Virtual Evolution of 2D Soft Robots

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Overview

- Project scope

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- 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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- Non-linear FEM

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  - Restricted to two dimensions

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

Project Scope (cont.)

- Computationally efficient
  - 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

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  - Modelling and evolving soft bodies is computationally expensive

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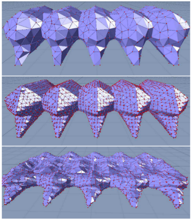

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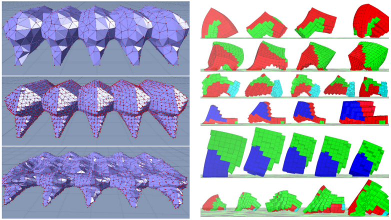
  - Modelling and evolving soft bodies is computationally expensive



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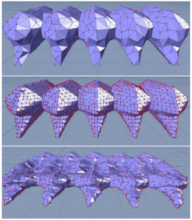
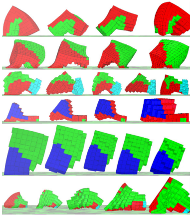
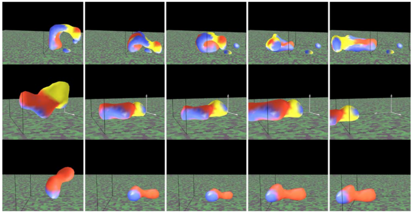

Background (cont.)

- Lindenmayer systems (L-systems)

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  - Built from axiom, variables, constants and rules

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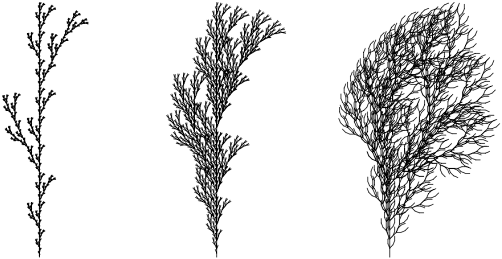

a
n=5, δ=25.7°
F
F → F[+F]F[-F]F

b
n=5, δ=20°
F
F → F[+F]F[-F][F]

c
n=4, δ=22.5°
F
F → FF-[-F+F+F]+
[+F-F-F]

Background (cont.)

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

Background (cont.)

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  - Neural networks

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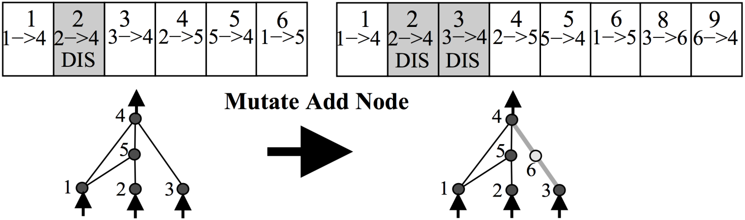

Software

- LSDyna

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- LSDyna
  - Commercial software
  - Support

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  - High level of control
  - Robust

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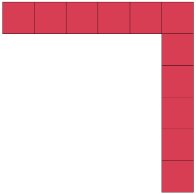

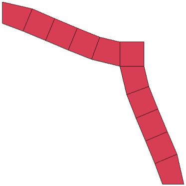

Basic Structure

- Unit cell

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- Unit cell
  - Square

Basic Structure

- Unit cell
  - Square
  - Modelled with Mold Star 15

Basic Structure

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  - Predefined behaviours

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- Complete soft body
  - Constructed from unit cells

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  - Recursive grammatical encodings

Recursive Encodings

- L-systems

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  - Refer to unit cells

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- CPPN-NEAT

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  - 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

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- Manufacture physical model

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- Use material properties obtained from testing
- Manufacture physical model
  - Unit cell and whole body
  - Produce at some thickness

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

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- Use material properties obtained from testing
- Manufacture physical model
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  - Place between glass plates
  - Apply internal pressure

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

- Improve computing time required

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- Prove practicality of recursive encodings

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- Adaptable
  - 3D
  - Different objective functions

Questions?