Morphogenic Shape Grammars for the Design of Engineering Structures

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AIMS

1: *To test the hypothesis that morphogen gradients can lay out engineering structures via an augmented shape grammar.*

2: *To encode the representation in an evolutionary algorithm to configure a search over multiple fitness objectives.*

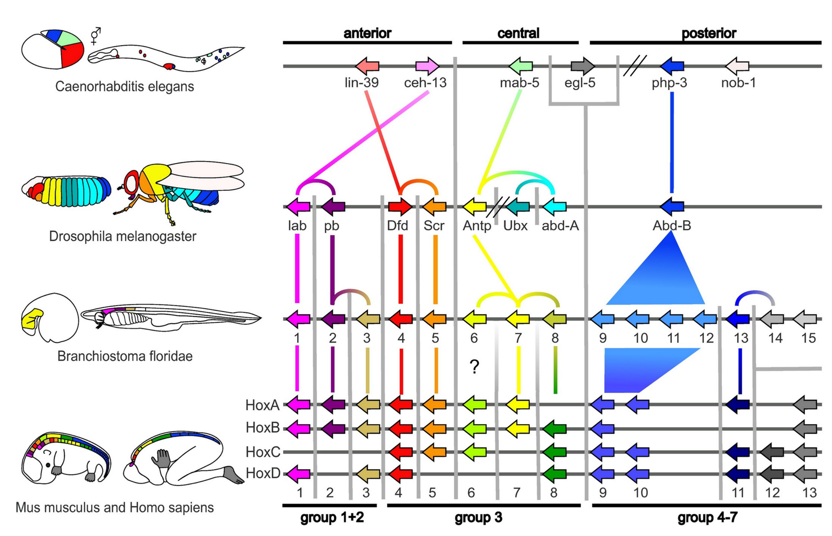
3: *...and so to generate a diverse set of solutions to engineering design challenges*

1: Introduction

Morphogenesis is the process by which the growth of an organism is controlled and is akin to the systems architecting phase in design.

A new class of **shape grammar** is developed that allows gradients of morphogen agents to be emulated. The complexity of the design problem is managed by exploiting the grammar hierarchy.

NSGA-II is used to explore the expressive power of the grammar for a classic engineering problem, bridge design



