Virtual Open Heart Surgery - Training Complex Surgical Procedures in Congenital Heart Disease

Thomas Sangild Sørensen
CAVI
University of Aarhus, Denmark
sangild@cavi.dk

Jesper Mosegaard
Dept. Computer Science
University of Aarhus, Denmark
mosegard@daimi.au.dk

1 Introduction

We have developed a new training tool for complex heart surgery and present an open heart surgery simulator on congenitally malformed hearts. The purpose of the simulator is (at least) two-fold: 1) To illustrate various elements of difficult surgical procedures, and 2) To allow surgeons to rehearse these elements virtually. In time, virtual surgery is expected to become a natural supplement to and even replace parts of current surgical training. In a foreseeable future, new tools will take younger surgeons faster and more safely through their inevitable learning curves. We also expect these tools to help experienced surgeons during their preoperative planning of the most complex cases.

2 Surgical simulation

Morphologically accurate models of congenitally malformed hearts were reconstructed from 3D MRI data [Sørensen and Mosegaard 2005] and integrated in graphical settings representing the surgical environment (Figure 1). It is possible to reconstruct the morphology of individual patients or alternatively, through post-processing "invent" more generalised malformations.

The simulator resolves a volumetric spring-mass system entirely on the GPU [Mosegaard and Sørensen 2005a]. Visualisation is decoupled from the underlying simulation [Mosegaard and Sørensen 2005b]. Supported gestures include elastic tissue deformation by grabbing, cutting, and suturing. Haptic feedback is provided at 500 Hz [Sørensen and Mosegaard 2006].

The system achieves visual feedback at 30 Hz on a Geforce 7900 GTX when a surface of 135,000 faces is visualized based on deformation of an underlying spring-mass system of 20,000 nodes. The spring-mass system is updated off-screen at approximately 500 Hz.

3 Discussion

Using the GPU as a processor, we can now harvest the computational power necessary to simulate the deformation of complex morphology in real time. For the first time, surgeons can rehearse open-heart surgery interactively in a virtual environment. As a consequence, an entire new field of surgical education is emerging to help cardiac surgeons accelerate their learning curve for the safety of patients. As complex cardiac malformations are never identical from patient to patient, the presented tool greatly enhances the surgeon's spatial understanding of the individual morphology prior to the surgical procedure.

SIGGRAPH 2006 attendees are invited to test their skills in closing a ventricular septal defect (a hole between the two main chambers of the heart).

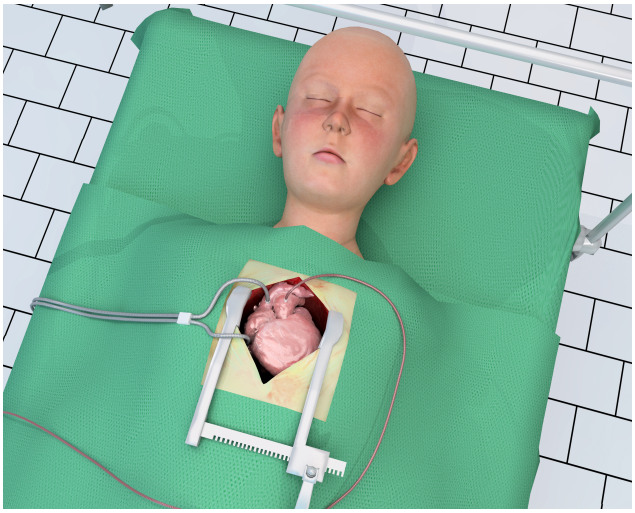

Figure 1: Ray-traced rendering of our open heart surgery graphics. The heart is reconstructed from patient specific 3D MRI.

Acknowledgments

Funding from the Danish Research Council's Program Committee on IT-Research (grant #2059-03-0004) and the Danish Heart Foundation (grant #05-10-B359-A657-22265). Contributions by Dagur Ballisager, Bo Søndergaard Carstensen, and Allan Rasmusson from CAVI, University of Aarhus, Denmark, and paediatric heart surgeons Ole Kromann Hansen and Vibeke Hjortdal, Aarhus University Hospital.

References

MOSEGAARD, J., AND SØRENSEN, T.S. 2005a. GPU accelerated surgical simulators for complex morphology. *IEEE Virtual Reality*, 147-153.

MOSEGAARD, J., AND SØRENSEN, T.S. 2005b. Real-time deformation of detailed geometry based on mappings to a less detailed physical simulation on the GPU. *Eurographics Virtual Environments*, 105-110.

SØRENSEN, T.S., AND MOSEGAARD, J. 2005. Surgical planning in congenital heart disease by means of real-time medical visualisation and simulation. *ACM SIGGRAPH Animation Festival*, 295.

SØRENSEN, T.S., AND MOSEGAARD, J. 2006. Haptic feedback for the GPU-based surgical simulator. *Medicine Meets Virtual Reality*, 119:523-528.