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Dynamic Anatomical Model for Medical Education using Free Form Projection Display

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Abstract. Authors are developing Virtual Anatomical Model for medical education using a Free Form Projection technology.
In the system, a screen in the shape of human torso is used. An image of virtual organs is projected onto the curved screen surface. The torso can be handled directly by the user's hand and examined, and the virtual organ is shown as if it is fixed inside the body surface, and gives the user a sense of motion parallax.
In our previous system, however, the organs themselves are static and fixed objects. To give medical students an essential anatomical learning, It is necessary that the virtual organs provides a reaction that reflects the user's action. In this paper, we realized a function that the objects are changed dynamically according to user's movement and user's action.
Keywords: Medical Education, Virtual Anatomical Model, Free Form Projection Display

1. Introduction

For medical students, it is important to learn the complexities of human body structure. Human anatomical models are sometimes used by medical students to master the human body structure. The medical student can learn the position, size and shape of internal organs exactly by handling and examining those parts of the human anatomical model.

The authors are developing Virtual Anatomical Model (VAM) [1] that is the combination of a physical body figure with superimposed computer graphics (CG) of internal organs. Using VAM, the virtual object can be handled directly by the user's hand and examined. The goal of VAM is to promote medical students understanding using graphical expression and direct manipulation.

1.1. Free Form Projection Display (FFPD)

The projection display is sometimes used for the mixed reality. By projecting virtual object into the real space or the real object, we can easily achieve the situation where the virtual object is neighboring to the real object in the same space. In most studies, however, the image is projected onto limited only fixed screen surface [2][3].

FFPD is a technology to compensate the projection distortion according to location of the user's viewpoint, location of the projector and the screen's position and shape [4]. The shape of the screen is measured in advance, and the position and rotation of the screen and the position of the user's viewpoint are measured in real time. A distortion eliminating method is performed according to those measured parameters. Using FFPD, the image of virtual object projected onto the curved surface will be seen by user without distortion. Furthermore, FFPD gives the user a feel of motion parallax, and displays the virtual object as if it lies inside the actual object.

FFPD enables the user to handle virtual objects directly by their hand easily. The error and distortion in the observed image derived from the angular and positional error of the user's head measurement is less than the case of HMD/CAVE system, because the screen is similar to the shape of the virtual object and the virtual object is located near to the surface of screen. [5]

1.2. Virtual Anatomical Model

Virtual Anatomical Model (VAM) for medical education has been developed using FFPD. It is an anatomy education system using a screen in the shape of a human figure on which images of internal organs are represented by projection, and can be handled directly by the user's hand and examined. VAM is shown in fig 1.

The CG of the internal organs is projected from a video projector hung from the ceiling. The electro magnetic 3D position sensors (Polhemus FASTRAK) attached on the torso screen and the user's head measure the position and rotation of the torso screen and the user’s viewpoint.

Computer generates the image to project like fig.1 (a). The image will be distorted by the curve on the screen surface (fig 1.(b)). Because of Distortion elimination, the user can see the correct image like fig. 1(c).

VAM is currently monoscopic display, but the motion parallax gives the user the depth cues. When the torso screen was being handled, the virtual internal organs moved along with it. By movement vision and object handling, the user can observe the model of internal organs from various angles. Furthermore, internal organs are viewed as if they are inside the transparent torso.

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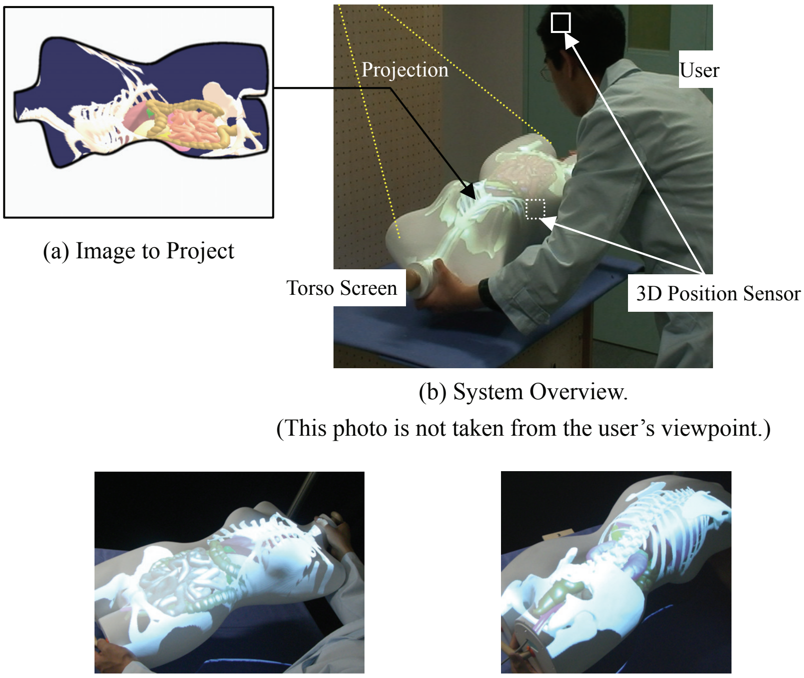

(a) Image to Project

(b) System Overview.
(This photo is not taken from the user's viewpoint.)

