ME 471/AE 420/CSE 451: Programming Assignment 2
Spring 2016

Due: Friday, February 19, 2016 at 11:59pm (subversion)

General Instructions for Programming Assignments

To complete your submission, follow the steps below:

1. Go to your working directory (for example, cd ME471-Programming-Assignments)
2. Download assignment

   (svn checkout https://subversion.ews.illinois.edu/svn/sp16-me471/your_netid/Assignment-Folder-Name)
3. Write your FEA code
4. In case you create new files (.m, .cpp, .h), you will need to use svn add (svn add schedule files and directories in your working copy for addition to the repository.)
5. Upload the changes (svn commit -m "COMMIT_MESSAGE")

<u>Before you commit your work, make sure all the files are following these guidelines:</u>

1. Matlab users:
   (a) Do not change the name of the main file. The grading script will execute this file.
   (b) Do not modify the following lines in the main file:
   // ================================
   // DO NOT MODIFY THE LINE BELOW!! //Autograding script will search for this variable definition
   filename = 'input.dat';
   // ================================
   Of course, you are free to modify the name of the input file when working on your local machine, but make sure the filename variable is set to 'input.dat' before you commit.
   (c) Do not delete the contents of the C-Code folder (mainly the Makefile file)
2. For C++ users:
   (a) Do not modify the variable EXENAME inside the Makefile. The grading script will execute the file defined by EXENAME.
   (b) Do not modify the following lines in the main file:
   // ================================
   // DO NOT MODIFY THE LINE BELOW!! //Autograding script will search for this variable definition
   string filename = "input.dat";
   // ================================
   Of course, you are free to modify the name of the input file when working on your local machine, but make sure the filename variable is set to 'input.dat' before you commit.

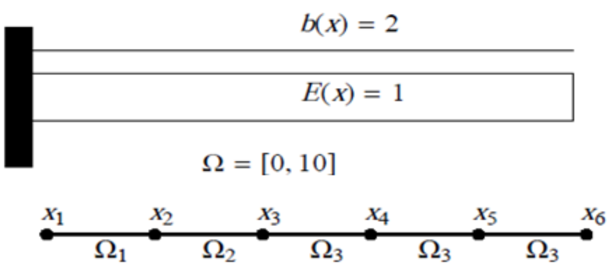
3. Do not modify the “PrintOutput” function. This will ensure your assignment will be graded properly.

It is good practice to commit regularly and frequently. For example, commit when you are done writing a function. This allows both simpler commit messages and greater confidence in the repository.

Part 1: required to all students

Download (checkout) the assignment folder **02-FEA-1D**. Modify your spring finite element program to approximate the response of a one-dimensional elastostatic system, as discussed in lecture 11. For this assignment, we assume:

- element-wise uniform body load
- element-wise uniform elasticity modulus
- domain with uniform cross-sectional area
- linear elements (use linear shape functions)



input.dat

```
6   5   0   1
0.0
2.0
4.0
6.0
8.0
10.0
1   2   1.0 2.0
2   3   1.0 2.0
3   4   1.0 2.0
4   5   1.0 2.0
5   6   1.0 2.0
1   0.0
```

Before solve module

$$
\begin{aligned}
KPP &= 0.5 \\
KPF &= \begin{bmatrix} -0.5 & 0. & 0. & 0. & 0. \end{bmatrix} \\
KFF &= \begin{bmatrix} 1. & -0.5 & 0. & 0. & 0. \\ -0.5 & 1. & -0.5 & 0. & 0. \\ 0. & -0.5 & 1. & -0.5 & 0. \\ 0. & 0. & -0.5 & 1. & -0.5 \\ 0. & 0. & 0. & -0.5 & 0.5 \end{bmatrix} \\
PP &= 2 \\
PF &= \begin{bmatrix} 4. \\ 4. \\ 4. \\ 4. \\ 2. \end{bmatrix}
\end{aligned}
$$

