

Thermal-Comfort Design of Personalized Casts

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¹



²



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Traditional Casts

Bulky, poor breathability, molding requires training



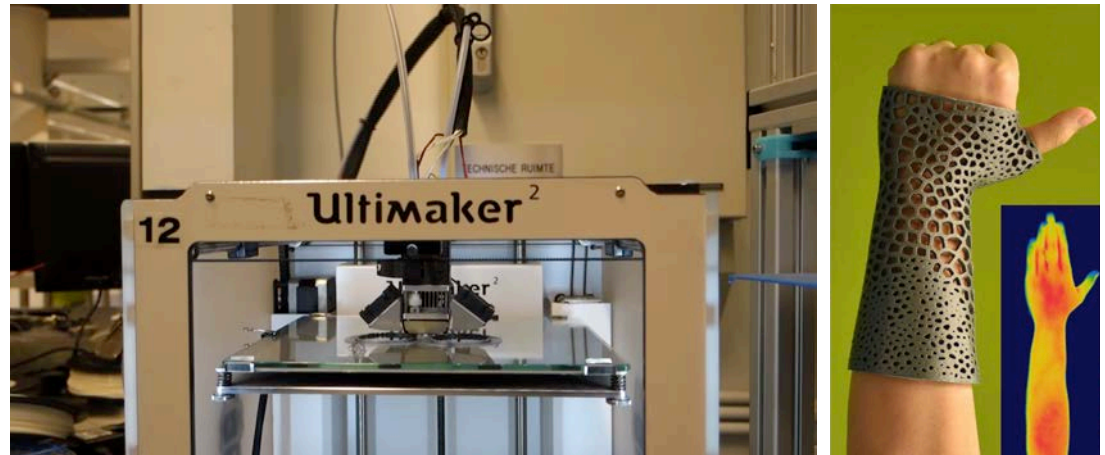
Traditional Casts



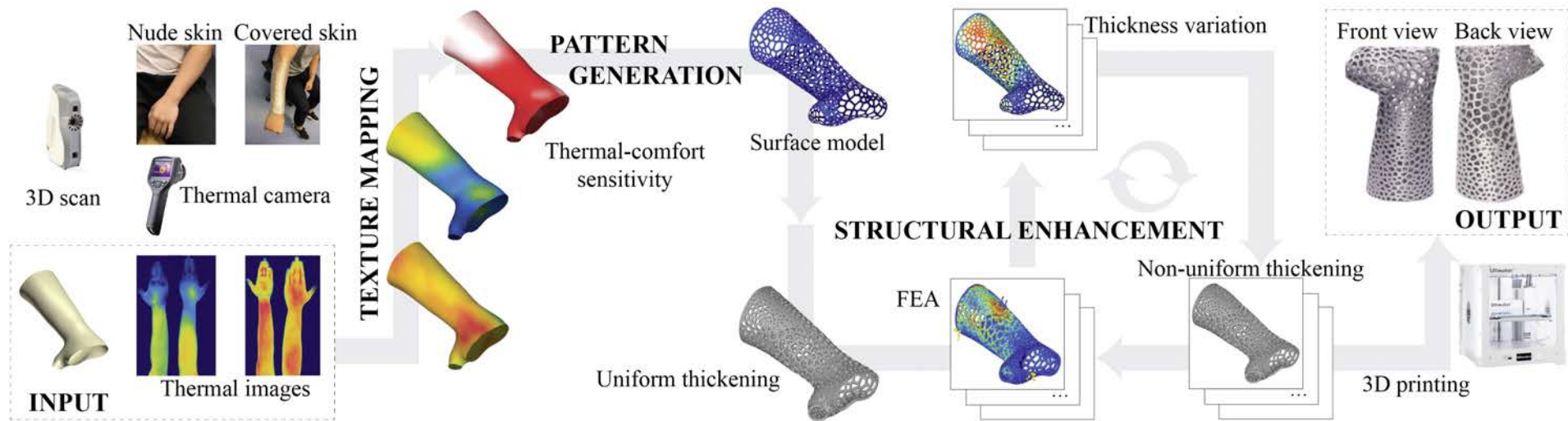
[Image source: www.drycast.com]

Our Casts

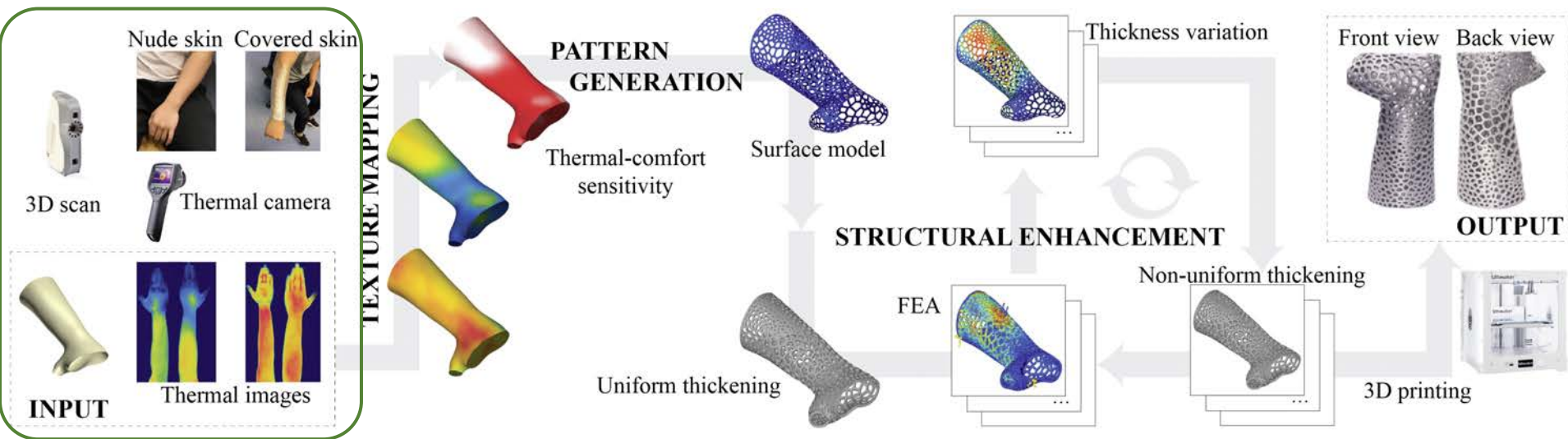
- Daily usage
- Thermal-comfort
- 3D printed



