Virtual Surgery System for Interactive Surgical Simulation

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1. Introduction

Medical virtual reality (VR) allows us to manipulate three dimensional (3D) human structures in 3D space in real-time.The aim of our study is to develop a surgical simulation system especially for surgical planning using virtual reality techniques. We made an efforts to allow performance of realistic surgery on 3D images. With our system, the surgeon can start the operation with a skin surface incision in order to create a more realistic impression with quantitative analysis. We also strove to enable it to handle large amount of data representing detailed anatomical information on the human body in real time.

2. Methods

The developed system allows surgery to be planned on 3D images using patients' anatomical data. Fig.1 is a blockdiagram of the system. With our system, the surgeon is able to incise organs and vessels within and retract them in a manner similar to actual soft tissue by calculation of the incision plane and transformation of organ model structures. This transformation of soft tissue is displayed in the schematic diagram in Fig.2. Fig.3 shows a typical scene of the operator performing a surgical simulation with our system. In this image the 3D image which the user observes with a head mount display (HMD) is composited.

This system is composed of a graphic work station and a pen-shaped and a glove shaped input devices with location sensor, that detect hand and finger movements of the user.

The patient's organ, including its internal structure, is reconstructed as a 3D image, and the portion to be incised is defined by the movements of the user's surgical knife or electric knife, as detected by the location sensor. Incision planes displays on CRT are opened to the left and right against incision plane, in a manner similar to an actual elastic organ, according to the direction, length and depth of the incision which was made by the user's will. The incised part can be widened at the discretion of the user, and the sectioned vessels or other internal structures of the organ are also displayed on the surface of the incised plane. It is also possible to manipulate organ with surgical tools such as various kinds of forceps and retractor etc. We used Onyx with Reality Engine2 (Silicon Graphics, USA) as a main image processor.

We tried to perform the facility with the ability to incise or manipulate more complicated structures in the human body. The human body has an architecture formed by organs which covered by skin and muscle layers. We would like to start our virtual surgery by incising the skin surface to make it more closely resemble actual surgery. The organs and skin should move or change their shape by interfering with surrounding soft tissues. In order to realize these facilities, we applied two methods to determining the transformation values for incisions.The first was the use of stored reference data for transformation of soft tissues. We collected those data from incision experiments on autopsy organs. The second was a "sphere filled model". In this method,organ model reconstructed from patient data is filled with sphere,and movement of each spheres depends on external force. These movements determine morphological changes on elastic organ models. This method is suitable for high speed processing of the deformation and interference of organs with complicated shapes. (Detail of this model is mentioned in this issue by Ezumi et al.)

