Automatic Segmentation of Micro CT Images

ME EN 6035 Final Project

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Abstract

1 Introduction and Background

Fiber-reinforced ceramic matrix composites (CMCs) are widely used in the aerospace industry due to their high specific strength and stiffness material properties, and their ability to withstand prolonged exposure to extreme high-temperature and oxidative environments. Despite their increased use, the fundamental physics governing their manufacturing, stochastic microstructure, and long-term structural performance remains largely undiscovered. Understanding the complete life-cycle of CMCs is critical towards improving currently existing and future applications of CMCs. In recent years, the emerging practice of in situ X-ray micro-computed tomography (X-ray CT) experiments has proven promising towards providing a holistic understanding into the behavior of CMCs on multiple length scales [1-6].

Unique to X-ray CT is the ability to image specimens through-thickness in 3-D compared to other surface specific imaging techniques. However, this imaging method comes at a high computational post processing price to analyze terabytes of potential image data. There exist active areas of research in improving best practices for the segmentation of X-ray CT reconstructions to extract useful properties. Segmentation is defined as the classification of pixels or groups of pixels into multiple segments. These segments often

correspond to a physical representation. There is no one segmentation method that works universally. Segmentation is often tailored towards the users needs my means of manual or automatic practices. To date, manual segmentation is heavily used due to the knowledge humans use when classifying individual pixels compared to computer based methods. Once trained, computer based methods significantly out produce humans in computational time, and are therefore more desirable.

In this study, a novel segmentation pipeline was developed to accurately segment porosity automatically from the microstructure of CMCs imaged via X-ray CT. A statistical validation was performed to compare the differences in segmentation ability of porosity between the novel automatic method and the manual segmentation based method. It was hypothesized that the mean percent error in porosity segmentation for the novel segmentation method was equal to zero under the assumption that the manual based method was considered ground truth. The alternative was the mean percent error in automatic porosity segmentation was greater than zero.

2 Materials and Methods

2.1 Composite CMC Micro CT

2.2 Data

2.3 Statistical Analysis

Several different statistical techniques were used to evaluate segmentation algorithms. First a one-way ANOVA was conducted on the porosity measurements for each technique to determine whether or not automatic calculations of porosity were significantly different from manual calculations. A multiple comparisons analysis (Tukey's HSD) was then conducted to determine which methods, if any, were significantly different.

An additional data set was constructed by calculating the percent error between each of the automatically segmented results and the manually segmented results. This data was no longer dependent on the underlying image and could be treated as a random variable. Normality of data was checked by plotting the histograms

for each automatic method. Finally, the four automatic methods segmentations were broken into two categories based on algorithm features with "high" and "low" treatments for each category. A 2 by 2 factorial and 2-way ANOVA were performed to determine which algorithm features (Analysis Dimensions and Edge Erosion), most effected the results.

