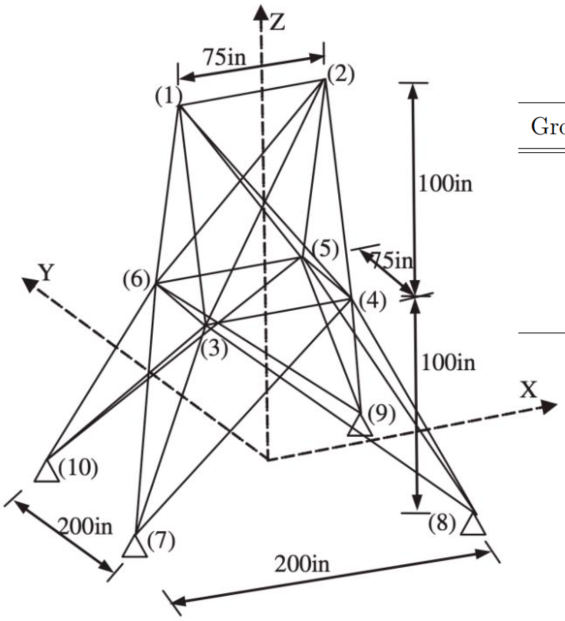


Figure 1: 25-bar Truss

Table 1: Bars membership of the spatial truss

Group Number	Bar Members	Group Number	Bar Members
1	1-2	5	3-4, 5-6
2	1-4, 2-3, 1-5, 2-6	6	3-10, 6-7, 4-9, 5-8
3	2-5, 2-4, 1-3, 1-6	7	3-8, 4-7, 6-9, 5-10
4	3-6, 4-5	8	3-7, 4-8, 5-9, 6-10

Table 2: Loading conditions for the 25-bar spatial truss

Node	F_x (kips)	F_y (kips)	F_z (kips)
1	1.0	-10.0	-10.0
2	0.0	-10.0	-10.0
3	0.5	0.0	0.0
6	0.6	0.0	0.0

1. (50%) Determine the optimal cross sections of all bar members with NO uncertainty. Identify active constraints.

2. (50%) What are the probability of violating active constraints when uncertainties in manufacturing and materials are considered? Please use Monte-Carlo with 1 million samples.

3. (10%) What's the changes in the overall weight when uncertainties are considered?

1. Used files: ***get_cns.m , get_model_result.m , get_obj.m , main.m***

The x result is in this picture:

x

1x8 double

	1	2	3	4	5	6	7	8
1	0.1000	0.3559	3.4643	0.1000	1.8920	0.7870	0.1302	4.0011

Compare to Table 1, we can find different groups of truss members have different cross sections.

group number	bar members	cross section (in^2)
1	1--2	0.1
2	1--4, 2--3, 1--5, 2--6	0.3559
3	2--5, 2--4, 1--3, 1--6	3.4643
4	3--6, 4--5	0.1
5	3--4, 5--6	1.892
6	3--10, 6--7, 4--9, 5--8	0.787
7	3--8, 4--7, 6--9, 5--10	0.1302
8	3--7, 4--8, 5--9, 6--10	4.0011

