Multi-Atlas-Based Bone Segmentation of the Lower Extremity Using Magnetic Resonance Images

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Abstract

Purpose: One approach to make biomechanical model person-specific is to use medical imaging as model input. This approach demands accurate segmentation of musculoskeletal structures (bones, muscles, cartilage, etc.). Segmentation of these structures has previously been performed manually, which is a time-demanding task. In this study, we present an advanced atlas-based segmentation algorithm that includes a fast similarity map and adaptive atlas selection step.

Methods: Given the limited availability of training data for this particular application, we used an atlas-based method that is applicable with less training data to segment ten bones (tibia, femur, pelvis, patella, and tarsal for both legs) from lower extremity MRI. The data we used consisted of 16 atlas and 5 test datasets. For the advanced atlas-based segmentation algorithm, we designed two new steps. First, we improved the computing speed of sliding local patch through initial bone searching, which allowed to compute a fast similarity map. Next is the adaptive atlas selection step, which removes incorrectly atlas candidates using region similarity. Automatic and manual segmentations were compared using the commonly used sensitivity, specificity, and accuracy metrics [Muller et al. 2022].

Results: The results of the five tests are as follows: sensitivity: 0.88±0.04, 0.86±0.03, 0.77±0.04, 0.83±0.06, 0.86±0.02, 0.84±0.05 (tibia, femur, pelvis, patella, tarsal, total), specificity: 0.87±0.00, 0.90±0.02, 0.76±0.03, 0.87±0.04, 0.84±0.02, 0.92±0.04, accuracy: 0.88±0.05, 0.90±0.02, 0.76±0.03, 0.87±0.04, 0.84±0.02, 0.85±0.06.

Conclusion: Overall, we obtained excellent segmentation results, but compared to other bones, pelvis showed the lowest performance, which is likely due to result of the larger anatomical variations for pelvis. In this study, we designed a similarity map using a fast-sliding local patch and an adaptive atlas selection step. A fast sliding patch method reduced the overall computing time by reducing unnecessary operations. Additionally, adaptive atlas selection techniques were useful in preventing segmentation performance degradation due to incorrect registration.

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