Assignment 2 – Part I

Biomedical Imaging (BioE 1340 / 2340) - Fall 2020

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Instructions: Please show your solutions to each problem in full, writing them neatly. For computer programs, please remember to turn in your code through the course's blackboard session, as well as any plots / figures that are requested. If you have collaborated with another student on solving this homework assignment please state so (e.g. "I helped John with question 1").

This assignment is due on **Sunday, 13 Sept 2020** via Canvas, including an MS Word Document "report" or scanned PDFs of hand-written ones for the written explanations associated with each question in the assignment, as well as any associated code and result files required to be submitted.

LEARNING GOALS:

- Working with Vectors & Matrices in Matlab
- Visualizing data in Matlab.
- Input & Output of essential file-types for this BioE 1330 / 2330.
- Visualization of data using Visualization Tool Kit (VTK).

BASIC MATH & APPLIED PROGRAMING

1. **Part I (25 points): Find the unit normal vector** the following three points P1(5,0,0), P2(0,0,5) and P3(10,0,5). **HINT:** The vector normal to two vectors in-plane is in the direction of their cross product. **Finally, write a Matlab function for this which accepts three vectors as input, *function computeNormals (P1, P2, P3)*, where P1, P2 and P3 are 1x3 vectors.** Remember to upload your code through Blackboard.

Part 2 (40 points) : Extrapolate this logic used above (i.e. Part I) to compute the normal directions of each of the triangles in the following STL surface geometry and subsequently write out a file containing the points (i.e. vertices), triangles and normal vectors of the geometry (one normal vector per vertex) as a Legacy VTK (visualization toolkit) file:

- Source STL File: *CoronaryArteryBranch.stl*

- Visualize your results using "Glyphs" shaped like "arrows" in Paraview (Kitware Inc., NY: www.paraview.org) – the open source visualization engine based on VTK. Please download and install Paraview for your personal computing devices for this assignment.

❖ ***[1]Code is provided on Blackboard to help you get started:***

- Matlab function to write VTK PolyData (surface) files: *write_vtk_Surface*
- Matlab function to read STL (binary) surface geometries: *stlread*
  - ✓ `[v, f, n, c, stltitle] = stlread(filename, verbose);`
  - ✓ `v` is the list of vertices of the geometry and `f` is the list of faces of the geometry.
  - ✓ Here, `n` is the list of normal vectors to the Faces of the geometry. You may use this to validate your results! But note, you are expected to write out your normal vectors at each 'vertex' and not each face.

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2. (20 points) Curve Fitting: For the production of X-ray in a CT scanner, we use Tungsten as a popular choice of material. However, not all the radiation produced by Tungsten results in strong X-rays; some are weak, with lower energy (measured in keV) and need to be filtered to prevent the patient from extra exposure to radiation. This process is called **Beam Hardening**. For this purpose, we install metal filters that can absorb this unwanted lower energy radiation. In this question, we want to design a beam hardening filter to absorb 25 keV of energy and our material of choice for a beam-hardening metal filter is copper. Let's say that copper has different energy-absorption capabilities at different temperatures given by the table below:

Energy Absorption (keV)	**Temperature, T (°C)**
15.4	-40
16.7	-20
18.6	0
19.8	20

❖ [1]*This symbol means that "code" provided on Blackboard which requires to be used in this assignment.* ***And remember,*** *this assignment will require submission / uploading of your final code in addition to an inserted snapshot of the final rendering outputted and visualized in Paraview for your reports.*

22.7	25
26.6	40
29.5	60

(1) Please find the best estimate for the temperature of the room where the CT scanner should be placed given that our target energy absorption is 25 keV. Solve this problem using MATLAB's inbuilt curve-fitting toolbox. The curve fitting function may be assumed as follows:

$$E(T) = a_o + a_1 T + a_2 T^2 + a_3 T^3$$

where $E(T)$ is energy absorbed at temperature T. Generate the code for your fit by selecting the option, "generate code" on the curve-fitting GUI. Generate a final plot or a screenshot of your fitting. Report your interpolated value of room temperature for the required absorption energy, using this curve fit.

(2) Solve this curve fitting problem by hand by now, assuming that the relationship between Energy and Temperature is linear. Obtain a system of linear equation of the form, $Ax = b$ and solve to obtain a linear fit after first conditioning the **A** matrix by pre-multiplying your matrix equation with A^T , first . What is your interpolated answer now?

(3) Find the linear fit from part (2) again using backslash ('\') operator of MATLAB also. Does your answer match the one obtained in part (2)..? If not, why..?