# Computer Aided Detection and Diagnosis of Colon Polyps with Morphological and Texture Features

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## ABSTRACT

In this paper, we propose a new technique to utilize both the morphological and the texture information of the colon wall for detection of colonic polyps. Firstly this method can quickly identify suspicious patches of the colon wall by employing special local and global geometrical information, different from other methods of utilizing local geometry only. By our edge-detection technology, the growing region of suspected polyps is identified and its internal textures are quantitatively analyzed based on an assumed ellipsoid polyp model. Both the extracted texture and morphological information are then applied to eliminate the false positives from the identified suspicious patches. With all the extracted geometrical, morphological and texture features, this presented computer-aided detection method have demonstrated significant improvement in detection of the colonic polyps for virtual colonoscopy.

**Keywords:** Texture, Morphological, Geometry, Computer-aided Detection, Colonic Polyps

## 1. INTRODUCTION

Colonic polyps have a high probability of developing into colon cancer, which is the second leading cause of the cancer death in United States. Early detection and removal of the colon polyps can reduce the risk of colon cancer greatly. Currently both the routine optical colonoscopy (OC) and the newly developed virtual colonoscopy (VC) [6, 14] can provide a similar procedure of high accuracy for detection of clinically significant colonic polyps. For mass screening purpose, VC may have several advantages over OC, in terms of safety, cost, and patient compliance. However, VC may need more than 15 minutes for an experienced radiologist to review a single colon study, mimicking the forward and backward navigation of OC through the colon. The anticipated large amount of VC procedures for mass screening purpose demands a computer-aided detection (CAD) scheme to help a radiologist to detect polyps efficiently. A CAD scheme that automatically detects polyps has the potential to substantially reduce radiologists' interpretation time and to increase radiologists' diagnostic performance in reducing false positive and false negative results.

Development of CAD for the colonic polyps is a challenging task, because the polyps have many different sizes and shapes, and the colon wall folds may mimic their size and shapes. Most recently reported CAD methods take the advantage of the geometrical features, such as gradient-, shape index-, and/or curvature-based information of the colon wall to find some suspected regions on the colon wall, which have characteristic features of the polyps. For example, Yoshida *et al*. [4, 5] employed the shape index and curvedness techniques to distinguish the polyps from the normal colon tissues. Summers *et al*. [11, 12] used some more features, such as the mean of the curvature, the maximum curvature, the minimum curvature and *etc*, to identify the colonic polyps. Gorturk *et al*. [13] proposed a pattern recognition method to detect the polyps. This latter method utilized some orthogonal triple planes to extract some feature vectors from the polyp candidates, and then used a three-dimensional (3D) pattern recognition strategy to make the final decision. Paik *et al*. [3] proposed another solution for the detection. They applied the normal information to find some geometrical features of the colon polyps. Although all these proposed methods performed relatively satisfactory for most types of the colonic polyps, the false positive rates were relatively high. One main reason is that these methods only focus on the geometrical information of the colon wall surface. Actually the growth of colonic

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polyps changes not only the shape of the colon wall, but also the shape of the adjacent tissues. Furthermore, the polyp texture information in CT images may also provide very useful information for identification of the colon polyps. To achieve the CAD goal of low false-positive rate and no false negative, all the geometrical, morphological and texture information from colon wall and from the inner tissues behind the colon wall shall be considered.

In this paper, we propose a new CAD technique for the detection of colon polyps. Different from most of previously reported CAD methods – which focus on the local geometrical information, our new technique utilizes both morphological and texture information for differentiation of false positives, where the initial finding of polyp suspects is performed by the use of both local and global geometrical information. A true polyp, which results in the shape change of the colon wall, will also cause the shape change of the adjacent tissues due to its growth. To detect the polyps, our method first finds the shape change of the adjacent tissues due to the growth of the suspected regions from the extracted geometrical shape information of the colon wall. An edge-detection method is then developed to identify the inner border between the suspected region and its adjacent tissues. With both outer and inner border information, a 3D ellipsoid polyp model is created to simulate the morphological shape information of the region of interest (ROI). Then several 3D morphological features and textures are extracted from the ROI to differentiate the false positives.

