Soft Body Truss Physics

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Goal:

The goal is to find a new of creating soft body physics using the idea of method of joints.

Method:

* On Paper:
  1. Figure out on which node the external force is being applied
     + This is all your choice. You can choose which node to apply the force to or how much it is.
  2. Place the supports for the truss and then the support forces
     + Before we place the supports, it is important to determine which direction to place the support forces, so that the sum of forces acting upon the truss is zero.
       - This will make the truss statically determinant.
     + You have 2 types of supports that you will use:
       - Pinned – typically represented as a triangle
         * This allows for rotation, but no translation.
         * Due to not allowing translation there will be two support forces.
         * The pinned can be on a surface at any angle.
       - Roller – typically represented as a circle
         * This allows for free rotation and translation along the surface upon which the roller rests.
         * The roller can be on a surface at any angle.
         * The force can be in any direction parallel to the surface the roller is on.
       - Used: <http://web.mit.edu/4.441/1_lectures/1_lecture13/1_lecture13.html>
     + Now that you have the info necessary, place the supports and draw the direction of the support forces
     + Once you have done all the above, find the sum of the forces (the external force and the support forces), such that the sum of all forces is zero in the x and y directions
       - You should have the external force as an initial value, so just find the support forces.
  3. Calculate the bar forces using the Method of Joints
     + The goal of the method of joints is to calculate the force acting on each bar.
     + This method makes this very easy by allowing you to separate out the problem into several problems. You can treat each vertex as an individual problem.
     + Create a force diagram for each vertex
       - These forces will include the bar forces, support forces, and the external force.
  4. Using the Equation for Young’s Modulus to calculate the deformation of the bars
     + The equation is Young’s Modulus = stress / strain
     + Stress = Bar Force / Cross-Sectional Area
     + Strain = Change in Length / Original Length
     + Rearranging you get:
       - Change in Length = (Length \* Force) / (Young’s Modulus \* Cross-Sectional Area)
  5. Apply the deformations on the nodes
     + First divide the “Change in Length” in half
     + Then separate the deformations into x and y parts
     + Then depending on whether the bar is under compression or tension, then add or subtract the displacement/2 from the vertex
* Programmatically: <- This will need a lot of work. A lot. WIP
  1. Figure out on which node the external force is being applied
     + This is calculated from the collision of the truss with another object.
  2. Place the supports for the truss
  3. Figure out the support forces
  4. Calculate the bar forces using the Method of Joints
  5. Using the Equation for Young’s Modulus to calculate the deformation of the bars
  6. Apply the deformations on the nodes

Lessons Learned:

* One of the things that we tried is instead of using the Young’s Modulus formula, we tried to use the stiffness matrices created from the direct stiffness method. We thought that it might be possible to calculate the nodal displacements using the Finite Element Method.
  + In this, the formula is F = ku
    - F = the matrix of forces on the nodes
    - k = The stiffness matrix
    - u = the displacements
  + The usually way is to create all the elemental stiffness matrices and combine them into a large global stiffness matrix, then apply boundary conditions, and then finally figuring out the deformations.
  + We were thinking about using a form of the method where you find the elemental stiffness matrices, then apply boundary conditions, finally multiple the force matrix by the inverted stiffness matrix with applied boundary conditions.
    - This doesn’t work as the elemental stiffness matrix may or may not be invertible, which means we can guarantee that this will work.
* Due to the way the method works, it will give you the final position, so you will want to do some form of interpolation to get to the final position.

Helpful Sources:

* <http://www.colorado.edu/engineering/CAS/courses.d/IFEM.d/IFEM.Ch02.d/IFEM.Ch02.pdf>
* <http://www.colorado.edu/engineering/CAS/courses.d/IFEM.d/IFEM.Ch03.d/IFEM.Ch03.pdf>
* <http://physicsnet.co.uk/a-level-physics-as-a2/materials/stress-strain/>
* <http://www.unm.edu/~bgreen/ME360/Finite%20Element%20Truss.pdf>
* http://www.colorado.edu/MCEN/MCEN4173/chap\_04.pdf