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Virtual Endoscopy using Spherical QuickTime-VR Panorama Views

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Abstract. Virtual endoscopy needs some precomputation of the data (segmentation, path finding) before the diagnostic process can take place. We propose a method that precomputes multinode spherical panorama movies using Quick-Time VR. This technique allows almost the same navigation and visualization capabilities as a real endoscopic procedure, a significant reduction of interaction input is achieved and the movie represents a document of the procedure.

1 Introduction

Virtual endoscopy (VE) and especially virtual colonoscopy (VC) have gained much attention in diagnostic radiology recently. After acquisition of a MRI or CT volume data set the procedure involves the following computation steps:

- segmentation of the colon
- determination of the (typically central) path through the colon
- navigation through the colon and visualisation of the colon wall
- documentation of the flight through the colon as a movie
- transfer of the document together with the report to the referring physician
- in a modern environment: archiving and communication of the document in a PACS

In clinical practice it has turned out to be advantageous to do the segmentation in advance and also to compute a path before viewing, because otherwise the navigation is extremely tedious and time consuming and needs a complex user interface. In ideal cases segmentation can be done automatically [1], however, in some cases manual control is required due to noise in the data or motion artefacts. A common approach for path computation is skeletonization [2]. For noisy data and due to wrickles in the colon highly sophisticated heuristics are needed to remove dead ends and loops, to end up with a smooth path. Another way to support navigation is described in [3]. Here a potential field is calculated, which is used to compute a force that pushes the virtual viewer back onto the central path. The strength of the force depends on the distance of the current view point to the path. At the colon wall the force is infinite thus inhibiting the user to pass through the wall. Other approaches unfold the inner colon surface to a 2D image map [4]. However, clinicians are unfamiliar with these images in addition to geometric distortion problems.

The visualization of the colon wall requires a conversion of the colon surface to polygonal meshes in order to utilize standard computer graphics hardware and software, which allow to compute 3D views at near real-time speed for modest size datasets. Available voxel-based accelerators (e.g. Mitsubishi VolumePro) cannot perform perspective transformations directly which are a essential for calculating endoscopic views [5].

Outgoing from the fact, that navigation is complex (even when a central path is already defined) and real-time visualization for high quality rendering cannot be achieved on standard PCs, we investigated an approach that also precomputes a large part of the visualization. Expected advantages are that visualization is restricted to "meaningful" images and interaction becomes easier.

2 Method and material

If we would try to include any possible view in a precomputed movie, the amount of data would be huge and navigation would not be simple at all. If we use only a fixed field of view and a constant viewing direction while moving through the colon along the central path one might miss important details which are outside the selected field of view (e.g. behind wrinkles). A well-known technique from classical photography is the use of wide angle ("fish-eye") lenses, but these yield strong geometric distortions. Another approach that we propose here is the generation of panorama images where a number of overlapping photographs are taken while the camera is rotated around the vertical axis. The single photographs are then connected to form a cylindrical image also known as a panorama view. While this technique needs some effort in photography it can easily be simulated in computer graphics. However, cylindrical projections do not allow straight views up and down, i.e. 90° upwards or downwards from the horizon due to geometric distortions that become apparent at viewing angles larger than 45°. A generalization of cylindrical panoramas are spherical panoramas, which allow viewing in all directions. Recently Apple Computer, Inc. has incorporated spherical panoramas into their QuickTime-VR technology. They provide a data structure where six images corresponding to the six faces of a cube are interpreted as a spherical panorama [6]. The QuickTime player has a build-in distortion correction method for viewing these *cubic panoramas* as spherical scenes. In contrast to other precomputed movies, the amount of data is thus decisively reduced. In addition the interaction with QTVR movies is very simple.

Cubic panoramas are computed as follows: From a given viewpoint we compute six 3D projections, which correspond to the six faces of a cube. The viewpoint is assumed to be located at the center of the cube, i.e. the first projection looks into the direction along the central path, then we turn 90° to the right, compute the 2nd image. Turn again 90° to the right, now we are looking back into the direction we came from, turn again and finally we compute the images when looking 90° upwards and downwards. As can easily be seen the six projections must be calculated with a field of view of exactly 90° so that the images fit nicely together and form the faces of a cube (Fig. 1). The images are stored as a sequence of frames together with additional information that allows QuickTime to recognize the images to be a cubic panorama. The QuickTime player then allows continuous navigation across the entire panorama in real-time using the two degrees of freedom of the mouse.

