

Automatic Image and Video Analysis for Capsule Endoscopy - An Open Frontier

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Abstract

Imaging the gastrointestinal (GI) tract is challenging due to the tortuous nature of colon and many of the traditional colonoscopy based imaging systems could not reach all the regions. Video capsule endoscopy (VCE) is a revolutionary imaging system wherein tiny cameras packed into a pill-sized capsule obtain images without any tethered wires and transmit the data using wireless technology. This has enabled the gastroenterologists to obtain almost painless endoscopy exams of patients with full visual coverage of the colon. However, VCE exams obtain video data that is composed of a large number of frames, thus require tedious manual viewing and analysis to identify possible GI tract anomalies. Automatic image and video analysis techniques are sorely lacking in this area and we provide a focused review of our developed solutions along with the challenges that remain to be solved in capsule endoscopy image/video processing and analysis.

Keywords

Capsule endoscopy, Image analysis, Video processing, Automatic inspection, Computer-aided diagnosis

Introduction

Capsule endoscopy is an imaging technique that provides visualizations of the gastrointestinal (GI) tract [1]. It opened the door for visualizations of hard to reach regions of the GI tract that are not captured by traditional colonoscopy systems. Video capsule endoscopy (VCE) is a wireless imaging system in a capsule form that contains cameras capturing continuous imaging data (color images) of the GI tract and transmits them to a signal receiver worn on the patient's waist. The capsule moves through the GI tract without any external forces and uses only the natural peristalsis motion. This unhindered motion means there is little or no discomfort to the patient, and the capsule exits naturally. Typically the video data consists of around 55000 frames in color (RGB data [2]), and are analyzed in a workstation by gastroenterologists for

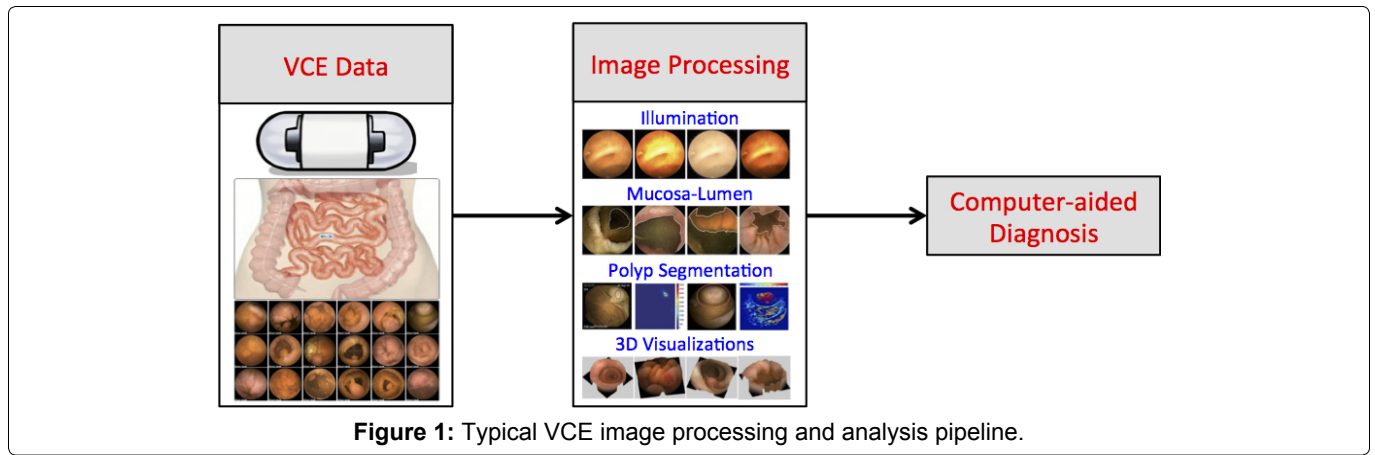
possible abnormalities.

Despite these imaging advantages, the sheer number of images gastroenterologists need to examine poses great challenges, as it requires careful attention and tedious manual processing of all the image frames per each VCE exams. Also, human operators can miss subtle abnormalities that can be captured by automatic image analysis methods that can discern at pixel, patches, and features levels. Despite the availability of mature automatic image and video processing techniques that work for natural images, and other medical imaging modalities with good performance/accuracy, there aren't many reliable automatic algorithms available for VCE imagery. After the introduction of VCE in 2000's there have been some automatic computer-aided diagnosis (CAD) systems that are designed to analyze the VCE data. In this

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review, we focus on some of the automatic image and video analysis methods developed by us for processing VCE images, and further challenges that remain to be solved.

Advances in Image/Video Processing for VCE

Similar to any other medical imaging modality VCE requires a well-defined sequence of image processing/analysis tools from low to high-level algorithms to obtain a fully developed CAD pipeline. Figure 1 shows a typical VCE image processing, and analysis pipeline that consist of the following important components.

- Illumination estimation/correction

VCE contains multiple near-lights, that is, the camera and the surrounding LED lights are situated closer to the surface (mucosa) that is being imaged. Thus, inhomogeneous light saturation is visible and requires robust illumination preprocessing to avoid missing important mucosa tissue characteristics [3].

- Mucosa-lumen separation

Separating mucosal tissue and lumen (the area in which the capsule moves) regions is another important preprocessing step required to characterize features on mucosa rather than the lumen [4,5].

- Polyp segmentation/localization

Polyps can be precursors to GI cancer, thus identifying and detecting them is an important image processing problem. However given the large amount of frames each VCE exam, this requires robust polyp indicator functions [6] and efficient algorithms [7].

- Bleeding segmentation/detection

GI bleeding require a careful analysis of the color information and machine learning algorithms that are trained on prior examples are essential in obtaining good detection results [8].

- 3D visualizations

Three dimensional visualizations of the GI tract can provide further insight into the GI tract [9].

A final CAD system that consists of these off-line image analysis tools can be of assistance to gastroenterologists in making decisions based on VCE images.

Challenges

Automatic abnormalities detection without manual supervision is perhaps one of the most important open challenges in this area. Despite the advancements in some of the low level image processing tasks such as illumination correction, mucosa-lumen separation, the higher-level tasks such as polyp segmentation/localization, bleeding segmentation/detection require further research. Moreover, automatic video processing methods that exploit the temporal information are required to obtain well-defined CAD systems.

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