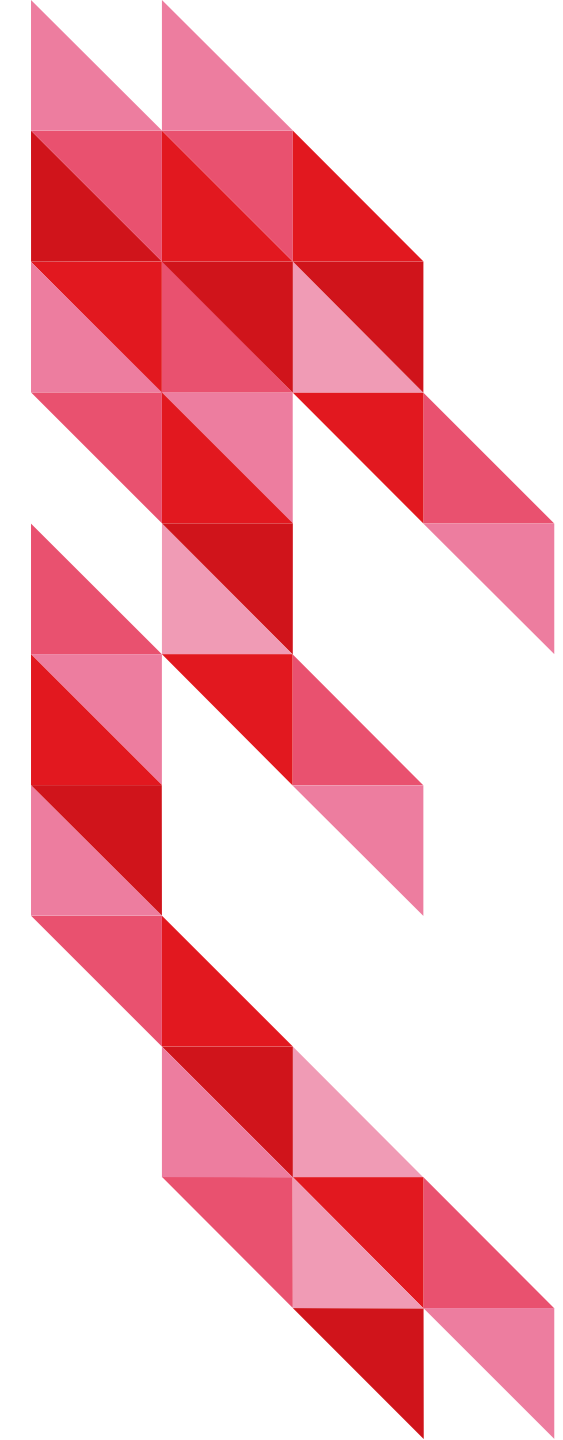




AUTOMATIC DESIGN OF MECHANICAL METAMATERIAL ACTUATORS

Stefano Zapperi

Department of Physics, University of Milan

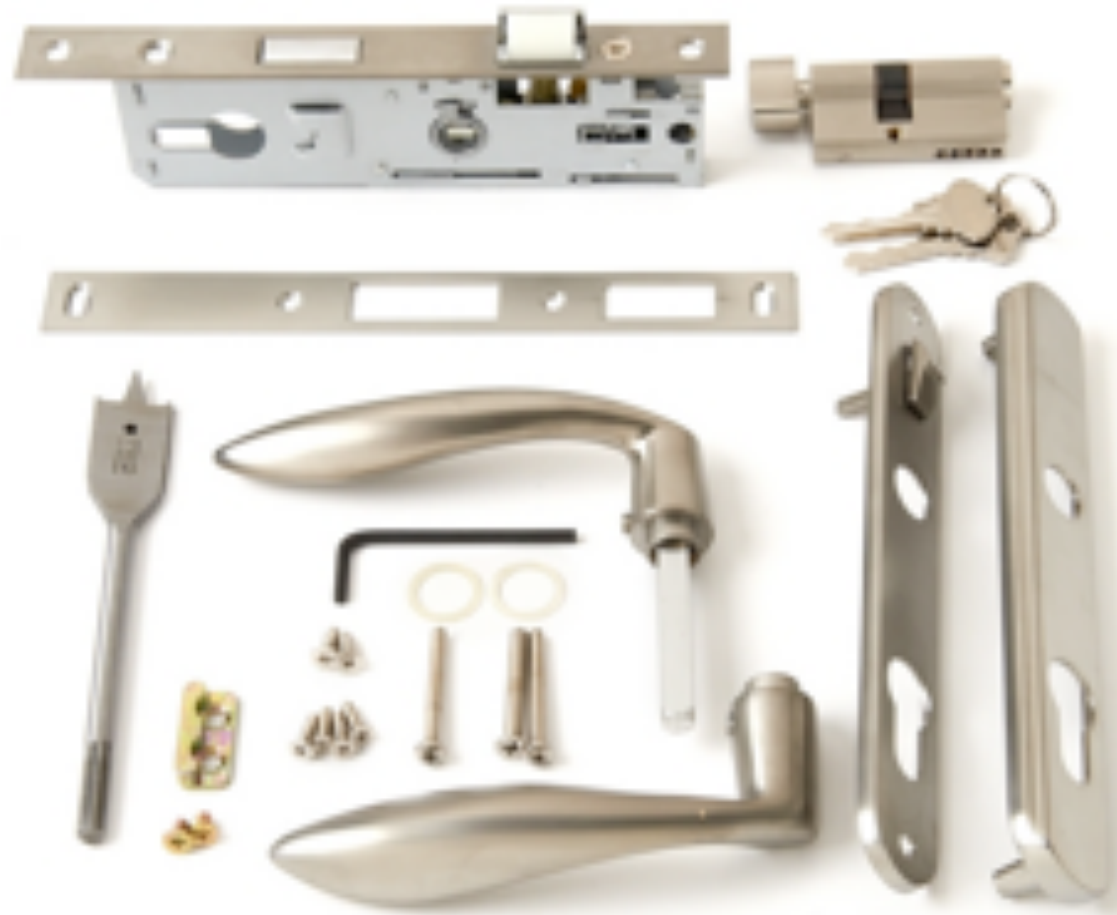
TOP WEBINAR 26.01.2021

Bonfanti, S., Guerra, R., Font-Clos, F., Rayneau-Kirkhope D., Zapperi, S., Automatic design of mechanical metamaterial actuators. *Nat Commun* **11**, 4162 (2020).



