Mechanical Deformation and Cancer Malignancy

Rupali Sarathy
Dublin High School, Class of 2021
USC Viterbi Department of Mechanical Engineering, SHINE 2020

USC Viterbi School of Engineering

SHINE — Summer High School Intensive in Next-Generation Engineering

Introduction

Professor Assad Oberai's research involved Ph.D. students Harisankar Ramasamy and Orazio Pinti to utilize the process of multi-fidelity modeling in order to perform deformation analyses on various simulations. This process combines both low and high fidelity data in order to maximize the accuracy of model estimates and predictions. Professor Oberai delved deeper into a specific type of simulation, one that included a firm, elliptical inclusion within a soft, rectangular surface, and focused on applying a mechanical stress onto the domain in order to analyze its deformities. This research focused on multi-fidelity modeling in a mechanical simulation in relation to medical diagnosis.

Objective & Impact of Research

The concept of heterogeneity in cancer tumors has been established, but it has been recently discovered that the study of deformation heterogeneity can be utilized in order to diagnose and determine the malignancy of a cancerous tumor.
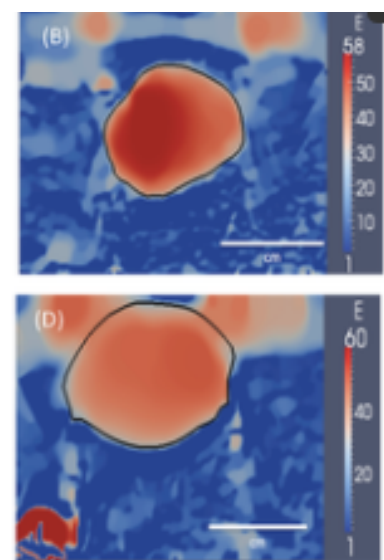
Liu, Babaniyi, Oberai
Benign Tumor

Tumors that have a heterogeneous distribution of deformation due to mechanical stress are considered malignant, which can be used to distinguish malignant tumors from benign. To view images of this deformation, the tissue can be compressed in order to view the displacement field to analyze the deformation.

The mechanical properties of a cancerous tumor can determine the severity of the disease, which can successfully diagnose malignant tumors in a non-invasive process. By using the elliptical domain and altering parameters such as tumor size, angle, and elasticity, a stress simulation was created for this specific biomedical objective.
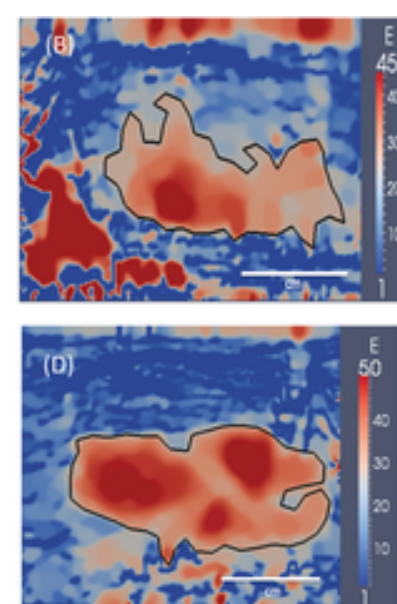

Liu, Babaniyi, Oberai
Malignant Tumor

Methods

In order to simulate the stress on a cancerous tumor, we created a domain using Python and Fenics *(Figure 1)*. The created domain consisted of a firm, elliptical inclusion inside of a rectangular tissue, which allowed us to accurately represent a cancerous tumor. A uniform stress was applied on top of the domain.


