Implant Deformation on Digital Preoperative Planning of Lower Extremities Fractures

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ABSTRACT

Preoperative planning is an essential step before performing any surgical procedure. Computer Aided Orthopedic Surgery (CAOS) systems are extensively used for the planning of surgeries for fractures of lower extremities. These systems are input an X-Ray image of the fracture and the planning can be digitally overlaid onto the image. In many cases, when an implant is added to the planning, it does not fit perfectly in the patient’s anatomy and therefore it is bended to be adjusted to the bone. This paper presents a new method for the deformation of implants in CAOS systems, based on the Moving Least Squares (MLS) method. Several improvements over the original MLS are introduced to achieve results visually similar to the real procedure and make the deformation process easier and simpler for the surgeon. Over 100 clinical surgeries have been already planned successfully using a CAOS system that employs the proposed technique.

Keywords: Computer Aided Orthopedic Surgery (CAOS) System, Computer Science, Digital Image Processing, Medical Application, Object Modeling

INTRODUCTION

Preoperative planning is a vital step that all surgeons should follow prior to performing any surgical procedure. The main purpose of this planning is determining the final result of the surgery and setting up the surgical technique to be applied during operation. As explained in the work of Stannard, Schmidt, and Kregor (2007), preoperative plans for fractures can be done manually by tracing on paper the patient’s fractured bones using previously captured standard radiography images. The main idea is puzzling together the traced pieces of bone, manually placing them on their correct anatomical position. When implants are required, they are traced on paper too using clear plastic templates of the implants.

Although this manual procedure has proven useful, it is very time consuming and error prone. In past years, a variety of software systems used on orthopedic surgeries has been developed, where the preoperative planning can be done digitally (Yusof et al., 2009). These kinds of systems are called CAOS (Computer Aided Orthopedic Surgery). In a CAOS system the surgeon can load X-Ray images and digitally
reassemble the pieces of the fractured bone. If an implant is required, the surgeon can select one from an implant library and overlay it over the X-Ray image. The surgeon can also add annotations and measurements which could be of help during surgery. The process is made completely digitally and so the preoperative surgery plan can simply be printed out and taken into the surgery room. Moreover, the plan could be digitally stored along with other patient information, in a PACS (Picture Archiving and Communication System) server for instance, if available.

In some cases the surgeon needs to bend the implant to make it fit in the correct anatomical position. This bending is done in the surgery room while the patient is lying on the surgery table, and can be done several times until the implant fits correctly. This step could also be planned digitally so as to avoid this repetitive manual bending, therefore reducing surgery time.

Previously, we presented a CAOS system which included an implant deformation stage (Ramírez & Coto, 2010). This stage consisted on a 4-step pipeline. The first step consists of loading the 3D model of the implant from an implant library. All models in the library are in STL (stereolithography) format. The second step projects the model using parallel projection onto the visualization plane from six different viewpoints (top, bottom, right, left, front and back). The third step is rendering this projection and overlaying it on the patient’s X-Ray. In the last step, a set of point handlers is located along the major axis of the implant image. Using these handlers the user can bend the implant more quickly.

In Ramírez and Coto (2010) we used the warping technique presented by Birkholz and Jackeln (2003), but this did not produce clinically acceptable visual results, since this technique deforms the complete image while in practice surgeons require only local deformations. In this paper, we present a new method for implant deformation for our CAOS system, which is focused on fractures of the lower extremity. This method is a new variant of the Moving Least Squares (MLS) approach for 2D image deformation presented by Schaefer, McPhail, and Warren (2006), which is a widely used method for surface reconstruction, image deformation and morphing processes.

In our proposed method, we include the automatic placing and distribution of deformation handlers, a new mechanism to manipulate the handlers and a new weight function based on the MLS technique, which improves the results of the deformation process. The presented method does not generate foldbacks and the deformation is very similar to the real bending in the surgery room.

This paper starts by describing works related to deformation in CAOS systems. Following that, it briefly explains the MLS deformation technique. Next, the proposed deformation method is explained in detail. Then, experiments and results are described. Finally, conclusions and future work are presented in the last section.

RELATED WORK

Michalíková, Bednarcikova, Petrik, Zivcak, and Rasi (2010) define the digital preoperative planning process as fast, precise and cost-efficient. Its main goal is to improve overall surgical performance and thus patient outcomes. Furthermore, it provides a permanent archived record of the templating process. A few medical areas require preoperative planning as essential part of daily practice.

CAOS systems are widely used in several studies and clinical trials for hip, spinal, knee, trauma and tumor surgeries, preplanning and simulation. For instance, Moscatiello et al. (2010) used a 3D radiologic viewer for the preoperative planning of rhinoplasty interventions. The 3D viewer was only used for visualization purposes, but it lead to an improved planning and a reduction in postoperative surgical corrections, proving the usefulness of new technologies in the preoperative period of rhinoplasties. A notable case of CAOS system is presented by Friederich and Verdonk (2008), which is used
Functionalization and the Real Virtual: What Happened to Us and How We Want to Overcome It Now
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