Project 1

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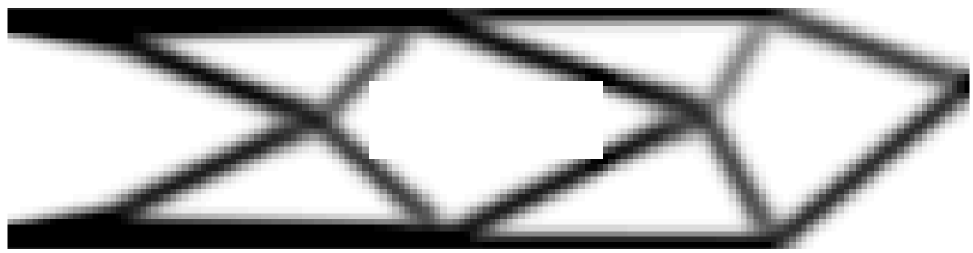
Code Explanation:

- My student number is 1010188967, which implies that according to the problem statement, A = 9, B = 6 and C = 7.
- According to Sigmund's 99-line code, through heuristic approaches, I have concluded that to achieve a reasonable speed of optimization, the number of elements need to be less than 7000.
- To achieve the number of elements to be less than 7000, I need to use a scaling factor of 2.5 and mathematically change the size of each element to represent a 2.5cm by 2.5cm square.
- When applying the scaling factor of 2.5, the placement of the hole based on the previous variable definition yields modified nodal positions in decimal values.
- Hence, I have approximated the value of variable B to 5 from 6, to ensure that I am able to maintain code accuracy.
- We are using passive elements to create void spaces within the structure, a few lines of code that we introduce to Sigmund's 99 line code will place the hole and ensure that the location mentioned are not filled in while the iterations of the topology optimization is carried out. To achieve the same, we mention the density to be 0.001.
- In addition, I have updated Sigmund's code with all the computations I have performed and hence, with a quick change in variable B, the approximate results for my student number is achievable.
- To achieve the exact values of displacement, I have multiplied the thickness value to the stiffness matrix. Here, I have applied the scaling factor to the thickness to ensure that the output displacement values represent the physical system accurately.
- To retrieve the nodal location for force application, I have subtracted the value of y position from the total degree of freedom, and computed the x and y displacement values.

Output:



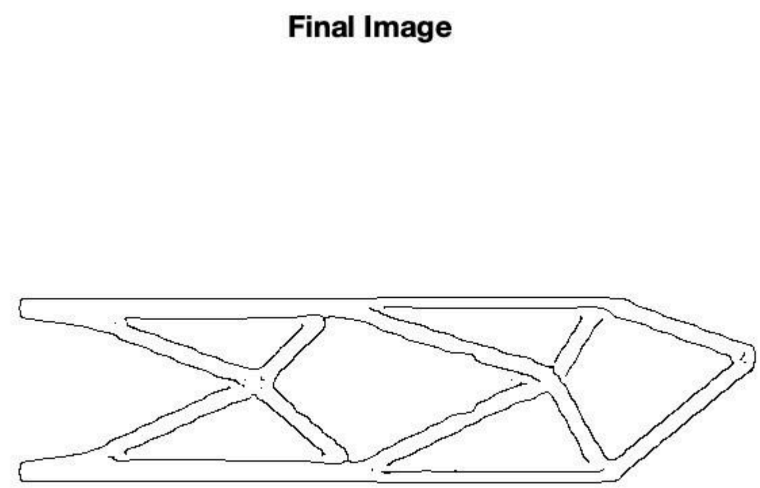
Problematic features:

- The stairsteps in the design are problematic, as they interrupt the smooth and continuous design that can be manufacturable. It's tricky to optimize material distribution when we have these breaks in the structure.
- We're finding that there are many areas of intermediate density throughout the design. It is physically impossible to manufacture a design that has intermediate densities. They're adding complexity to the structure that needs to be addressed heuristically with intermediate densities.
- The hole location proves a challenge to manufacturing the output, as they create sharp edges in the optimized output. This disrupts the structure's flow and makes it harder to optimize how material is distributed around them. Also, this result will increase stress acting on the members and lead to failure upon application of load to the members.
- In some places in the design, the cross-sections of the members are not evenly thick. They're throwing off the natural progression of the structure, making it harder to optimize for both strength and weight while maintaining structural integrity.

Displacement:

- Assuming the cantilever is made of aluminium 7075-T6 and the load P is 15 kN, the deflection at the point at which the load P is applied is
    - X-displacement : -0.0291 cm (towards fixed support)
    - Y-displacement : -0.41 cm (downwards - towards earth)
- This computation is concluded by applying values of
    - Young's modulus, E = 71.7 GPa
    - Poisson's ratio, nu = 0.33

Drawing of manufacturable output:



- Using a matlab code with pre-existing functions to draw a manufacturable output.

```
% Read an image
I = imread('finaloutput.png');
% Convert the image to grayscale
I_gray = rgb2gray(I);
% Apply Gaussian smoothing
I_smoothed = imgaussfilt(I_gray, 2); % Standard deviation of 2 for smoothing
% Use the Canny edge detector
BW = edge(I_smoothed, 'Canny');
% Close gaps in the edges
BW_closed = bwmorph(BW, 'close');
```

```
% Invert the image
BW_inverted = imcomplement(BW_closed);
% Create a new image with black lines on white background
final_image = uint8(255 * BW_inverted);
% Display the final image
imshow(final_image);
title('Final Image');
```

- To manufacture the output, I will utilise metal additive manufacturing and specify a thickness of 10mm for the same.
- Further, to ensure that the resulting structure is manufacturable, I will apply tolerances of 1mm to the design and then start the manufacturing process.

Custom Mesh and Heaviside Filter:

- We tweaked the mesh to match the beam's contours, setting values differently within and outside the hole, all without resorting to passive elements. This was achieved using if-else loops and specific limits to define the hole's boundaries.
- The Heaviside filter was a game-changer, refining the final outcome by smoothing out the rough edges and minimizing stair-step defects. While not flawless, it provided clearer design cues, though additional post-processing is necessary for manufacturing readiness.
- Customizing the mesh to fit the beam's shape, we distinguished values within and outside the hole without the need for passive elements. This process involved using if-else loops and clear-cut limits to define the hole's parameters.
- With the Heaviside filter in place, we polished the final result and reduced stair-step issues. Though not perfect, it offered better design clarity, although we still need to fine-tune it for manufacturing purposes.
- We fine-tuned the mesh to match the beam's form, assigning values differently inside and outside the hole, all without resorting to passive elements. This method utilized if-else loops and set boundaries to pinpoint the hole's location.