Chapter 78

Preoperative and Intraoperative Spatial Reasoning Support with 3D Organ and Vascular Models:
Derived from CT Data Using VTK and IGSTK

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ABSTRACT

Different imaging modalities (MRI/CT) are used to analyse/plan complex surgical procedures in order to minimize risks and complications. Although there are numerous computer tools for preoperative assistance (VR/AR simulators, 3D printed implants), intraoperative systems are less common, specifically for soft tissue related interventions. For this reason, this paper is focused on 3D reconstruction. The proposed reconstruction combines a surface approach for organs and a block approach for vascular networks. Layered closed surface(s) represent an organ and stacks of extruded individual contour blocks represent the vascular networks. The authors use IGSTK to show that their approach improves shape and transparency results when compared with other modelling methods and to communicate with trackers. With their method polygon contour correspondence/branching between slices is implicit/automatic, saving time; they show that traditional tiling problems become visually negligible. The authors' novel file format allows polygons segmented by other tools to be reconstructed in their contour annotation tool which uses VTK.

INTRODUCTION

In minimally invasive surgery, the performance or position in the learning curve of a surgeon when applying a new technique can be gauged by analysing indicators such as patient blood loss, and operation time (Li, et al., 2009). Before an operation takes place, computed tomography (CT) data and other modality data is studied to plan the intervention. Based on this information, computer-assisted surgery systems allow to perform surgical planning and intraoperative navigation. These systems enable surgeons to know structures which pose risks in the intervention increasing patient safety (Fang et al., 2015).

Baumhauer et al. (2008), note in a comprehensive survey that whilst there is a broad range of computer assisted surgery applications routinely deployed on rigid structure interventions, not much exists for intraoperative support for soft tissue interventions. An example amongst many of such an application, is the work of Ramírez & Coto (2012) where bone implants are digitally deformed and adjusted to a patient pre-operatively as part of planning, thus reducing surgery time later. Moscatiello et al. (2010) use commercial volume rendering software for rhinoplasty preoperative planning and have also reported reductions in surgery time.

For soft tissue interventions, liver imaging has multiple applications such as measurements of liver volume (Sánchez-Margallo et al., 2011); diagnosis and quantification of tumours and other diseases (Goryawala et al., 2012); surgical planning prior to hepatic resection or surgical navigation systems (Maeda et al., 2009). However, knowing or remembering where vascular structures lie underneath a surface during a surgery is challenging, see Figure 1. One possible solution would be to use intraoperative CT, but this is prohibitively expensive for widespread adoption (Craven et al., 2005). Instead 3D models built preoperatively from CT data could be used as a road map of the vascular network intraperatively. To create these models, one needs to previously solve the problem of the segmentation of organs and vascular structures and the problems associated with soft tissue reconstruction from the segmented CT contour polygons. Throughout this paper we use the liver as an example of a soft tissue target intervention.

Several factors contribute to make segmentation of an organ or soft tissue in a CT image a complex task: the morphological alterations and similarity of grey levels with other neighbouring structures; noise; and the variations of grey level inside the liver. Different types of segmentation exist, depending on the degree of user participation in the process: manual, semiautomatic and automatic. With manual segmentation, the user draws the contour of the anatomical structure in all slices of the study. An experienced radiologist, with a good knowledge of human anatomy and its variations must produce these

Figure 1. Laparoscopic surgery. left) operation room setting; right) typical video image
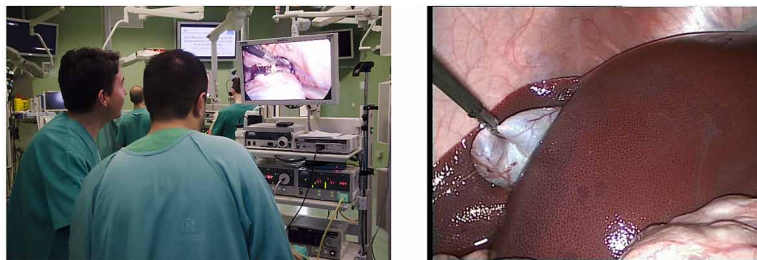
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