Lab 1: Computer Analysis of Structures in Static Equilibrium

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Theory Manual:

When analyzing the support reactions of a three dimensional body in static equilibrium the approach used is based around creating and solving static equilibrium equations for the support reactions. The pieces of information needed to execute this process are the direction, magnitude, and location of external forces and moments, the support locations, and number of support moment and force reactions. Given the external force information the code is able to calculate the induced moments and include them in the static equilibrium equations. This information can be used to create six static equilibrium equations, three for the sums of the forces along the x, y, and z axis’ and the three for the sums of the moments along the x, y, and z axis’, with the support reactions acting as unsolved variables. These six equations are each set equal to zero and then used to solve for the support reactions. The matrix division method utilized by the code to solve this system of equations will be explained in the Developer and User Manual.

The code developed in this lab is limited to solving for six unknown support reactions. This is due to the fact that a system of six equations can only be used to solve for six or less unknown variables. The code is also limited to a system that has a significant number of known values as stated above and can only be used for the calculation of the reaction moments and reaction forces, and no other aspects of the system.

This code was created under the assumption that the forces and moments will be acting on a structure that exists in three dimensions. It assumes an arbitrary number of forces, moments, and supports. This allows the user to edit the input file for any body acting in three dimensions despite the number of moments, forces, and reactions within the limitations.

Developer and User Manual:

This section of the lab report will walk through the steps of understanding and using this code. The main topics covered will be how to setup the input file, the logic of the code, and how to read the output file.

The input file is broken up into seven sections (refer to the example input file in the appendix). Each section of the output file is titled with comments distinguished by the ‘#’ symbol. The first section is titled, ‘number of external forces and moments’, and exists of two horizontally consecutive numbers: the first being the number of forces and the second being the number of moments. If you do not have any external forces, or moments, enter a zero for that value. The second section is, ‘the coordinates of the points at which external forces are applied. Under the ‘x’, ‘y’, and ‘z’ column labels enter the x, y, and z coordinates of the external force location respectively. Do this for as many external forces as you wish the analyze. The third section is, ‘magnitude and direction of external forces’. The first column denoted by ‘F’ should consist of the magnitude of the force. The following three columns labeled ‘dx’, ‘dy’, and ‘dz’ should be filled in with the x, y, and z components of a vector parallel to the force vector. These values will be normalized to a unit vector to provide direction. The next section is titled, ‘location at which external couple moments are applied’. The ‘x’, ‘y’, and ‘z’ columns should be filled in with the coordinates of the location of the external couple moments respectively. The following section, ‘magnitude and direction of external couple moments’ should be filled in a similar manner to the force magnitude and direction section. Under ‘M’ the magnitude of the moment is entered and under the three following columns the components of a parallel vector are entered. The section, ‘location of supports’, consists of the following column headers ‘x’, ‘y’, and ‘z’. These should be filled in with the x, y, and z components of the location of the supports. The last section, ‘Type (F/M) and direction of supports’, should include the type of support reaction, force or moment, and the direction in which this support reaction occurs. Under the column header ‘type’ enter either ‘M’ or ‘F’ for moment or force followed by parallel vector components, which will be normalized, to distinguish the direction of the support reaction.

The code is modulated into a main script which then calls seven functions. The functions operate the following processes, explained below, in sequential order as called by the main script. The first step is opening the input file and reading it in a usable form. The program reads the first non-comment line which consists of the number of forces and moments and uses this information to then preallocate cells for the information stored in the file distinguished by comment line categories. The individual categories of information are then read and stored in these cells for further use. The main script then calls a function to calculate the unit vector of the given force or moment directional vectors. Using another function, this unit vector is multiplied by the magnitude of the correlated external force, or moment, to find the complete vectors for these interactions. The moments induced by the external forces are then calculated by crossing the the force vector with the position vector. The external force vectors, external moment vectors, and induced moment vectors are then used to create a six-by-one matrix that consists of the sum of the forces and moments individually in the x direction, y direction, and z directions. These act as the known quantities in the static equilibrium questions. The next step is to find a matrix of coefficients which is essentially the direction of each support reaction. This is calculated using the direction vectors given in the file and is then placed in a six-by-six matrix. This matrix is organized with the first three rows representing the forces along the three axis and the last three rows representing the moments along each axis. The columns represent the support reaction coefficients for each support. The last matrix created is a six-by-one that includes the six unknown support reactions. The order descending down the column is the same order as the rows of the coefficients matrix. To set up the matrix equation to solve for the unknown support reactions, which are stored in the third matrix described, we multiply the matrix storing all of our known values with the inverse of the matrix which stores the coefficients. This results in solving for the support reactions that were previously unknown.

Finally, these results are written to an output file that displays the information from the input file as well as support reactions. The output file is made up of the information given in the input file followed by the calculated support reactions. This last part of the file is formatted with an ‘F’ or an ‘M’ to represent rather the reaction is a force or moment respectively followed by the resulting magnitude of that value.

It is important to run verification code to ensure that you are setting up the input file correctly and that the code is running as intended. The examples used by the creators come from the book, *Statics and Mechanics of Materials fourth edition*, written by R.C. Hibbeler. Using examples that include the answers is necessary so that the output of the code can be compared with the correct solution. To test the code using the given verification examples run the main script with the name of one of the given input files.

Appendix:

Example input file:

# number of external forces and moments

2  1

# coordinates of the points at which external forces are applied

# x    y    z

0.0  1.0  1.0

5.0  3.0  0.0

# magnitude and direction of external forces

# F   dx   dy    dz

11.0  3.0  2.0  -9.0

0.1  3.0  1.0   1.0

# location at which external couple moments are applied

# x    y    z

0.0  1.0  1.0

# magnitude and direction of external couple moments

# M   ux    uy   uz

10.0  4.0  -2.0  9.0

# location of supports

# x    y    z

1.0  1.0  1.0

1.0  1.0  1.0

1.0  1.0  1.0

0.0  1.0  0.0

0.0  1.0  1.0

1.0  1.0  0.0

# type (F/M) and direction of reaction

# type  dx    dy    uz

F      1.0   6.0  -7.0

F     4.0   1.0   1.1

F      1.0   8.0   1.0

F      6.0   1.0   0.0

M      0.0   9.0   1.0

M     -1.0   1.0   0.0

References:

1. <http://www.huffingtonpost.com/2014/07/22/cities-with-fog_n_5591902.html>, Huffington Post, 2014.