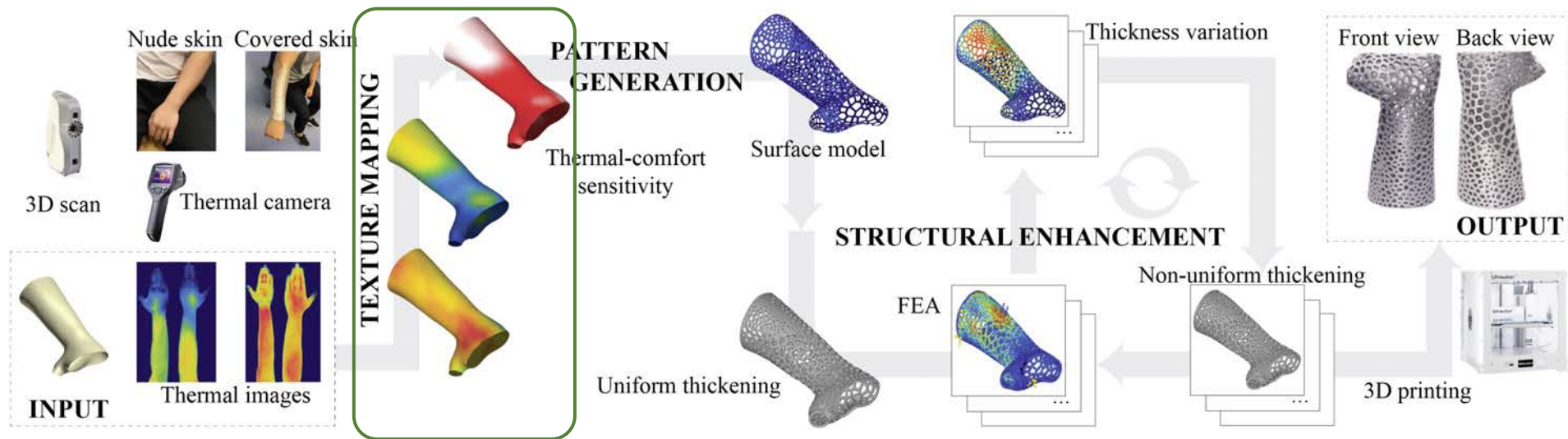
Pipeline



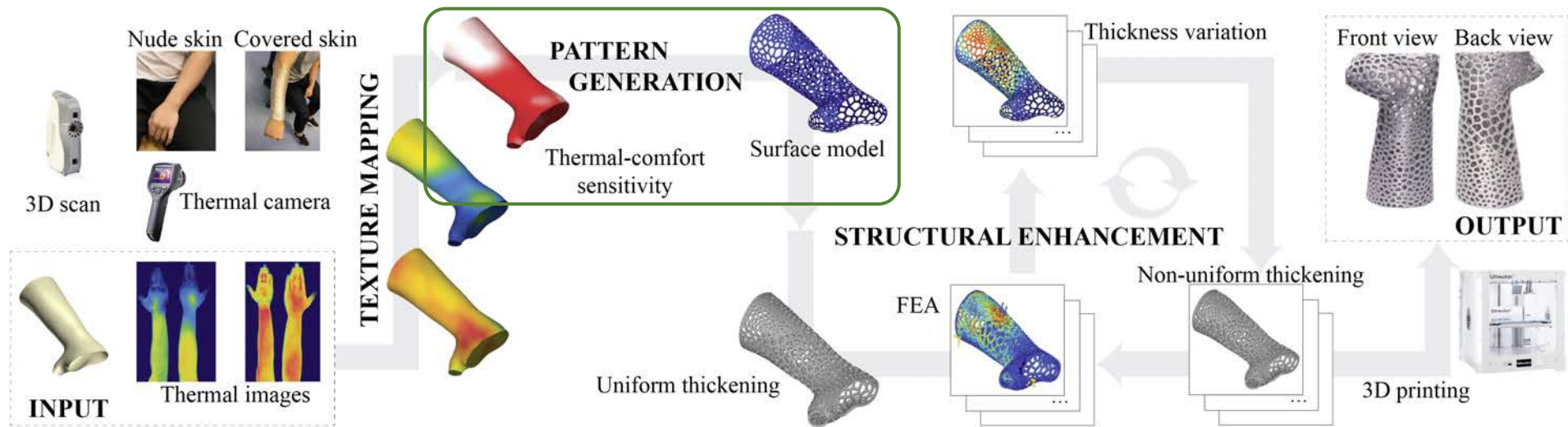
Pipeline



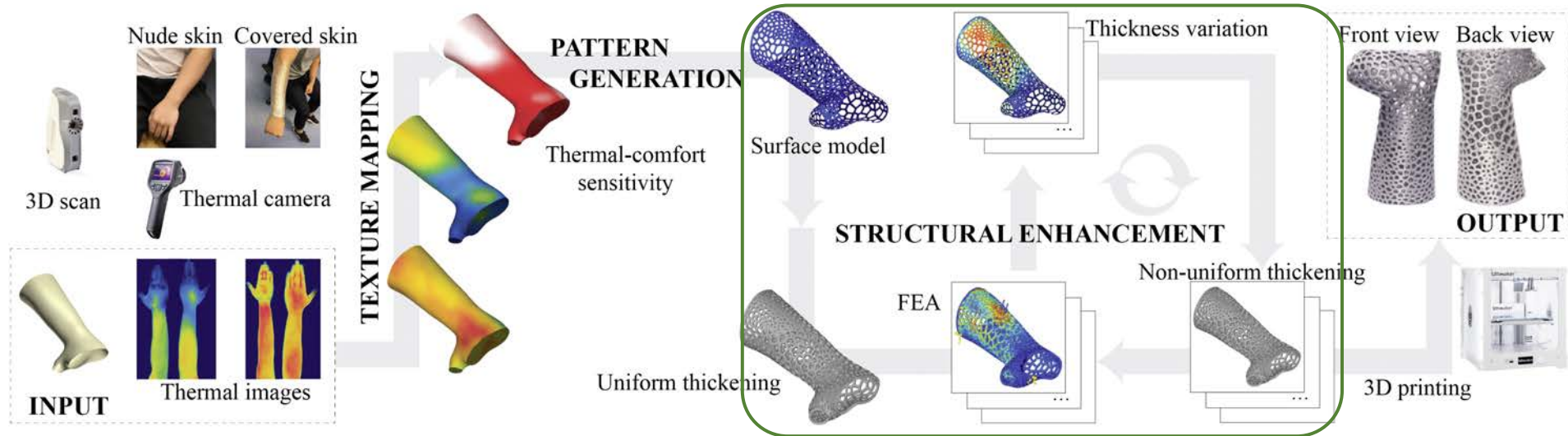
Pipeline



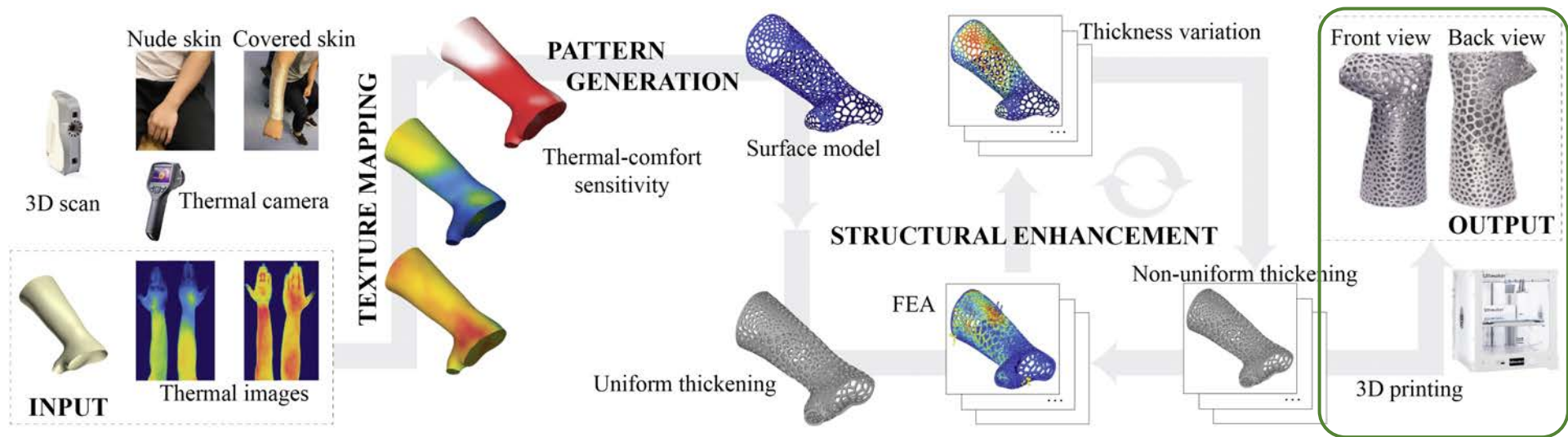
Pipeline



Pipeline



Pipeline



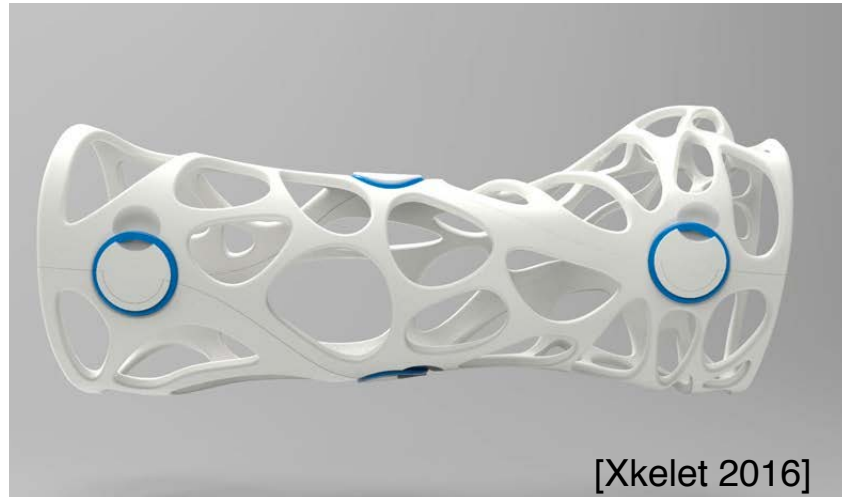
Related Work

-- 3D Printed Casts

[Evill 2016]



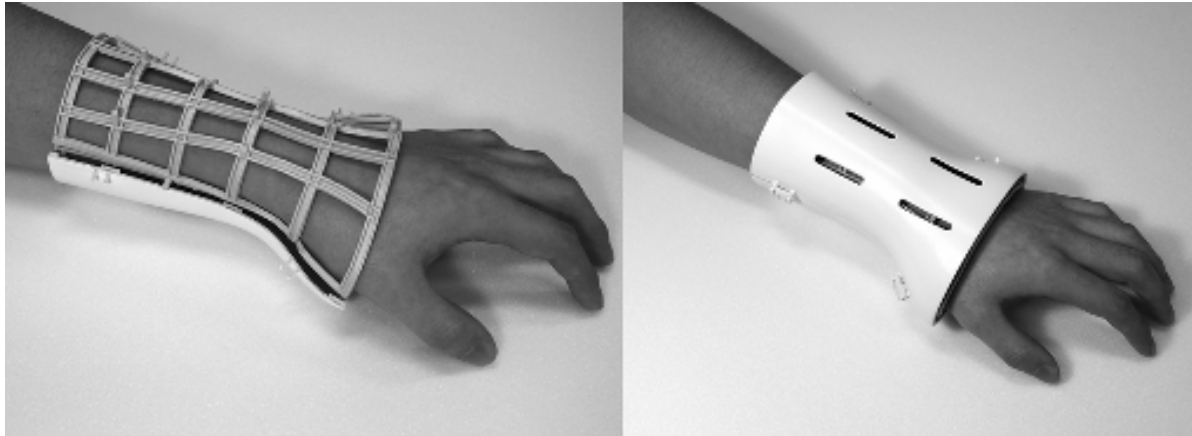
[Karasahin 2016]



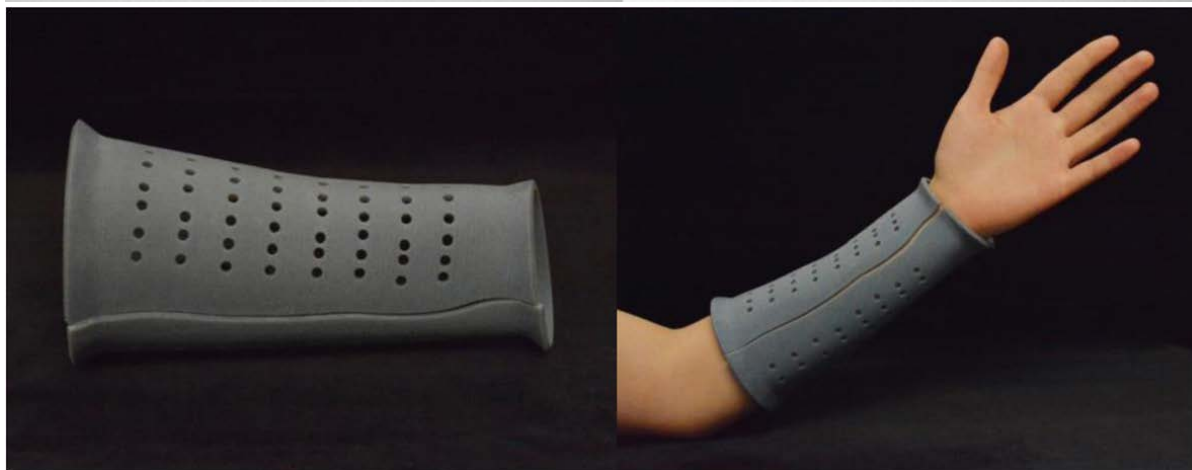
[Xkelet 2016]

