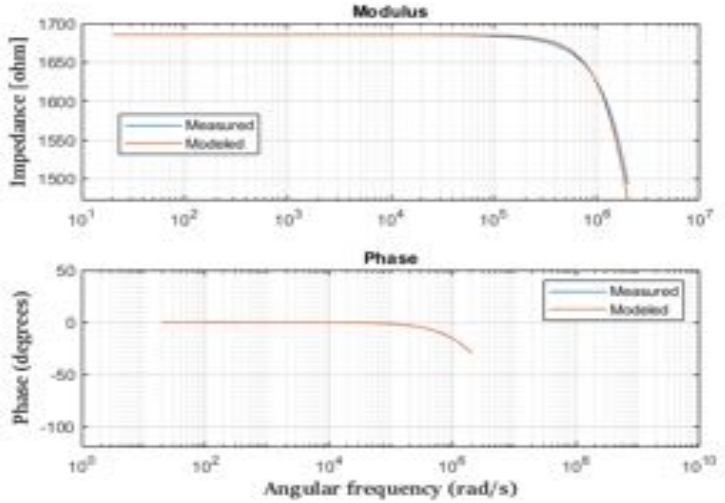
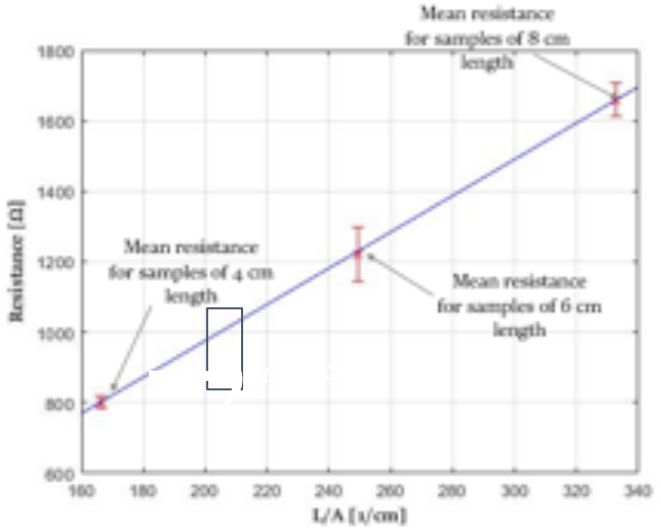
4D printed gripper

Materials Characterization

Materials	
Conductive	Conductive Polylactic Acid (cPLA) Ø = 2.85 mm
Non-conductive	Polylactic Acid (PLA) Ø = 2.85 mm



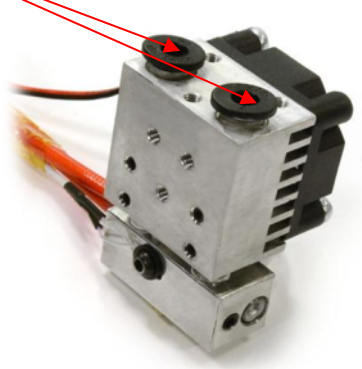
Resistivity				
	Spool filament		Extruded filament	
Resistivity ρ[Ωcm]	Measured	Modeled	Measured	Modeled
cPLA	5.5±0.25	5.1±1.5	4±0.3	3.8±2.3

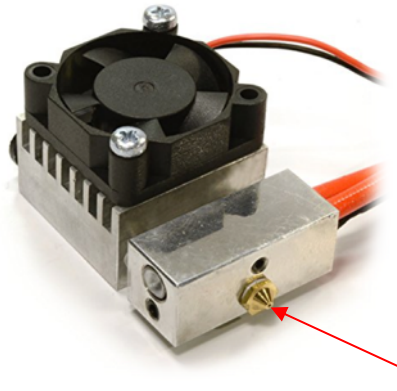


3D Printing Technologies: Dual extrusion mode

Single hot-end

Double Inlet





Singole Outlet

Pros
- No need nozzle calibration
- Extruded materials mixing

Cons
- Materials with same characterstics
- Cleaning nozzle every material change
- Material waste
- Nozzle clogging

