Computer Methods and Programs in Biomedicine 145 (2017) 53–66

Contents lists available at ScienceDirect

Computer Methods and Programs in Biomedicine

journal homepage: www.elsevier.com/locate/cmpb

Hue-texture-embedded region-based model for magnifying endoscopy with narrow-band imaging image segmentation based on visual features

Xiaoqi Liu [a,*], Chengliang Wang [a,b], Jianying Bai [c], Guobin Liao [c], Yanjun Zhao [d]

[a] College of Computer Science, Chongqing University, Chongqing 400044, China
[b] Key Laboratory of Dependable Service Computing in Cyber Physical Society, Chongqing University, Ministry of Education, China
[c] Department of Gastroenterology, Second Affiliated Hospital, Third Military Medical University, Chongqing, China
[d] Computer Science Department Troy University, Alabama, USA

ARTICLE INFO

Article history:
Received 20 June 2016
Revised 27 February 2017
Accepted 12 April 2017

Keywords:
ME-NBI
Precancerous lesions
Early gastric cancer
Segmentation
Hue-texture-embedded region-based active contour model

ABSTRACT

Background and objective: Magnification endoscopy with narrow-band imaging (ME-NBI) has become a feasible tool for detecting diseases within the human gastrointestinal tract, and is more applied by physicians to search for pathological abnormalities with gastric cancer such as precancerous lesions, early gastric cancer and advanced cancer. In order to improve the reliability of diseases detection, there is a need for applying or proposing computer-assisted methodologies to efficiently analyze and process ME-NBI images. However, traditional computer vision methodologies, mainly segmentation, do not express well to the specific visual characteristics of NBI scenario.
Methods: In this paper, two energy functional items based on specific visual characteristics of ME-NBI images have been integrated in the framework of Chan–Vese model to construct the Hue-texture-embedded model. On the one hand, a global hue energy functional was proposed representing a global color information extracted in H channel (HSI color space). On the other hand, a texture energy was put forward presenting local microvascular textures extracted by the PIF of adaptive threshold in S channel.
Results: The results of our model have been compared with Chan–Vese model and manual annotations marked by physicians using F-measure and false positive rate. The value of average F-measure and FPR was 0.61 and 0.16 achieved through the Hue-texture-embedded region-based model. And the C-V model achieved the average F-measure and FPR value of 0.52 and 0.32, respectively. Experiments showed that the Hue-texture-embedded region-based outperforms Chan–Vese model in terms of efficiency, universality and lesion detection.
Conclusions: Better segmentation results are acquired by the Hue-texture-embedded region-based model compared with the traditional region-based active contour in these five cases: chronic gastritis, intestinal metaplasia and atrophy, low grade neoplasia, high grade neoplasia and early gastric cancer. In the future, we are planning to expand the universality of our proposed methodology to segment other lesions such as intramucosal cancer etc. As long as these issues are solved, we can proceed with the classification of clinically relevant diseases in ME-NBI images to implement a fully automatic computer-assisted diagnosis system.

1. Introduction

Gastric cancer (GC) was the fourth most common cancer and third-leading cause of cancer death in the world, with 951,000 new cases diagnosed and 723,000 case of death in 2012, and more than 70% cases occurred and died in developing countries (mainly in Eastern Asia) [1,2]. In China, reports estimated that about 420,489 people with gastric cancer have been confirmed in 2011 [3] and 679,100 people in 2015 [4]. In addition, 297,496 Chinese have died from gastric cancer in 2011 [3] and 498,000 Chinese in 2015 [4], in other words, the survival rates were all lower than 40%. The primary cause is that GC is not immediately predicted and treated. That is to say, detection and proper treatment of early gastric cancer (EGC) or gastric precancerous lesions(GPCLs) are closely related to improve the overall cure rate of GC, when it is possible to be removed completely. As for the stomach, magnification endoscopy with narrow-band imaging (ME-NBI) that highlights suspicious le-

* Corresponding author.
E-mail address: 252146521@qq.com (X. Liu).

http://dx.doi.org/10.1016/j.cmpb.2017.04.010
0169-2607/

sions and rings better diagnostic efficacy [18] for detection of GPCLs and EGC is slowly being developed currently. There are two causes:

1) Equipment of ME-NBI is easy to get, but expensive. However, this is not the most major problem;
2) The main cause is the lack of skilled endoscopy doctors since it is difficult to skillfully master ME-NBI diagnostic skills in a short time [19,20].

Because of the huge number of ME-NBI images of patients, a lot of unskilled non-experts and possible subjective diagnoses, there is an urgent need to develop computer-assisted decision systems to provide an objective evaluation of EGC and GPCLs for physicians and to help non-experts achieve high diagnostic accuracy. Additionally, the medical community is aware that computer-assisted diagnosis will help and support a medical diagnosis preventing unnecessary errors and improving the health quality of their patients [5–9]. But for that to happen, segmentation as one of the most fundamental challenges in computer-assisted decision systems must be considered for high diagnostic accuracy. This need is also motivated by that physician who is interested in specific regions related to clinical diagnosis on an ME-NBI image in artificial diagnosis.