Parameter 1 = θ
Parameter 2 = a/b
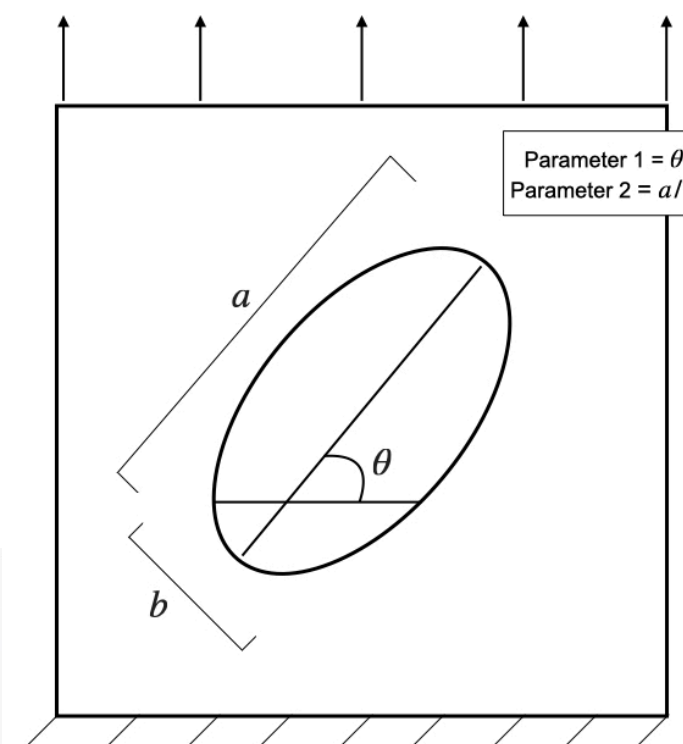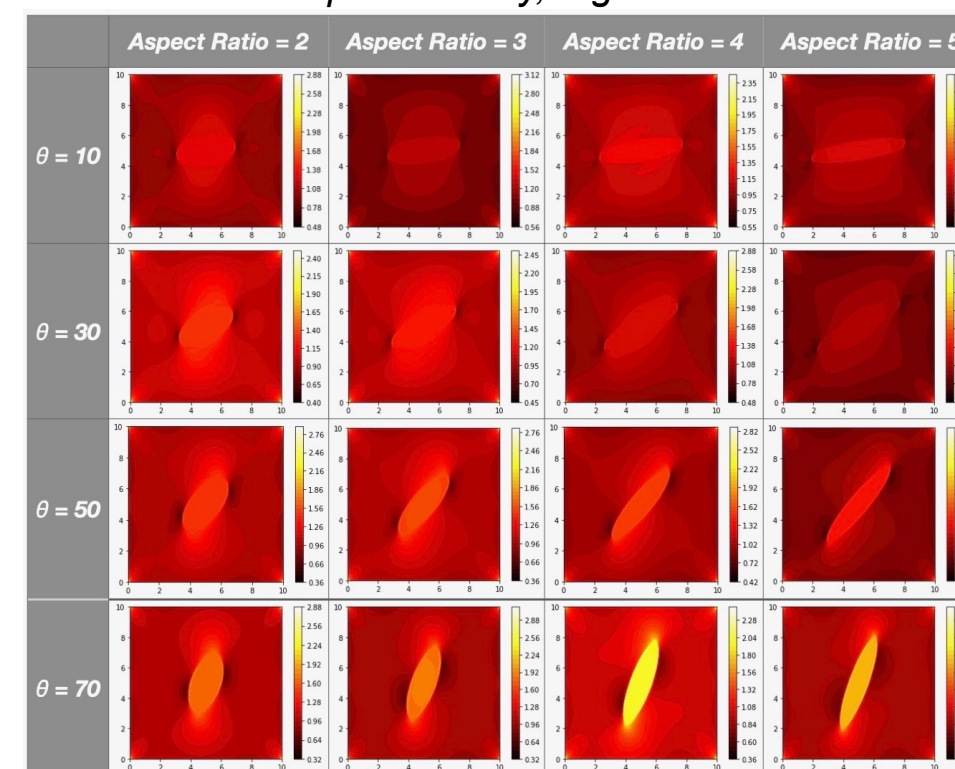
Rupali Sarathy, Figure 1

Rupali Sarathy, Figure 2

Parameters such as length, width, angle, and elasticity could be changed to correctly simulate different tumor types. Using Fenics, stress analyses were computed *(Figure 2)*.

Gaussian Processes uses the concept of machine learning to predict the value of an unseen point. Both high fidelity and low fidelity data points were collected; using the high fidelity (slope representative) database, the low fidelity (local behavior representative) model was adjusted to strengthen the trend accuracy. Once this is created, a final Gaussian Process can be implemented in order to compute a final predictive distribution.

