

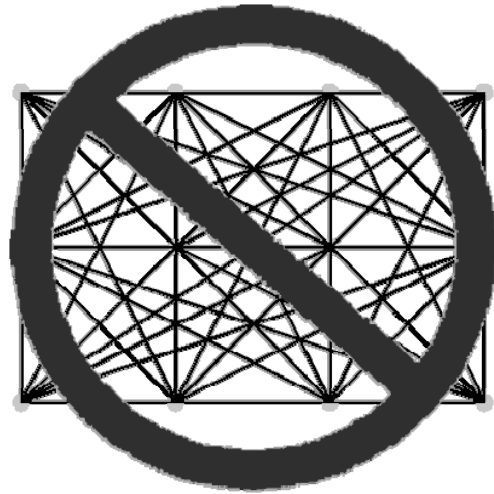
# Using Evolutionary Computation to explore geometry and topology without ground structures

IASS-IACM 2008  
Ithaca, NY USA

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University of Michigan  
TCAUP

30 May 2008

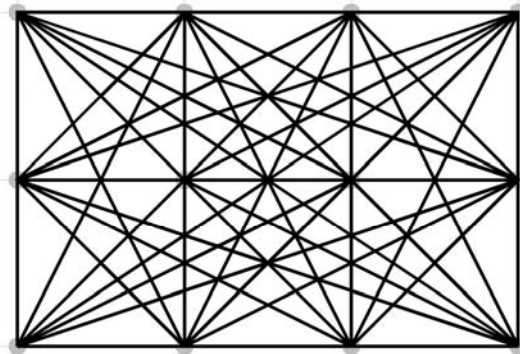


## What are ground structures?

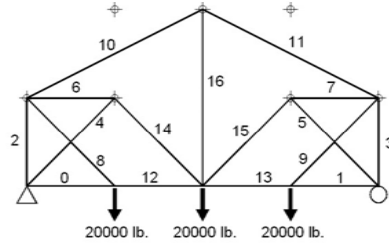
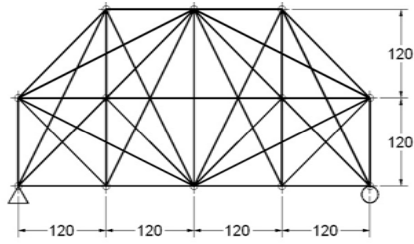
### Definition

A set of all admissible bars  
connecting a set of  
admissible joints.

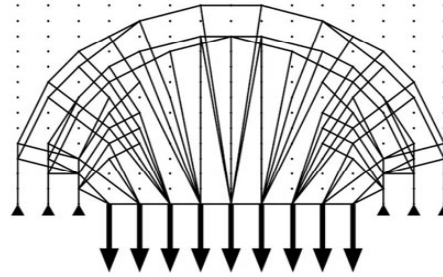
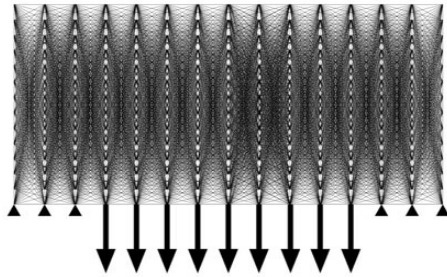
(Dorn, et al. 1964)



# Examples of ground structures



12 nodes and 39 bars (Deb et al., 1999)



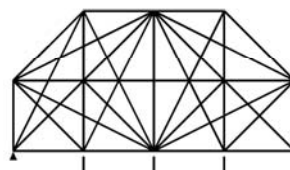
210 nodes and 21945 (max) bars (Klarbring, 1995)

# Effect of ground structure on results with EC

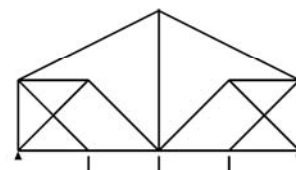
Ground structures have  
2 effects on EC:

## 1. Results

- Resolution
- Geometry
- Topology



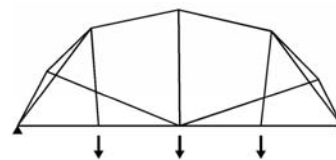
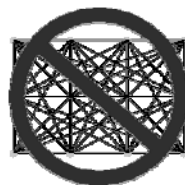
Ground Structure



Final Truss (505 kg)

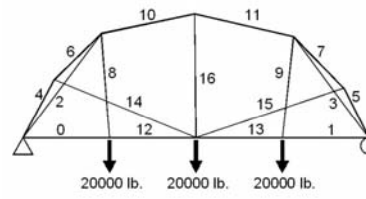
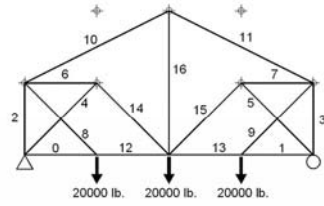
## 2. Computation

- Chromosome
- Population
- Analysis

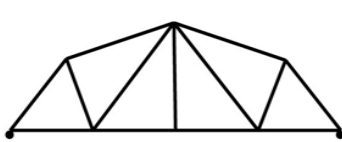


weight = 322 kg

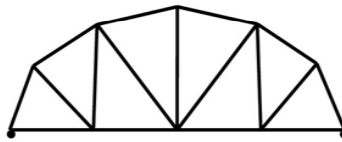
# Effect of ground structure on results



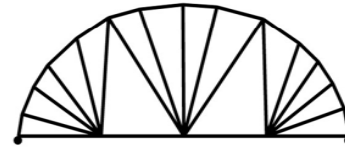
With ground structure (505 kg)      without ground structure (322 kg)



Topo ID: 1  
jnt 8    mbr 13  
weight = 337 kg



Topo ID: 8  
jnt 10   mbr 17  
weight = 281 kg



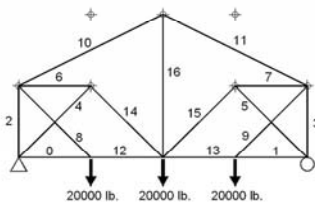
Topo ID: 18  
jnt 18   mbr 33  
weight = 237 kg

