



Virtual Evolution of 2D Soft Robots

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- Project scope

Overview

- Project scope
- Background

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- Methodology

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- Results and Conclusions

Project Scope

- Automate design of shape-changing soft robots

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- Automate design of shape-changing soft robots
 - Change internal pressure

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Project Scope

- Automate design of shape-changing soft robots
 - Change internal pressure
- Non-linear FEM
 - Restricted to two dimensions
 - Modelled with real material properties

Project Scope (cont.)

- Computationally efficient

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 - Use recursive grammatical encodings

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 - L-systems for cellular level

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 - L-systems for cellular level
 - CPPNs for organism level

Project Scope (cont.)

- Computationally efficient
 - Use recursive grammatical encodings
 - L-systems for cellular level
 - CPPNs for organism level
- Evolve a population to obtain best model

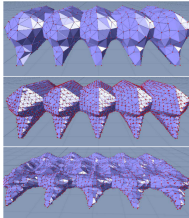
Background

- Soft robotics

- Soft robotics
 - Modelling and evolving soft bodies is computationally expensive

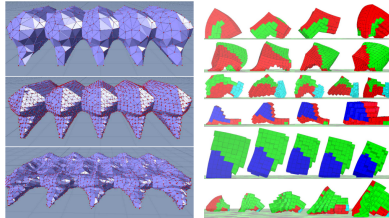
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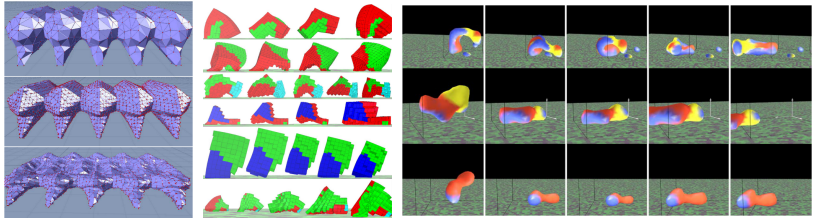
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Background (cont.)

- Lindenmayer systems (L-systems)

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 - Recursive grammatical encodings

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 - Built from axiom, variables, constants and rules

Background (cont.)

- Lindenmayer systems (L-systems)
 - Recursive grammatical encodings
 - Built from axiom, variables, constants and rules



a
 $n=5, \delta=25.7^\circ$
 F
 $F \rightarrow F[+F]F[-F]F$



b
 $n=5, \delta=20^\circ$
 F
 $F \rightarrow F[+F]F[-F][F]$



c
 $n=4, \delta=22.5^\circ$
 F
 $F \rightarrow FF[-F+FF]+$
 $[+F-F-F]$

Background (cont.)

- Compositional Pattern-Producing Network - NeuroEvolution of Augmenting Technologies (CPPN-NEAT)

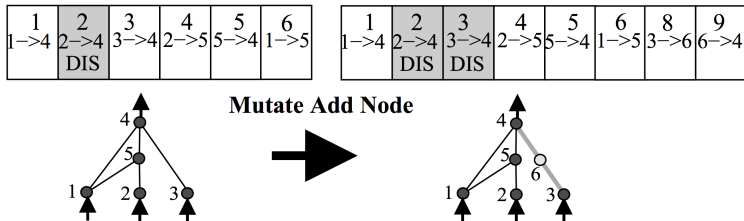
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 - Neural networks

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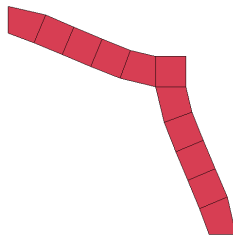
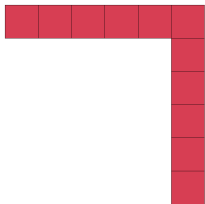


- LSDyna

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 - Commercial software
 - Support

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 - High level of control
 - Robust

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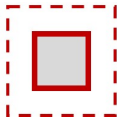
- Unit cell

- Unit cell
 - Square

- Unit cell
 - Square
 - Modelled with Mold Star 15

Basic Structure

- Unit cell
 - Square
 - Modelled with Mold Star 15
 - Predefined behaviours



Basic Structure (cont.)

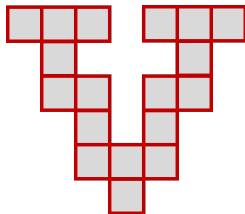
- Complete soft body

Basic Structure (cont.)

- Complete soft body
 - Constructed from unit cells

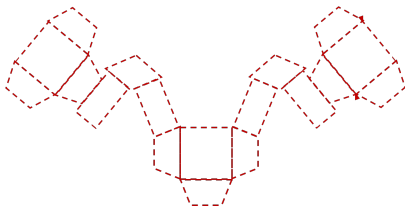
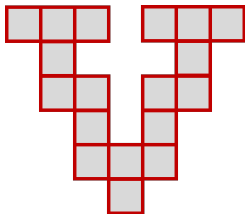
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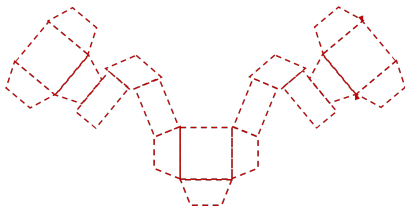
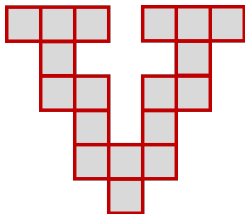
Basic Structure (cont.)

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Basic Structure (cont.)

- Complete soft body
 - Constructed from unit cells
 - Recursive grammatical encodings



Recursive Encodings

- L-systems

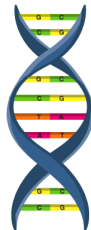
Recursive Encodings

- L-systems
 - Refer to unit cells

Recursive Encodings

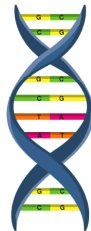
- L-systems
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- L-systems
 - Refer to unit cells
 - Construct soft body
 - Genotype



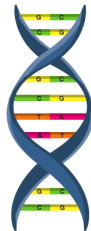
Recursive Encodings

- L-systems
 - Refer to unit cells
 - Construct soft body
 - Genotype
- CPPN-NEAT



Recursive Encodings

- L-systems
 - Refer to unit cells
 - Construct soft body
 - Genotype
- CPPN-NEAT
 - Refer to whole body



Recursive Encodings

- L-systems
 - Refer to unit cells
 - Construct soft body
 - Genotype
- CPPN-NEAT
 - Refer to whole body
 - Phenotype



Proof of Concept

- Use material properties obtained from testing



Proof of Concept

- Use material properties obtained from testing
- Manufacture physical model



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- Manufacture physical model
 - Unit cell and whole body



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 - Unit cell and whole body
 - Produce at some thickness



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- Use material properties obtained from testing
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 - Place between glass plates



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Proof of Concept

- Use material properties obtained from testing
- Manufacture physical model
 - Unit cell and whole body
 - Produce at some thickness
 - Place between glass plates
 - Apply internal pressure
 - Observe behaviour



Results and Conclusions

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 - 3D

Results and Conclusions

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- Replicable
- Adaptable
 - 3D
 - Different objective functions

Questions?