Reconstruction par la technique de fabrication additive robotisée des formes funiculaires issues du patrimoine historique et culturel.

Robotique, Patrimoine et Archéologie

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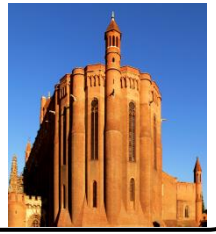


< 20ème siècle

- Durée de construction ↑
- Complexité de l'architecture ↑

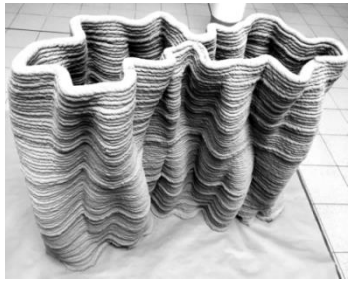
> 20ème siècle

- Durée de construction ↓
- Complexité de l'architecture ↓

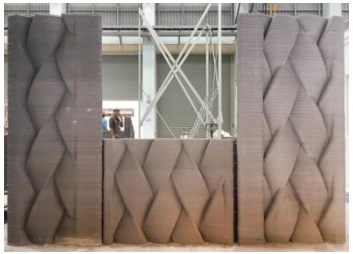
3D printing

Xtree 2017

Andrey Rudenko 2015 – minature castle



Project MATRICE 2017

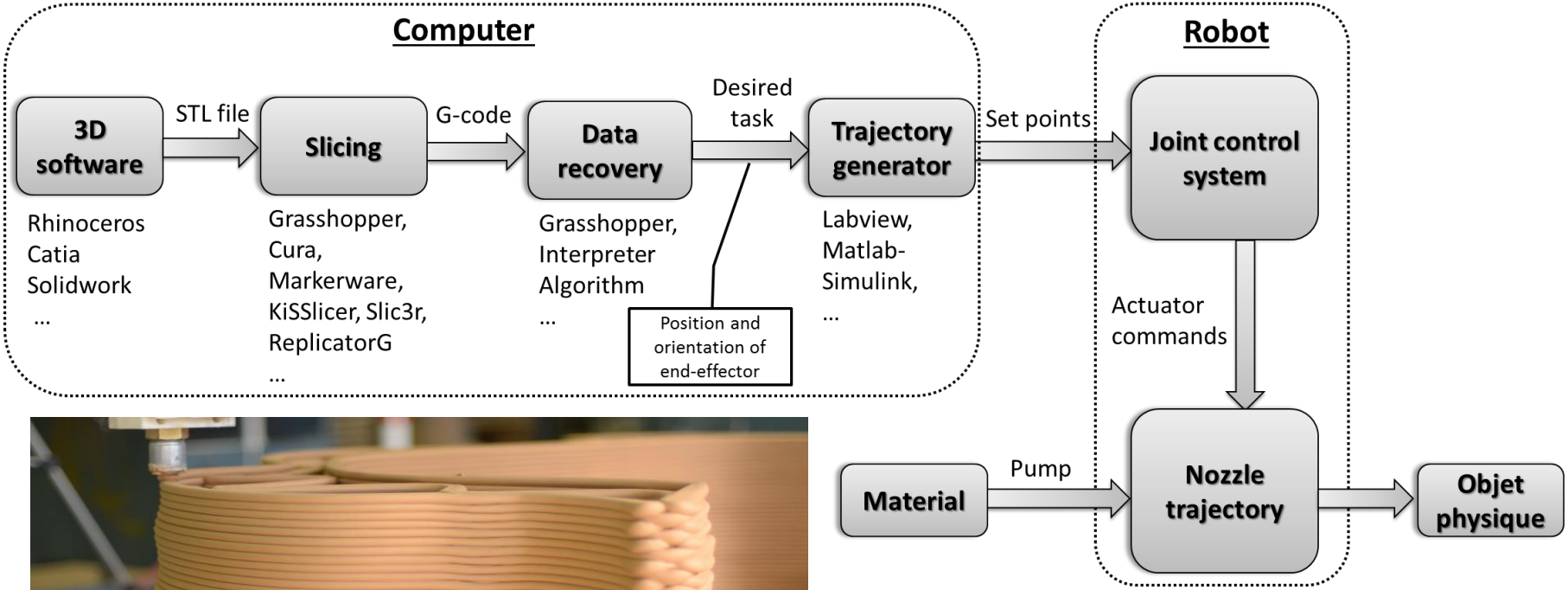


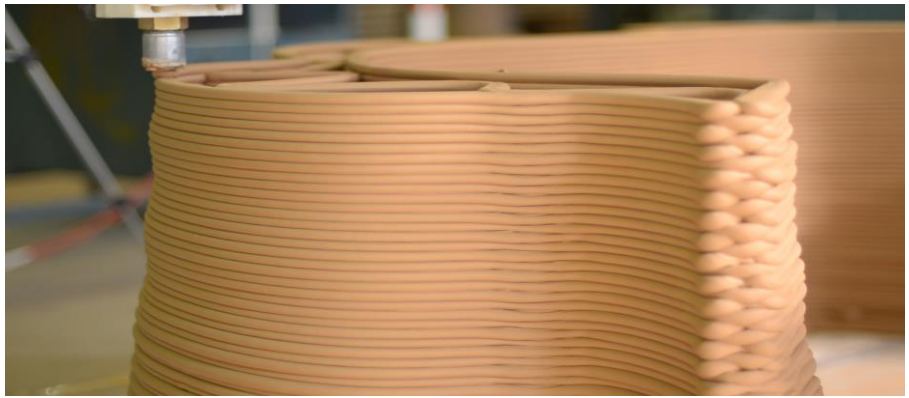
Siam Research and Innovation Compagny (SCG-SRI)

