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# A Survey on the State of Art Techniques for the Identification of Polyps for Colorectal Cancer

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***Abstract*-**Computer Aided Diagnosis (CAD) is available for automatic detection of suspicious colorectal polyps in the CT images of the colon. These schemes help the radiologist to identify the location of the polyps in an efficient and accurate manner. A detailed survey was made on the different CAD scheme proposed by different authors for the detection of different categories of polyps. The different CAD schemes was implemented by incorporating some modification in the segmentation phase such as automatic colon segmentation or vary the identification of features in the feature extraction phase in the classical polyp detection system for the identification of polyps. Their performances were measured by two parameters sensitivity and specificity. Thus the ultimate aim of the authors was to improve the sensitivity and decrease the chance of missing sessile and flat polyps, with acceptable false-positive rates.

***Keywords*-** Computer Aided Detection, Virtual Colonoscopy, Polyps, Polyp detection

## I. INTRODUCTION

Colorectal cancer is cancer that occurs either in the colon or rectum. Most colorectal cancers develop first as colorectal polyps, which are growths inside the colon or rectum that may later become cancerous as shown in fig 1.It affects both men and women mostly above the age of 50.It is the third most common cancer among men after prostate and lung cancers. For women, colorectal cancer is the third most common cancer after breast and lung cancers. (American Cancer Society, Annual Report Online)

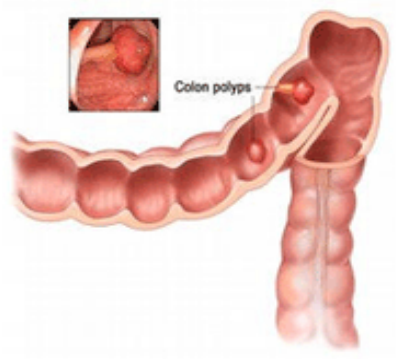


**Fig 1 :** Polyps situated on the colon wall

The Colorectal Polyps can be classified as shown in the table 1.The two most common types are adenomas and hyperplastic polyps. Benign are tumors which rarely or never give rise to cancer but the cells in tubular adenomas frequently progress to cancer, show certain abnormalities of cell maturation and appearance collectively known as dysplasia.

**Table 1:** Classification of colorectal polyps

| Histological Classification | Polyp Type | Malignant Potential |
|---|---|---|
| Non-neoplastic | Hyperplastic polyps | No |
| | Hamartomas | |
| | Lymphoid aggregates | |
| | Inflammatory polyps | |
| Neoplastic (adenomas) | Tubular adenomas (0–25% villous tissue) | Yes |
| | Tubulovillous adenomas (25–75% villous tissue) | |
| | Villous adenoma (75–100% villous tissue) | |

The most important colorectal polyp is the adenoma, a small benign tumor growing to about 2 cm in size. Colonic adenomas are common, and in the majority of patients there is no side effect on health. They are more common with increasing age. Appropriate evidence are shown that colonic adenomas are the early stage of colorectal cancer, although only a very small percentage of adenomas turn into malignant tumour and it may take nearly five to 15 years to change. The larger the polyp, the greater the probability that the polyp will have undergone malignant change and contain cancer (adenocarcinoma).

Hyperplastic (or metaplastic) polyps are usually small, pale curved elevations of the colon lining. These are very common. Although hyperplastic polyps themselves do not turn into colorectal cancer, occasionally hyperplastic polyps (particular those which are large and multiple) will contain adenomas, known as mixed hyperplastic adenomatous polyps. In these polyps, development of cancer may occur but it is very rare.

 

Computed tomographic colonography (CTC) or virtual colonoscopy is an evolving method for detecting colon polyps which records the 3D image of the patient's abdomen. Virtual colonoscopy combines axial spiral CT data acquisition of the air-filled and cleansed colon with 3-dimensional imagin g software to create endoscopic images of the colonic surface (Xiaoyun Yang, Yalin Zheng, Musib Siddique and Gareth Beddoe, 2008). Two main factors that limit CT colonography are its excessive interpretation time and the variable sensitivity among readers. This paper focuses the advantages of computer-aided detection (CAD) techniques to overcome the above problems faced by the radiologist [Guest Editorial, 2001].