Related Work

-- 3D Printed Casts

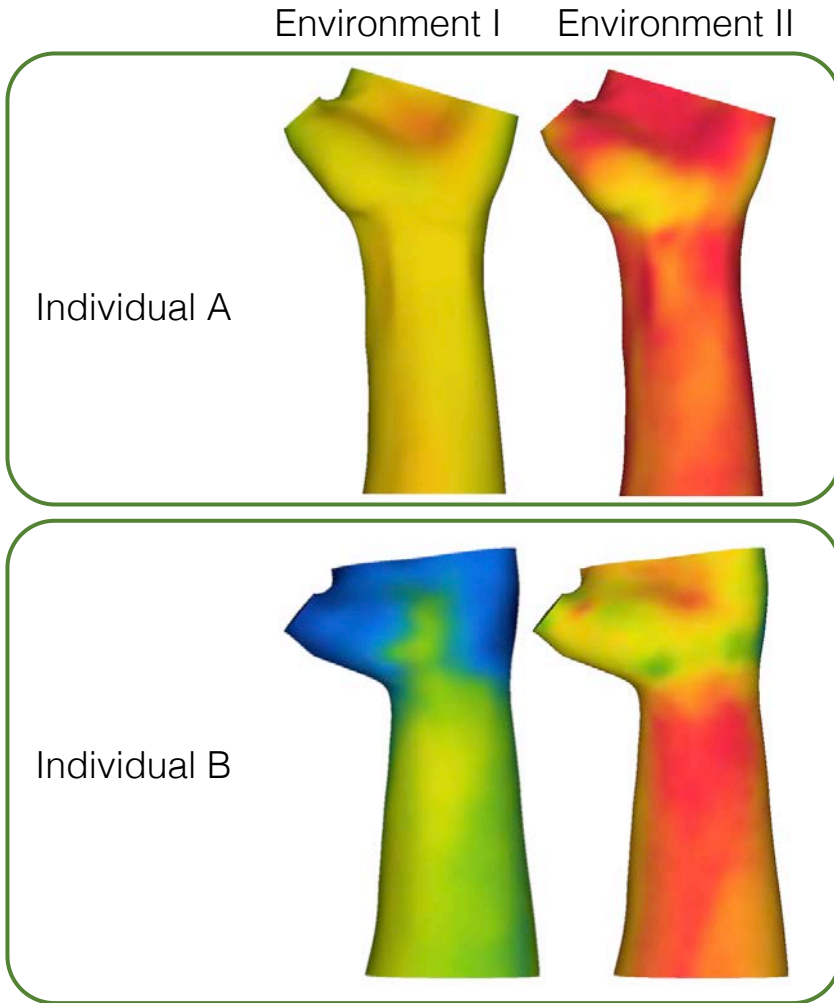


[Kim and Jeong 2016]



[Lin et al. 2016]

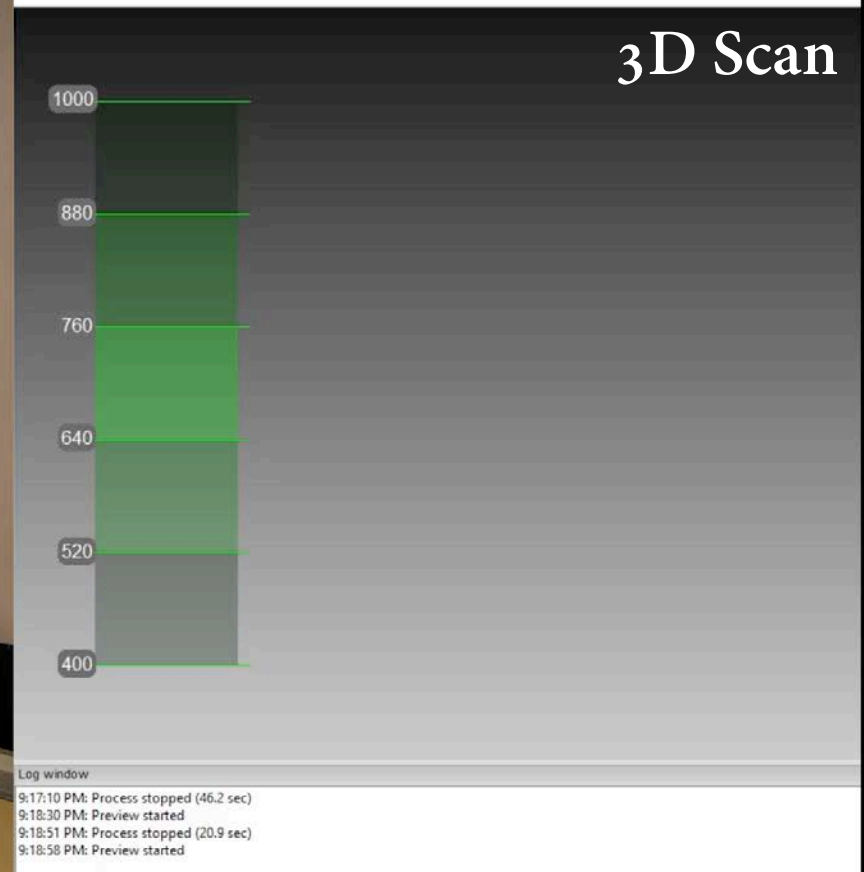
Design Principles



cast design goals:

1. custom shape
2. mechanical stiffness
3. thermal-comfort

Thermal-Comfort: Data Acquisition



Thermal-Comfort: Data Acquisition



Thermal-Comfort: Data Acquisition



Thermal-Comfort Sensitivity

index	thermal-comfort
4	very comfortable
2	comfortable
+0	just comfortable
-0	just uncomfortable
-2	uncomfortable
-4	very uncomfortable

thermal-comfort sensitivity

$$C(\mathbf{x}) = \frac{1}{1 + e^{-\alpha \Delta T(x)}}$$

$\Delta T(x)$: local skin temperature change

α : coefficient

[Zhang et al. 2010]

Thermal-Comfort Sensitivity

bare skin temperature distribution



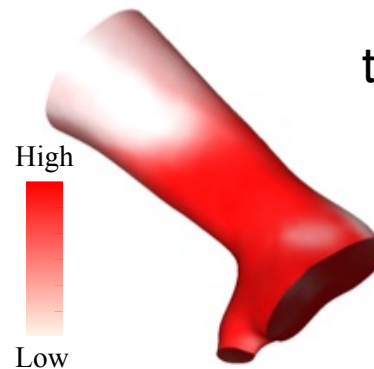
covered skin temperature distribution



+



thermal-comfort sensitivity



Voronoi Tessellation

$$\min \hat{E}(\Psi) = \boxed{E_P(\Psi)} + \lambda E_T(\Psi)$$

Pattern control term

$E_P(\Psi) =$ centroidal Voronoi tessellation

Uniform distribution



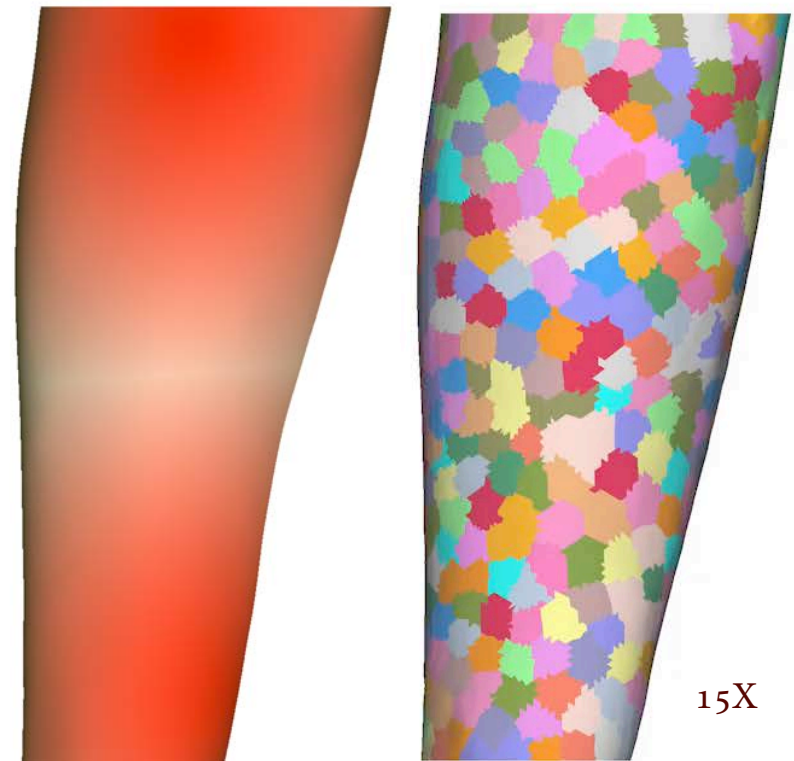
Voronoi Tessellation

$$\min \hat{E}(\Psi) = E_P(\Psi) + \lambda \boxed{E_T(\Psi)}$$

Thermal term

Thermally sensitive distribution

$E_P(\Psi) =$ centroidal Voronoi tessellation



- Sensitive to temperature
- Not sensitive

Voronoi Tessellation

$$\min \hat{E}(\Psi) = E_P(\Psi) + \lambda \boxed{E_T(\Psi)}$$

Thermal term

Thermally sensitive distribution

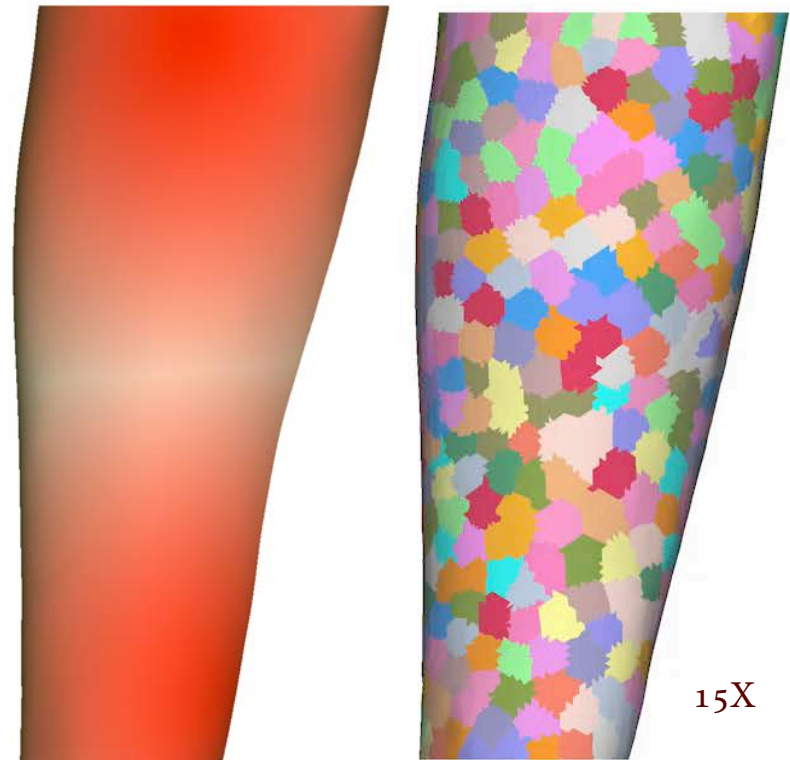
$E_P(\Psi) =$ centroidal Voronoi tessellation