> 21ème siècle

- Durée de construction ↓
- Complexité de l'architecture ↑

Principe de la fabrication additive





Projet MATRICE

MATRICE

FABRICATION ADDITIVE POUR LE BÂTIMENT

2015-2017

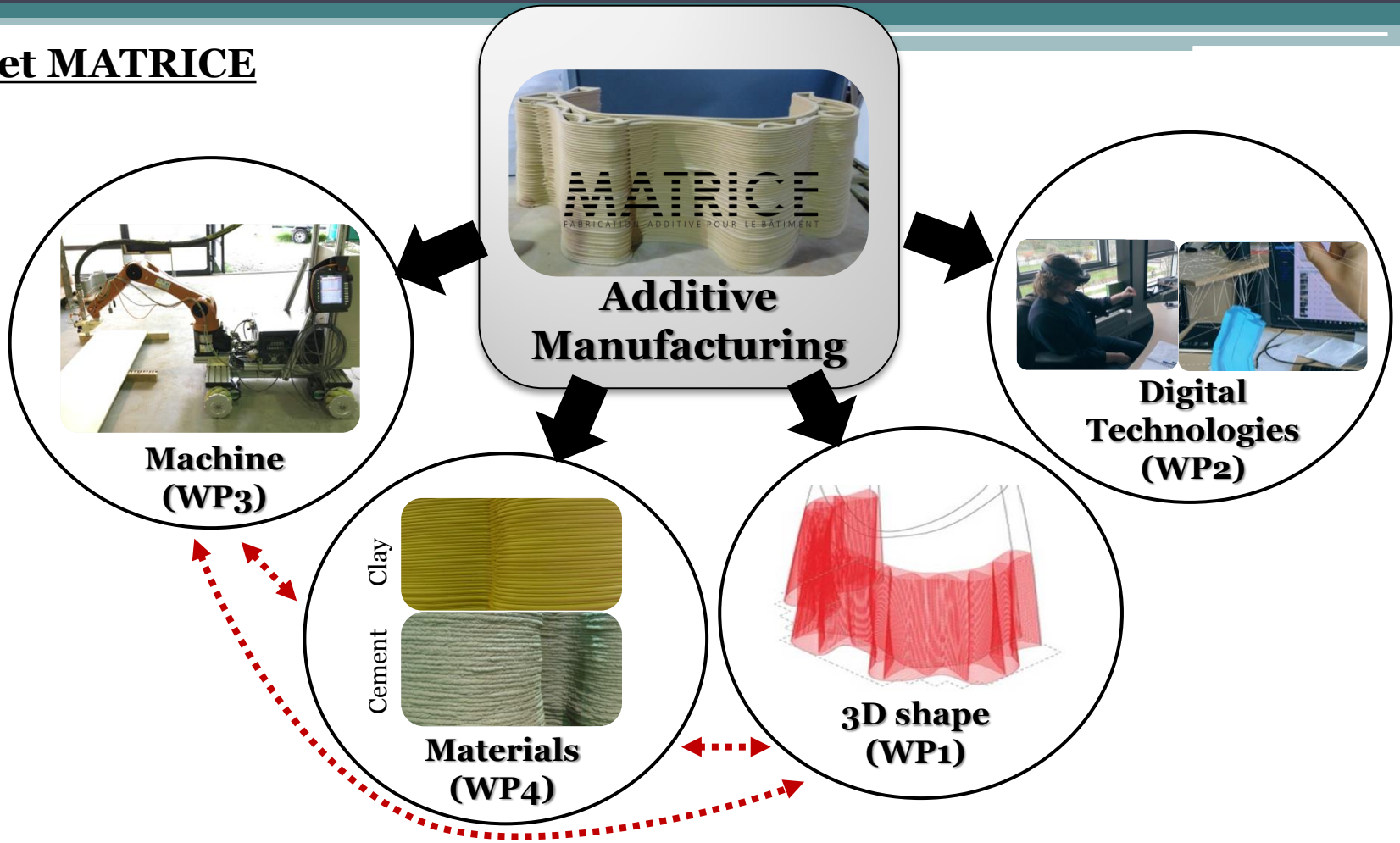
Région Hauts-de-France

l'Europe s'engage en Hauts-de-France avec le FEDER

The MATRICE project was co-funded by the FEDER (European Regional Development Funds, fund created in 1975) and the regional council "Hauts-de-France".