Polyps are small growths that arise from the inner lining of the colon. CAD detects the polyps by identifying their characteristic "bump-like" shape fig 2. CAD is fundamentally based on highly complex pattern recognition. In recent years a number of prototype Colon CAD schemes with CTC have been proposed for detecting polyps to reduce the false positive (FP) polyps. About 95% of all cases of colon cancers arise from adenomatous polyps are initially benign, but at later stage they turn into malignant. The malignancy is normally referred with the size of polyps. The size of a detected polyp is an important criterion for further diagnosing and decision making. In this paper, the survey is made on the computer aided diagnosis (CAD) technique that is proposed by different authors for varying size of polyps.

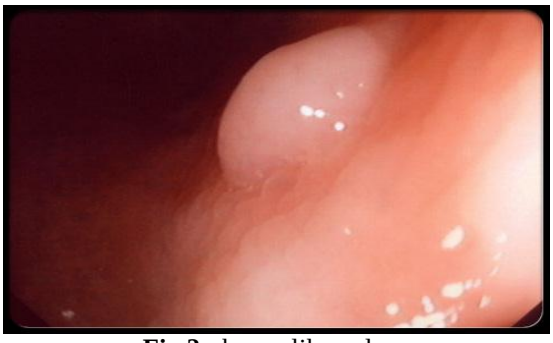

**Fig 2 :** bump-like polyps

This paper is going to investigate the techniques used in different CAD schemes by different authors for the reduction of fault positive (FP) finding of polyps of various sizes and improve the sensitivity.

## II. PERFORMANCE MEASURES

Computer aided diagnosis (CAD) system for the colonic polyps detection is a challenging task, because the polyps have many different sizes and shapes, and the colon wall folds may mimic their size and shapes. If any part of detection matched any part of a manual tracing of a polyp, the detection was considered a true positive (TP) otherwise, the detection was considered a false positive(FP).CAD techniques proposed by different authors for detection of polyps is based on the following two measures

1. Sensitivity

It is considered as one of the performance measure for the detection of polyps.100 % sensitivity means the CAD technique is capable of detecting even a very small suspicious polyp that may result into malignant tumour. Sensitivity is defined as

$$\text{sensitivity} = \frac{\text{number of true positive}}{\text{number of true positive} + \text{number of false negative}}$$

2. Specificity

It is the second important measure.There are numerous folds and residual colonic materials which will be misinterpreted as polyps and thus result into false positives (FP) polyps. The CAD schemes should have the ability to discriminate between the true polyps and remove the FPs to prevent the generation of false alarms in the CAD systems.100% specificity means CAD should fail at folds and residue colonic material and identify true polyps. Specificity is defined as

$$\text{sensitivity} = \frac{\text{number of true negative}}{\text{number of true negative} + \text{number of false positive}}$$

Ideally, the CAD systems should have 100% sensitivity and 100% specificity but difficult to realise in practise, sometimes one of these measures can attain 100% but on the compromise of other factors. Non ideal CAD systems should high sensitivity and specificity, that is, a low false positive rate. In normal CAD scheme, the sensitivity for small sized polyps is relatively low, while sensitivity for medium sized polyps is between 70% and 90%, and large polyps greater than 10 mm can be detected with 90–100% sensitivity (Farhan Riaz, Mario Dinis Ribeiro and Miguel Tavares Coimbra).

## III. METHODOLOGY

CAD system for the detection of polyps can be generally decomposed into four stages (Graser.A, Kolligs.F.T, Mang.T, Schaefer.C, Geisbüsch.S, Reiser.M.F and Becker.C.R., 2007). Digital image data that is copied to a CAD server in a DICOM-format are prepared and analyzed in several steps as shown in figure 3 along with the methodologies adopted by different authors. During the data pre-processing phase, steps for the removal of noise, reducing artifact and segmentation of colon is performed. In the candidate generation phase possible locations of polyps are identified. Potential polyp candidates are identified and then segmented. At this stage, a lot of false positive (FP) regions are produced. These are sequentially processed during the next phase, in which multiple features are extracted. This stage identifies the special characteristics like Tissue Intensity Characteristics, Texture Characteristics, Volumetric and Surface Shape

 

Characteristics in the detected polyp region during the previous phase. Both polyp size and morphology affect the incidence of carcinoma within a polyp. Candidate uniquely identified with the above associated features are then fed to a classifier for final evaluation with the help of training set or test set. Only 1% of polyps smaller than 1 cm in diameter are malignant, whereas about 46% of polyps over 2 cm are malignant (Abraham H. Dachman and Hiro Yoshida., 2003).