www.smmlab.it
www.complexitybiosystems.it
metamech.design

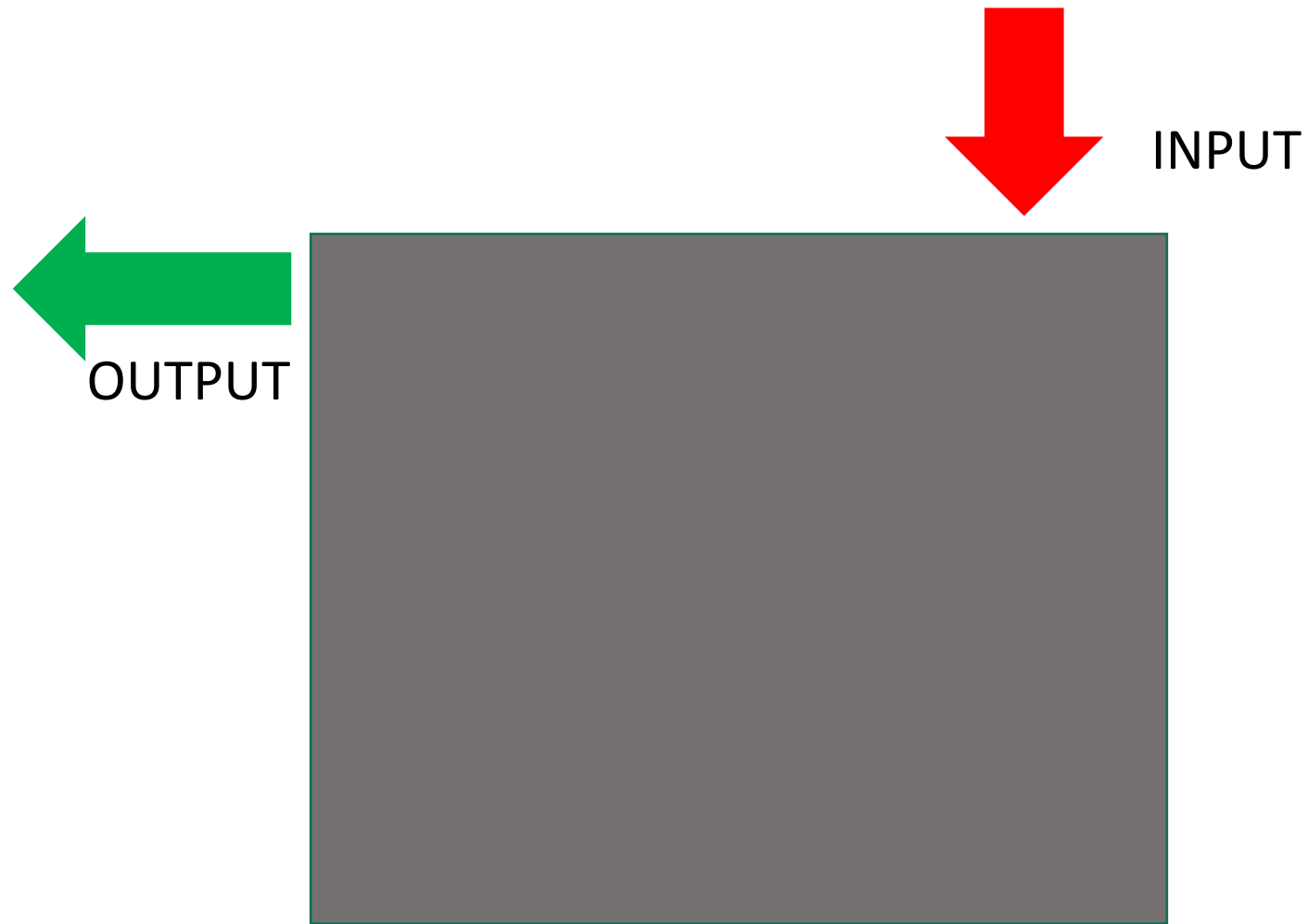
MECHANICAL ACTUATORS



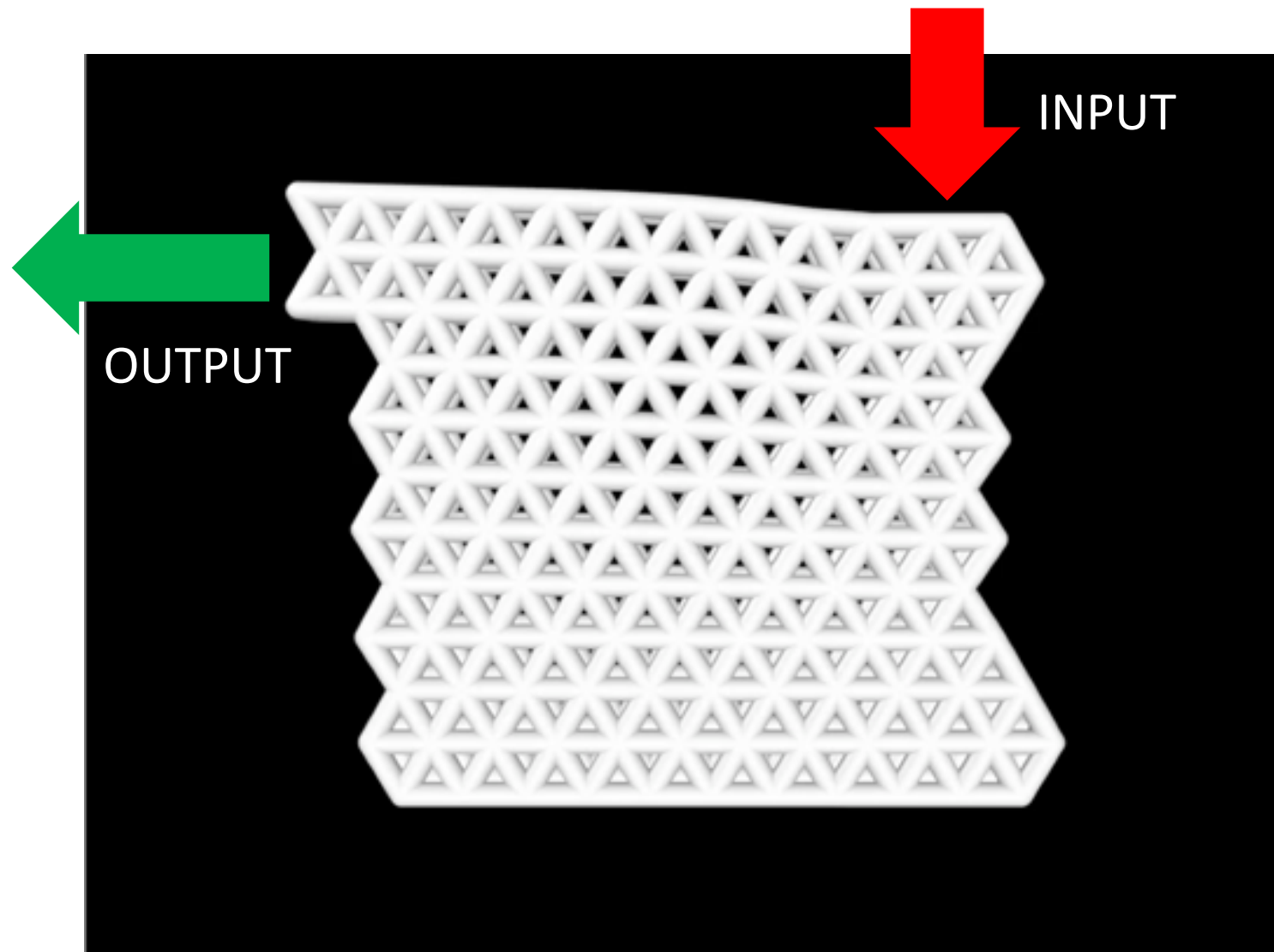
METAMATERIAL ACTUATORS



AUTOMATIC DESIGN



AUTOMATIC DESIGN



DISCRETE ELEMENT MODEL

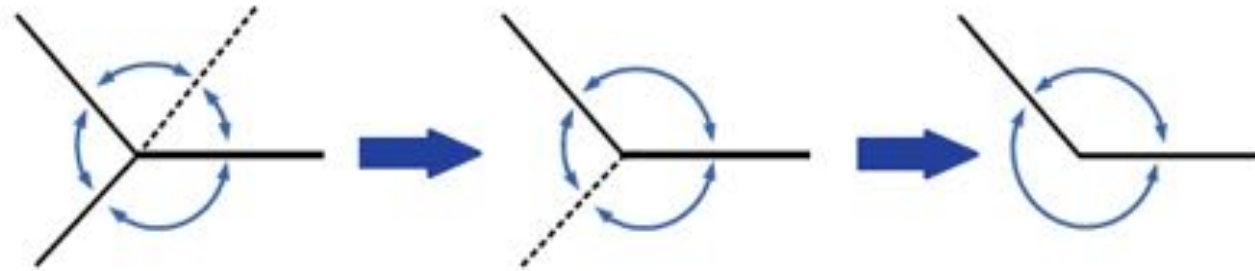
Elastic energy:

$$E = \sum_i \sum_{j>i} \phi_2(\mathbf{r}_{ij}) + \sum_i \sum_{j>i} \sum_{k \neq j} \phi_3(\mathbf{r}_{ij}, \mathbf{r}_{ik}, \theta_{ijk})$$