The content of this paper are organized as follows. In section 2.1, we present our geometry-based CAD for finding the initial candidates based on our mixture-based image segmentation and both local and global shape information. In section 2.2, our ROI extraction method is introduced. Meanwhile, the ROI morphological features are described. In section 2.3, we present the extracted ROI texture features. Some experimental examples of polyp detection will be shown in section 3, followed by some discussions and conclusions.

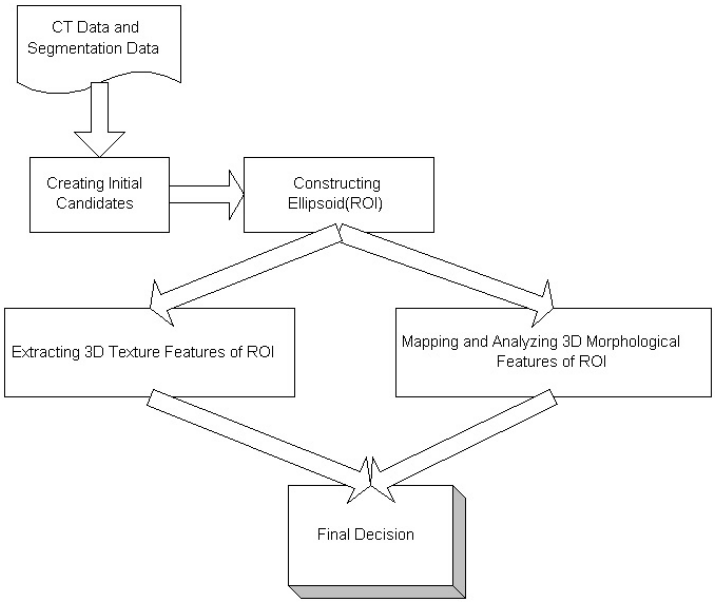



Figure 1: Flowchart of the presented CAD Method.

## 2.METHODS

### 2.1. Creating initial candidates based on geometrical information

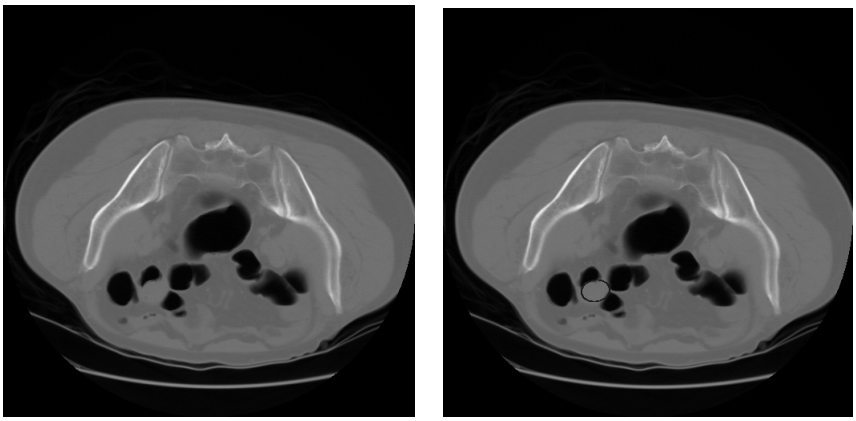
Firstly, the colon wall mucosa layer was segmented and extracted by our mixture-based segmentation method [7, 8, 16]. Different to the conventional segmentation methods, our segmentation method uses the partial volume percentages to represent exactly the distribution of different materials in each voxel. It provides more accurate geometrical information of the colon wall from the original scanned data then the conventional segmentation. This ensures that

more details will be retained after image segmentation for polyp detection. Then all the 3D geometrical (both local and global) features of the colonic polyps were utilized, as described in our previous published global shape-based CAD method [15], for the detection of initial candidates. The shape information of the colon wall mimics the "polyps-likely" abnormal sections. All these abnormal sections have some kinds of "elliptical" shape which are the typical shape of the true polyps. They are called as initial candidates (see Figure 1).

Due to the complexity of colon wall and residue colonic materials, there are many small folds or residue materials whose shapes are also "elliptical" like. It is extremely challenging to distinguish all these false candidates from the true polyps by only analyzing the shape information of the colon wall. Previous work of geometry-based CAD (including ours) has shown high false-positive rates in the initial candidates, although there was very low rate of missing true polyps. More information is necessary to reduce the false-positive rate.