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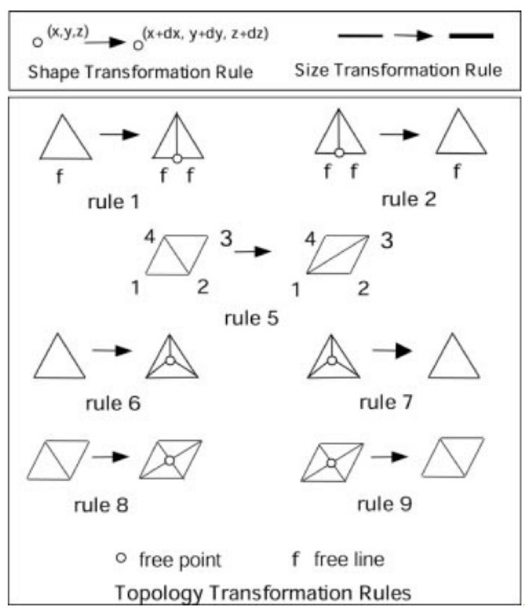
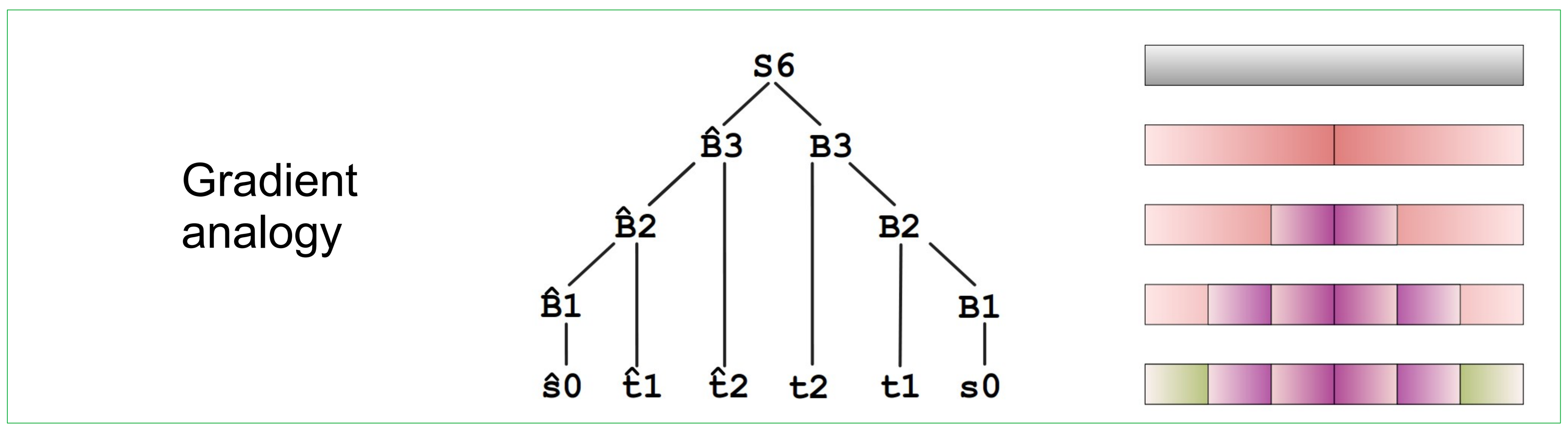
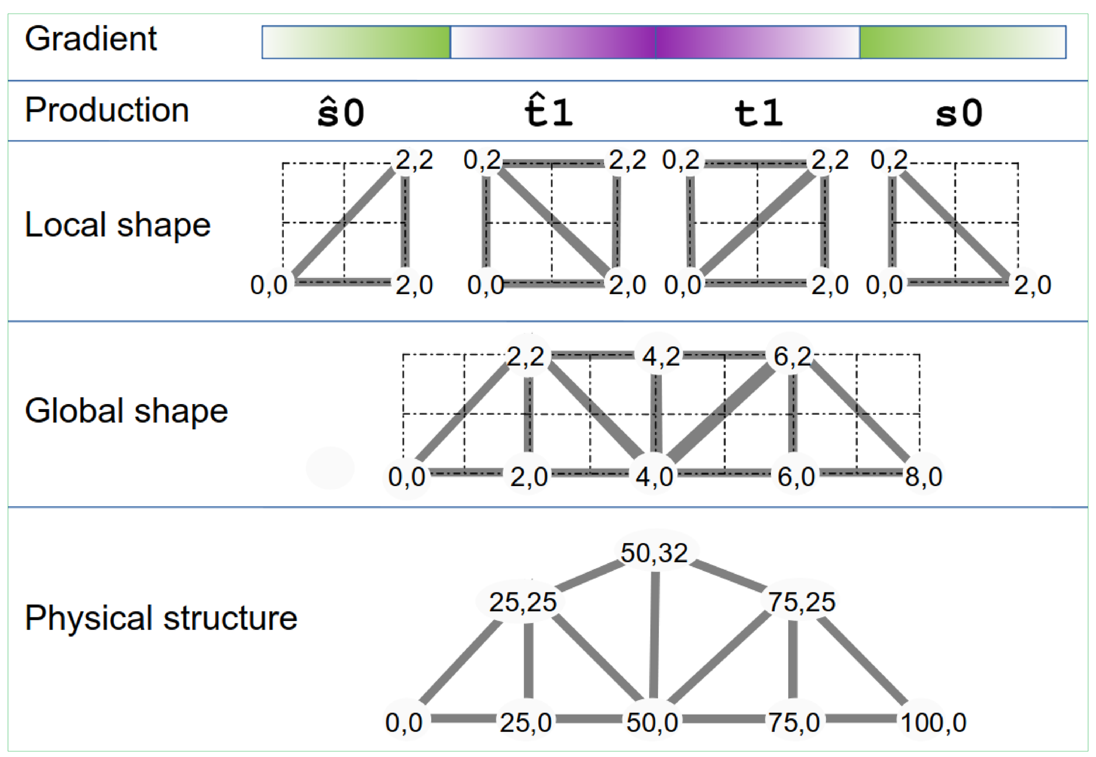


Figure from T. Knight and G. Stiny "Classical and non-classical computation", Arq: architectural research quarterly 5(4), 355-372 (2001)

