TOPOLOGY OPTIMIZATION

PROJECT 3 REPORT

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MAE 598: Design Optimization (Fall 2021)

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Under the guidance of

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ACKNOWLEDGEMENT

I consider myself highly fortunate for the opportunity to do this project under the guidance of **YI (MAX) REN** who provided us a sample template code and instructions to work on.

ABSTRACT

In this project, you will learn to implement an optimization algorithm for minimizing the compliance of a cantilever beam with a point load in y direction at its equilibrium state with respect to its topology.

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```
%%%% Modified by Max Yi Ren (ASU) %%%%%%%%%%%%%%%%%%%%%%%%
%%%% AN 88 LINE TOPOLOGY OPTIMIZATION CODE Nov, 2010 %%%%
nelx=300;
nely=150;
volfrac=0.3;
penal=3;
rmin=1.5;
%function Designproject3(nelx,nely,volfrac,penal,rmin,ft)
```

MATERIAL PROPERTIES

```
E0 = 1;
Emin = 1e-9;
nu = 0.3;
```

PREPARE FINITE ELEMENT ANALYSIS

```
A11 = [12  3 -6 -3;  3 12  3  0; -6  3 12 -3; -3  0 -3 12];
A12 = [-6 -3  0  3; -3 -6 -3 -6;  0 -3 -6  3;  3 -6  3 -6];
B11 = [-4  3 -2  9;  3 -4 -9  4; -2 -9 -4 -3;  9  4 -3 -4];
B12 = [ 2 -3  4 -9; -3  2  9 -2;  4  9  2  3; -9 -2  3  2];
KE = 1/(1-nu^2)/24*([A11 A12;A12' A11]+nu*[B11 B12;B12' B11]);
nodenrs = reshape(1:(1+nelx)*(1+nely),1+nely,1+nelx);
edofVec = reshape(2*nodenrs(1:end-1,1:end-1)+1,nelx*nely,1);
edofMat = repmat(edofVec,1,8)+repmat([0 1 2*nely+[2 3 0 1] -2
 -1],nelx*nely,1);
iK = reshape(kron(edofMat,ones(8,1))',64*nelx*nely,1);
jK = reshape(kron(edofMat,ones(1,8))',64*nelx*nely,1);
% DEFINE LOADS AND SUPPORTS (HALF MBB-BEAM)
F = sparse(2,1,-1,2*(nely+1)*(nelx+1),1);
U = zeros(2*(nely+1)*(nelx+1),1);
fixeddofs = union((1:2:2*(nely+1)),(2*(nelx+1)*(nely+1)));
alldofs = (1:2*(nely+1)*(nelx+1));
```

```
freedofs = setdiff(alldofs,fixeddofs);
```

PREPARE FILTER

```
iH = ones(nelx*nely*(2*(ceil(rmin)-1)+1)^2,1);
jH = ones(size(iH));
sH = zeros(size(iH));
k = 0;
for i1 = 1:nelx
    for j1 = 1:nely
        e1 = (i1-1)*nely+j1;
        for i2 = max(i1-(ceil(rmin)-1),1):min(i1+(ceil(rmin)-1),nelx)
            for j2 = max(j1-(ceil(rmin)-1),1):min(j1+(ceil(rmin)-1),nely)
                e2 = (i2-1)*nely+j2;
                k = k+1;
                iH(k) = e1;
                jH(k) = e2;
                sH(k) = max(0,rmin-sqrt((i1-i2)^2+(j1-j2)^2));
            end
        end
    end
end
H = sparse(iH,jH,sH);
Hs = sum(H,2);
```

INITIALIZE ITERATION

```
x = repmat(volfrac,nely,nelx);
xPhys = x;
loop = 0;
change = 1;
```

START ITERATION

```
while change > 0.01

    loop = loop + 1;
```

FE-ANALYSIS

```
    sK= reshape(KE(:)*(Emin+xPhys(:)'.^penal*(E0-Emin)),64*nelx*nely,1);
    K = sparse(iK,jK,sK); K = (K+K')/2;
    U(freedofs) = K(freedofs,freedofs)\F(freedofs);
```

OBJECTIVE FUNCTION AND SENSITIVITY ANALYSIS