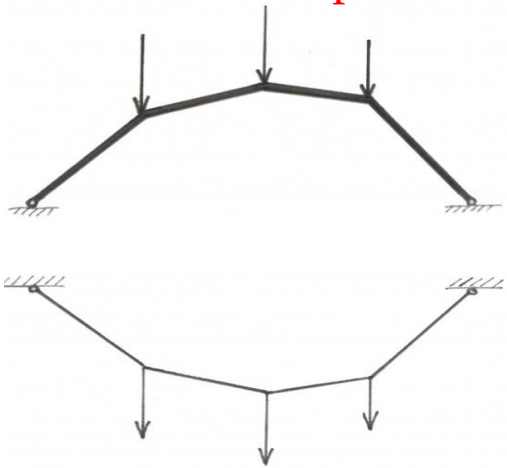
http://www.matrice-impression3d.fr/

Projet MATRICE

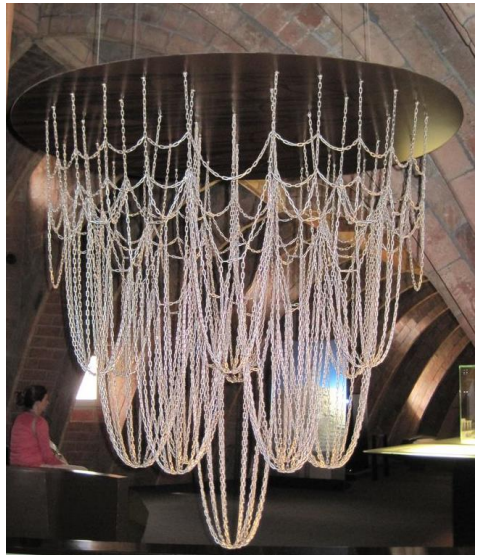


Forme funiculaire

Forces de compression



Forces de tension



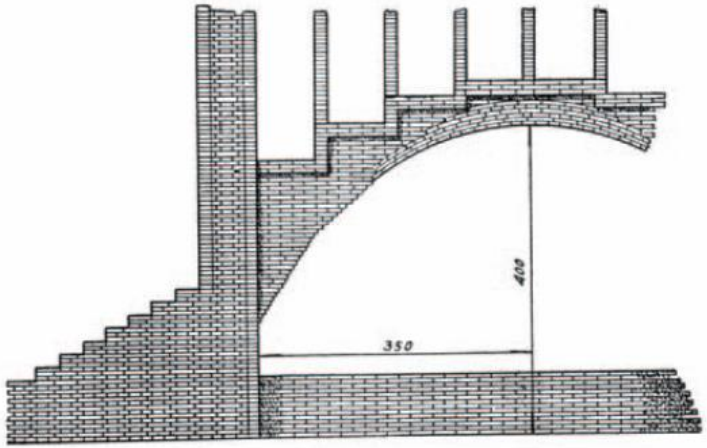
Antoni Gaudi, funicular model

Cette forme pourrait être construite à partir d'éléments simplement empilés qui ne sont pas reliés de manière rigide (une "chaîne de compression") de sorte que la structure résultante serait stable.

*Un **câble soumis à des charges externes** se **déformera** naturellement en **fonction** de la **gravité** et de la **répartition des forces externes**.*

*La forme acquise est souvent appelée la **forme funiculaire** du câble (le terme funiculaire est dérivé du mot latin "corde").*

***L'inversion** de la forme structurelle obtenue donnera une nouvelle structure qui est exactement **semblable** à la structure du câble, hormis le fait que des **forces de compression sont développées** plutôt que des forces de tension.*



Funicular arch for the cascade-fountain in the Casa Vicens (Bergós 1953)

Forme funiculaire

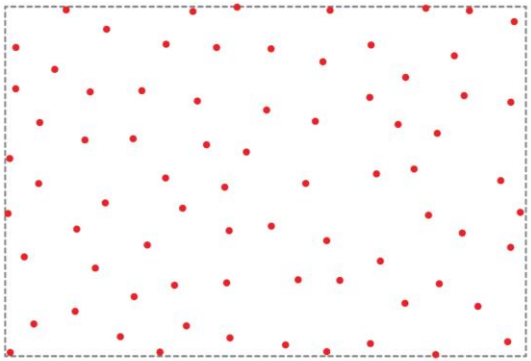
La Sagrada Familia : basilique de Barcelone
Début de la construction a commencé : 1882.

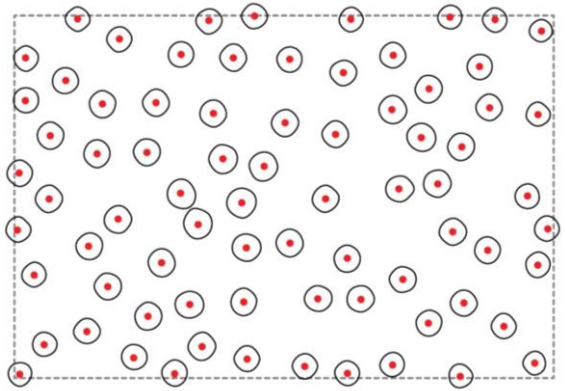
Antoni Gaudi

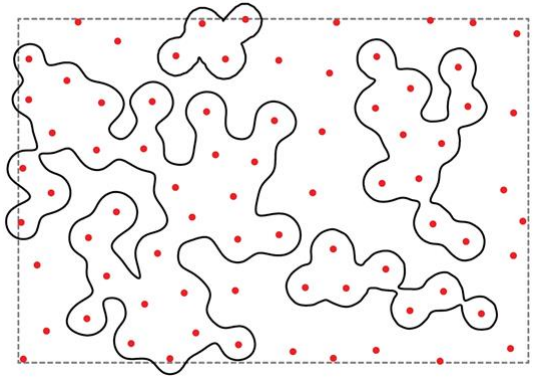
Forme funiculaire

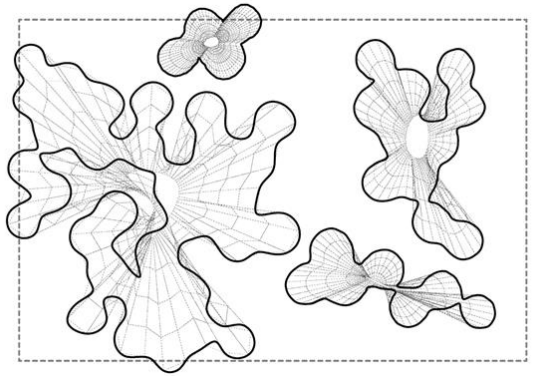
Antoni Gaudi , Maquette des voûtes de la Sagrada Familia

