Abstract: Automatic Path Planning for Safe Guide Pin Insertion in PCL Reconstruction Surgery

Florian Kordon[1,2,3], Andreas Maier[1,3,4], Benedict Swartman[5], Maxim Privalov[5], Jan S. El Barbari[5], Holger Kunze[1,2]

[1]Pattern Recognition Lab, Universität Erlangen-Nürnberg (FAU), Erlangen
[2]Siemens Healthcare GmbH, Forchheim
[3]Erlangen Graduate School in Advanced Optical Technologies (SAOT), Universität Erlangen-Nürnberg (FAU), Erlangen
[4]Machine Intelligence, Universität Erlangen-Nürnberg (FAU), Erlangen
[5]Department for Trauma and Orthopaedic Surgery, BG Trauma Center Ludwigshafen, Ludwigshafen
florian.kordon@fau.de

Reconstruction surgery of torn ligaments requires anatomically correct fixation of the graft substitute on the bone surface. Several planning methodologies have been proposed to standardise the surgical workflow by localising drill sites or defining the drill tunnel orientation. A precise drill tunnel is of high clinical relevance to prevent detrimental changes in the reconstructed ligament's biomechanics as well as early wall breakout with the risk of damaging neurovascular structures. Unfortunately, the practical implementation of these guidelines is limited by the often complex and time-consuming nature of the planning steps. In this work, we propose an automatic solution to support the trauma surgeon in guide pin path planning in double-bundle posterior cruciate ligament (PCL) reconstruction surgery on the lateral tibia [1]. A two-stage algorithm is proposed that operates on a single intra-operative 2D X-ray image: First, key anatomic cues are extracted from the image using a multi-task deep learning algorithm. Then, these cues are forwarded to a geometric pipeline in which a logical partitioning of the bone contour is used to orient the drilling path optimally and ensure a safe distance between the drill tunnel and the bone edge. In contrast to a single-stage algorithm that directly calculates the tunnel positioning parameters, this allows the user to adjust the location of the inferred anatomical features interactively and enables low-latency modification of the path proposal. We evaluate the approach on 38 radiographs of the tibia where we observe a median path angulation error of 0.37° and a median localisation error of 0.96 mm for the ligament attachment centre. The results suggest further clinical validation and comparison to the accuracy of manual plannings.

References

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