Abstract: Multi-Task Framework for X-Ray Guided Planning in Knee Surgery

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X-ray imaging is frequently used to facilitate planning and operative guidance for surgical interventions. By capturing patient-specific information prior to and during the procedure, such image-based tools benefit a more reliable and minimally invasive workflow at reduced risk for the patient. To this end, typical assessment involves geometric measurements of patient anatomy, verification of correct positioning of surgical tools and implants, as well as navigational guidance with help of anatomical landmarks and bone morphology. However, performing the involved steps manually is prone to intra-/inter-rater variability and increases the task complexity for the surgeon. To remedy these issues and using femoral drill site planning for medial patellofemoral ligament reconstruction as an example, we present a framework which allows fully-automatic localization of anatomical landmarks, segmentation of bone structures, and prediction of ROIs for geometric line features on X-ray images [1]. We exploit recent advances in sequential deep learning architectures in form of deep stacked hourglass networks to refine predictions based on the learned residual information between intermediate estimates. We propose an extension to a multi-task learning approach to incorporate cross-task information and introduce a novel adaption of gradient normalization for automatic task weighting in stacked network architectures. On 38 clinical test images the framework achieves a median localization error of 1.50 mm for the femoral drill site and mean IOU scores of 0.99, 0.97, 0.98, and 0.96 for the femur, patella, tibia, and fibula respectively. The demonstrated approach consistently performs surgical planning at expert-level precision without a need for manual correction.

References

1. Kordon F, Fischer P, Privalov M, et al. Multi-task localization and segmentation for x-ray guided planning in knee surgery. Proc Med Image Comput Comput Assist Interv. 2019; p. 622–630.