLUID-STRUCTURE SYSTEM
# WITH UNSTRUCTED MESH

(also irregular)



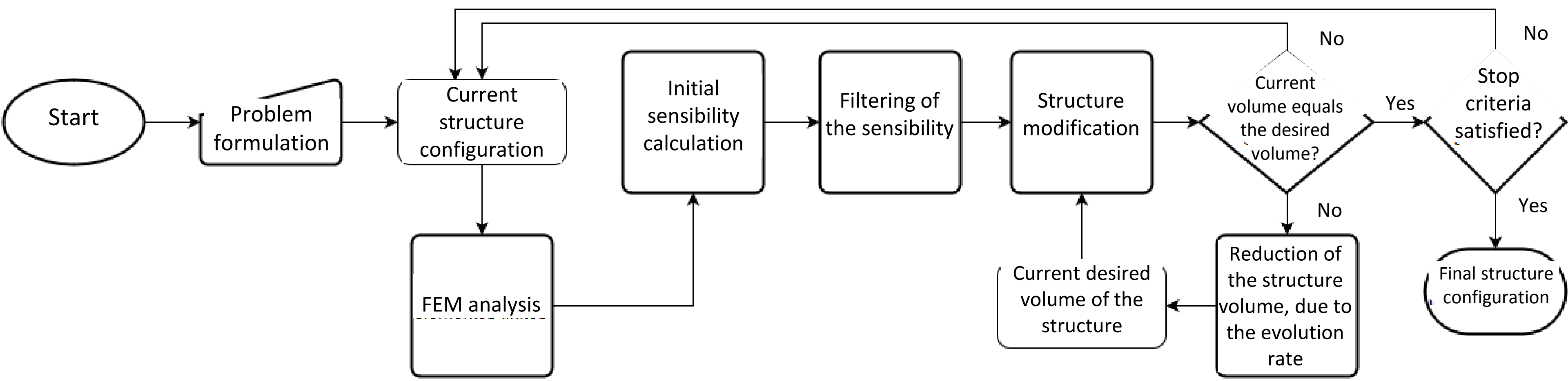
# 2 - Objectives

- Modify the BEFSO topology optimization method to obtain this functionality

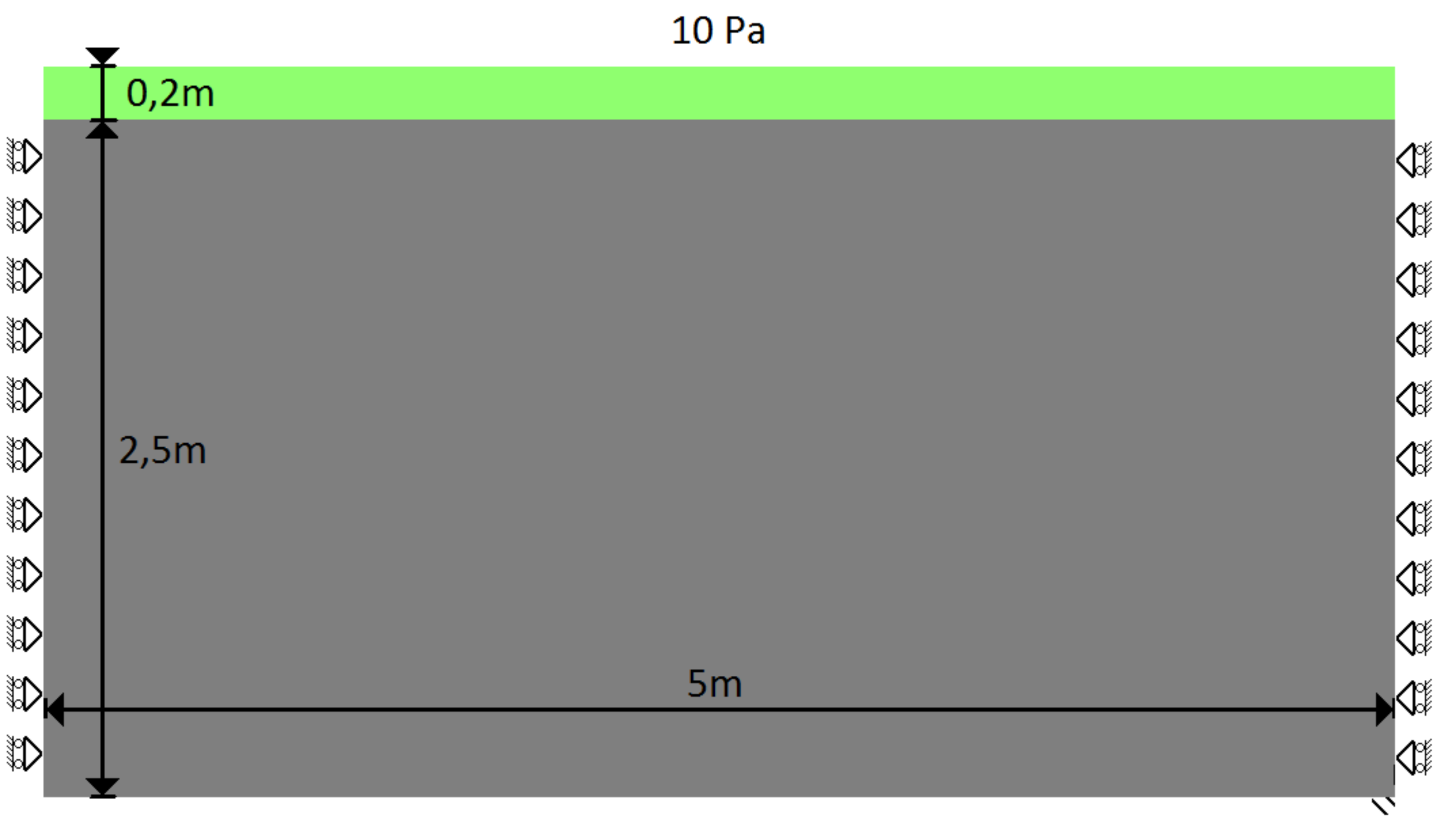
# 3 - Justification

- Build upon the topology optimization method, so it can be used in cases with more complex geometry using less elements

