A Virtual Reality System for Knee Diagnosis and Surgery Simulation

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Abstract

This paper describes the design and development of a VR system that can assist orthopedic diagnosis and surgery. A realistic 3D knee surface model, integrated with motion analysis, is used to visualize the geometrical and biomechanical characteristics of human knee joint. The system can be used to perform pre-operative surgery simulation and evaluation in VR environment.

1. Introduction

Human knee joint is the most frequently treated anatomic area in orthopedic surgeries. Some of the knee surgeries, such as osteotomy, require very high accuracy and therefore are difficult to perform.

This paper describes the design and development of a VR system that can assist surgeons to diagnose knee problems and virtually practice the difficult knee surgeries. The system is based on a realistic 3D knee joint surface model that is animated by the motion data gathered from the walking patient. The system can also simulate the knee surgery process in virtual environment, which allows surgeons to conduct realistic rehearsal without risk to the patient.

2. 3D model and motion capture

To achieve realistic effect in VR environment, we reconstruct a 3D knee surface model using model-based reconstruction technique. First, a reference knee surface model is obtained by scanning an artificial plastic knee model in 3D space. The obtained reference model, which includes femur, tibia and meniscus, is in very high resolution. Next, the reference model is deformed to match a set of knee MRI images taken from the patient.

In order to accurately diagnose the problem with knee joint, doctors need to observe the knee behavior during gait cycle. A 3D motion capture system is used to collect motion data from the patient. The system captures the changing 3D coordinates of a number of markers put on the leg of the walking patient**.** The femur and tibia flexion, extension and rotation angles can be calculated from those coordinates.

3. Motion and surgery simulation

The knee joint behavior of the patient during gait cycle is visualized in virtual environment by animating the 3D knee surface model based on the knee joint flexion, extension and rotation calculated from the motion data. By comparing the motion of the abnormal knee with that of the normal one, the malfunction can be identified. Moreover, the system is able to calculate the femur and tibia contact area and the changing of load distribution on the knee surface. The visualization of those parameters can provide further information for the diagnosis.

The surgery simulation is also based on the 3D knee model. Taking osteotomy as example, during the surgery simulation, the 3D knee model and a virtual cutting device are displayed in the virtual environment. The user can navigate the cutting device to cut through 3D knee model. The system will calculate the intersection and split the knee model along the intersected curve. The user can turn the knee model around during the cutting process to examine the path of incision. This process, which may not be possible in real surgery, will help surgeon find the best incision, gain experience and improve the skill.

4. Conclusion

This project shows that integrating motion analysis with VR visualization is highly beneficial to the orthopedic diagnosis. The surgery simulation in the VR environment can provide a better training opportunity that may not be available in the real world.