1.1. Related works

In this paper, we chiefly resolve the automatic segmentation problem of ME-NBI images with GPCLs and EGC, nevertheless, segmentation of ME-NBI images is a hard task given the very specific nature of image, because of reduced color space, abundant geometric textures, poor focusing, illumination conditions, variations lesions and weak boundaries etc.

Some researchers have directly employed clinical relevant regions manually annotated by physicians to avoid this hard automatic segmentation task [6,7]. However, manual segmentation is undesirable as well as unfeasible because this process is time-consuming and exhausting; additionally, this method may relatively decrease the diagnostic efficiency. Coimbra et al. [8] have measured the impact of the three segmentation algorithms (mean-shift, normalized cuts and level-sets) on two different gastroenterology (GE) images: choromoendoscopy (CH) images and narrow-band imaging (NBI) images. This work has given an approximate direction for automatic segmentation of two modal GE images has not yet proposed an appropriate and fine approach for each modal image to obtain perfect results. However, literatures mentioned above entirely prove that segmentation is a vital and essential procedure for image processing (*i.e.* classification) especially for automatic diagnostic systems. Other researchers have proposed or applied some new or mature approaches based on visual features of these GE images for more accurate segmentation. Riza et al. [9] have proposed a novel method which is based on three different visual features (edgemaps, creaseness and color) individually and their combinations in normalized cuts for segmentation of two distinct GE images from CH for diagnosis of stomach cancer and NBI for the diagnosis of Barrett's esophagus. An undesirable aspect they have pointed out is that the computational time which is a necessary factor in automatic diagnostic systems has been ignored to improve the segmentation performance. While a large amount of researches on GE images analysis has been done, none of groups have worked on automatic precise segmentation of ME-NBI for the diagnosis of EGC and GPCLs.

1.2. Contributions

In this paper, we choose region-based active contour models (ACMs) to accomplish this tough segmentation task. Our choice is mainly driven by two causes. On the one hand, region-based ACMs utilize statistic information inside and outside a evolution contour not image gradient in a given image to control the evolution curve, which is less sensitive to noise and can successfully segment objects with weak boundaries or even without boundaries. On the other hand, the region-based model allows incorporation of various prior knowledge, such as shape, intensity distribution [10] and texture descriptor [11], for robust image segmentation and can provide smooth and closed contours as region edge. Our contributions are made in the present paper as follows.

1) Analyze and discuss the formation process of ME-NBI image with respect to GPCLs and EGC in depth combined with NBI principles and pathological evolutions.
2) Propose an automatic segmentation model in combination with two different visual features: global hue feature and local microvascular texture feature with region-based ACMs for modeling the boundaries of clinically relevant regions.
3) Apply the proposed methodology in ME-NBI image segmentation from stomach from five different lesions, *i.e.* chronic gastritis (IMF), intestinal metaplasia and atrophy(IM), low grade neoplasia(LGN), high grade neoplasia (HGN) and EGC.
4) Establish a NBI-based diagnosis database on the basis of patient, diagnostic, and pathology information for image segmentation, lesion recognition, gastric cancer data mining, big data analytics, etc.

The rest of the paper is organized as follows. Section 2 gives a particular formation process of the ME-NBI image and discusses concepts, relationships and evolution of GPCLs and EGC. In Section 3, we analyze features of ME-NBI images and give synergistic methodology for ME-NBI image segmentation. Section 4 proposes a Hue-texture-embedded region-based model for segmenting ME-NBI images, integrated with global color and local microvascular texture information. In Section 5, experimental results have been shown, which were acquired by the proposed model and C-V model. Section 6 discusses and validates the accuracy and efficiency of our method by comparing with C-V model and manual annotations. Conclusions and possible future work are in Section 7. In the last section we thank our data providers and sponsors.

2. Formation of ME-NBI image with GPCLs and EGC

To better understand particularity and property of ME-NBI images, this section explains the principles of ME-NBI in detail and gives the formation process of ME-NBI images. The concepts, relationships and evolution of GPCLs and EGC are talked about in following.

2.1. Principles of magnifying endoscopy with narrow-band imaging

It is noteworthy that human eyes perceive an object as being a certain color via seeing light of certain wavelength reflected from the object. In other words, all incident lights are absorbed by the object, and as a result the perception is that the object has no color, or is black. Based on the theory, to improve characterization of capillaries and observational ability of structure of mucosal surface, the dual wavelengths (415 nm (blue) and 540 nm (green)) strongly reflected by the mucosal surface and absorbed by hemoglobin were applied in NBI systems as over 90% of pigment in the mucosa of digestive tract consists of hemoglobin [12]. Simultaneously, to omit the superfluous light that tends to lower the contrast of the target vessel, narrow-band light with a bandwidth of 30 nm is applied. As a result, we could be able to see the blood vessels as black with a high degree of contrast and delineation of the mucosal surface and the superficial microstructure from the NBI images (see Fig. 1a). Based on this special technique, it becomes probable to visually inspect the faint or diminutive changes