Other topologies found without using ground structure

# Effect of ground structure on GA computation

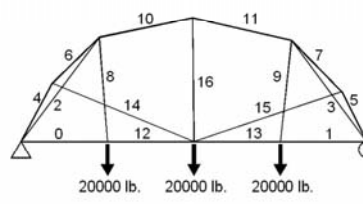
GA computation depends on chromosome string length

Size of ground structure

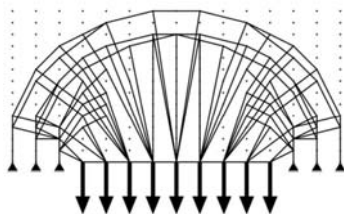


Length = 39 (actually used)

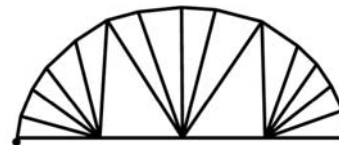
1/2 of the incidence matrix



Length =  $n(n-1)/2 = 45$



Length = 21945 (all possible)

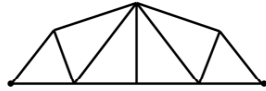


Topo ID: 18  
jnt 18   mbr 33  
Length = 153

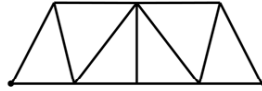
# Distinction of geometry and topology

## definitions

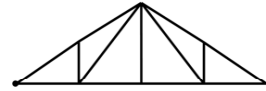
Three Examples of Geometry:



Topo ID: 1  
jnt 8 mbr 13

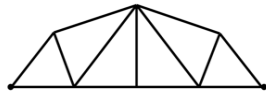


Topo ID: 1  
jnt 8 mbr 13

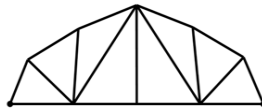


Topo ID: 1  
jnt 8 mbr 13

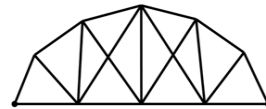
Three Examples of Topology:



Topo ID: 1  
jnt 8 mbr 13



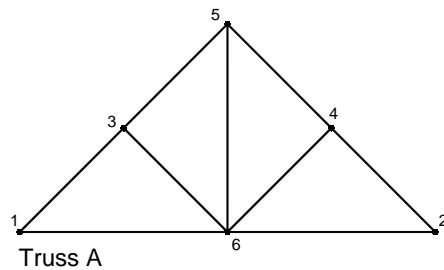
Topo ID: 2  
jnt 10 mbr 17



Topo ID: 3  
jnt 10 mbr 19

# Encoding Topology without ground structure

'binary string' from incidence matrix

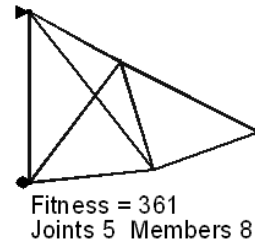
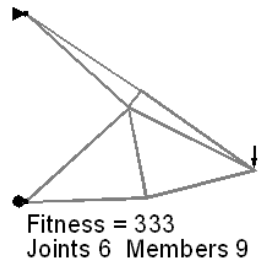


0	0	1	0	0	1
	0	0	1	0	1
		0	0	1	1
			0	1	1
				0	1
					0

[0 1 0 0 1 0 1 0 1 0 1 1 1 1 1]

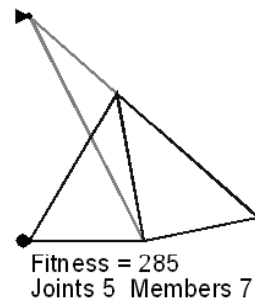
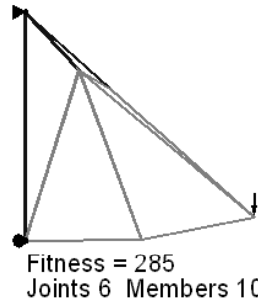
# Breeding Topology

one-point crossover



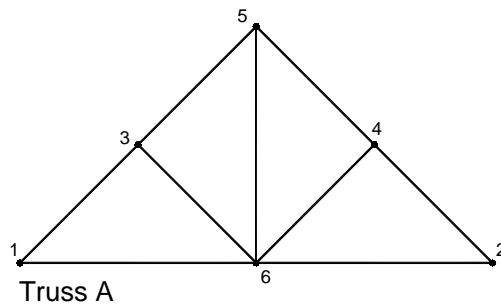
```

00110 | 0101111110 | 10110 | 11111
-----|-----
10110 | 0101111110 | 00110 | 11111
    
```



# Encoding Geometry without ground structure

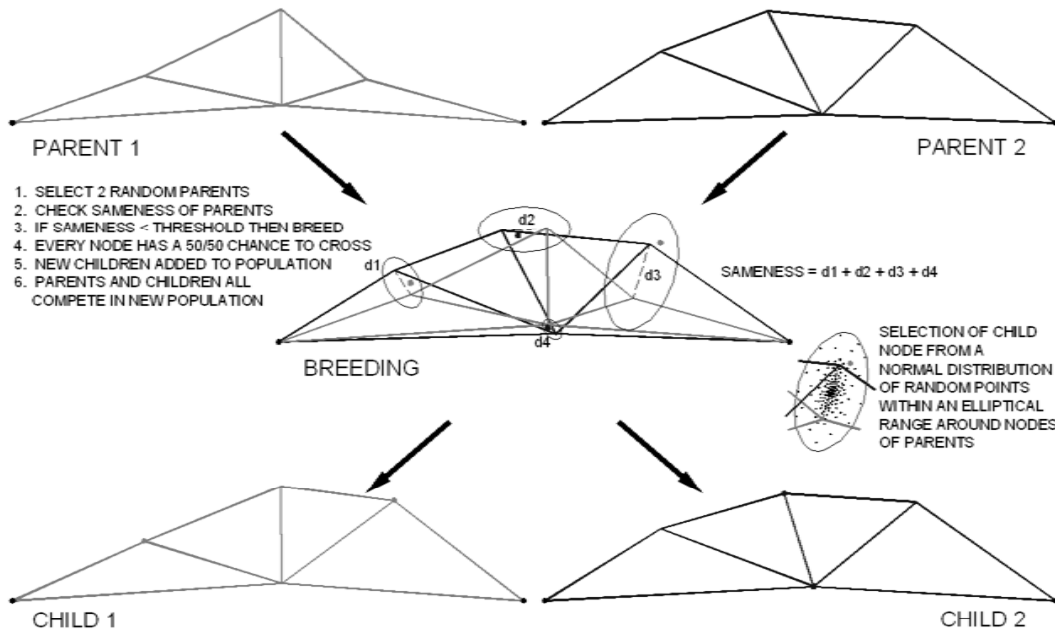
Array of real number nodal coordinates



0.	0.
360.	0.
90.	90.
270.	90.
180.	180.
180.	0.