2: Morphogen Grammars



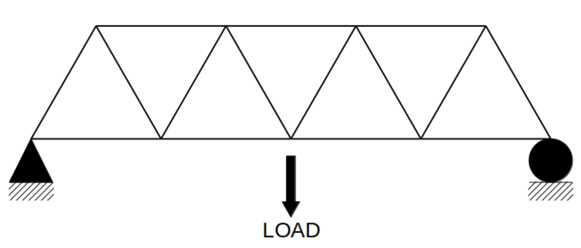


Steps from grammar production to physical structure

Key Idea:
The "body plan" of the structure is laid out before the local arrangement is placed

3: Experiment

The **NSGA-II** algorithm was used to optimise this bridge design:

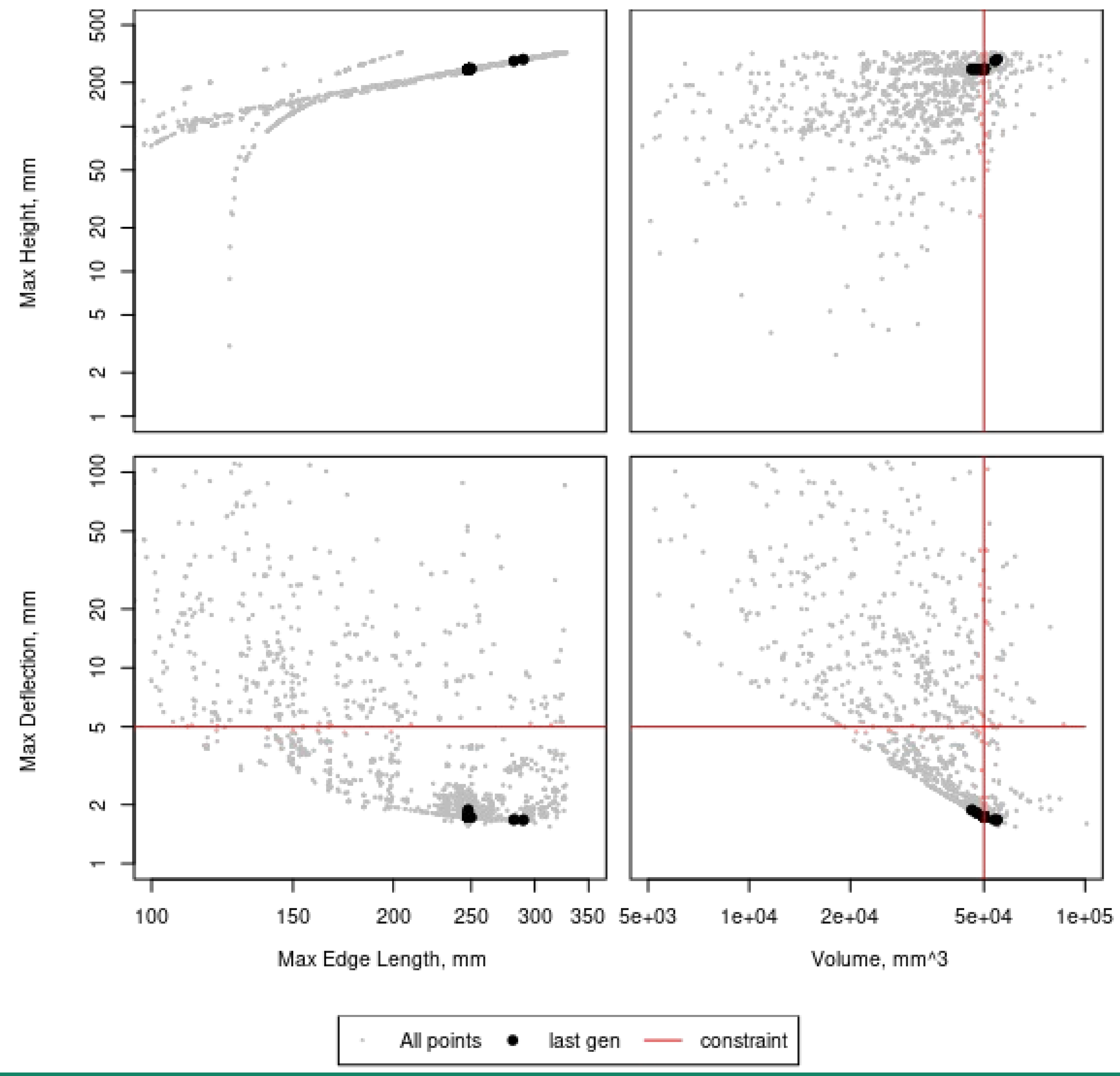


Genes: truss type; number of terminal symbols; vertical growth; member cross-sectional area. **Constraints:** deflection < 5mm; volume < 5e05 mm^3

Objectives to minimise: material volume; load displacement; total height; member length.

