Truss Optimisation in Grammatical Evolution

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Science Foundation Ireland
For what's next

Housekeeping: What is a truss?

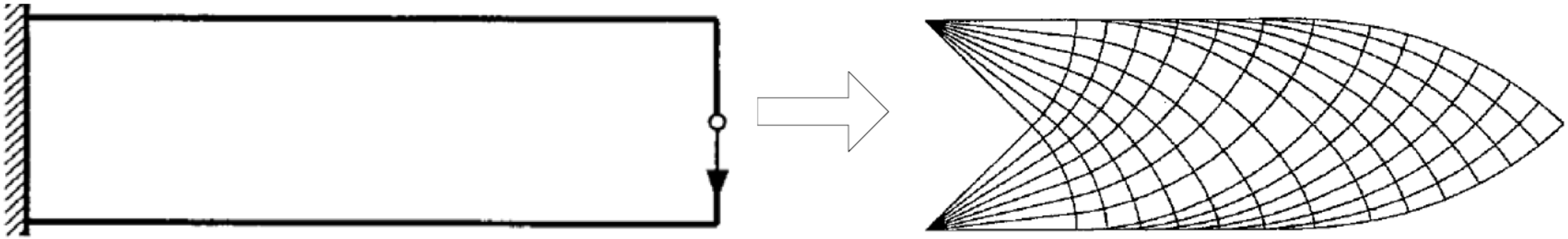
Why is this important?

- Eiffel Tower
  - 7,300 tons
  - Wrought Iron
  - 10% weight saving = 730 tons
- Savings "snowball" and scale down through entire structure
  - Lighter structure needs less support, etc.

Why Human-Competitive?

Theoretical Limitations

- Michell, A.G.M., 1904. LVIII. The limits of economy of material in frame-structures. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 8(47), pp.589-597.



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Traditional Ground Structure

