ME-504: Course Project

Consider the case of a cantilever beam subjected to point load at random locations(Fig 1). The structure is divided into NxN grid elements as shown in Figure 2. The beam of different topologies can be created by randomly generating the holes at the various grid points.

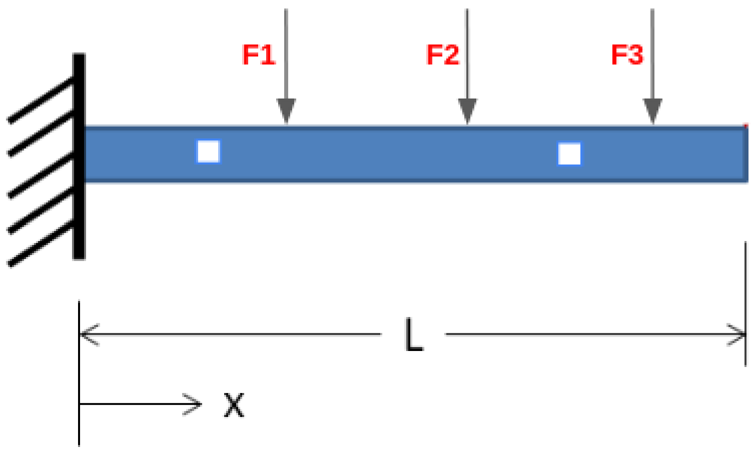


Fig 1: Cantilever Beam

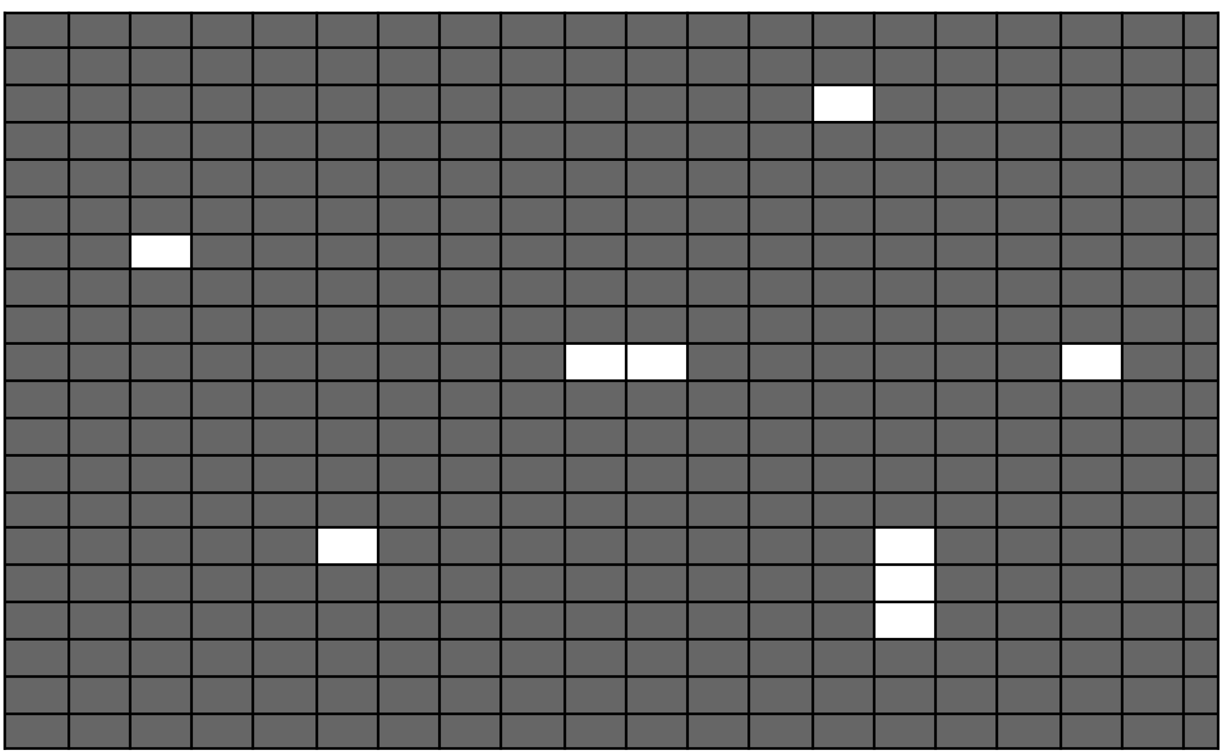


Fig 2: A random topology of the beam.

