Development of an orthopedic surgery planning system for implant positioning with user-definable constraints

PARK SY[1], HA YC[2], YEOM JS[3], KIM NK[4]

[1]*University of Ulsan College of Medicine, Asan Medical Center, Seoul, South Korea*
[2]*Department of Orthopaedic Surgery, Chung-ang University Colledge of Medicine, Seoul, South Korea*
[3]*Spine Center and Department of Orthopaedic Surgery, Seoul National University Bundang Hospital, Sungnam, South Korea*
[4]*Radiology, Asan Medical Center, Seoul, South Korea*

seyoun.park@gmail.com

Optimal positioning problem of implants in the pre-operation for the orthopedic surgery usually can be determined from some specific constraints mating features. Related to this problem, there have been massive previous works to perform implant positioning using anatomical, geometrical and mechanical features. Since there are trade-offs to compare each other quantitatively, an automatic surgical planner for the general usage with one algorithm is hard to satisfy various surgical needs due to variety of patient variation and different features of implants by different production companies. In addition, surgeons might have their own planning method. For these reasons, we proposed a software system to assist total heap replacement (THR) and total knee arthroplasty (TKA) surgical planning in the pre-operation step by a constraint-based approach widely used in computer-aided design (CAD) to modify and re-define constraints flexibly.

Our surgical planner is composed of two parts. The first phase allows the user to define the planning work with constraints and to save them as a script. Since we only need to consider the hard tissues when positioning implants for THR and TKA, simple 2D and 3D sketch elements can be defined at this stage based on implants or bone template models, represented as polygonal surfaces using interactive interface. Constraints are defined through these sketched geometric elements with pre-defined features and important axial lines of the implants or bone template. The features or geometric elements of an implant and an anatomic template model were pair-wised to find the best position and orientation of the implant, mostly fitting to the anatomic model. This characteristic is similar to the assembly features in the mechanical CAD system. Then, the relational constraints between paired features were used to determine the position of implants. In addition, users could adjust the position of implants within remaining degree-of-freedom, or modify the position interactively after releasing all or some of the constraints. At the second phase, if users load the constraints, the planner automatically determines the best position of implants satisfying constraints on the pre-operative CT image. Implants are stored in the form of library with pre-defined features inside the system. For this work, we represented the anatomical geometry as a boundary representation (B-rep) type polygonal surface which could be composed of several surface patches. These constraints consist of a geometric part such as distance, angle, arc radius and a relational part such as mate, parallel, and tangency at the end point of an arc, etc. They are stored as a graph data structure in the system, the sequence of constraints is checked along the graph whether there is a confict. The 3D coordinates and orientations of implants are computed by a variational solver in our system. Determining the size and position of implants only depends on hard tissues, which is similar to solid modeling of industrial CAD system.

The proposed constraint-based modeling system could be one solution for the various patient data and surgical planning methods, even though the verification in the aspect of usability, efficiency, and quality is remaining as a follow-up studies.