# Breeding Geometry

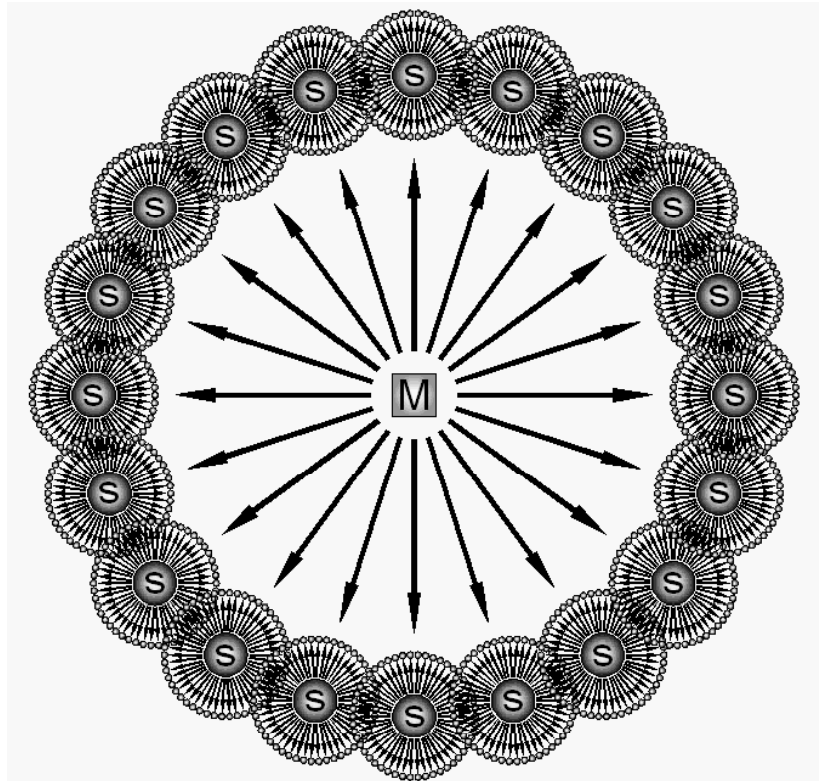
# Half Uniform Crossover breeding



## Procedure

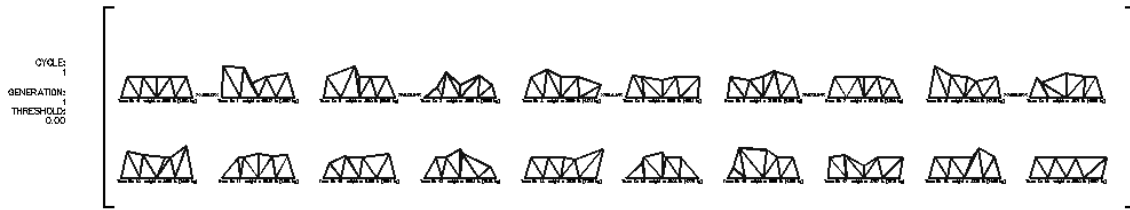
M - the master sends and gathers all topologies