3 Results and Discussion

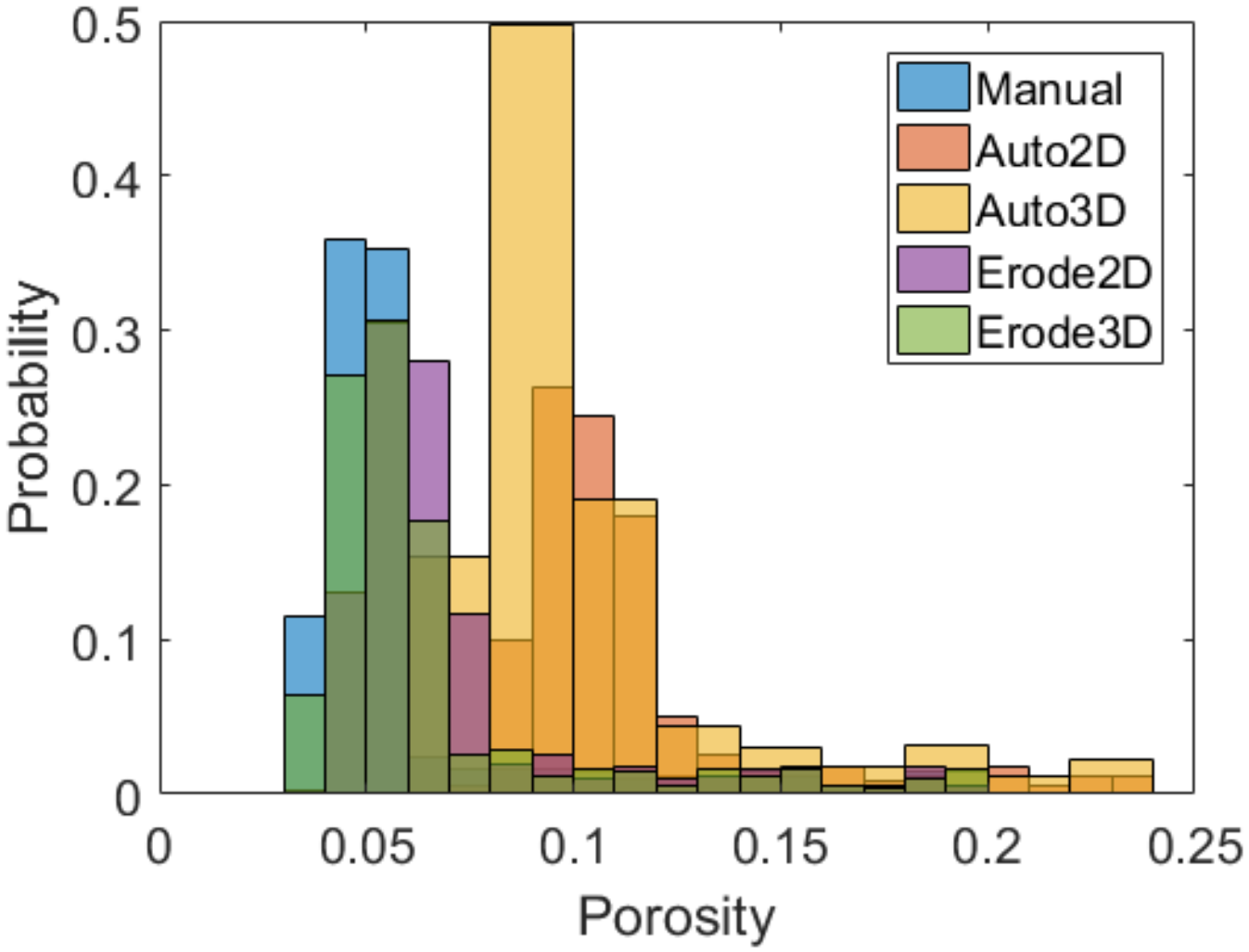

Figure 1: Histogram of porosity distribution for each segmentation method

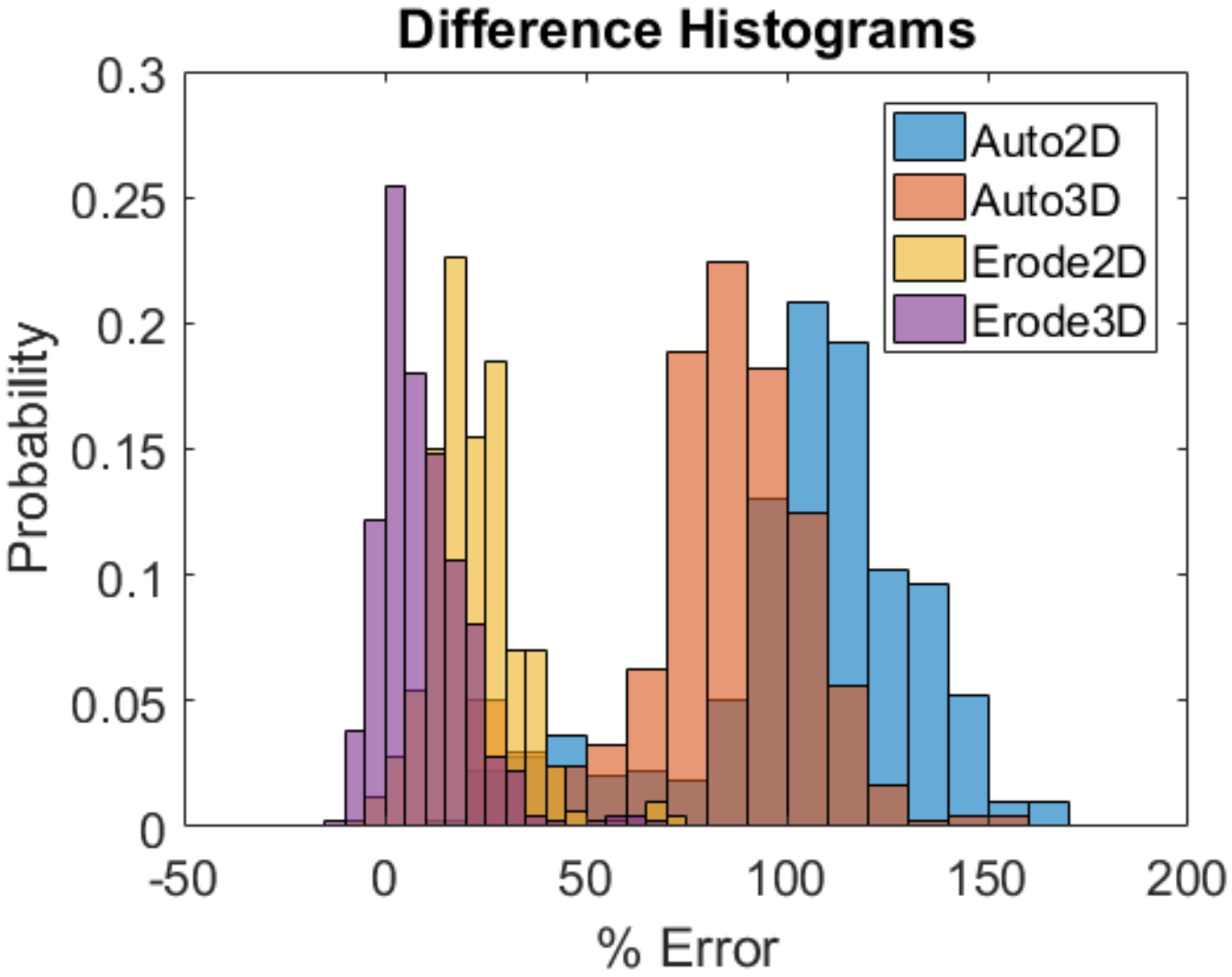

Figure 2: Histogram of percent error for