### 2.2. Extracting 3D morphological features from initial candidates

The initial candidates, which are generated using the shape change analysis of the colon wall, are usually only some suspected region of the colon wall. These sections are frequently too small to provide enough description information for the whole ROI (Figure 2a). What we need to do is to "dig out" the whole ROI from the surrounding tissues of a suspected region, especially along the direction of outward the lumen. Previous research findings of ours as well as others have revealed that most colonic polyps have some "elliptical" shapes, and especially the true polyps (or malignant polyps) are growing along every direction outward from their center points. In other words, the existence of polyps not only changes the shape of the colon wall at the site of polyp, but also changes the shape of the internal normal tissues adjacent to the polyp site.



(a) The initial candidates.

(b) The extracted final ellipsoid ROI using the original voxels and added edge points.

Figure 2: Construction of ellipsoid model.

To "dig out" the whole ROI, we proposed an edge-detection method to identify the inner border between the suspected region and its adjacent tissues. With both outer and inner border information, a 3D ellipsoid was generated to simulate the whole polyps region or the similar suspected regions (Figure 2b). Once we have the whole ROI, our analysis of the polyps will not be limited on the colon wall any more. By analyzing the morphological attributes of this ellipsoid ROI, such as the volume of the ellipsoid, the ratio among the length of three axes of the ellipsoid, the mean, standard variance, maximum, minimum of the CT value and so on, we can have a global as well as detailed understanding of the ROI. The information or understanding of the extracted ROI can be utilized to differentiate a polyp from the initial candidates and, therefore, reduce the false-positive rate of the previous geometry-based CAD methods.

In clinical cases, most polyps do not have a smooth surface. To obtain correct morphological information of the ROI, we firstly constructed the outer and inner layers of the ellipsoid. Then all voxels between these two layers were mapped onto the surface of the ellipsoid according to some criteria. Finally, we obtained an elliptical mapping texture

image of this polyp (Figure 3). By analyzing the mapped image, we extracted two more morphological features. One is the "Coverage Rate", which calculates the ratio of area of mapped region to the area of the whole surface. Another measure is the "Distribution Rate", which describes the distribution of the mapped region along the whole surface. All these two measures can reflect if the polyps are growing and if this candidate really has an elliptical shape.

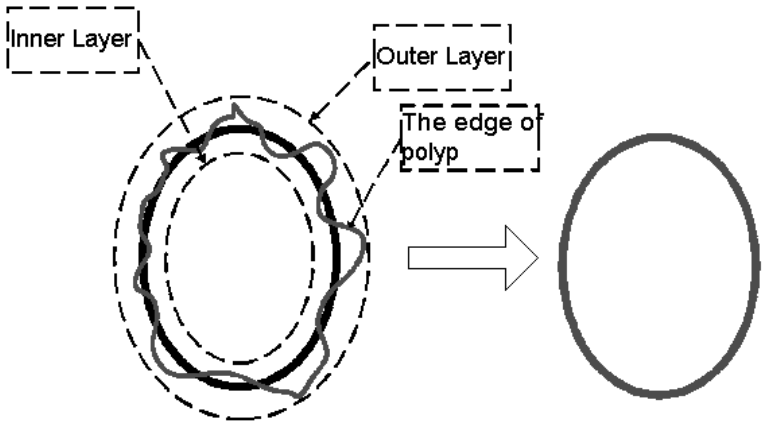



Figure 3: Illustration of the mapping procedure.

### 2.3. Extracting 3D texture features from morphology of initial candidates

Besides the morphological features as mentioned above, other important texture features were also extracted and used in our new method, such as the intensity texture feature. By analyzing more than ten polyp samples, we observed that the intensity values of the voxels inside the polyps are not uniform, and the variance of the intensity shows some special patterns. These observations can be depicted by 3D/2D texture information. In this work, we presented a new 3D texture measure for detection of this special growth pattern of a polyp.