For a continuous motion through the colon we compute such cubic panoramas along the central path every few millimeters with a high resolution rendering algorithm described in [7]. The single panoramas, which are called nodes in QuickTime terminology, must then be connected to enable the player to "jump" from one node to the next. This is accomplished using so called hot spots, which are just an additional image layer, where the pixel values correspond to the node number the player may move to. These hot spot images are very simple and can be calculated automatically for colonoscopy, because there are no bifurcations. Thus if we are at node n the pixel value of the hot spot for all possible forward-looking directions, i.e. 180° field of view from the initial viewing direction, is n+1, and the value for all backward-looking directions is n-1. The result is a multi-node cubic panorama movie.

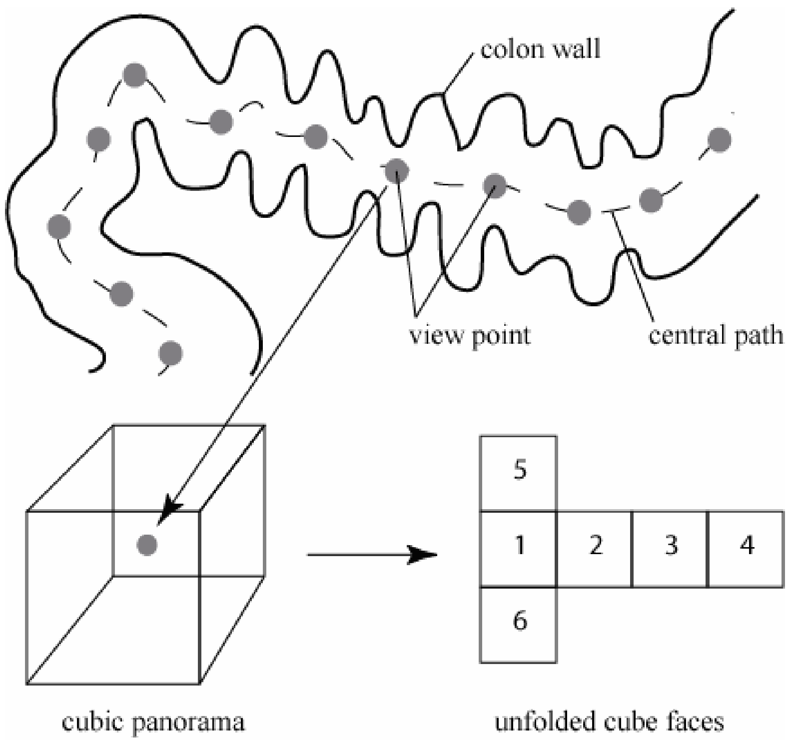

Fig. 1: Cubic panorama generation. At any viewing position 6 projections corresponding to the 6 faces of a cube are computed with a field of view of 90°.

As each panorama node has its own initial viewing parameters, i.e. pan and tilt angles and field of view, it is important for a smooth transition from one node to the next not to use these initial values to preserve and transfer the parameters of the current node. We modified the behaviour of the player to handle this requirement, so that it become possible to move through the colon while inspecting the colon wall laterally.

For diagnostic purposes it is not sufficient to provide endoscopic views only. For the radiologist, who is familiar with interpreting CT and MR images, it is a necessity to have access to the original data at any stage of the viewing process. Therefore we do not only store the panorama images but the corresponding z-buffers and the related viewing transformation matrices as well (Fig. 2). With this additional information available we can easily get back from any surface location into the original gray scale volume. Furthermore this allows the simultaneous display of different views such as 3D outside views, in which the current virtual camera position and orientation can be marked to facilitate orientation.