$$E_T(\Psi) = \int_{P_\Psi} C(\mathbf{x}) d\mathbf{x}$$

↑
solid part of cast:
Voronoi cell edges

■ Sensitive to temperature

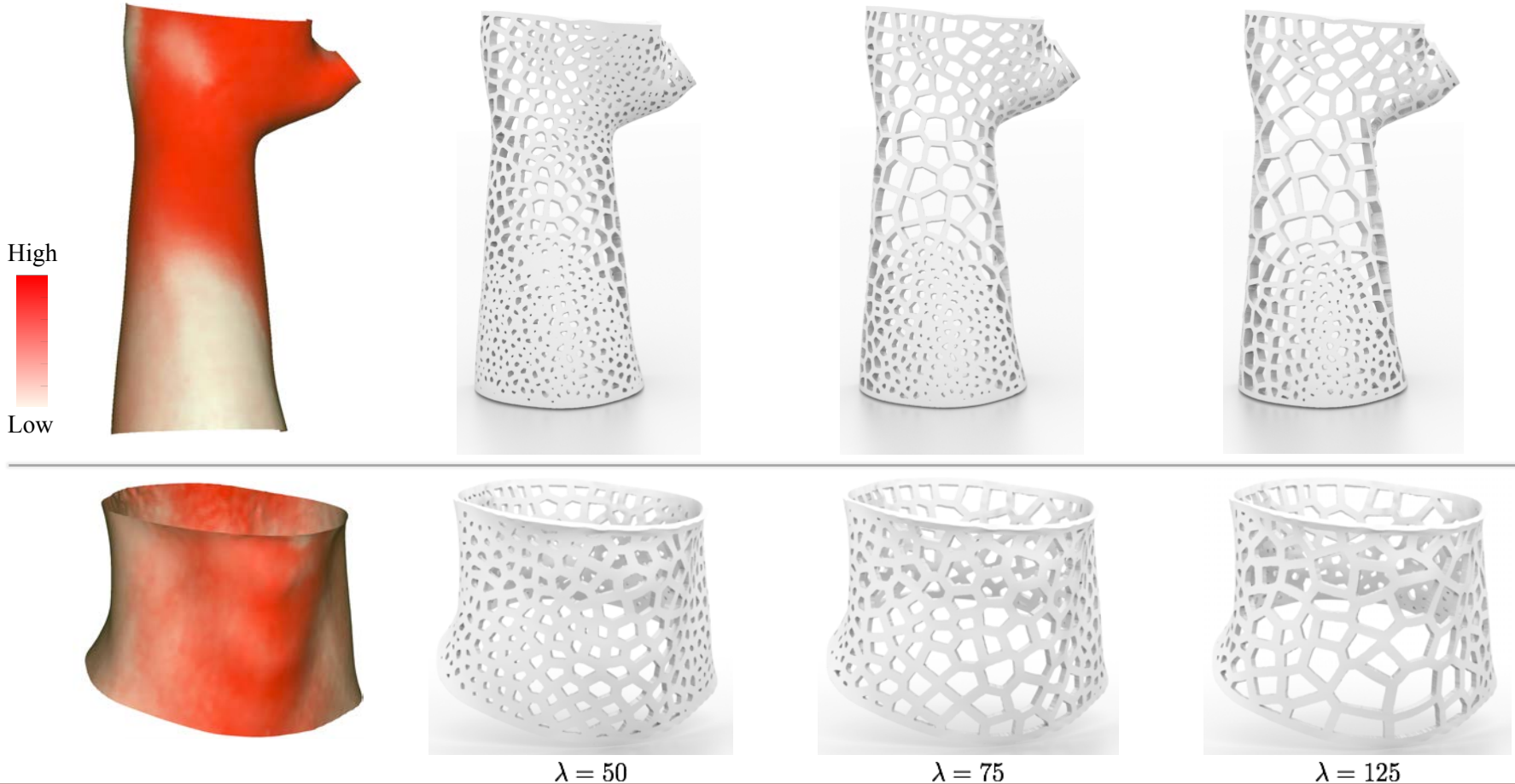
□ Not sensitive



Pattern Generation

$$\min \hat{E}(\Psi) = E_P(\Psi) + \boxed{\lambda} E_T(\Psi)$$

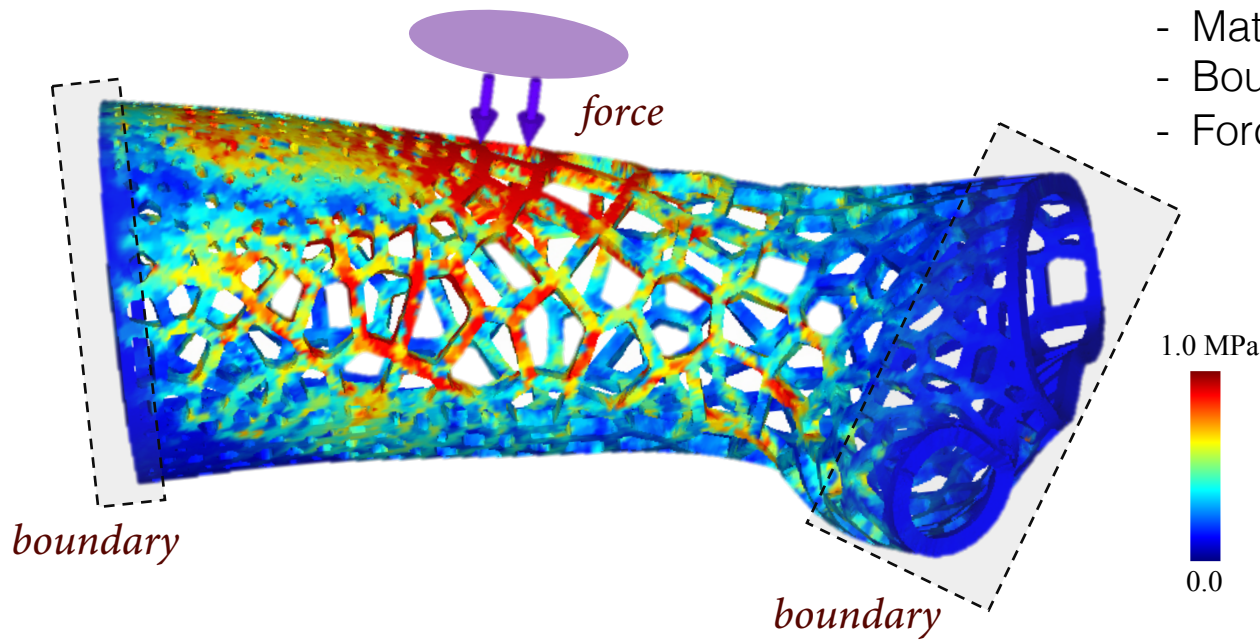
Contrast coefficient



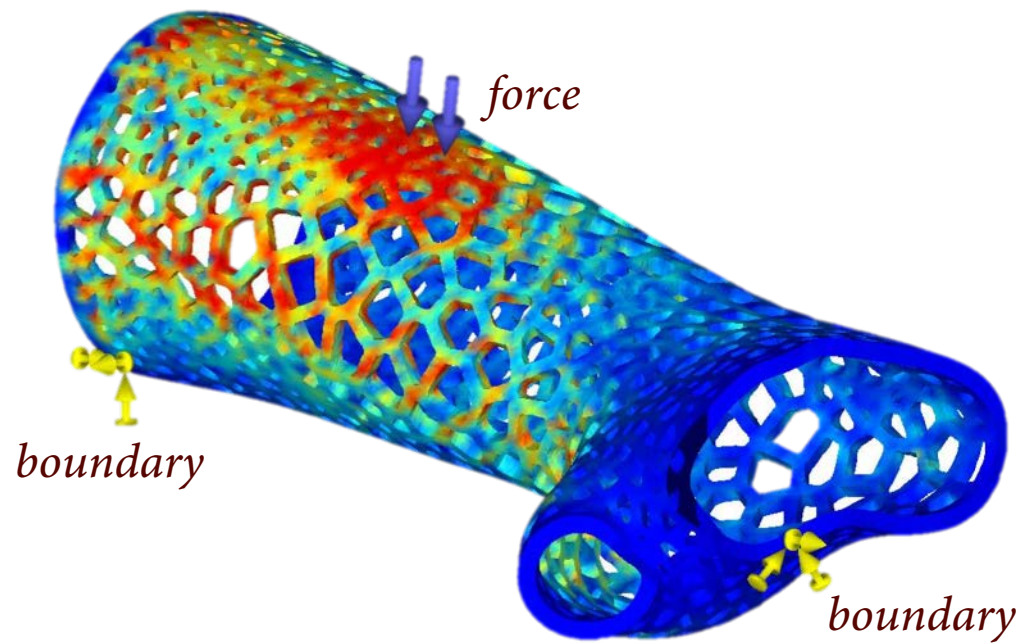
Structural Enhancement

3-point bending test

- Material: PLA
- Boundary: 2 extreme sides
- Force: applied mid-span

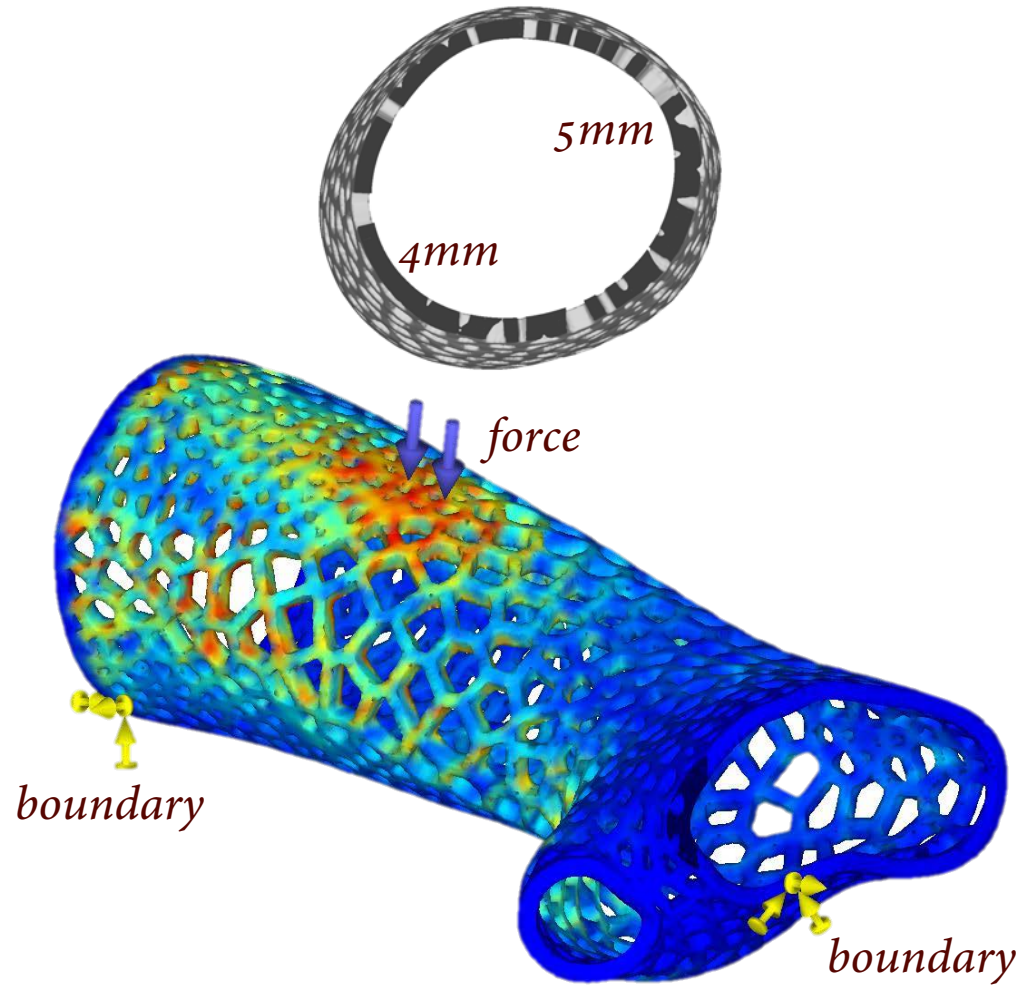


Structural Enhancement