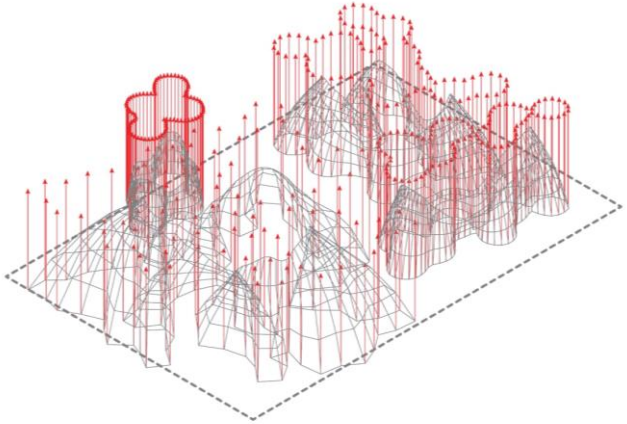
Génération de surfaces funiculaires

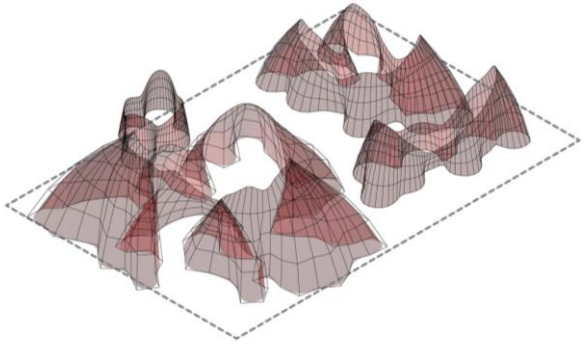




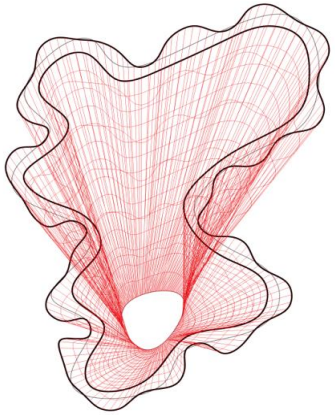


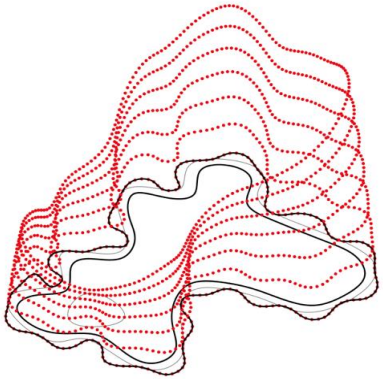


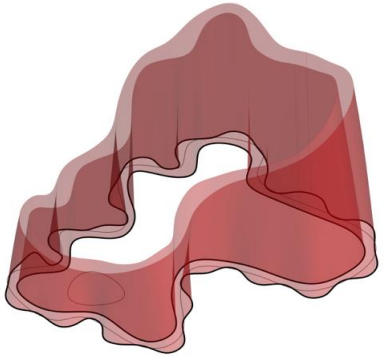


