CP-Miner : A hybrid Approach for Colorectal Polyp Detection

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***Abstract*— Computed Tomography Colonography (CTC) is the new generation technique for detecting colorectal polyps using volumetric CT data combined with Computer Aided Detection (CAD) system. The aim of this paper is to detail the implementation of a fully integrated CP-Miner system that is able to identify the polyps in the CT data. The CP-Miner system has a multistage implementation whose main system components are:**
1. Interpolation, 2. Automatic Colon Segmentation, 3.Feature extraction, 4.Polyp Detection. The proposed system has the aim to reduce the number of false positives than the existing system. The developed system provides 100% sensitivity for polyps greater than 6mm, provides 83.33% sensitivity for polyps within 3 to 6mm, 69.23% sensitivity for polyps less than 3mm. The overall sensitivity of the CP-Miner system is 84.18%.

Index Terms-- Colorectal polyps(CP), Computed Tomography Colonography(CTC), Computer Aided Detection (CAD), Segmentation, Polyp Detection.

I. INTRODUCTION

Colorectal cancer (CRC) is the second most common cancer in women and the third in men [2]. Due to more effective chemotherapeutic agents and improved surgical techniques, CRC is still the most cause of cancer related deaths in world. A possible explanation is that CRC is often diagnosed at an advanced stage.

Colon cancer is the leading cause of cancer-related deaths in the developed nations [2],[3]. Corresponding to 8% of the total number of cancer diagnoses in 2007, with a total of approximately 4600 new cases. Although the 5-year survival rate has improved in the last two decades and nowadays is approximately 60%.

Typically, colon cancer develops as an intestinal polyp which is an abnormal growth of the colon tissue and in time the colorectal polyps may become cancerous. The process of polyp growth is slow and the early detection and removal of polyps via screening has proven to be an effective procedure to reduce the colon cancer mortality [4],[5]. Colonoscopy is widely accepted as the screening technique that returns the highest sensitivity in polyp detection.

The main aim of this system is to detail the full implementation of a CAD-CTC system that has been developed as a modular system where all components are interconnected using a systems engineering approach. CAD system [8] can be integrated with the CTC system to robustly identify the clinically significant polyps in the CT data.

A. Diagnostic Tests

Diagnostic tests should be able to detect early CRC and adenomatous polyps. The most common methods used in identifying the presence of colorectal polyps in a clinical setting are [1]:

Fecal occult blood tests (FOBT)

FOBT detect the presence of blood in the stool, which might be caused by a bleeding CRC or large polyps. Subjects with positive FOBT need to undergo colonoscopy.

Flexible Sigmoidoscopy

An Endoscopic procedure where only the distal part of the colon and the rectum is examined. No sedation is required. As at least one third of polyps are located in more proximal parts of the colon, it cannot be considered a complete diagnostic test.

Barium Enema (BE)

A Radiological procedure performed after rectal administration of a radiopaque contrast medium (barium sulphate) and air. No sedation is required. Barium Enema has a relatively high sensitivity and specificity for CRC.

Optical colonoscopy (OC)

It has a very high sensitivity and specificity for detection of CRC and polyps. It allows visual inspection of inflammatory changes. It is also possible to perform biopsies and resects polyps. Although Optical Colonoscopy is the most accurate diagnostic test to screen for CRC and polyps, the compliance of individuals to endoscopic screening has been reported to be low.

CT Colonography

Computed Tomographic Colonography (CTC) uses CT technique and dedicated interactive three-dimensional (3D) and two-dimensional (2D) imaging software to evaluate the colon [5]. Since its introduction in 1994, CTC has undergone extensive clinical assessment and technological advancements. As with OC and BE, patients should undergo colon cleansing prior to the examination. The colon is distended by insufflations of air or carbon dioxide, via a small plastic rectal tube. Antispasmodic agents (Buscopan or Glucagon) and/or contrast media may be administered intravenously before the CT scan. Recently, the use of oral contrast agents has been introduced. Additionally, it is possible to perform an "electronic cleansing", i.e. the CTC [7] software recognizes areas with high density (corresponding to oral contrast mixed with stool or fluid) and subtracts it from the images. The CT scan is performed in supine and prone positions during breath-holding. No sedation is required.

