New developments in topology optimization

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Based on V. Bhat's work (Msc)

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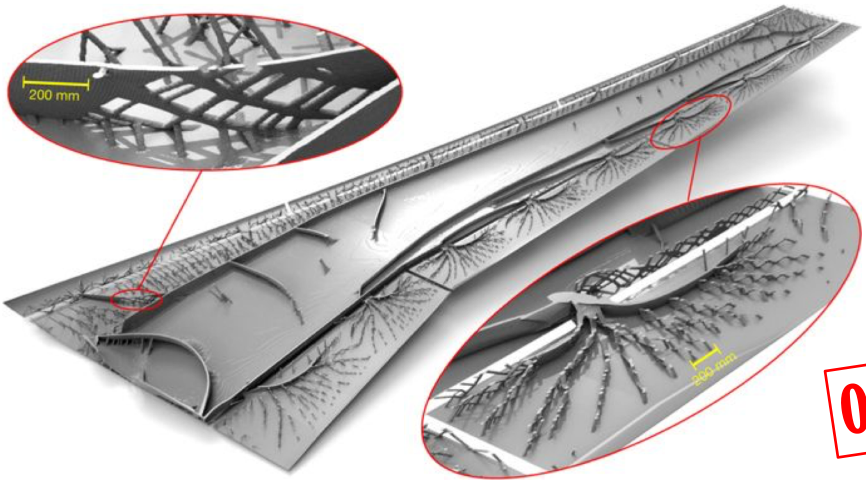
Use HPC and lot of time

Niels Aage, Erik Andreassen, Boyan S Lazarov, and Ole Sigmund. Giga-voxel computational morphogenesis for structural design. Nature, 550(7674):84, 2017.



Or ...

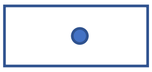
Moving Node Approach (MNA)

6 variables per node

G. Raze, M. Charlotte, J.Morlier, Vers la reconnaissance d'éléments structuraux, CSMA, 2017
J. Overvelde, PHD thesis, TU Delft, 2012

Optimization variables :

- Positions (x,y)
- Orientation (θ)
- Dimensions (Lx,Ly)
- Mass (M)

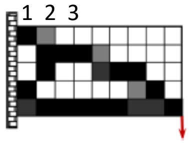


Structural Members engineering bricks like: beam, plate, geometric primitives

Moving Node Approach (MNA)

Projection

Design variables update → Interpretation → Model update Density, Young modulus



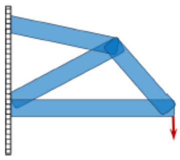
SIMP
Implicit framework
variables : material density

$x_1 = 1$
$x_2 = 0.5$
$x_3 = 0$
...

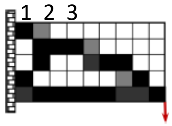
Innovative approach to help engineering solution identification :
Components are placed in design space according to variables and material density are derived accordingly.

Explicit framework
Variables : geometrical data

$x_1 = Position$
$x_2 = Length, Height$ ...



Projection

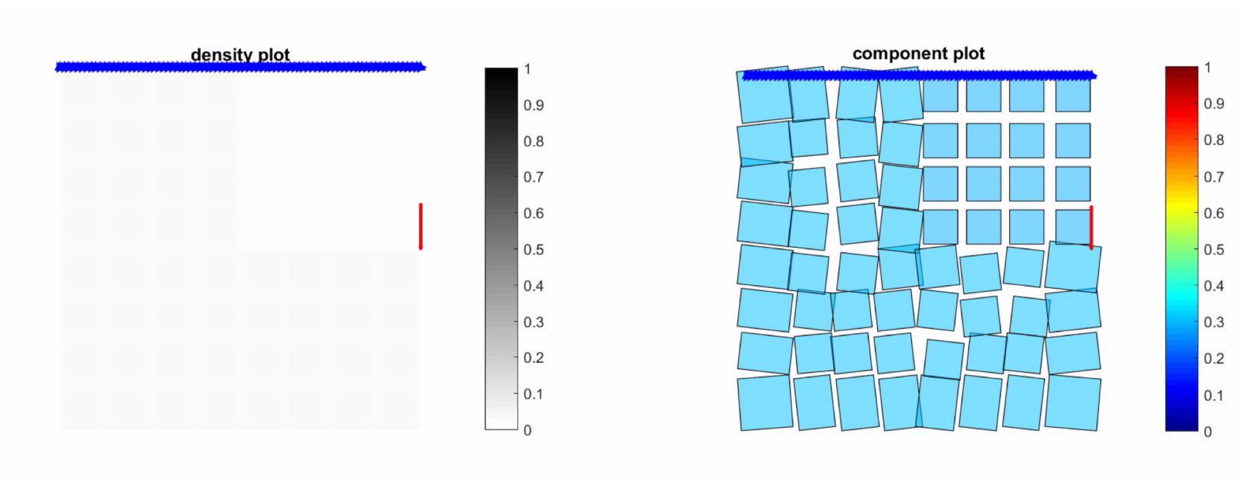


(GUO et al. 2015) A new topology optimization approach based on Moving Morphable Components (MMC) and the ersatz material model

Design is made of engineering bricks like: beam, plate, brick….