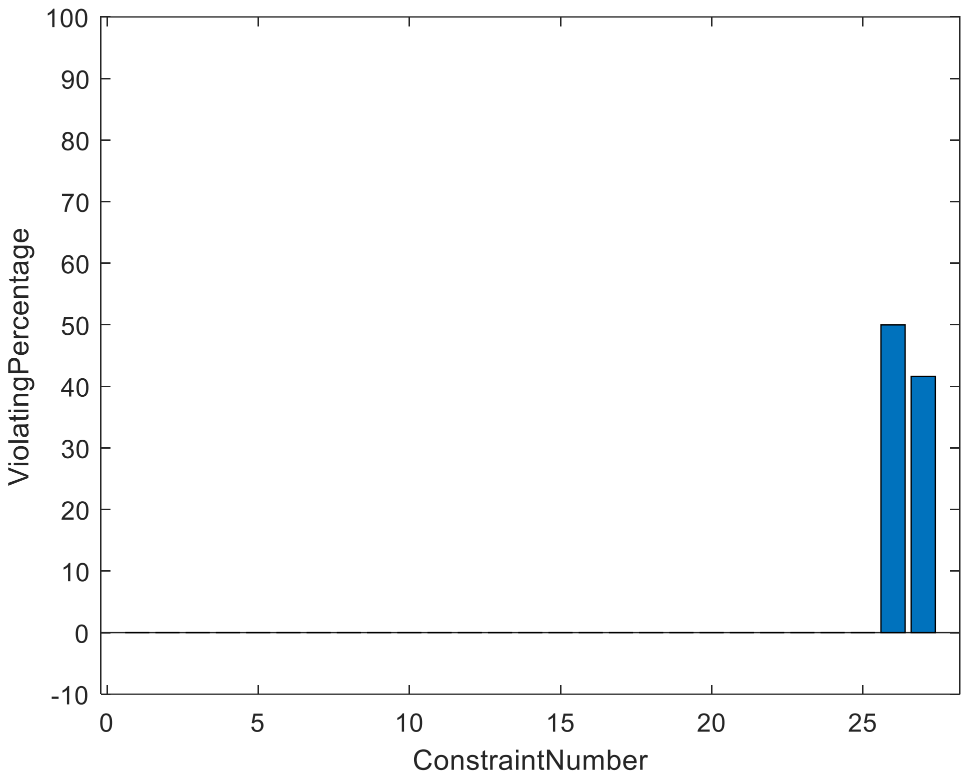
The active constraint is number 26, which is the constraint limits the displacement of node 1 in an allowance value.

```
Active inequalities (to within options.ConstraintTolerance = 1e-06):
  lower      upper      ineqlin    ineqnonlin
    1                                  26
    4
```

2. Used files: ***get_cns.m* , *get_model_result.m* , *get_obj.m* , *main.m* , *hw4_2***

   The probability of violating active constraints:

```
ans =

    'Failure probability using MCS with number 1 constraint is 0 percent '


ans =

    'Failure probability using MCS with number 2 constraint is 0 percent '

                              .
                              .
                              .
ans =

    'Failure probability using MCS with number 26 constraint is 49.982 percent '


ans =

    'Failure probability using MCS with number 27 constraint is 41.626 percent '
```



constraint number	constraint meaning	violating persentage
1	the stress executed on truss 1 should not exceed Yielding point of the material	0%
2	the stress executed on truss 2 should not exceed Yielding point of the material	0%
3	the stress executed on truss 3 should not exceed Yielding point of the material	0%
4	the stress executed on truss 4 should not exceed Yielding point of the material	0%
5	the stress executed on truss 5 should not exceed Yielding point of the material	0%
6	the stress executed on truss 6 should not exceed Yielding point of the material	0%
7	the stress executed on truss 7 should not exceed Yielding point of the material	0%
8	the stress executed on truss 8 should not exceed Yielding point of the material	0%
9	the stress executed on truss 9 should not exceed Yielding point of the material	0%
10	the stress executed on truss 10 should not exceed Yielding point of the material	0%
11	the stress executed on truss 11 should not exceed Yielding point of the material	0%
12	the stress executed on truss 12 should not exceed Yielding point of the material	0%
13	the stress executed on truss 13 should not exceed Yielding point of the material	0%
14	the stress executed on truss 14 should not exceed Yielding point of the material	0%
15	the stress executed on truss 15 should not exceed Yielding point of the material	0%
16	the stress executed on truss 16 should not exceed Yielding point of the material	0%
17	the stress executed on truss 17 should not exceed Yielding point of the material	0%
18	the stress executed on truss 18 should not exceed Yielding point of the material	0%
19	the stress executed on truss 19 should not exceed Yielding point of the material	0%
20	the stress executed on truss 20 should not exceed Yielding point of the material	0%
21	the stress executed on truss 21 should not exceed Yielding point of the material	0%
22	the stress executed on truss 22 should not exceed Yielding point of the material	0%
23	the stress executed on truss 23 should not exceed Yielding point of the material	0%
24	the stress executed on truss 24 should not exceed Yielding point of the material	0%
25	the stress executed on truss 25 should not exceed Yielding point of the material	0%
26	the displacement of node 1 should not exceed the allowable value	50.01%
27	the displacement of node 2 should not exceed the allowable value	41.73%

3. Because the displacements of node 1 & node 2 will exceed the allowance value when considering the uncertainties, the new structure of this twenty-five bars tower should become stronger. Thus, when uncertainties are considered, the overall weight will become heavier.