S - each slave finds geometry for each topology



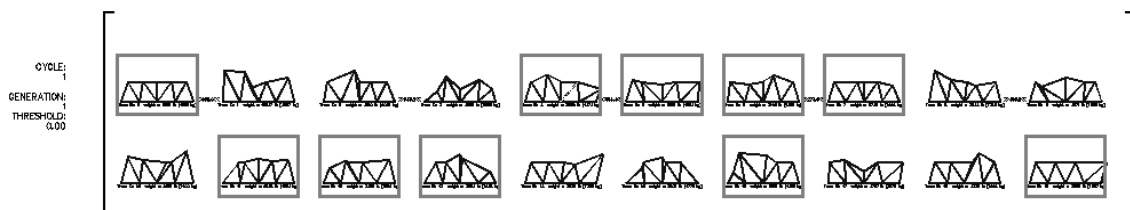
# Geometry Generations

Random start with progenitor



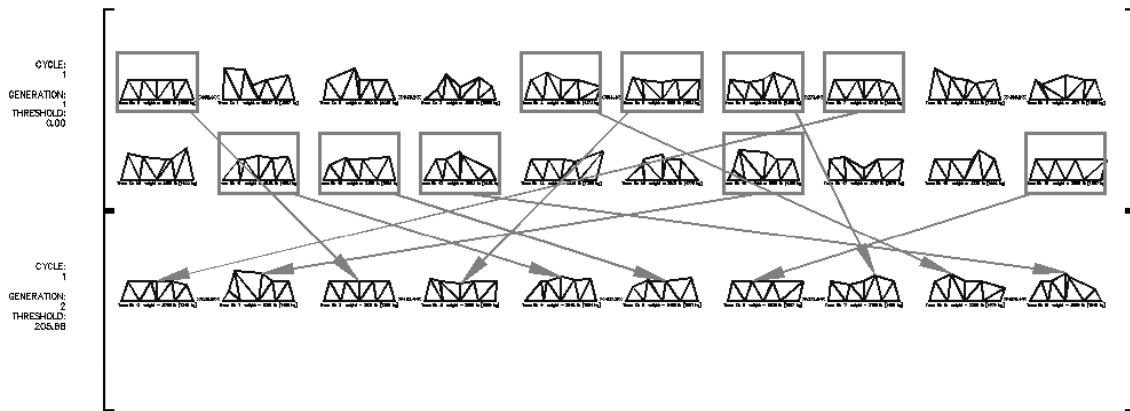
# Geometry Generations

Selection from generation 1



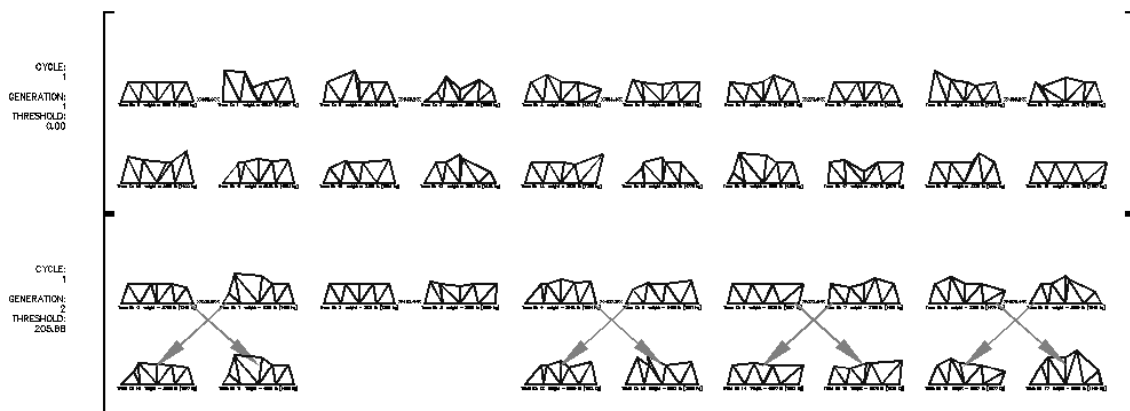
# Geometry Generations

Setup parents for generation 2



# Geometry Generations

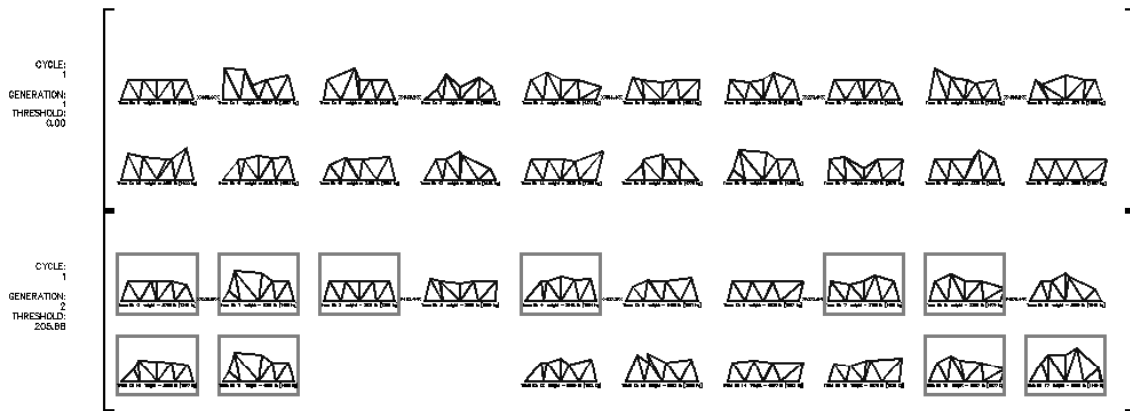
Breed parents to fill generation 2





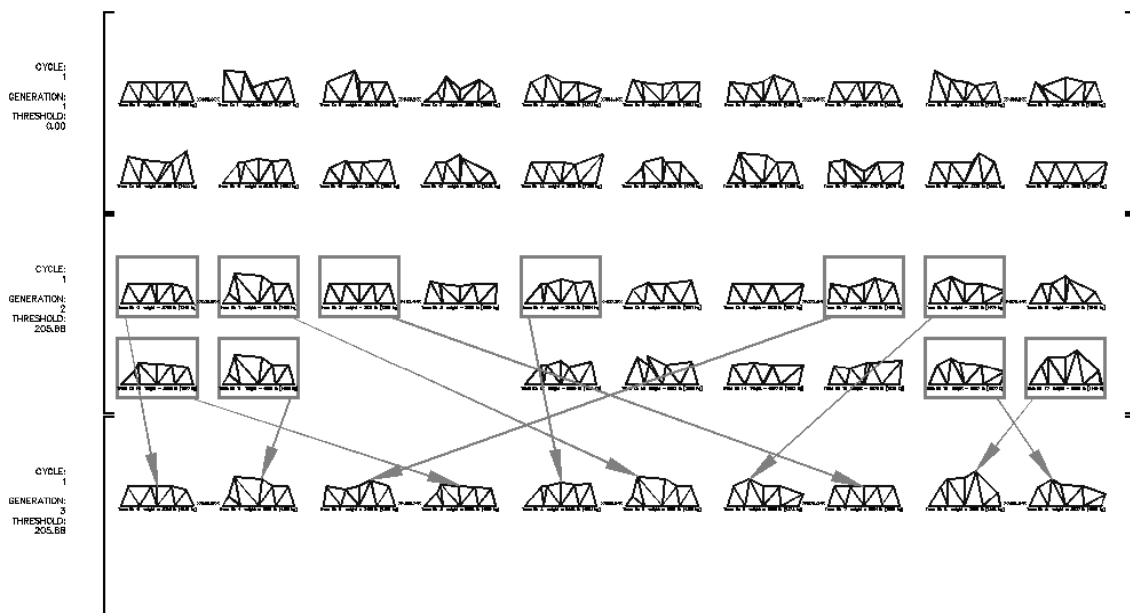