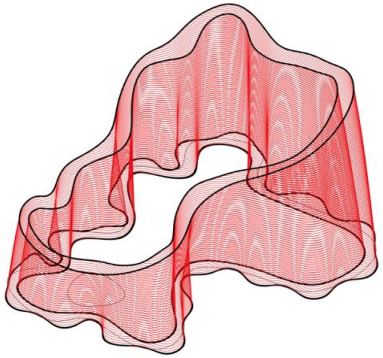


Pavillon MATRICE









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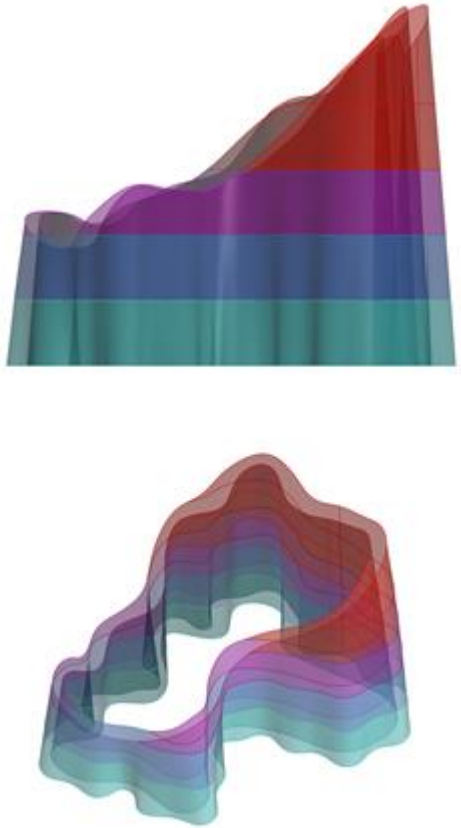
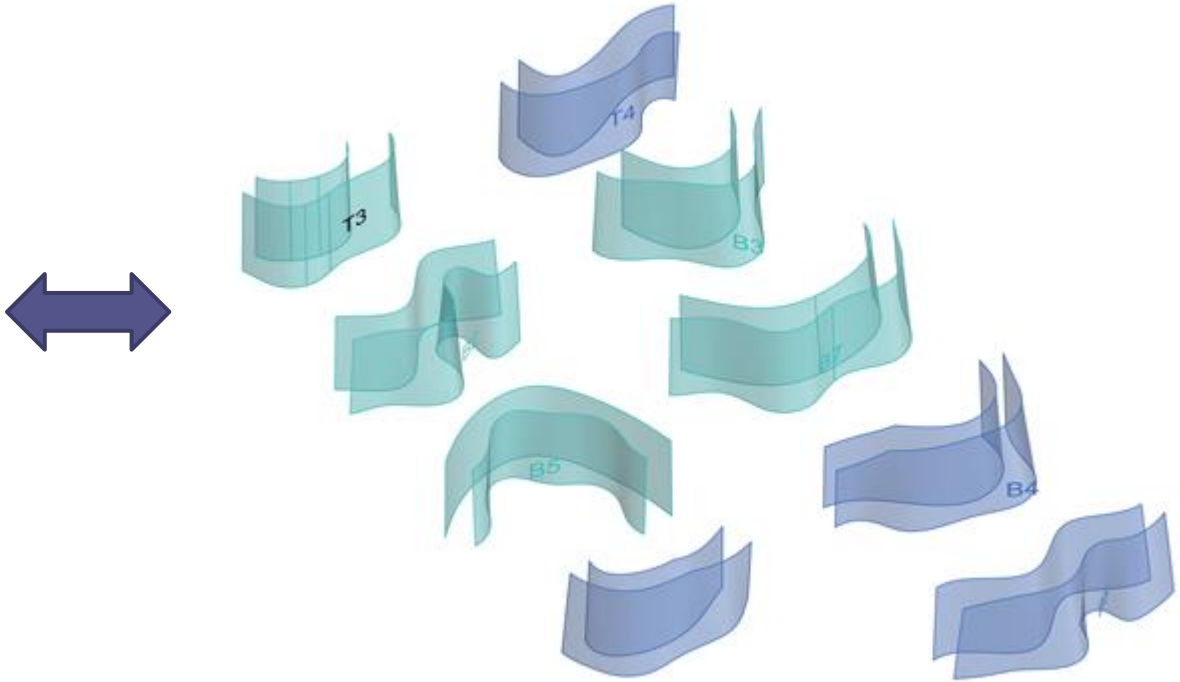
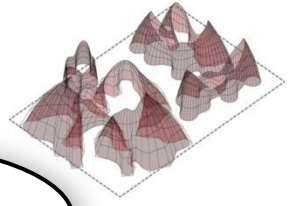
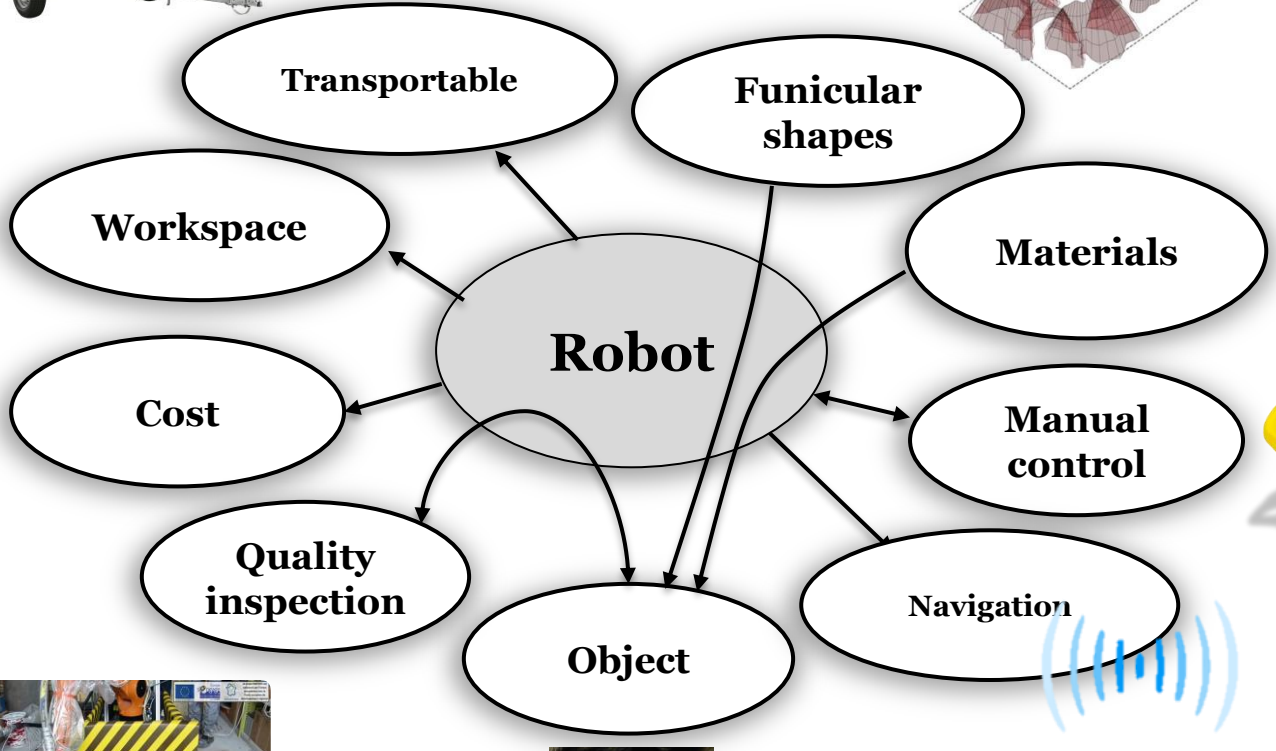




