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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(:,5)=conVect(1,6,8);
C(:,6)=conVect(2,5,8);
C(:,7)=conVect(2,7,8);
C(:,8)=conVect(3,6,8);
C(:,9)=conVect(3,8,8);
C(:,10)=conVect(4,7,8);
C(:,11)=conVect(1,8,8);
C(:,12)=conVect(4,5,8);
%C(:,15)=conVect(6,8,8);
%C(:,16)=conVect(5,7,8);
C(:,13)=conVect(1,2,8);
C(:,14)=conVect(2,3,8);
C(:,15)=conVect(3,4,8);
C(:,16)=conVect(4,1,8);
C(:,17)=conVect(1,5,8);
C(:,18)=conVect(2,6,8);
C(:,19)=conVect(3,7,8);
C(:,20)=conVect(4,8,8);
C(:,21)=conVect(5,6,8);
C(:,22)=conVect(6,7,8);
C(:,23)=conVect(7,8,8);
C(:,24)=conVect(8,5,8); s = 20;
%{
% 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
```

```
mhat =

    24


nhat =

    24


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 1.8751e-14.
```

```
c_bars =

    1.2048    1.2048    1.2048    1.2048

No bars under tension.  Good.

t_strings =

  Columns 1 through 7

   -1.2048   -4.8527   -1.2048   -4.8527   -1.2048   -4.8527   -4.8527

  Columns 8 through 14

   -1.2048    2.5000    2.5000    2.5000    2.5000   -4.8527   -4.8527

  Columns 15 through 20

   -4.8527   -4.8527    2.5000    2.5000    2.5000    2.5000

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

Ase is underdetermined with 6 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    4.3541    4.3541    4.3541    4.3541   -3.3619   -3.3619

  Columns 15 through 20

   -3.3619   -3.3619    4.3541    4.3541    4.3541    4.3541

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