Variant 1: Consider a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the positions, sizes, and quantities of the holes in a random manner. 1) Use CNN to predict the tip displacement of the beam and compare its performance with ANN. 2) Now, explore the use of any unsupervised technique to reduce the data requirement.

Variant 2: Consider a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the positions, sizes, and quantities of the holes in a random manner. Use DeepOnet to predict the displacement field and compare its performance with ANN.

Variant 3: Consider a configuration with three point load of known magnitude at fixed locations on top of the beam. Generate the random topologies of the beam by altering the positions of the holes in a random manner. Use CNN to predict the stress hotspot.

Variant 4: Consider a configuration with three point load of known magnitude at fixed locations on top of the beam. Generate the random topologies of the beam by altering the positions of the holes in a random manner. 1) Use CNN to predict the maximum displacement of the beam. 2) Now, explore the use of active learning to improve the accuracy of CNN's prediction.

Variant 5: Consider a configuration with three point load of known magnitude at fixed locations on top of the beam. Generate the random topologies of the beam by altering the positions of the holes in a random manner. Use CNN to predict the displacement field and compare its performance with UNet.

Variant 6: Consider three fixed forces of the known magnitude. Generate the random topologies of the beam by altering the positions, sizes, and quantities of the holes in a random manner. 1) Train a CNN network to predict the displacement of the beam. 2) Now allow any one force to vary in magnitude and location and predict the displacement of the beam. Carry out the same thing for the maximum stress in the beam.

Variant 7: Consider three fixed forces of the known magnitude. Generate the random topologies of the beam by altering the positions, sizes, and quantities of the holes in a random manner. 1) Train a CNN network to predict the displacement of the beam. 2) Now allow any two forces to vary in magnitude and location and predict the displacement of the beam. Carry out the same thing for the maximum stress in the beam.

Variant 8: Consider three fixed forces of the known magnitude. Generate the random topologies of the beam by altering the positions, sizes, and quantities of the holes in a random manner. 1) Train a CNN network to predict the displacement of the beam. 2) Now allow the three forces to vary in magnitude and location and predict the displacement of the beam. Carry out the same thing for the maximum stress in the beam.

Variant 9: Consider a beam configuration with two rectangular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the position and size of the holes in a random manner. Generate the displacement field for these random configurations and use this to predict the size and position of holes.

Variant 10: Consider a beam configuration with two rectangular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the position and size of the holes in a random manner. Generate the stress field for these random configurations and use this to predict the size and position of holes.

Variant 11: Consider a beam configuration with three rectangular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the position and size of the holes in a random manner. Generate the displacement field for these random configurations and use this to predict the size and position of holes.

Variant 12: Consider a beam configuration with three rectangular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the position and size of the holes in a random manner. Generate the stress field for these random configurations and use this to predict the size and position of holes.

Variant 13: Consider a beam configuration with two circular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the position and size of the holes in a random manner. Generate the displacement field for these random configurations and use this to predict the size and position of holes.

Variant 14: Consider a beam configuration with two circular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the position and size of the holes in a random manner. Generate the stress field for these random configurations and use this to predict the size and position of holes.

Variant 15: Consider a beam configuration with three circular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the position and size of the holes in a random manner. Generate the displacement field for these random configurations and use this to predict the size and position of holes.

Variant 16: Consider a beam configuration with three circular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the position and size of the holes in a random manner. Generate the stress field for these random configurations and use this to predict the size and position of holes.

Variant 17: Consider a beam configuration with circular holes with a single point load of known magnitude at the top right end of the beam. Generate the random topologies of the beam by altering the number, position, and size of the holes in a random manner. 1) Use CNN to predict the displacement field. 2) Now, explore the use of ensemble and bootstrap techniques to improve the predictions.