Robotique pour la fabrication additive

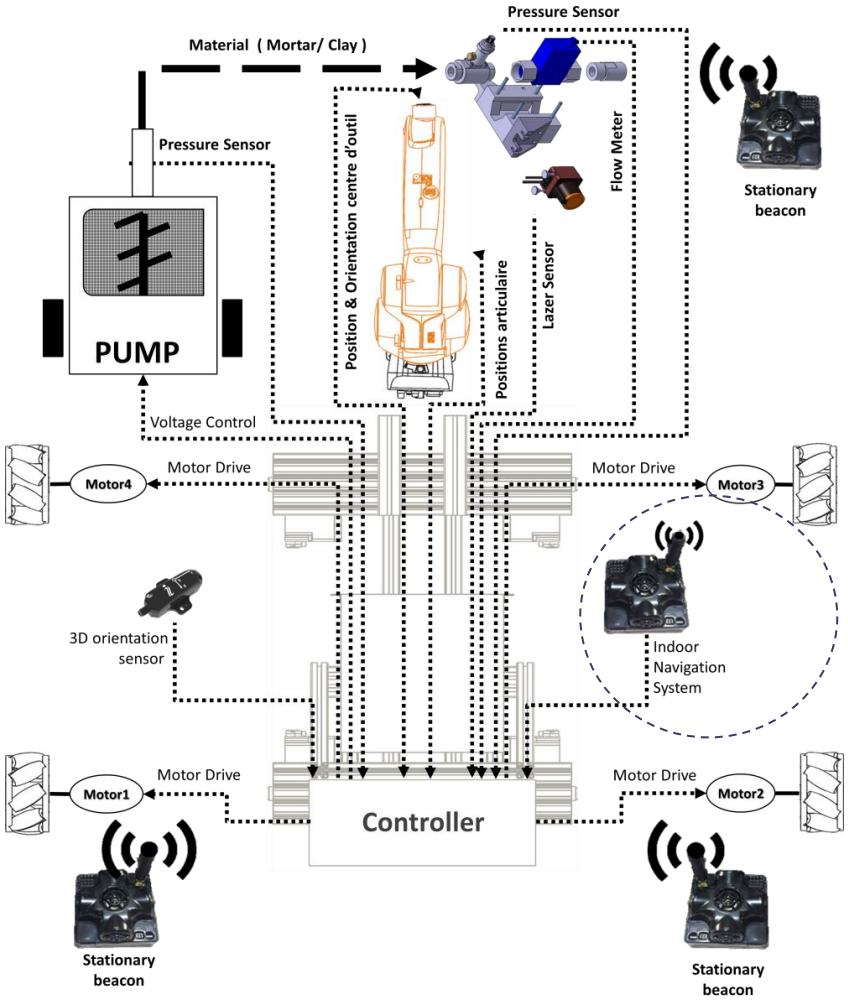




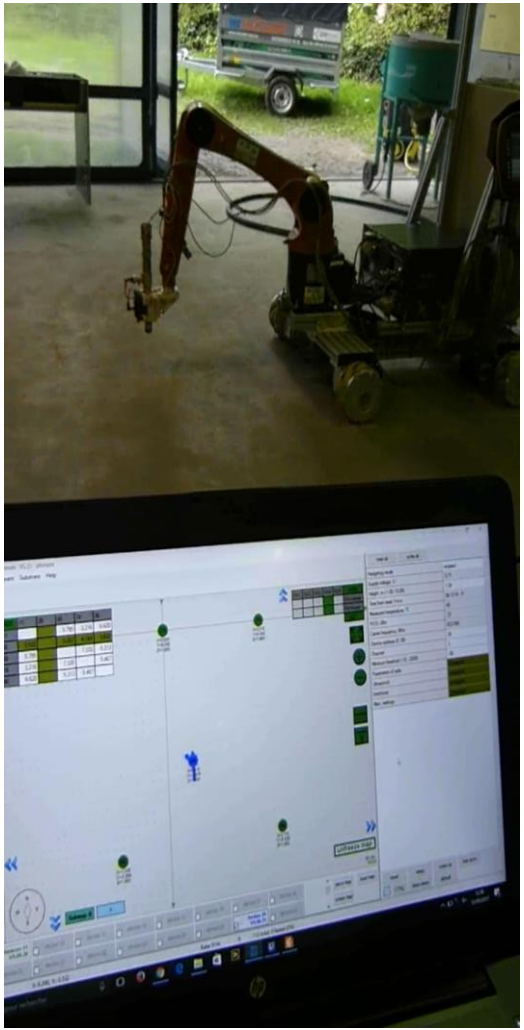
€
<50k

Layer dimensions : 30mm x 9*mm*
Accuracy of material deposit : 10mm
Complex architectural shapes >1m^3