Two separated nozzles

Pros
- Faster printing process
- Materials different in characteristics
- No material waste

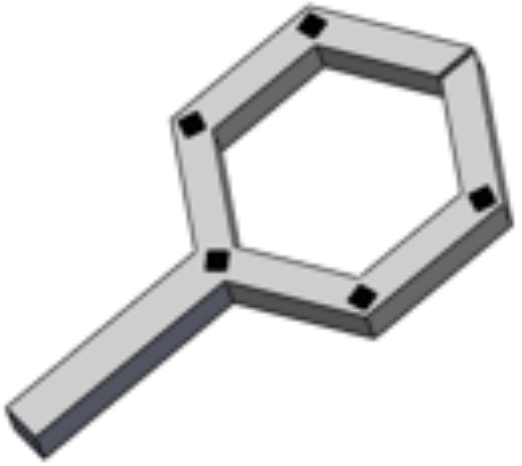
Cons
- Nozzle level calibration
- Material mixing not allowed

Actuators design

Linear Kinematic Chain

Bio-inspired structure

Gripper



Dimension (mm)	Actuators		
	Kinematic chain	Snake	Gripper
Length	140	75	76
Width	10	7	5
Heigth	10	7	6

Thermal FEM analysys

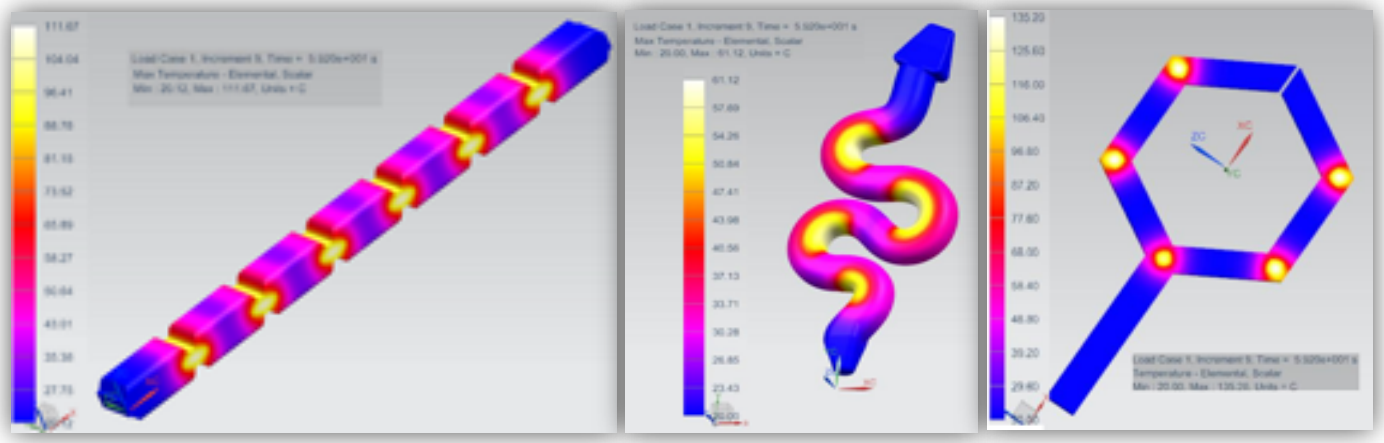
Evaluation of the maximum temperature reached by the conductive parts under an applied voltage of 24[V]

Boundary conditions:

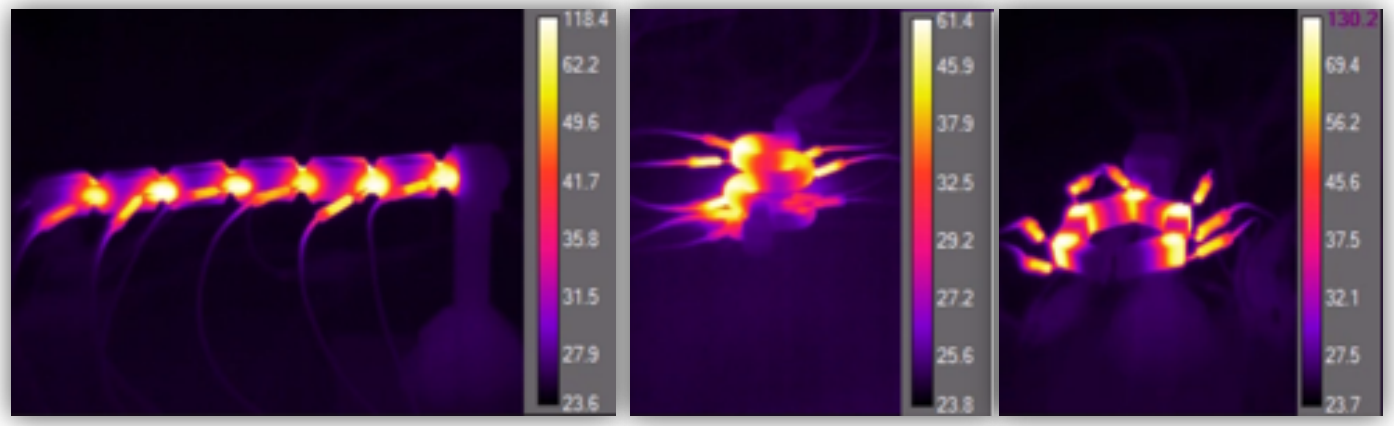
- Thermal convection:

  Heat transfer coefficient h = 10 $W/(m^2 \cdot K)$
- Voltage : 24 [v]

