What is Computer Graphics? And Computational Fabrication?

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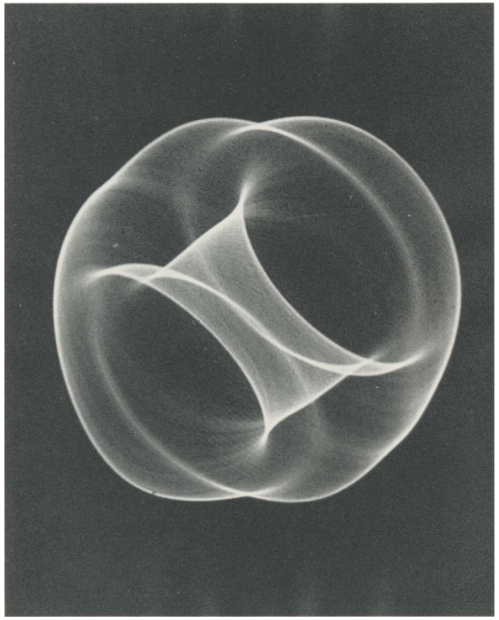
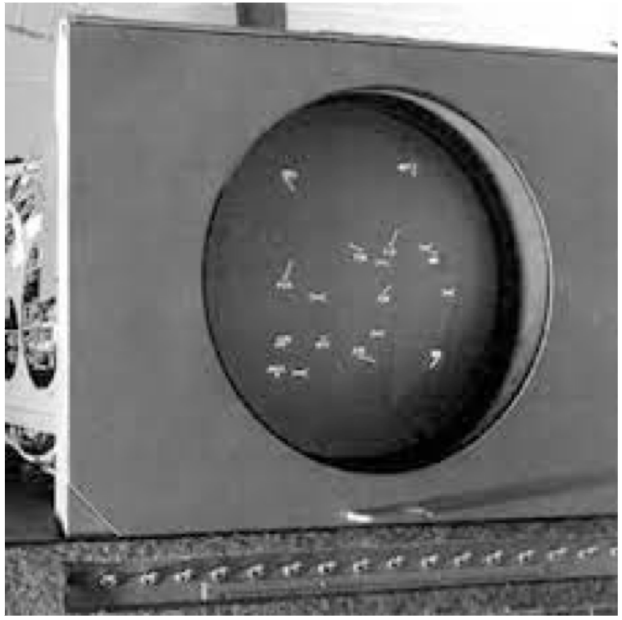
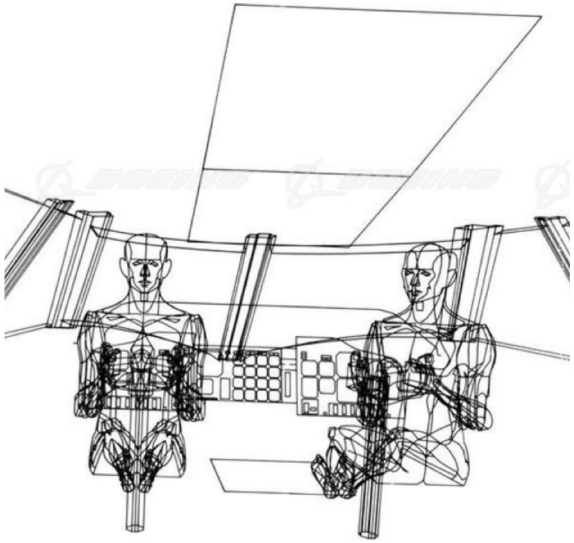
Computer Graphics - Origins



Ben F. Laposky: Oscillon 40, 1952



SAGE air defense system, MIT, 1955



The « First man », The Boing Company, 1964

ACM SIGGRAPH ‘74 Proceedings

- A model for human faces that allows speech synchronized animation
- Practical computer graphics for scientific users
- Graphics geometric perception and communication
- Solution plans and interactive problem solving
- A graphical display system utilizing plasma panels
- Graphics in business where we are and where we are going
- A macromodular graphics system for protein structure research
- Interactive graphics for transportation systems planning and design
- Interactive modeling system for bridges
- Traffic analysis and display for the San Francisco vessel traffic system

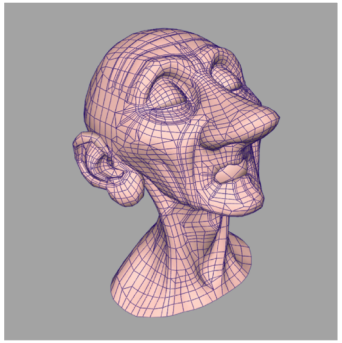
Computer Graphics - Today

Computer Graphics - Today

Rendering

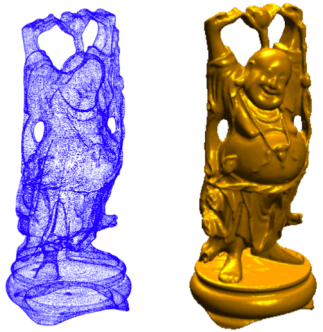
[Novák et al. 2012]