```
    ce = reshape(sum((U(edofMat)*KE).*U(edofMat),2),nely,nelx); % element-wise
 strain energy
```

```
    c  = sum(sum((Emin+xPhys.^penal*(E0-Emin)).*ce)); % total strain energy
    dc = -penal*(E0-Emin)*xPhys.^(penal-1).*ce; % design sensitivity
    dv = ones(nely,nelx);
```

FILTERING/MODIFICATION OF SENSITIVITIES

```
ft=heaviside(x);
    if ft == 2
        dc(:) = H*(x(:).*dc(:))./Hs./max(1e-3,x(:));
    elseif ft == 3
        dc(:) = H*(dc(:)./Hs);
        dv(:) = H*(dv(:)./Hs);
    end
```

OPTIMALITY CRITERIA UPDATE OF DESIGN VARIABLES AND PHYSICAL DENSITIES

```
    l1 = 0; l2 = 1e9; move=0.2;
    while (l2-l1)/(l1+l2) > 1e-3
        lmid = 0.5*(l2+l1);
        xnew = max(0,max(x-move,min(1,min(x+move,x.*sqrt(-dc./dv/lmid)))));
        if ft == 1
            xPhys = xnew;
        elseif ft==2
            xPhys(:) = (H*xnew(:))./Hs;
        end
        if sum(xPhys(:)) > volfrac*nelx*nely, l1 = lmid;
        else
            l2 = lmid;
        end
    end
    change = max(abs(xnew(:)-x(:)));
    x = xnew;
```

PRINT RESULTS

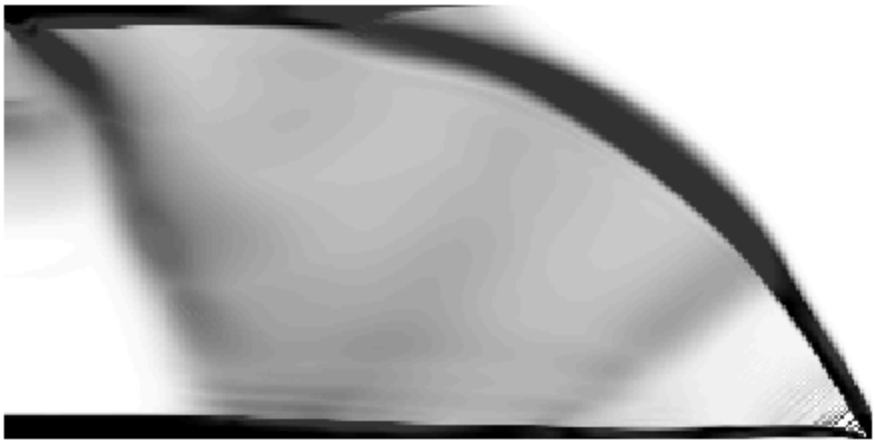
```
    fprintf(' It.:%5i Obj.:%11.4f Vol.:%7.3f ch.:%7.3f\n',loop,c, ...
        mean(xPhys(:)),change);
```

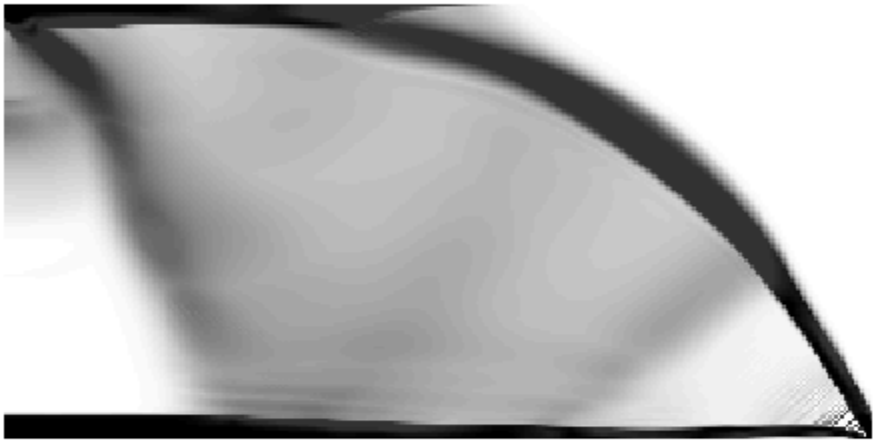
```
 It.:    1 Obj.:  2018.6979 Vol.:  0.300 ch.:  0.200
 It.:    2 Obj.:  1051.4536 Vol.:  0.300 ch.:  0.200
