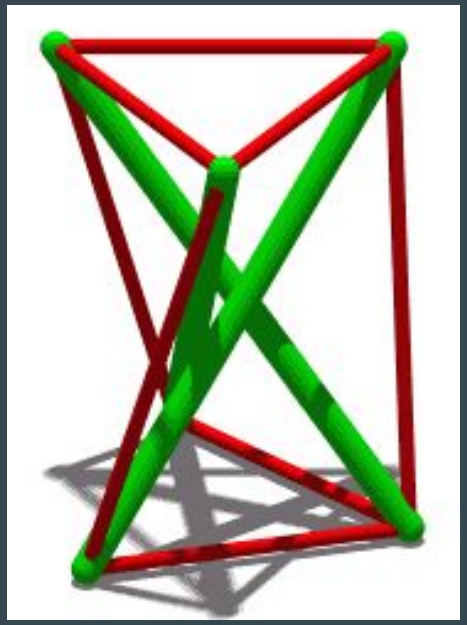
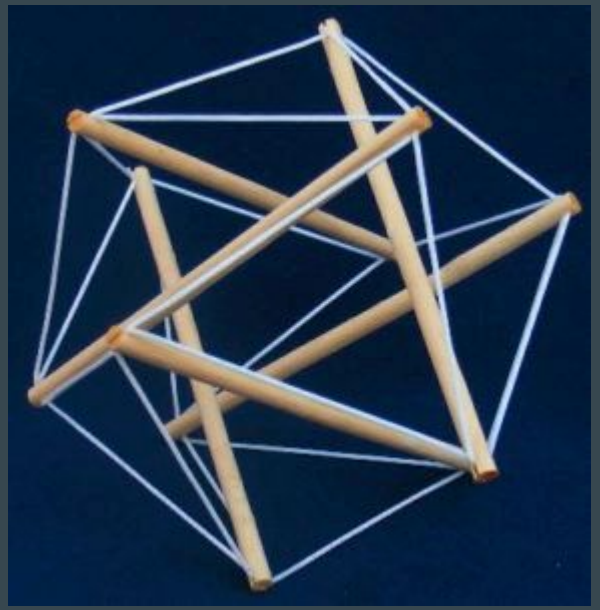
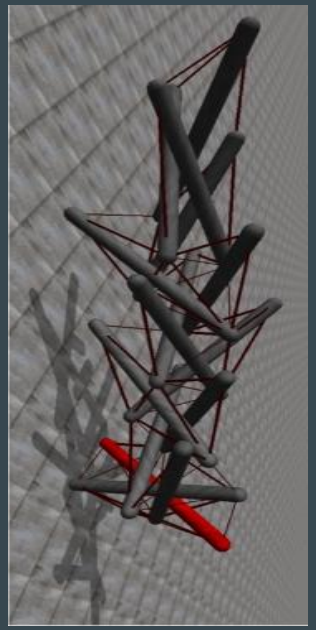
A Better Way to Construct Tensegrities: Planar Embeddings Inform Tensegrity Assembly

