

MODELING TENSEGRITY STRUCTURES WITH ARTISYNTH

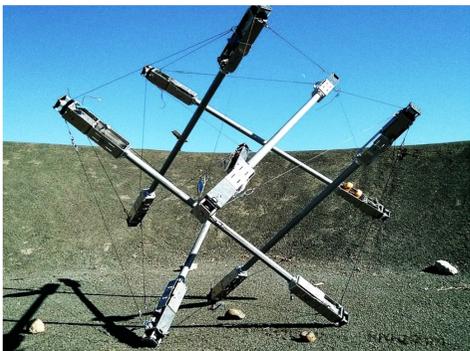


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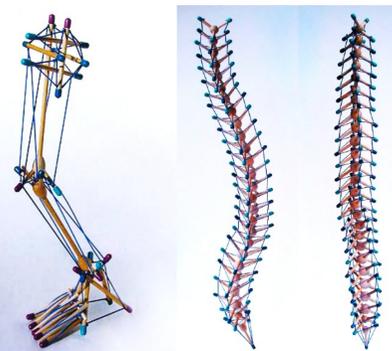


INTRODUCTION TO TENSEGRITY AND ARTISYNTH

Tensegrity structures are comprised of rods and strings held together by tension. They have important applications in architecture, biology and robotics. In biomechanics, they are used to model arms, legs, spines, torsos, and other components of human physiology.

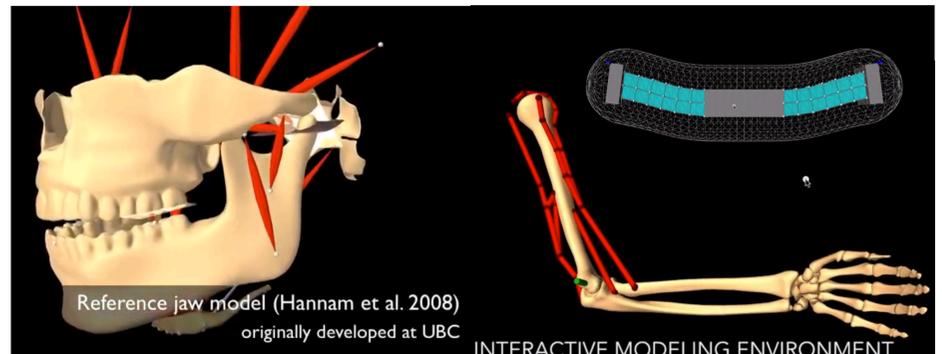


Tensegrity superballed lander prototype by NASA



Tensegrity leg/foot and spine by Tom Flemons

ArtiSynth is a 3D mechanical modeling program combining multibody and finite element simulation. It is open source and written in Java. The goal of this project is to create a framework in ArtiSynth to implement and simulate different types of tensegrity structures.



Simulated jaws, arms and skin from the ArtiSynth 2015 Demo Reel

IMPLEMENTATION, SIMULATION & DISCUSSION

Implementation of tensegrity models in ArtiSynth is done through a custom Rod class and adjustments to the AxialSpring class.

Each Rod object is composed of two end markers and a rigid body. Each string is a modified spring that does not exert forces when compressed. New rods and springs can be created with the addRod and addSpring functions.

Below is the Java and YAML declaration for a 3-strut prism. YAML is the file format used by the NASA Tensegrity Robotics Toolkit (NTRT). A future goal is to translate between YAML and Java so that structures can be exchanged between NTRT and ArtiSynth.

Java

```
// Nodes
Point3d bottom1 = new Point3d (-2.5, 0, 0);
Point3d bottom2 = new Point3d (2.5, 0, 0);
Point3d bottom3 = new Point3d (0, 0, 5);
Point3d top1 = new Point3d (-2.5, 10, 0);
Point3d top2 = new Point3d (2.5, 10, 0);
Point3d top3 = new Point3d (0, 10, 5);

// Rods
Rod bottom1top2 = addRod (mech, bottom1, top2, rad);
Rod bottom2top3 = addRod (mech, bottom2, top3, rad);
Rod bottom3top1 = addRod (mech, bottom3, top1, rad);

// Strings
addSpring (mech, bottom1top2.marker2, bottom2top3.marker2, len);
addSpring (mech, bottom2top3.marker2, bottom3top1.marker2, len);
addSpring (mech, bottom1top2.marker2, bottom3top1.marker2, len);
addSpring (mech, bottom3top1.marker1, bottom1top2.marker1, len);
addSpring (mech, bottom1top2.marker1, bottom2top3.marker1, len);
addSpring (mech, bottom3top1.marker1, bottom2top3.marker1, len);
addSpring (mech, bottom1top2.marker2, bottom3top1.marker1, len);
addSpring (mech, bottom2top3.marker2, bottom1top2.marker1, len);
addSpring (mech, bottom3top1.marker2, bottom2top3.marker1, len);
```