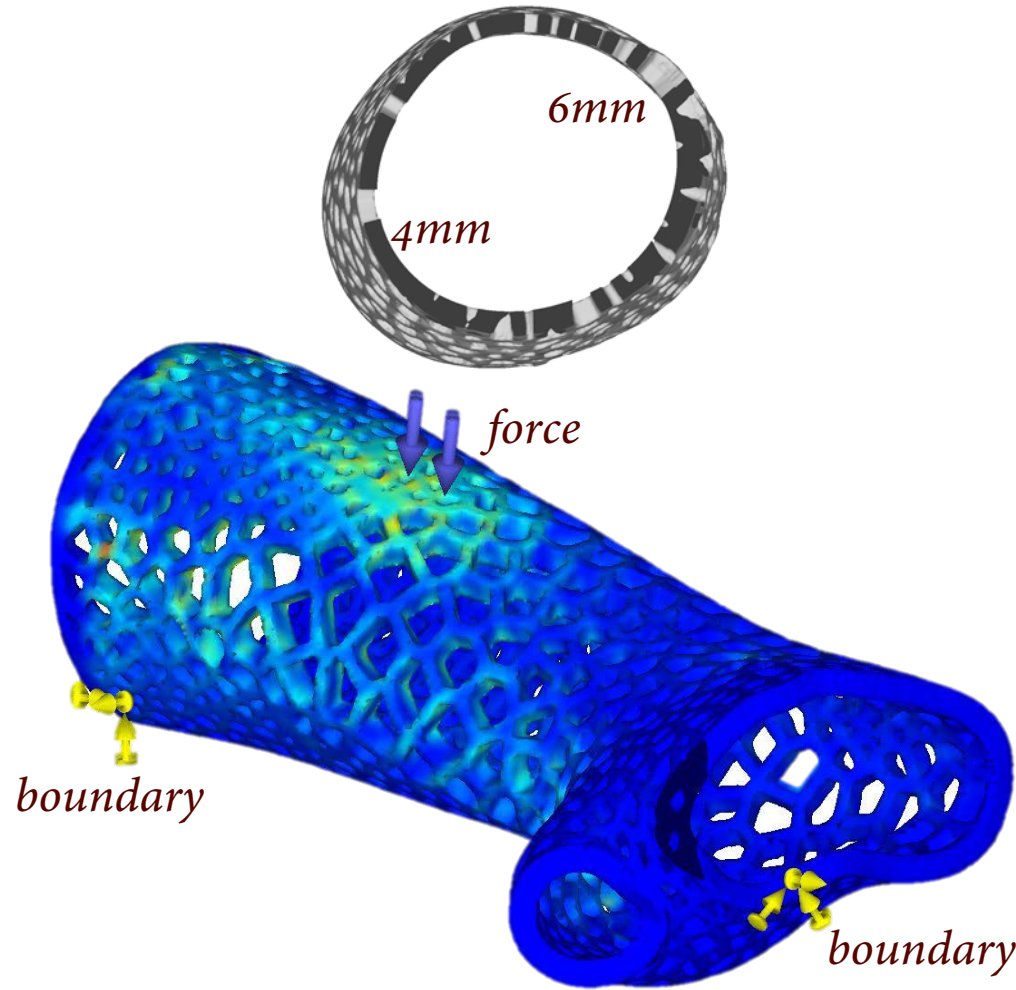
FEA result for uniform thickening (4mm)

Structural Enhancement



FEA result for non-uniform thickening (4-5mm)

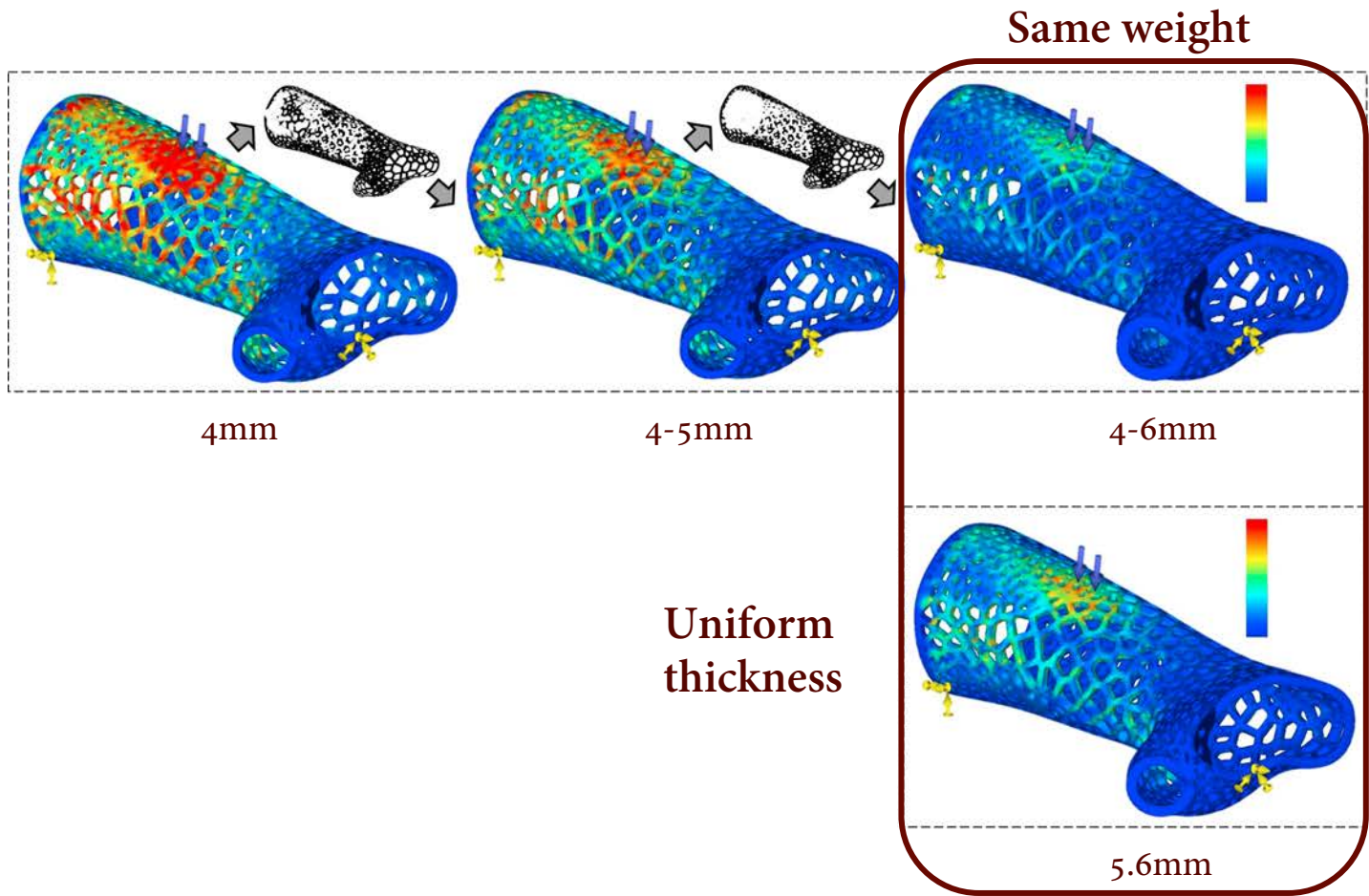
Structural Enhancement



FEA result for non-uniform thickening (4-6mm)

Structural Enhancement

Non-uniform thickness



Our Casts



Thermal Verification

Uniform Cast



Our Cast



Conditions:

- office
- raised temperature
- 30 minutes

Thermal Verification

Uniform Cast

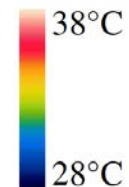
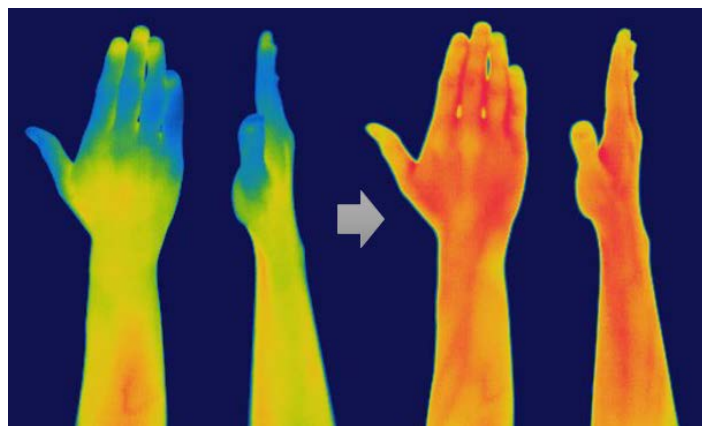
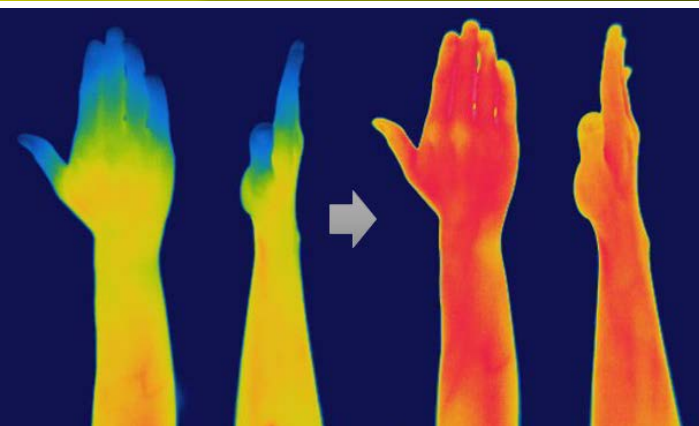