Geometry Modeling



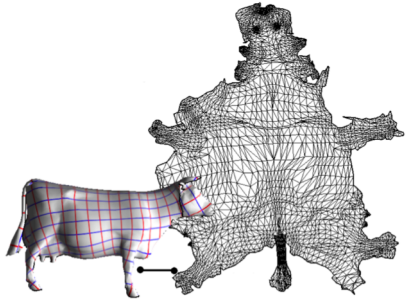
[DeRose et al. 1998]

Capture & Reconstruction



[Carr et al. 2001]

Geometry Processing

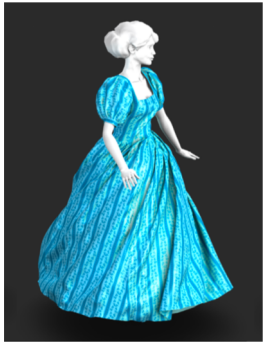


[Sheffer et al. 2004]

Character Animation

[Coros et al. 2010]

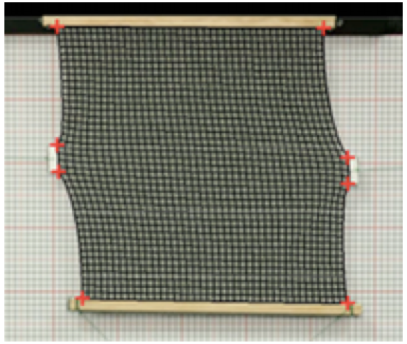
Simulation



[Ly et al. 2020]

[Pfaff et al. 2010]

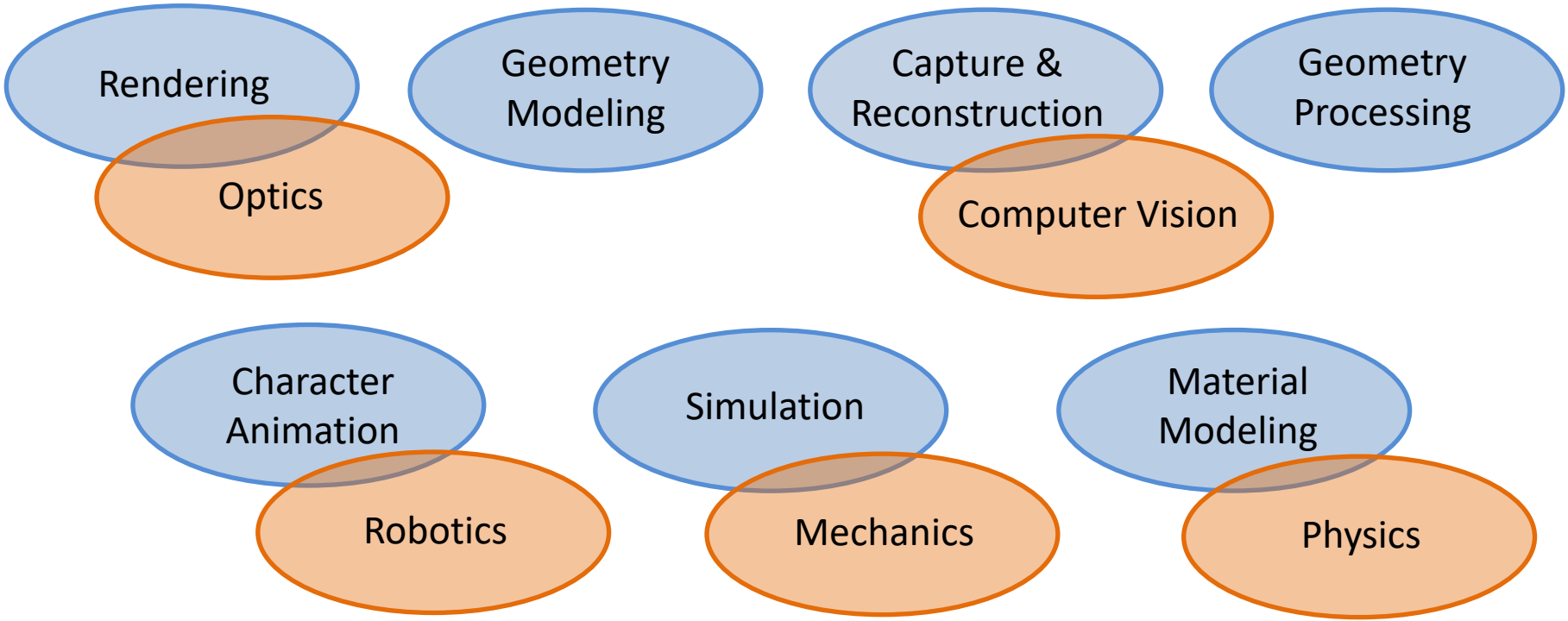
Material Modeling



[Wang et al. 2011]

Etc.

