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A comparison study assessing the feasibility of ultrasound-initialized deformable bone models

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Abstract

This article presents a feasibility and evaluation study for using 2D ultrasound in conjunction with our statistical deformable bone model within the scope of computer-assisted surgery. The final aim is to provide the surgeon with enhanced 3D visualization for surgical navigation in orthopedic surgery without the need for preoperative CT or MRI scans. We unified our earlier work to combine several automatic methods for statistical bone shape prediction and ultrasound segmentation and calibration to provide the intended rapid and accurate visualization. We compared the use of a tracked digitizing pointer and ultrasound for acquiring landmarks and bone surface points for the estimation of two cast proximal femurs.

Keywords: *Intra-operative ultrasound, statistical shape modeling, computer-assisted orthopedic surgery, minimally invasive surgery*

Introduction

The use of 3D anatomical models in computer-assisted surgery (CAS) provides the surgeon with image guidance and enhanced visualization to assist navigation and planning. Such models are typically obtained from preoperatively acquired CT or MRI scans, which may not always be available or may not even be necessary if cheaper, radiation-free and/or intra-operative solutions can be provided.

Consequently, intra-operative 3D anatomical visualization can potentially be achieved using an image-free or sparse information approach through the use of statistical shape models. Building a patient-specific anatomical model is a nontrivial challenge given sparse *a priori* patient anatomical data. Statistical model building consists of establishing legal variations of shape from a training population. The statistical model is then adapted, or *fitted*, to the patient anatomy using intra-operatively digitized bone surface points. Thus, the aim of statistical shape model fitting is to extrapolate from an extremely sparse set of 3D points a complete and accurate anatomical surface representation.

Surface points are typically acquired by use of a tracked digitizing pointer. In cases of limited surgical access, it can be difficult to acquire a set of points that spans the patient's anatomy sufficiently to ensure accurate shape prediction of a given statistical model. As such, a natural extension is to use ultrasound imaging for noninvasive intra-operative digitization of surface points. The use of ultrasound in CAS is a subject that has been broached by several scientists. Chan *et al.* [1] and Lavallée *et al.* [2] have explored methods using ultrasound to instantiate 3D deformable bone models without the need for preoperative CT or MRI scans. We present here our first experiences using our method for automatic segmentation of 2D B-mode ultrasound contours [3], concurrently with our 3D bone deformation method [4], to provide rapid, automatic intra-operative visualization for navigation and planning in minimally invasive orthopedic surgery.

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