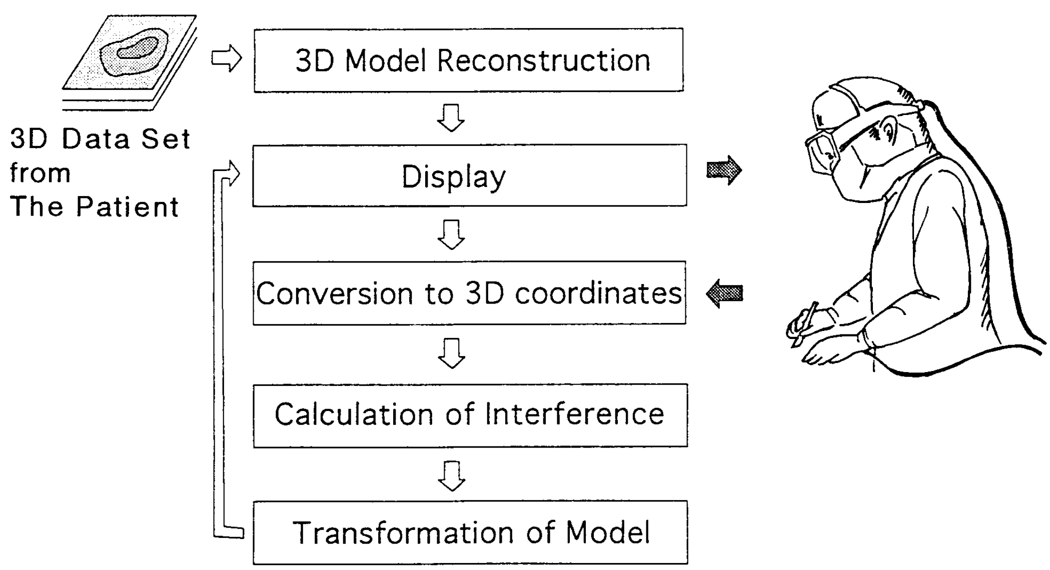

Fig.1 Blockdiagram of the system

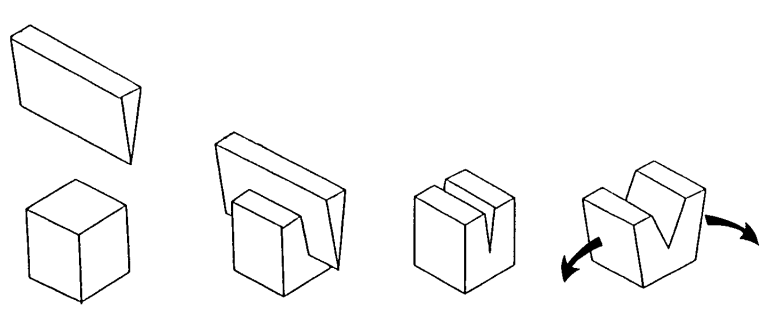

Fig.2 Transformation process of the model by incision

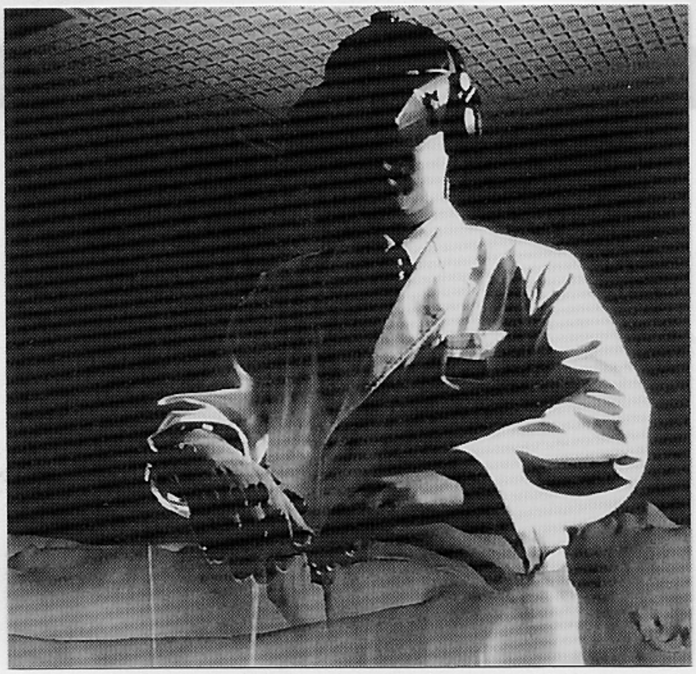

Fig.3 A scene of the user performing a surgical simulation with the system. In this image the 3D image which the operator observes with a head mount display (HMD) is composited.

3. Results

Fig.4 shows the procedure used for making an incision on the surface of the liver using a surgical knife. The incised part is widened and the dissected vessels are seen on the incised plane. Fig.5 shows the procedure in case of hepatectomy lobectomy and the virtual environment were made more similar to the environment in the operating room. Fig.6 shows serial images of the process of incision at abdominal part in the system. Images shows that the user is able to make incision in optional direction and depth. Fig.7 shows the scene of abdominal section using various kind of surgical tools such as abdominal retractor and forceps. All 3D models in this paper (Fig.4 - Fig.8) are reconstructed from MRI data sets measured from volunteers and patients. Surface information on patients has been added on both cases in order to identify the incision place in relational location of the navel or surgical scars. Organ models are also added surface texture information in Fig.5 - Fig.8. Organ surface information are provided in these images by collecting data from autopsy. These texture is mapped on the 3D reconstructed organ surface by identifying anatomical features. However these information are able to turn off if it is not required by the user. This system is also able to applied for the endoscopic surgery using the same algorithm and Fig.8 shows the view one of them.