Our Cast



Conditions:

- office
- raised temperature
- 30 minutes



Thermal Verification

Uniform Cast



Our Cast

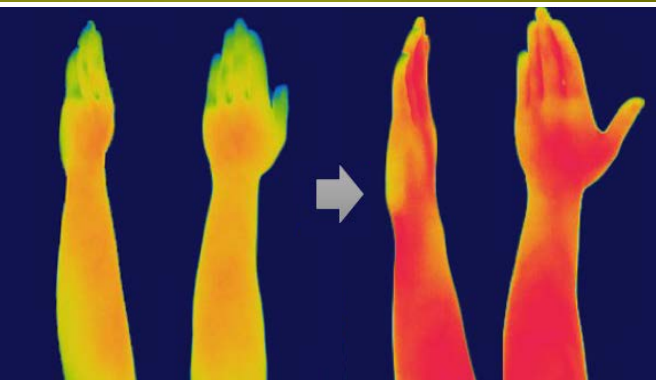


Conditions:

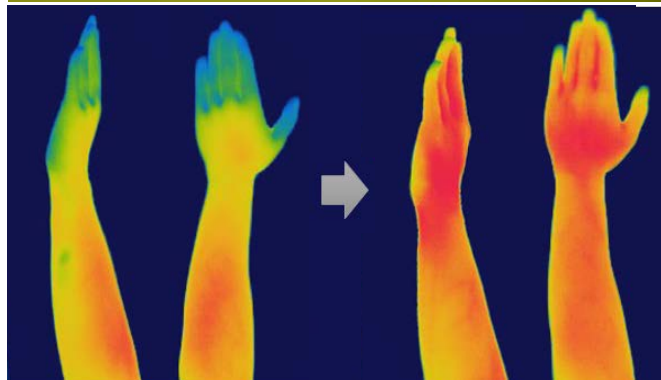
- sauna room
- raised temperature
- 30 minutes

Thermal Verification

Uniform Cast

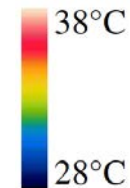


Our Cast



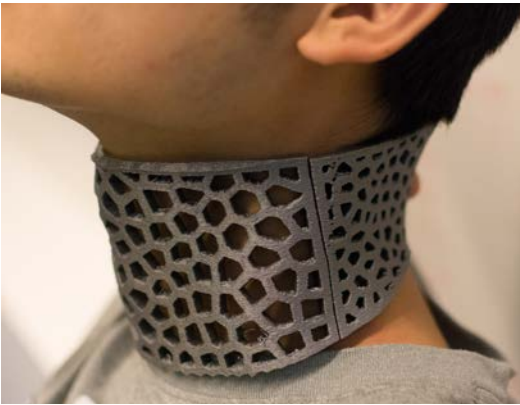
Conditions:

- sauna room
- raised temperature
- 30 minutes



Thermal Verification

Uniform Cast



Our Cast



Conditions:

- office
- raised temperature
- 15 minutes

Thermal Verification

Uniform Cast

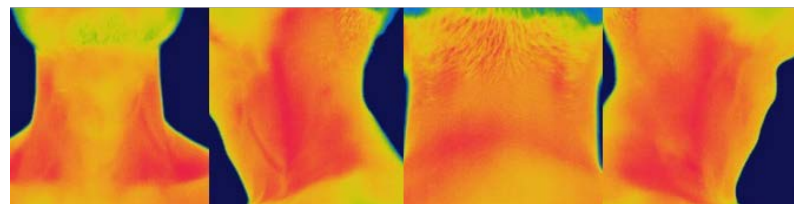
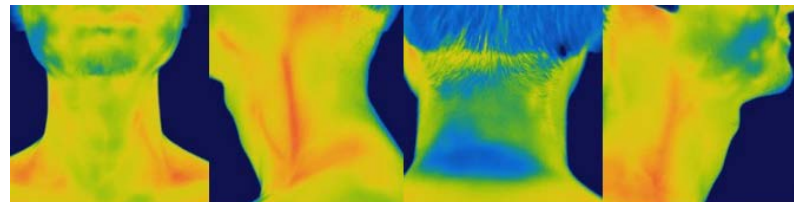
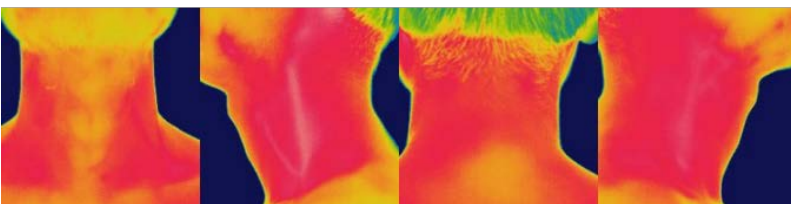
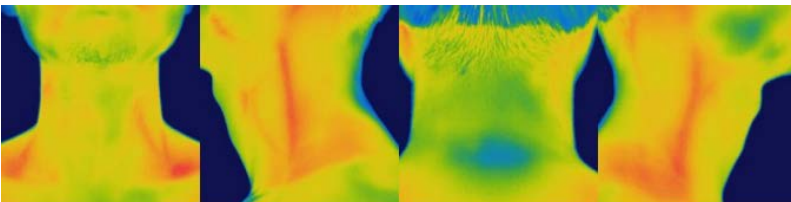


Our Cast



Conditions:

- office
- raised temperature
- 15 minutes



Thermal Verification

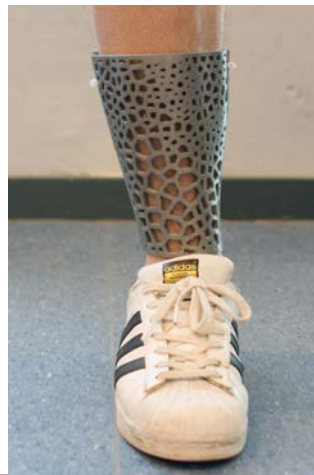
Uniform Cast



Conditions:

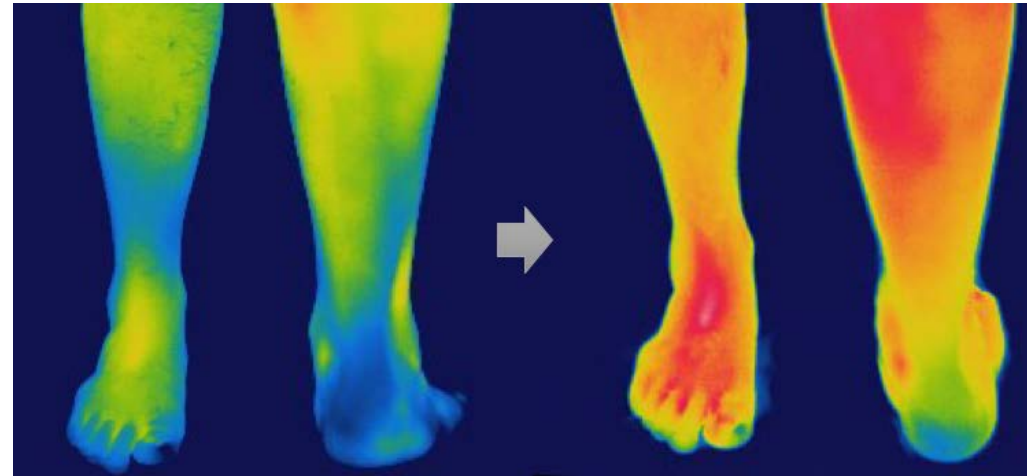
- office
- raised temperature
- 30 minutes

Our Cast



Thermal Verification

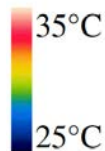
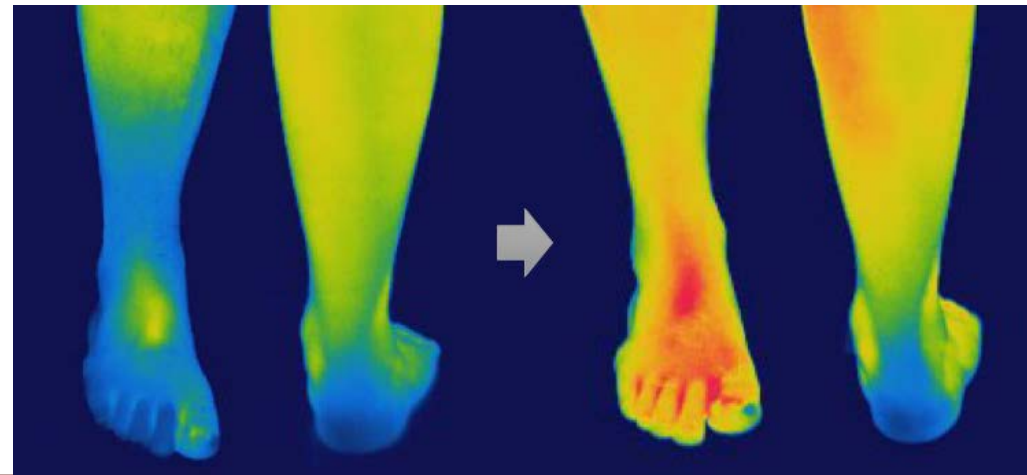
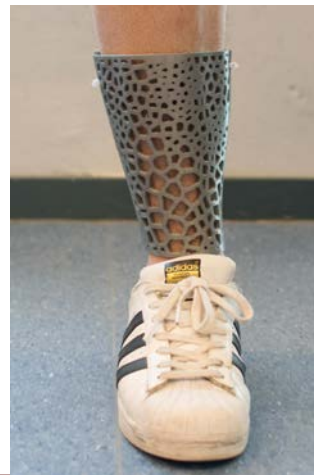
Uniform Cast



