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Automated Polyp Detection in Colon Capsule Endoscopy

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Abstract: *Colorectal Cancer is disease in which abnormal cells grow in the colon, ultimately forming a malignant tumor. Colon Capsule Endoscopy is procedure that uses wireless camera providing minimally invasive examination process to take images inside the colon. The images are recorded by the recorder outside the patient's body. The recorded images are examined by technician for the presence of polyps. We propose an algorithm which relieves the burden of human operators of analyzing thousands of the images in the video sequence. Depending upon the geometrical features & texture content the binary classifier classifies the images as either containing polyps or not. Generally, the polyps are round shape. Thus, here we used ball fitting as a decision parameter of the classifier. Data set collected from the hospital of five adult patients. Evaluation of statistical performance is done on the data set of around 100 frames from the video sequence. The algorithm gives 48% sensitivity per frame & 82% per polyp at a specificity of 90%. On an average, out of 100 frames, only 10 false positive images need to be inspected by the technician.*

Keywords: *Binary Classifier, Capsule Endoscopy, Colorectal Cancer, Image Processing, Polyp Detection, etc.*

I. Introduction

The Colorectal cancer is a disease in which a malignant tumor arising from the inner wall of the large intestine (the colon). Colonoscopy is a test which will look at the inner lining of the colon tract or large intestine through camera. Doctor uses a thin, flexible tube called colonoscope to look at the colon. Colon Capsule Endoscopy [1], [8], [12], [17], [26] is a small imaging device, with a small vitamin-sized capsuled camera that patient swallow. As the capsule passes through the digestive tract, the camera takes thousands of pictures and is transmitted wirelessly to the recorder mounted outside the patient's body. The images are captured at a rate of 2 to 30 frames per second or more frames per second. Once, the whole video sequence is recorded, it has to be analyzed by the technician for the presence of polyps. The video sequence of a single patient may contain thousands of frames. And analyzing these thousands of frame makes burdensome task for the technician. Using an automated approach of detecting colon polyps reduces the time required. Thus, it should provide high sensitivity and high specificity giving low rate of false positive detections.

Previously, to acquire the colonographic images from patient, Computed Tomography (CT) was used. Firstly, the shape based algorithm and curvedness was used, that outlines masses which stand out in the lumen [31]. Then secondly, 3D Computer Aided Diagnostic (CAD) Scheme was used for detection of colonic polyps using CT colonographic datasets. Polyps are detected by computing 3D geometric features. Fuzzy clustering is applied to classify the polyps from surroundings [34]. Colonic Polyp Segmentation is obtained using intensity adjustment, fuzzy c-mean clustering & deformable models [33]. Using Colon Capsule Endoscopy [6] the colonograpjic dataset is collected, segmented with simple curvature descriptors and classified as polyp or non-polyp using Support Vector Machine(SVM). All these methods are sensitive to noise and image artifacts. In the presence of noise the computations are unstable, which requires smoothing to be applied. But the curvatures are still sensitive to noise.

The objective of this paper is to classify the polyp frame and normal frame from the colonoscopic images. Here, binary segmentation is performed on colonoscopic images and analysis is done in frame by frame manner. The polyp containing frame will give the warning dialogue box as 'Image contains polyp' else as 'Image is Normal'. In this paper, an efficient algorithm is provided to detect the colon polyps automatically from the CCE frames.

II. Proposed Method

This section provides detailed step by step description of algorithm. It classifies the colonoscopic images correctly as either 'Image contains polyp' (Polyp Frame) or 'Image is Normal' (Normal frame). The values of numerical parameters for the classification are chosen manually. The parameter required to classify the frame is study of texture content in the frame. In this algorithm color image is converted to grayscale image before processing for segmentation with a normalized intensity. And after this the image is transformed or scaled to colormap. From that we used measure of color component. In further processing classification is mostly depend on geometrical information for polyp detection.

The basic block diagram of proposed automated polyp detection is as shown in Fig. 1

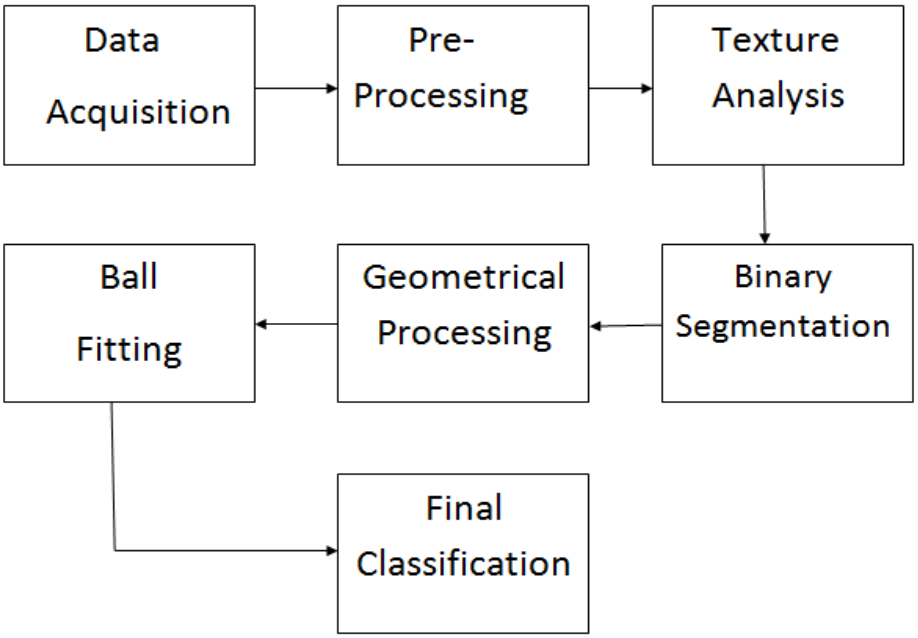

Fig. 1 Block Diagram of Proposed Method

Detailed explanation of each block of polyp detection based on binary segmentation is given below:

A. Data Acquisition

The colonoscopic images are acquired from the wireless capsule endoscope. Capsule endoscopy is a procedure that uses a tiny wireless camera to take pictures of your digestive tract. As it passes through the colon tract it captures thousands of images and transmits it to the recorder outside the patient's body.