# Geometry Generations

Select best for parents in next generation



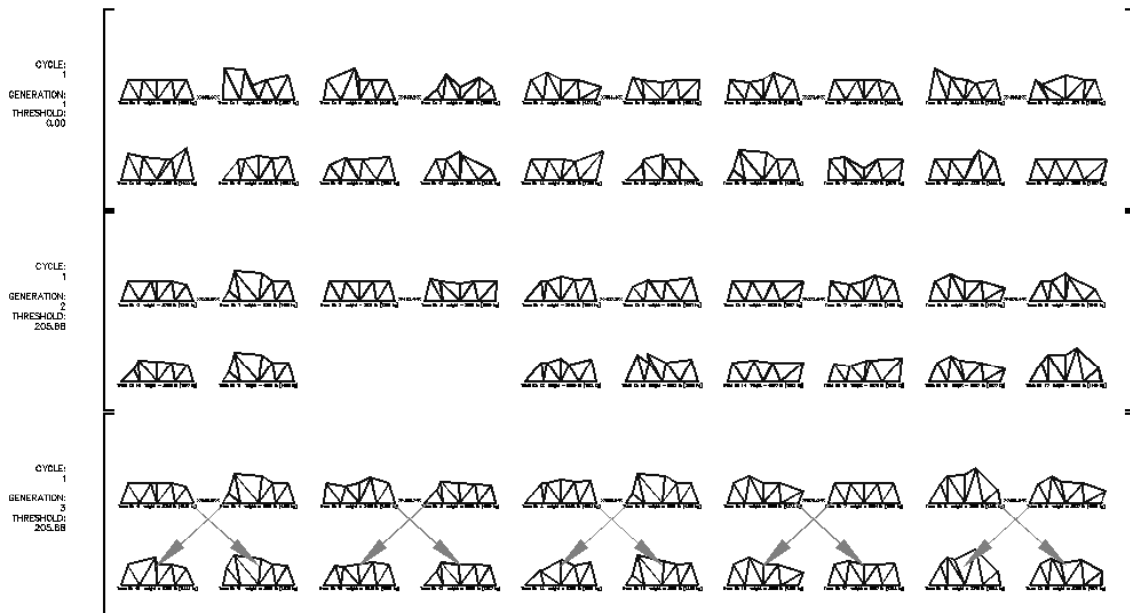
# Geometry Generations

Setup parents for next generation



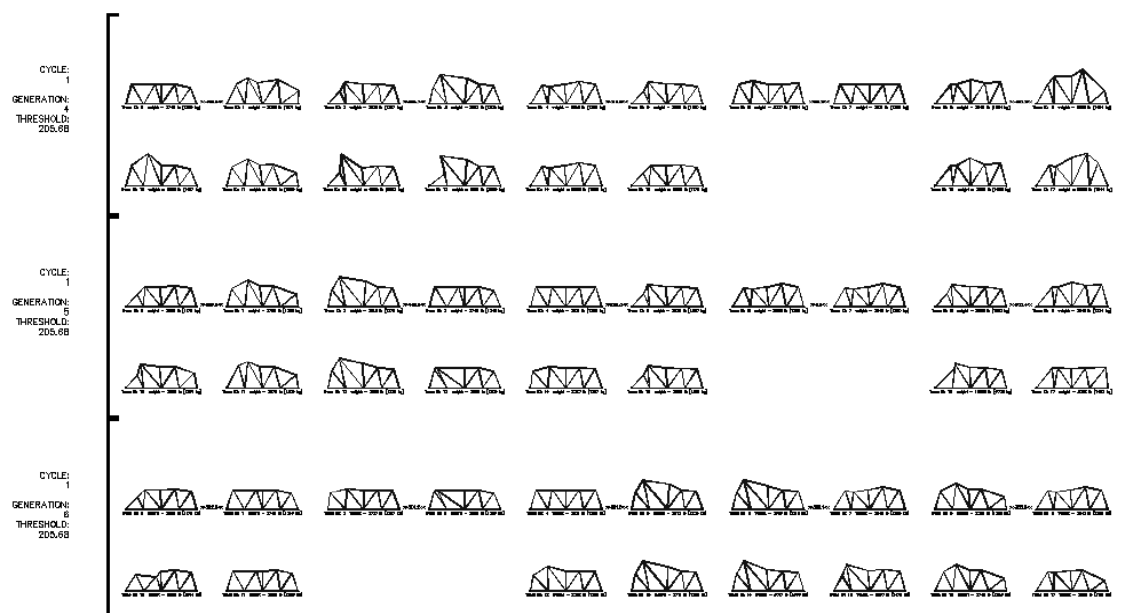
# Geometry Generations

Breed parents for next generation



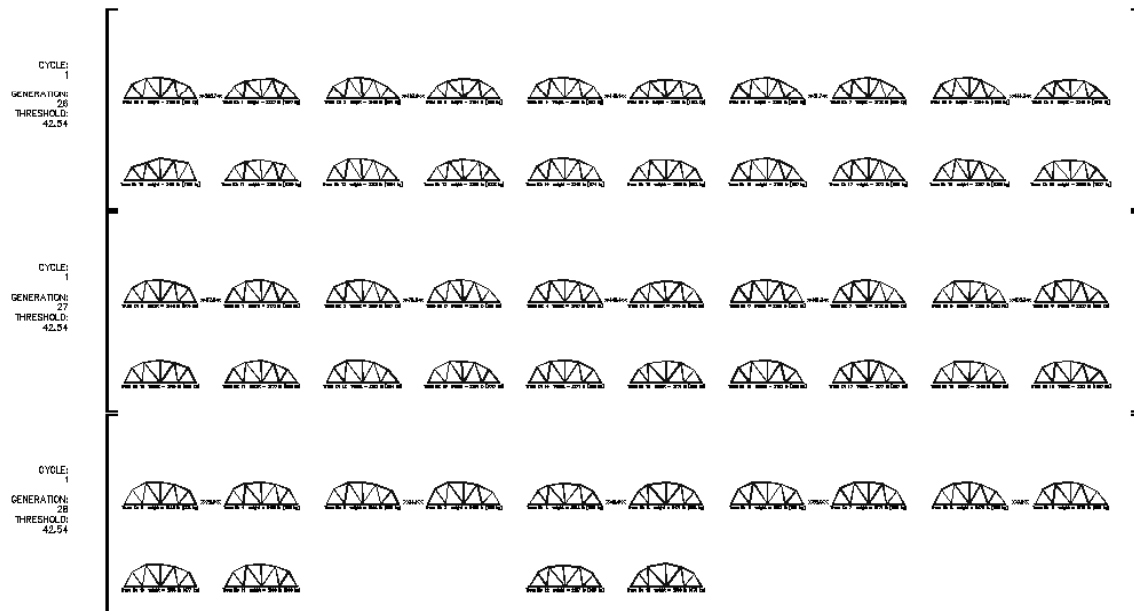
# Geometry Generations

Cycle 1 Generations 4-6



# Geometry Generations

Cycle 1 Generations 26-28



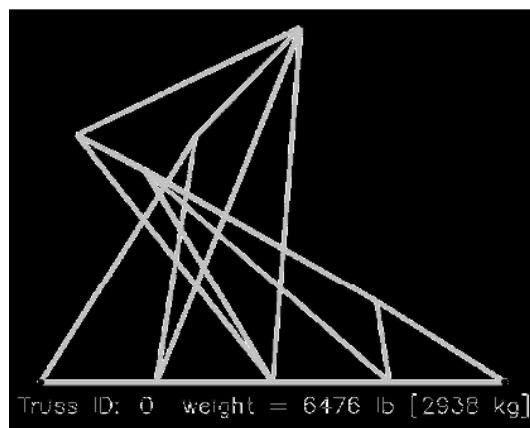
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# Geometry GA