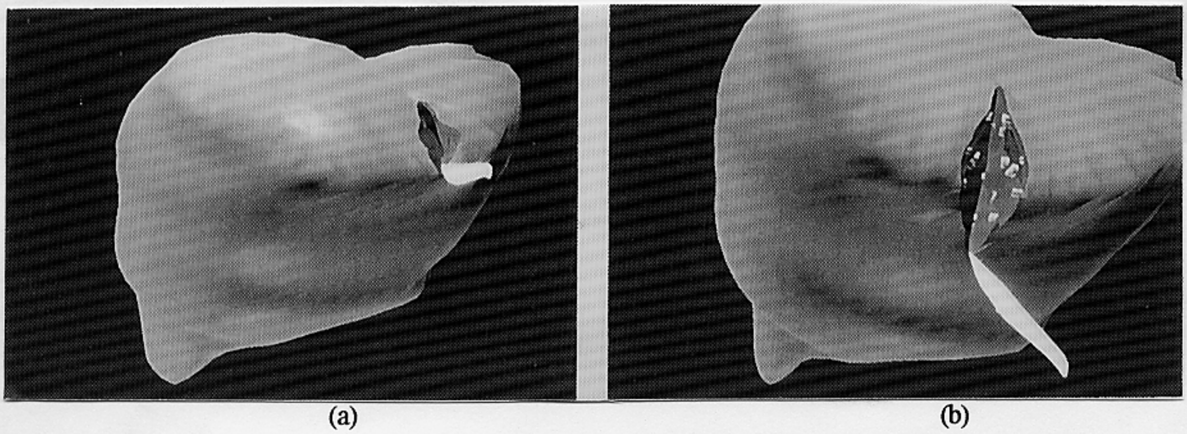

Fig.4 The condition of the incision on the surface of the liver model reconstructed from MRI data set

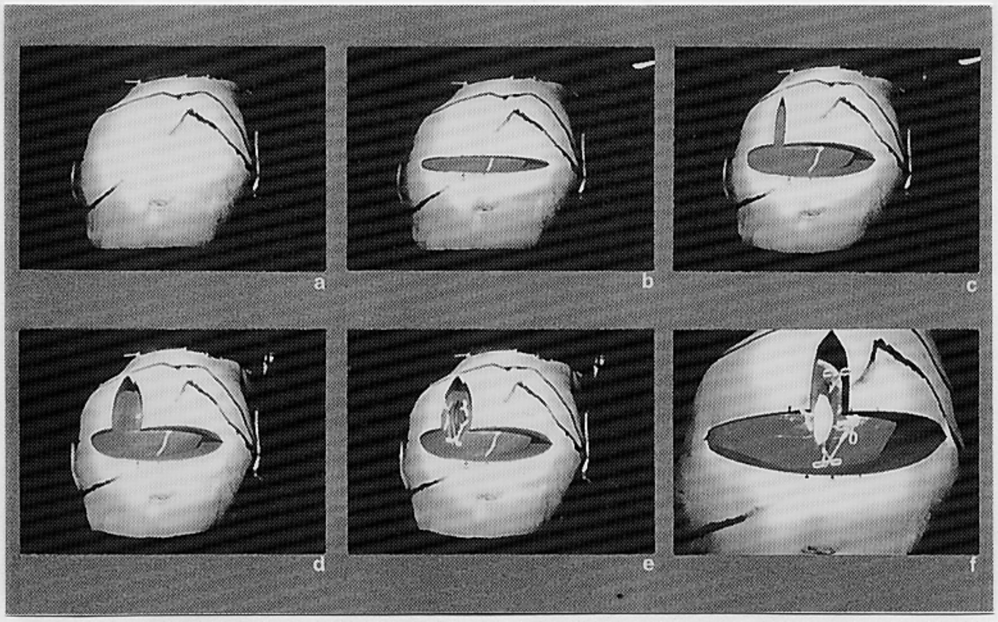

Fig.5 Virtual surgery in case the environment were made similar to an operating room.

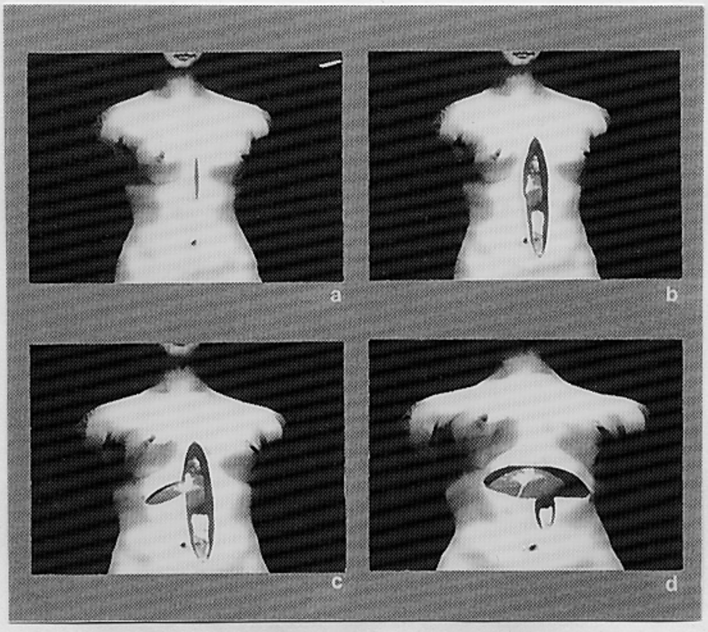

Fig.6 Variation of the condition of incised part according to the location of incision.

