Modelling Breast Tissue Mechanics Under Gravity Loading

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Abstract

This thesis presents research that was conducted to develop anatomically realistic finite element models of breast deformation under a variety of gravity loading conditions to assist clinicians in tracking suspicious tissues across multiple imaging modalities.

Firstly, the accuracy of the modelling framework in predicting deformations of a homogeneous body was measured using custom designed silicon gel phantoms. The model predicted surface deformations with an average RMS error of 1.5 mm $\pm$ 0.2 mm and tracked internal marker locations with an average RMS error of 1.4 mm $\pm$ 0.7 mm.

A novel method was then developed to determine the reference configuration of a body, when given its mechanical properties, boundary conditions and a deformed configuration. The theoretical validity of the technique was confirmed with an analytic solution. The accuracy of the method was also measured using silicon gel experiments, predicting the reference configuration surface with an average RMS error of 1.3 mm $\pm$ 0.1 mm, and tracking internal marker locations with an average error of 1.5 mm $\pm$ 0.8 mm.

Silicon gel composites were then created to measure the accuracy of standard techniques to model heterogeneity. The models did not match the experimentally recorded deformations. This highlighted the need for further validation exercises on modelling heterogeneity before modelling them in the breast.

A semi-automated algorithm was developed to fit finite element models to the skin and muscle surfaces of each individual, which were segmented from breast MR images. The code represented the skin with an average RMS error of 1.46 mm $\pm$ 0.32 mm and the muscle with an average RMS error of 1.52 mm $\pm$ 0.3 mm.

The framework was then tested using images of the breast obtained under different gravity loading conditions and neutral buoyancy. A homogeneous model was first developed using the neutral buoyancy images as a representation of the reference configuration. The model did not accurately capture the regional deformations of the breast under gravity loading. However, the gross shape of the breast was

reproduced, indicating that a biomechanical model of the breast could be useful to reliably track tissues across multiple images for cancer diagnosis.

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Srimannarayana

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