# 4 - Methodology

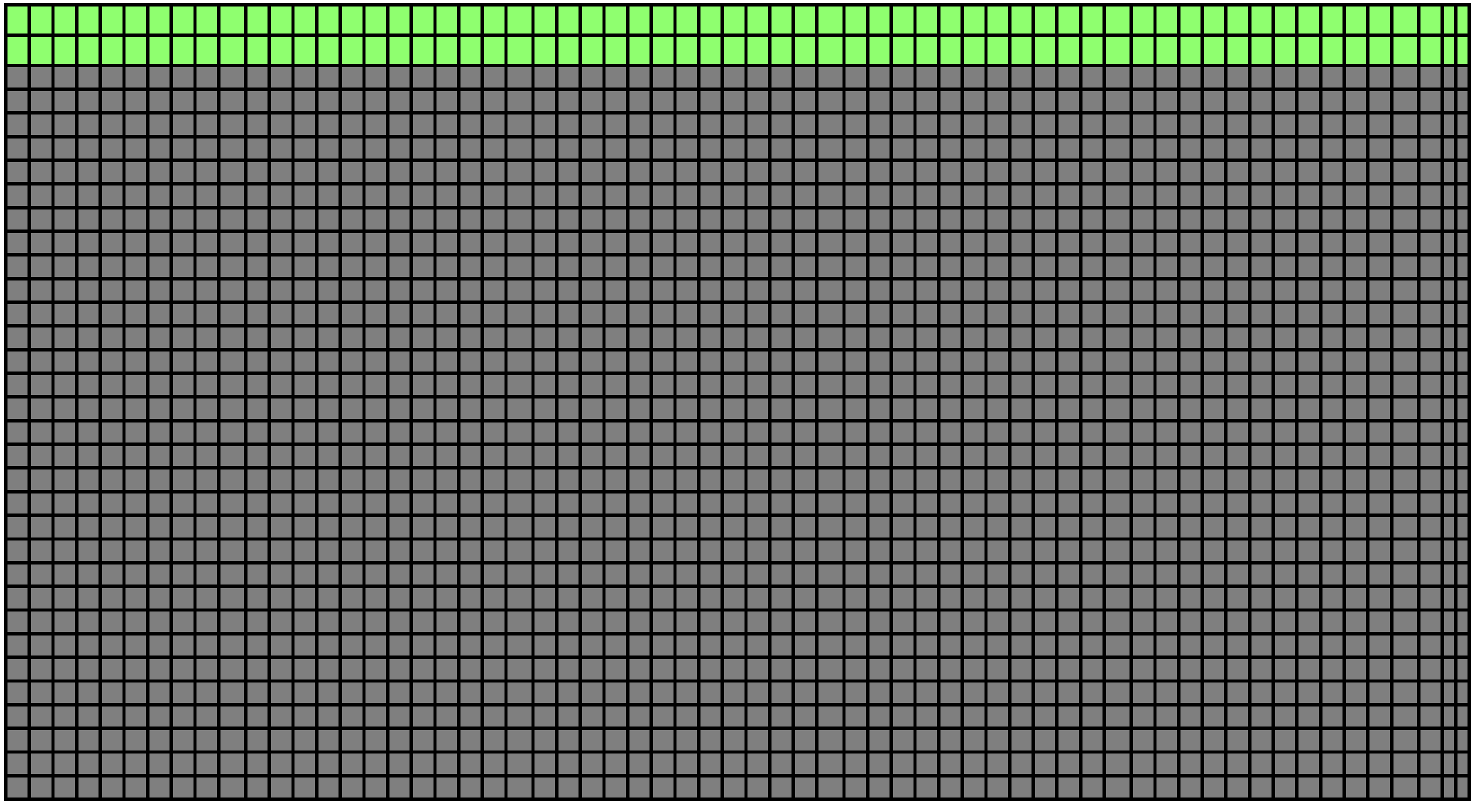


# 4 - Methodology