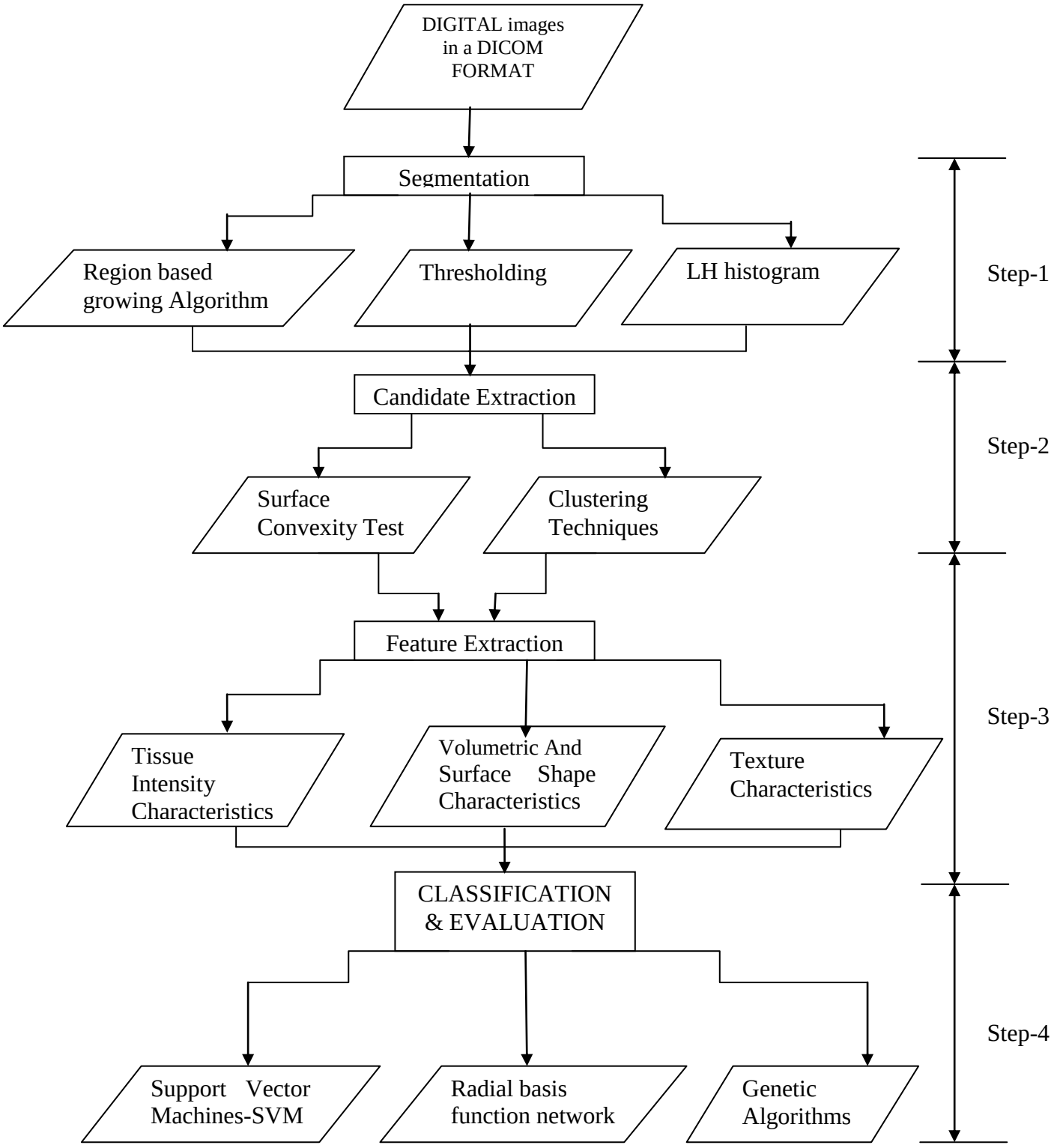


**Fig.3 :** Flowchart of the main steps in the classical polyp detection CAD scheme with the techniques

 

## IV. DIFFERENT CAD SCHEMES

This paper focused on the sensitivity and Specificity of the different CAD schemes to the three categories of polyps. Polyps were classified as small (≤ 5 mm), medium (6 – 9 mm), and large ( ≥10 mm) (A.Graser, F.T. Kolligs, T,Mang, C,Schaefer, S. Geisbüsch, M.F. Reiser and C. R. Becker.,2007).