 It.:    3 Obj.:   719.4513 Vol.:  0.300 ch.:  0.200
 It.:    4 Obj.:   544.0387 Vol.:  0.300 ch.:  0.200
 It.:    5 Obj.:   446.0797 Vol.:  0.300 ch.:  0.200
 It.:    6 Obj.:   384.1671 Vol.:  0.300 ch.:  0.200
 It.:    7 Obj.:   343.3330 Vol.:  0.300 ch.:  0.200
```

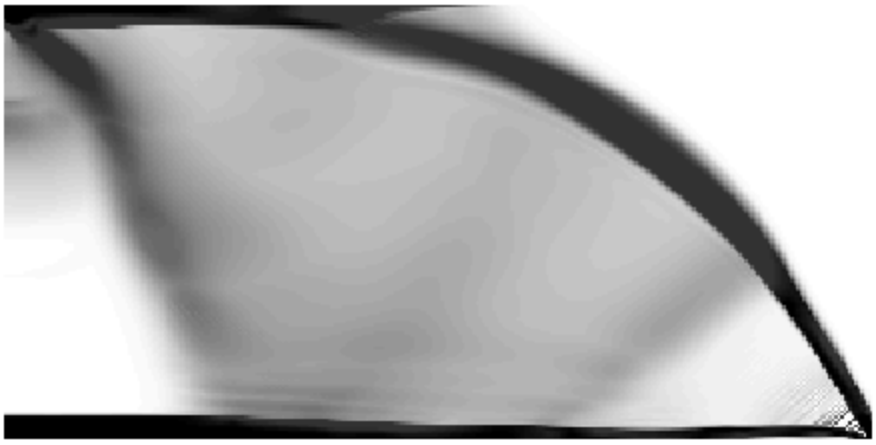
```
It.:    8 Obj.:   309.5958 Vol.:  0.300 ch.:  0.200
It.:    9 Obj.:   281.9777 Vol.:  0.300 ch.:  0.200
It.:   10 Obj.:   281.9777 Vol.:  0.300 ch.:  0.200
It.:   11 Obj.:   297.3464 Vol.:  0.300 ch.:  0.200
It.:   12 Obj.:   297.3464 Vol.:  0.300 ch.:  0.200
It.:   13 Obj.:   298.3209 Vol.:  0.300 ch.:  0.200
It.:   14 Obj.:   298.3209 Vol.:  0.300 ch.:  0.200
It.:   15 Obj.:   298.3209 Vol.:  0.300 ch.:  0.200
It.:   16 Obj.:   298.3209 Vol.:  0.300 ch.:  0.200
It.:   17 Obj.:   298.3209 Vol.:  0.300 ch.:  0.200
It.:   18 Obj.:   298.3209 Vol.:  0.300 ch.:  0.000
```

PLOT DENSITIES

```
   colormap(gray); imagesc(1-xPhys); caxis([0 1]); axis equal; axis off;
drawnow;
```







```
end
```

Published with MATLAB® R2021b

References:

1. Efficient topology optimization in MATLAB using 88 lines of code- Erik Andreassen, Anders Clausen, Mattias Schevenels, Boyan S. Lazarov, Ole Sigmund.
2. A 99 line topology optimization code written in Matlab - Ole Sigmond.
3. Topology optimization tutorial – Yi (Max) Ren.