Best from one cycle



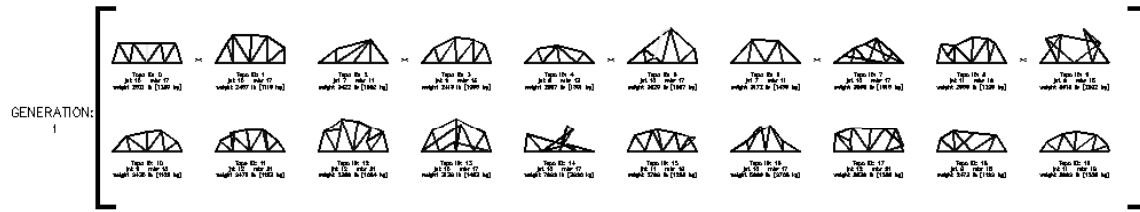
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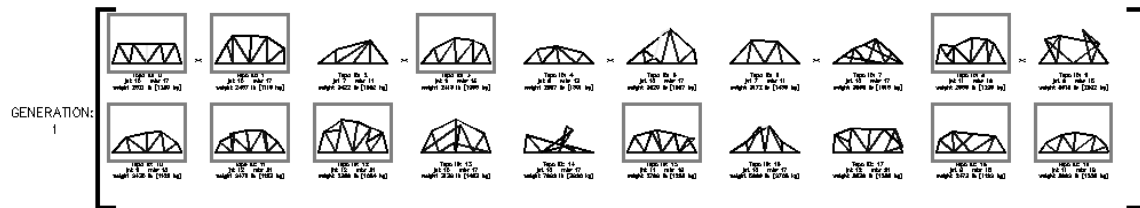
# Topology Generations