Computer Graphics - Today



Particularities

- Large motions and complex effects
- Cheating is allowed!
- Behaviour should be controllable
- Performance (often) matters

[Li et al. 2021]

[McNamara et al 2004]

What we know how to do

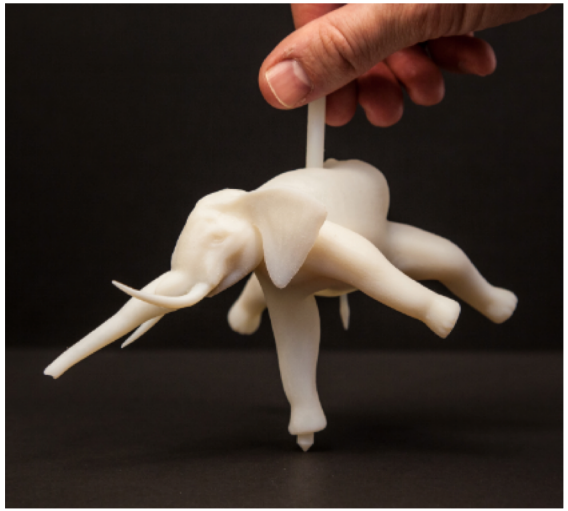
Develop numerical methods that are:

- Fast
- Controllable
- Powerful
- Inaccurate (often) or even wrong (sometimes)

Computational Fabrication

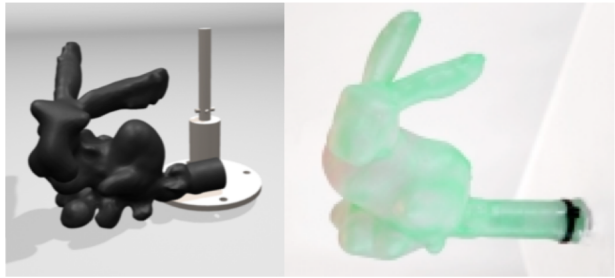
- Using computers to create real objects

[Skouras et al. 2015]

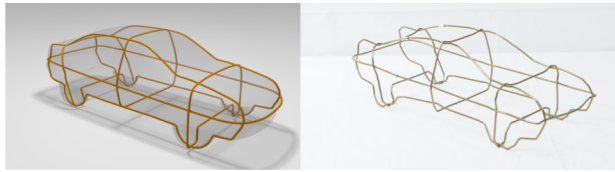


[Bächer et al. 2014]

[Hildebrandt et al. 2012]

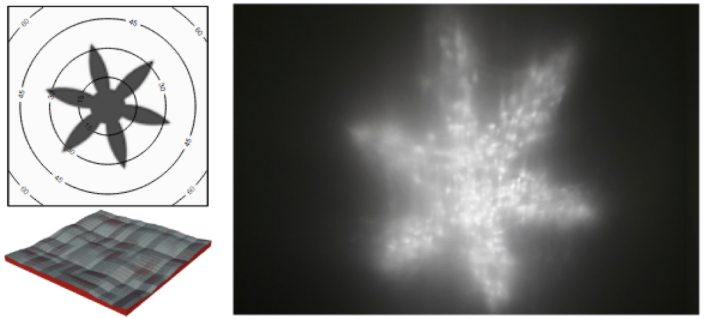


Skouras et al. 2012



Miguel et al. 2017

From Computer Graphics to Computational Fabrication



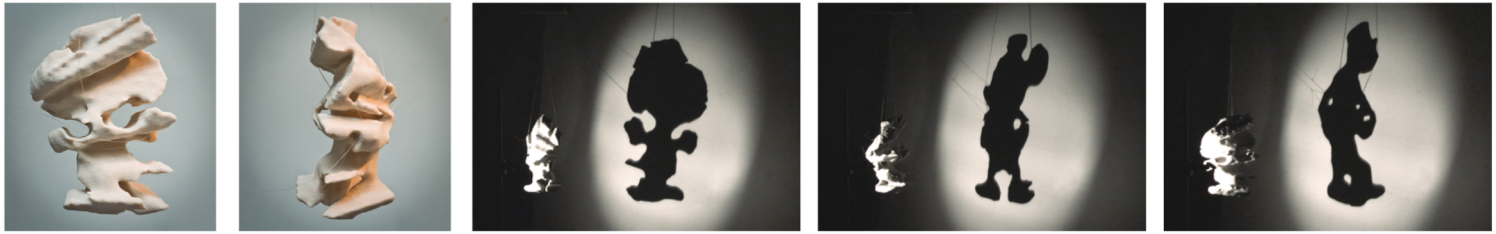
[Weyrich et al. 2009]

[Hašan et al. 2010]

[Papas et al. 2013]

[Auzinger et al. 2018]

From Computer Graphics to Computational Fabrication

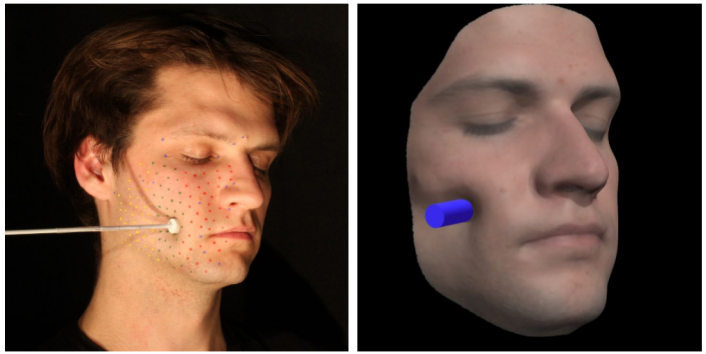


[Mitra & Pauly 2009]