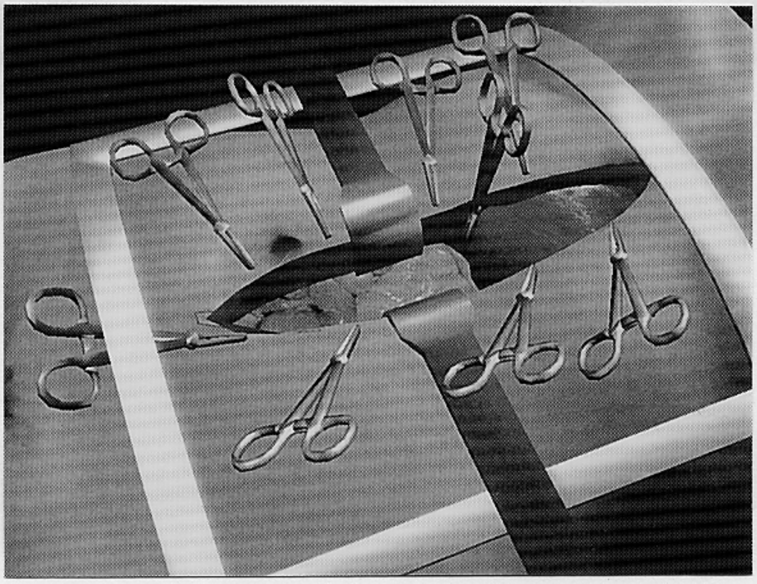

Fig.7 A scene of abdominal section with an abdominal retractor and forceps

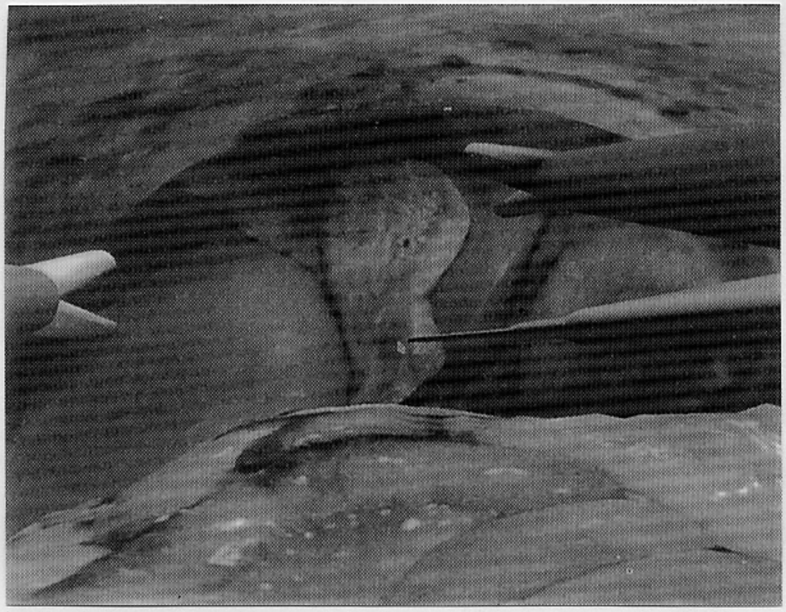

Fig.8 A scene of endoscopic surgery with the present system

4. Conclusion

Virtual surgery is based on an interface technique between surgeon and surgical simulation, and is most effective for obtaining practical information from simulation and relaying surgery decision in natural way in a short time. It is considered that the selection of an optimal surgical plan will be possible based on the experimental results in a 3D image, and it may also be possible to practice an operation prior to surgery according to a patient's specific anatomical characteristics with this system.

It has become possible to perform real surgical operation with the developed system. However,the problem of increasing lag time in the face of large quantities of anatomical information which increase its amount according the progress of surgical works has not yet solved. We will continue to improve the system to be able to simulate more complicated surgery in more natural way with the force feed back system in the near future.

5. References

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