Chapter 4.19
Variational Approach Based Image Pre-Processing Techniques for Virtual Colonoscopy

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ABSTRACT

Colorectal cancer includes cancer of the colon, rectum, anus and appendix. Since it is largely preventable, it is extremely important to detect and treat the colorectal cancer in the earliest stage. Virtual colonoscopy is an emerging screening technique for colon cancer. One component of virtual colonoscopy, image pre-processing, is important for colonic polyp detection/diagnosis, feature extraction and classification. This chapter aims at an accurate and fast colon segmentation algorithm and a general variational-approach based framework for image pre-processing techniques, which include 3D colon isosurface generation and 3D centerline extraction for navigation. The proposed framework has been validated on 20 real CT Colonography (CTC) datasets. The average segmentation accuracy has achieved 96.06%, and it just takes about 5 minutes for a single CT scan of 512*512*440. All the 12 colonic polyps with sizes of 6 mm and above in the 20 clinical CTC datasets are found by this work.

INTRODUCTION

Colorectal cancer includes cancer of the colon, rectum, anus, and appendix. Colorectal cancer can develop from the mucosa located throughout the colon or rectum. Most colorectal cancers progress through a series of mutations which confer a growth advantage, leading to polyp formation and eventually an invasive tumor.

In most cases, colorectal cancers develop slowly and normally take a period of several years to grow from the earliest lesion to an advanced cancer. Adenocarcinomas account for about 95 percent of colorectal cancers, arising from the intestinal epithelial cells that line the colon and rectum. It is the second leading cause of cancer-related death and the third most common form of cancer in the United States (Abbruzzese, 2004).

Colorectal cancer is largely preventable. Several screening tests, including the digital rectal exam, fecal occult blood test (via guaiac or fecal immunochemical test), flexible sigmoidoscopy, double-contrast barium enema, and colonoscopy are recommended for all people age 50 and over. Currently, optical colonoscopy is considered the gold standard for colorectal cancer screening. During optical colonoscopy, a thin flexible video endoscope is inserted into the patient's rectum and advanced to the cecum. Inspection of the colon for polyps generally occurs during the withdrawal phase of the colonoscopy.

Although a colonoscopy can detect more than 90% of colorectal cancers, it is invasive, sometimes uncomfortable, the preparation is inconvenient, and inability to the cecum results in an incomplete exam (Macari, 1999).

On the other hand, computed tomographic colonography (CTC), also known as virtual colonoscopy (VC), is a computer-based alternative to optical colonoscopy. It has evolved rapidly over the past decade due to advances in manufacturing of high-resolution helical spiral computed tomography scanners. Ferrucci (2001) comprehensively analyzed the promise, polyp detection and politics of colon cancer screening with VC. The accuracy (mainly the sensitivity and specificity of polyp detection) is comparable to the conventional colonoscopy for the significant size greater than 10 mm with few false-positive.

VC has many advantages, including relative lack of invasiveness, lower incidence of complications and side effects, patient tolerability and preference (Juchems, 2005). VC is not intended to replace traditional optical colonoscopy (Summers, 2002; Zalis, 2005; Chen, 2008), but rather to complement it by providing an additional mechanism for providing CRC screening. Benefits of VC include visualization of neighboring structures outside the colon, visualization of difficult anatomical locations (i.e. behind flexures), the ability to bypass high grade stenoses, and providing an alternative to colonoscopy in those patients who either refuse optical colonoscopy or cannot tolerate it due to severe illness.

The process for computer aided diagnosis (CAD) assistance for colorectal cancer screening involves: 1) colon segmentation, 2) colon isosurface generation and rendering, 3) 3D centerline extraction for navigation, 4) colonic polyp detection, 5) color coding for polyp candidate visualization, 6) features extraction, and 7) benign/ malignant polyp classification.

Accurate and reliable colon segmentation are important, since any incorrect segmentation, for example, missing colonic segments, containing non-colon tissue (e.g. small bowel) or reconstructing colon wall of poor quality, impairs interpretation of 3D visualization. Moreover, inaccurate 3D colon segmentation and visualization diminish the perception of polyp detection, classification and the whole performance of CAD system. The 3D colon segmentation normally suffers from the following difficulties. First, CTC sometimes contains disconnected regions of the colon because collapsed segments result from different reasons such as colon spasm, insufficient distension, *etc*. Second, in clinical practice, oral contrast agent may be given to patients for CTC, however, oral contrast

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