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% Static force analysis of 2D TBar (Fig 3.3 of Skelton & de Oliviera 2009)
% By Thomas Bewley, UC San Diego (+ faculty fellow at JPL)
clear; clf; figure(1);

theta = 45*pi/180;
r = [cos(theta),0,-sin(theta);0,1,0;sin(theta),0,cos(theta)];
% Free [Q=Q_(dim x q)] and fixed [Q=Q_(dim x q)] node locations
Q(:,1)=[-1,0,-1];
Q(:,2)=[-1,0,1];
Q(:,3)=[1,0,1];
Q(:,4)=[1,0,-1];
Q(:,5)=[-1,2,-1]*r;
Q(:,6)=[-1,2,1]*r;
Q(:,7)=[1,2,1]*r;
Q(:,8)=[1,2,-1]*r;
P=[];
%Q=Q';
[dim,q]=size(Q); p=size(P,2); n=q+p;

C(:,1)=conVect(1,7,8);
C(:,2)=conVect(2,8,8);
C(:,3)=conVect(3,5,8);
C(:,4)=conVect(4,6,8); b = 4;
C(:,5)=conVect(1,3,8);
C(:,6)=conVect(2,4,8);
C(:,7)=conVect(1,6,8);
C(:,8)=conVect(2,5,8);
C(:,9)=conVect(2,7,8);
C(:,10)=conVect(3,6,8);
C(:,11)=conVect(3,8,8);
C(:,12)=conVect(4,7,8);
C(:,13)=conVect(1,8,8);
C(:,14)=conVect(4,5,8);
C(:,15)=conVect(6,8,8);
C(:,16)=conVect(5,7,8);
C(:,17)=conVect(1,2,8);
C(:,18)=conVect(2,3,8);
C(:,19)=conVect(3,4,8);
C(:,20)=conVect(4,1,8);
C(:,21)=conVect(1,5,8);
C(:,22)=conVect(2,6,8);
C(:,23)=conVect(3,7,8);
C(:,24)=conVect(4,8,8);
C(:,25)=conVect(5,6,8);
C(:,26)=conVect(6,7,8);
C(:,27)=conVect(7,8,8);
C(:,28)=conVect(8,5,8); s = 24;
%{
% Connectivity matrix
C(  1,1)=1; C(  1,2)=-1;       % bars
C(  2,2)=1; C(  2,3)=-1;
C(  3,2)=1; C(  3,4)=-1;
C(  4,2)=1; C(  4,5)=-1;
C(  5,2)=1; C(  5,6)=-1; b=5;
C(b+1,1)=1; C(b+1,4)=-1;       % strings
```

```
C(b+2,1)=1; C(b+2,5)=-1;
C(b+3,1)=1; C(b+3,6)=-1;
C(b+4,3)=1; C(b+4,4)=-1;
C(b+5,3)=1; C(b+5,5)=-1;
C(b+6,3)=1; C(b+6,6)=-1;
C(b+7,4)=1; C(b+7,5)=-1;
C(b+8,5)=1; C(b+8,6)=-1;
C(b+9,6)=1; C(b+9,4)=-1; s=9; m=b+s;
%}
C = C';
% Applied external force U=U_(dim x q)
U(1:dim,1:q)=0;
%U(1,1)=1; U(1,3)=-1;
U(:,1) = [0; 10; 0];
U(:,2) = [0; 10; 0];
U(:,3) = [0; 10; 0];
U(:,4) = [0; 10; 0];
U(:,5) = [0; -10; 0];
U(:,6) = [0; -10; 0];
U(:,7) = [0; -10; 0];
U(:,8) = [0; -10; 0];

% Solve for the forces at equilibrium, and plot
[c_bars,t_strings,V]=tensegrity_statics(b,s,q,p,dim,Q,P,C,U);
tensegrity_plot(Q,P,C,b,s,U,V,true,1,0.08); grid on;

function C_vect = conVect(start,finish,total_nodes)
C_vect = zeros(1,total_nodes);
C_vect(1,start) = -1;
C_vect(1,finish) = 1;
return
end
% end script TBar3
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```
mhat =

    24


nhat =

    28


r =

    18

Warning: Ase is potentially inconsistent, implying the presence of soft modes,
or instability!  More strings or fixed points should fix the problem.

Bar compressions and string tensions with loads as specified,
least squares solution (i.e., NO pretensioning):
u in column space of Ase, so at least one solution exists, with residual 2.2558e-14.
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```
c_bars =

    1.7865    1.7865    1.7865    1.7865

No bars under tension.  Good.

t_strings =

  Columns 1 through 7

    2.1213    2.1213   -1.7865   -4.4507   -1.7865   -4.4507   -1.7865

  Columns 8 through 14

   -4.4507   -4.4507   -1.7865    2.1213    2.1213    1.5000    1.5000

  Columns 15 through 21

    1.5000    1.5000   -4.4507   -4.4507   -4.4507   -4.4507    1.5000

  Columns 22 through 24

    1.5000    1.5000    1.5000

Some strings not under tension. Needs different tensioning or external loads.

Ase is underdetermined with 10 DOF. Checking now to see if system is pretensionable,
with tension >= 0.1 in all tethers for zero applied load.

Not pretensionable!
Results with external forces u as specified and tensioned to maximize tau_min:

c_bars =

    3.3619    3.3619    3.3619    3.3619

No bars under tension.  Good.

t_strings =

  Columns 1 through 7

   -3.3619   -3.3619   -3.3619   -3.3619   -3.3619   -3.3619   -3.3619

  Columns 8 through 14

   -3.3619   -3.3619   -3.3619   10.9122   10.9122    6.7314    6.7314

  Columns 15 through 21

    6.7314    6.7314   -3.3619   -3.3619   -3.3619   -3.3619   -3.3619

  Columns 22 through 24

   -3.3619   -3.3619   -3.3619

Some strings not under tension. Needs different tensioning or external loads.
```