Variant 18: Consider the duffing oscillator problem, which is governed by the ODE:

$$\ddot{x} + \gamma \dot{x} + \left(\beta x^3 + \omega_0^2 x\right) = A \cos(\omega t + \phi).$$

Fix the system constraints γ, β, ω_0, and ω along with x(t=0) and x’(t=0). Now generate the velocity and displacement field at random timesteps on an interval of your choice. Use RNN to predict the displacement and compare the result with ANN.

FEM CODE:

So in order to run the FEM analysis, we need to provide the material properties of each cell (element). In the case of the holes, you have to provide zero on that element. The properties can be provided to the analysis code through the file:

“femcode(DL_executed)\cont_ver2\Prop.dat“

Note: This file will be different for all the iterations and must be replaced every time the code runs.

(write python code for generating this file)

- For variation of properties- Prop.dat

E6	E12	–			–
E5	E11	–			
E4	E10	—-			
E3	E9	—			
E2	E8	—			
E1	E7	E3			

E = elastic modulus

```
         1          101          Types of material , number of constant needed to define that material|100 elastic modulus , 1 poisson ratio
  7.00000010E+10                 E1
  7.00000010E+10                 E2
  7.00000010E+10                 E3
  7.00000010E+10                 E4
  7.00000010E+10         .       .
  7.00000010E+10         .       .
  7.00000010E+10         .       .
  7.00000010E+10         .       .
  7.00000010E+10         .       .
  7.00000010E+10         .       .
  7.10000003E+10
  7.00000010E+10
  7.00000010E+10
  7.00000010E+10
  7.00000010E+10
```

```
  7.00000010E+10
  7.10000003E+10                 E98
  7.00000010E+10                 E99
  7.00000010E+10                 E100
 0.30000000                      Poisson ratio
          0          0          0          0          0          0          0
```

```
          0          0          0          0          0          0
```

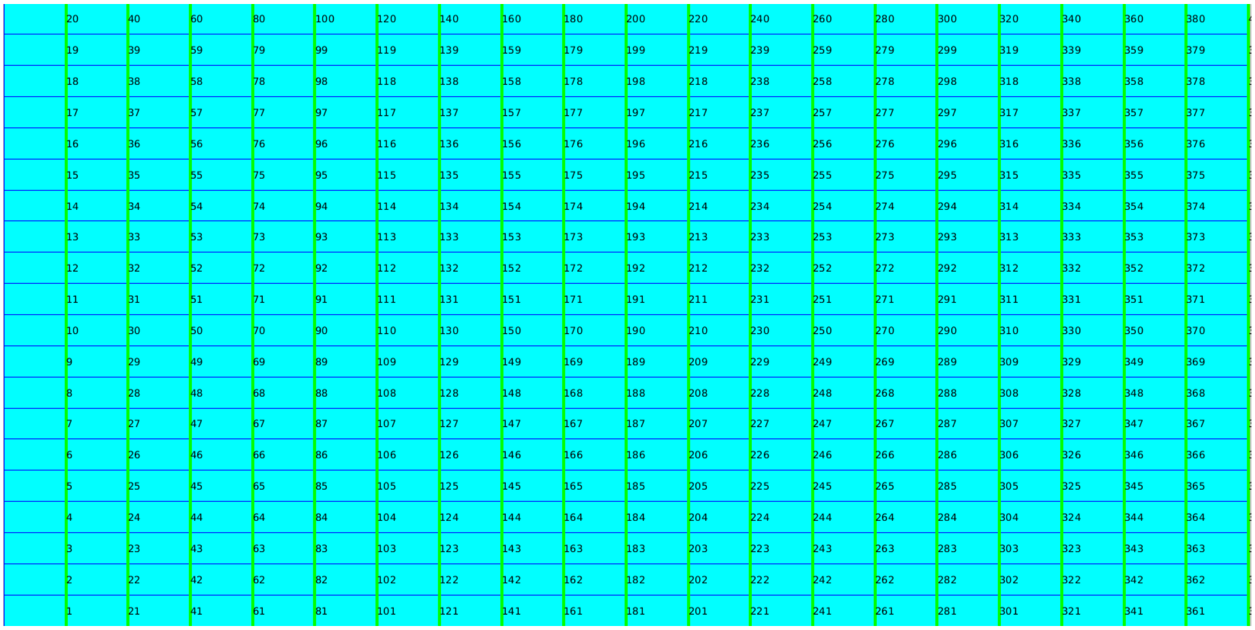
- For the loading, you have to provide force at the nodes of the structure using the file load.dat