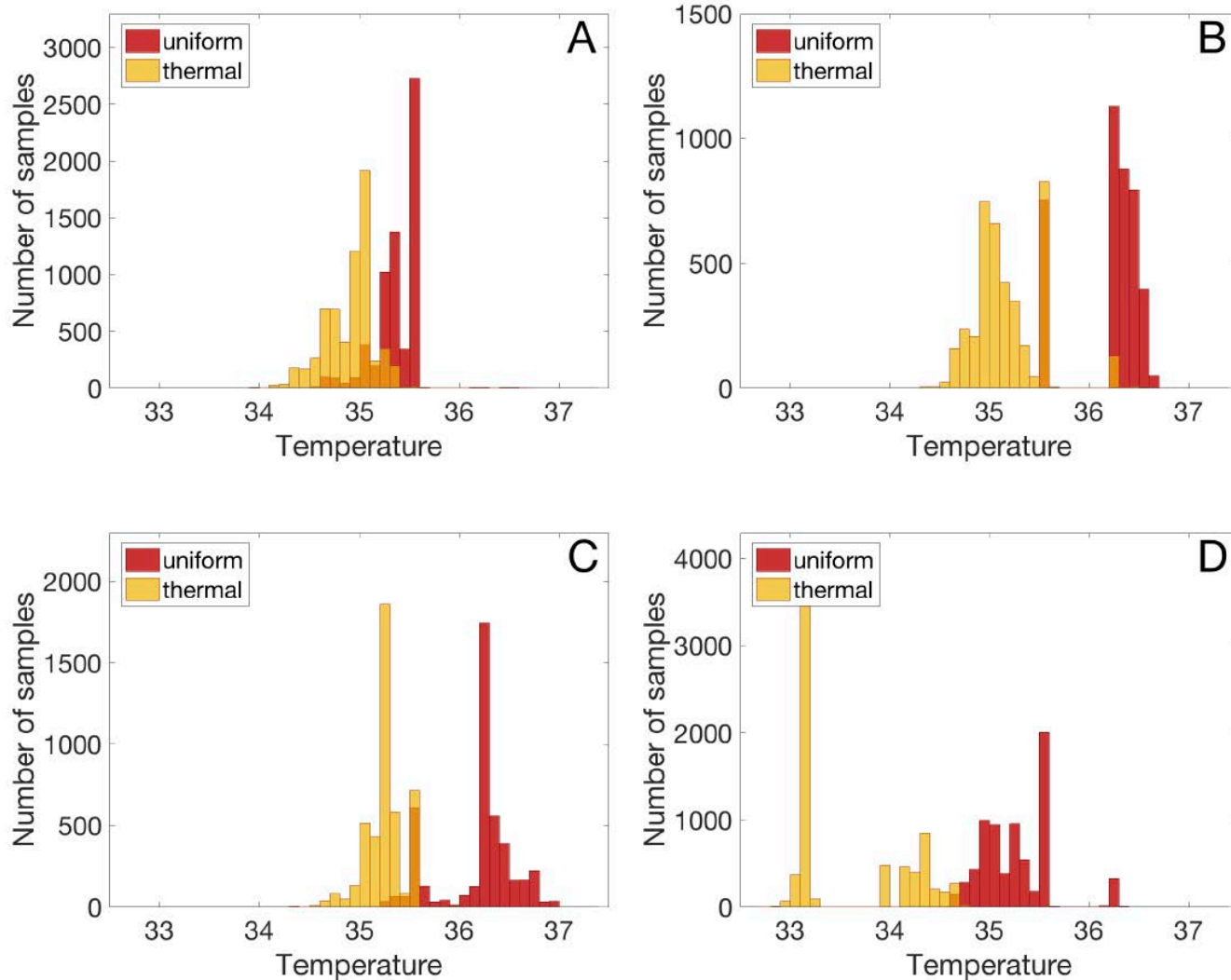
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Our Cast

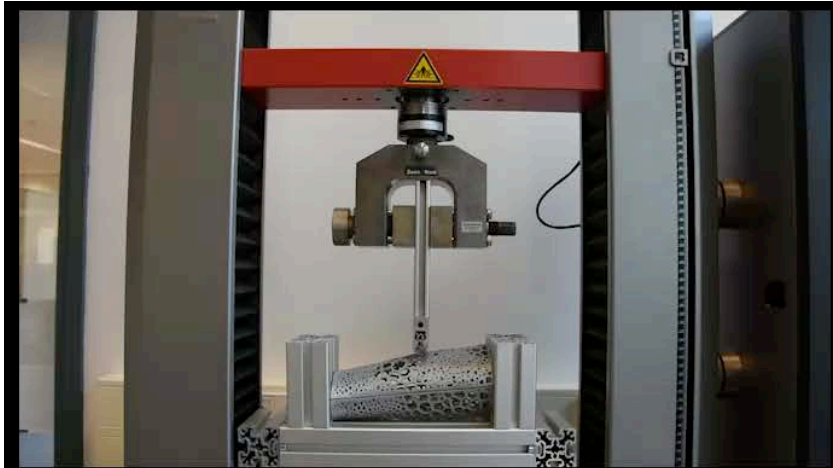


Thermal Verification

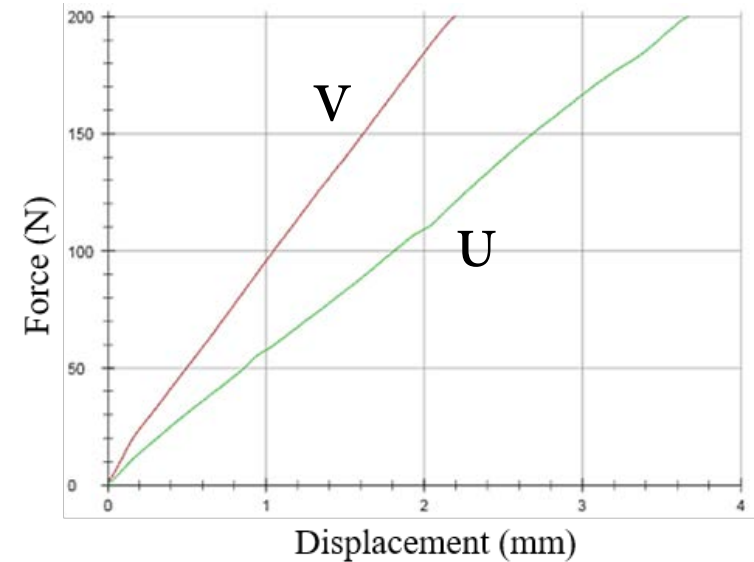


Mechanical Verification

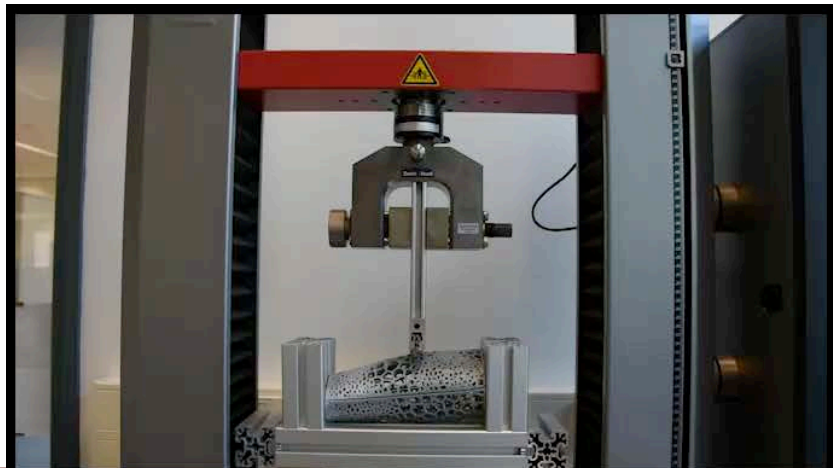
Uniform Thickness Cast (U) (4.4mm)



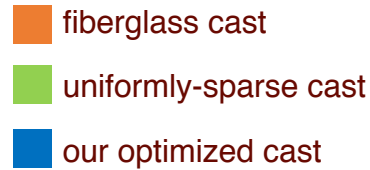
$$\text{weight}(V) = \text{weight}(U)$$



Our Cast (V) (4-6mm)



User Feedback

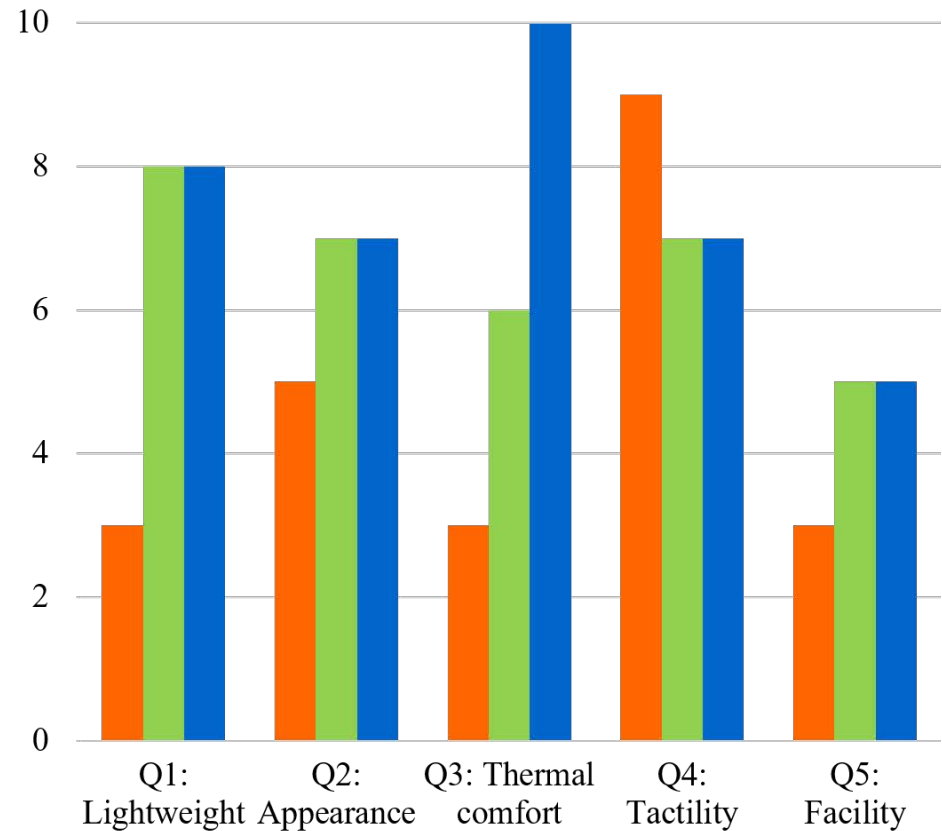


Questionnaire on 5 aspects:

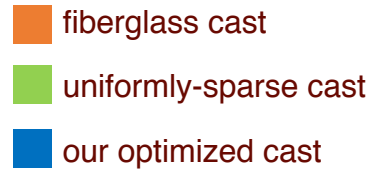
- Q1 --- lightweight
- Q2 --- appearance
- Q3 --- thermal-comfort
- Q4 --- tactility
- Q5 --- facility

* facility is an overall assessment of perception with the cast regarding regular activities, itchiness and its resistance to wear and tear