### 4.1 Medium Lesion detection

Wei Hong, Feng Qiu, and Arie Kaufman., (2006) have proposed a method to highlight the polyp candidate larger than 5 mm in a endoscopic view in virtual colonoscopy (VC).This was implemented by first segmenting and digital cleansing the colon acquired using CT from abdominal data set by partial volume segmentation algorithm. This algorithm separates voxels in the air lumen into three categories and this step produces segmentation of the colon and a clean colon lumen. A region growing based segmentation algorithm is used to extract a topologically simple segmentation of the colon lumen. This segmentation requires seed point and from this initial point, region is grown by appending other points which satisfies the adjacency condition that this point should be adjacent to just one object component and one background component. After this step, we obtain both the colon surface mesh with genus zero and the colon centerline. The 3D colon surface is mapped to a 2D rectangle and this conformal mapping simplifies our polyp detection problem from 3D to 2D. High resolution 2D biopsy images are generated using volumetric ray-casting algorithm by passing a ray which is allowed to traverse up to 40 steps. The K-L transformation matrix is applied to the local vector series belonging to hand segmented polyps on the 2D flattened electronic biopsy images. The representative vector V and similarity threshold T is used to classify the feature vectors in the K-L domain. If the Euclidean distance between a feature vector V is less than T, the corresponding pixel is classified as belonging to a polyp. A 2D image is generated where the pixels classified belonging to a polyp are colored in red whose diameter is larger than 5 mm. The red regions in this 2D image are highly suspicious for being polyps, indicating that the physicians should observe these areas in the 3D view very carefully.

L Bogoni, P Cathier, M Dundar, A Jerebko, S Lakare, J Liang, S Periaswamy, M E Baker, and M Macari.,(2005) have proposed a method for the identification of medium sized polyp's ≥ 6 mm by modifying feature extraction phase in the classical polyp detection scheme by implementing the wrapper method for feature selection, in which the classifier decides which features are useful.

June-Goo Lee , Jong Hyo Kim , Se Hyung Kim , Hee Sun Park ans Byung Ihn Choi. ,(2011) proposed a method for the identification of medium sized polyps (3-6 mm) with 100% sensitivity by producing a numerical phantom . The filtering procedure begins with 3-D Gaussian filtering, followed by a Hessian matrix computation and its eigen decomposition.This phantom is used for the evaluation of effectiveness of the volumetric structural features such as Gaussian kernel (GK), suppression threshold (ST), and volume threshold (VT) to discriminate basic structures in the colon. The former two are parameters of the blob-likeness filter, and the third was used for candidate detection.

Vincent F. van Ravesteijn, Cees van Wijk, Frans M. Vos, Roel Truyen, Joost F. Peters, Jaap Stoker, and Lucas J. van Vliet., (2010) proposed a system for the identification of polyps >=6mm with a sensitivity 88.8%.This system was implemented by using candidate extraction and a logistic classifier. The extracted candidates from the candidate extraction stage are ordered by a linear logistic classifier which classifies based on only three features: the protrusionof the colon wall, the mean internal intensity, and a feature to discard detections on the rectal enema tube.

### 4.2 Large Lesion detection

Simona E. Grigorescu, , Shelly T. Nevo, Marjolein H. Liedenbaum, Roel Truyen, Jaap Stoker,Lucas J. Van Vliet, and Frans M. Vos., (2010) have proposed a method for the automatic detection and segmentation of polyps larger than 10 mm in diameter while the previous CAD technique narrated was for polyp size larger than 5 mm. This paper modifies the segmentation phase in the classical polyp detection scheme by evaluating the LH histogram which separates the fat and muscle density in CTC data. It focuses mainly on the tissue separation surrounding the colon lumen and finds the appropriate region for poly detection. This Large lesion detection is started with a preselection step, which is divided into many stages. The first stage removes the image noise and the small food remnants by using the intensity information. The next stage in the preselection step is to group the location that passed the above stage based on the proximity of closeness to each other. The segmentation is done based on the LH histogram representation of the local gray value data. LH histogram is a method to identify the boundaries where L and H represent the lowest and highest intensity value. The points that belongs to the material and border are plotted in the LH space, for materials centered at (L, L) and for borders centered at (L,H).If two materials are to be segmented LH space is split into four quadrant and by repeated iteration suitable threshold that separates the two material can be found out. After segmentation and

 

performing morphological operation to remove the small connection between muscles like structure, the diameter of the segmented region is calculated if it has a diameter greater than 50 mm it is to be considered as a larger polyp.