3 Results

We applied the described method to about 20 contrast enhanced MRI datasets of the colon. The datasets were segmented by thresholding and the central path as well as up to 200

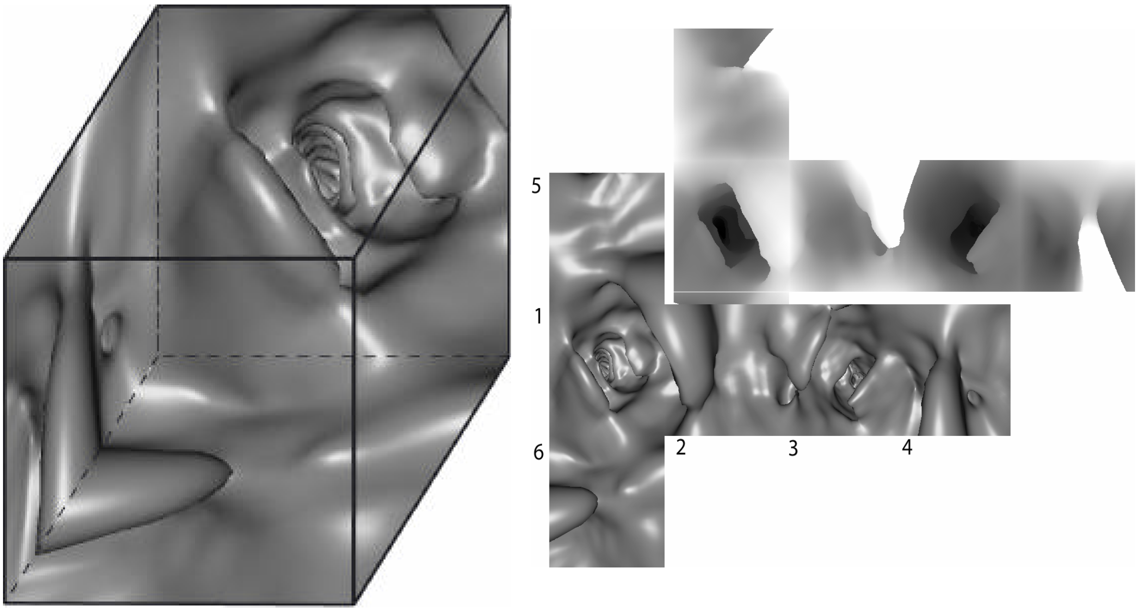

Fig. 2: Left: Cubic panorama projections. Right: Image map of the 6 unfolded cube faces (front) and their corresponding z-buffers (rear). The distortion correction for viewing a panorama is performed automatically by the QuickTime player

high resolution cubic panoramas together with their corresponding z-buffers were computed and stored in the QuickTime VR movie format. Additionally a matrix of 3D overview images that show the colon from outside were created to facilitate orientation. These images are stored as a QuickTime VR object movie which is very similar to panorama movies. The radiologist can then access the final movie over the intranet on his desktop PC. He can "move" through the colon in real-time while looking around in all directions searching for abnormalities. On the 3D overview he can verify were the virtual endoscope is currently located. Also, just by clicking on the colon surface at any location, the corresponding position is marked on three orthogonal cross-sections showing the original MR values. This helps the radiologist who is familiar with 2D cross-sections in the assessment of suspected lesions. Fig. 3 shows the simple graphical interface we have developed for virtual colonoscopy. Our radiologists feel comfortable with the user interface. The entire procedure takes a couple of minutes for establishing a diagnosis.

4 Conclusion

Using precomputed spherical panorama images for virtual endoscopy allows quasi real-time viewing and easy navigation on a standard PC. Especially the very simple user interface has proved helpful for the acceptance of the procedure. The method can also be applied to structures with bifurcations like blood vessels or the bronchi. Fig. 4 shows as an example the bifurcation of the bronchi computed from the Visible Human data set [8]. As a decisive advantage the panorama movie represents a document similar to classical video recordings of real endoscopic examinations with additional functionality that can be viewed with standard software at any PC or with browser technology in an Intranet. Due to the fact that computation time is not an issue, also more sophisticated rendering methods like automatic color labeling of suspicious regions can easily be incorporated. If connected to a knowledge base [9] additional features like symbolic descriptions and manipulation capabilities become possible, which allow to generate even more comprehensive teaching and learning material [10].

