ME 395 Homework #2: A Problem Solved by MDS

Over the course of the last few decades, 3D printing has become increasingly relevant as a fabrication method for a wide variety of applications. Specifically, stereolithography has recently seen drastic increases in fabrication speed, especially on the micro-scale. Namely, micro continuous liquid interface production, abbreviated as μCLIP, has shown potential for use in biomedicine and optics due to its precision and speed. Because μCLIP has traditionally been used for the main purpose of rapid prototyping, existing methods of analyzing printed parts can often waste both time and materials. To avoid "blind" manufacturing, simulations have begun to be developed to provide more information about performance of theoretical devices before printing and motivate design changes while minimizing wasted resources. However, some gaps still exist between simulation and actual prints which limit the degree to which knowledge about device performance can be obtained via computer analysis. One of the largest gaps at present in translation of simulation to experimental performance has to do with discrepancies between the ideal created image and the actual "projected" image. Actual printed parts often end up with somewhat more rounded edges than anticipated (shown in Figure 1), and the lack of knowledge surrounding the small change in geometry that occurs can hinder simulations significantly. Through utilizing mechanistic data science, discrepancies between the ideal image and the projected image for a variety of geometries, sizes, proportions, and edge angles can be further analyzed, and the projected image can be predicted prior to actual printing, better informing simulation and closing the existing knowledge gap between computer analysis and experimentation. Beyond predicting the projected image, a decision as to whether or not there will be a significant discrepancy (perhaps defined by percentage of pixels different from the original) could also be developed as a result of this system.

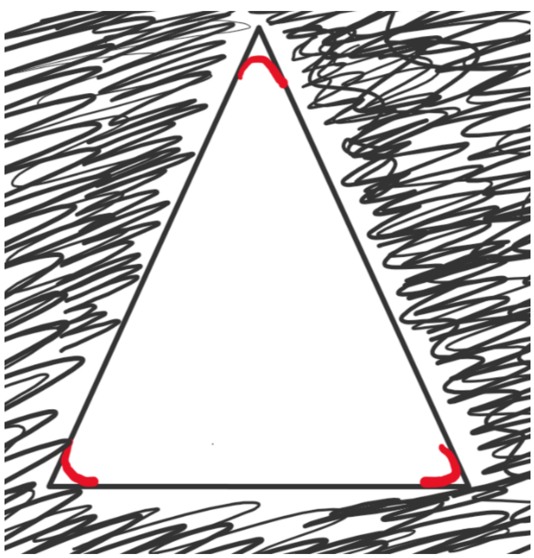

Figure 1. Example of ideal shape (white area enclosed in black boundary) and corresponding realistically projected shape (changes denoted by the red curves).

Utilizing the six modules of mechanistic data science, the resulting system design would appear something like the following:

1. **Gathering of multimodal data**
   Due to the layer-by-layer nature of μCLIP, cross-sections of drastically varying shape and size already exist from prior research completed. These cross-sections and their base geometry can be utilized as the basis for model development. Other quantitative parameters can easily be gathered from CAD files or the existing bitmaps, as is evident in module 2. If additional cross-sections are needed, a simple MATLAB code could be written to generate randomized images for projection. These would serve as a sufficient input for the system. Similarly, projected image information corresponding to each cross-sectional projection can easily be gathered by obtaining feedback from the printing system via the attached computer and converting the gathered images into bitmaps.
2. **Extraction of mechanistic features**
   The data from these bitmaps could easily be imported as arrays alongside information about the intended shape, size, and proportion of dimensions in the X-Y plane of the area. More than being limited in scope of data, identifying all important parameters would likely be the main concern with this project (ensuring all relevant information is included in the data set).
3. **Dimension reduction & 4. Reduced order surrogate models**
   By investigating any potential relationships between the chosen mechanistic features (like size, shape, edge angles, and proportion of dimensions) and the discrepancy between final shape projected and initial shape created (perhaps via percentage or number of pixels differing between the two images), it could be determined which parameters are actually key in identifying if a discrepancy occurs and the severity of the discrepancy. This could also be important in determining which factors influence the final image projected most.
5. **Neural networks for regression/classification**
   A significant portion of this system will likely involve machine learning based on the large number of initial images and projected images which will be gathered in the first step. Coding for this can be completed in MATLAB, Python, or C++. The percentage of or number of pixels which differ can also be analyzed while analyzing the impact of the various parameters determined in steps three and four to determine the best model for determining the final shape and amount of curvature that will be added from the initial image to the final one.
6. **System and design**
   Eventually, a system will be created which is capable of taking information from an initial figure (size, shape, angle of sharp edges, etc.) alongside a bitmap of the initial figure and outputting a predictive shape that mirrors what the projected image will likely be. Additionally, the system will output a decision on or possible degree to which significant changes in the geometry will occur from one image to the next. One further step which could be completed would be to output a suggested image which shows the ideal input image in order to avoid any potential curvature issues, but for now, the first two objectives (predictive shape and information on geometry changes between the two images) are the priority.