Visualization of three-dimensional stomach shapes for virtual observation

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Abstract

Double contrast radiography provides a detailed information of stomach inner-fold patterns that are very important to diagnose stomach. Taking a good quality of this radiograph is difficult because radiologists have to control many things during inspection time. We propose a virtualized stomach and its deformation method based on the approximation of physical features around the stomach. We use both X-ray TV images and external appearances of the subject while taking X-ray images, to transform the shapes of virtualized stomach. Several types of simulated results are presented. © 2001 Elsevier Science B.V. All rights reserved.

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1. Purpose

In this paper, we propose a virtualized stomach wall and its deformation method based on the approximation of physical features around the stomach. In Japan, stomach cancer is one of the serious causes of death from cancer [1]. Mass screening of stomach cancer by radiographs is effective in finding stomach disease. It is said that more than one million people undergo mass screening by stomach radiographs every year in Japan. The double contrast radiography was originally developed in Japan. It provides a detailed information of stomach inner-fold patterns that are very important to diagnose stomach [2]. It is also suitable for computer-aided diagnosis [3,4]. A good quality of this radiograph is difficult to take because radiologists have to control many things during inspection time, such as the posture of subject and the quantity of the contrast medium and carbonic gas in the stomach.

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We visualize stomach shape and its inner conditions by using two kinds of video images while taking stomach radiographs. One is the external appearance of the subject for estimating the posture of the subject, and another is the X-ray TV image, which is the cine image of stomach for extracting two-dimensional stomach contours. This virtualized stomach is useful to understand the three-dimensional features, because one can observe it from various directions without exposing X-ray. We can make any situations that we are not able to take during real inspection. It will be the educational simulator of double contrast radiography for unskilled radiologists.

2. Methods

The virtualized stomach should have to utilize various deformations of stomach, such as variation of the contrast medium state according to the posture of the subject. We realize such deformation by using the three-dimensional active contour model. This model is based on the minimization of energy function that is defined by the physical features of target object. Initial stomach surface model of the subject has been made from two X-ray TV images that are taken from front to back and from right to left projection. First, 193 of the control points that compose the stomach surface are selected by using the front view of X-ray TV image and that of the side (see Fig. 1). We define the deformation factors that approximate physical model around the stomach. We consider the elasticity of stomach wall, stomach inner pressure, pressure from stomach surrounding organs and gravity. Brief explanations of these elements are the discussed below.

2.1. Elasticity of stomach wall

We define two forces that express the elasticity of stomach and keep the characteristic shape of it (see Fig. 2). One is the force that is proportional to the difference

Fig. 1. Illustration of the surface model of virtualized stomach.
between the initial length of each two neighbor control points and that of deformed results. We assume that there is a control point \( P \) that is connected to \( n \) control points \( Q_i \). Then, the force that works for control point \( P \) follows the law of Hooke. Another is the force that is proportional to the difference between the initial angle of each three neighbor control points and the angle of deformed results. We assume that there is a control point \( P \) that is connected to \( n \) control points \( Q_i \), and that each \( Q_i \) is connected to two control points \( R_1 \) and \( R_2 \). Then, the force works as torque from all control points \( Q_i \), for a control point \( P \) is proportional to the each difference from the angle of its initial angle.

2.2. Gas pressure in the stomach

On taking double contrast stomach radiograph, the stomach is stretched by the carbonic gas in it. The quantity of such gas is very important in taking good-quality X-ray image. The force from this gas to each control point is the vector that amplitude is proportional to the difference between the volume of initial stomach and that of deformed results, and its direction is the same as the normal vector at this point.

2.3. Gravity of stomach wall

This is the force by the gravitation of stomach itself. We define this force as the product of the mass of a control point that is defined manually. The force is the gravitation of stomach that is defined as the multiple of mass of control point \( P \) and gravity acceleration.

2.4. Force from the contrast medium

This is the force caused by the contrast medium, which is the most important factor in formulating the stomach shape in double contrast radiography. We assume that the force by the contrast medium is like the water pressure.
Fig. 3. Experimental results: *1 (upper left of each image set (a1, b1, c1)) is the external appearance of the subject; *2 is the X-ray TV image corresponding to *1; *3 is the surface rendering of virtualized stomach; *4 is the wire-frame rendering of virtualized stomach.
2.5. The pressure from surrounding organs

This is the force by stomach surrounding-organs (lung, liver, etc). It is difficult to consider the pressure from the stomach-surrounding organs because the shape and the stiffness of these organs are quite complex. So, we make the three-dimensional potential image that is the approximated index of pressure from the surrounding organs. We apply Euclidean distance transformation from the stomach surface [5]. The Euclidean distance transformation is a picture-to-picture transformation. Each non-zero value voxel changes to the minimum Euclidean distance from zero voxel (stomach surface). The gradient vector of intensity value at point P defines the force from stomach-surrounding organs for a control point P.

We define the energy of this model by the sum of the amplitude of vector corresponding to these factors like Snakes [6]. To minimize this energy, each control point moves along to this vector.

3. Experiment and results

In the experiment, three-dimensional visualization of the stomach surface during real inspection by the skillful doctor was done. We extract the posture of the subject from the external appearance of the subject. We also extract two-dimensional stomach contour at same time from the X-ray TV image. In order to reduce the change of camera parameter and stomach shape during inspection, the affine transformation is applied to the three-dimensional potential image. The affine parameter is decided as the value that the extracted two-dimensional contour of the stomach looked like to the form of the projected virtualized stomach shadow. The virtualized stomach form changes in accordance with the extracted conditions above. An example of processing result is shown in Fig. 3.

Reproduction of stomach during real inspection by the skillful radiologist is achieved. One can observe the three-dimensional shapes of the stomach and the quantity of the contrast medium from any direction. These features are satisfying the educational simulator of double contrast radiography.

4. Conclusion

In this paper, we proposed and constructed the model of stomach from real inspection images. Active contour methods were used for the transformation of the virtualized stomach. We extract the set of control points from these images and define their deforming factors through many experiments. To minimize the energy function defined by these deforming factors, virtualized stomach is deformed as the change of the subject’s posture and quantity of contrast medium.

As a result, we obtain the good results of deformed stomach. Virtualized stomach is observed from any position and X-ray-less, there is the possibility of training simulator for unskilled radiologists.
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