Virtual Polypectomy

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1 Introduction

Colorectal cancer is the second leading cause of cancer-related death in the United States and in Europe. If benign adenomas are removed prior to the development of malignancy, colon cancer is essentially preventable [1]. With the introduction of multidetector CT and advanced strategies for fast 3D MR imaging, the concept of virtual colonoscopy has become realistic. Promoting colon polyp screening programs, even more polyps will be found and therefore more polyp extractions are requested. Colonoscopy and endoscopic interventions are already procedures for experienced professionals and for difficult tasks, years of experience is needed [2]. To address a professional learning experience, we have assembled a preliminary environment for simulating tasks that are performed in colonoscopy. Different commercial prototype endoscopy simulators exist and provide realistic interfaces using the same hardware as used for conventional colonoscopy, but none of these products are able to simulate realistic soft tissue deformations using patient specific preoperative CT or MRI colon datasets. This paper presents a virtual environment for the simulation of colonoscopy procedures incorporating patient specific data providing an interactive, semi-immersive, haptic interface to the user.

2 Data Acquisition / Virtual Colonoscopy

Virtual endoscopy (VE) examinations and virtual polyp extractions were performed on clinical cases, using both, multidetector CT as well as MRI. The CTC and MRC techniques require proper patient preparation prior to scanning and instillation of colonic contrast (air for CTC or dilute gadolinium solution for MRC). The segmentation for virtual endoscopy was performed using Amira 2.0 (TGS Inc., San Diego, CA). Amira provides a component for 3D-image segmentation with several special-purpose features, ranging from purely manual to fully automatic methods. Once the lumina of the bowel have been segmented, a corresponding polygonal surface model by using the Generalized Marching Cubes module was created. The high-resolution mesh consisting over 1.4 million triangles was then simplified resulting in a mesh of under 200,000 polygons, which is more reasonable for interactive simulations, yet still provides sufficient fidelity for simulation.

3 Soft-Tissue Deformation and Polyp Extraction

In order to provide real-time, haptic-compatible update rates (>1000 Hz) of truly arbitrary deformations, a simplified mass-spring system was used to represent objects within the physically-based modeling simulation system. Solution of the deformation equations is done using a semi-static solver, which ignores inertial and damping forces but provides a significant increase in performance. In order to speed up the simulation further, we track the regions of deformation and only solve those that are currently undergoing interaction or distortion. Finally, we solve the deformation equations asynchronously, using a multithreaded model on multi-processor workstation. The simulation system is written in C++ using the OpenGL, GLUT, and POSIX libraries. The custom haptic handle is achieved by using a prototype device. For probing and tissue extraction, different endoscopic tools were developed and integrated. The score tip of the colonoscope with instrument channel, irrigation, lens and light are modeled and the working channel allows interactions with different instruments (biopsy forceps, snare) for polyp extraction.

Fig.1. (a) Colonoscope reaching the polyp with the lasso tool. (b) Lasso ensnares the base of the polyp, deforming the tissue. (c) Cutting the polyp

4 Conclusions

We can import patient specific high-resolution meshes into a system that models colon polyps with different physical properties for interaction with both non-force-feedback and haptic devices. This virtual reality system for simulating virtual colonoscopy and polyp extraction can be used to simulate diverse procedures on a variety of pathologies in a novel physical environment and hopefully can shorten training periods and reduce complications.

References

1. Toribara, N.W. and M.H. Sleisenger, *Screening for colorectal cancer [see comments]*. N Engl J Med, Vol. 332 (1995) 861-7
2. Tassios PS, et al. Acquisition of competence in colonoscopy: the learning curve of trainees. Endoscopy. Vol. 3 (1999) 702-6