



Generation of Lofted NURBS Curves for 3D Model Generation with COMSOL

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Introduction: A key challenge to finding quantitative solutions to biological problems is to model the complex 3D geometry of naturally occurring structures. Model generation often starts from serial sections from CT or MRI scans, confocal microscopy, or physical sectioning. Prior to V4 of COMSOL, there was a “loft” command to allow construction of 3D models from serial sections within COMSOL. However, the loft feature is not currently available in COMSOL, presenting a hurdle for problems that depend on geometry construction within COMSOL (as opposed to a third party package).

Computational Methods: A solution for building 3D structures from serial sections has been developed based on the use of the COMSOL LiveLink for MATLAB module to construct lofted 3D NURBS (Non-uniform Rational B-Spline) geometries. The method, which could be generalized for other cases, was developed for generating the 3D geometry for a rat tibia as part of ongoing bone adaptation studies.

In brief, the process depends upon:

1. a. COMSOL (commercial software)
b. COMSOL LiveLink for MATLAB module
2. a. MATLAB (commercial software)
b. MATLAB Curve Fitting Toolbox
3. The `nurbs_toolbox` for MATLAB, free from <http://www.aria.uklinux.net/nurbs.php3>
4. `igesout` function for MATLAB, free by Daniel Claxton available from Mathworks file exchange site
5. Data files with points on the periphery of serial sections (this will depend on the structures of interest).

The example data are files with x,y,z-coordinates representing points on the periphery of bone (rat tibia) sections taken from MicroCT scans. There are distinct files for each slice, on the periosteal surface and the endosteal (endocortical) surface that were output from the NIH Image package. Users will want to change this portion of the code to meet their own needs.

Results: The method to generate complex 3D models was developed using serial sections representing a portion of a rat tibia. Figures show points on serial sections, spline fits, lofted NURBS surfaces, the COMSOL solid model, and the COMSOL FE mesh to demonstrate the implementation of the method.

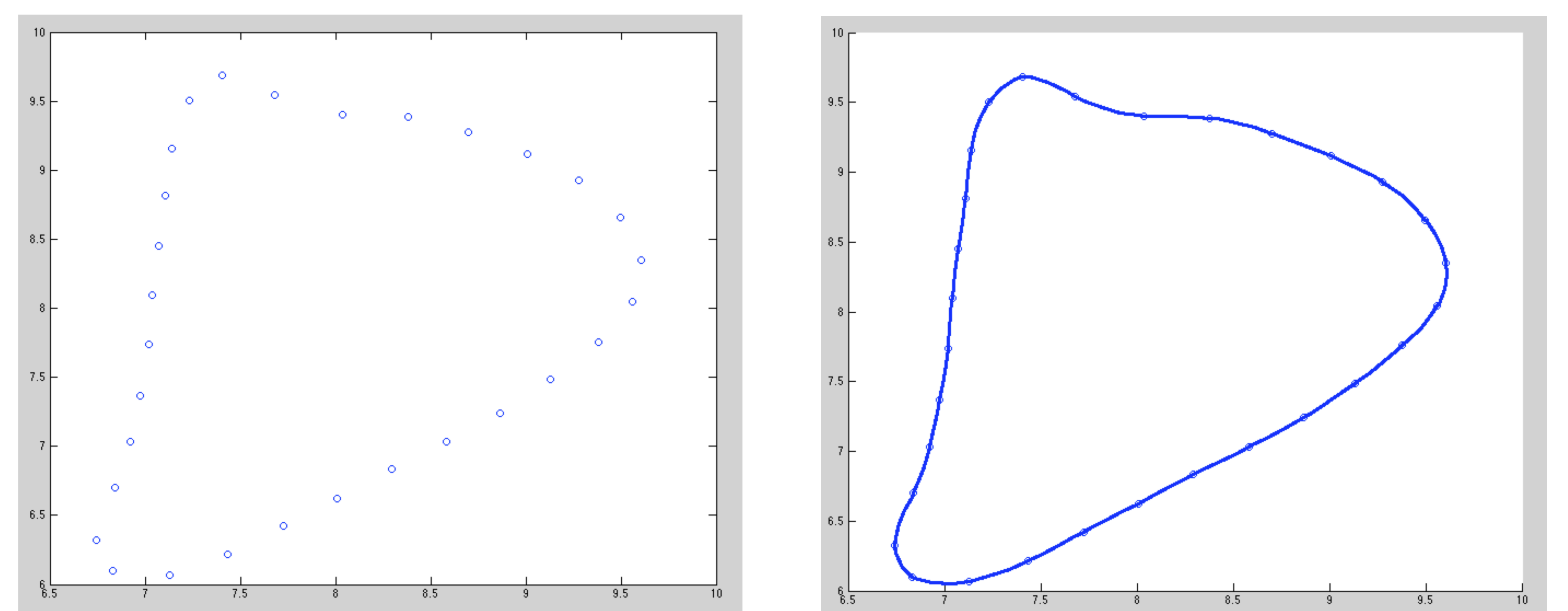


Figure 1. a.) Points on one slice of the bone periosteal (outer) surface. b.) Points with the corresponding spline curve.