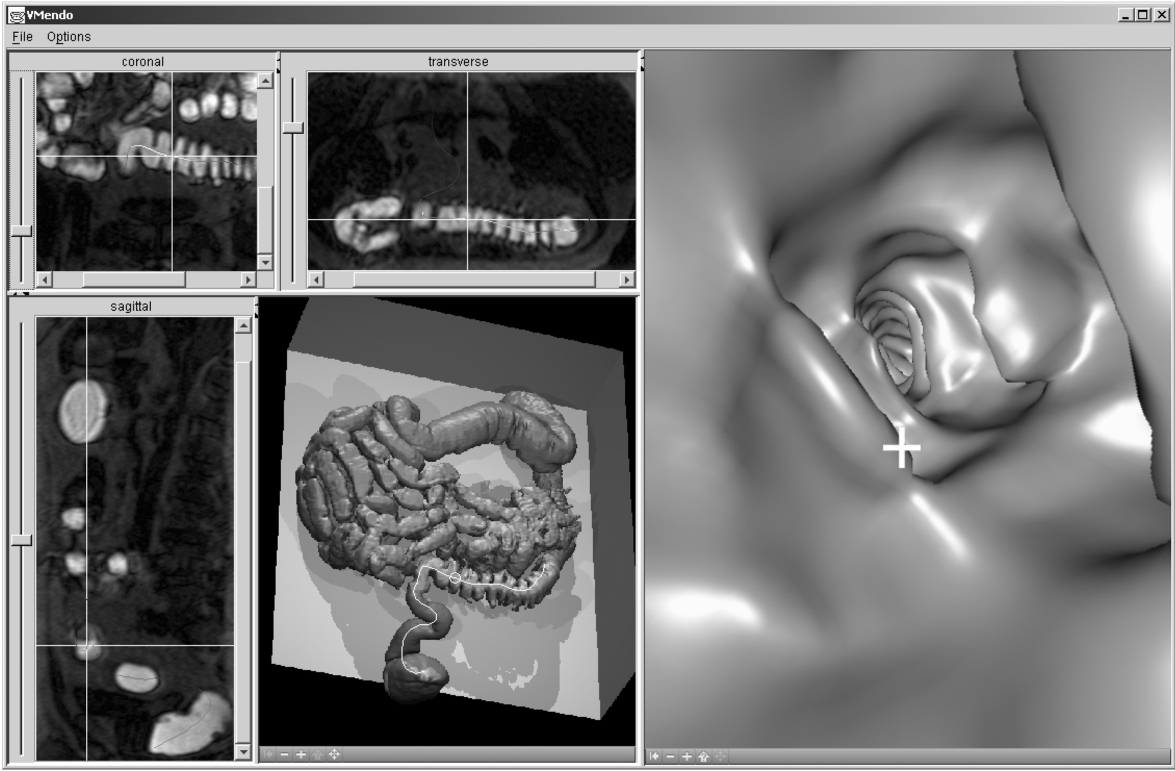

Fig. 3: User interface showing an endoscopic view (right), a 3D overview image (middle bottom) and three orthogonal MR cross-sections. The marked position on the colon wall (white cross) corresponds to the positions on the cross-sections and in the overview.

Currently the number of panoramas in a single QuickTime VR movie is limited to 255 which is not a real restriction for the application shown here. Further research should also take stereoscopic viewing into account.

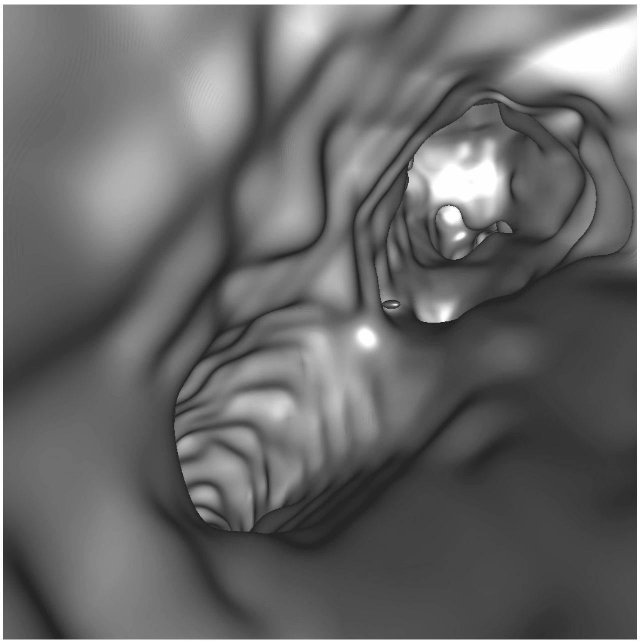

Fig. 4: Panorama view of the main bifurcation of the bronchi computed from the Visible Human Dataset.

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