Tarik A. Chowdhury et al. (2008) have proposed a method for the detection and segmentation of polyps larger than 10 mm with 100% sensitivity with 3.38 FP/dataset when applied to low dose real patient data while the other categories of polyps have lesser sensitivity. The important phase in the polyp detection, automatic colon segmentation was performed with the following steps based on the normalized histogram as shown in the figure 4 .This similar type of colon segmentation was also proposed by (Alberto Berta, Ivan Dmitrievb,Silvano Agliozzoa, Natalia Pietrosemolib,Mark Mandelkernc, Teresa Gallod and Daniele Regge.,2009).

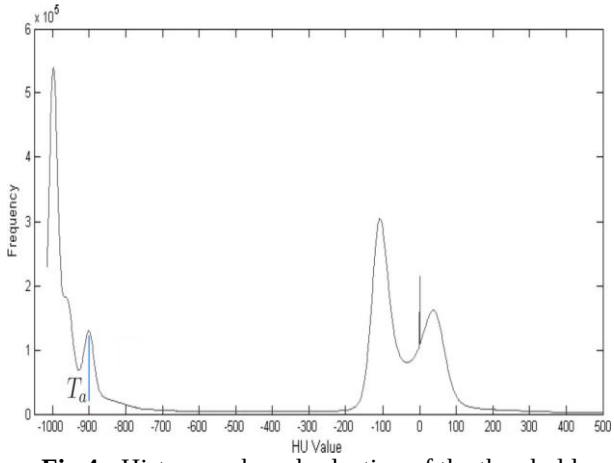


**Fig 4:** Histogram-based selection of the threshold

Parameters
To Lowest possible seed Value : -1000 HU
Range of CT air values : To and -700HU
Range of CT fat values : -300 HU to 0

- Region growing algorithm is followed for the removal of air around the body. Any region growing algorithm requires a seed point from which the region is grown by appending to the seed point the voxel which satisfy the threshold property Ta-900 Hounsfield Unit (HU).Here the seed point is selected as the top left most voxel.
- Next the removal of the lung portion is implemented with the same region growing algorithm but the property that voxel should satisfy a threshold value less than $T_a$. The colon segmentation is achieved as they are yellow in color and the lung tissue is green in color.
- Colon segmentation is achieved by again performing region growing algorithm to find the labeled connected components, shortest distance between the end points is calculated and the Volume/Length is performed.

The candidate generation is performed with Surface Convexity Test, which evaluates the convexity of all voxels that define the candidate surface. The features that were used for the identification of polyps were the standard deviation (SD) of the surface variation,the SD of the three axes of the fitted ellipsoid, SD of the ellipsoid fit error, and SD of the sphere fit error and the value of the Gaussian distribution. The classifications of polyps were performed by feature normalized nearest neighbour (FNNN) classifier and the probabilistic neural network (PNN) classifier.

David S. Paik et al. (2004) achieved 100% sensitivity for colonic polyps 10 mm and larger at 7.0 false positives (FPs)/dataset. He proposed the techniques as follows

- Preprocessing and Segmentation of colon lumen is done by thresholding all the air intensity voxels < -700 HU including air outside the body. The inferior portion of lungs is removed by using negative masking 3-D region-filling seeded with air intensity regions with a width or depth of greater than 60 mm. The binary image $S_2$ is derived which is limited only to the edges of air-tissue interfaces.
- First derivative gradient operation, a modification of the canny edge detector is applied to binary image $S_2$ to identify the edges in $S_2$ resulting in 3-D orientation of the image surface normals represented as N(x,y,z).
- The surface normal overlap step is next performed for detecting lesions.

In addition to this, theoretical model were also developed to compare the behaviour of the surface normal overlap (SNO) method to the 3-D Hough transform for spheres to distinguish colonic polyps from folds.

### 4.3. Small Lesion Detection

In the consensus (Zalis.M.E, Barish. M. A,Choi.J.R,Dachman. A. H, Fenlon. H. M,Ferrucci. J.T,Glick. S. N, Laghi.A, Macari.M, McFarland.E.G, Morrin.M.M, Pickhardt.P.J, Soto.J, and Yee.J, 2005) prposed that patients with a polyp of at least 10 mm must be referred to optical colonoscopy for polypectomy and it is advised that diminutive polyps ( 5 mm) should not even be reported but still detection of small and diminutive are performed (Perry J. Pickhardt,Cesare Hassan,Andrea Laghi,Angelo Zullo,David H. Kim,Franco Iafrate and Sergio Morini.,2008).