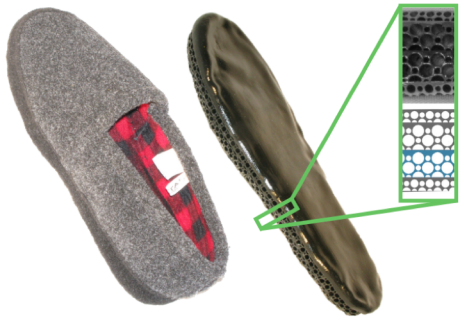
[Xin et al. 2011]

[Herholz et al.2015]

From Computer Graphics to Computational Fabrication



[Bickel et al. 2009]

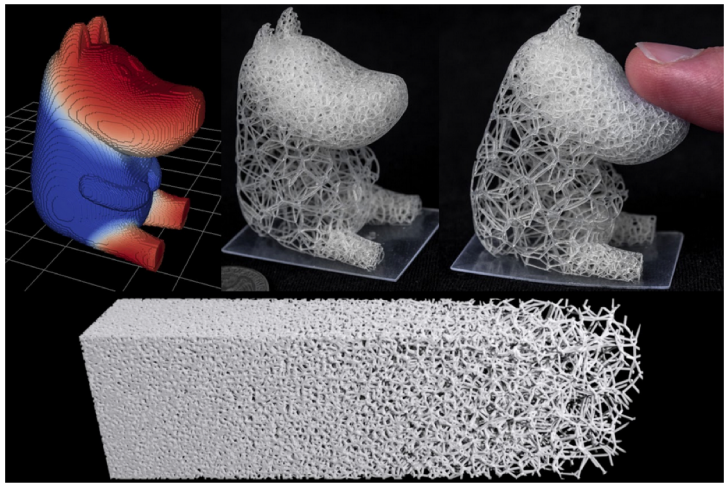


[Bickel et al. 2010]

[Schumacher et al. 2015]

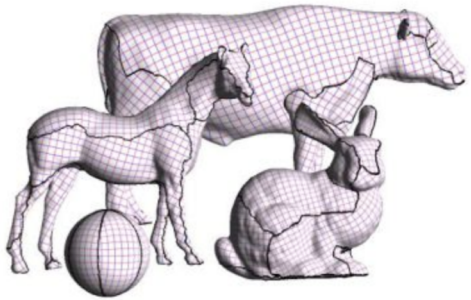
From Computer Graphics to Computational Fabrication

[Dumas et al.2015]

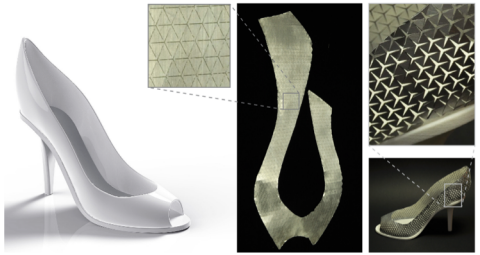


[Martinez et al.2016]

From Computer Graphics to Computational Fabrication



[Mitani & Suzuki 2004]



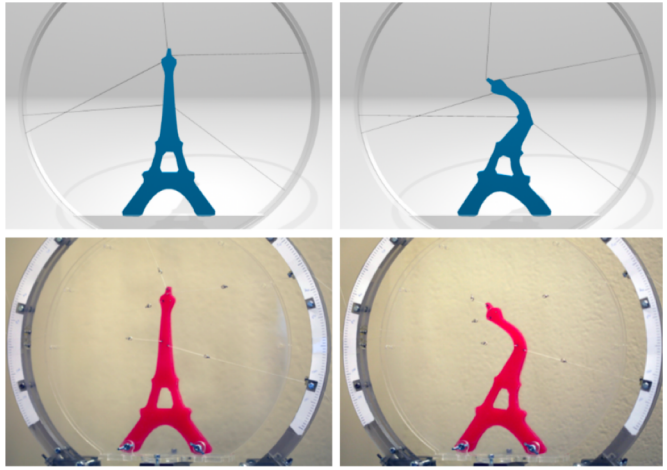
[Konakovic et al. 2016]

[Julius et al. 2005]

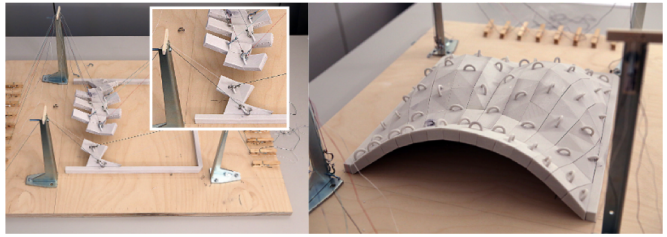
[Mori & Igarashi 2007]

[Malomo et al. 2018]