Maximum difference between measured and modeled temperature of T = 7°C

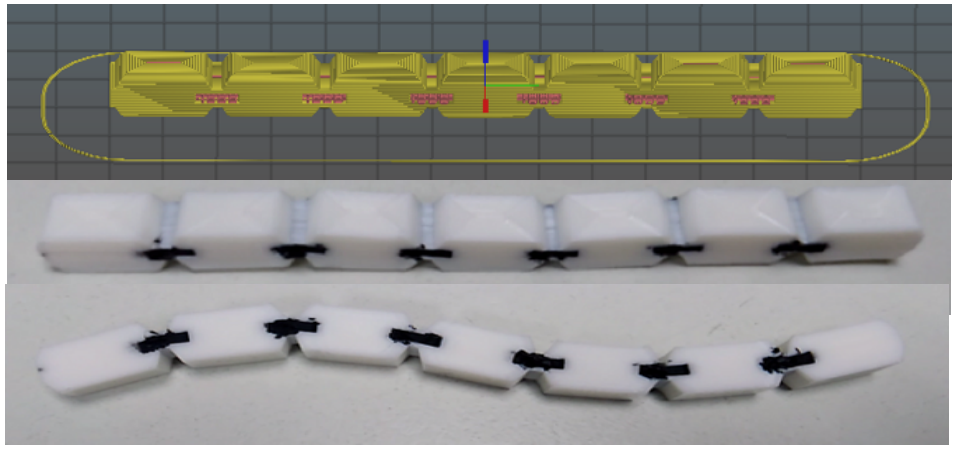


IR Thermography

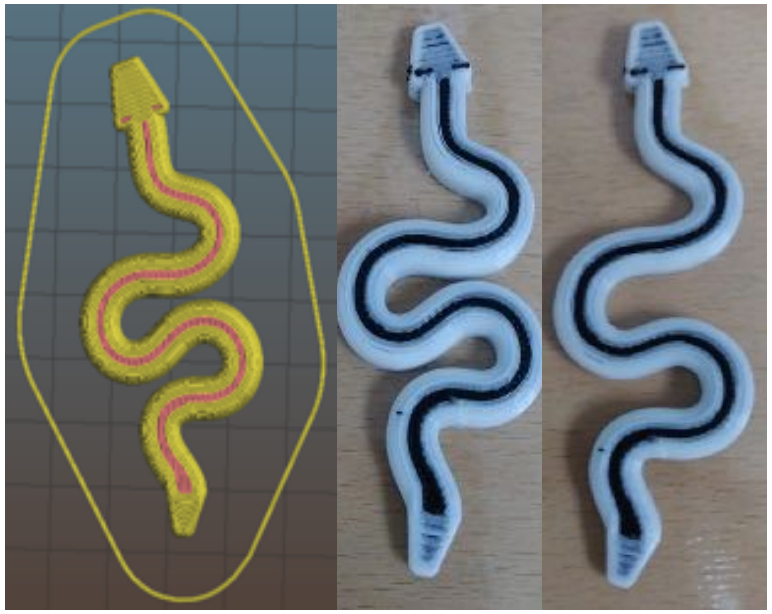


Actuators Manufacturing & Shape-memory Programming

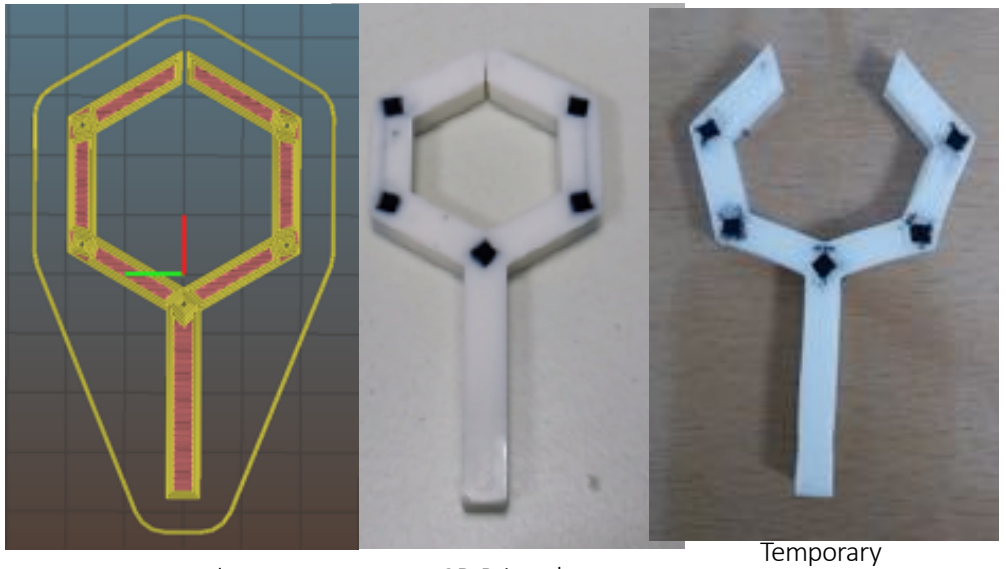
1. Heating in water at T = 70 °C > Tg
2. Gently deformed
3. Rapdly cooled in cold water