II. OVERVIEW OF THE DEVELOPED CP-MINER SYSTEM

The CP-Miner system performs the tight integration of CAD-CTC system for the detection of colorectal polyp detection. The Figure 1 gives an overview of our CP-Miner system. This system involves preprocessing, colon segmentation, Feature extraction and Polyp detection.

Preprocessing is the first element of the CP-Miner System. In preprocessing stage, interpolation methods like bilinear interpolation or bicubic interpolation methods are used to get an isometric dataset. CT abdomen images are taken as inputs to a system. In the second stage, to get successful segmentation edge detection algorithm can be applied. The third and the most important component of the system is represented by the feature extraction. It is used to extract the most robust features and that can be used for the identification of polyps from the CT data. Polyp detection is the final component of the CP-Miner system. In this stage polyps from the CT images are identified and the details of that polyp like location, size are presented.

These stages are detailed in the following sections of this paper. Section 3 details the interpolation method. Section 4 explains the technique used for segmentation. Section 5 discusses the feature extraction method. Section 6 introduces the polyp detection scheme required for the identification of polyps. Section 7 discusses the experimental results.

III. INTERPOLATION

Interpolation methods are used to decode the CT data. Interpolation methods are applied in order to obtain an isometric dataset. Isometric dataset means that the voxel resolution is approximately the same in all directions. There are several interpolation methods are available.

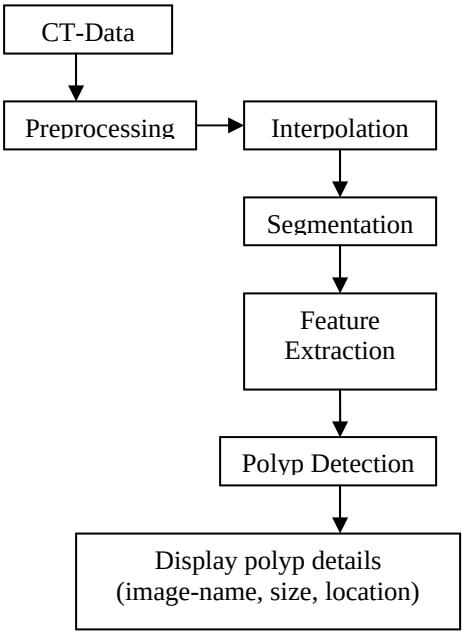

Figure 1. Overview of CP-Miner System

Our CP-Miner System uses bicubic interpolation to obtain an isometric dataset. This bicubic interpolation method is more sophisticated and produces smoother edges of an input image. In this stage, a new pixel is a bicubic function using 16 pixels in the nearest 4 x 4 neighborhood of the pixel in the original image.

IV. COLON SEGMENTATION

Image segmentation is the process of partitioning a digital image into multiple regions or set of pixels. The result of image segmentation is a set of regions that collectively cover the entire image or set of contours extracted from the image. The main purpose of colon image segmentation is to identify the colon form the CT data. CT data not only have the colon, it also have air filled regions, air filled organs include the lungs, stomach and small intestines. So the identification of colon from the CT data plays an important role in the CP-Miner system.

For segmentation, CP-Miner system uses edge detection techniques. Edge detection techniques transform images to edge images benefiting from the changes of gray tones in the images. Edges are the sign of lack of continuity and ending. As a result of this transformation, edge image is obtained without encountering any changes in physical qualities of the main image.

Edge detection process involves three steps namely, Filtering, Enhancement and Detection [11] . Images are often corrupted by random variations in intensity values, called noise. More filtering is to reduce noise results in a loss of edge strength. In order to facilitate the detection of edges, it is essential to determine changes in intensity in the neighborhood of a point. Enhancement emphasizes pixels where there is a significant change in local intensity values. In detection step, we can find all points which are edges of a particular application.