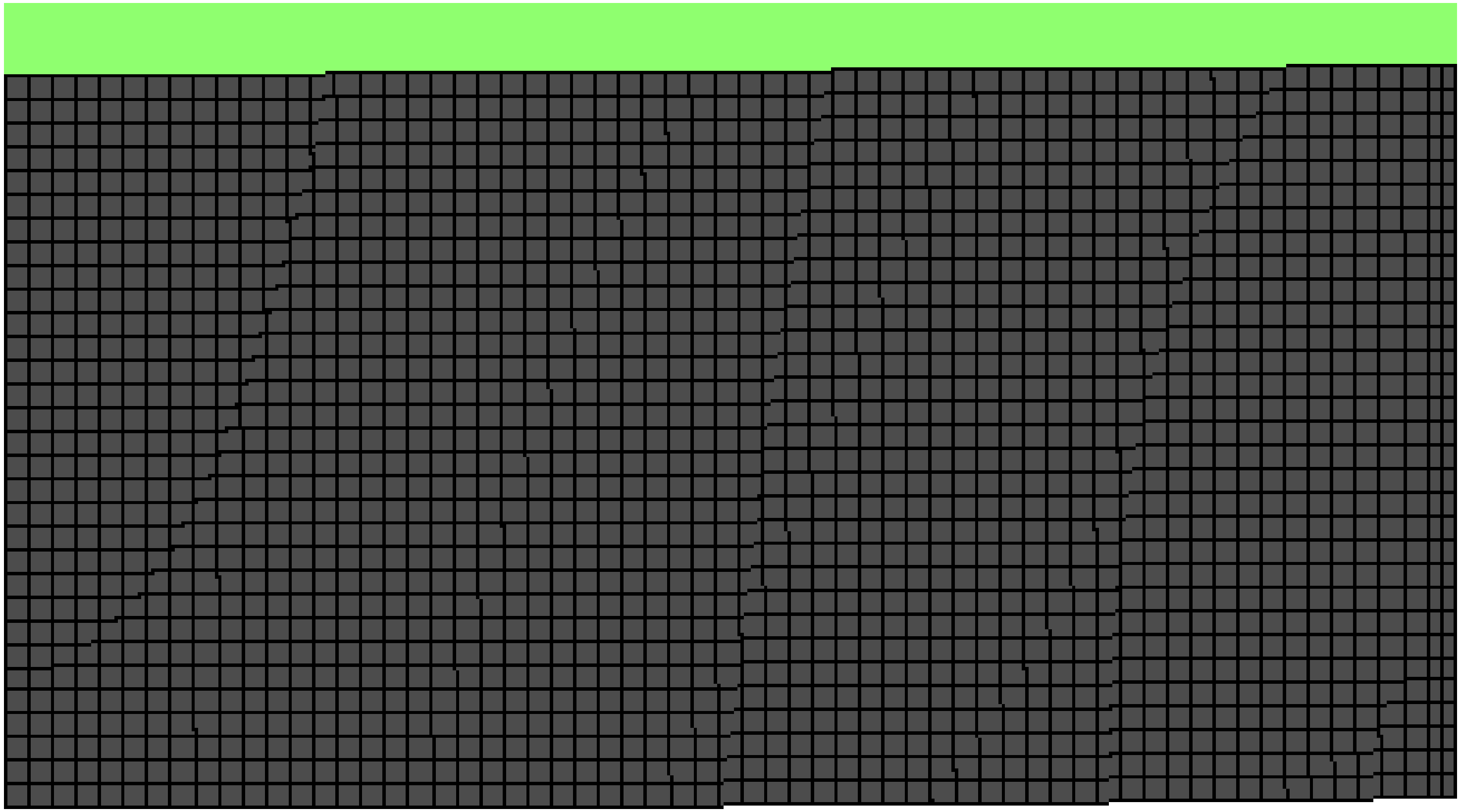

Definition of the domain and boundary conditions