Mutate progenitor to start topology cycle



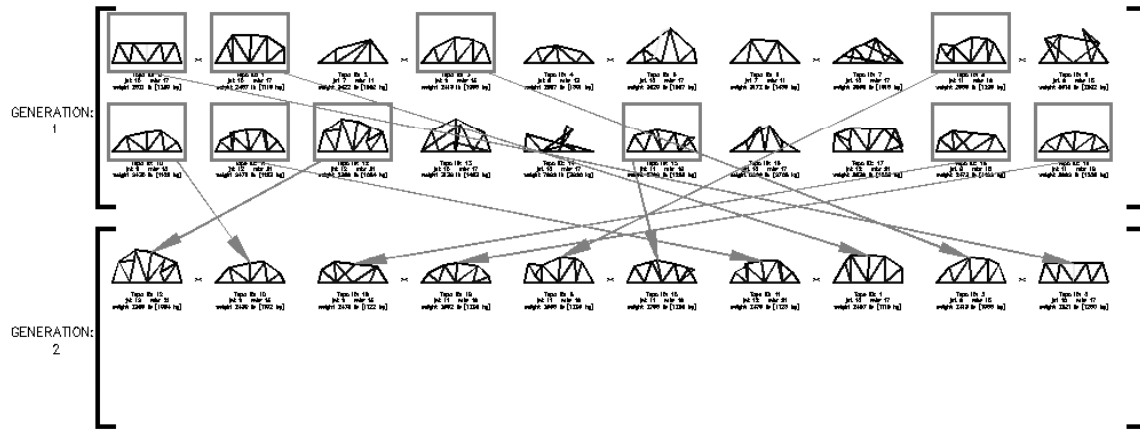
# Topology Generations

Select best for next generation



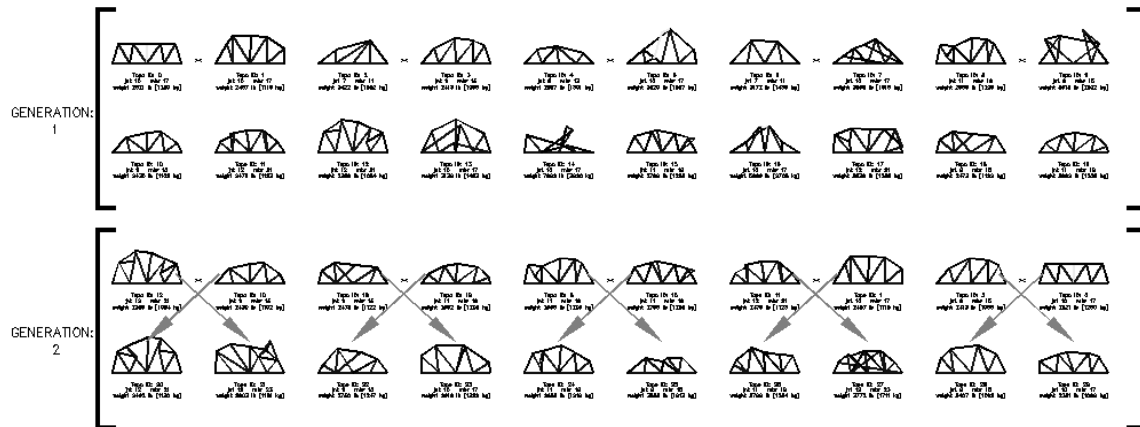
# Topology Generations

Set selection as parents for next generation



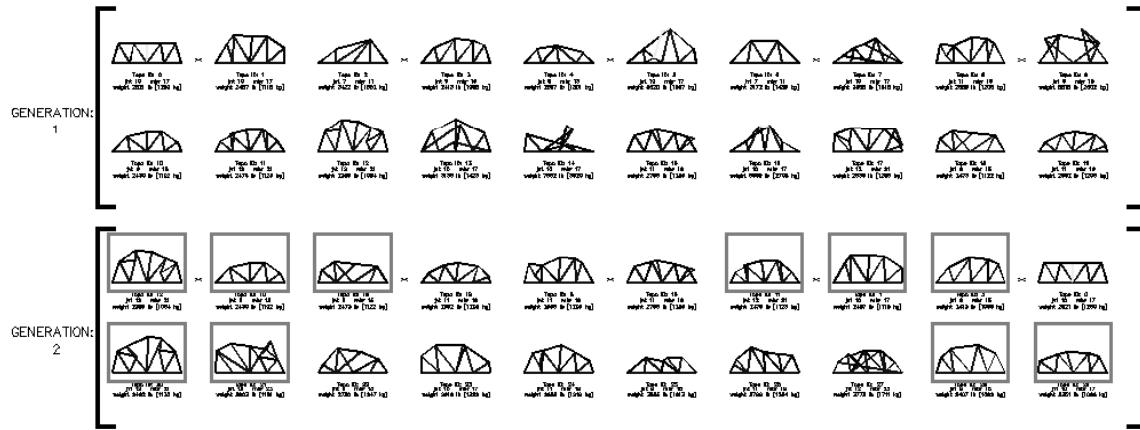
# Topology Generations

Breed parents to obtain full generation



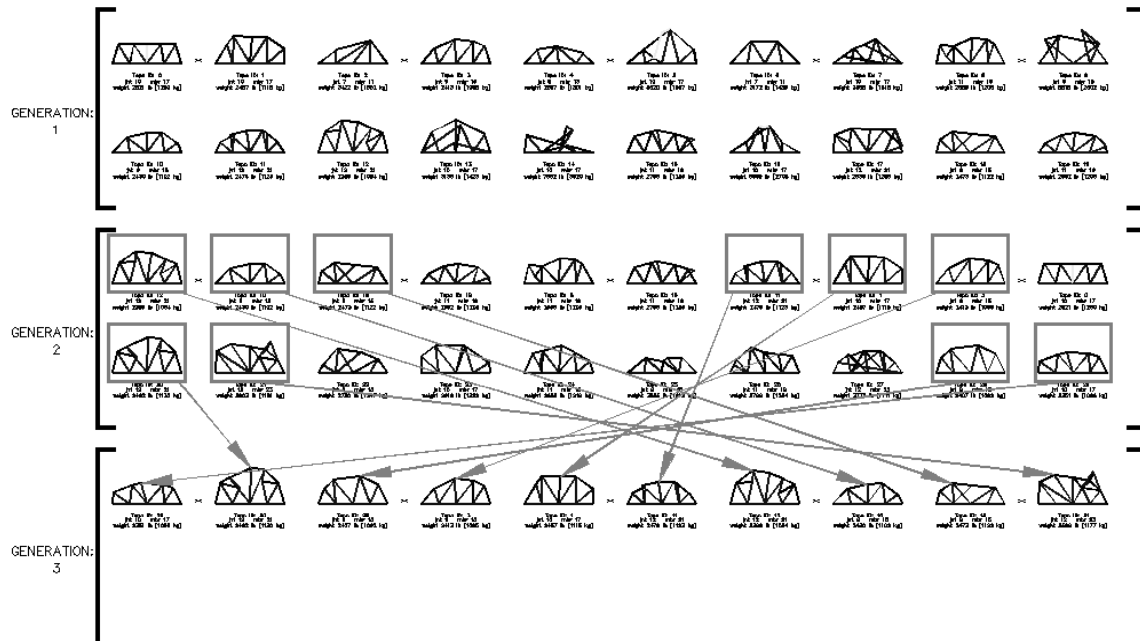
# Topology Generations

Select best from full generation



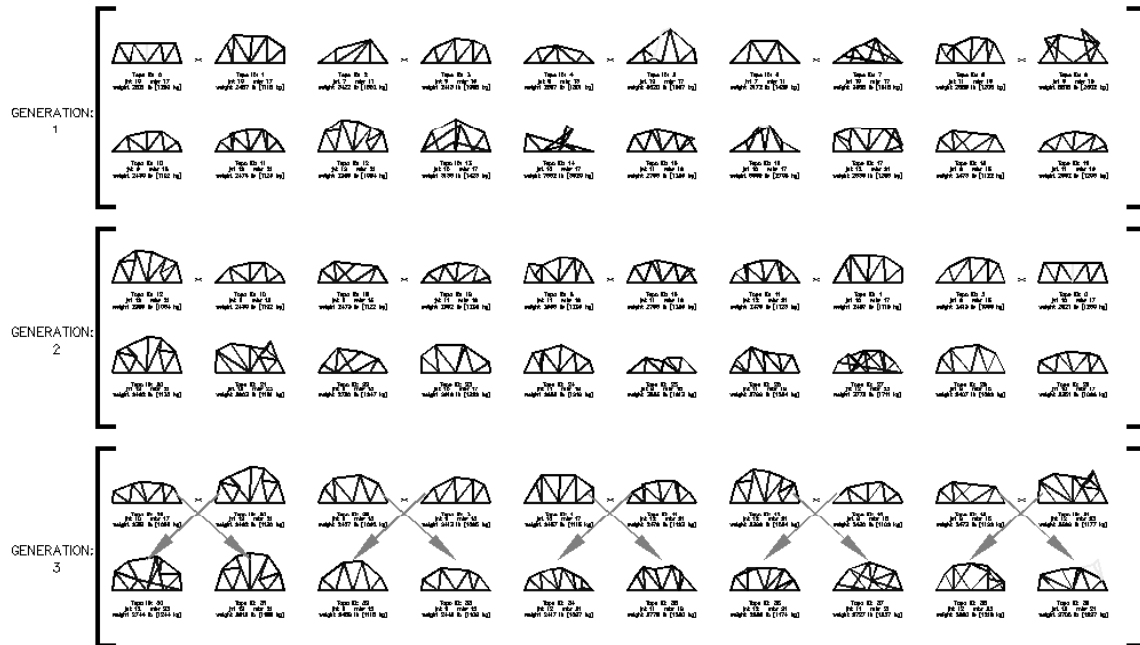
# Topology Generations

Set selection as parents for next generation



# Topology Generations

Breed parents to obtain full generation



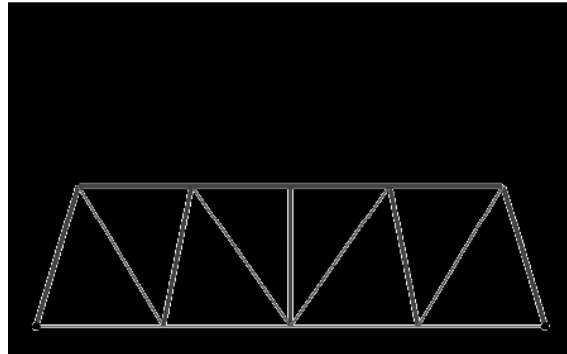
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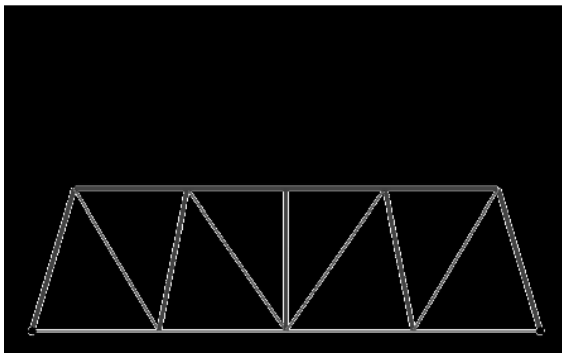
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# Topology

Best individuals  
from cycles 1- 4



All individuals  
from cycle 1



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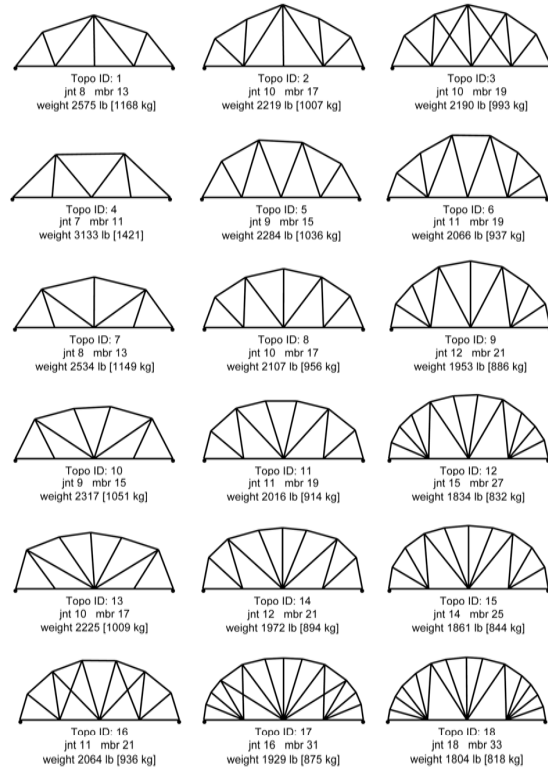