After solve module

$$
\begin{aligned}
UUR &= \begin{bmatrix} 0. \\ 36. \\ 64. \\ 84. \\ 96. \\ 100. \end{bmatrix} = \begin{Bmatrix} U^p \\ \mathbf{U}^f \end{Bmatrix} \\
PUR &= \begin{bmatrix} 20. \\ 4. \\ 4. \\ 4. \\ 4. \\ 2. \end{bmatrix} = \begin{Bmatrix} P^p \\ \mathbf{P}^f \end{Bmatrix}
\end{aligned}
$$

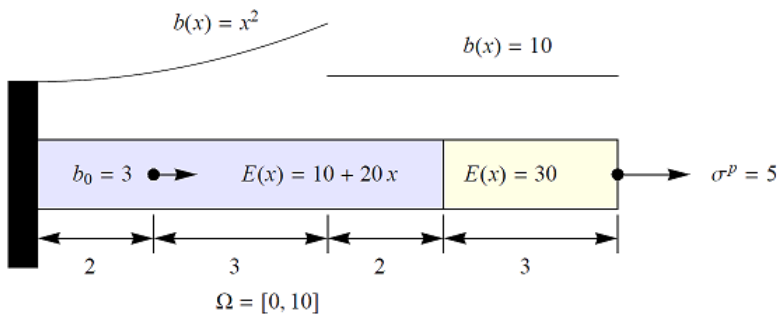
Figure 1: 1D rod example solved in lecture

Your program should read a file named "input.dat" that is structured in the same way as presented in the lecture example. The program should use the same "PrintOutput" function used for the Spring code. Submit your complete code (svn commit) following the guidelines explained above.

You should be able to reproduce the results depicted in Figures 1 and 2. Note that for the problem of Figure 2, $E(x)$ and $b(x)$ are not uniform inside the domain Ω and therefore violates the first two assumptions above. However, when placing the nodes at the discontinuity sites (here at $x = 0, 2, 5, 7, 10$), we can define the element-wise average E_i and b_i such that

$$E_i = \frac{1}{h_i}\int_{\Omega_i} E(x)dx \text{ and } b_i = \frac{1}{h_i}\int_{\Omega_i} b(x)dx$$

and h_i is the element size. You can evaluate these integrals by hand, or using computer software. Then update the input.dat file, so that instead of E_1, b_1,..., you should write the computed quantities. Similar to PA1, we will be checking your code using a different 1D rod configuration that satisfies the assumptions above.



Nodal displacements

```
0.00000000
6.55553333
9.34928333
10.04159103
12.04159103
```

Input.dat

```
5    4    2    1
0.0
2.0
5.0
7.0
10.0
1    2    E1   b1
2    3    E2   b2
3    4    E3   b3
4    5    E4   b4
2    3
5    5
1    0.0
```

Figure 2: 1D rod example - the same you solved in HW#2

Part 2: required only to students registered for 4 credit hours

Download (checkout) ANOTHER assignment folder: **02-FEA-1D-G**. Generalize your 02-FEA-1D code to include rods with varying cross-sectional areas (similar to approach discussed in HW#3). The new set of assumptions are listed below:

- element-wise uniform body load
- element-wise uniform elasticity modulus
- **element-wise uniform cross-sectional area**
- linear elements (use linear shape functions)

Modify your input file by adding a 5th column to the element section, containing the cross-sectional area of each element (see Fig.3). Obtain the element-wise average A_i such that

$A_i = \frac{1}{h_i} \int_{\Omega_i} A(x)dx$

Discretize your domain with 3 elements of same size. You should recover the results presented in Figure 3.