# 4 - Methodology



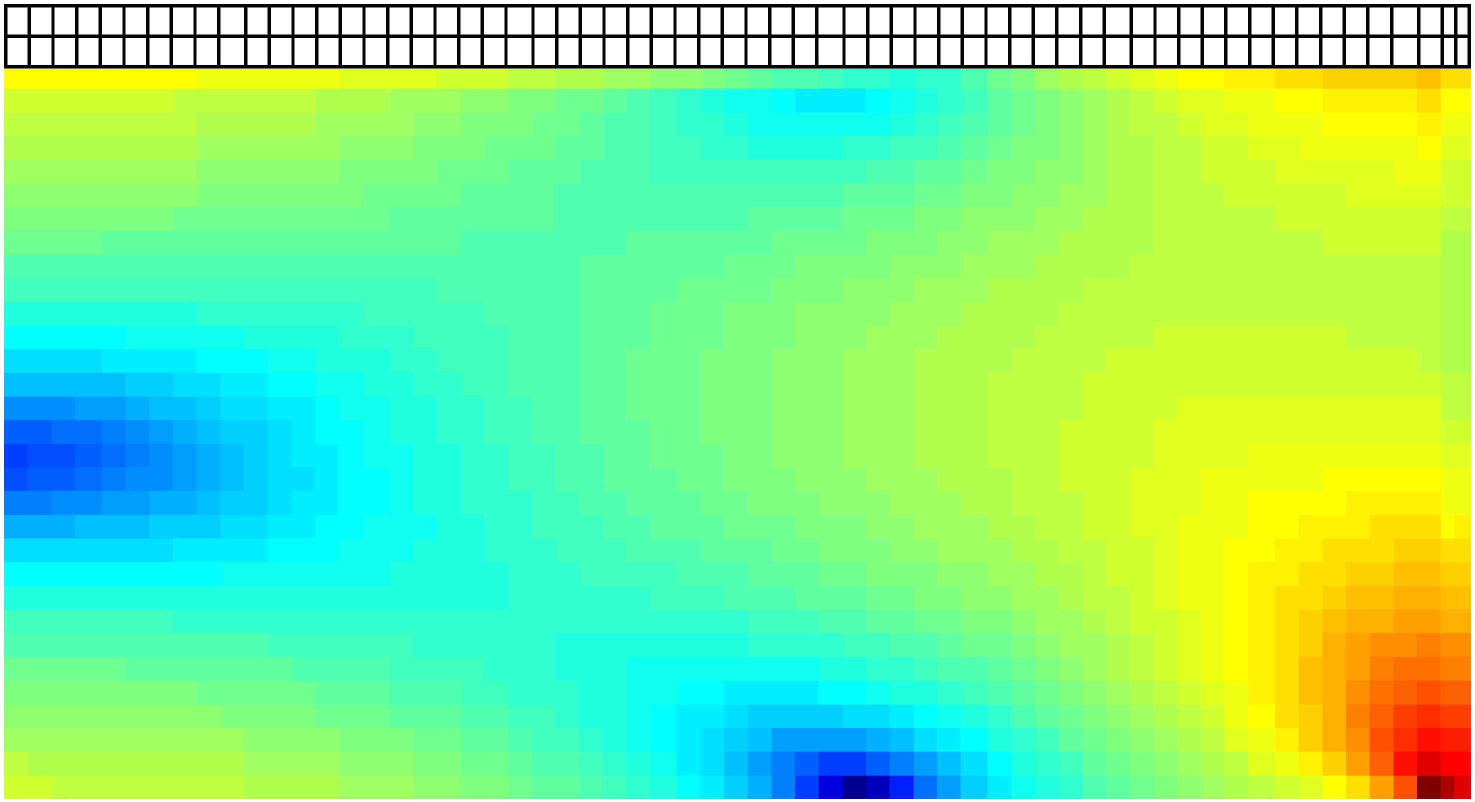
Mesh generation

# 4 - Methodology



