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FAST SUBJECT SPECIFIC FINITE ELEMENT MESH GENERATION OF KNEE JOINT FROM BIPLANAR X-RAY IMAGES

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Summary: Numerous finite element models of the knee joint have been developed to investigate knee pathology, post-surgery assessment and knee biomechanics. However, because of extensive computational effort required for preparing subject specific model from CT-scan or MRI data, most of the models in literature are done only for one subject resulting in poor validation of the model, limiting the predictive power of conclusions. Biplanar X-ray is a promising alternative to perform 3D reconstruction of bony structures because of low radiation dose and very less reconstruction time, of about 10 min per subject [1]. However, an accurate and fast computational mesh is a prerequisite for generating subject specific mesh in order to perform personalized FE analysis. Traditionally, both triangular/tetrahedral and quadrilateral/hexahedral FE elements are used for 3D mesh generation. But because of distinct numerical advantages quadrilateral/hexahedral elements are preferred to avoid numerical instability, specifically for problems involving high strains at soft tissues [2].
The aim of the current study is to develop fast and automatic subject specific mesh for knee joint from biplanar X-ray images. This approach was successfully tested for 11 cadaveric specimens, where from the biplanar radiographic image of each, 3D reconstruction models were built by adapting the strategy of [1]. From the reconstruction models, subject specific mesh (shell) for bony and cartilage structures were generated based on the mapping from the generic model to subject specific model with about 10 sec of time for each specimen. Both the meniscus were meshed (hex elements) using the nodes of femoral and tibial cartilage with numerical cost less than 1 min in a non-optimized matlab code. So, a total of about 12 min computational time was required to build each knee from 3D reconstruction to mesh generation. Quality of mesh for individual specimen was checked using mesh quality indicators (Jacobian ratio etc.), which showed less than 0.35% warning and no error. As for surface representation accuracy for all specimens, mean (RMS) errors in mm were respectively less than or equal to 0.2 (0.3), 0.3 (0.55) and 0.0 (0.1) for femur, tibia and patella which are less than the uncertainties of 3D reconstruction.