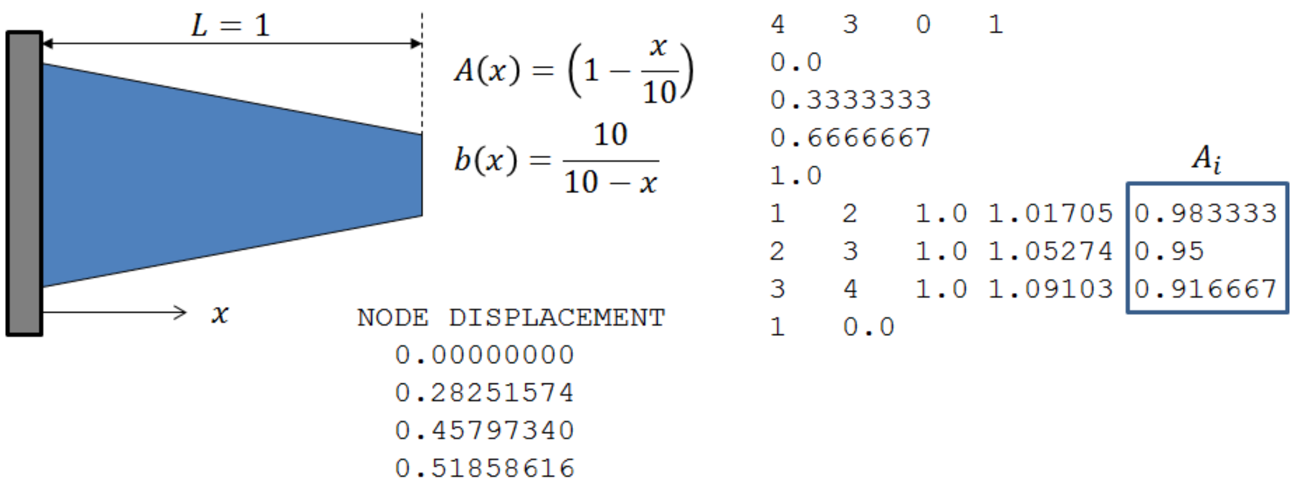


Figure 3: 1D rod example with varying area (students taking 4 credit hour course)

Figure 4 has another example to help you debug your code. Here we consider a plate with uniform thickness $t = 1$in, elasticity modulus $E = 30 \times 10^6$ psi and specific weight $\gamma = 0.2836$ lb/in^3. In addition to the self-weight, the plate is subject to a point load $P = 100$ lb at its midpoint. When modeling the plate with 2 linear elements, the displacement and reactions for a mesh with 5 evenly spaced nodes is also presented in Figure 4.

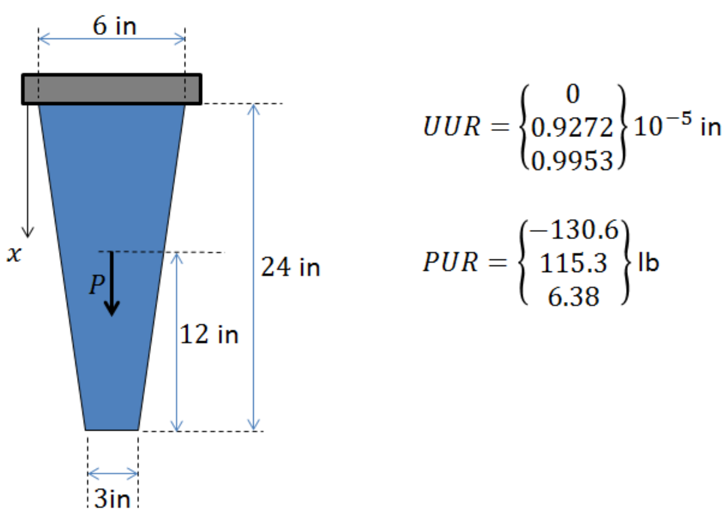


Figure 4: Another 1D rod example with varying area (students taking 4 credit hour course)

Grading schedule

We will start running the grading script on Wednesday Feb 17th at 00:01am. Scores and feedback should be available to you by 8am. In case you don't get a satisfactory score, you can change your code, make another commit, and your code will be re-graded. The grading script will run again on Thursday, Friday and Saturday, always at 00:01am. You final score will be the maximum of your last two scores.