Snake

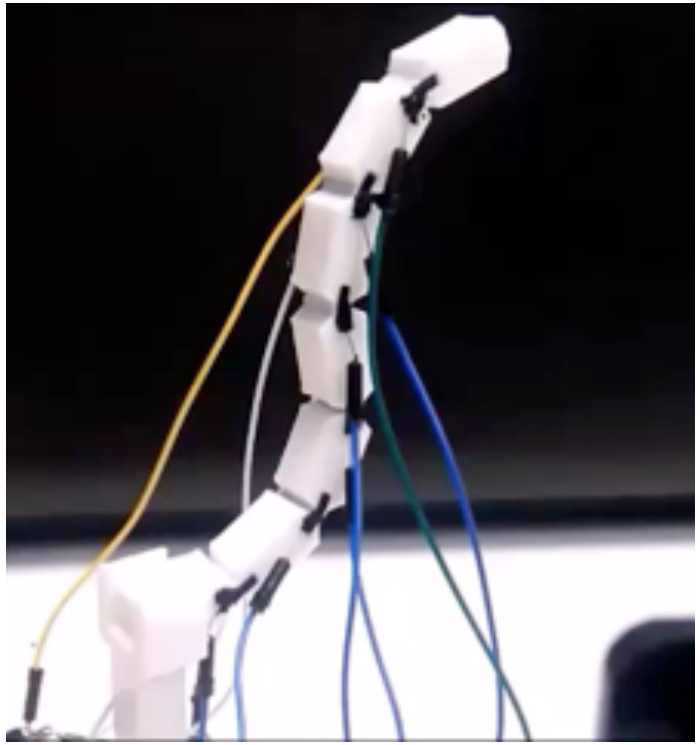


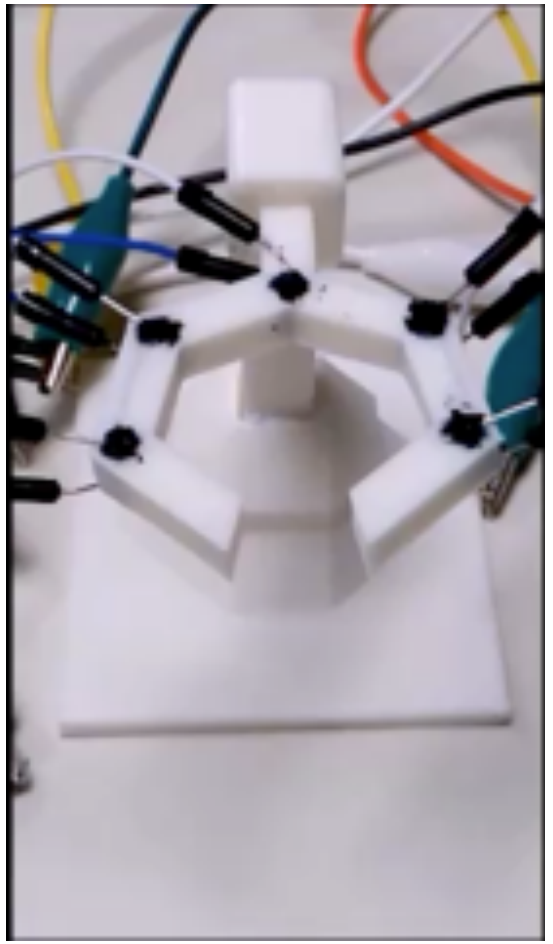
Slicing 3D Printed Temporary deformed



Slicing 3D Printed Temporary deformed

Actuation





Gripper Actuation FEM model

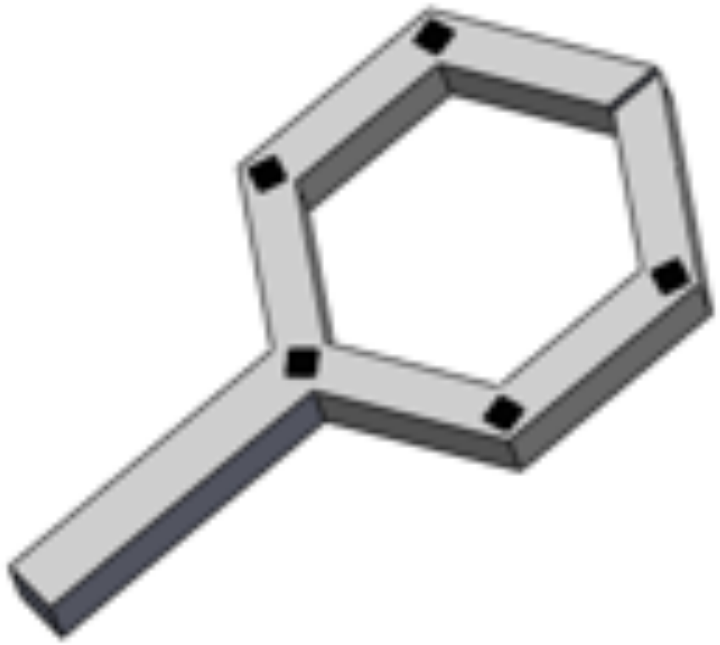
Boundary conditions:

- Fixed and free boundaries:
- Thermal convection:

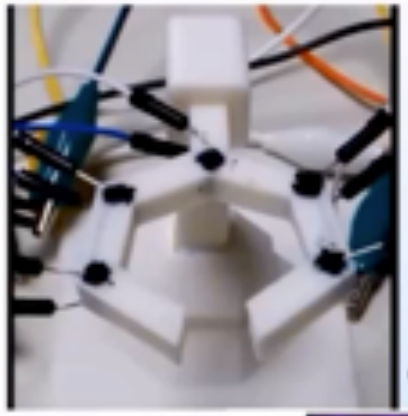
  Heat transfer coefficient

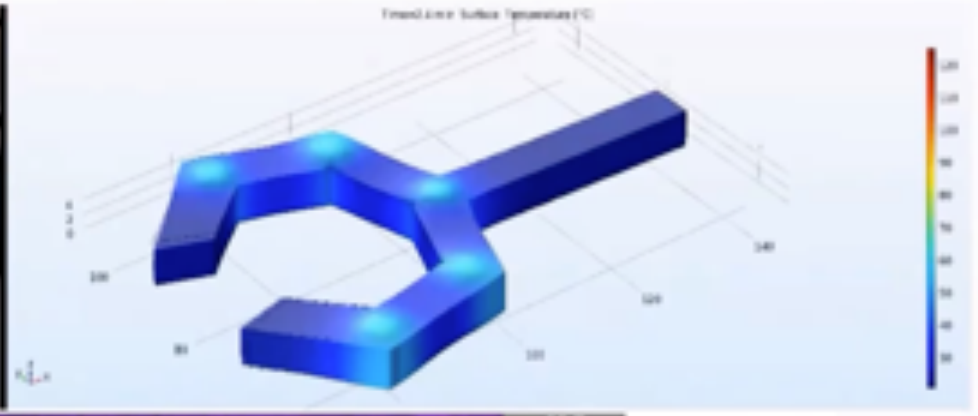
  h = 10 W/($\mathrm{m}^2 \cdot \mathrm{K}$)
- Thermal expansion:

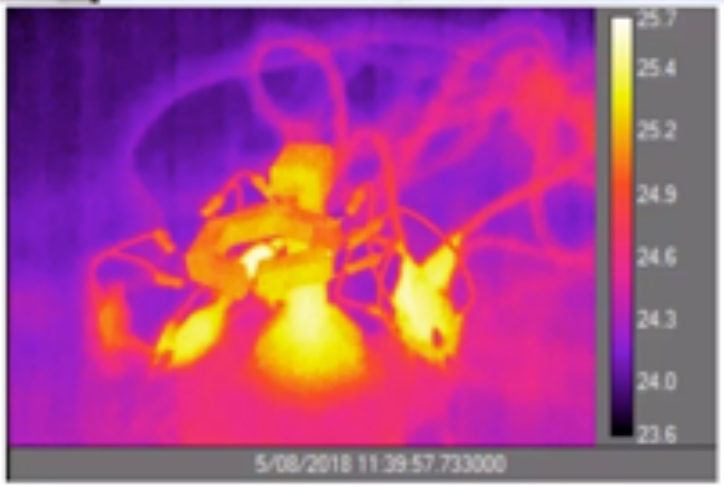
  CTE = $5.6 \cdot 10^{-4}$
- Voltage : 24 [v]



Gripper Actuation FEM model







Maximum Temperature (°C):

