Probabilistic model of bone structure based on CT scan data and validation of simulation results using the Finite Cell Method

**Abstract:**
A probabilistic model of bone structure in the trabecular region of the femur head is constructed. In a first step, a probabilistic model for the bone density based on computed tomography (CT) scan data is developed. The data consist of a number of cubes cut from fresh-frozen bones belonging to three different patients. The model accounts for the spatial variability of the bone structure as well as the correlation between samples (inter-sample correlation). Based on the statistical analysis of the data, a homogeneous Gaussian field with separable autocorrelation coefficient function is developed for modeling the bone structure. The Finite Cell Method (FCM) is used for estimation of the mechanical properties of the bone. This method has shown advantages in terms of efficiency and accuracy compared to the classical finite element method for this type of applications. Monte Carlo samples of the mechanical properties of the bone are simulated based on the probabilistic model of the bone density. For each realization of the random field, density values at each location are obtained and further mapped to material values through empirical
relationships. Furthermore, the homogenized material properties are computed using the FCM assuming an isotropic material. The sample elasticity moduli are compared with the ones obtained experimentally from laboratory tests in order to validate the applicability of the material models at different scales.