Alexis Quesada-Arencibia
José Carlos Rodríguez
Roberto Moreno-Díaz jr.
Roberto Moreno-Díaz (Eds.)

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EXTENDED ABSTRACTS

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Prototyping a laparoscopic skill trainer based on virtual reality and image processing

Jan Nikodem[1], Andrzej Wytyczak-Partyka[1], Ryszard Klempous[1], and Jerzy Rozenblit[2]

[1] Faculty of Electronics, Wrocław University of Technology, 11/17 Janiszewskiego, 50-372 Wrocław, Poland,
{jan.nikodem,andrzej.wytyczak-partyka,ryszard.klempous}@pwr.edu.pl
[2] The University of Arizona, Department of Electrical and Computer Engineering, Tucson, Arizona, jr@ece.arizona.edu

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Extended abstract

In this paper, we describe an innovative software and hardware system for 3D localization of the laparoscopic instruments and realistic organ geometries in workspaces of minimally invasive surgery.

Interactivity is a very important aspect of developing a successful laparoscopic surgery simulation system [2–4].

In what follows, we discuss software and hardware aspects. Software design requires graphics displayed on a computer monitor with a 30 frames per second refresh rate. Such a rate provides sufficient interactivity for eye-hand coordination requirements. A higher rate is necessary when collision detection compete with modelling of complex interactions of tissues and deformable objects. Finally, a much higher rate is necessary for smooth haptic interactions, where collision detection and collision response [5] during surgical simulation should be calculated in real time. Task/events compete with each other for available computational resources and efficient algorithms are necessary to achieve the required interactive rates.

Hardware requires methods for 3D tracking of each laparoscopic instrument in vivo. Works have been published [1], based on multi-DOF arms combined with electro-optical encoders/resolvers. Next, using the geometric transformations based on trigonometric and cyclometric functions, we can calculate the instrument tip position in a three dimensional space. The main drawbacks of such an electro-mechanical coupling are repeatability and acceptable inaccuracy of obtained/calculated instrument position.

The described work involves several innovations in designing laparoscopic skill trainer based on virtual reality and image processing. We postulate a considerable simplification of hardware contribution in laparoscopic surgery simulator. Of course, "there ain't no such thing as a free lunch", so this implies that software needs to be more sophisticated. Just like it happened with the mice to your computer, we suggest substitution of mechanical layouts by image processing.

Of course, we do not turn away from hardware, but we simplify it considerably, by modifying it, so that it only serves to implement the haptic feedback.

To cope with 3D graphics and real time image processing, we use an open-source library Object-Oriented Graphics Rendering Engine (OGRE). It is a scene-oriented, real-time, flexible 3D rendering engine written in C++. It is designed to make it easier and intuitive for programmers to produce applications utilizing hardware-accelerated 3D graphics. To realize a physical modelling that have contributed to the development of a laparoscopic skill trainer, we need to model physical phenomena such as gravity, dynamics and collisions. For this purpose we use Bullet software, which is a physics engine. It simulates soft and rigid body dynamics with discrete and continuous collision detection.

In order to provide greater level of 3D graphics fidelity, we are currently working on implementation of Compute Unified Device Architecture (CUDA) for this data-intensive task. For complex scenarios involving multiple organs interacting with one or more laparoscopic instruments, the expected advantage of the CUDA is the ability to effectively parallelize pair-wise collision checks.

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