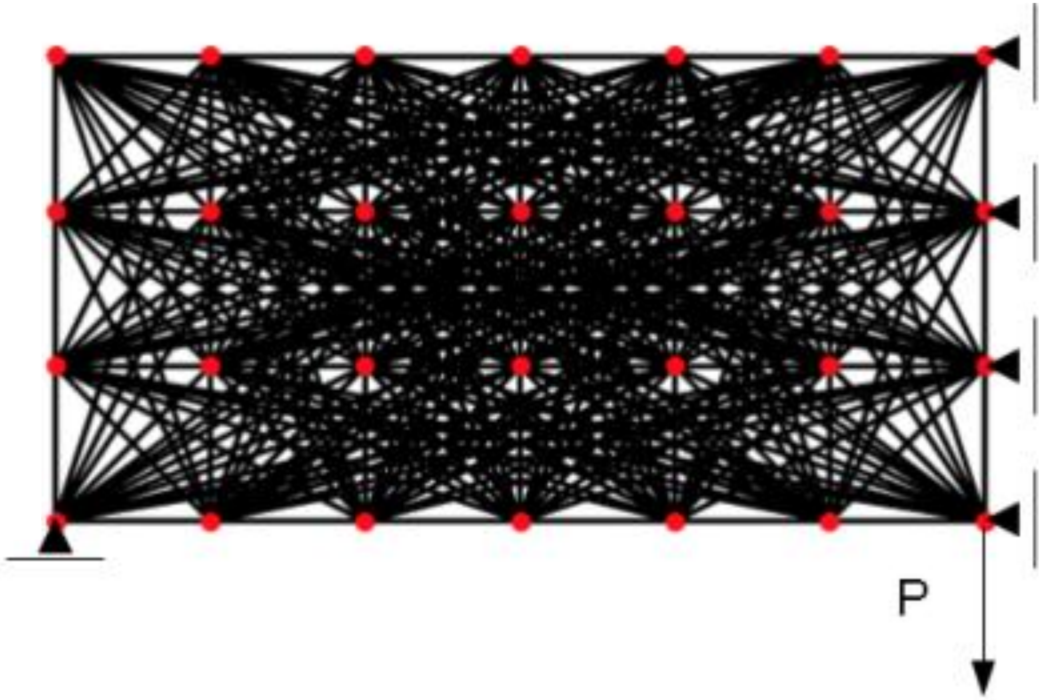
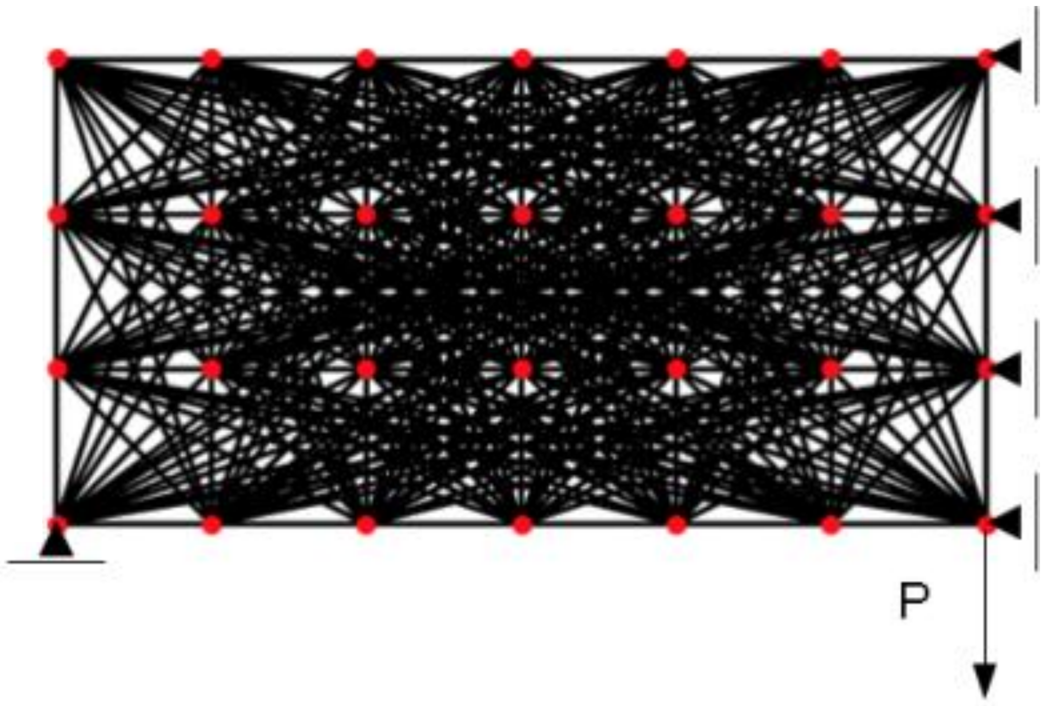