Efficiency:

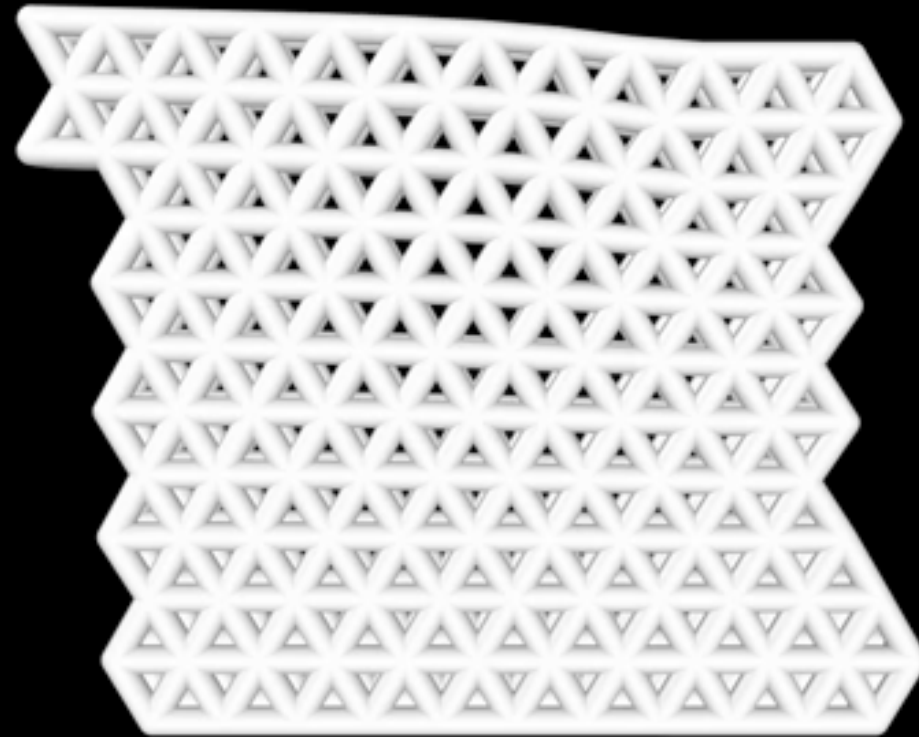
$$\eta = \frac{\mathbf{t}_{\text{out}} \cdot (\mathbf{r}_j - \mathbf{r}_{0j})}{\mathbf{t}_{\text{inp}} \cdot (\mathbf{r}_i - \mathbf{r}_{0i})}$$

Add or remove bonds:

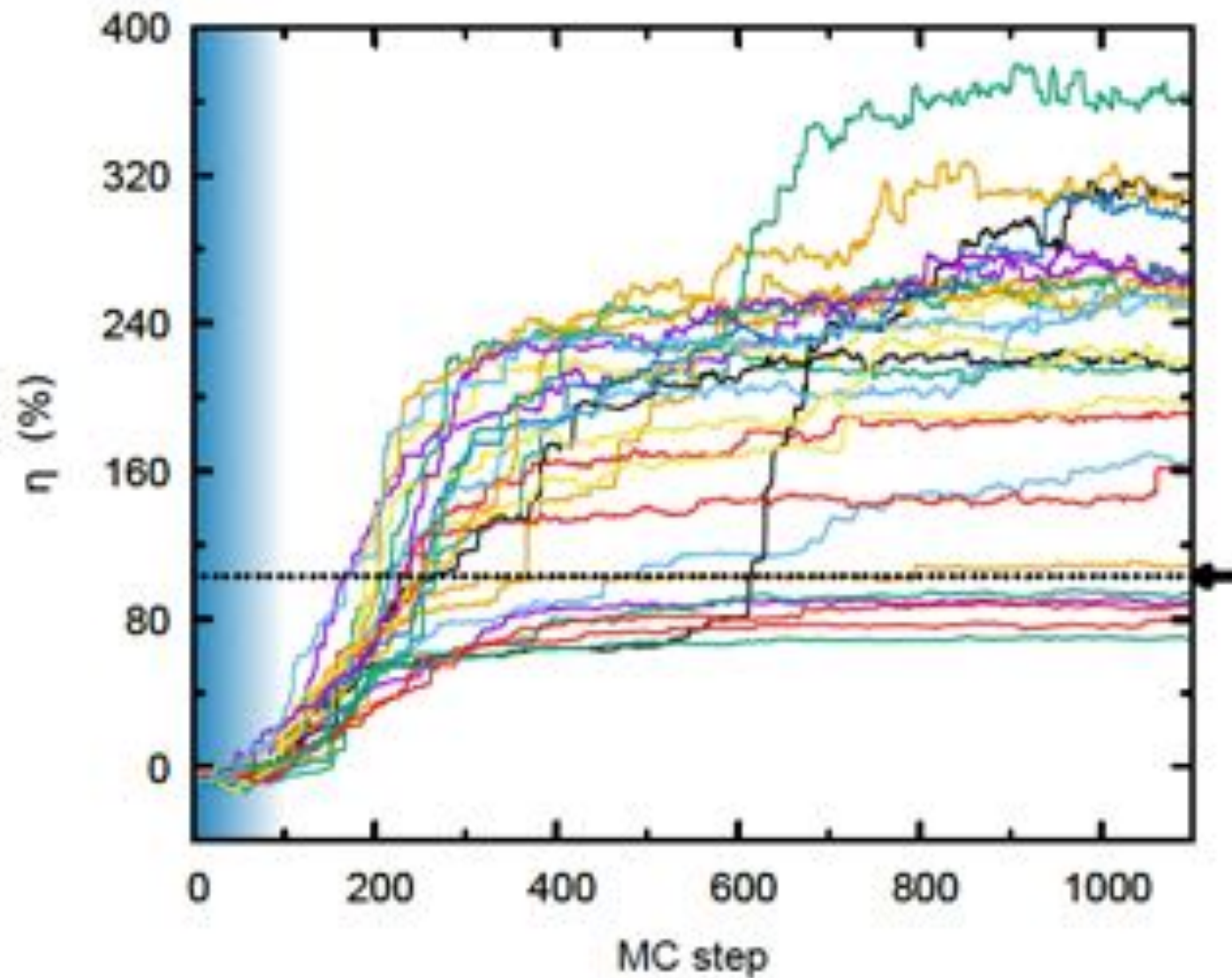


Minimize cost function: $\Delta = \exp(-\eta)$

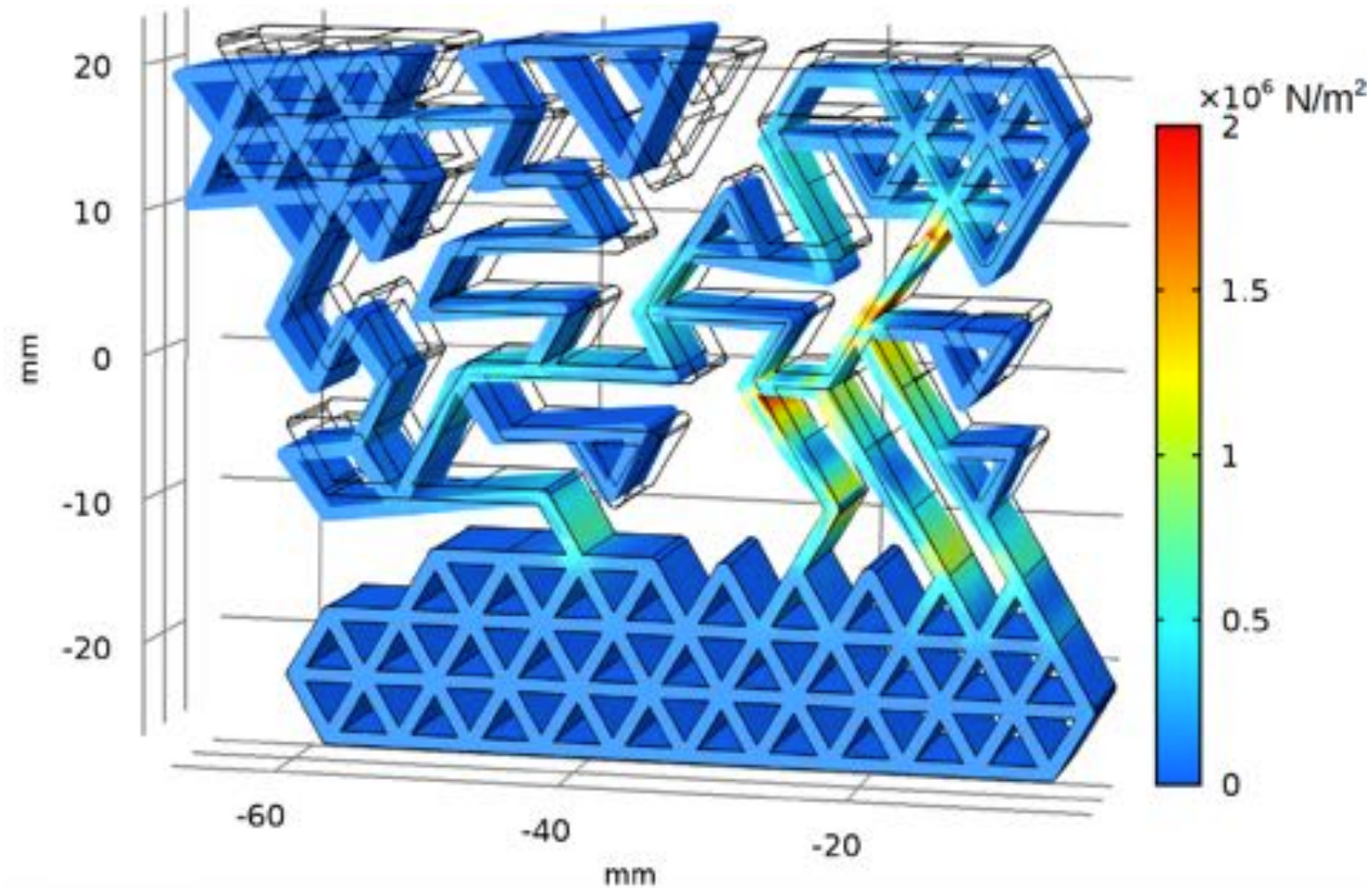
MONTE-CARLO **OPTIMIZATION**



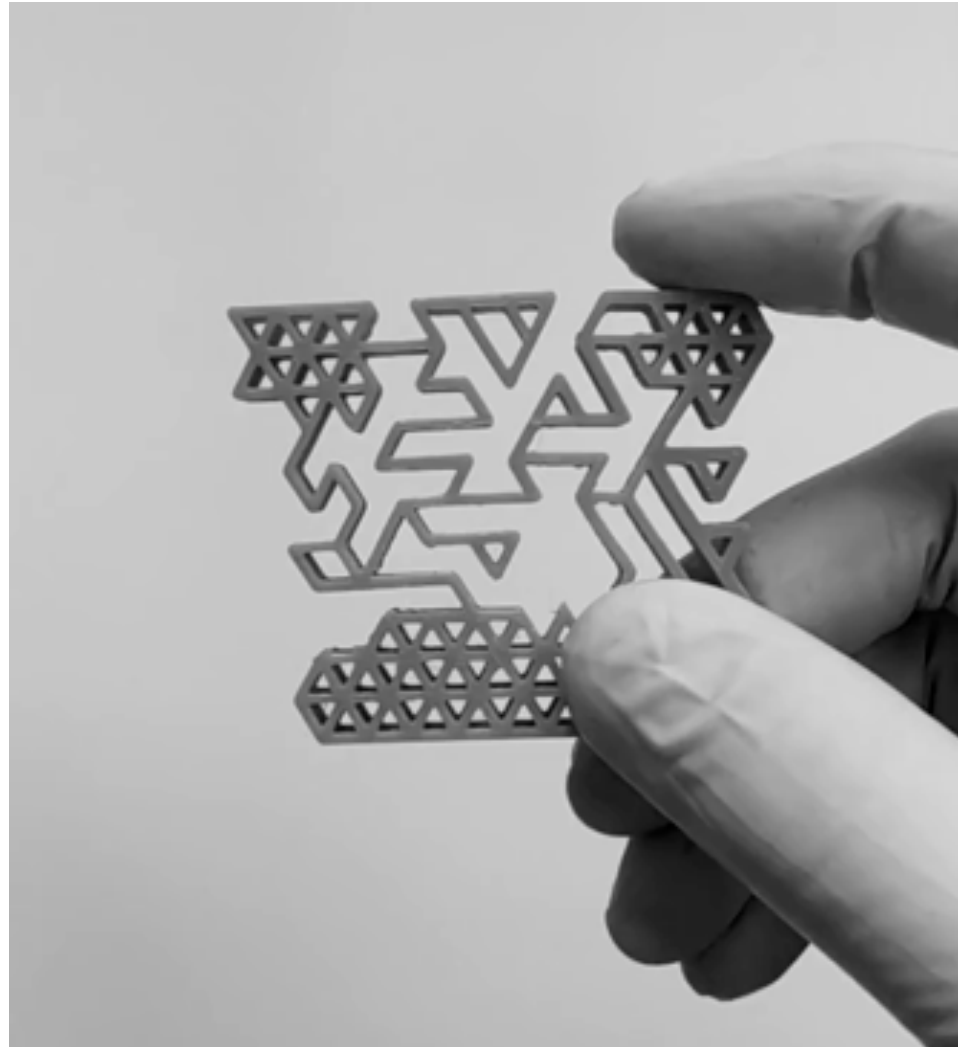
