Statistical Biomechanics of the Breast

Ryan Lim-Yip; Supervised by Dr. Duane Malcolm, Prof. Martyn Nash & Prof. Poul Nielsen; The University of Auckland, New Zealand

Background

Breast cancer is the most prevalent form of cancer for NZ women, with one in nine being affected by the disease[1]. However, early detection and diagnosis can greatly improve survival outcomes.

The *Biomechanics for Breast Imaging (BBI)* group is focused on developing computational biomechanical models to more accurately track breast tissue deformation during various imaging procedures such as X-ray mammography, MRI and ultrasound[1]. These tools will aid clinicians in tumour detection.

Aim

The aim of my project is to model the movement of the breasts and the shoulders due to gravity as the patient re-orients from a prone to supine position. The model will be generated with spatial data obtained from the prone and supine MRI scans of 61 volunteers using a statistical technique called *Partial Least Squares Regression (PLSR).* PLSR is useful when predicting a set of dependent variables from a large set of independent variables as it avoids over-fitting[2]. *Cross-validation* will be employed to assess the predictive accuracy of the model[2].

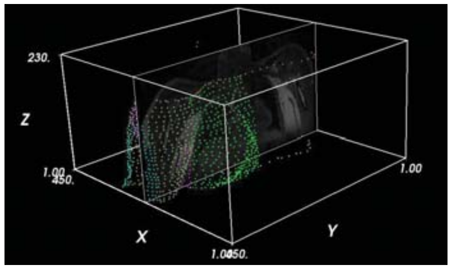

Figure 1. Phaser 3D plot depicting subject in supine position

Method

The 3D positions of 9 landmarks were mapped onto the prone and supine MRI scans in Phaser 3D for 61 subjects. Functions were then written in Python to construct the PLSR model. First, the landmark co-ordinates from each scan were loaded into prone (X) and supine (Y) data arrays. Next, *Leave-One-Out Cross-Validation (LOOCV)* was performed for all subjects at each mode from 1 to 23. Finally, summary statistics (mean and SD) of the absolute errors $(Y_{pred} - Y)$ and percent errors $(Y_{pred} - Y/Y - X \times 100\%)$ across the subjects were outputted and graphed. For comparison, the entire process was repeated using Δ-based PLSR models where $\Delta = Y - X$.

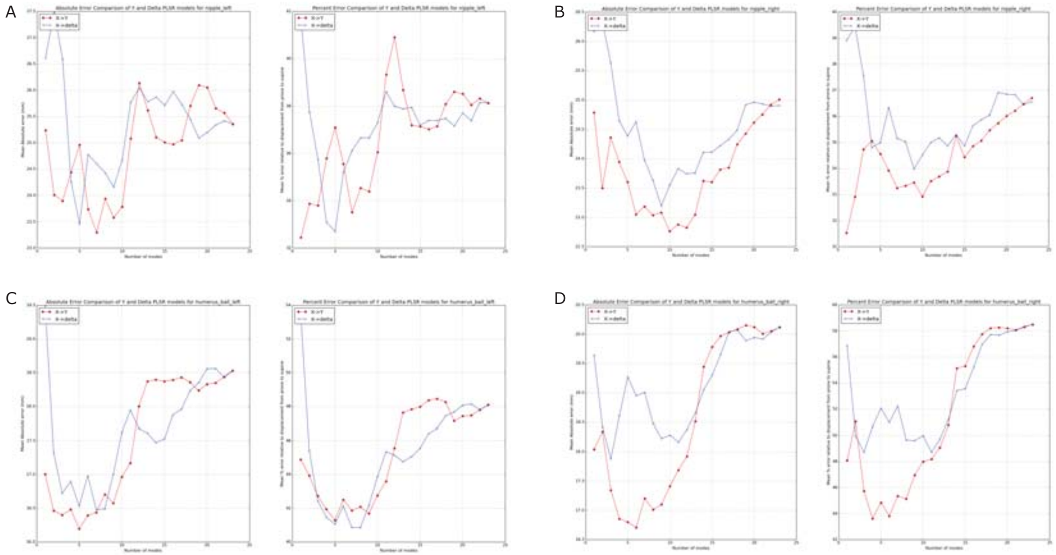

Figure 2. Graphs comparing mean absolute and percent errors of Y- and delta-based PLSR models across multiple modes/components for predicting supine positions of the (A) left nipple, (B) right nipple, (C) left humerus ball and (D) right humerus ball.

Results

Figure 2 shows that Y-based PLSR models generally predict the supine positions of the four target landmarks more accurately than Δ-based models. The graphs also depict that models with too many components (over-fitting) have greater predictive error as they describe the noise rather than the underlying relationship between prone and supine landmark positions[2]. The optimal number of modes (minimum error) of the Y-based models for each target landmark are: left nipple – 7, right nipple – 10, left humerus ball – 5, right humerus ball – 6. The absolute errors are smaller when predicting the supine position of the humerus balls compared to the nipples, however the percent errors relative to prone-supine displacement are larger.

Conclusions

Cross-validation shows that PLSR models can reasonably predict the prone-to-supine displacement of breast and shoulder landmarks if the optimal number of modes is chosen. These results could assist other members of the BBI group by providing boundary conditions for finite element models.

My next step is to investigate whether including front, back and shoulder meshes of the skin surface as parameters will improve the accuracy of the PLSR model.

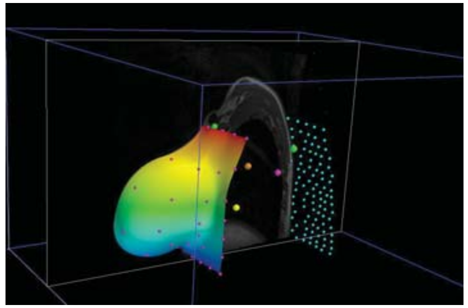

Figure 3. Phaser 3D plot depicting subject in prone position with fitted front mesh

References

1. http://www.abi.auckland.ac.nz/en/about/our-research/biomechanics-for-breast-imaging.html
2. *An Introduction to Partial Least Squares Regression.* Randall D. Tobias, SAS Institute Inc., Cary, NC.

Acknowledgements

My supervisors: Dr. Duane Malcolm, Prof. Martyn Nash and Prof. Poul Nielsen; Biomechanics for Breast Imaging Group members: Dr. Habib Yusufi Balawala, Barbara Curteis, Dr. Jessica Jor and Chun Meng (Alex) Goh; the Centre for Advanced MRI and the 61 volunteers who provided their prone and supine MRI scans