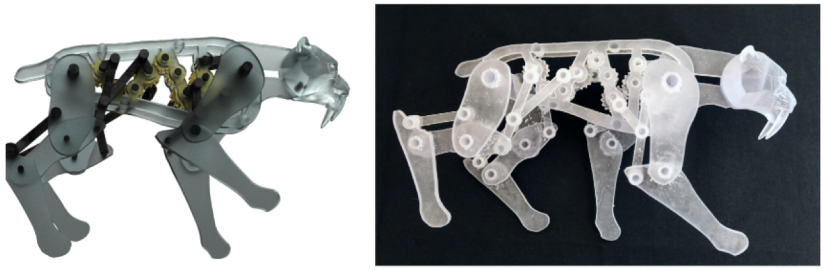
Other Topics



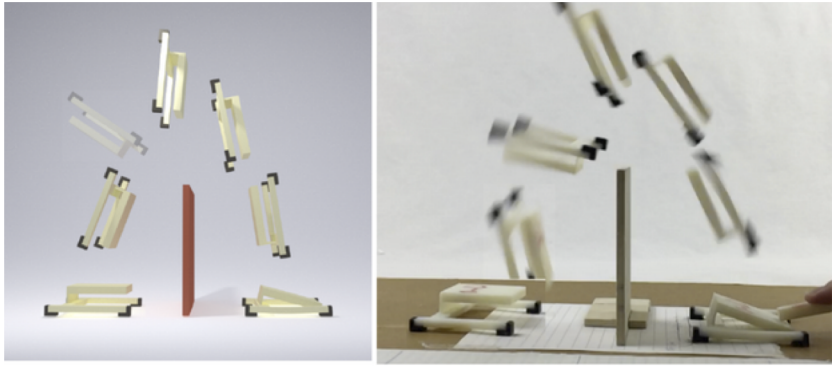
[Skouras et al. 2013]



[Deuss et al. 2014]



[Coros et al. 2013]



[Chen et al. 2015]

Challenges

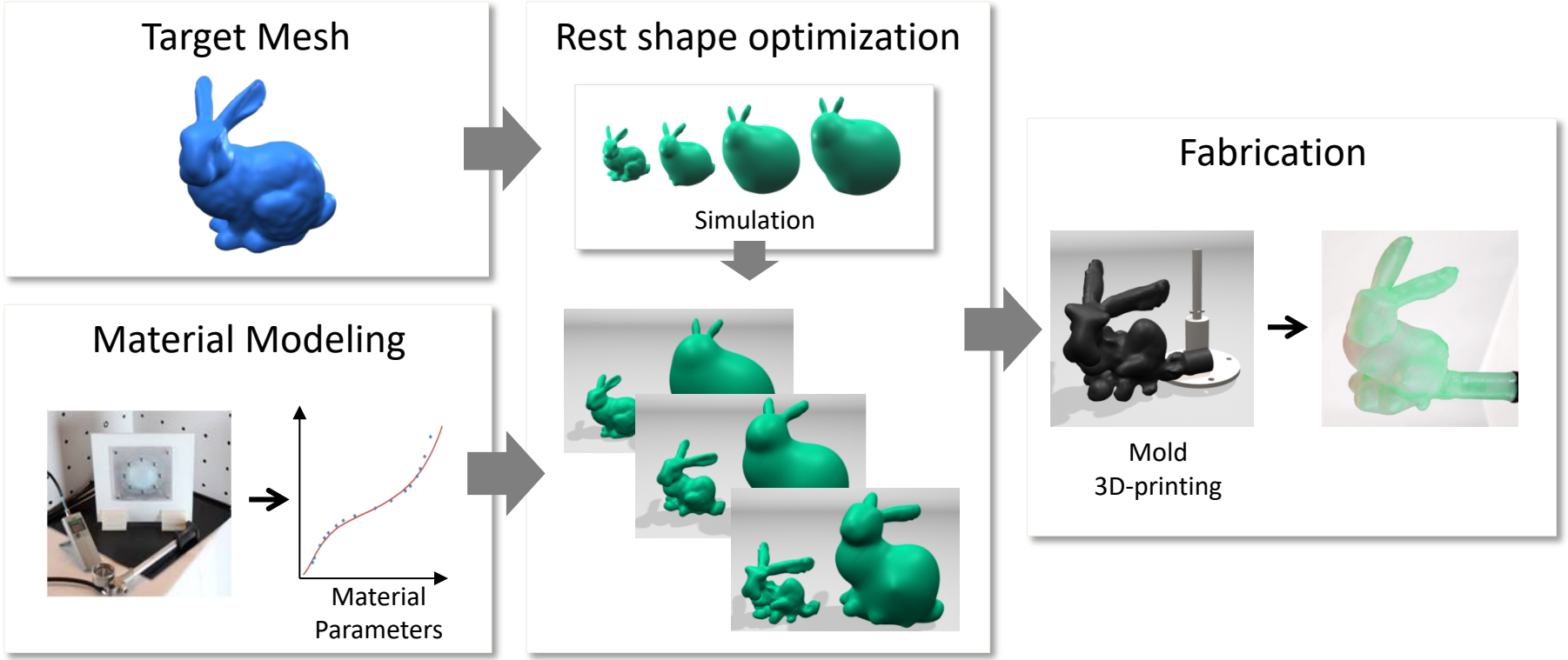
- Cheating is not allowed anymore
- Material properties need to be inferred
- Fabrication constraints/inaccuracies need to be accounted for
- Proper validation is needed

Example

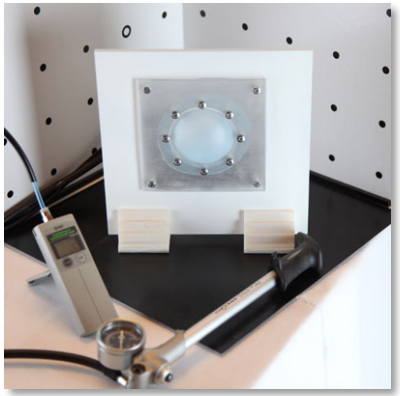
?