Front Side Back Side

(c) User's View

Fig. 1 Virtual Anatomical Model. Example of result;
Virtual organs are represented in the torso screen.

1.3. Purpose

VAM is effective to learn the complicate shape, size, and position of internal organs. In our previous system, however, the organs themselves were static and fixed objects. That was not enough to give medical students an essential anatomical learning.

Studying anatomy, medical students have to learn the flexibility of the organs, structure inside the internal organs and so on. To learn them, the virtual organs must change and move dynamically reflecting user's action.

To give the students that advanced knowledge, the following functions are required:

(1) Mobility of internal organs acceding to body posture.
(2) Optimal cut-out model.
(3) Physiological response of palpation.
(4) Specular reflection.

The purpose in this paper is implementation those reactions to construct a powerful medical education system using dynamic anatomical model.

2. Medical Educational Applications

2.1. Application Framework

First of all, the framework of the system is described. As shown in fig 2, the VAM system is constructed by framework and contents layer. Each of these layers is described in this section.

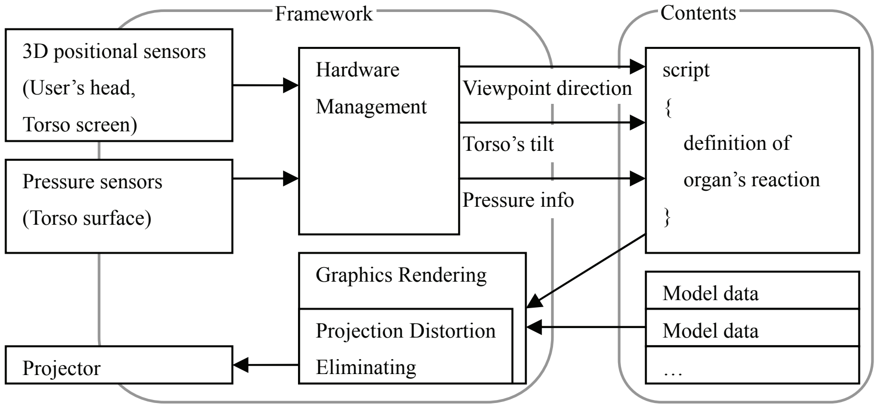

Fig. 2. Application Framework.

Framework

Framework controls the input/output of VAM. The measured torso screen's tilt and the direction of the user's eye from the screen are sent to contents layer. When the pressure sensor attached on the screen detects pushing by user's hand, the sensor id and strength of pressure is informed to contents layer. The framework contains the rendering module, witch eliminates the projection distortion according to screen and user's position using FFPD algorithm.

Contents

Contents layer manages the internal organ's 3D shape data and their reactions. When the torso screen's tilt, the direction of the user's eye from the screen object, and the pressure from the pressure sensors are received from the framework, contents controller changes and moves the 3D model data according to the information.

2.2. Movements of internal Organs

Several internal organs move inside the human cavity. The position of an organ changes according to standing or lying. For medical students, it is important to gain an understanding of the mobility of the internal organs.

For example, to give a medical examination of cholecystitis or appendicitis, understanding of exact position of organs inside the patient lying on the bed is necessary to palpate a patient.

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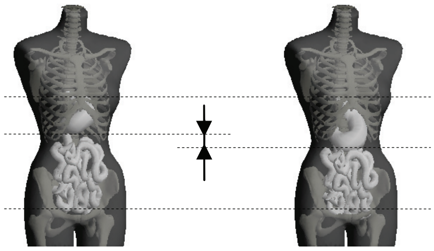
When the orientation of the torso screen is detected by 3D sensor, the system will slide some internal organ models marked as “flexible” to direction of gravity force. As shown in fig. 3, The stomach and small intestine are in their neutral position when the screen object is lying on the table, and when the user handle the body and stand it up, the virtual internal organs are slide. Stomach and small intestine are flexible organs. On the other hand, the bones are fixed to the body.



(a) Lying  (supine position)

(b) Standing  (standard position)

Fig. 3 Mobility of internal organs.

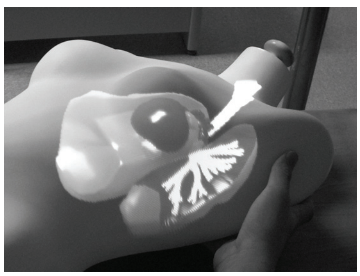
2.3. Viewpoint Dependent Cut-Out Model

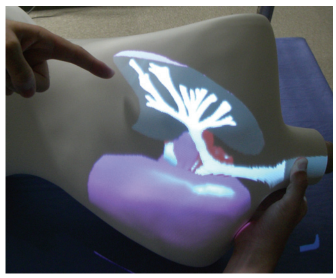
The cut-out illustration is sometimes used for medical education. The organ is cut and partly removed to show the internal structure. The cutting-plane is decided by the illustrator considering which part or structure to be shown to the user. Please note that in this case the viewpoint is the fundamental selection behind the decision of the cutting-plane.