OPTIMIZATION DYNAMICS



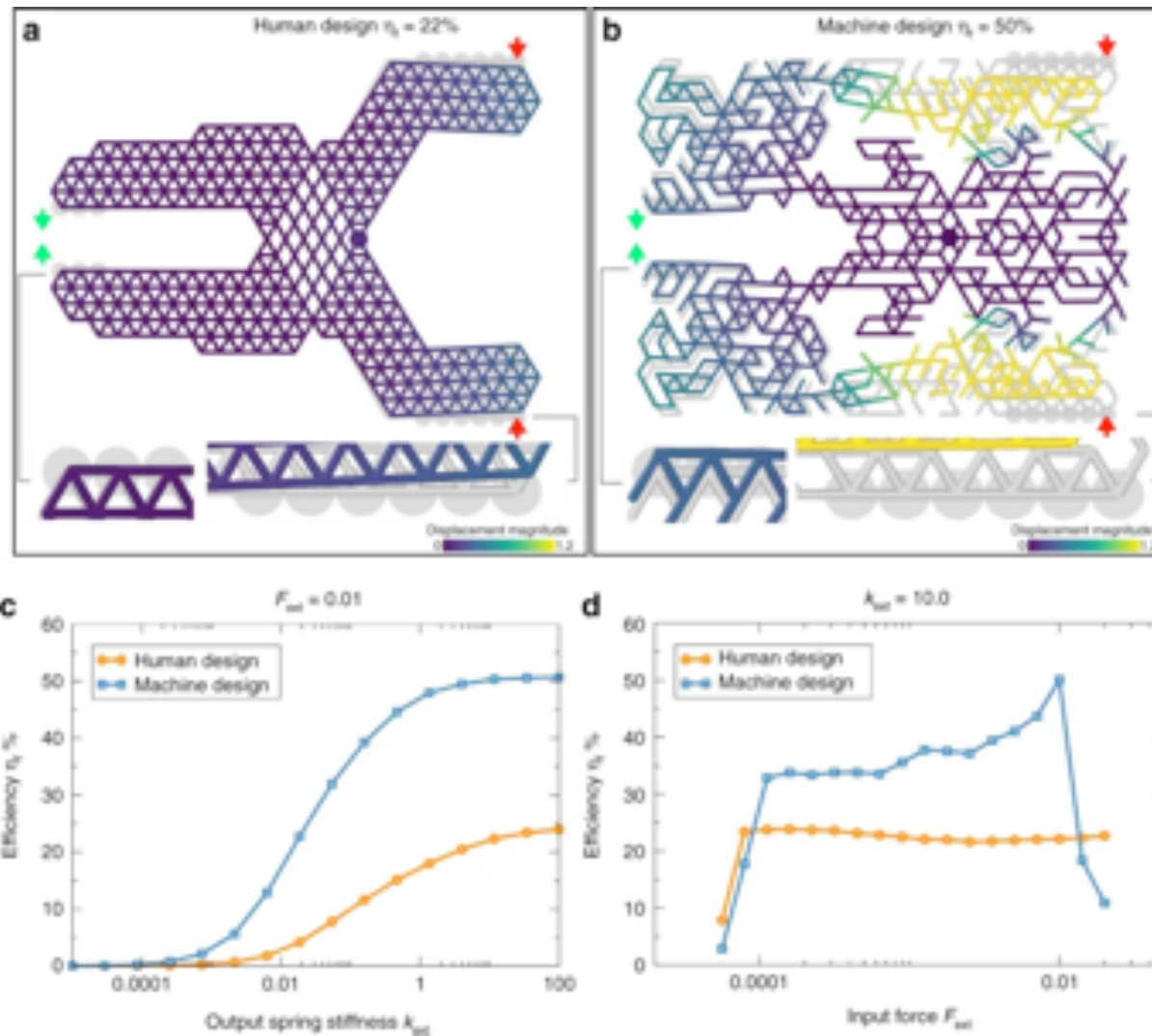
FEM CALCULATIONS



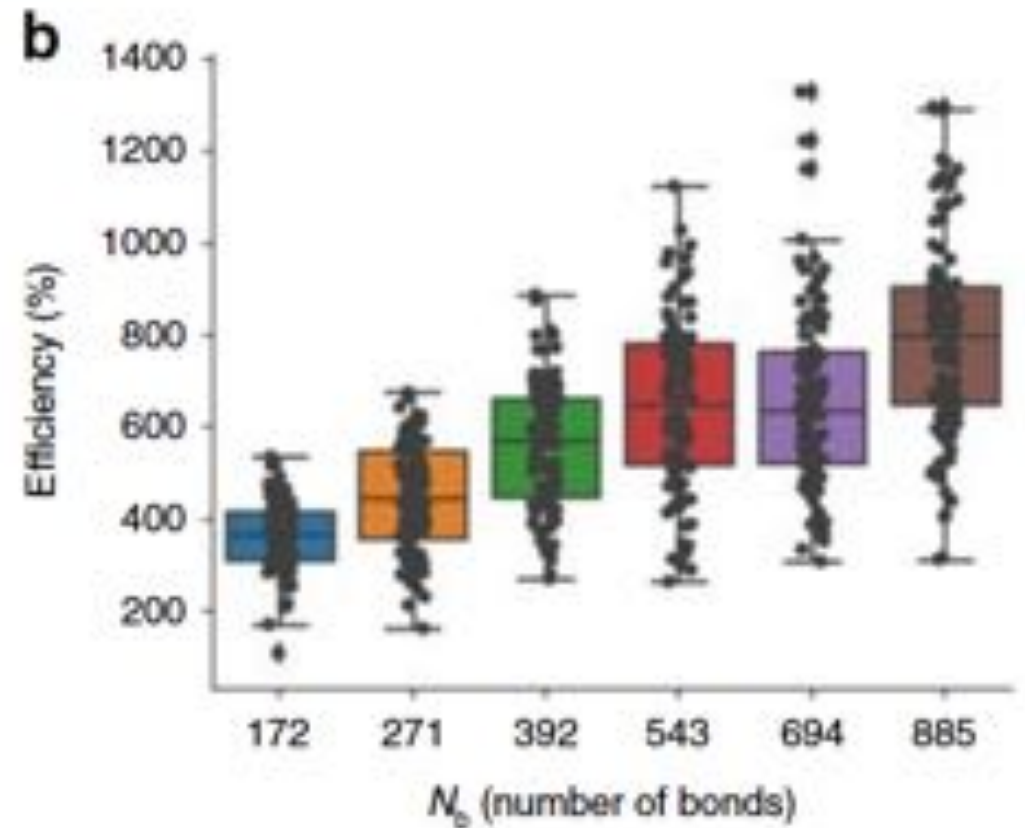
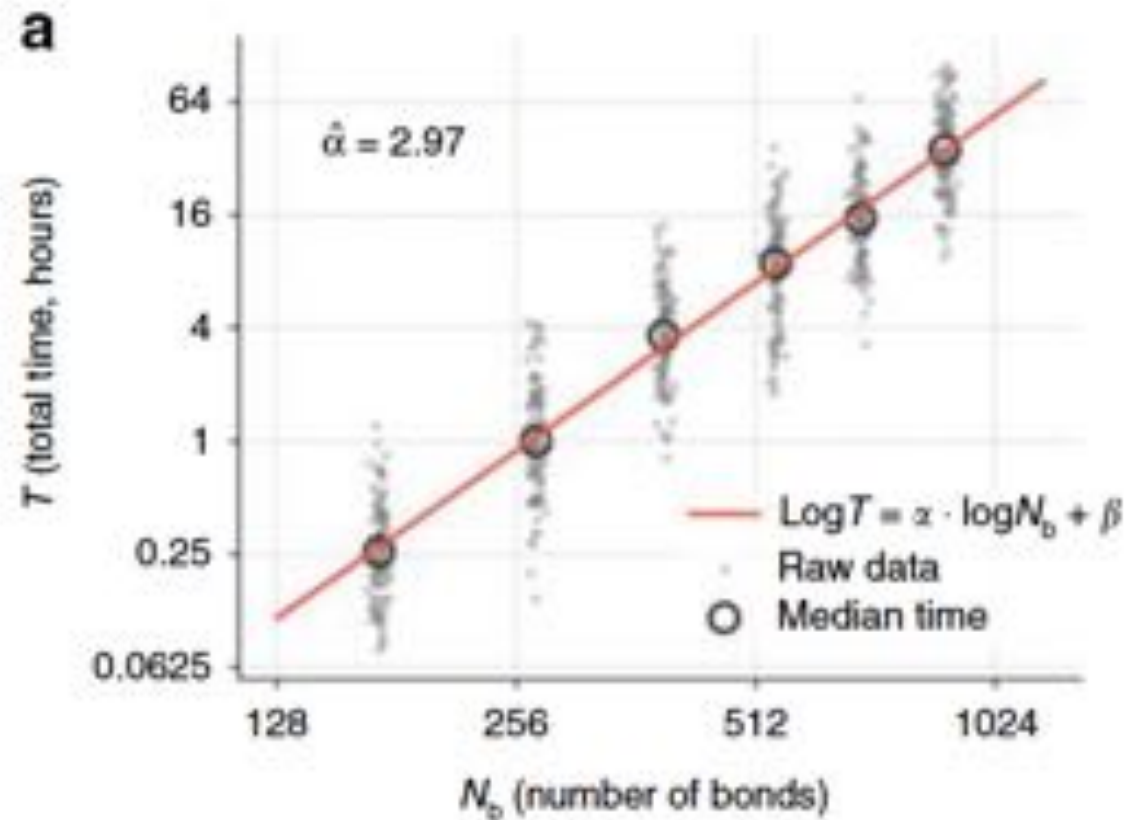
3D PRINTING