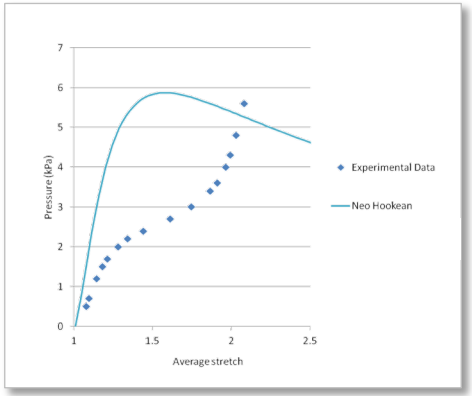
[Skouras et al. 2012]

Pipeline


Target Mesh
Material Modeling
Material
Parameters
Rest shape optimization
Simulation
Fabrication
Mold
3D-printing

Material Law



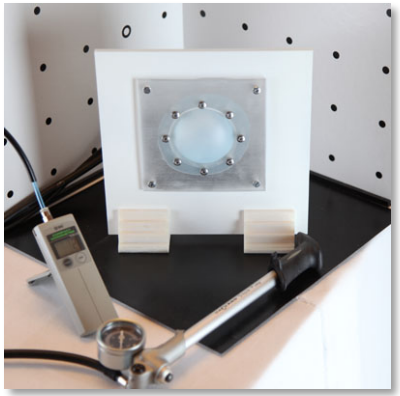


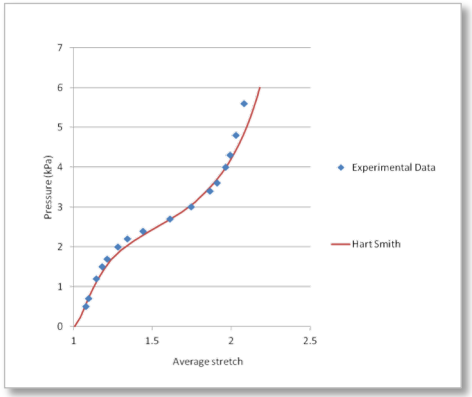
Neo-Hookean

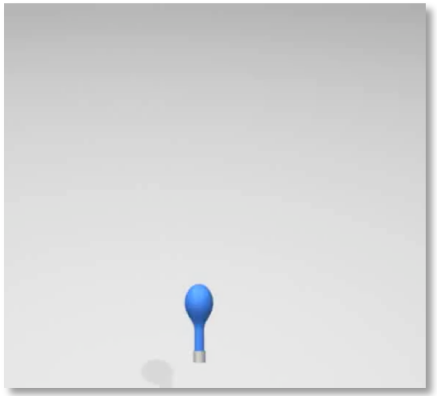
$$\psi(I_1, I_2) = C_{10}(I_1 - 3)$$

$$I_1 = \mathrm{tr}(\mathbf{C}), \quad I_2 = \frac{1}{2}\left[I_1^{\,2} - \mathrm{tr}(\mathbf{C}^{\mathrm{t}}\mathbf{C})\right]$$