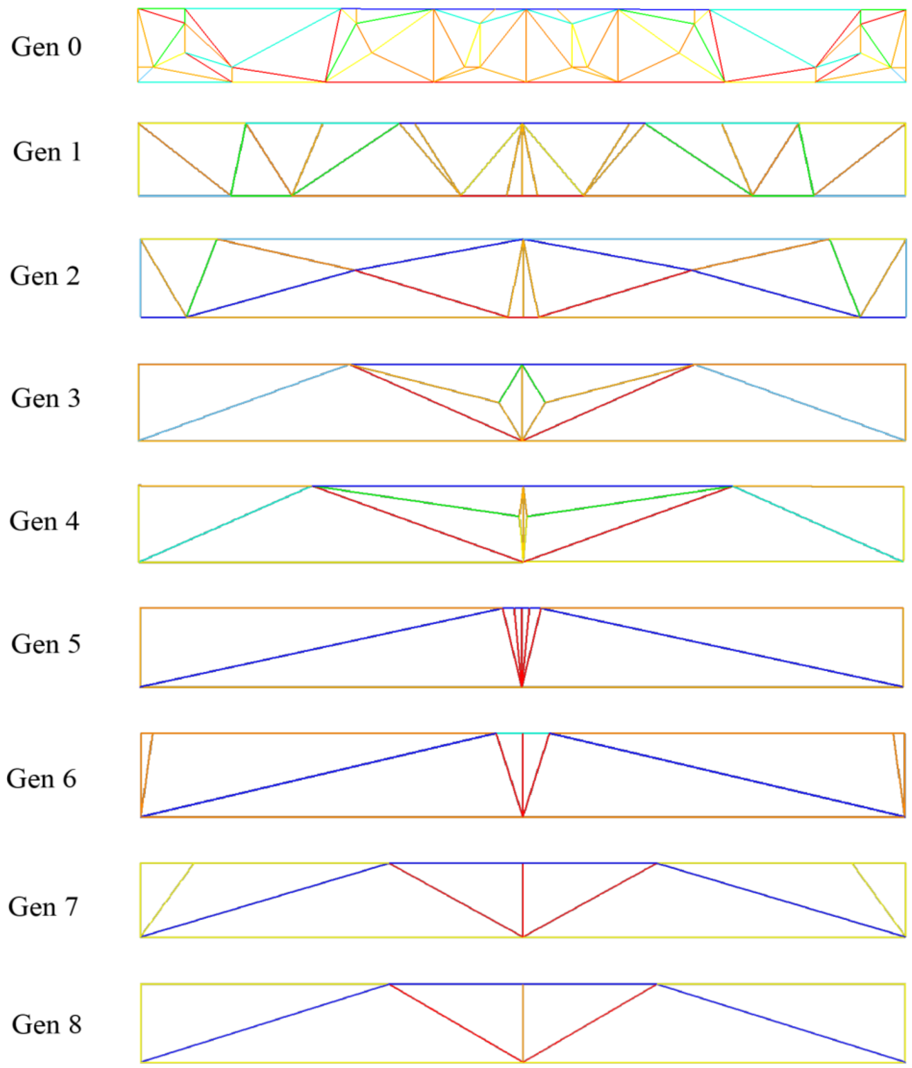
Image credit: [4]

Traditional Ground Structure



Nodes	= n
Connections	c = ((n-1)n)/2
Permutations	= tetrahedral number + number of connections
	= ((c-1)*c*(c+1))/6 + c
	~ O(n^6)

SEOIGE [2]



Blue = Compression
Red = Tension

SEOIGE [2]

Recursive node-based grammar:

```
a         ::= [<nodes>]
<nodes>   ::= <node> | <node>,<nodes>
<node>    ::= [<%>, <%>]
<%>       ::= <n><n>.<n><n>
<n>       ::= 0|1|2|3|4|5|6|7|8|9
```

- $\mathbf{10^{8*(d-2)}}$ unique solutions at depth d

Why Best HUMIES Entrant?

Why Best HUMIES Entrant?

- The methods described in paper [2] represent an entirely new way to generate truss structures, previously unseen in the literature.
- Intelligent, lightweight representation.
  - Use of triangulation: all generated solutions are kinematically stable, and as such are structurally viable (constraints notwithstanding).
- Pinnacle of engineering optimisation after over 100 years of research in the field.
- Real-world application with commercial appeal.
  - Designed with this in mind.
  - Real-world materials and constraints.

Sustainable Development

- Minimizing material usage has a number of benefits:
  - Immediate cost benefit.
  - “Snowball” effect of weight reduction over entire structure.
  - Material minimisation: effect on supply and demand.
    - With an average estimate of 2 tons of CO_2 being emitted for every 1 ton of steel produced [5], any reduction in production has significant environmental implications.

Acknowledgements

This research is based upon works supported by Science Foundation Ireland under grant 13/IA/1850.

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References

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2. Fenton, M., McNally, C., Byrne, J., Hemberg, E., McDermott, J. and O’Neill, M., 2016. Discrete planar truss optimization by node position variation using grammatical evolution. *IEEE Transactions on Evolutionary Computation*, 20(4), pp.577-589.
3. Michell, A.G.M., 1904. LVIII. The limits of economy of material in frame-structures. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 8(47), pp.589-597.
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5. Global CCS Institute, 2013. CCS for iron and steel production. Available online at: *https://www.globalccsinstitute.com/insights/authors/dennisvanpuyvelde/2013/08/23/ccs-iron-and-steel-production*

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