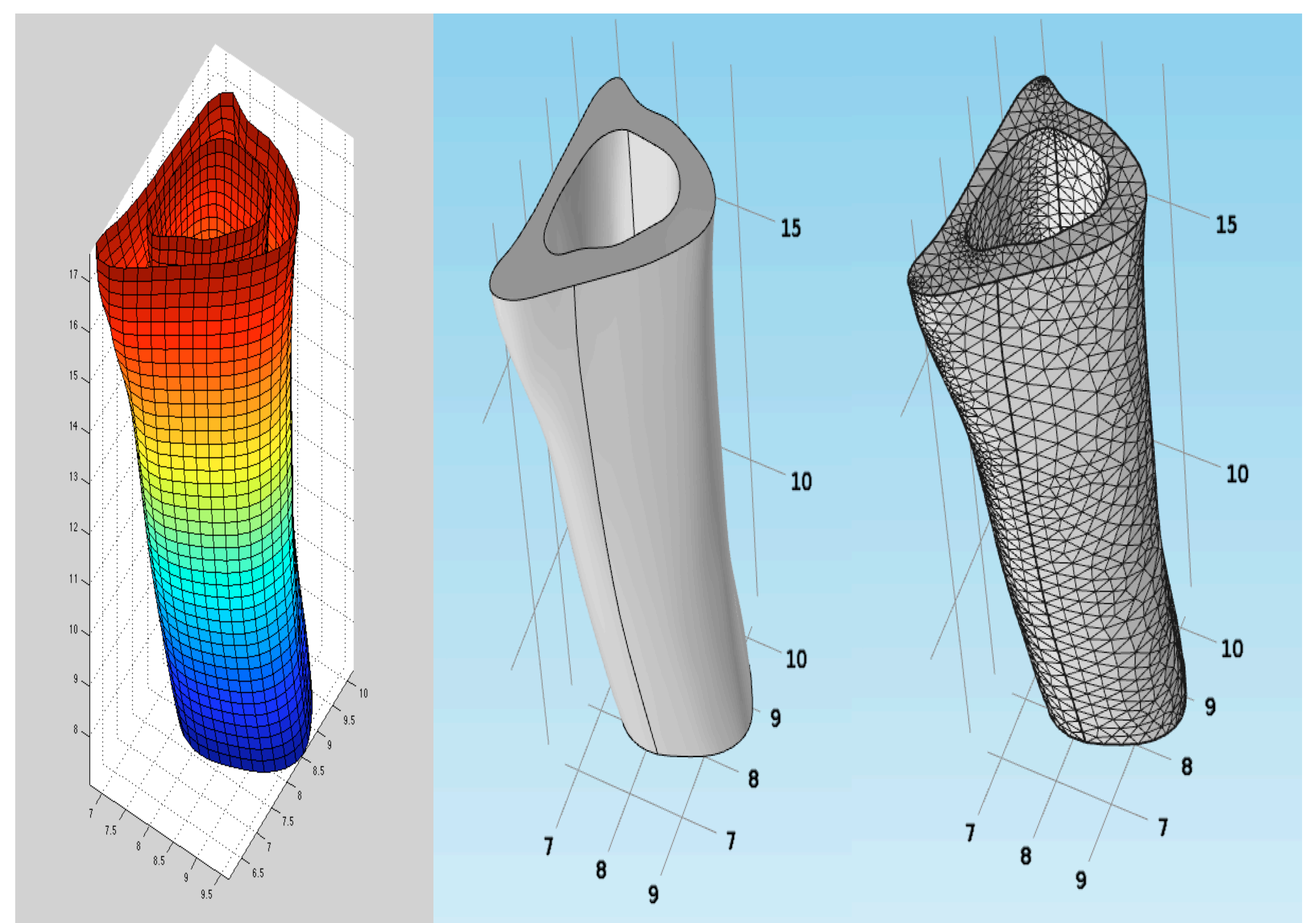


Figure 2. a.) Lofted NURBS surfaces generated by MATLAB b.) 3D COMSOL solid (capped) based on imported NURBS c.) FE Mesh

Conclusions: The process described here for generating 3D geometry for naturally occurring, irregular geometries, can be adapted for a wide variety of problems including 3D blood vessels, neural tissues, bone, etc. Data and MATLAB scripts will be uploaded to the COMSOL Model Exchange page following the conference.

Reference:

Roberts, M.D., Santner, T.J., and Hart, R.T., “Local Bone Formation Due to Combined Mechanical Loading and Intermittent hPTH-(1-34) Treatment and its Correlation to Mechanical Signal Distributions,” *Journal of Biomechanics*, **42**:2431-2438, 2009