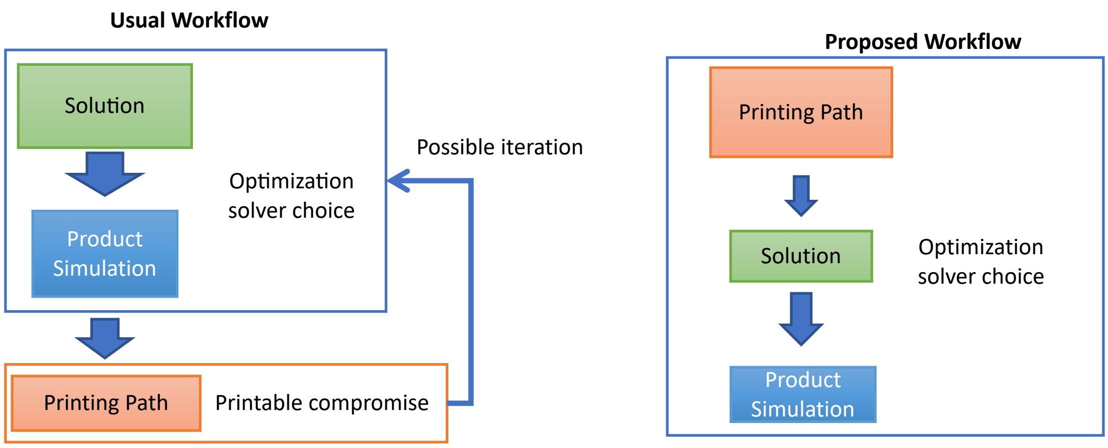
Results MNA, 8*8*6=384 design variables minC st Volfrac=0,4

At the end, explicit assembly of components!



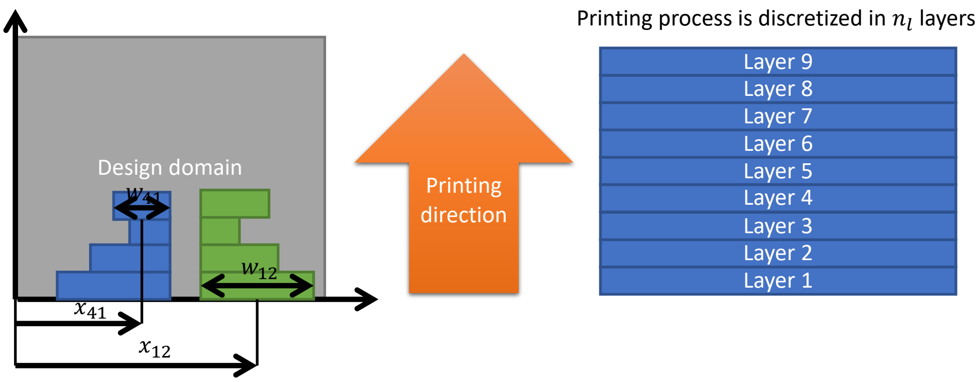
ALM based projection

ALM based projection



ALM based projection

A solution is determined by its manufacturing process: (in this case printing path)



- MNA Components are replaced by printed branches
- Design variables will be printed branch position and width per layer: x_{li}, w_{li}
- For each layer a projection is made to get the solid model modulus

ALM based projection

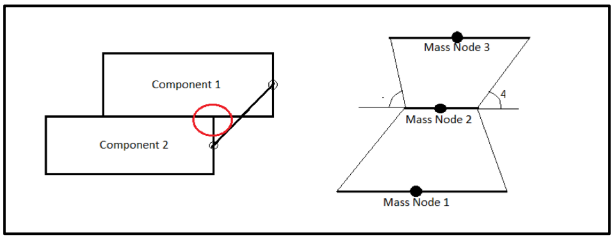
Optimization formulation

$$\begin{cases} \min\limits_{X} c = F^T \cdot U \\ \quad s.t. \\ \sum\limits_{i=1}^{N} \rho_i - v_f N \leq 0 \\ \theta_l \leq \theta \quad \leq \pi - \theta_l \end{cases}$$