For each voxel $p$ in 3D volume dataset, let $\lambda 1$, $\lambda 2$, $\lambda 3$ be the three eigenvalues of the Hessian matrix and $\lambda 1 > \lambda 2 > \lambda 3$. We define three pattern parameters $TP1$, $TP2$, $TP3$ which can be calculated by:

$$TP1 = -\frac{1}{\pi}\arctan\frac{\lambda 1 + \lambda 2}{\lambda 1 - \lambda 2}$$
$$TP2 = -\frac{1}{\pi}\arctan\frac{\lambda 2 + \lambda 3}{\lambda 2 - \lambda 3}$$
$$TP3 = -\frac{1}{\pi}\arctan\frac{\lambda 1 + \lambda 3}{\lambda 1 - \lambda 3}$$

In Figurer 4, the difference of the relations among the pattern parameters between the polyps and their surrounding normal tissues are showed. From the figure, we can see that the distribution of the pattern parameters is different between sample points of the polyps and of the normal tissues. Thus the triple pattern parameters ($TP1$, $TP2$, $TP3$) can be used as a 3D texture feature for detection of the polyps.

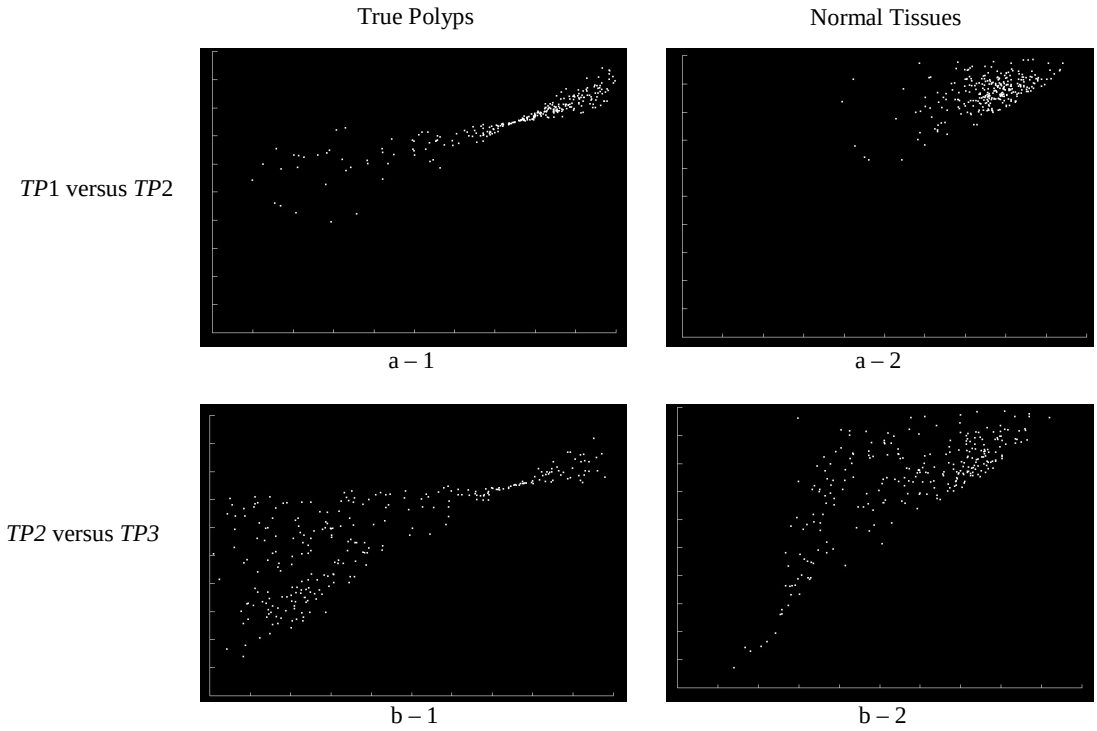



Figure 4: Comparison of the texture attributes between the polyps and the normal tissues. The sample points are selected randomly from 10 positive polyps and their surrounding tissues. a-1 and b-1 show the plots of texture attributes of the sample points from the polyps. In the plots, each sample point is represented as a 2D points located at (*TP*1, *TP*2) or (*TP2*, *TP3*). a-2 and b-2 show the plots of texture attributes of the sample points from the normal tissues.