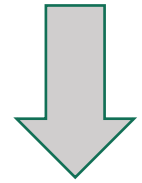
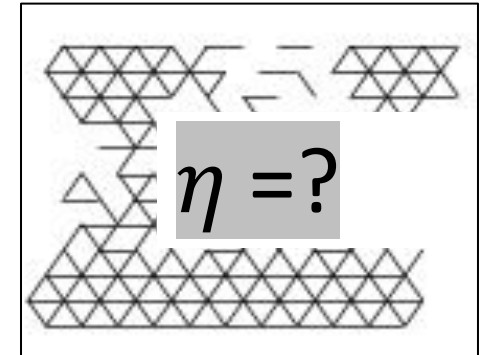
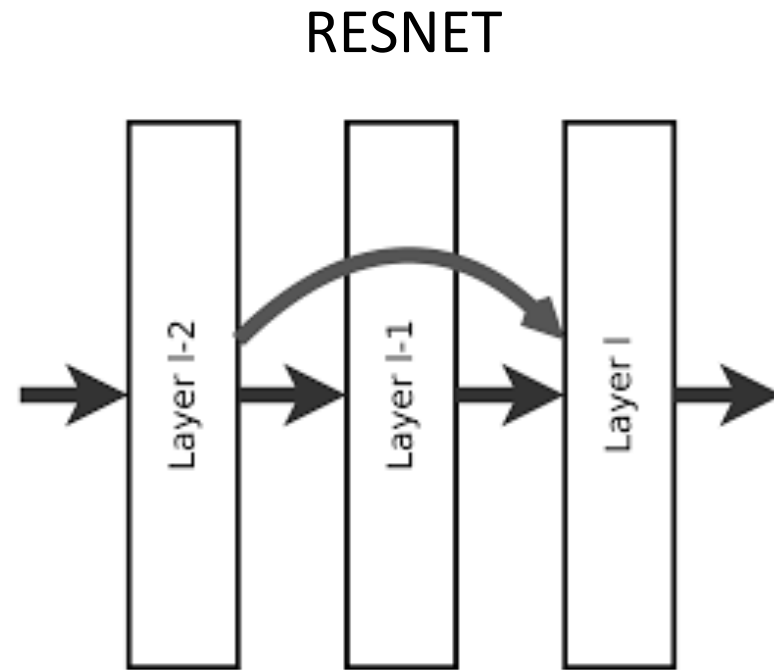
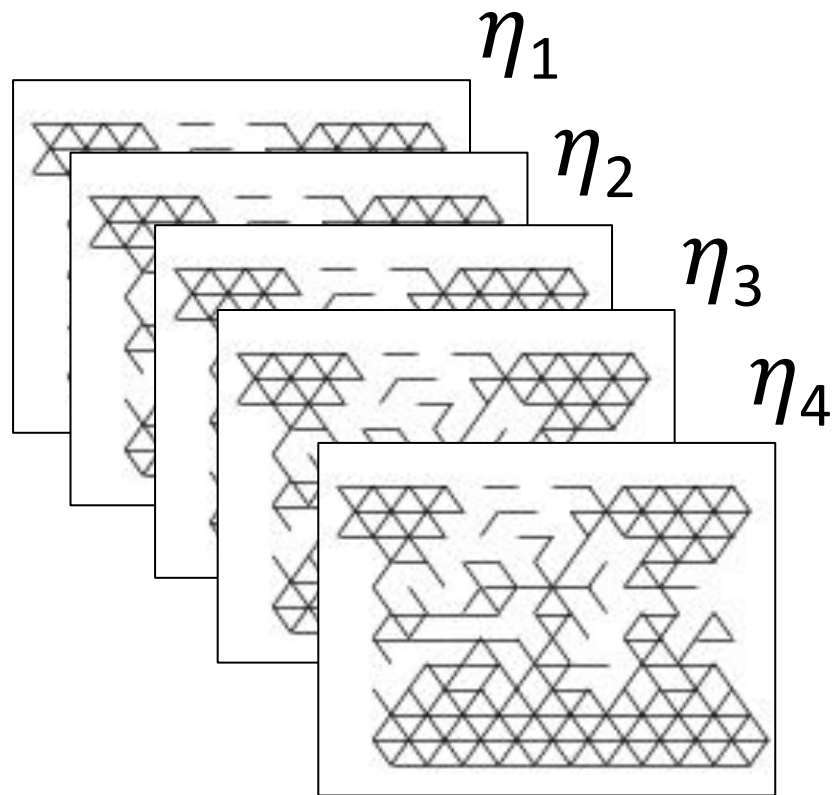
HUMAN vs MACHINE