Material Law



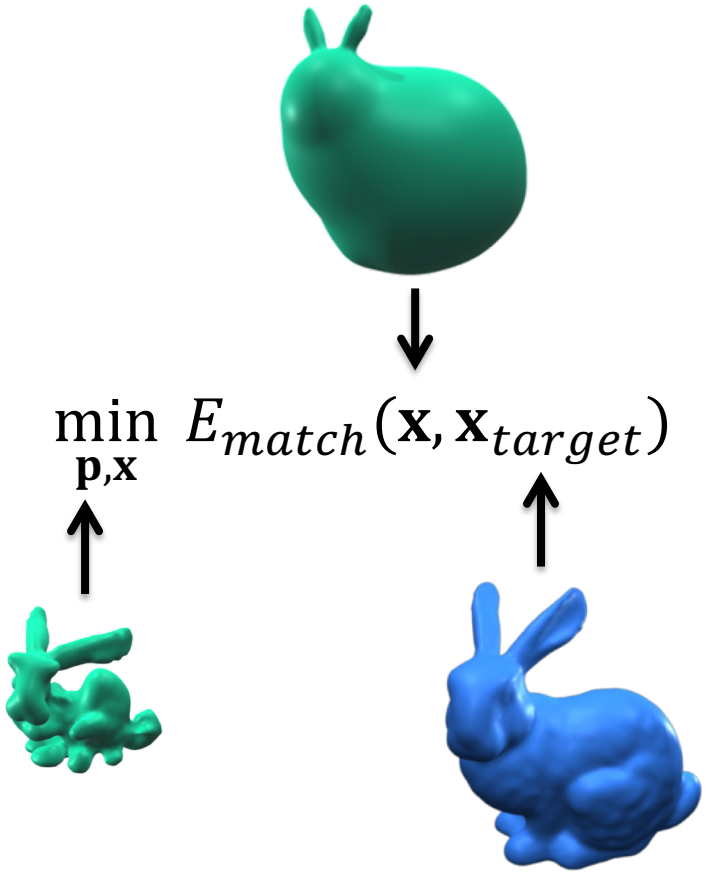




Hart-Smith

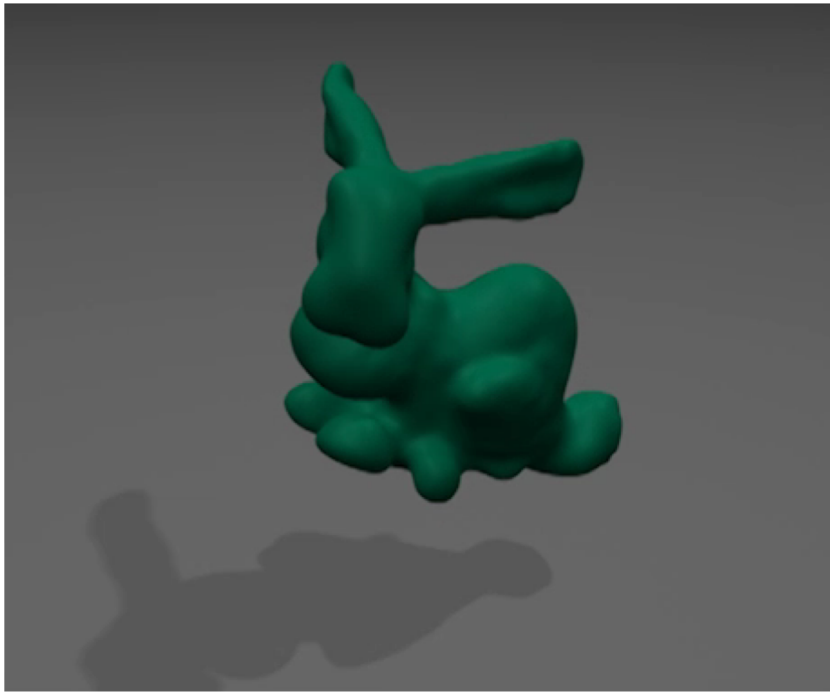
$$\frac{\partial \psi}{\partial I_1} = G \cdot e^{k_1 (I_1 - 3)^2} \qquad \frac{\partial \psi}{\partial I_2} = G \cdot \frac{k_2}{I_2}$$

Rest Shape Optimization

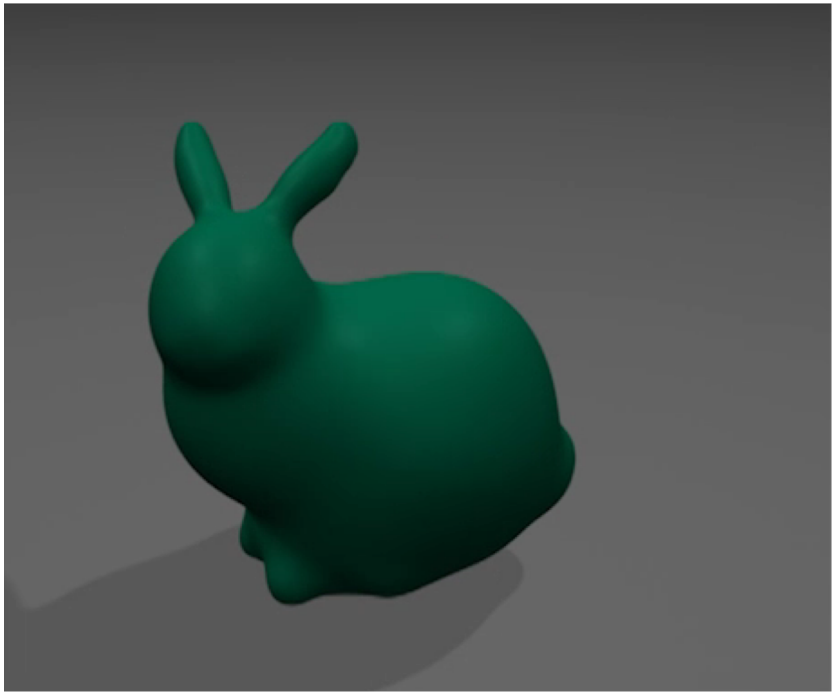


$$\min_{\mathbf{p},\mathbf{x}} E_{match}(\mathbf{x}, \mathbf{x}_{target}) \quad \text{subject to} \quad \frac{\partial \psi}{\partial \mathbf{x}}(\mathbf{x}, \mathbf{p}) = -\mathbf{f}^p(\mathbf{x})$$