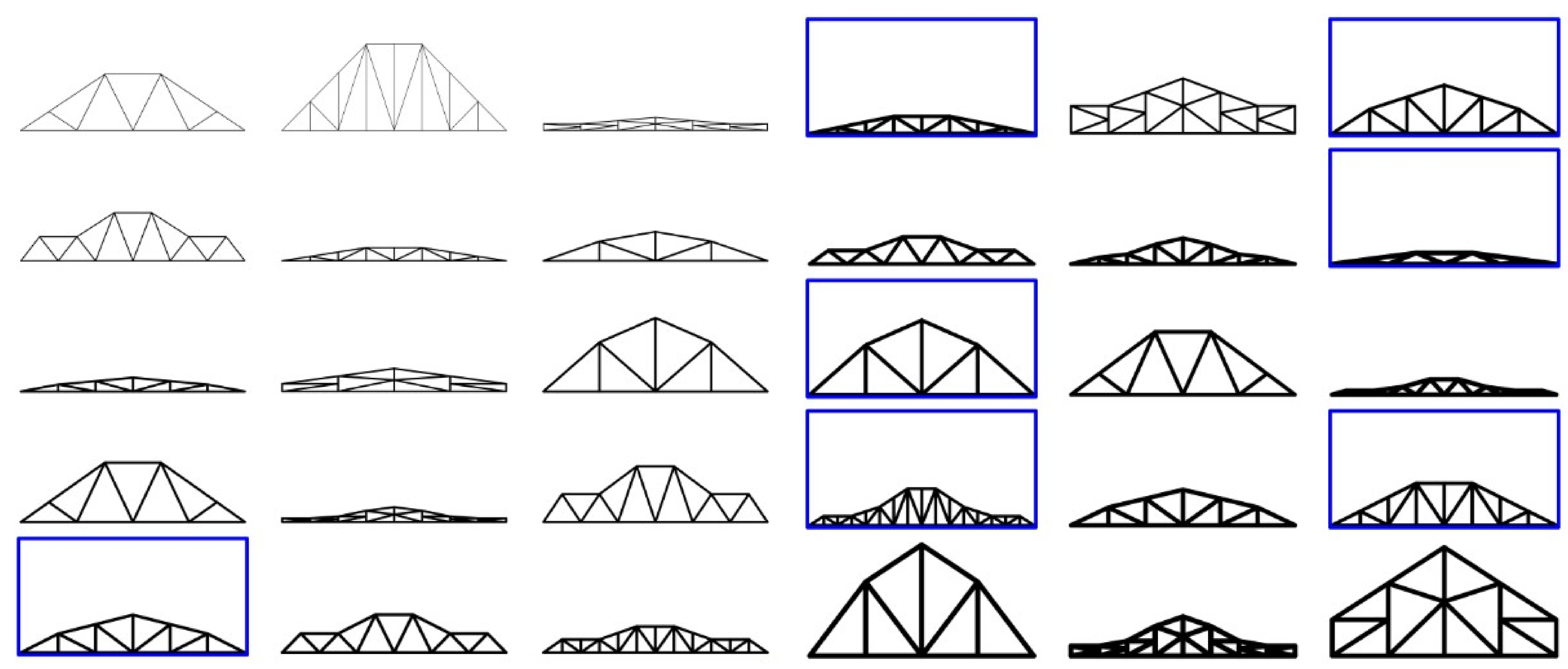
4: Pareto Front

Each individual in the run sits in the four-dimensional fitness landscape as shown below. Constraints on material volume and deflection drive the population to a particular region of the landscape



5: Resulting Structures

Examples of individuals from the pareto front are shown below. Those marked in blue meet the constraints



6: Conclusions

1: *The layout of structures can be achieved by evolution of morphogen grammars*

2: *Grammar attributes that emulate chemical gradients offer a means of handling the complexity of real engineering structures*

3: *This approach allows feedback from FEA simulations to influence the gestalt form of engineering designs*

7: Further Work & References

1: Encode the production rules and shape graphs on a genome and perform an evolutionary search *ab initio*

2: Extend the morphogen gradient model to full 3D; allow more than simple linear gradients

3: Implement behavioural switching via feedback from the environment

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