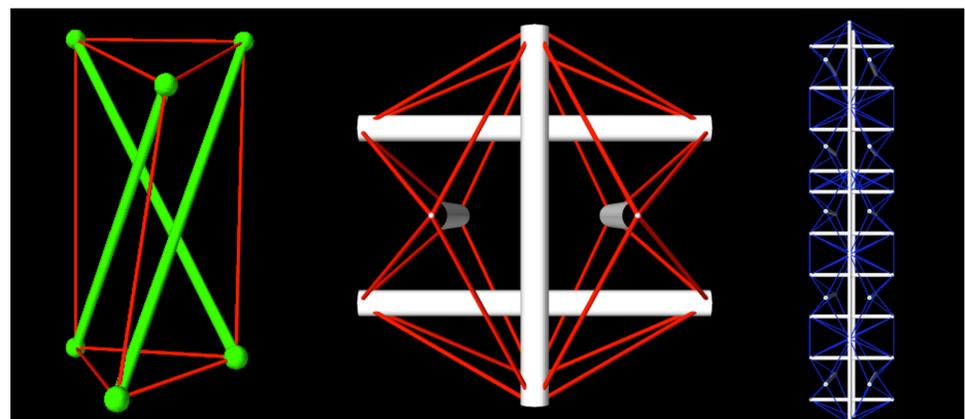
YAML

```
nodes:
  bottom1: [-2.5, 0, 0]
  bottom2: [2.5, 0, 0]
  bottom3: [0, 0, 5]
  top1: [-2.5, 10, 0]
  top2: [2.5, 10, 0]
  top3: [0, 10, 5]

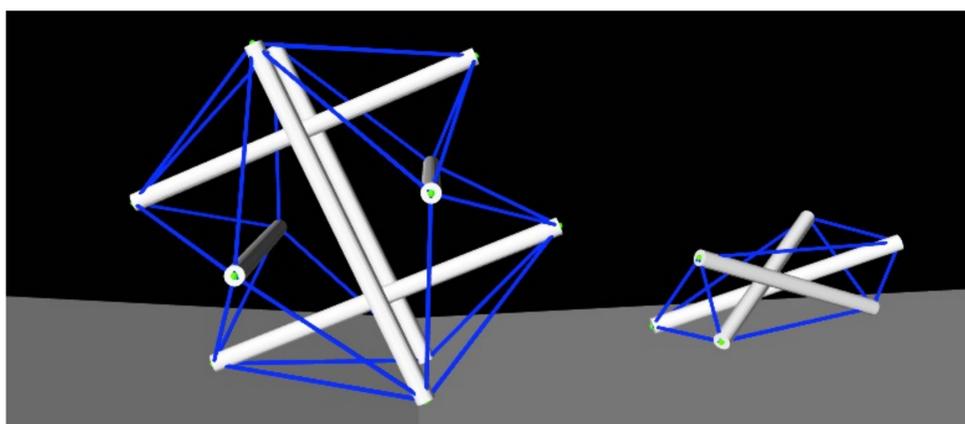
prism_rods:
  - ["bottom1", "top2"]
  - ["bottom2", "top3"]
  - ["bottom3", "top1"]

prism_strings:
  - ["bottom1", "bottom2"]
  - ["bottom2", "bottom3"]
  - ["bottom1", "bottom3"]
  - ["top1", "top2"]
  - ["top2", "top3"]
  - ["top1", "top3"]
  - ["bottom1", "top1"]
  - ["bottom2", "top2"]
  - ["bottom3", "top3"]
```

Simulation of tensegrity structures is observed through ArtiSynth's user interface. The structures are subject to gravity and can interact with a terrain and other objects. This is a useful tool for tensegrity model builders to visualize the structure and behavior of a large range of possible models.



3-strut prism, 6-strut superballed, and five superballed connected to form a chain.



3-strut prism and 6-strut superballed interacting with a rigid body terrain.

FUTURE GOALS

- Add **adjustable sliders** to change string tension during simulation
- Allow coding of rods and strings **without** specifying the specific coordinates of every single node
- Implement a **text parser** to translate between Java and YAML notation; this will enable data exchange with NTRT
- Develop a **graphical interface** for users to create and simulate tensegrity models without the need to input text

REFERENCES

References

John E. Lloyd, Ian Stavness, and Sidney Fels, "ArtiSynth: A fast interactive biomechanical modeling toolkit combining multibody and finite element simulation", *Soft Tissue Biomechanical Modeling for Computer Assisted Surgery*, pp. 355-394, Springer, 2012.

Acknowledgments

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