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%%%% A 99 LINE TOPOLOGY OPTIMIZATION CODE BY OLE SIGMUND, JANUARY 2000 %%%
%%%% CODE MODIFIED FOR INCREASED SPEED, September 2002, BY OLE SIGMUND %%%
nelx = 30; % Example values, adjust as needed
nely = 10;
volfrac = 0.5;
penal = 3.0;
rmin = 1.5;

% INITIALIZE
x(1:nely, 1:nelx) = volfrac;
loop = 0;
change = 1.;

% START ITERATION
while change > 0.01
    loop = loop + 1;
    xold = x;

    % FE-ANALYSIS
    [U, K] = FE(nelx, nely, x, penal); % Capture K matrix from FE

    % OBJECTIVE FUNCTION AND SENSITIVITY ANALYSIS
    [KE] = lk;
    c = 0.;
    for ely = 1:nely
        for elx = 1:nelx
            n1 = (nely+1)*(elx-1) + ely;
            n2 = (nely+1)*elx + ely;
            Ue = U([2*n1-1; 2*n1; 2*n2-1; 2*n2; 2*n2+1; 2*n2+2; 2*n1+1;
2*n1+2], 1);
            c = c + x(ely, elx)^penal * Ue' * KE * Ue;
            dc(ely, elx) = -penal * x(ely, elx)^(penal-1) * Ue' * KE * Ue;
        end
    end

    % FILTERING OF SENSITIVITIES
    [dc] = check(nelx, nely, rmin, x, dc);

    % DESIGN UPDATE BY THE OPTIMALITY CRITERIA METHOD
    [x] = OC(nelx, nely, x, volfrac, dc);

    % PRINT RESULTS
    change = max(max(abs(x - xold)));
    disp([' It.: ' sprintf('%4i', loop) ' Obj.: ' sprintf('%10.4f', c) ...
          ' Vol.: ' sprintf('%6.3f', sum(sum(x)) / (nelx * nely)) ...
          ' ch.: ' sprintf('%6.3f', change)])

    % PLOT DENSITIES (if needed)
    colormap(gray); imagesc(-x); axis equal; axis tight; axis off;
pause(1e-6);
end
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%%%%%%%%%% OPTIMALITY CRITERIA UPDATE %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [xnew]=OC(nelx,nely,x,volfrac,dc)
l1 = 0; l2 = 100000; move = 0.2;
while (l2-l1 > 1e-4)
  lmid = 0.5*(l2+l1);
  xnew = max(0.001,max(x-move,min(1.,min(x+move,x.*sqrt(-dc./lmid)))));
  if sum(sum(xnew)) - volfrac*nelx*nely > 0
    l1 = lmid;
  else
    l2 = lmid;
  end
end
end
%%%%%%%%%% MESH-INDEPENDENCY FILTER %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [dcn]=check(nelx,nely,rmin,x,dc)
dcn=zeros(nely,nelx);
for i = 1:nelx
  for j = 1:nely
    sum=0.0;
    for k = max(i-floor(rmin),1):min(i+floor(rmin),nelx)
      for l = max(j-floor(rmin),1):min(j+floor(rmin),nely)
        fac = rmin-sqrt((i-k)^2+(j-l)^2);
        sum = sum+max(0,fac);
        dcn(j,i) = dcn(j,i) + max(0,fac)*x(l,k)*dc(l,k);
      end
    end
    dcn(j,i) = dcn(j,i)/(x(j,i)*sum);
  end
end
end
%%%%%%%%%% FE-ANALYSIS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [U, K] = FE(nelx, nely, x, penal)
    [KE] = lk;
    K = sparse(2*(nelx+1)*(nely+1), 2*(nelx+1)*(nely+1));
    F = sparse(2*(nely+1)*(nelx+1), 1);
    U = zeros(2*(nely+1)*(nelx+1), 1);

    for elx = 1:nelx
        for ely = 1:nely
            n1 = (nely+1)*(elx-1) + ely;
            n2 = (nely+1)*elx + ely;
            edof = [2*n1-1; 2*n1; 2*n2-1; 2*n2; 2*n2+1; 2*n2+2; 2*n1+1;
2*n1+2];
            K(edof, edof) = K(edof, edof) + x(ely, elx)^penal * KE;
        end
    end
% DEFINE LOADS AND SUPPORTS (HALF MBB-BEAM)
F(2, 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);

    % SOLVING
    U(freedofs, :) = K(freedofs, freedofs) \ F(freedofs, :);
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    U(fixeddofs, :) = 0;
end
%%%%%%%%%% ELEMENT STIFFNESS MATRIX %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [KE]=lk
E = 1.;
nu = 0.3;
k=[ 1/2-nu/6   1/8+nu/8 -1/4-nu/12 -1/8+3*nu/8 ...
   -1/4+nu/12 -1/8-nu/8  nu/6       1/8-3*nu/8];
KE = E/(1-nu^2)*[ k(1) k(2) k(3) k(4) k(5) k(6) k(7) k(8)
                  k(2) k(1) k(8) k(7) k(6) k(5) k(4) k(3)
                  k(3) k(8) k(1) k(6) k(7) k(4) k(5) k(2)
                  k(4) k(7) k(6) k(1) k(8) k(3) k(2) k(5)
                  k(5) k(6) k(7) k(8) k(1) k(2) k(3) k(4)
                  k(6) k(5) k(4) k(3) k(2) k(1) k(8) k(7)
                  k(7) k(4) k(5) k(2) k(3) k(8) k(1) k(6)
                  k(8) k(3) k(2) k(5) k(4) k(7) k(6) k(1)];
end
% Total it takes 72 iteration.
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 It.:   35 Obj.:   229.7230 Vol.:  0.500 ch.:  0.018
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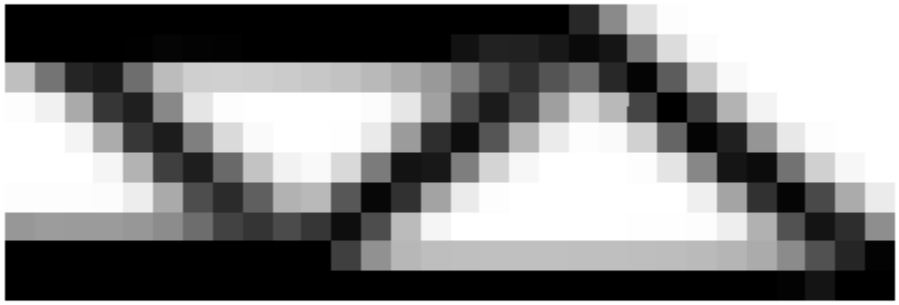

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