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# Topology

selection

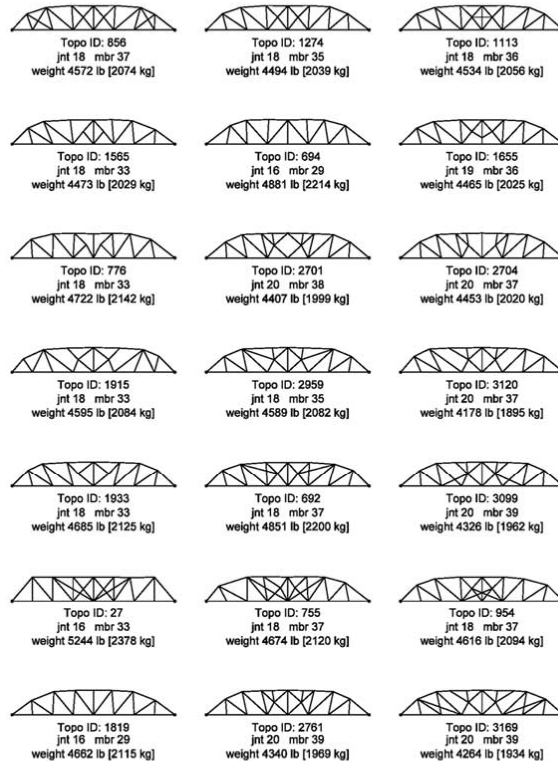
list of 'pretty good'  
solutions



# Bridge Design

automatic generation

list of 'pretty good'  
solutions





# Interactive Group Design

Idea generator

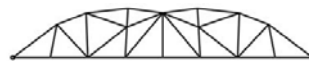


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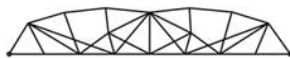
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## User Selections



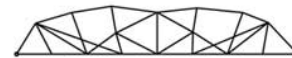
Topo ID: 0  
jnt 18 mbr 35  
weight 5394 lb [2447 kg]



Topo ID: 162  
jnt 18 mbr 37  
weight 4823 lb [2188 kg]



Topo ID: 179  
jnt 18 mbr 33  
weight 4802 lb [2178 kg]



Topo ID: 190  
jnt 18 mbr 35  
weight 4723 lb [2142 kg]

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# Final Bridge Design

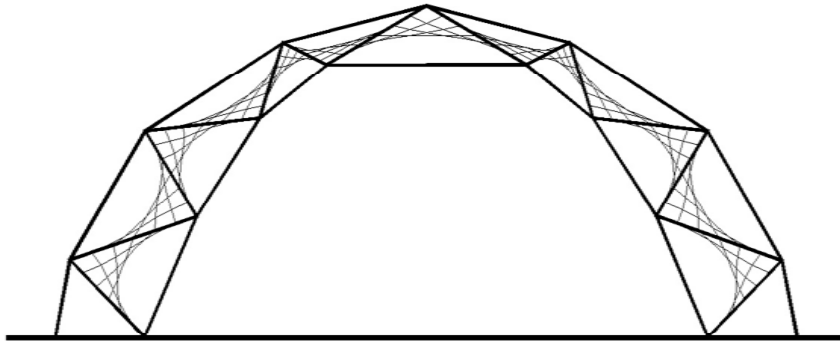


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# 3D Trusses



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# 3D Trusses

