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Abstract

This work presents a data-driven method to simulate, in real-time, the biomechanical behavior of the breast tissues in some image-guided interventions such as biopsies or radiotherapy dose delivery as well as to speed up multimodal registration algorithms. Ten real breasts were used for this work. Their deformation due to the displacement of two compression plates was simulated off-line using the finite element (FE) method. Three machine learning models were trained with the data from those simulations. Then, they were used to predict in real-time the deformation of the breast tissues during the compression. The models were a decision tree and two tree-based ensemble methods (extremely randomized trees and random forest). Two different experimental setups were designed to validate and study the performance of these models under different conditions. The mean 3D Euclidean distance between nodes predicted by the models and those extracted from the FE simulations was calculated to assess the performance of the models in the validation set. The experiments proved that extremely randomized trees performed better than the other two models. The mean error committed by the three models in the prediction of the nodal displacements was under 2 mm, a threshold usually set for clinical applications. The time needed for breast compression prediction is sufficiently short to allow its use in real-time (<0.2 s).

Keywords: Breast biomechanics, finite element methods, machine learning, modeling, breast compression

1. Introduction

Breast cancer is one of the major causes of mortality and morbidity in women today. Its mortality is related to the tumor size and the time of detection [1]. A wide range of imaging methods are available for detection and diagnosis, from projection X-ray mammography (XRM), magnetic resonance imaging (MRI), and ultrasound (US), to the more recent technologies such as digital breast tomosynthesis (DBT), positron emission mammography (PET) and ultrasound tomography (UST) [2]. However, each imaging modality displays the information in a different way and in consequence, undetectable tumors in one modality can be detected by other modalities, and lesions considered to be suspicious in one modality

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