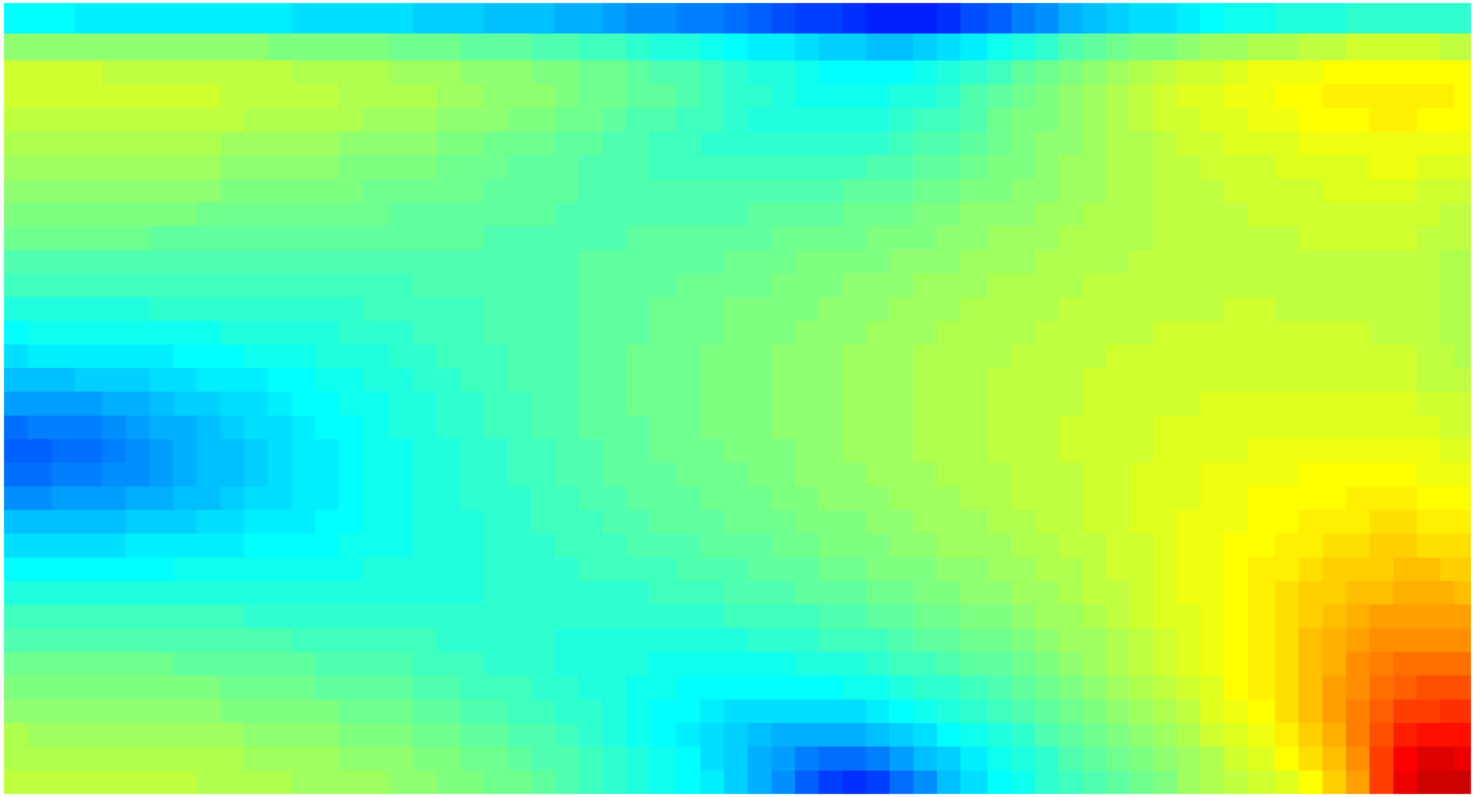
FEM analysis

# 4 - Methodology