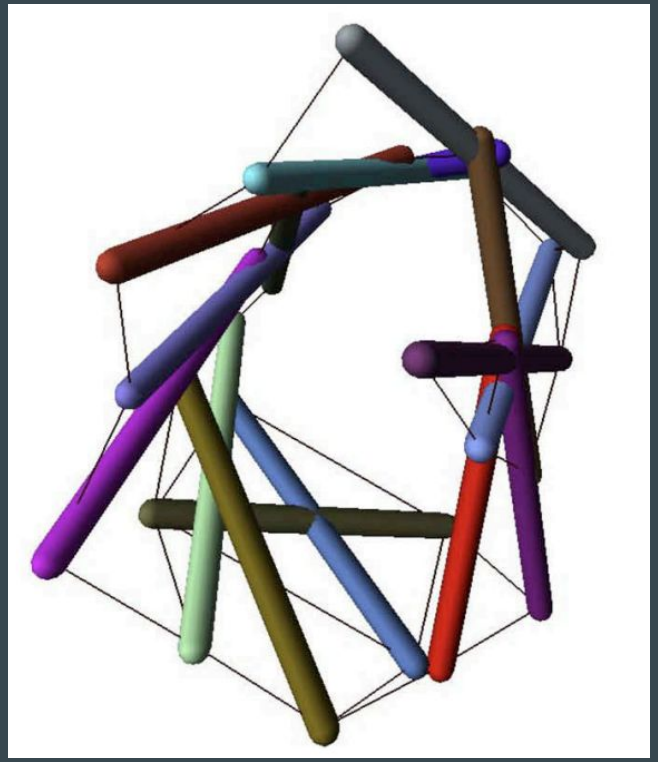
Elizabeth Ricci
Advisor: John Rieffel

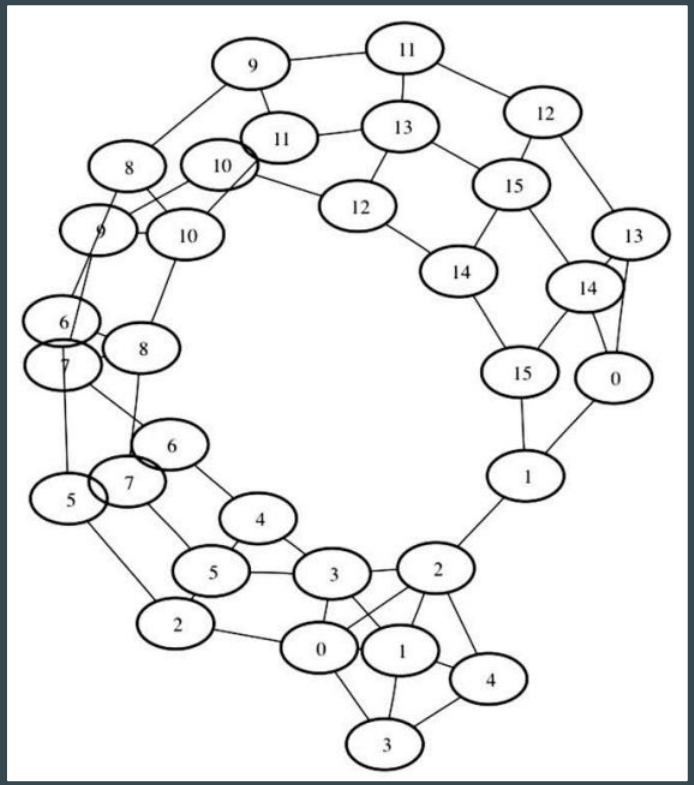
Introduction





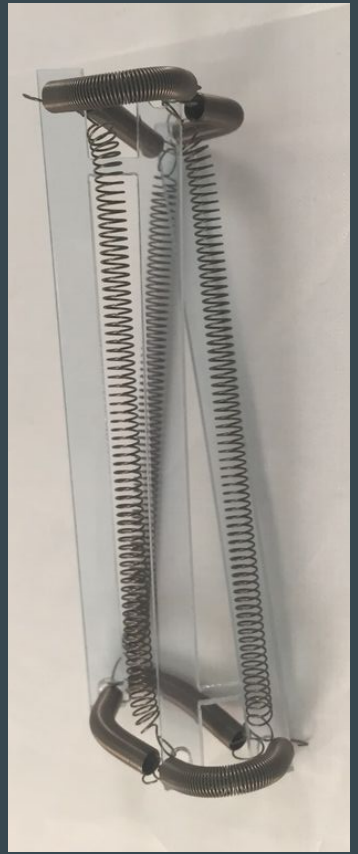




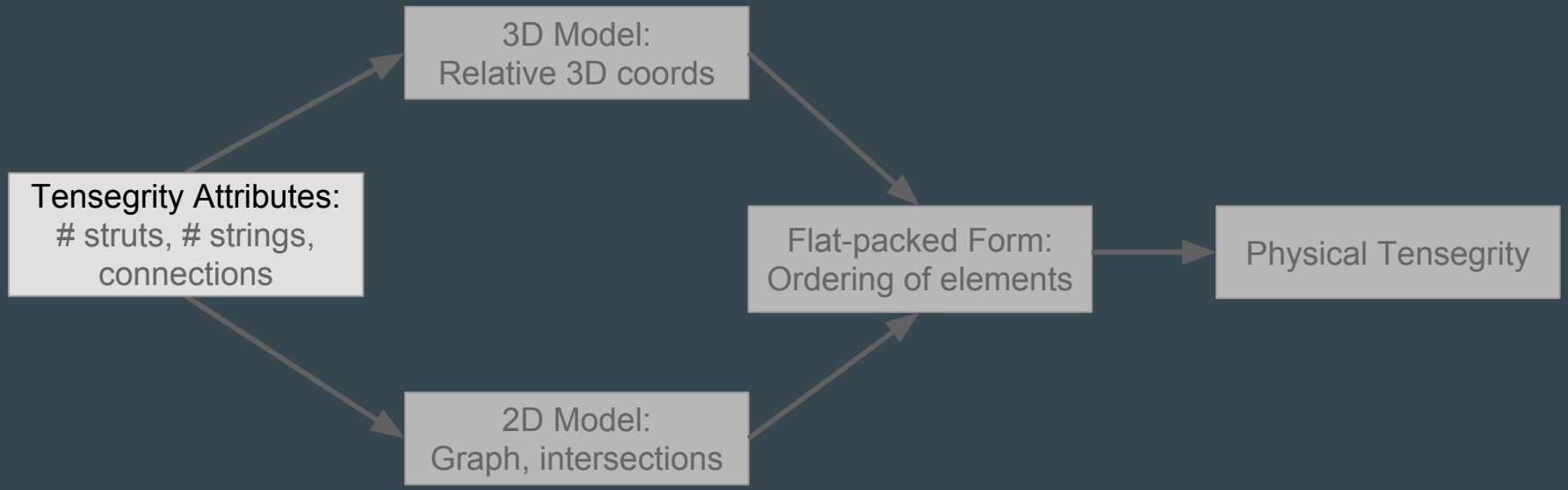


John Rieffel, Francisco Valero-Cuevas, and Hod Lipson. “Automated discovery and optimization of large irregular tensegrity structures”. In: Computers & Structures 87.5-6 (2009), pp. 368–379. ISSN : 0045-7949.

Concept Construction

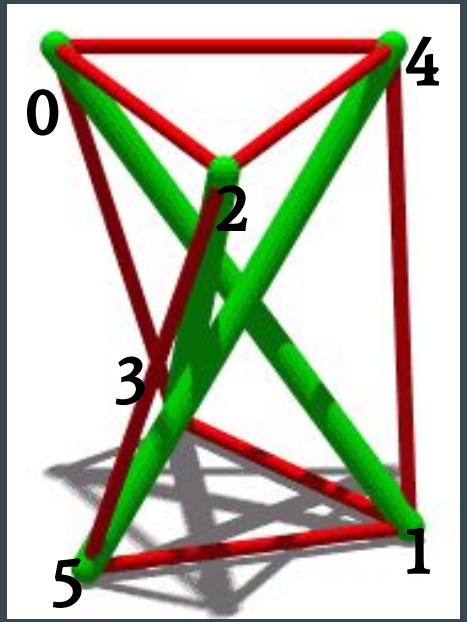


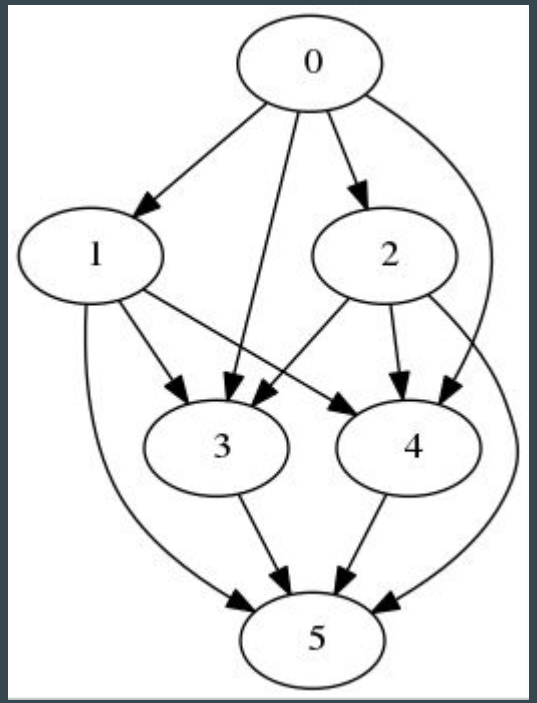
The Process


3D Model:
Relative 3D coords
Tensegrity Attributes:
struts, # strings,
connections
Flat-packed Form:
Ordering of elements
Physical Tensegrity
2D Model:
Graph, intersections

