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# Edge density based automatic detection of inflammation in colonoscopy videos

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## Highlights

- A model based method for automatic inflammation detection in colonoscopy videos is introduced.
- The method relies on a high quality display provided by Olympus colonoscopy probe.
- The proposed method is suitable for parallel implementation and real-time processing of high-resolution colonoscopy videos.
- Real-time inflammation detection can provide the gastroenterologist with a useful tool to enable faster and more accurate diagnosis.

## Abstract

Colon cancer is one of the deadliest diseases where early detection can prolong life and can increase the survival rates. The early stage disease is typically associated with polyps and mucosa inflammation. The often used diagnostic tools rely on high quality videos obtained from colonoscopy or capsule endoscope. The state-of-the-art image processing techniques of video analysis for automatic detection of anomalies use statistical and neural network methods. In this paper, we investigated a simple alternative model-based approach using texture analysis. The method can easily be implemented in parallel processing mode for real-time applications. A characteristic texture of inflamed tissue is used to distinguish between inflammatory and healthy tissues, where an appropriate filter kernel was proposed and implemented to efficiently detect this specific texture. The basic method is further improved to eliminate the effect of blood vessels present in the lower part of the descending colon. Both approaches of the proposed method were described in detail and tested in two different computer experiments. Our results show that the inflammatory region can be detected in real-time with an accuracy of over 84%. Furthermore, the experimental study showed that it is possible to detect certain segments of video frames containing inflammations with the detection accuracy above 90%.

## Introduction

Colon cancer is recognized as one of the most common malignant diseases, thus regular examination of colon gains importance, especially for high risk populations [1]. Prevention of colon cancer is related to the detection of polyps, since untreated polyps can develop into cancer [2]. Inflammatory bowel diseases (most commonly Crohns disease and ulcerative colitis) are chronic diseases that include inflammation in the gastrointestinal tract. Early stage detection of inflammatory diseases is very important as it allows the patient to be provided with dietary advice and precaution. Polyps and inflammation can be detected during various medical procedures which include analysis of high-length videos, implying the necessity of computer-aided diagnostics of the gastrointestinal tract and its discussion within the scientific community.

The most effective colon screening method is colonoscopy, which is a bowel examination procedure that uses a camera and a flexible tube. Colonoscopy provides high resolution video, suitable for easy visual detection of pathological inflammation and colon diseases. Although colonoscopy can provide high quality videos and efficient ways to visually detect anomalies and ability to collect tissue samples in vivo, it is invasive and often uncomfortable [3] and gives view to colon only. One alternative medical approach for examination of the digestive tract is the so-called virtual colonoscopy, which includes the analysis of computer tomography (CT) scans. This method irradiates the patient. In the last decade, capsule endoscopy (CE) treatment has gained popularity. It is a minimally invasive screening approach which allows viewing the complete digestive tract without sedation, radiation or air-inflation. Capsule endoscopy uses a smart pill equipped with a camera and a radio transmitter that sends images to a recorder attached to the patient's waist. Smart pill can record over an eight hour long period, providing thousands of images. An overview and manual annotation of the complete dataset from one examination is time consuming. It would be helpful to automatically select images showing anomalies, such as internal bleeding, polyps and inflammation. If a physician is focused on images with higher priority, diagnosis requires less time. The main advantage of CE is the possibility of image acquisition throughout the whole digestive tract.

Even though physicians are able to observe live video during the colonoscopy examination, during which visual overview is usually sufficient to detect anomalies, additional real-time processing may be helpful for pinpointing the exact location of anomalies and faster visual detection. Another motivation for real-time processing of colonoscopy videos can be supported by the study showing that accuracy of real-time optical small polyp (less than 1 cm) detection made by gastroenterologists, is approximately 76% [4]. Therefore, real-time processing of high definition video can be useful to provide the gastroenterologist with a decision making tool to improve the human performance. Nevertheless, it is hard to implement real-time processing, especially if complex algorithms need to be included. On the other hand, parallel implementation can provide fast processing and less time consumption.

Two main starting goals of this research were enabling fast video processing and achieving a high detection rate of inflammatory tissue. The algorithm proposed in this paper relies on neither computationally expensive feature extraction nor statistical learning. We took advantage of new technological developments in video acquisition, which can provide high quality video data. We used videos obtained by the Olympus probe [5] which delivers images with increased brightness and contrast, enabling close mucosal observation. The probe has an optical system with depth of field from 2 to 100 mm. Observing from closer distance can reveal fine texture of mucous when it is either healthy or inflamed. The first contribution of this research is a proposal of a simple and fast texture analysis based on edge density estimation, which is used for automatic inflammation detection. The second contribution is the fact that parallel implementation of the proposed algorithm based on General Purpose computing on Graphics Processing Units (GPGPU) using OpenCL and C♯proved that colonoscopy videos can be automatically annotated in real time.

The rest of the paper is organized as follows. Section 2 gives a brief overview of the related literature, Section 3 describes the data used, while Section 4 describes the proposed algorithm in details. Section 5 describes the experimental setup and discusses the experimental results. Section 6 is a conclusion.

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## Section snippets

## Related work

As it was briefly described in the previous section, recent technology improvements enabled acquisition of high resolution colonoscopy videos as well as large amounts of capsule endoscopy images. For automatic polyp detection in colonoscopy videos two major approaches are block-based classification and model-based detection. In [6] analysis of frames extracted from colonoscopy video footage is used for automatic polyp detection based on simple spatial-color features, Support Vector Machines…

## Used data

We used three colonoscopy videos with different durations and with a frame resolution of 768×576 pixels and a frame rate of 25 fps, all of which were obtained using the Olympus probe. This video footage contains segments showing pathological inflammation and segments with healthy tissue, including upper and lower part of the descending colon. All videos were examined and tagged by specialists so that we can differentiate between frames showing inflammatory and healthy tissue without ambiguities. …

## The proposed algorithm

Since real-time processing of high-resolution colonoscopy video is the primary goal of the research, the detection algorithm must be optimized for fast execution. This implies simplicity in design which often implies a high error rate, or high degree of parallelism. Since processing is meant to be integrated with a portable device, the hardware could be constrained in terms of size and power usage which implies limited parallelism. A simplified parallel approach combining high performance and…

## Methodology

We tested the proposed algorithm by two experiments using high resolution colonoscopy videos described in Section 3. The first experiment is designed to verify the ability to automatically detect inflammatory regions within one specific frame and the second experiment examines whether the proposed algorithm is able to differentiate between frames in which inflammation is shown and other frames. All experiments are executed using the parallelized implementation of the proposed algorithm,…

## Conclusion

In this paper we proposed an algorithm suitable for parallel implementation and real-time processing with the aim to have a detection accuracy of inflammation in a video as high as possible. One specific characterization of inflammatory tissue, which is submucosal bleeding, is used to distinguish between inflamed and healthy tissue. The *Basic* approach can be tuned to achieve detection accuracy around 84% and can be executed in real-time, thus it can be used during the examination procedure to…

## Conflict of interest statement

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