Improved visualization in virtual colonoscopy using image-based rendering

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Abstract

Virtual colonoscopy (VC) is a patient-friendly alternative for colorectal endoscopic examination. We explore visualization aspects of VC such as surface in view, navigation and communication of a diagnosis. A series of unfolded cubes presents an animated full 360-degree omnidirectional field-of-view to the physician, to facilitate thorough and rapid inspection. For communication between physicians a tool has been designed that uses image-based rendering. Clinical evaluation has shown a reduction in inspection time from 19 minutes to 7 minutes without loss of sensitivity. With current virtual colonoscopy using a 2-sided view only 94% of the surface is available for exploration. In our approach the surface in view is increased to potentially 100%. Thus, the entire colon can be explored with better confidence that no regions are missed.

1 Introduction

Colon cancer is the second cause of cancer deaths in the Western world [1]. Early detection of colonic polyps has proven to lead to a decrease in incidence [2]. However, the traditional technique for detection and removal of polyps, optical colonoscopy, causes serious discomfort. In the past few years, virtual colonoscopy (VC) has been developed as a more patient-friendly screening alternative [4][5][6][7].

In general, the VC procedure consists of the following stages. First, the patient’s colon is cleansed and inflated with air. Next, a 3D image volume of the abdomen is acquired using CT imaging. The bowel surface is then extracted from the volume and visualized in a way similar to camera colonoscopy. Finally, the physician navigates through the virtual colon and examines the surface for abnormalities from intra-luminal perspective. The last step may take as long as 30 minutes.

For practical application, virtual colonoscopy must meet general requirements
regarding:

- efficiency (time spent by the radiologist)
- effectiveness (part of the surface area in view)
- sensitivity (number of polyps detected)

Because of the trade-offs between accuracy, speed and hardware costs, volume rendering is not always feasible at the required quality level. Current systems often use fly-through sequences to reduce the time needed for diagnostic inspection. Such fly-throughs are often based on an automatically generated path in the center of the lumen, with evenly-spaced views in both forward and backward viewing directions. This approach still yields selective imaging of the inner surface. It may well be however that important parts of the surface are missed, while insignificant parts are reviewed twice (Figure 1). In addition, the inspection/navigation is restricted by the central path through the colon.

![Figure 1. Surface parts missed in two sided views.](image)

Identified polyps can be removed by the endoscopic surgeon. For proper communication of the diagnosis to the surgeon it is required that properties of detected polyps such as their location, size and appearance are reported.

So-called panoramic views have been considered to solve the described missed surface parts. Such an approach implies folding out the colon, and spreading the inner wall on a flat plane, so that the full inner surface is exposed for examination. To do this, several techniques are described in the literature, ranging from simple cylindrical coordinate transforms, to complex conformal mappings [8][9]. The cylindrical transformation produces excessive distortions, while local geometry is much better preserved in a conformal transformation. We are not aware of any work on tools for communication of diagnosis.

In this paper, a number of visualization aspects from virtual colonoscopy will be analyzed. We will introduce a novel visual representation. A series of unfolded cubes presents an animated full 360-degree omnidirectional field-of-view to the physician, to facilitate a more thorough and rapid inspection. Consequently, almost the entire colon surface is visible for examination. For annotation and communication of a diagnosis, a tool has been designed using a selected series of views that are generated by image-based volume rendering. To test our technique, a clinical evaluation study has been conducted.

The paper is organized as follows. In Section 2.1, we will review image-based ren-