Marcelo Fiori et al. (2007) have proposed a method for the detection and segmentation of small polyps that is greater than 3 mm in diameter, flat polyps and polyps greater than 6 mm in diameter. Small polyps are normally ignored by the radiologist because only a small percentage of those polyps turn into malignant. This paper segment the colon from the abdominal volume in the CT by proposing a probability map for three classes of interest air, liquid and interface, the union of these three

 

classes P forms the inside of the colon. The segmentation of air and liquid can be done manually based on the distribution of the gray level value. The segmentation of interface is done by a predefined algorithm that computes the probability of that interface. Thus the union of these three classes P segments the colon from the CT slice. The curvature-based surface motions with suitable modification is implemented to smoothen the colon surface and to remove the noise after segmentation step. Feature Extraction extracts 6 geometric features by considering the shape of neighborhood area of the polyp in addition to polyp intrinsic geometry and structure. In addition to feature extraction 5 texture feature entropy, energy, contrast, sumMean, and homogeneity are also extracted to aid the classification and extraction of polyps.

Anna K. Jerebko et al. (2003) implemented the CAD technique in the two-dimensional subimages of polyp candidates selected using various 3-D shape and curvature characteristics for a polyp size greater than 3mm in diameter. The classical CAD technique was implemented with suitable modification. Preprocessing was done with median filter to remove salt and pepper noise. Edges are the boundaries of the colon wall with the surrounding tissue. Among the various edge operators which detect the edges canny edge detector is used to identify the polyp boundaries. The proposed algorithm is able to quantitatively measure particular features (polyp boundary length, number of boundary pixels, polyp base length, polyp internal area, mean intensity, polyp height, and inscribed circle radius) of the polyp and use them for classification. After applying the canny filter, the Radon transformation is applied to the edge detected image. The Radon transform computes projections in the contour image c(x,y) along specified directions. This projection parameters help in extracting and measuring polyp features. The thresholding technique was used to categorize the polyps of various sizes. Upper thresholds are set to remove shapes which are too flat and too big to be a polyp.

## V. PERFORMANCE

### 5.1. Medium Lesion detection

Wei Hong et al. (2006) implemented the CAD technique with 52 CT data sets from the National Institute of Health (NIH) and 46 CT data sets from Stony Brook University Hospital (SBUH). 100% sensitivity implies all the polyps have been detected but among the detected polyps some false finding polyps was located. The no of false positive (FP) polyps in NIH was on an average of 3.1 per data set and in SBUH 2.7 per data set. The Specificity was not 100% as a result of this Fault positive detection.

Bogoni et al. (2005) trained 88 cases in the training set using the 15 features selected in the ‘‘Feature Selection’’ phase. A total of 53 unique polyps were extracted after the feature extraction which produced 25 midsize polyps of size between 6 –9 mm. In the candidate generation phase all the polyps were detected which resulted in 100% sensitivity but during the classification phase it produced false positive (FP) rate of 3.5 per volume resulting in 92% sensitivity. A total of 39 unique polyps were identified in the test set which produced 11 mid-size polyps of size between 6–9 mm. In the candidate generation phase one polyp out of 11 polyp were missed which resulted in 10/11=90.9% sensitivity but during the classification phase it missed 2 polyps thus producing 9/11 = 81.8% sensitivity.

June-Goo Lee et al. (2011) trained 103 polyps. It was divided into training and test datasets. After tuning for the optimal parameter settings, the per-polyp sensitivities of the developed CAD scheme for clinically relevant polyps (> 6 mm) were 100% at 8.5 false positives (FPs) / patient using the training dataset,and 93.3% at 7.7 FPs/patient using the test dataset.

### 5.2. Large Lesion Detection

Simona E. Grigorescu et al. (2010) assessed the performance for 41 polyps with both the classical polyp system and proposed system. The detection of both benign and malignant tumor were considered at different rates of 8 FP/scan, 5 FP/scan and 2 FP/scan .The result shown below in the table 2 is for malignant tumor where the sensitivity of the detection of this tumor is high only for the rates of 5 FP/scan and 2 FP/scan when compared with normal CAD system. For a rate of 8 FP/scan the no of polyp detected of the proposed CAD system and the normal CAD system is same.