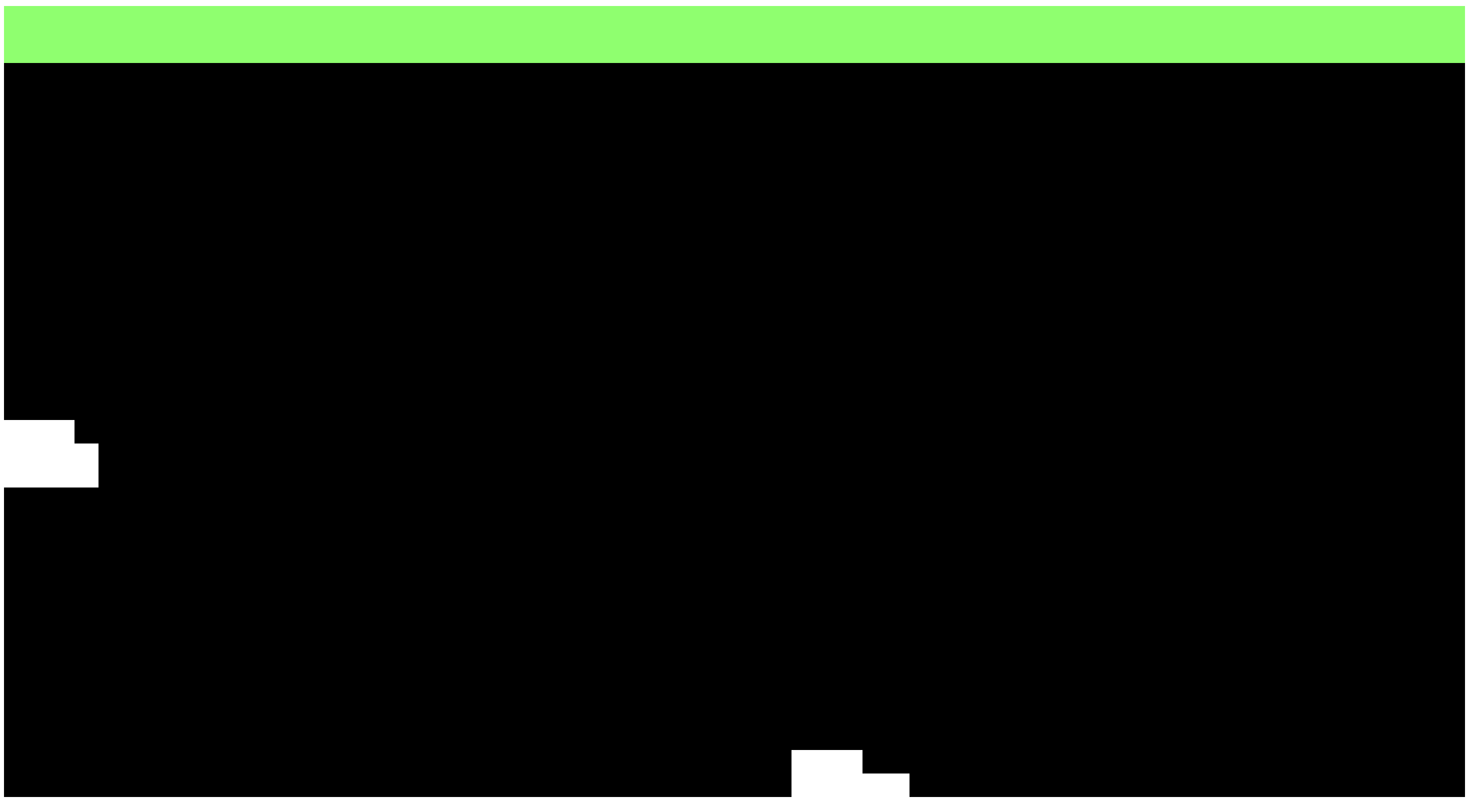
Calculation of the sensibility (contribution) of each element

