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Construction and Validation of a Hybrid Lumbar Spine Model for the Fast Evaluation of Intradiscal Pressure and Mobility

Authors : Dicko Ali Hamadi, Tong-Yette Nicolas, Gilles Benjamin, Faure Francois, Palombi Olivier

Abstract : A novel hybrid model of the lumbar spine, allowing fast static and dynamic simulations of the disc pressure and the spine mobility, is introduced in this work. Our contribution is to combine rigid bodies, deformable finite elements, articular constraints, and springs into a unique model of the spine. Each vertebra is represented by a rigid body controlling a surface mesh to model contacts on the facet joints and the spinous process. The discs are modeled using a heterogeneous tetrahedral finite element model. The facet joints are represented as elastic joints with six degrees of freedom, while the ligaments are modeled using non-linear one-dimensional elastic elements. The challenge we tackle is to make these different models efficiently interact while respecting the principles of Anatomy and Mechanics. The mobility, the intradiscal pressure, the facet joint force and the instantaneous center of rotation of the lumbar spine are validated against the experimental and theoretical results of the literature on flexion, extension, lateral bending as well as axial rotation. Our hybrid model greatly simplifies the modeling task and dramatically accelerates the simulation of pressure within the discs, as well as the evaluation of the range of motion and the instantaneous centers of rotation, without penalizing precision. These results suggest that for some types of biomechanical simulations, simplified models allow far easier modeling and faster simulations compared to usual full-FEM approaches without any loss of accuracy.

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