Tarik A. Chowdhury et al. (2008) have evaluated the CAD-CTC system under different categories. Evaluation were done with real patient data, synthetic data and standard dose phantom data by applying automatic colon segmentation algorithm and the other segmentation algorithm proposed by different authors. Next evaluations were done by applying the proposed polyp detection to different data set and comparison were done with other polyp detection techniques.

David S. Paik et al. (2004) used database of 116 CT colonography exams performed at either Stanford University or at the San Francisco VA hospital, 8 exams were selected and the performance are as follows- 80% of polyps ≥ 10 mm in diameter were detected at 4.6 FPs/dataset. 90% were detected at 6.0 FPs/dataset. 95% were detected at 6.5 FPs/dataset. 100% were detected at 7.0 FPs/dataset.

 

**5.3. Small Lesion Detection**

Marcelo Fiori et al. (2011) implemented the CAD technique with 49 polyps. Among these 49 polyps, 15 polyps were between 3mm and 6mm in size. The detection of polyps greater than 3mm in size has a sensitivity of 100% at a rate of 2.2 FP/ scan is as remarkable as the 0.8 FP /rate for polyps beyond 6mm in size. Adding the texture features to the geometric ones, the sensitivity reaches 100%, and at the same time the false positives rate is decreased by 30%.

Anna K. Jerebko et al. (2003) tested with data set containing 15 polyps larger than 3 mm and 617 false positives taken from 80 CTC studies. The sensitivity was 100% at an average of 3 false positives per study.

**Table-2 :** Survey of the performance measure; information for entries marked as unk.(unknown) was not available in the literature

| Source | Data Source | Total Polyps | Polyp Size /polyps | FP per data set | Sensitivity (%) |
|---|---|---|---|---|---|
| Wei Hong et al | National Institute of Health-NIH | 58 | All category | 3.1 | 100 |
| | Stony Brook University Hospital-SBUH | 46 | | 2.6 | 100 |
| L Bogoni et al. | New York University Medical Center-NYU & Cleveland Clinic Foundation –CCF | 53-Training data set | > 6 mm /25 | 3.5 | 92 |
| | | 39 – Test data set | > 6 mm /11 | 3 | 81.8 |
| June-Goo Lee et al. | CTC | 53-Training data set | > 6 mm /25 | 8.5 | 100 |
| | | 39 – Test data set | > 6 mm /11 | 7.7 | 93.3 |
| Simona E. Grigorescu et al. | Academic Medical Center, Amsterdam | 41 | >10 mm/19 | 8 | 83 |
| | | | | 5 | 95 |
| | | | | 2 | 84 |
| Tarik A. Chowdhury et al. | Siemens Somatom Sensation multislice CT scanner | 127-Real patient data | ≥ 10 mm | 4 | 100 |
| David S. Paik et al. | Stanford University or San Francisco VA hospital | 116 | ≥ 10mm/ 7 | 7 | 100 |
| | | | | 6 | 90 |
| | | | | 4.6 | 80 |
| Marcelo Fiori et al. | WRAMC database | 49 | > 3 mm/ 15 | 2.2 | 100 |
| Anna K. Jerebko et al. | CTC Studies | 80 | > 3 mm/ 15 | 3 | 100 |

## VI. CONCLUSION

For medium sized polyps Wei Hong et al. focused on the 3D mapping of the colon surface to 2D mapping for easy visualization for the radiologist, L Bogoni et al. made some challenges in the feature extraction phase to improve the sensitivity and June-Goo Lee et al. focused on the volumetric structural features to improve the sensitivity and reduce the false detection. Both Simona E. Grigorescu et al. and Tarik A. Chowdhury et al. focused on the detection of larger lesion by incorporating some changes in the segmentation and detection phase of the classical

 

polyp system detection of for polyps >=10mm. David S. Paik et al. developed a computer-aided detection (CAD) algorithm called the surface normal overlap method that help in the detection of large colonic polyps 10 mm with100% sensitivity.The no of papers focusing only on the detection of small polyps is very limited because only small fraction of polyp turn into malignant .Hence two papers Marcelo Fiori et al. and Anna K. Jerebko et al. have been selected since these paper emphasize the importance of detecting small polyps. Thus the ultimate aim of the authors was to improve the sensitivity and decrease the chance of missing sessile and flat polyps, by implementing some modification in the classical polyp detection. Future improvements in CAD algorithms will likely lead to even better performance.

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