Project 3 Documentation

Problem

In this project, the 88 line MATLAB code for topological optimization will be modified to solve a structural optimization problem with different boundary and loading conditions. The optimization problem aims to minimize the compliance or deflection of a rectangular structure while meeting a volume constraint and equality condition. The structure is divided into square elements all with the same element stiffness matrices. Each element has a density that can range from 0 to 1.

$$\min_{x}: \ c(x) = U^T K U$$

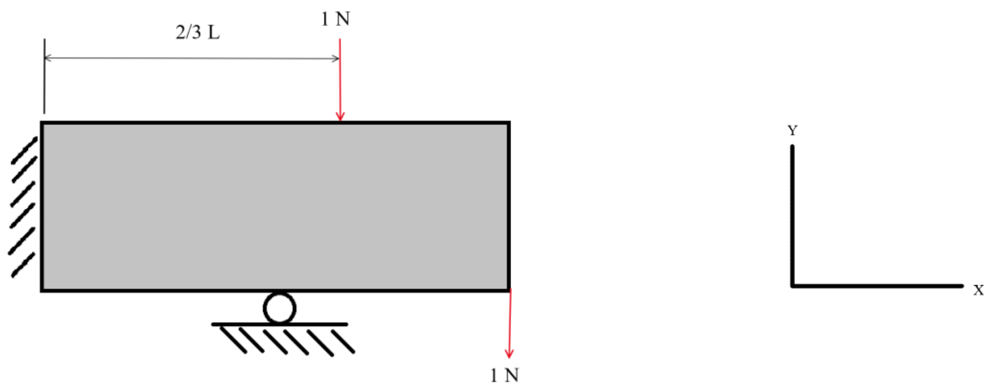
$$g := \frac{V(x)}{V_0} = f$$

$$h := KU = F$$

$$x_e \in [0,1]$$

where,
c(x) is the compliance,
U is the global displacement,
K is the global stiffness matrix,
V(x) is the material volume,
V_0 is the design domain volume,
f is the volume fraction,
F is the force vector, and
x_e is the density of an element

Support and Loading Conditions



Dimensions:122 by 40 elements

Supports: (1) Fixed support on left side, (2) Rolling support at bottom center

Forces: (1) to simulate a distributed load, a 1N force was applied at 2/3 the length of the structure, (2) 1N force at the bottom right corner

```
% DEFINE LOADS AND SUPPORTS
F = sparse([2*(nely+1)*((2/3)*(nelx+1))-(2*nely),2*(nely+1)*(nelx+1)], …
[1 2],[-1 -1],2*(nely+1)*(nelx+1),2); %force on top at 2/3L and bottom right
% F = sparse(2*(nely+1)*(nelx+1),1,-1,2*(nely+1)*(nelx+1),1); % 1 Force
U = zeros(2*(nely+1)*(nelx+1),2);
fixeddofs = union([1:2*(nely+1)],[((nelx/2)+1)*(nely+1)]); %left side fixed,
rolling bottom center
alldofs = [1:2*(nely+1)*(nelx+1)];
freedofs = setdiff(alldofs,fixeddofs);
```

Material Properties

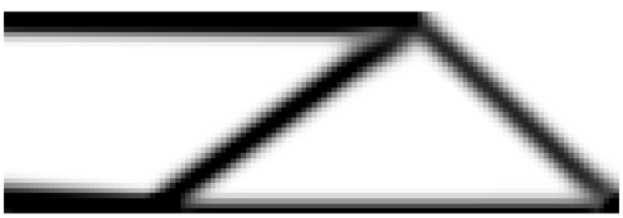
```
%% MATERIAL PROPERTIES
E0 = 2; % Modulus of Elasticity for Low Alloy Steel = 2.0*10^11 Pa
Source:AmesWeb
Emin = 1e-9; % Minimum E assigned to void regions to prevent singularities
nu = 0.3; % Poisson's ratio for steel
```

Results

Optimized structure for various prescribed volumes:

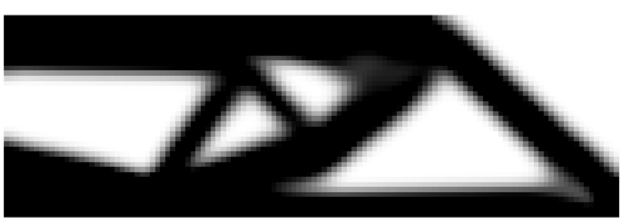
$V(x)/V_0$ =

f = 0.25



f = 0.5

f = 0.6



f = 0.7

When f = 0.7, the optimized structure does not provide a meaningful position as seen by the blurry region. This can somewhat be improved by reducing the filter radius at the cost of increased computation time for each iteration. Although slightly improved, the solution is not practical for manufacturing. Additionally at a certain point, the checkerboard pattern will emerge which is a mathematically sound, but impractical solution.

f = 0.7 after reducing the filter radius from 3 to 2:

f = 0.7 after reducing the filter radius to 1.5:

f = 0.7 after reducing the filter radius to 1:

Note: The sensitivity filter (not the density filter) was used for the above simulations.