Tensegrity Attributes

- Number of Struts
- Number of Springs
- Array of Connections

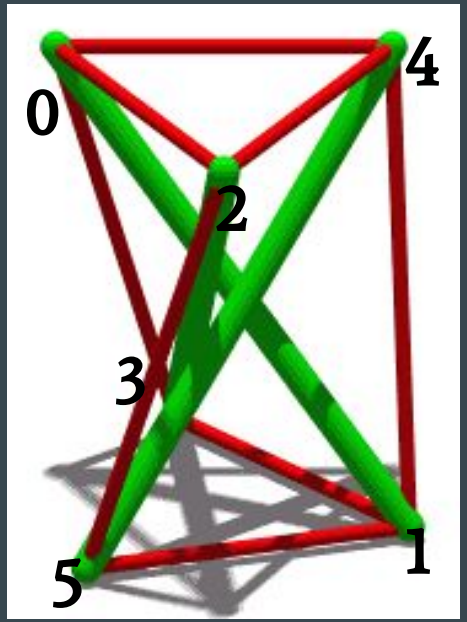


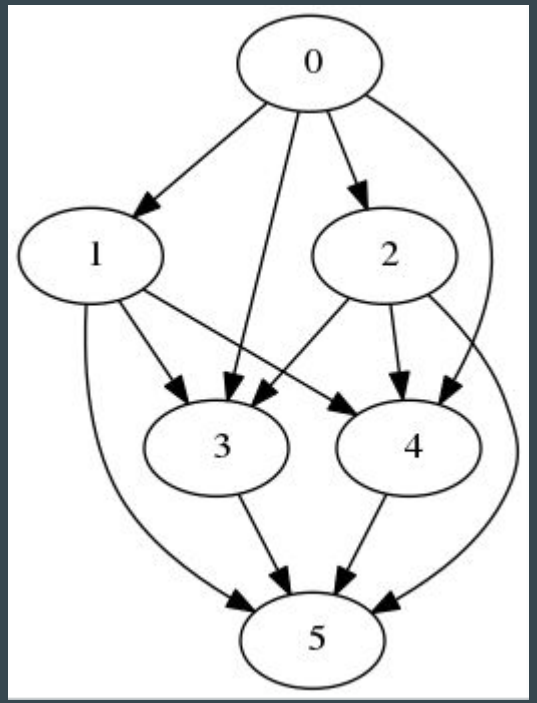


Tensegrity Attributes

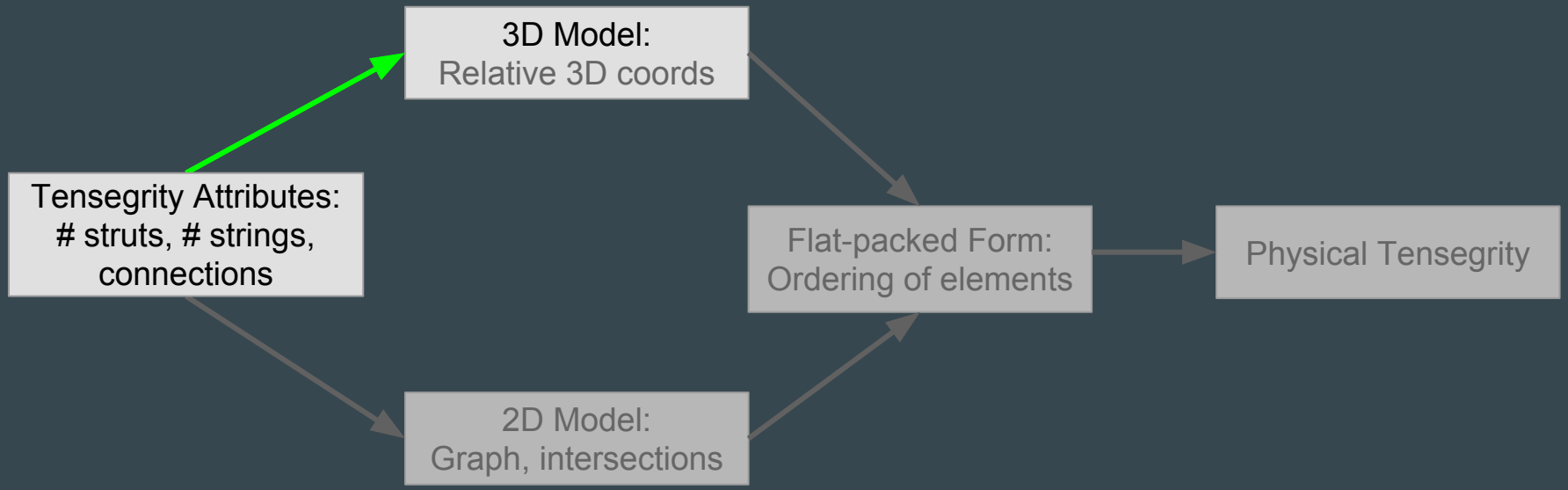
- Number of Struts: 3
- Number of Springs: 9
- Array of Connections:

{(0,1),(0,2),(0,3),(0,4),(1,3),
(1,4),(1,5),(2,3),(2,4),(2,5),
(3,5),(4,5)}

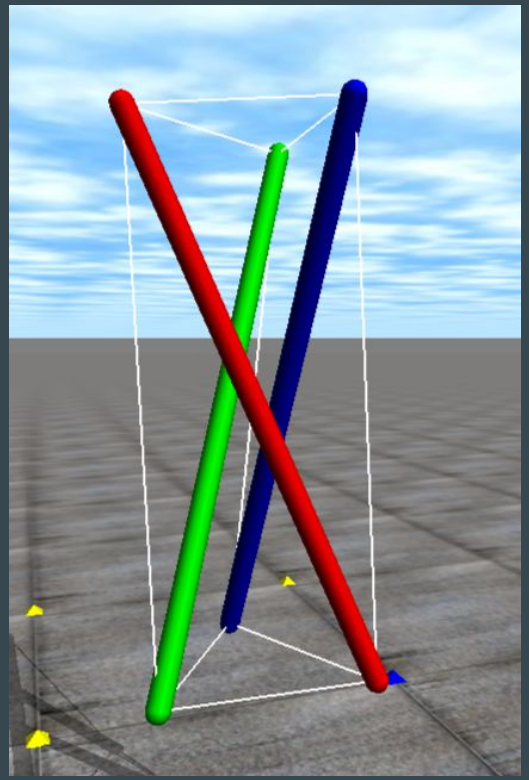


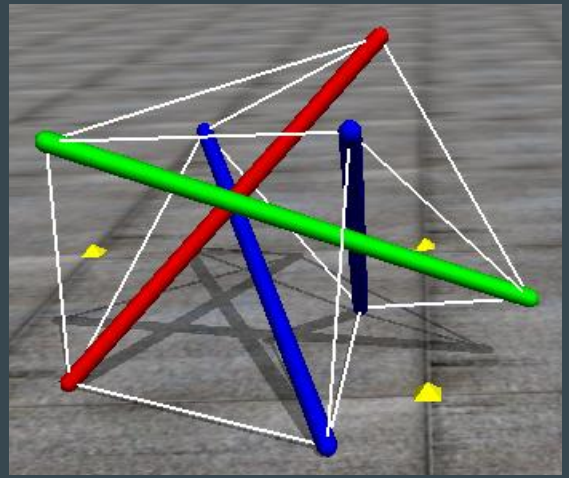


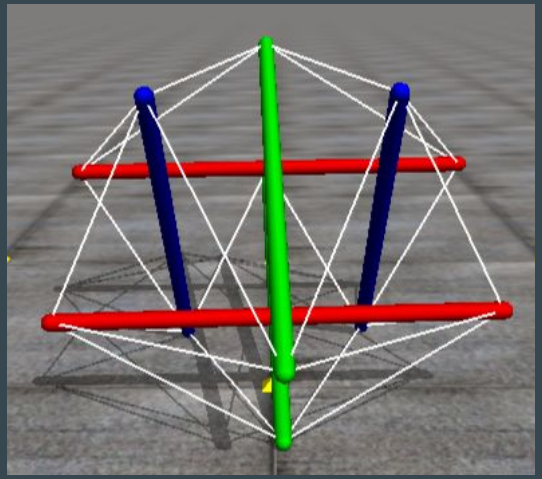
The Process


3D Model:
Relative 3D coords
Tensegrity Attributes:
struts, # strings,
connections
Flat-packed Form:
Ordering of elements
Physical Tensegrity
2D Model:
Graph, intersections