Files: ***get_cns.m , get_model_result.m , get_obj.m , main.m , hw4_2***

get_cns.m:

```
function [c, ceq] = get_cns(x,E)

[Q, stress] = get_model_result(x,E);

allow_stress = 40000;  % psi
allow_disp = 0.35;  % inch

c(1:25) = abs(stress)/allow_stress - 1.0;

disp = zeros(1,2);
for i = 1:2  % node 1, 2
    disp(i) = sqrt(Q(3*i-2)^2 + Q(3*i-1)^2 + Q(3*i)^2); % total
displacementof node 1,2 =square_root(displacement in x,y,z directions)
end

c = [c, disp./allow_disp - 1.0];
ceq = [];
```

get_model_result.m:

```
function [Q, stress] = get_model_result(x,E)

    %E = 1e7;  %E is young's modulus in psi

    node_coord(1,:) = [-37.5, 0, 200];
    node_coord(2,:) = [37.5, 0, 200];
    node_coord(3,:) = [-37.5, 37.5, 100];
    node_coord(4,:) = [37.5, 37.5, 100];
    node_coord(5,:) = [37.5, -37.5, 100];
    node_coord(6,:) = [-37.5,-37.5,100];
```

```matlab
    node_coord(7,:) = [-100, 100, 0];
    node_coord(8,:) = [100, 100, 0];
    node_coord(9,:) = [100, -100, 0];
    node_coord(10,:) = [-100, -100, 0];  % node coord.

    en_pair = [ ...
        1,2; 1,4; 2,3; 1,5; 2,6; ...
        2,4; 2,5; 1,3; 1,6; 3,6; ...
        4,5; 3,4; 5,6; 3,10; 6,7; ...
        4,9; 5,8; 4,7; 3,8; 5,10; ...
        6,9; 6,10; 3,7; 4,8; 5,9];  % elemenet node pair

    A = [x(1)*ones(1,1); ...
         x(2)*ones(4,1); ...
         x(3)*ones(4,1); ...
         x(4)*ones(2,1); ...
         x(5)*ones(2,1); ...
         x(6)*ones(4,1); ...
         x(7)*ones(4,1); ...
         x(8)*ones(4,1)]';  % element section area

    F = zeros(18,1);
    F(1) = 1;
    F(2) = -10;
    F(3) = -10;
    F(4) = 0;
    F(5) = -10;
    F(6) = -10;
    F(7) = 0.5;
    F(8) = 0;
    F(9) = 0;
    F(16) = 0.6;
    F(17) = 0;
    F(18) = 0;
    F = F*1e3;

    % -- stiffness matrixs
    for i = 1:25
```

```
        ni = en_pair(i,1);
        nj = en_pair(i,2);
        Le(i) = norm( (node_coord(ni,:) - node_coord(nj,:)) );
        cx(i) = (node_coord(ni,1) - node_coord(nj,1)) / Le(i); % x
        cy(i) = (node_coord(ni,2) - node_coord(nj,2)) / Le(i); % y
        cz(i) = (node_coord(ni,3) - node_coord(nj,3)) / Le(i); % z
    end

    K = zeros(30,30);  % stiffness matrix
    for i = 1:25
        ni = en_pair(i,1);
        nj = en_pair(i,2);
        sk = [cx(i), cy(i), cz(i)]'*[cx(i), cy(i), cz(i)];
        tmp = zeros(30,30);
        tmp(3*ni-2:3*ni, 3*ni-2:3*ni) =  sk;
        tmp(3*nj-2:3*nj, 3*nj-2:3*nj) =  sk;
        tmp(3*ni-2:3*ni, 3*nj-2:3*nj) = -sk;
        tmp(3*nj-2:3*nj, 3*ni-2:3*ni) = -sk;
        K = K + E*A(i)/Le(i)*tmp;
    end

    Kr = K(1:18,1:18);  % Reduce matrix of K

    % -- displacement
    Qr = Kr^-1*F;
    Q = [Qr; zeros(12,1)];

    % -- stress
    stress = zeros(1,25);
    for i = 1:25
        ni = en_pair(i,1);
        nj = en_pair(i,2);
        stress(1,i) = ...
            E/Le(i)* ...
            [-1*cx(i), -1*cy(i), -1*cz(i), cx(i), cy(i), cz(i)]* ...
            [Q(ni*3-2); Q(ni*3-1); Q(ni*3); Q(nj*3-2); Q(nj*3-1); Q(nj*3)];
    end
end
```