# 4 - Methodology



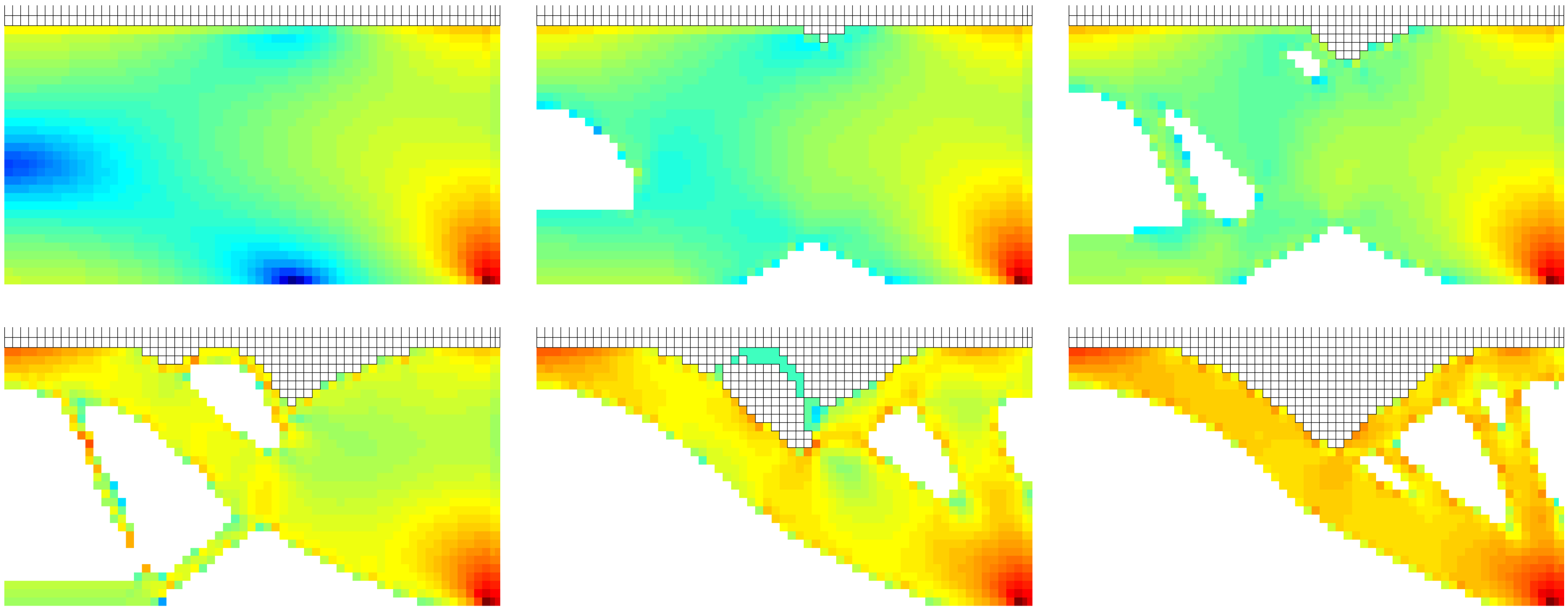
Filtering of the sensibility values

# 4 - Methodology

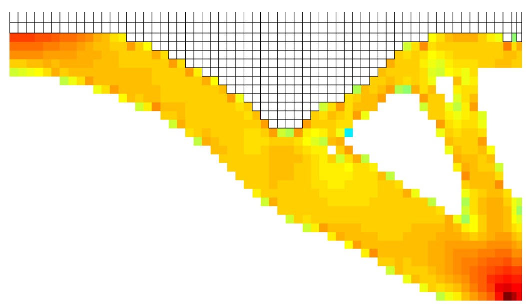


New structure with less material, without the elements with the lowest contributing elements

# 4 - Methodology



Several iterations until the final structure

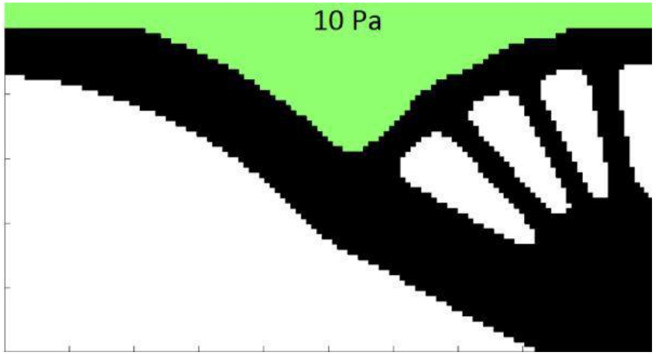


# 5 - Results

**Half piston**

Regular mesh
Movable F-S interface

a) Result found by Vicente (2013)*




b) Result achieved with 8375 elements

* Vicente, W.M. 2013 Otimização Topológica Evolucionária Aplicada a Sistemas Elasto-Acústicos. Doctoral Thesis in Mechanical Engineering, Campinas State University, Campinas, SP, Brazil.

