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Methods to Visualize Interiors of Human Colons in Volumetric Datasets

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Abstract

This paper examines three categories for visualizing the interior of the human colon. In the 2D slice-viewing category, axial, coronal and saggital slices of the colon volume are displayed. In the 3D endoluminal viewing category, also called "virtual fly-through", a virtual camera is placed inside the colon lumen, and renditions of the scene are generated. In the category of unwinding / flattening methods, the tortuous colon is either transformed into straighter, cylindrical geometry or the whole colon lumen is mapped onto a single 2D image. In each category, advantages and limitations or challenges are discussed.

Introduction

In the National Library of Medicine's Visible Human Project, visualizing interiors of hollow organs is one important topic. In the hollow organs, the human colon is a typical example, which has the tortuous and tubular geometry. Techniques developed to visualize the colon interiors can be applied to other hollow organs. In clinical applications, it is also highly desirable to develop effective and efficient methods to show interior structures and pathologies of the colon embedded in the acquired 3D volumetric dataset (CT, MRI, etc) for colorectal cancer detection.

Two-dimensional Slice Viewing Methods

These methods are based on viewing slices of the acquired colon images, usually 2D axial, coronal and sagittal slices.

This type of methods is easy to design and use. However, the burden lies squarely on the user to reconstruct the 3D colon surface and imagine structures mentally. The learning curve can be long. Since one colon image volume usually contains several hundred slices, even for experienced viewers, inspecting the entire colon lumen with this type of method is time consuming.

Three-dimensional Endoluminal Viewing Methods

This type of methods is also called "virtual fly-through". It places a virtual camera inside the colon lumen, and then generates renditions of the scene while the camera is moving through the lumen, thus providing endoluminal views of the colon lumen similar to those seen in conventional fiberoptical colonoscopy.

The three-dimensional endoluminal viewing methods can provide an effective way to observe colon interiors. The endoluminal views of the colon lumen are presented in a natural and easy to understand way, similar to those seen in conventional fiberoptical colonoscopy. Users have much greater freedom to maneuver the virtual camera than they do with the conventional fiberoptical colonoscopy.

The three-dimensional endoluminal viewing methods often suffer from navigational disorientation or bumping into the colon wall. It is often easy to overlook or miss some regions of the colon surface.

Colon Unwinding and Flattening Methods

Unwinding refers to transforming the colon into a straight, cylinder-like shape, thus reducing the overall tortuosity of the colon geometry. Unwinding facilitates the fly-through process in the aforementioned three-dimensional endoluminal viewing methods given that the overall tortuosity of colon geometry is reduced.

Flattening refers to mapping the entire colon lumen onto a single 2D image. Flattening sets up another paradigm to inspect the undulated tubular colon. It facilitates rapid and complete colon surface inspection. In some flattening methods, morphometric information of the colon surface can be presented in the 2D image, enabling the inspection of colon interiors in a fashion different from directly rendering the surface shapes.

This type of methods is usually hindered by geometric distortion in the results, because unwinding / flattening is essentially geometric mapping, thus distortion is inevitable.

Conclusion

The 2D slice-viewing methods are the simplest to design; however interpreting the results is neither easy nor intuitive. The 3D endoluminal viewing methods display the colon interior in a natural and easy to understand fashion; more research work is needed in order to improve the navigational guidance and to increase the surface inspection coverage in the fly-through process. In the colon unwinding and flattening methods, unwinding greatly eases the process of flying-through the colon lumen, and flattening maps the entire colon surface onto a single 2D image, thus enabling easy, complete and rapid inspection of the whole colon; more research work is needed to reduce geometric distortion on the colon surface caused by the unwinding or flattening operations.

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