get_obj.m:

```
function weight = get_obj(x)

    node_coord(1,:) = [-37.5, 0, 200];
    node_coord(2,:) = [37.5, 0, 200];
    node_coord(3,:) = [-37.5, 37.5, 100];
    node_coord(4,:) = [37.5, 37.5, 100];
    node_coord(5,:) = [37.5, -37.5, 100];
    node_coord(6,:) = [-37.5,-37.5,100];
    node_coord(7,:) = [-100, 100, 0];
    node_coord(8,:) = [100, 100, 0];
    node_coord(9,:) = [100, -100, 0];
    node_coord(10,:) = [-100, -100, 0];  % node coord.
    
    en_pair = [ ...
        1,2; 1,4; 2,3; 1,5; 2,6; ...
        2,4; 2,5; 1,3; 1,6; 3,6; ...
        4,5; 3,4; 5,6; 3,10; 6,7; ...
        4,9; 5,8; 4,7; 3,8; 5,10; ...
        6,9; 6,10; 3,7; 4,8; 5,9];  % elemenet's node pair
    
    Le = zeros(1,25);
    for i = 1:25
        ni = en_pair(i,1);
        nj = en_pair(i,2);
        Le(i) = norm( (node_coord(ni,:) - node_coord(nj,:)) );  % element 
length
    end

    A = [x(1)*ones(1,1); ...
         x(2)*ones(4,1); ...
         x(3)*ones(4,1); ...
         x(4)*ones(2,1); ...
         x(5)*ones(2,1); ...
         x(6)*ones(4,1); ...
         x(7)*ones(4,1); ...
         x(8)*ones(4,1)]';
```

```
    D = 0.1;  % density lb/in3
    weight = sum(D*A.*Le);
    
end
```

main.m:

```
% -- 25-bar truss optimization
% -- Units: in-lb-s-lbf-psi

clear
close
clc

E=1e7;
x0 = 1.0*ones(1,8);
lb = 0.1*ones(1,8);
ub = 5.0*ones(1,8);
options = optimoptions('fmincon', 'Display', 'iter', 'Algorithm', 'active-
set');

[x, fval, exitflag] = fmincon('get_obj', x0, [], [], [], [], lb, ub, @(x) 
get_cns(x,E), options);
```

hw4_2:

```
% -- 25-bar truss optimization
% -- Units: in-lb-s-lbf-psi

clear
close
clc

E=1e7;
x0 = 1.0*ones(1,8);
lb = 0.1*ones(1,8);
ub = 5.0*ones(1,8);
options = optimoptions('fmincon', 'Display', 'iter', 'Algorithm', 'active-
set');
```

```
[x, fval, exitflag] = fmincon('get_obj', x0, [], [], [], [], lb, ub, @(x)
get_cns(x,E), options);

mux=x; % you should change to the optimal design you obtained
stdx=0.0052*ones(1,8); % you should change this value according to the
homework descriptions
covX=diag(stdx.^2);

std_E=1e6;
cov_E=std_E.^2;

% Basic MCS

N=1e6;
RandX=mvnrnd(mux, covX, N);
RandE=mvnrnd(E,cov_E,N);

g=zeros(N,27);
for ii=1:N
    [c,ceq]=get_cns(RandX(ii,:),RandE(ii));
    g(ii,:)=c;
end

Nf=zeros(1,27);
for ii=1:27
    Nf(ii)=sum(g(:,ii)>0);
end
pf=Nf/N;

for ii=1:27
    sprintf('Failure probability using MCS with number %d constraint is
%0.5g percent ', ii, pf(ii)*100)
end
bar(pf*100);
xlabel ConstraintNumber
ylabel ViolatingPercentage
ax=gca;
ax.YLim=[-10,100];
```