V. FEATURE EXTRACTION

The main objective of having feature extraction is to find the best discrimination between polyps and folds. Polyps and folds have various shapes and sizes. In some cases polyps and folds can't be distinguishable. So feature extraction is needed to distinguish them. Features extracted from this phase will be used to make the decision that whether the polyp is present or not. With the knowledge that the nominal model for polyps is either spherical or ellipsoidal [9],[10], we compute the number of key features are: Gaussian distribution, sphere fitting error and radius, standard deviation of three axis of the ellipsoid, ellipsoid fit error. These features generate a low dimensional model that describes the candidate surface that is used to classify the candidate surfaces into polyps and folds.

The Gaussian distribution is used to estimate the center and radius of each cluster which are calculated in the candidate surface extraction. Error in the least square sphere fitting [6] was calculated using the existing Gaussian center and the Gaussian radius of the center. For folds the least square estimated radius is higher than the Gaussian radius. For polyps sphere fitting error is significantly higher than the fitting error[12].

VI. POLYP DETECTION

Polyp detection phase is the final and important phase of our CP-Miner system. The main aim of polyp detection phase is to identify whether the polyp is present or not. In polyp detection phase, we make the decision whether the polyp is present or not based on the extracted features from an input image. If the polyp is present means, our CP-Miner system identify the location of polyp and display the details of polyp like location, size.

VII. EXPERIMENTS AND RESULTS

Here some experimental results are presented. For implementation CT abdomen images are taken as inputs to a CP-Miner system. 8 bit or 16 bit images are valid input images. Figure 2 shows that input image. Figure 3 represents the segmentation and polyp detection. Figure 4 shows the details of polyps of an some input images.

Figure 2. Sample Input Image

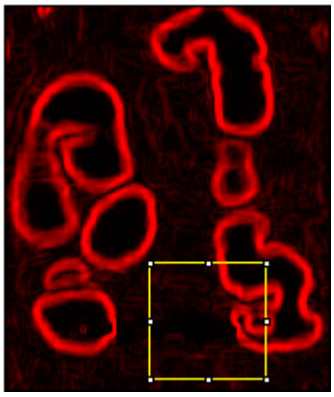

Figure 3. Segmentation and Polyp Detection

Image Name	Type	Location	Size (in mm)
17-1.jpg	polyps	java.awt.Point[x=42,y=42]	0.7
f2m-1.JPG	polyps	java.awt.Point[x=129,y=1...	5.8
ff11aj1-1.jpg	polyps	java.awt.Point[x=155,y=1...	5.0
f5aj1-1.jpg	polyps	java.awt.Point[x=233,y=2...	4.8
f5aj1-1.jpg	polyps	java.awt.Point[x=153,y=1...	6.3
faaj1-1.jpg	polyps	java.awt.Point[x=96,y=96]	0.6
8aaj1-1.JPG	polyps	java.awt.Point[x=37,y=37]	1.8
8aaj1-1.JPG	polyps	java.awt.Point[x=74,y=74]	0.5
f66m3-1.JPG	polyps	java.awt.Point[x=180,y=1...	5.5

Figure 4. Polyp details

A. Sensitivity Analysis

Table I shows the performance of the developed CP-Miner system.

The developed system provides 100% sensitivity for polyps greater than 6mm, provides 83.33% sensitivity for polyps within 3 to 6mm, 69.23% sensitivity for polyps less than 3mm. The overall sensitivity of the CP-Miner system is 84.18%.The overall sensitivity of the existing system is 83%.

Type	Total	True Positive	False Positive	Sensitivity
>6mm	6	6	0	100.00%
3-6mm	12	10	2	83.33%
<3mm	13	9	4	69.23%
Total	31	25	6	84.18%

Table I. Sensivity Analysis of Our CP-Miner System

VIII. CONCLUSION

The aim of this paper is the description of a fully integrated CAD polyp detection system. The CP-Miner system is non invasive in nature. The time required by this system to process completely is lower than the time required to analyze the data manually. One particular advantage of our CP-Miner system is that is has low computational overhead. The CP-Miner system is fully integrated so its performance makes it suitable to be applied in clinical examinations. The radiation dose does not have a severe impact on the performance in polyp detection of our CP-Miner system.

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