Model A

Model B
(Back Side)

(a) The models.





(Back Side)

(b) The model shown on Human Figure.

Fig.4 3D cut out models of the left lung.

On the contrary in our system, the virtual organs are observed from their arbitrary directions. Since the cut-out illustration depends largely on the fixed viewpoint, it is necessary to develop an alternative expression method of the cut-illustration for this type of system. In this section, the authors propose "viewpoint dependent cut-out model" based on the idea above.

First, the designer creates some model data of lungs shown in a Fig.4(a). Model A is cut from the front of lungs and the bronchi are exposed. It is optimized to be seen from front side. Model B is cut from the back to be seen from its back side.

Next, every model data is registered with one particular direction of viewpoint. Finally, the model of lungs is shown on VAM (Fig. 4(b)). If the observed direction is changed, the system switches the model to a corresponding model, then the user can see the optimal cut-out lungs model constantly.

2.4. Palpation Simulation

Palpation is frequently used during medical examinations of abdominal pain. To palpate, medical students must grasp the exact point and exact pressure of pressurization.

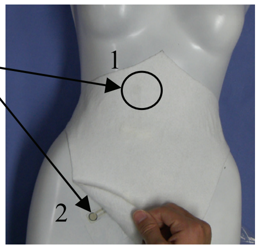


Fig.5 Pressure Sensors attached on well-known tender points.
ID 1 is tender point of cholecystitis, and ID 2 is tender point of appendicitis.

A palpation training application using physical touching on the torso screen and visual feedback has been built [6]. Using this application, the medical student can learn the palpation techniques. The student presses on the human model, and the pressure and pressed sensor ID are detected by the pressure sensors shown in Fig 5. If the position of pressurization and pressure are correct, the system returns pressure pain reaction as a flash and animations. Then students observe the reactions to study how to carry out a medical examination of cholecystitis or appendicitis.

2.5. Specular Reflection Map

In this section, specular reflection that we are planning to implement is described. In real world, an object that have gloss surface exhibits specular reflection. When the observer or the object moves, the reflection is changes dynamically.

The reflection can be implemented using environment-mapping technique in

3D graphics. Fig. 6 shows the example result of reflection mapping; the environment texture image is generated in advance, and mapped onto the shape data. Reflection mapping is performed using the OpenGL [7] texture operation with GL_TEXTURE_CUBE_MAP and GL_REFRECTION_MAP parameters.

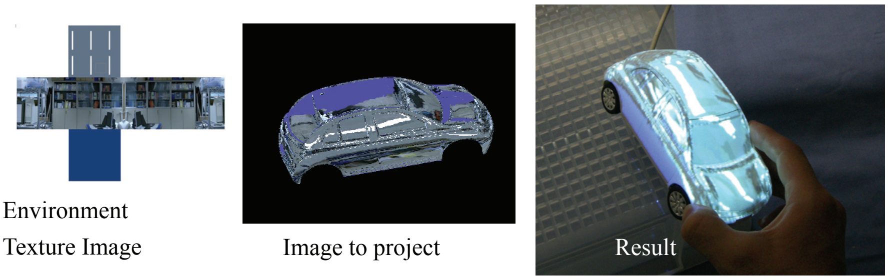


Fig.6 Example result of reflection simulation.
Simulated reflection is projected onto the model of a car. The image projected is changes according to the movement of the user and the car.

The reflection mapping can be applied to an organ witch has the gloss surface; liver, intestine, etc.

A small curve and irregularity largely affect warping of the reflected image. Thus, the specular refection sometimes provides better cues for perceiving the actual shape and the curve on the surface.

3. Conclusions

Virtual Anatomical Model using Free Form Projection Display has been developed. The CG of organs is generated and projected onto screen in the shape of human figure. And the user can see the projected image on the curved screen surface without distortion. Using this construction, the virtual organs can be handled directly and watched freely in the same way as the actual anatomical model.

Dynamic anatomical model is realized to give the medical student an essential learning of anatomy. A framework that manages user's action and organ model's reaction was designed. The following functions are implemented:

Organ's Mobility: The positional shift of internal organs according to the body’s tilt is implemented. Medical students can learn the difference between the fixed organs and the movable organs, through graphical interaction.
Viewpoint Dependent Cut-Out Model: The multiple cut-out models are prepared and the system shows optimal one according to the user's direction. The student can

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see the inside of the organ from any angle.

Palpation simulation: An interactive guidance of palpation techniques has been realized using the pressure sensors embedded in the torso screen.

Specular Reflection: The combination of specular refraction and movement vision makes the virtual object more realistic. Furthermore, it provides better cues for perceiving the actual shape and the curve on the surface.

A powerful medical education system using dynamic anatomical model becomes possible. The medical students can learn the internal organ's flexibility, complexity of human body structures and palpation techniques, trough the dynamic reaction of internal organ models according to the user's action.

In the near future, the framework will be improved, and more types of contents are implemented for learning advanced medical knowledge.

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