each of the automatic segmentation methods

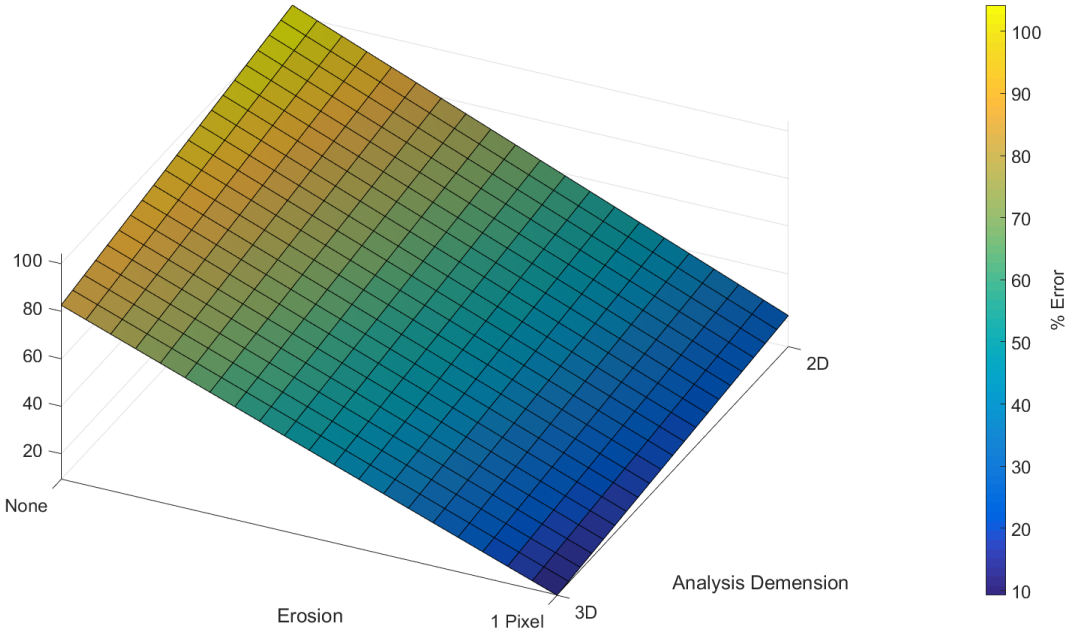

Figure 3: Response surface model for two different algorithm features

3.1 Error and Uncertainties

4 Conclusion and Future Directions

5 Figures