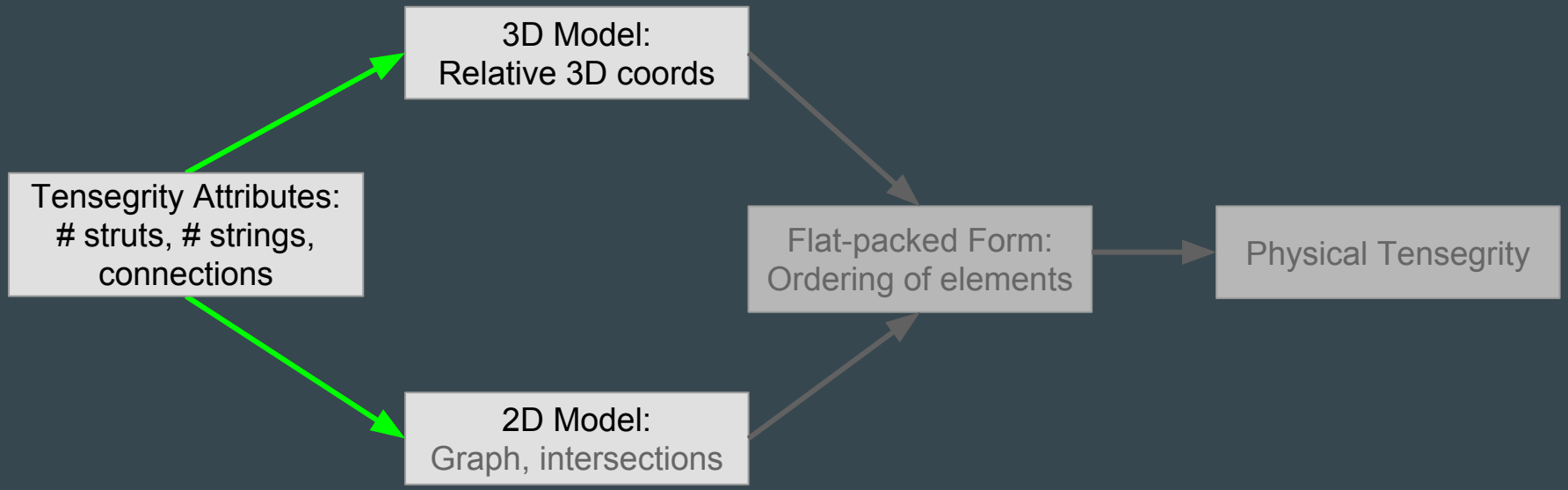
3D Model







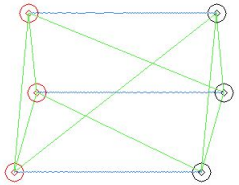
The Process


3D Model:
Relative 3D coords
Tensegrity Attributes:
struts, # strings,
connections
Flat-packed Form:
Ordering of elements
Physical Tensegrity
2D Model:
Graph, intersections

2D Model: Force-Directed Graph Drawing

- Repulsive forces between all vertices
  - $repulsiveForce = \frac{K_r}{distance^2}$
- Spring forces within springs
  - $springForce = \frac{K_s}{distance - L}$
- Update positions

$$positionChange = timeStep \times force$$



Michael J McGuffin. “Simple algorithms for network visualization: A tutorial”. In: Tsinghua Science and Technology 17.4 (2012), pp. 383–398.

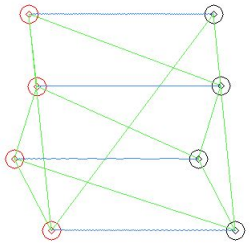
2D Model: Preserving Strut Length

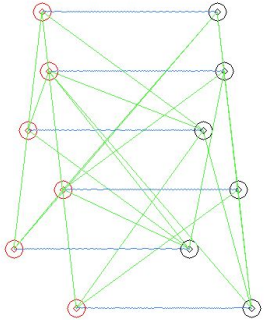
- Determine equations from end points
  - $y = m_1 x + b_1$ and $y = m_2 x + b_2$
- Consider distance formula:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$
$$d = \sqrt{(x_2 - x_1)^2 + ((mx_2 + b) - y_1)^2}$$

$$newx_2 = \frac{(2x_1 + 2y_1 m - 2mb) \pm \sqrt{(-2x_1 - 2y_1 m + 2mb)^2 + 4(1 + m^2)(d^2 - x_1^2 - y_1^2 + 2y_1 b - b^2)}}{2(1 + m^2)}$$