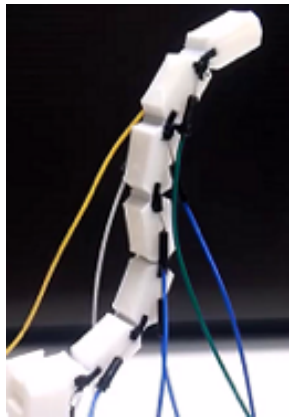
- Measured: 123
- Modeled: 122

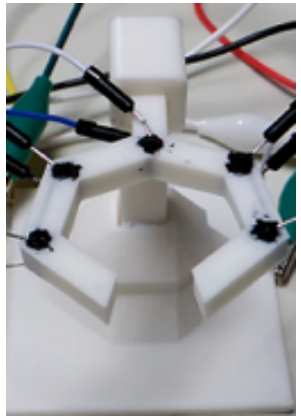
Maximum deformation: 25 mm

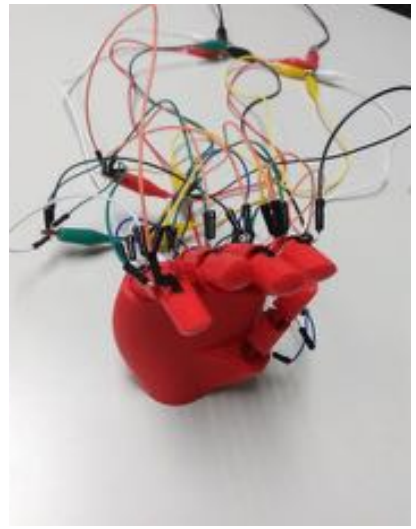
Residual deformation:

- Estimated: 6 mm
- Modeled: 6.5 mm

Other possible embodiments

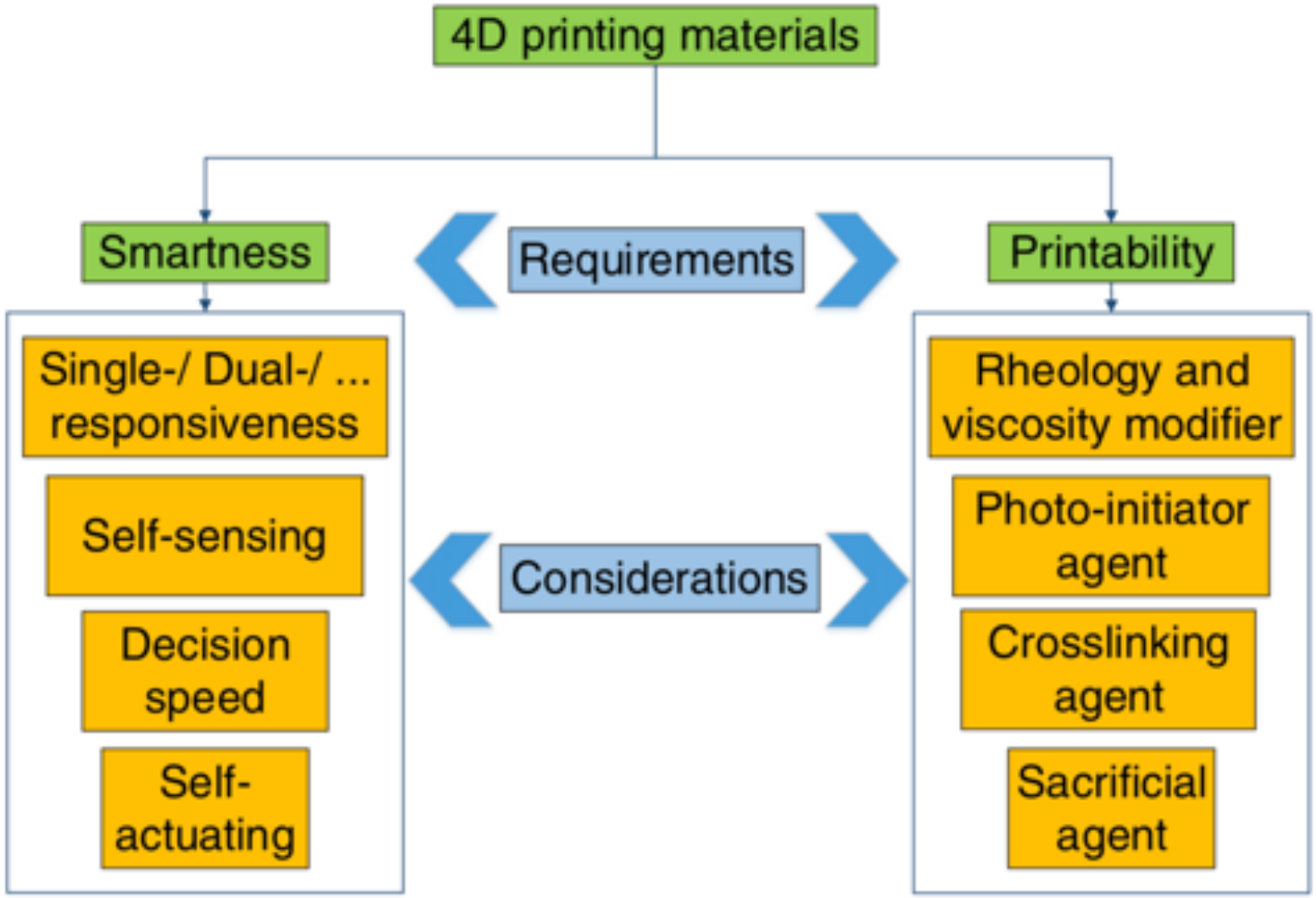




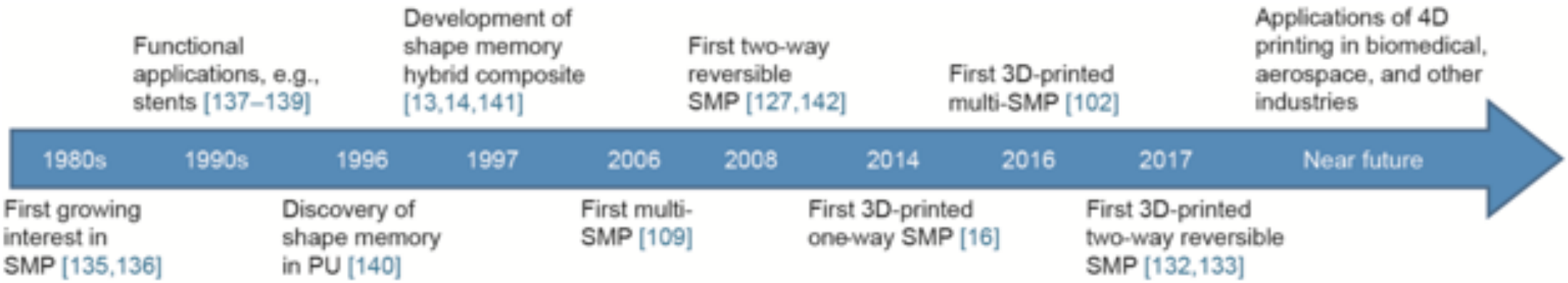


Micalizzi, S., Lantada, A. D., & De Maria, C. (2019). Shape-memory actuators manufactured by dual extrusion multimaterial 3d printing of conductive and non-conductive filaments. Smart Materials and Structures, 28(10), 105025.

Final consideration



Conclusion



Lee, A. Y., An, J., & Chua, C. K. (2017). Two-way 4D printing: A review on the reversibility of 3D-printed shape memory materials. Engineering, 3(5), 663-674.

Thanks for your attention!

Questions?

Carmelo De Maria, PhD

carmelo.demaria@unipi.it

Biofabrication Group, University of Pisa

Prof. Giovanni Vozzi, Ph.D

Francesca Montemurro, Ph.D

Aurora De Acutis, Ph.D

Anna Lapomarda, M.Sc

Gabriele Maria Fortunato M.Sc

Francesco Biagini, M.Sc

Amedeo Franco Bonatti, M.Sc

Irene Chiesa, M.Sc

Simone Micalizzi, M.Sc

Mario Boccia, B.Sc

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

IN SUPREMÆ DIGNITATIS 1343 UNIVERSITÀ DI PISA

Research Center E. Piaggio University of Pisa

BIO MEMBRANE

M-era.Net

PRIN 2017 Programmi di Ricerca Scientifica di Rilevante Interesse Nazionale

Farnesina Ministero degli Affari Esteri e della Cooperazione Internazionale

kerapack manu net

MAGO

@BioFabUNIPI

www.centropiaggio.unipi.it/research/biofabrication.html