### 2.4. Final decision by extracted 3D morphological and texture features

After the above ROI extraction and analysis stages, we obtained more than twenty morphological and texture features of the ROI for detection of the colonic polyps from the initial candidates. It is expected that not all features are useful for the final decision. Some features may even provide misleading information. A feature selection should be performed to choose the useful features for the CAD on the initial candidates.

After the feature selection, each remaining feature was given different weight according to its importance for the final decision. For example, the "Coverage Rate" reflects how "elliptical" this candidate is, and the "Radiation Rate" can provide the information that "if this candidate is growing". If we consider the shape information is more important than the texture information for these cases, we can give the Coverage Rate a higher weight. Otherwise, we can give the Radiation Rate a higher weight.

## 3.EXPERIMENTS

To testify the efficacy of our proposed CAD technique, eight clinical abdominal CT datasets were selected for an experimental pilot trial. A high-speed single-slice helical CT scanner (HiSpeed/CTI, GE Medical Systems, Milwaukee, WI) was used to acquire these abdominal CT images by a routine CT protocol in a single breath-holding

mode, i.e., 120 kVp, 100 mA, 1.7-2.0:1.0 pitch, 35-40 cm field-of-view, 5 mm collimation, and 1 mm image reconstruction on a 512x512 array size. In the experiment, we used only 3 morphological features (minimum axis length, maximum length axis, and ratio of the maximum to minimum axis length) and one texture feature (radiation rate). The final decision is only the finding of the threshold selection, and the findings are shown in Table 1.

| Feature/Parameter | Threshold/Value |
|---|---|
| Maximum Axis Length | <= 30 mm |
| Minimum Axis Length | >= 2.5mm |
| Maximum/Minimum | <= 3.5 |
| Core Layer | 0.0 |
| Edge layer | 0.7 |
| Radiation Rate | >= 50% |

Table 1: The threshold values of several selected features.

Based on the findings, the final detection results are showed in Table 2. From these results, it can be seen that our CAD technique performs very well for the clinical datasets. Since the method we proposed in this paper uses both morphological and texture information of the colon to detect the colonic polyps, this method was shown to provide more accurate detection results.

| Cases | Number of Initial Candidates | Result after Morphological and Texture Filter | Number of Optical Positive Polyps | Number of True-Positive Polyps |
|---|---|---|---|---|
| 1 | 9 | 1 | 1 | 1 |
| 2 | 12 | 1 | 1 | 1 |
| 3 | 58 | 3 | 1 | 1 |
| 4 | 9 | 2 | 1 | 1 |
| 5 | 91 | 5 | 1 | 1 |
| 6 | 81 | 2 | 1 | 1 |
| 7 | 14 | 1 | 1 | 1 |
| 8 | 21 | 3 | 1 | 1 |

Table 2: The final results of our CAD technique.

## 4. CONCLUSION

The proposed CAD technique in this paper utilizes both morphological and texture information of the colon wall to detect the colonic polyps from initial candidates which were identified by our previously reported geometry-based CAD method [15] on the entire colon wall. All the geometrical, morphological and texture information were extracted based on our mixture-based image segmentation, which preserves rich information on the colon mucosa with material percentages in each image voxel. From the initial candidate location, we found the border between the suspected region and inner normal tissues by the use of our developed edge-detection method. The border information provides sufficient information to find and extract the whole region or volume for each suspect ROI. Then both the morphological and texture features of the whole volume were analyzed and used to eliminate the false positives in the

initial candidates. This entire CAD framework takes the advantage of utilizing both texture and geometrical information to detect the colonic polyp, and was shown to provide more accurate detection results than the CAD with geometrical information only.

There are two breakthrough points in our CAD framework. One is the combination of both shape information of the colon wall and the other tissues behind the colon wall. With both outer and inner shape information, improved detection of colonic polyps is expected. The other breakthrough work is the introduction of the texture information into the detection of the colonic polyps. With the additional texture information, we will be able to go beyond the shape information and achieve a significant improvement in reduction of false positives. For the detection of colonic polyps, especially the malignant (growing) polyps, the texture features are different from the texture features of normal tissues. Since the entire procedure can be computerized, a more efficient utilization of computer for CAD objective -- to perform more work for the physicians -- is realized.

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