More Examples



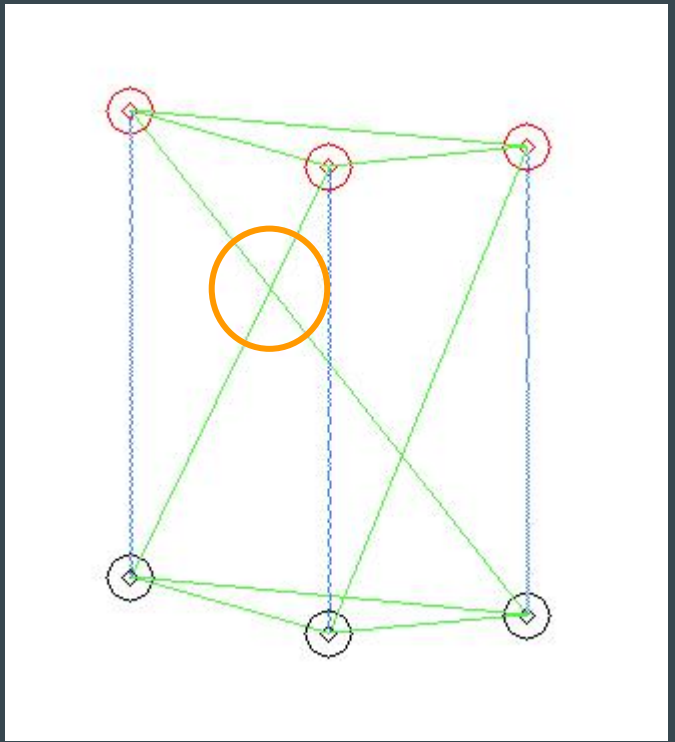


2D Model: Determine Intersections

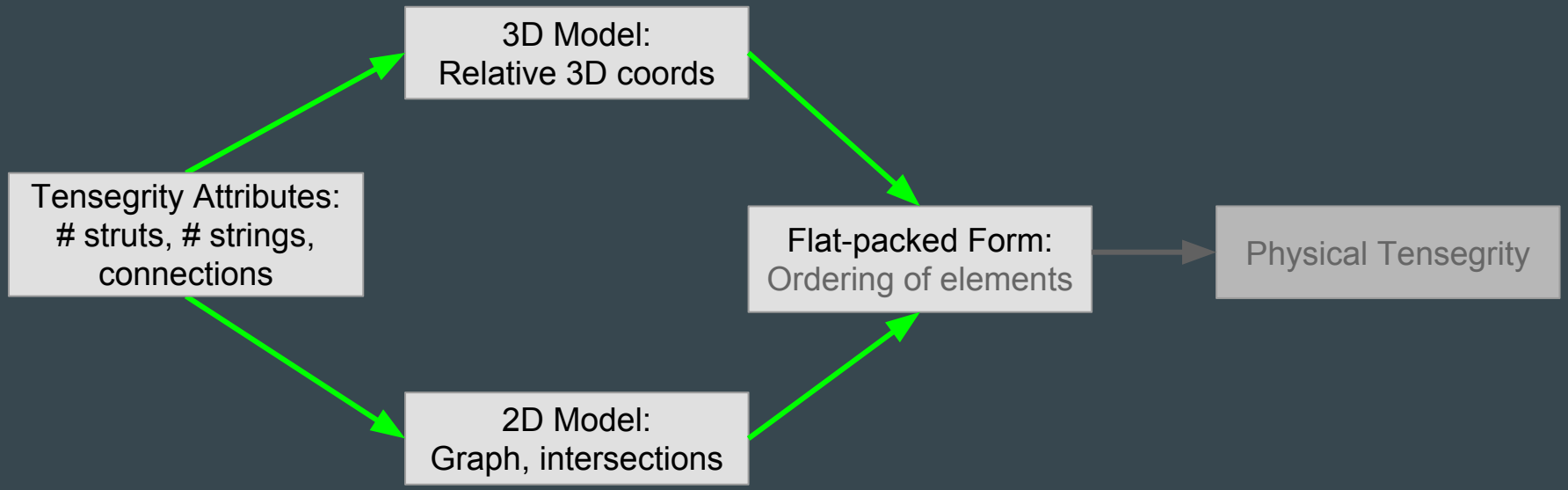
- Determine equations from end points
  - $y = m_1x + b_1$ and $y = m_2x + b_2$
- Find x-intercept:
  - $m_1x + b_1 = m_2x + b_2$

$$x = \frac{b_1 - b_2}{m_2 - m_1}$$

- Solve for y
- Intersect if y in range of endpoints



The Process

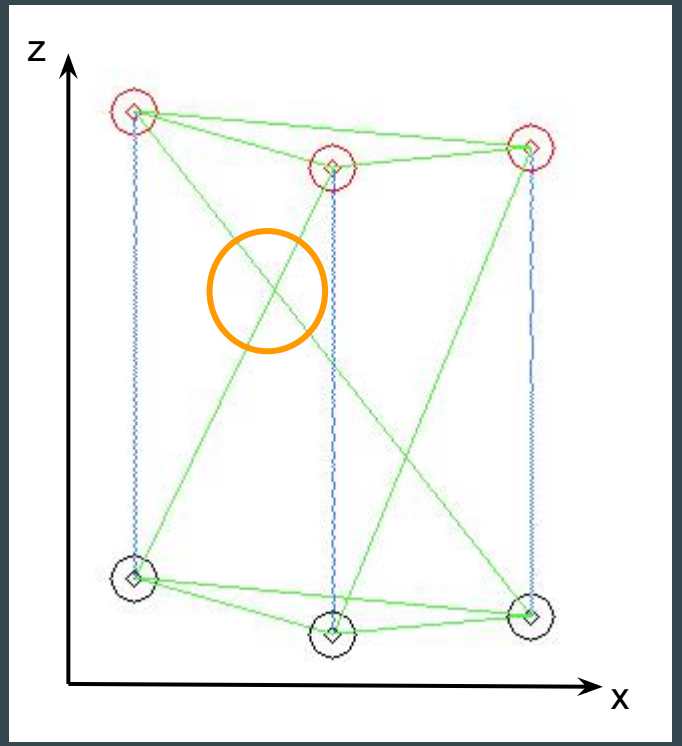

3D Model:
Relative 3D coords
Tensegrity Attributes:
struts, # strings,
connections
Flat-packed Form:
Ordering of elements
Physical Tensegrity
2D Model:
Graph, intersections

Flat-Packed Form: Determine Ordering

Use coords from 3D simulation: (x_n, y_n, z_n)

