

A Virtual Reality Simulating Catheter Manipulations

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Abstract

This paper describes a virtual reality system for catheter manipulation. This is a part of a novel education system for medical personal and students who aspire to become catheter specialists. It teaches not only catheter procedures but also clinical procedures of Electrophysiology Study (EPS) and catheter ablation with domain knowledge of electrophysiology.

A input device is connected to the system. During manipulation, it sends values to the simulation system: immersion length, rotation angle, and bend angle. The system simulates the position and the shape of the virtual catheter using those arguments. A virtual catheter is constructed using a spring mass model and calculated using a penalty method. Our system also displays virtual X-ray images. Watching the virtual roentgen images, an operator can confirm catheter position by sight as in clinical practice.

Experimental results show it is sufficient educating the manipulation of catheter. However, challenges about force feedback still exists.

1 Introduction

Recently, cardiac catheterization has been used for diagnosis and therapy of cardiac disease with arrhythmias. However, advanced technology and experience are required for study and therapy using a catheter. In particular, EPS and catheter ablation require deep knowledge of electric physiology and skilled dexterity. For example, the American College of Cardiology and American Heart Association guidelines specify 100 cases of EPS practice in a year and require no less than nine sorts of skills, from operation to measurement. Other advanced nations have also specified

the generally same training.

Some biomedical manufacturers, in the U.S. and Sweden, have already developed an apparatus for catheter practice. Such devices are appropriate, however, only for catheter procedure practice, inadequate for electrophysiological operation. There is no simulation system for training experts in this field.

Therefore, we are developing a novel education system with which medical personnel can master the techniques of electrophysiology study and catheter ablation. Using our system, they can gain a better comprehension of electrophysiology beyond conventional training by actually simulating the surgery. This is the world's first simulation system for EPS practice [1].

The purpose of this paper is to describe development of a virtual reality system for the catheter procedure education, approximating real operations. The input device is small in size for connecting to computers and produced at low cost. Also, it affords real feeling in manipulation.

2 The system configuration

In clinical practice, a doctor insert catheters to suitable positions in a patient, looking at an X-ray monitor. To simulate such operations, our simulator is set up with an actuator (Fig. 1) as catheter input device and a computer graphics display as virtual X-ray monitor (Fig. 2).

The actuator simulates the catheter manipulation. Equipped with three sensors per catheter, two linear encoders and one rotary, it measures immersion length, rotation angle, and bend angle, and sends these values to the simulation system during manipulation. Immersion length and bend angle are measured by the linear encoders, and rotation angle is measured by the

rotary encoder.

The simulator calculates the position and shape of the spring-mass modelled catheter in a mesh heart model from received values and displays rendered computer graphics simulating X-ray images[2]. Accumulating all forces extracted on each element using a penalty method and solved using Newtonian equations, the shape of the catheter model is deformed. The forces comprise deformation force of transforming and bending by manipulation, repulsion from blood vessel walls by collision detection, and spring tension.

Finally, the simulator renders virtual X-ray images and displays them. To render virtual X-ray images, a shader was written in HLSL of Microsoft®DirectX®9. The shader accurately emulates roentgen scope, by virtually measuring the organ thickness and modulating the pixel intensity of simulated X-ray shadow.

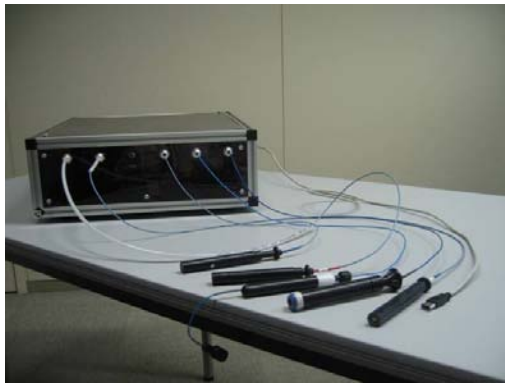


Figure 1. The actuator.



Figure 2. The Virtual X-ray monitor

3 Results and Discussion

The experiments were conducted on Pentium®D machine with 2.8 GHz CPU and 2 GB RAM. Since the shader requires D3DFMT A16B16G16R16 support, we chose ATI®RADEON®1950XTX as GPU. The virtual X-ray monitor display is shown in Figure 2.

Manipulating the actuator, the catheter model tips are moved from starting point to arbitrary selected locations, such as high right atrium or right ventricular apex. When it simulates a single catheter, the response is adequate but, increasing the number of simulated catheters, however, causes the simulation to slow noticeably.

4 Conclusion

A virtual reality environment was developed as a simulation system for catheter manipulation. In this system, an actuator deployed as input device is connected to the computer. It measures catheter manipulation and sends the values. A simulator tracks the catheter model in a virtual environment and displays virtual X-ray images.

Since collision detection is calculated for all polygons and elements in this system, response suffers under load of multiple catheters. Future tasks include system performance enhancement, such as making the calculation using a physical processing unit or optimizing the algorithm. Also, force feedback should also be implemented.

References

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