Hierarchical Structure Optimization using Neural Networks

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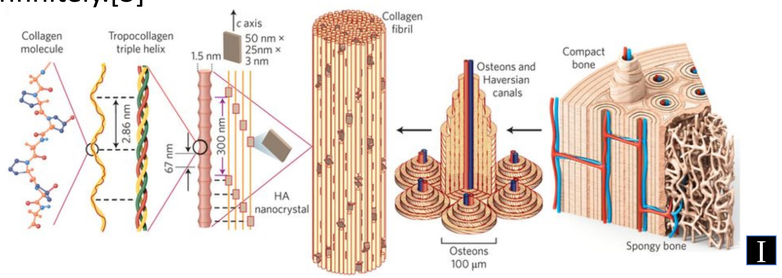
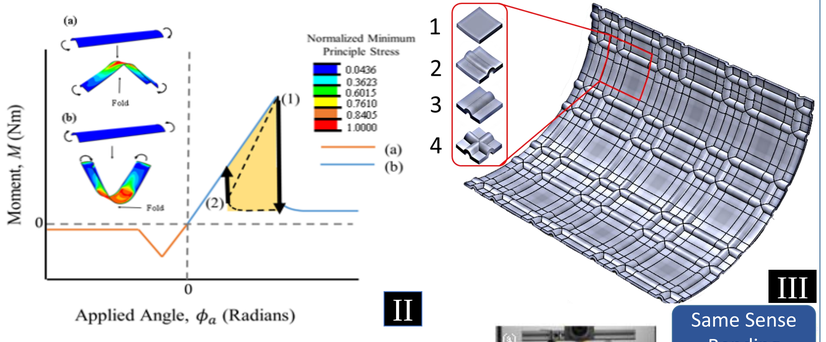
Background and Motivation

Neural Networks are algorithms that can discern patterns in complex systems. This research investigates their utility in the design of hierarchical materials, whose design space can vary infinitely.[3]



(I) Hierarchical materials predominantly found in nature are made of simple constituents built on top of one another which collectively, in this case, make up the structure of a bone.

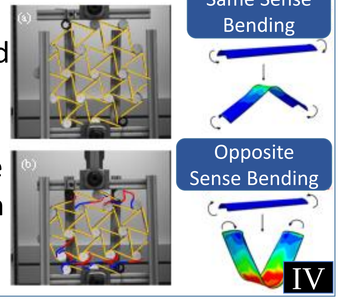
Focus: The structure to be optimized is a tape spring ligament capable of energy dissipation and snap-through instability regardless of the sense of the bending. (II)



II

III

A neural network can be used to find patterns composed of the 4 unique unit cells shown above(III) to produce tapes that can dissipate the most energy, to be then placed in an architectured material(IV).



Same Sense Bending

Opposite Sense Bending

IV

Methodology

IDENTIFY CONSTITUENTS AND MECHANICAL PROPERTIES OF STRUCTURE

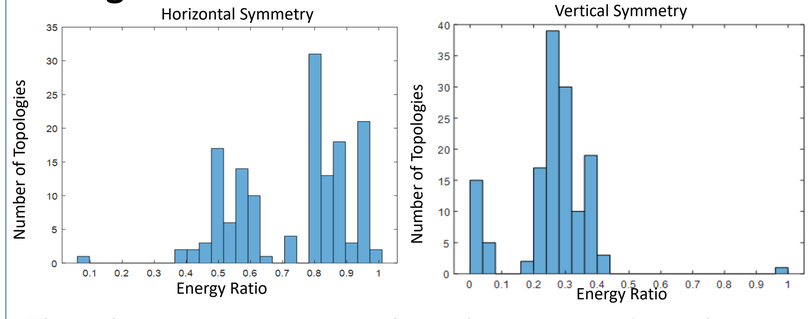
GENERATE UNIQUE TOPOLOGIES USING A BRUTE FORCE ALGORITHM[6]

CREATE AND RUN THE FINITE ELEMENT SIMULATIONS TO OBTAIN THE MATERIAL PROPERITES

TRAIN THE NEURAL NETWORK USING DIFFERENT BATCHES OF DATA

USE THE NEURAL NETWORK TO OBTAIN THE TOP PERFORMING TOPOLOGIES

Histogram:



These histograms represent how the generated topologies are distributed based on the energy dissipated(normalized)

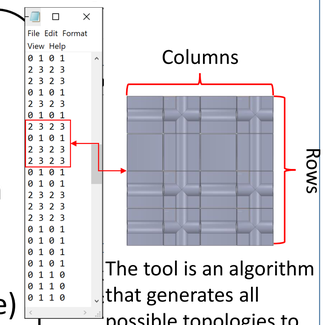
NanoHUB tool: Hierarchical Material Optimization

Inputs:

- Structure dimensions (Rows & Columns)
- Constituent images

Outputs:

- Text files containing matrix representation of all topologies. (Downloadable)
- Total number of topologies.



The tool is an algorithm that generates all possible topologies to help with data variety.

Future Work

- Manufacture optimal tape spring ligaments via stamping.
- Integrate parts to a Phase Transforming Cellular Material (PXCM). (V)
- Introduce data to the neural network for training.

V

(V) A single PXCM cell with a tape spring ligament as a constituent.

Acknowledgements and References

[1]Ulrike G. K. Wegst, Hao Bai, Eduardo Saiz, Antoni P. Tomsia & Robert O. Ritchie. “Bioinspired structural materials”
[2]Kristiaan W. Hector, et al. “Mechanics of Chiral Honeycomb Architectures with Phase Transformations”
[3]Markus J. Buehler, et al. “De novo composite design based on machine learning algorithm” & “Bioinspired hierarchical composite design using machine learning: simulation, additive manufacturing, and experiment.”
[4]K.A Seffen, S. Pellegrino. ”Deployment dynamics of tape springs”
[5]General Motors
[6]Dr. Pablo Zavattieri
[7]Sam B. Benemerito
[8]Hierarchical Material Optimization @ nanoHUB.com

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