ALGORITHMIC SCALING

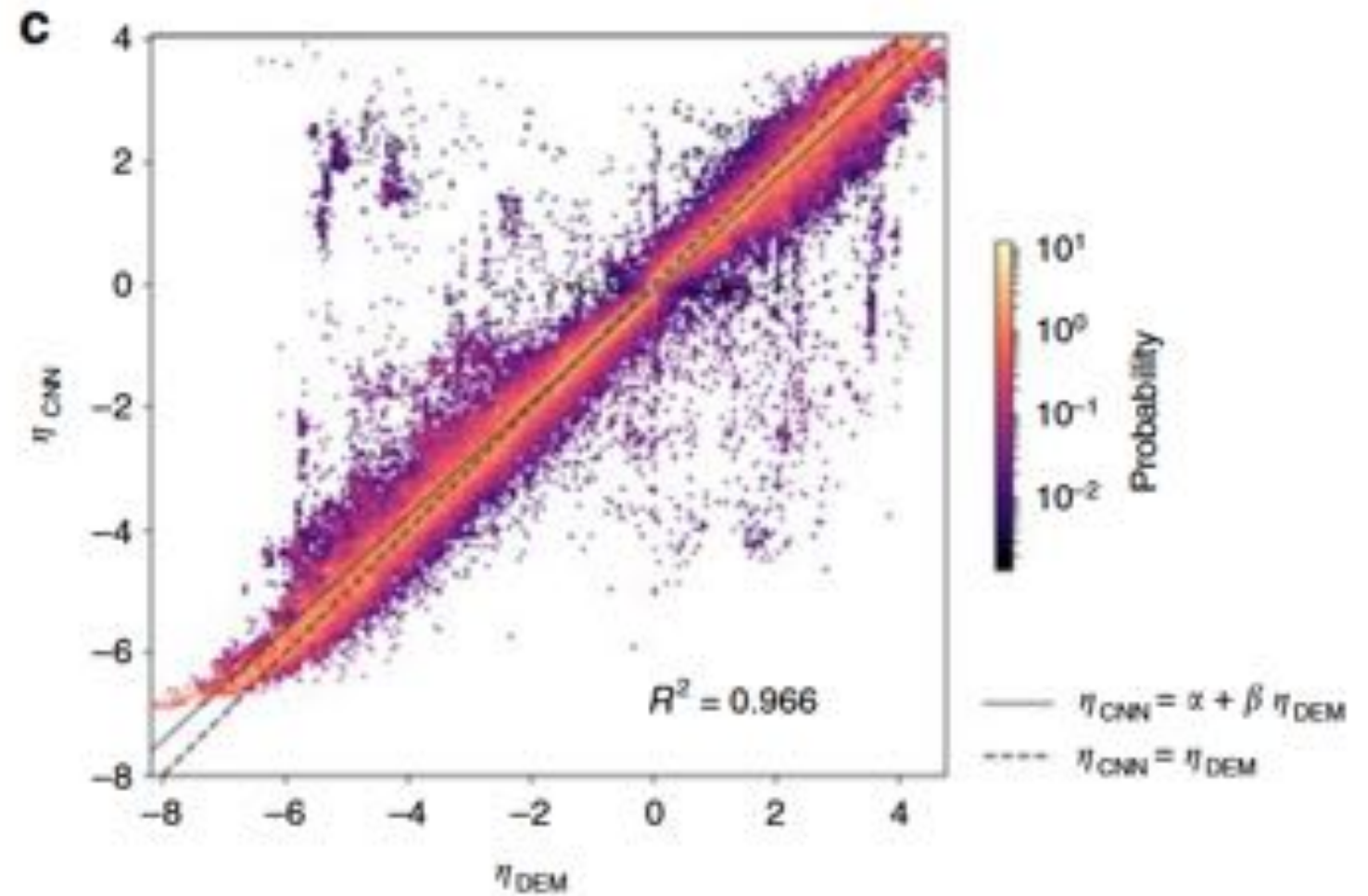
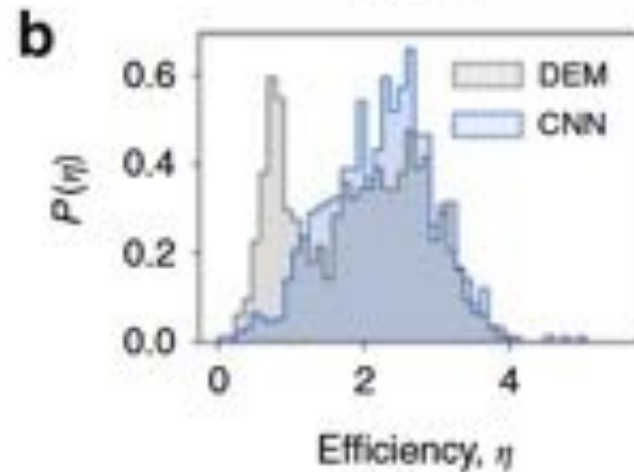
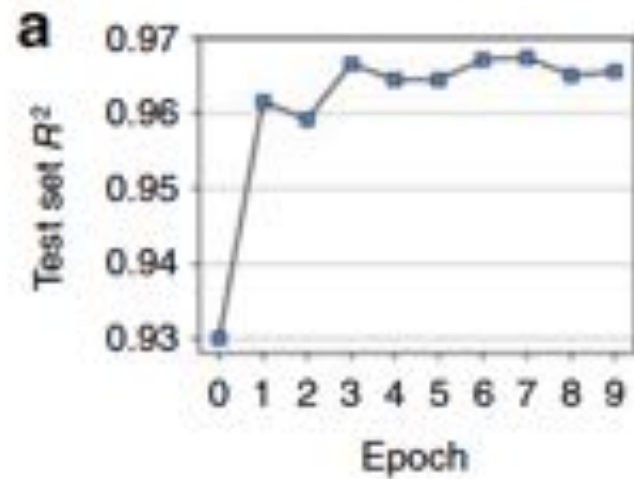