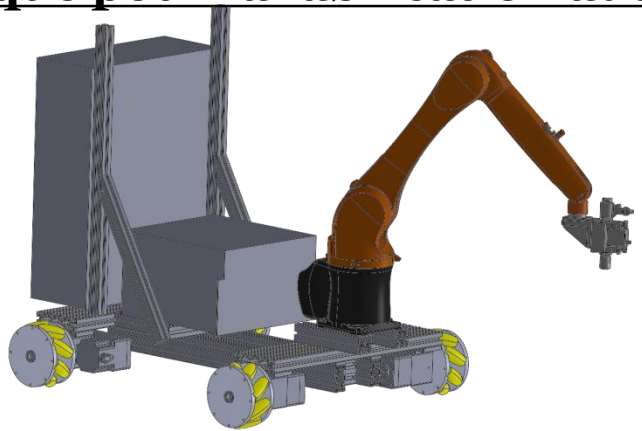
Robotique pour la fabrication additive



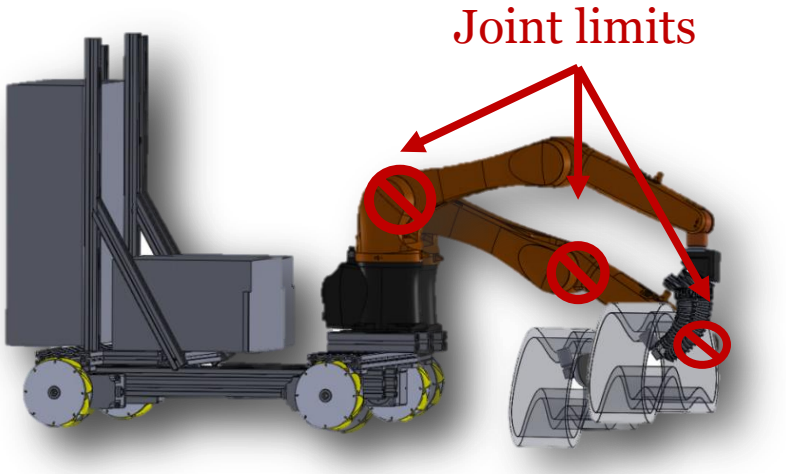
Geo-localisation



Robotique pour la fabrication additive



Redundant robot for 3D material Deposit

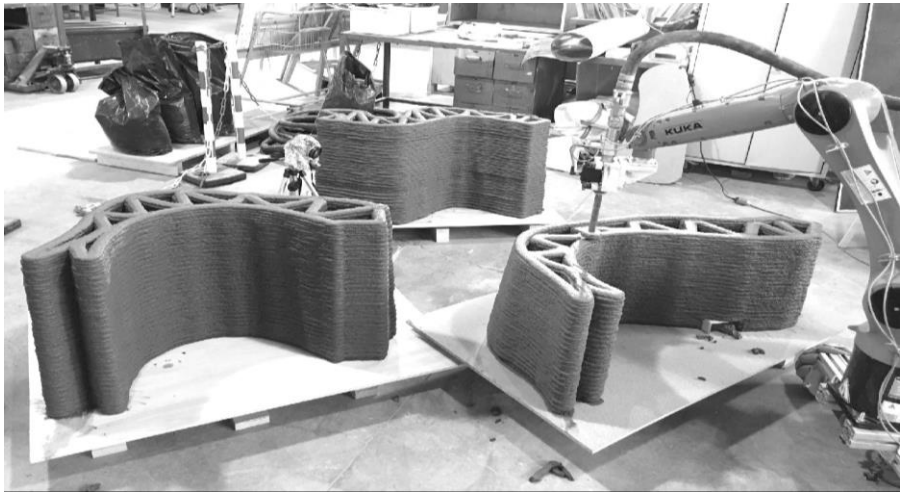


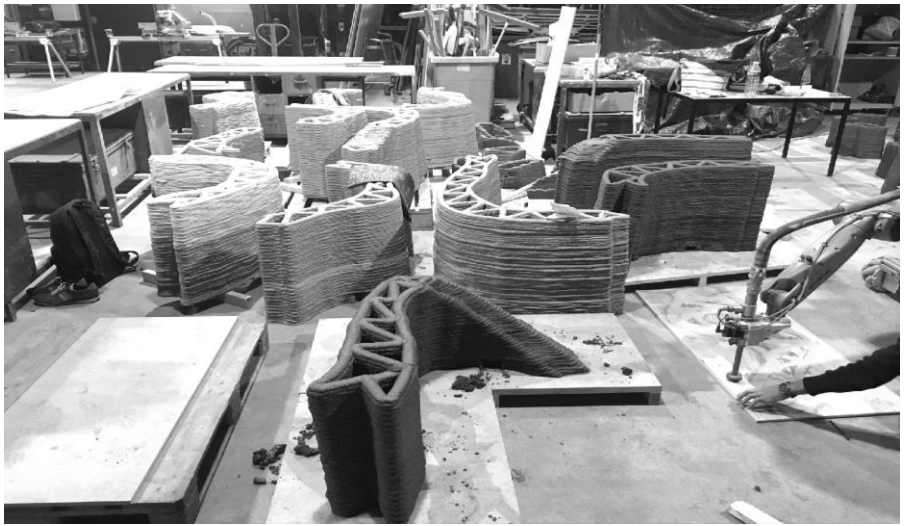
Hyper-redundant robot for quality inspection