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# 5 - Results

NACA 4412 profile with an angle of attack of 13°57’

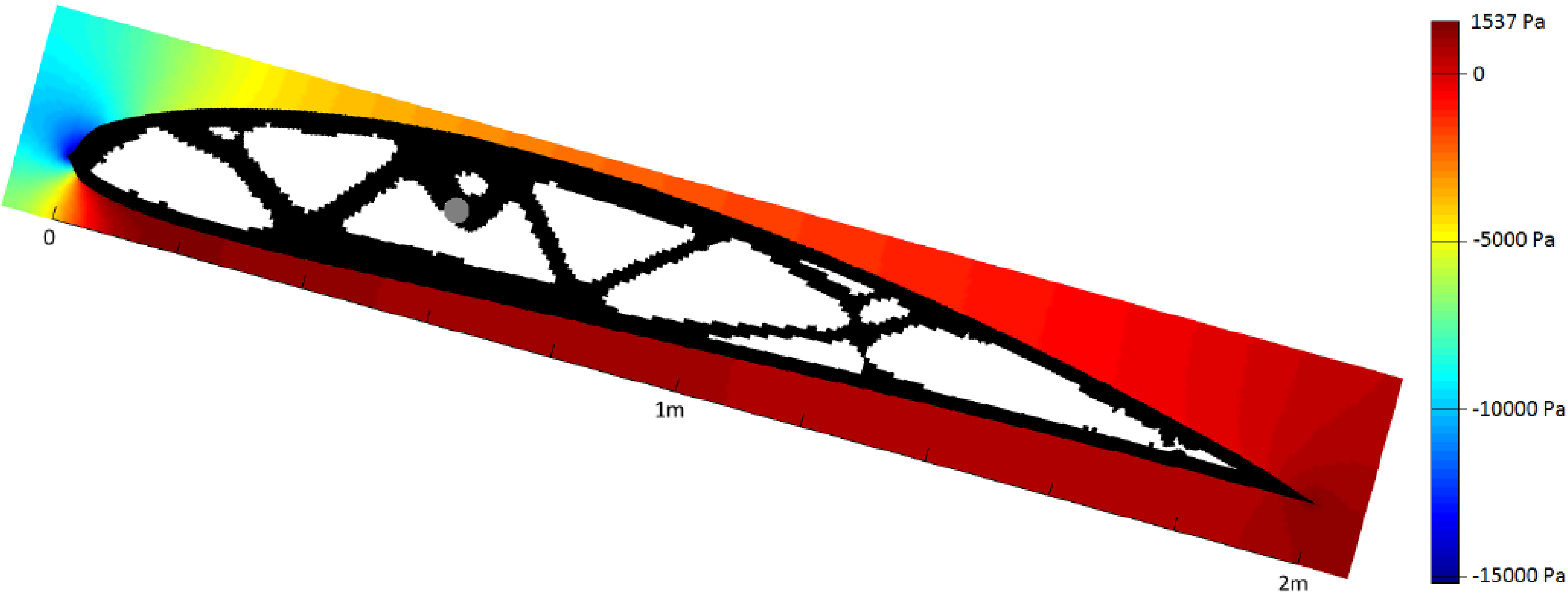
Optimization of internal cross structure of an airplane wing. In this case, there is a fixed interface between the fluid and the structure, because the external profile of the wing is determined by its aerodynamic behavior that is not simulated here.

The distribution of external pressure caused by air during its operation is given by Allen (1939)*, function of the dynamic pressure.

| Flow Velocity | $U$ | 200 km/h (55.57 m/s) |
|---|---|---|
| Air density | $\rho_{air}$ | 1.007 kg/m$^3$ |
| Dynamic pressure | $q$ | 1554.0 Pa |
| Altitude | $H$ | 2000 m |
| Wing profile | | NACA 4412 |
| Angle of attack | $A$ | 13º57’ |
| Chord | $c$ | 2 m |
| Thickness of the fixed interface layer | $T$ | 10 mm |
| Number of elements | $n$ | 15790 |

* Allen, H.J. 1939 A Simplified Method for the Calculation of Airfoil Pressure Distribution. Langley Aeronautical Lab., Langley Field, VA, USA, NACA-TN-708, 17p

# 5 - Results




Results for optimization of the internal structural cross section in a wing profile NACA 4412. The colored regions represent the fluid with the fringe indicating the pressure levels. The gray circular region represents a beam perpendicular to image, where the fixed conditions are applied

# 6 - Conclusions

✓ The developed software was capable to optimize cases with unstructured and irregular meshes, and with or without movable interface.

✓ It was possible to implement the topology optimization code BEFSO without any dependence on external commercial programs. As example, one aircraft wing was optimized using an unstructured and irregular mesh.