DIFFERENT NUMERICAL APPROACHES FOR THE PREDICTION OF PROXIMAL FEMUR LOADS

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Introduction

Patient-specific modeling is becoming increasingly important. One of the most challenging difficulties in creating patient-specific models is the determination of the specific load that the bone is really supporting.

Many theories and mathematical models have been developed to analyse the evolution of bone microstructure and its mechanical properties depending on a certain loading pattern. But solving the inverse problem is certainly more important. Then, the main goal of this work is to present a general methodology in order to accurately solve the inverse bone remodeling problem. For this purpose, we develop, evaluate and compare three existing numerical approaches to estimate the musculoskeletal loads (output data) in the femur from a patient-specific bone density (input data).

Methods

The inverse bone remodeling problem is solved using three mathematical techniques: linear regression (LR), artificial neural networks (ANN) and support vector regression (SVM). The input data for these techniques is the solution of bone density distribution obtained from solving multiple bone remodeling problems [Jacobs,1995] (Figure 1).

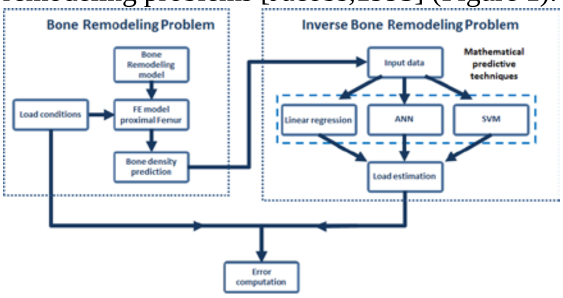

Figure 1: Schematic diagram of the computational approach.

An isotropic bone remodeling model was implemented in the FE mesh and the analyses were performed in Abaqus v.6.11. Different combinations of loading parameters (force magnitude, angle and position-three output data) have been simulated. We assume 24 representative points of the bone density distribution as input data for the mathematical techniques.

Results

For evaluating and comparing learning algorithms, the absolute of relative error (RE) and the correlation coefficient (RSQ) have been used. When estimating the total RE, the ANN gives the lowest RE value (lower than 1%). Using linear regression and SVM, the total training RE is 1.26% and 15.2%, respectively. A quantitative comparison has been also done (Figure 2). The error in the bone density prediction is 3 ‰.

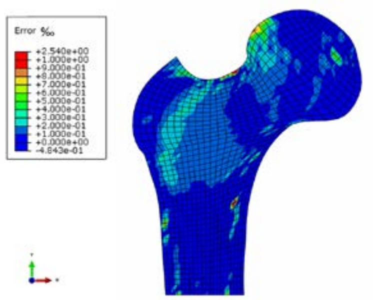

Figure 2: Error ‰ at bone density distribution computed between the load from ANN and the predictions of the bone remodeling model.

Discussion

The methodology proposed predicts the bone density distribution accurately. Good agreement was obtained (qualitatively and quantitatively). The three methods achieved this goal, but not with the same results. ANN and linear regression demonstrate a good load prediction with an RE lower than 1% for both training and testing methods. These techniques provide an extensive database, which allows us to obtain a specific load case in the short time.

Acknowledgements

The CAD-BONE project 286179 of the European Commission and the Spanish Ministry of Economy and Competitiveness through projects DPI 2011-22413

References

Jacobs C *et al*, J Biomech, 28(4):449-459,1995