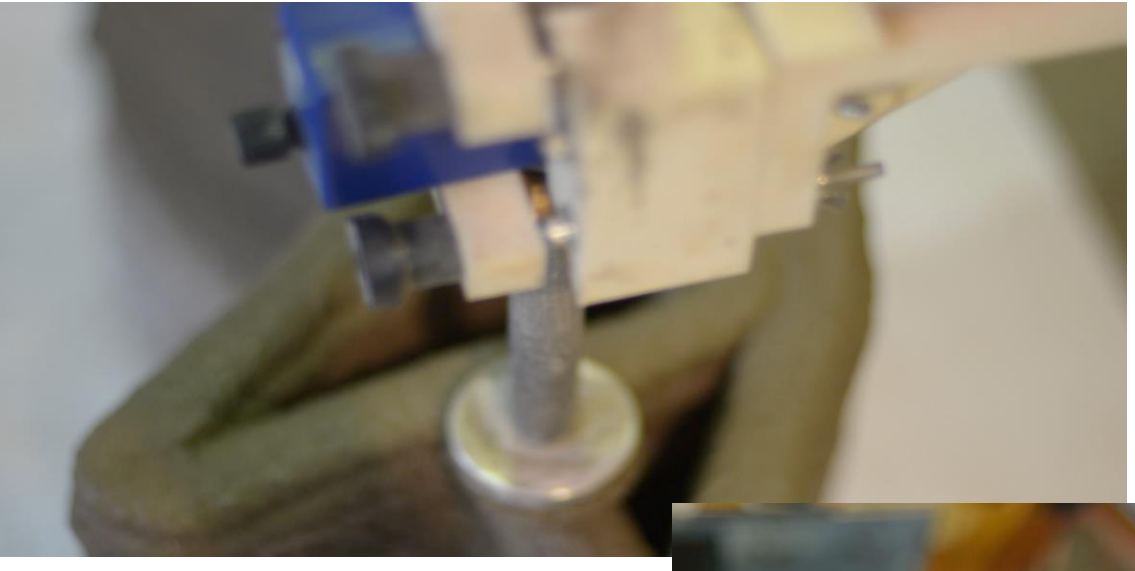
✓ 3D material deposit

✓ Quality inspection

Impression 3D





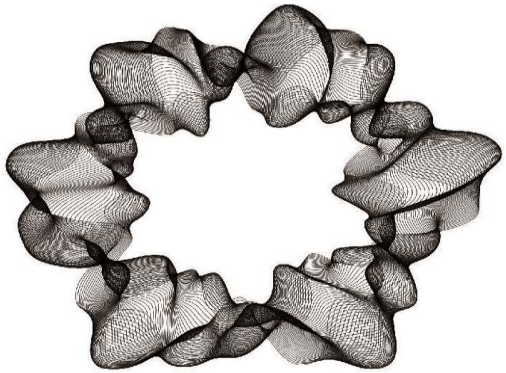


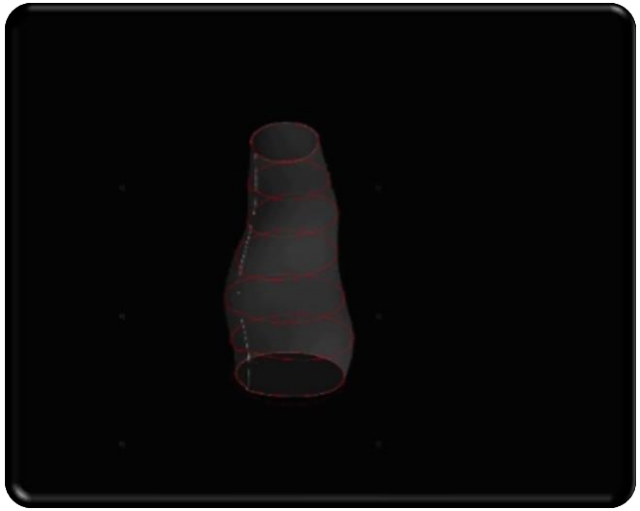
Assemblage des modules

Assemblage des modules

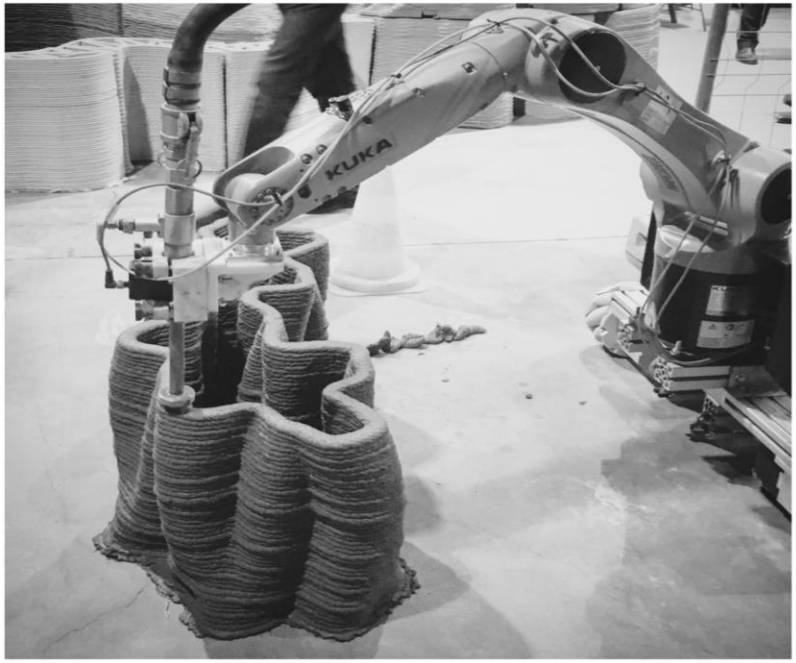
Assemblage des modules

Verticality / Variations



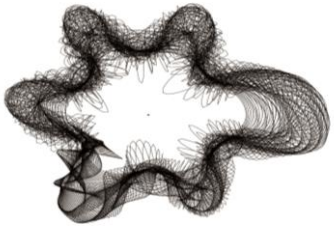


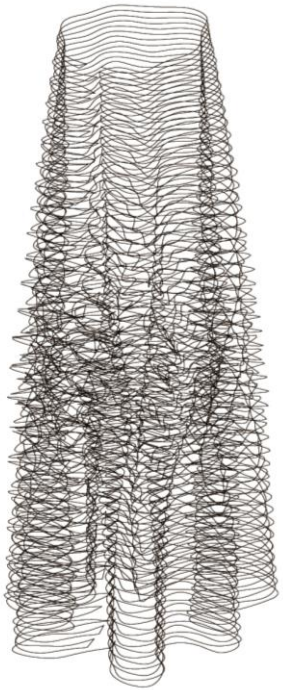
Verticality / Variations

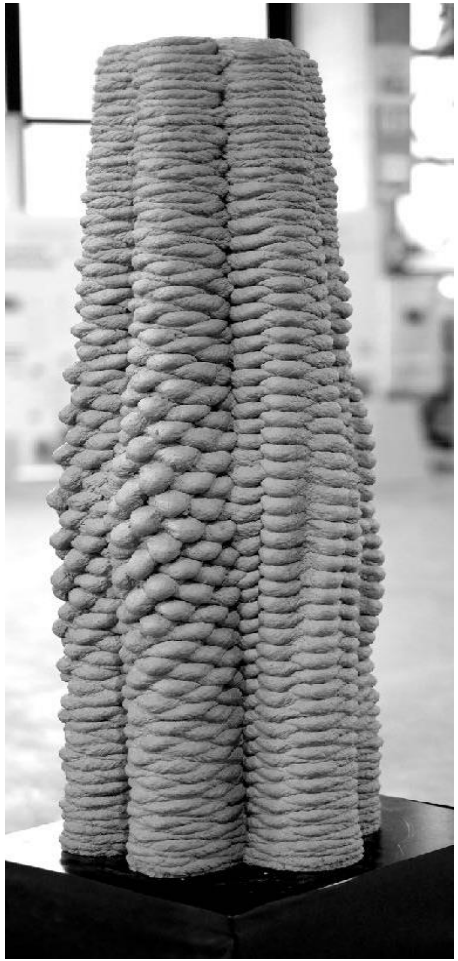


Verticality / Variations

Textures







Thank you

For your attention

[1] Othman Lakhal, Taha Chettibi, Abdelkader Belarouci, Gerald Dherbomez , Rochdi Merzouki..Robotized Additive Manufacturing of Funicular Architectural Geometries Based on Building Materials. *IEEE/ASME Transactions on Mechatronics*, Institute of Electrical and Electronics Engineers, 2020

[2] Othman Lakhal, Achille Melingui, Gérald Dherbomez, Rochdi Merzouki. Control of a Hyper-Redundant Robot for Quality Inspection in Additive Manufacturing for Construction. *RoboSoft 2019 - IEEE International Conference on Soft Robotics*, Apr 2019, Seoul, South Korea. pp.1-6. ⟨hal-02058069⟩

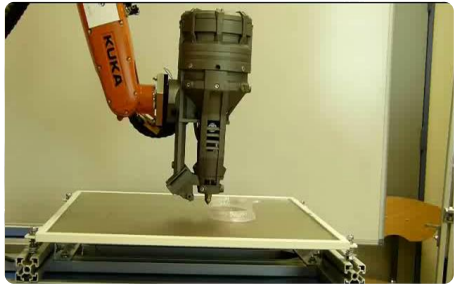
[3] Othman Lakhal. Contribution to the modeling and control of hyper-redundant robots: application to additive manufacturing in the construction. Robotics [cs.RO]. Université de Lille, CRIStAL UMR 9189, 2018. English. ⟨tel-01969334⟩

[4] Othman Lakhal, Taha Chettibi, Rochdi Merzouki. Vers des robots redondants pour l'impression additive dans le bâtiment. *S-MART19, 16 ème Colloque Nationnal*, Apr 2019, Les Karellis - Vallée de la Maurienne, France. ⟨hal-02063434⟩





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