  “femcode(DL_executed)\cont_ver2\load.dat“

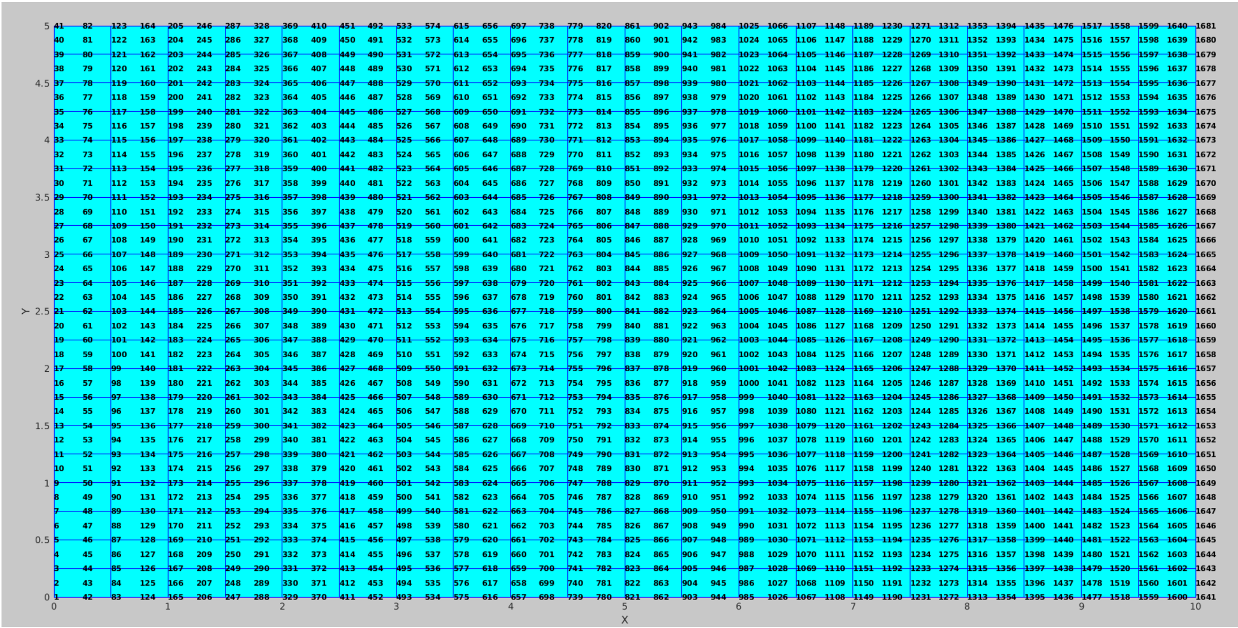
```
1681   0.00   5.00E+05   0.00E+00
1641   0.00   5.00E+05   0.00E+00
0   0   0   0
```

Where 1681, 1641 are the node numbers on which load is acting and 5.00e5 are the magnitude of the load.

Note: you have to keep 0 line below always to keep the format the same of the file.



Element number for the beam



Node number for the beam

- While running the command first time run the command:
  "**sudo apt-get install libomp-dev**"
- Open the terminal in that folder and
  Run this code - "**./main.e > shape**"

```
numeric@numeric-OptiPlex-5090:~/Documents/femcode(DL)/cont_ver2$ ./main.e > shape
```

- Output files

You'll find these files in the same folders:

1. displacement **"femcode(DL_executed)\cont_ver2\displacement"**
2. Stressnode **"femcode(DL_executed)\cont_ver2\stressnode"**