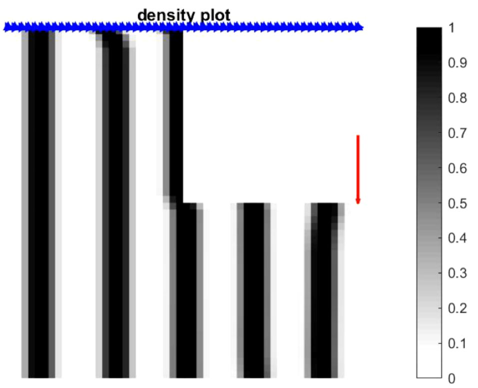
External forces work

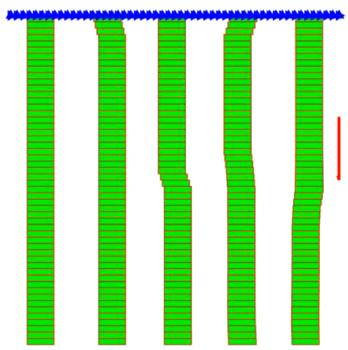
Mass constraint

Overhang angle constraint



ALM based projection





$N_x = N_y = 52$

$v_f = 0.4$

$5\ printing\ components$

$18\ printing\ intervals$

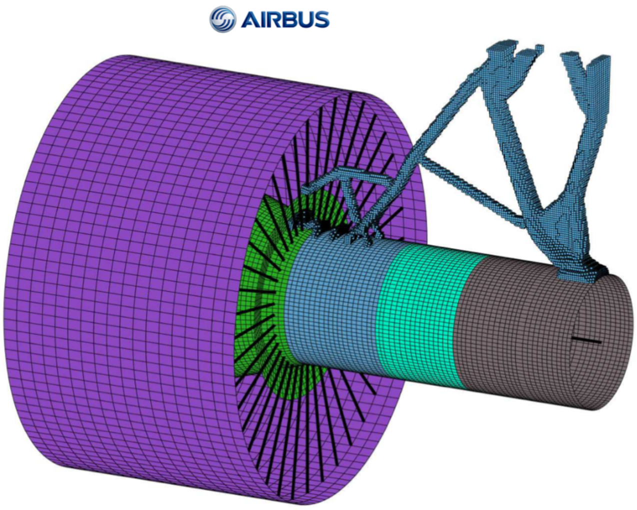
$5 \times 18 \times 2\ design\ variables$

Conclusion and future works

Conclusion

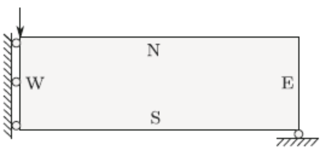
- A new framework has been released fully compatible with FDM (Fuse Deposition Modeling)
- Overhang angle constraints was succesfully enforced in the optimization loop
- The solution is described by an explicit trajectory
- We are ready to adapt our methodology with others ALM processes

AIRBUS CIFRE results : innovative pylon



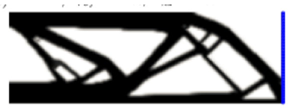
Future works (1)

- Ongoing works→ comparison with Amfliter



Langelaar, M. (2017). An additive manufacturing filter for topology optimization of print-ready designs. Structural and multidisciplinary optimization, 55(3), 871-883

a) N case: $C/C_{ref} = 111\%$, M_{nd}=21.7%



b) E case: $C/C_{ref} = 101\%$, M_{nd}=14.0%

c) S case: $C/C_{ref} = 106\%$, M_{nd}=18.1%

d) W case: $C/C_{ref} = 100.0\%$, M_{nd}=12.7%

e) Reference case (unrestricted): $C = C_{ref}$, M_{nd}=14.8%

Papers & conf on this topic

Thanks !!

Coniglio, S., Gogu, C., Amargier, R., & Morlier, J. (2017, June). Pylon and engine mounts performance driven structural topology optimization. In World Congress of Structural and Multidisciplinary Optimisation (pp. 1349-1363). Springer, Cham.

Coniglio, S., Gogu, C., & Morlier, J. (2018). Weighted Average Continuity Approach and Moment Correction: New Strategies for Non-consistent Mesh Projection in Structural Mechanics. Archives of Computational Methods in Engineering, 1-29.

Coniglio, S., Morlier, J., Gogu, C., & Amargier, R. (2018). Original Pylon Architecture Design Using 3D HPC Topology Optimization. In 2018 AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference (p. 1388).

G. Raze et al, Optimisation topologique sans maillage : vers la reconnaissance d'éléments structuraux, CSMA 2017

Several Papers in preparation

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