Participant A – Right Arm



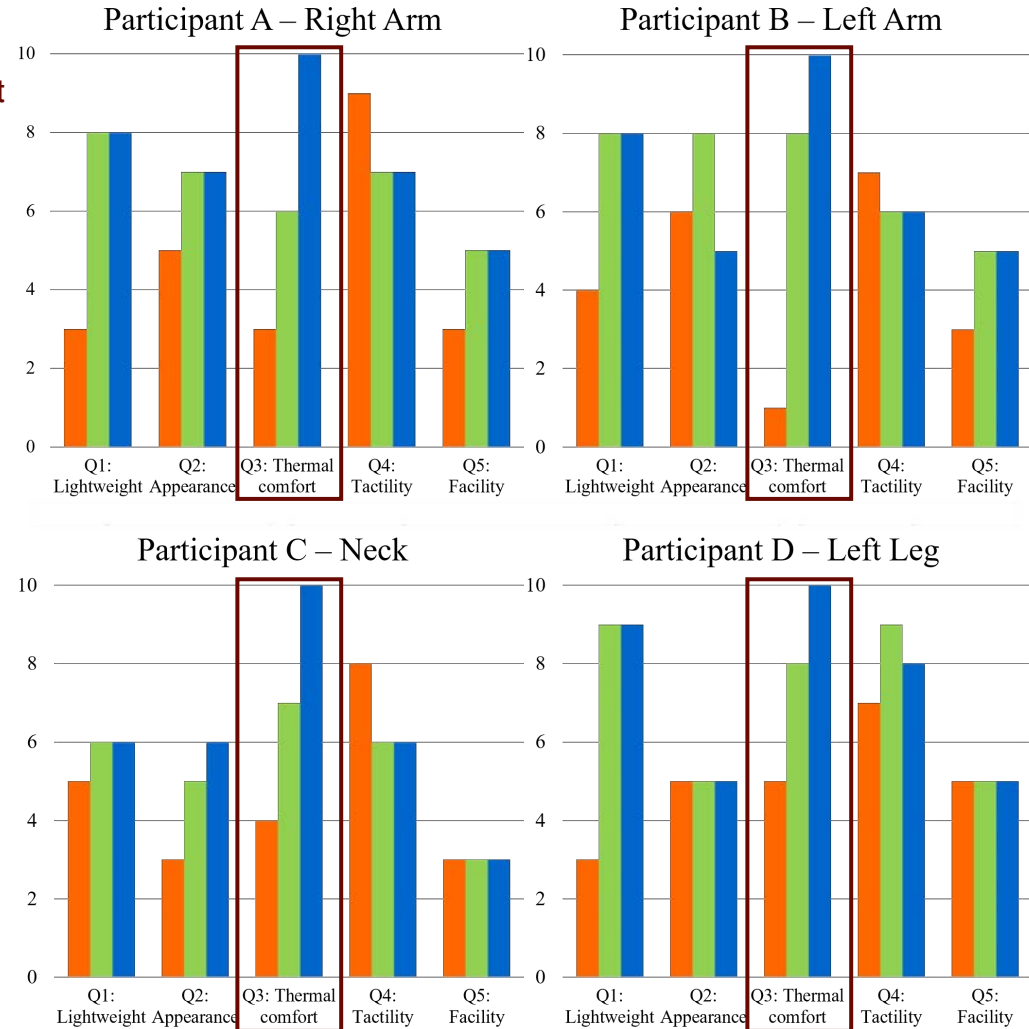
User Feedback



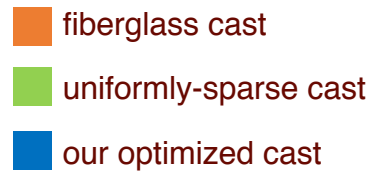
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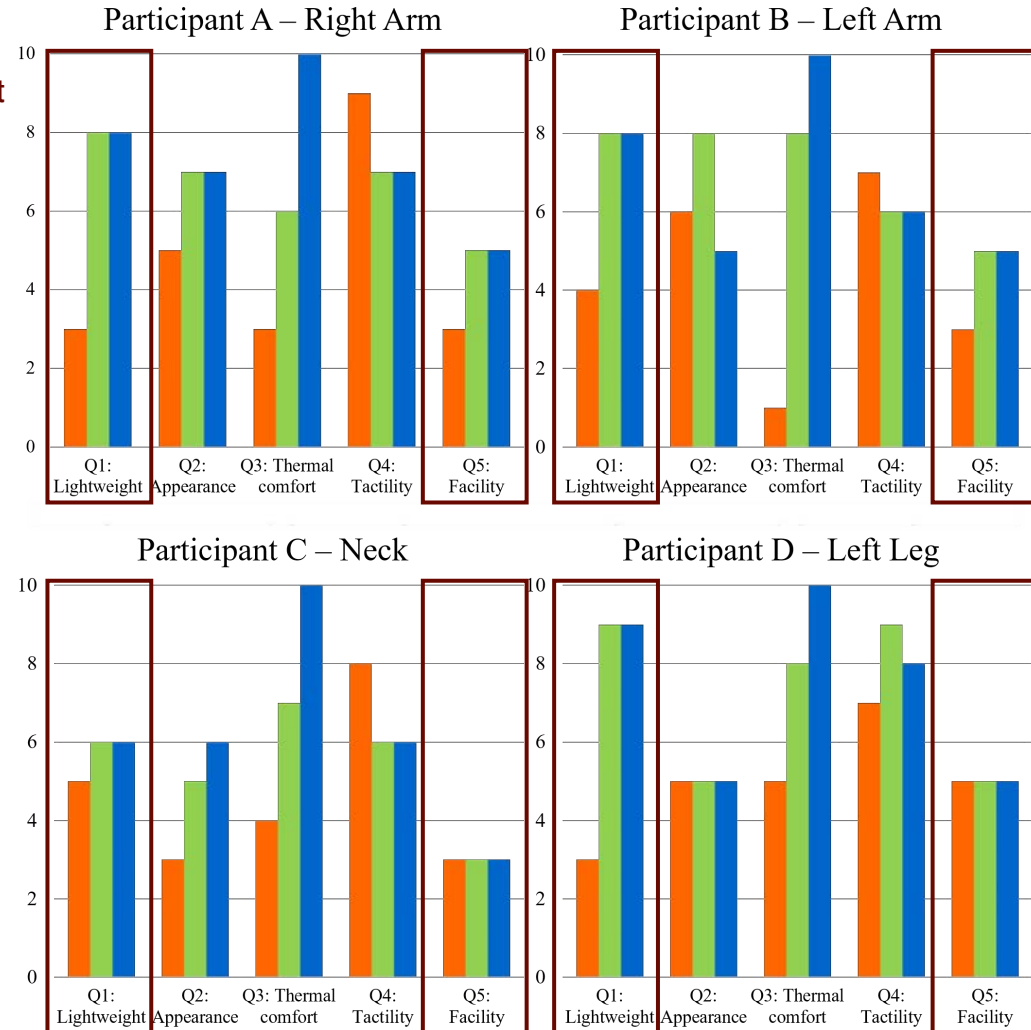
User Feedback



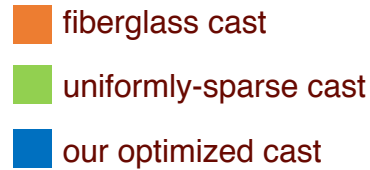
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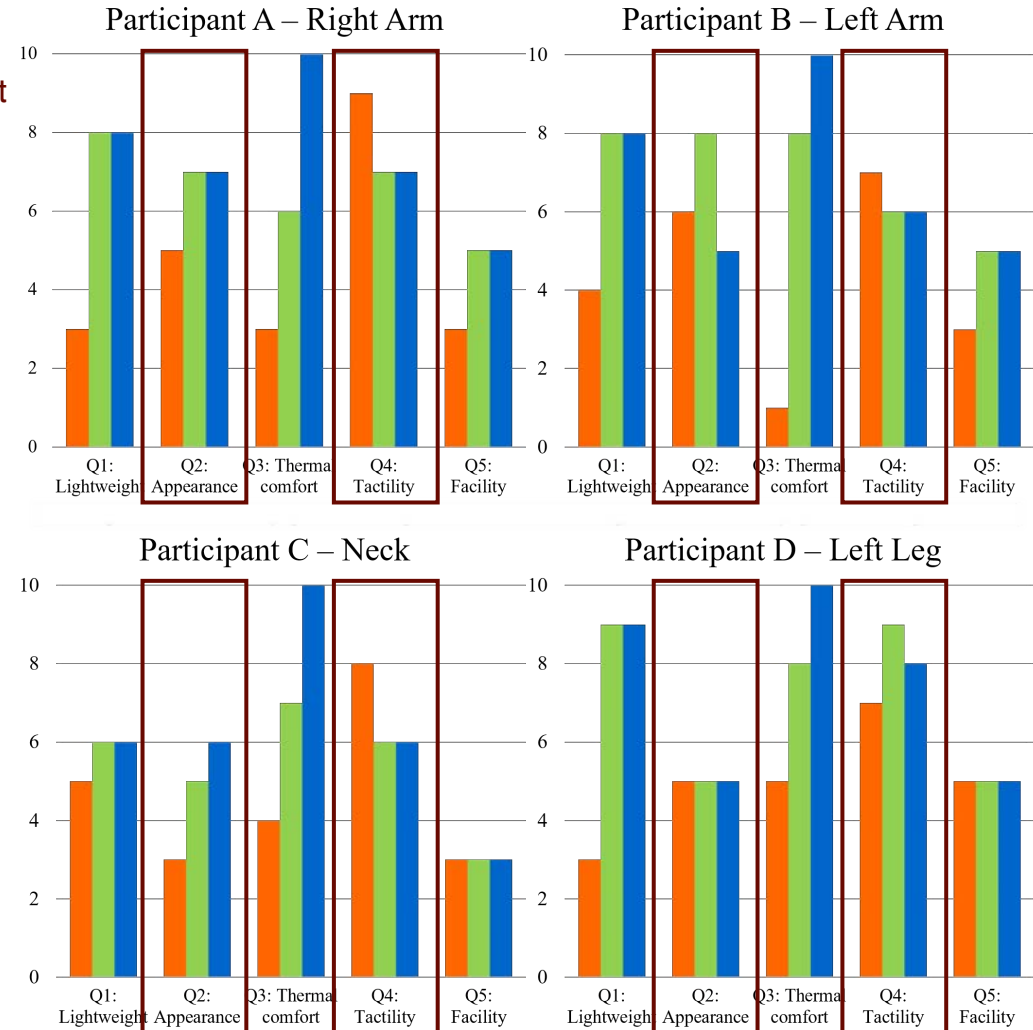
User Feedback



Questionnaire on 5 aspects:

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- Q3 --- thermal-comfort
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* facility is an overall assessment of perception with the cast regarding regular activities, itchiness and its resistance to wear and tear



Heuristic Evaluation

Interview with an orthopedic surgeon

- Improvements
 - Thermal-comfort
 - Custom-fit
- Challenges
 - 3D scanning of injured body
 - Tactile-comfort
 - Post-processing



Doctor Leon Diederix

THANK YOU FOR YOUR ATTENTION!

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