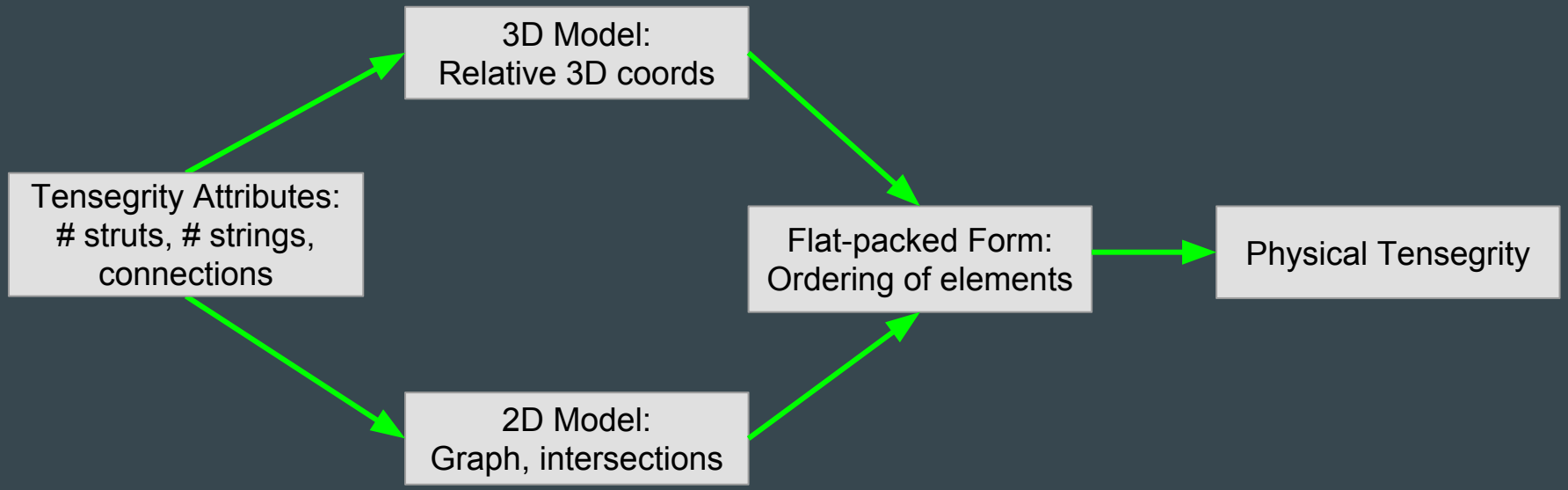
$$z = m_1 x + b_1 \text{ and } z = m_2 x + b_2$$

$$xIntercept = \frac{b_1 - b_2}{m_2 - m_1}$$



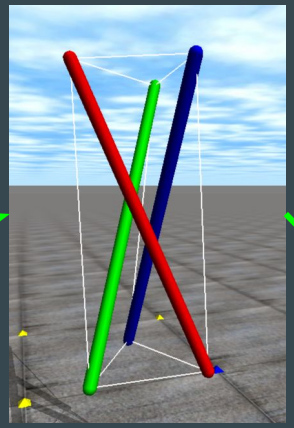
$$newy = \frac{(xIntercept - x_1) * (y_2 - y_1)}{x_2 - x_1} + y_1$$

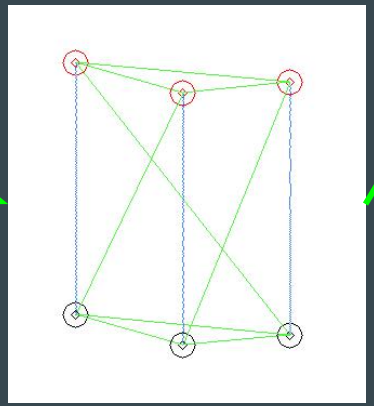
The Process

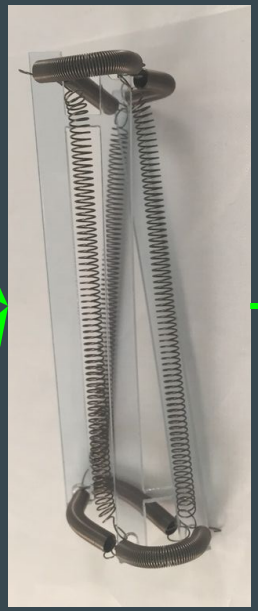

3D Model:
Relative 3D coords
Tensegrity Attributes:
struts, # strings,
connections
Flat-packed Form:
Ordering of elements
Physical Tensegrity
2D Model:
Graph, intersections

The process

3 struts
9 strings
connection
matrix







Future Work

- More physical verification.
- Automated creation of laser-cutting file.
- Transition to all laser-cutting, no springs.