AI ACCELERATED DESIGN



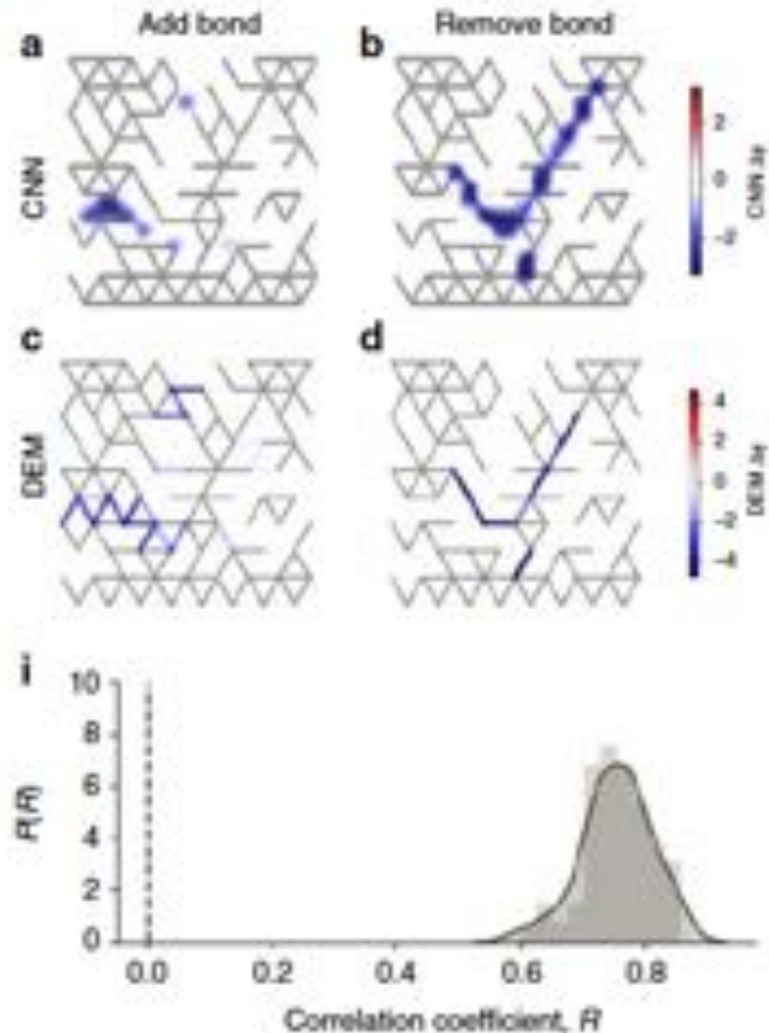
Predict efficiency
from images

PERFORMANCE PREDICTION BY NEURAL NETWORK

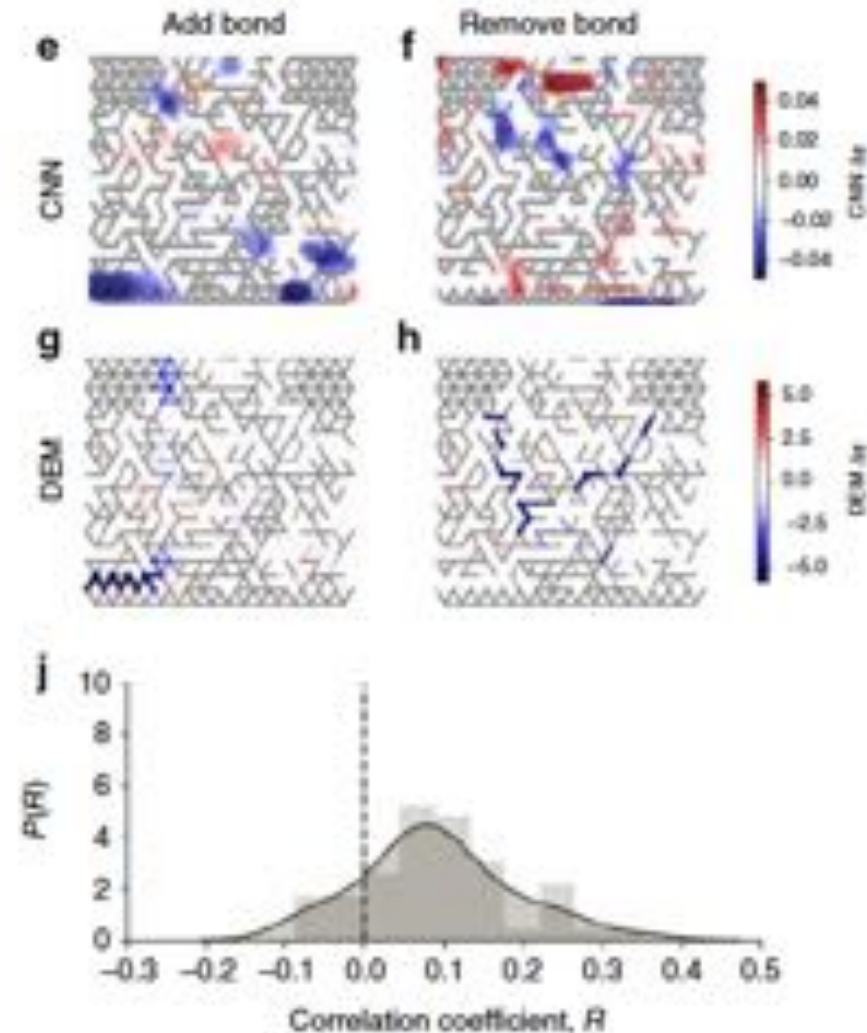


MOVE EVALUATION BY **NEURAL NETWORK**

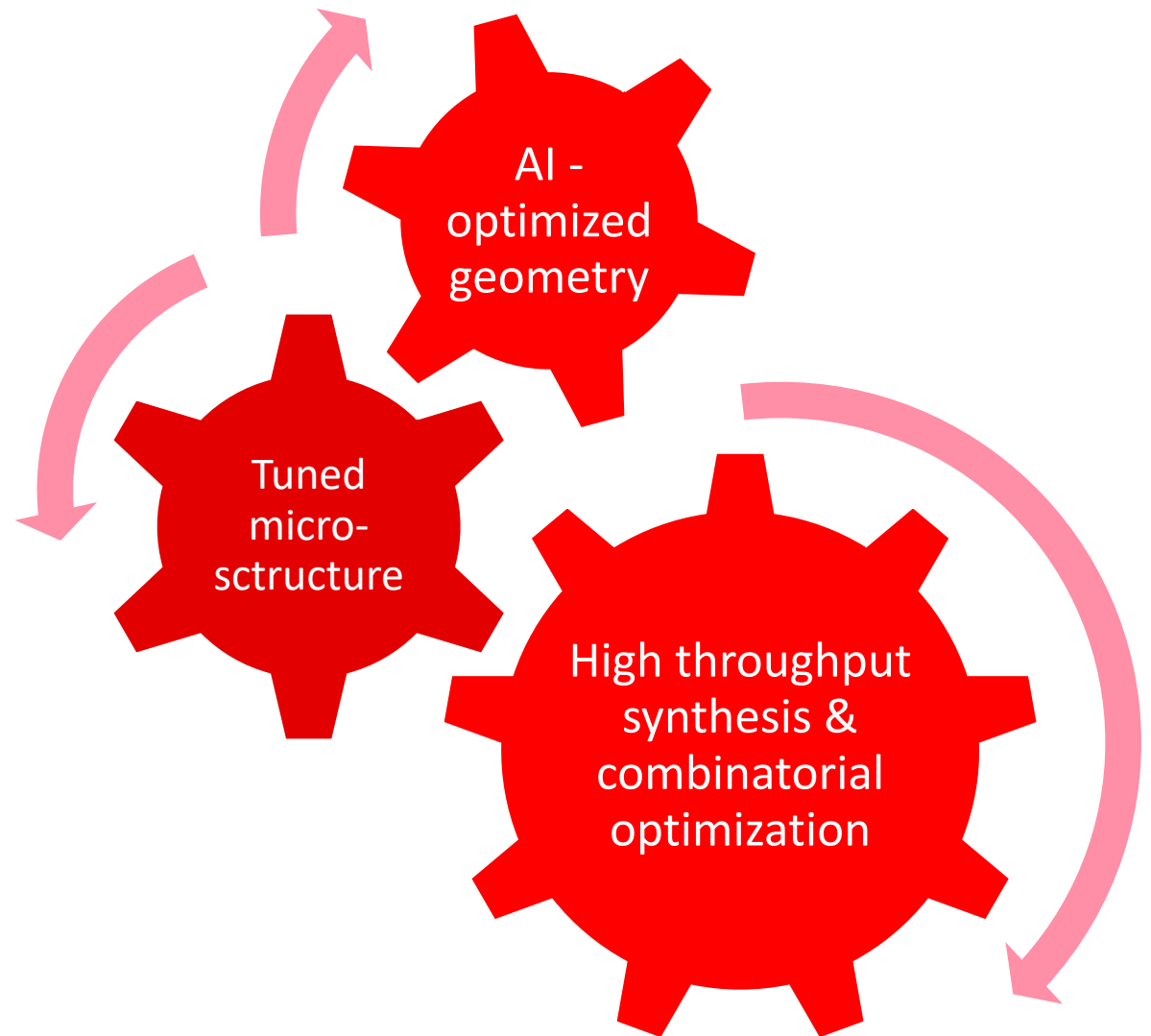
ORIGINAL SYSTEM



LARGER SYSTEM (TRANSFER LEARNING)



DIGITALLY ASSISTED ADDITIVE MANUFACTURING





◆ FRANCESC FONT-CLOS

Postdoc at
Department of Physics
University of Milan

◆ ROBERTO GUERRA

.....Researcher at.....
Department of Physics
University of Milan

◆ SILVIA BONFANTI

Postdoc at
Department of Physics
University of Milan

◆ LORENZO BERETTA

Master Student at
Department of Physics
University of Milan





THANK YOU

stefano.zapperi@unimi.it
www.smmlab.it
metamech.design