A METHOD FOR VISUALIZING THE INSIDE OF CAVITIES AND ITS APPLICATION TO MEDICAL CT DATA

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ABSTRACT

This paper introduces a novel method for drawing the surface of a 3D cavity in a single view, along with some results from its application to CT images. This type of view can be very useful for observing a hollow organ since it resembles a specimen of the organ that is resected from surgery. We use a physically-based approach to unfold the organ wall to a planar shape, then reconstruct image data based on the unfolded shape to reproduce the luminal surface. The method has a potential of being used for surgical simulation and product inspection.

1. INTRODUCTION

The remarkable progress of multi-detector row CT scanners has enabled us to acquire hundreds of sub-millimeter resolution CT slices from a human body in only 5 to 20 seconds [1]. For the observation of anatomic structures, virtual endoscopy [2] is now becoming an effective volume visualization technique that allows one to virtually enter an hollow organ and inspect its luminal surface. However, virtual-endoscopy-based navigation is still challenging and sometimes leads to incomplete examinations because one has to shift the viewpoint and change the view directions frequently to reach some regions of interest, or to confirm whether all such regions have been observed.

In this paper we introduce a method that unfolds an organ and draws its luminal surface in a single view. Unfolded views are very useful since they resemble resected specimens which are commonly used for the pathological diagnosis and the documentation of the treatment procedure. In Section 2, a brief description of the method is given. Unfolding results of hollow organs including stomachs, colons, and bronchial branches in CT images of actual patients are shown in Section 3. This paper is based on our work presented in [3].

2. METHOD

Unfolded views of an organ are generated by cutting and deforming the organ wall region in CT data and then visualizing the deformed data by volume rendering. Our method consists of three steps : (1) geometric and elastic modeling of the organ wall, (2) cutting and deforming the model, (3) reconstructing image data and visualizing the reconstructed data.

2.1. Geometric and elastic modeling

An elastic model of the organ wall is generated. First, a set of hexahedra is generated from the segmented organ wall region. Next, mass points and Voigt elements are allocated for the generated hexahedra to represent the viscoelastic behavior of the model. The inner and outer surfaces of the model are represented as sets of hexahedron faces. Deformation of the model is represented by motions of individual mass points under external forces. These motions are computed by the Newmark-β method [4], a stable numerical method, so that most hexahedra preserve their topology during deformation.

2.2. Model cutting and deforming

A cutting line on the model is specified and the model is cut and stretched over a plane until its inner surface become open. Cutting is implemented as the removal of mass points and viscoelastic elements in hexahedra which hit the cutting line. Stretching forces are applied to mass points near the cutting line. After stretching, surface normals of the stretched model are then used to automatically determine flattening forces to direct the model to a planar shape. The model is flattened by these forces until the weighted sum of force magnitudes is less than a given threshold. To keep the model lying on the plane, the motion of any mass point that collides with the plane is modified by taking into account the effects of repulsion and friction so that it bounces off the plane.

2.3. Image reconstruction and visualization

An unfolded view of the organ is generated by reconstructing image data based on the geometric relation between the initial and deformed models then visualizing the resultant dataset by volume rendering. Our image reconstruction algorithm guarantees one-to-one mapping between hexahedra of the initial and deformed organ models. Hence, it is possible to generate views in which the luminal surface is accurately reproduced.

3. RESULTS

The method is validated on CT images acquired from 17 actual patients. Unfolding results of three datasets are shown in Fig. 1. It can be seen that observing the entire luminal surface by unfolded views is much easier than by virtual endoscopic views. Several concave or bending parts of the organ wall are well unfolded to a planar shape. Organs having thin wall, such as the colon or the bronchus can also be unfolded. Computation costs about 5 minutes in modeling, 2 minutes in stretching, 7 seconds in flattening, and 6 seconds in image reconstruction for each dataset on a conventional PC (CPU: Xeon 3.4 GHz x 2, Memory: 2 GB, OS: Windows XP) without parallel computing.

4. CONCLUSION

A novel method for generating unfolded views of hollow organs based on volumetric image deformation was introduced along with some experimental results of unfolding several organs from CT images of actual patients. The method can be useful for unfolding various kinds of organs including stomachs, bladders, colons, bronchial branches, or any cavity in 3D images. It has a potential of being used for surgical simulation and product inspection.

5. REFERENCES

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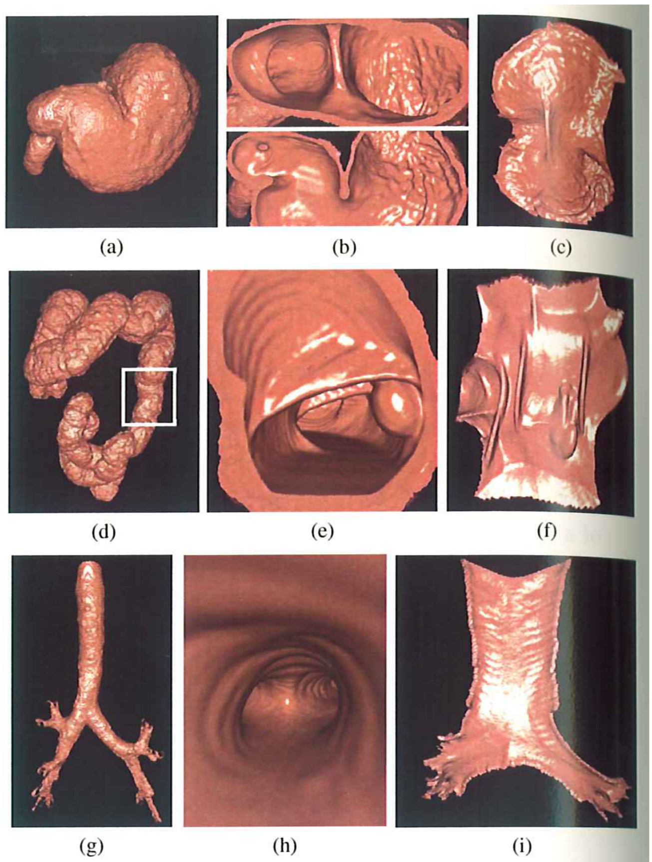

Fig. 1. Unfolding results of hollow organs in CT images (top row: stomach, middle row: colon, bottom row: bronchus). (a, d, g) outside views, (b, e, h) virtual endoscopic views, (c, f, i) unfolded views.

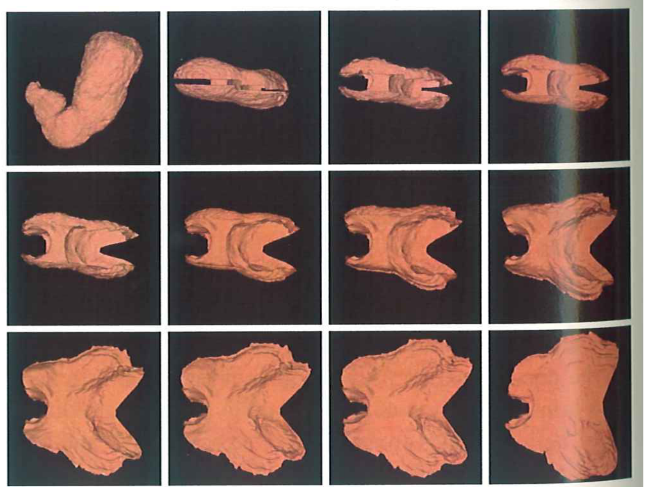

Fig. 2. Some views generated in time sequence during simulation. (1): initial view, (2): cut view, (3)-(12): unfolded views. All views except (1) were generated from the same viewpoint and view direction.