High-Fidelity Model

Low-Fidelity Model

Multi-Fidelity Model
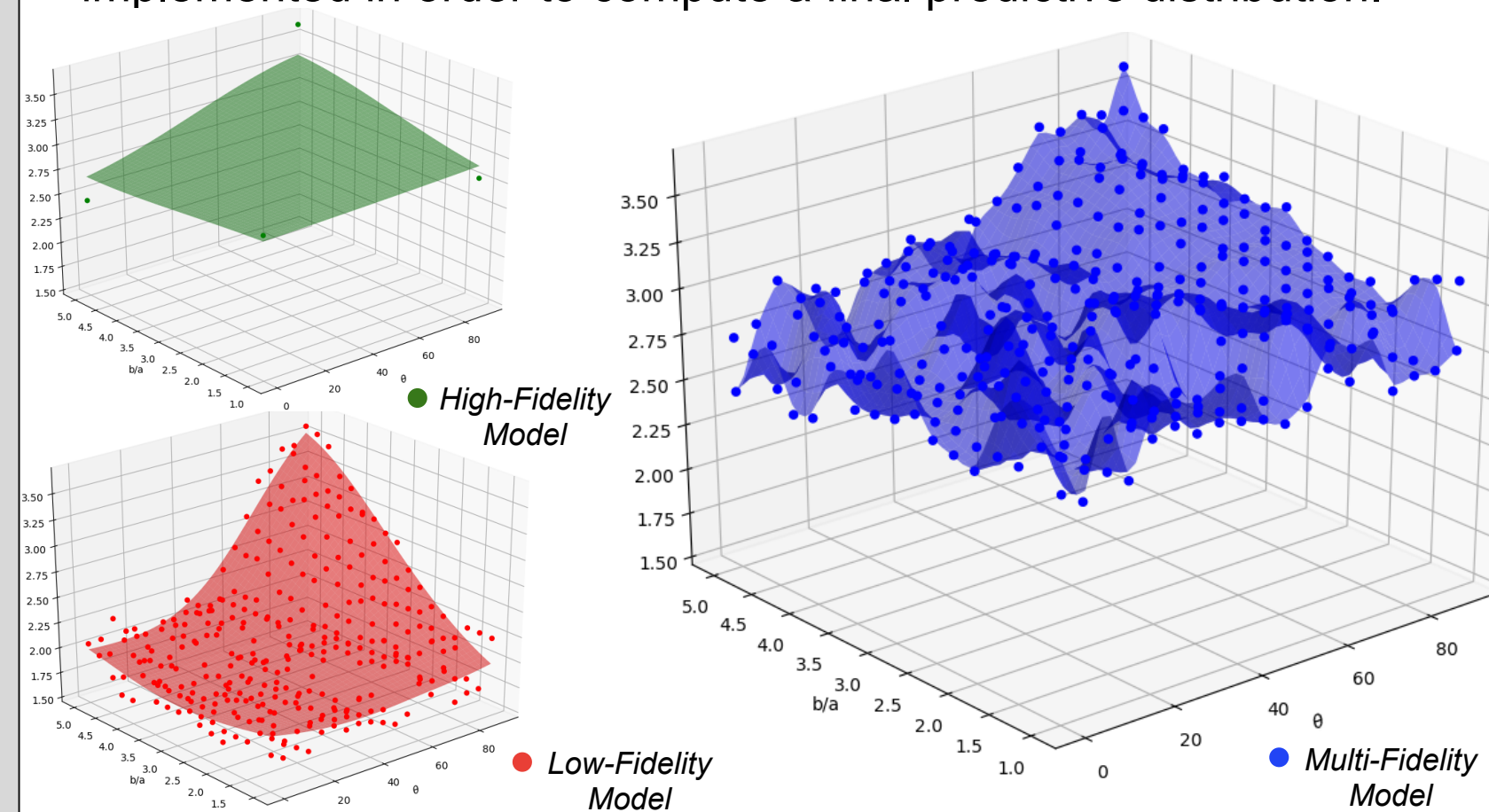
Results and Achievements

Once complete, the distribution and model creates a clear prediction of tumor deformation due to an applied mechanical stress. For cancer research, this simulation can be utilized in reverse methodology to predict the size, angle, and location of cancerous tumors based on the calculated deformation. This model can revolutionize the process of diagnosing, locating, and treating malignant tumors to assist the recovery of cancer patients. This research generated data that is a benchmark for multi-fidelity modeling and Gaussian Processes.

Next Steps

Several peer-reviewed sources have motivated me to take my SHINE research to the next level. "Enhanced Gene Delivery in Tumor Cells Using Chemical Carriers and Mechanical Loadings" and "Cell Stiffness Is a Biomarker of the Metastatic Potential of Ovarian Cancer Cells" are a demonstration of how my research at SHINE is continuing to evolve, and how it can continue to improve in the next few years with an increase in technology and new methodology. Although they include the basic foundation of my research, these two articles go more in depth to move past diagnosis and find a better solution to cancerous tumors. These scholarly articles are a perfect example of how I can continue my initial research at SHINE in order to not just diagnose, but improve medical conditions by including different testing scenarios with an innovative approach.

Acknowledgements