Rest Shape Optimization



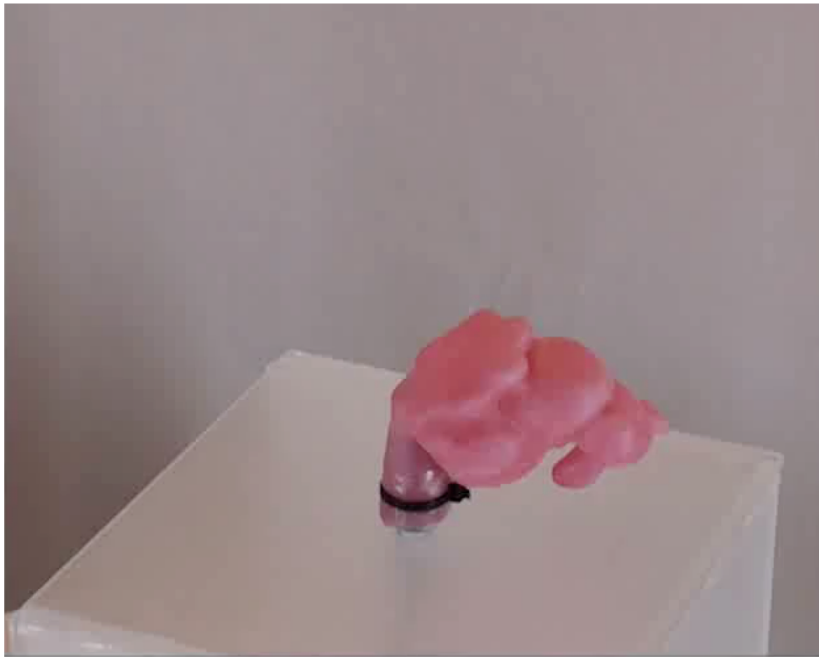
Rest shape



Inflated shape (scaled)

Fabrication

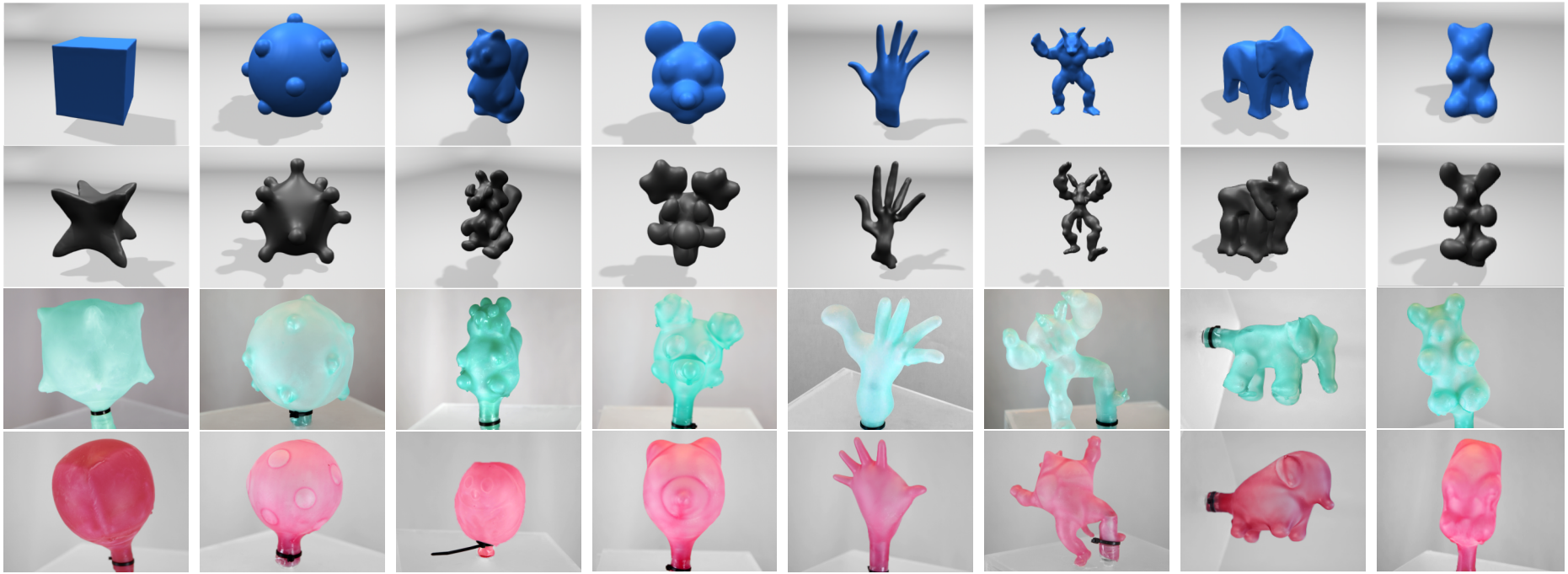
Bunny Result



Non-optimized

Optimized

More Results



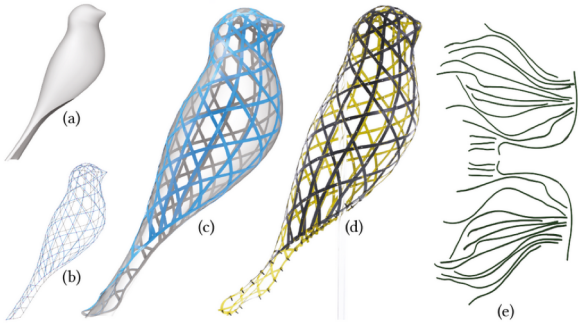
Conclusion

- Physicists and Mechanicists can bring
  - Expertises regarding theoretical aspects
  - Expertise regarding the design of experiments
  - Expertise regarding validation

- We can bring
  - Expertise with numerical tools
  - Creative approaches to solve challenging problems

Thank you!

[Hafner & Bickel 2021]



[Ren et al. 2021]

[Kaspar et al. 2021]

[Nindal et al. 2021]