B. Preprocessing

The images taken from the colonoscope are sometimes suffers from artifacts. The images are pre-processed through following three steps:

1. **Cropping:** The images taken from the capsule endoscope are hexagonal in shape. So the area outside the hexagonal mask is filled with a solid color to the rectangular shape. It creates a discontinuity along the edges of the frame, so to avoid this; the frames are cropped to rectangular shape. The rectangular frame is having uniform dimension of $N_y \times N_x$. Suppose, the rectangular frame f is having particular dimension of $Ny \times Nx$. Where, Ny is the height of the frame in pixels & Nx is the width of the frame in pixels. The frame is cropped to new dimensions having rectangular shape.

2. **RGB to Gray:** The color image is converted to grayscale image so that it takes only the information about geometry. Segmentation will be easy with the grayscale image.

3. **Intensity Normalization:** The converted grayscale image is adjusted with equalized intensity values all over the frame. Because the one directional nature of the light source & optical properties of camera lens, the frames often suffer from an artifact. So, it can be reduced by intensity normalization, which is done here using Gaussian filter. It will reduce the number of false results. All the pixels in the frame will have now the same intensity value.

C. Texture Analysis

Texture analysis refers to the characterization of regions in an image by their texture content. Texture analysis attempts to quantify intuitive qualities described by terms such as rough, smooth, silky, or bumpy as a function of the spatial variation in pixel intensities. In this sense, the roughness or bumpiness refers to variations in the intensity values, or gray levels. These statistics can characterize the texture of an image because they provide information about the local variability of the intensity values of pixels in an image. The entropy filter calculates the entropy of the neighborhood and assigns that value to the output pixel. For analysis of texture content, the entropy function is used. Analyzing the texture content in the frame is an important step of the algorithm. Here used the thresholding on the texture content as a pre-selection criterion. Some frames are discarded from the consideration and labeled as "Normal" based on the texture content alone. The use of texture in pre-selection is motivated by two considerations:

- The surface of polyps is often textured, so discarding the frames with low texture content helps to distinguish the polyp frames from the frames with flat mucosa.
- When trash liquids or bubbles are present in the frame, it is expected the texture content to be abnormally high. Since detecting polyps in the frames polluted with trash or bubbles is not feasible anyway, therefore these kinds of frames are discarded.

D. Binary Segmentation

Polyps are often highly vascularised, so here we expected that polyps have stronger texture. In our algorithm, polyps are classified depend on texture content. Once, the image is classified as per the texture content, then the image had gone through binary segmentation. It shows the binary segmented image displaying only black & white color. It will help to easily classify the polyp frame & normal frame. For separating the features from each other, following binary segmentation equation is used:

$$s = H(u - \theta) \in \{0,1\}^{N_y \times N^x} \tag{1}$$

Where, H is taken pixel wise,

θ is scalar threshold,

u is the most prominent feature corresponding to polyp.

Here, the mid-pass filter is used to identify the connected regions correctly. If the region after segmentation has an area in between the bounds specified, then only it will process further. Otherwise, if the region is less than or above the bounds specified, then it will discard that region. The scalar threshold θ is defined by,

$$\theta = max\left(min\left(\frac{1}{2}\max u_{ij}, M_U\right), M_L\right)$$
$$1 \le i \le N_y, 1 \le j \le N_x \tag{2}$$

M_U & M_L are bounds as $M_U > M_L > 0$. Threshold θ is taken to be a half of maximum value of u, so it remains in between the upper bound M_U & lower bound M_L. The connected regions can be found using harlick & shapiro algorithm [14]. It gives decomposition:

$$s = \sum_{k=1}^{N_c} S^{(k)} \tag{3}$$

Where, N_c is total no. of connected regions $S^{(k)}$ disjoint connected components.

The pixel values of $S_{ij}^{(k)}$ of $s^{(k)}$ are defined as:

$$s_{ij}^{(k)} = \begin{cases} 1, & if\ pixel\ (i,j)belongs\ to\ k^{th}\ connected\ coponent \\ 0, & otherwise. \end{cases} \quad (4)$$

E. Geometrical Processing

After binary segmentation & mid-pass filtering the image is decomposed into separate features. These features are now individually processed for determining which of them corresponds to polyps. Here applied the simple criteria of filtering the features by their sizes.

$$K_s = \{k \in \{1,2,\dots,N_c\} | S_L < S^{(k)} < S_U\} \quad (5)$$

Features that are too large may correspond to folds of normal mucosal tissue. Very small features are likely to be the artifacts. So, too large and too small regions are discarded and the region having the size in between is taken & processed further. If none of the features in the image satisfies the size criteria then the image is labeled as 'Normal frame'. It is applied as the pre-selection criteria, thus, in order to avoid false positive cases.

F. Binary Classifier and Ball Fitting

The binary classifier is defined by the following equation:

$$BC = \begin{cases} Polyp, if\ R_{max} \geq R_p \\ Normal, if\ R_{max} < R_p \end{cases} \quad (6)$$

Here, thresholding is applied as binary classifier. R_p is the discrimination threshold value which is set for some particular value. R_{max} is the radius of circle. If the value of R_{max} is greater than or equal to the threshold value then the frame is classified as 'Polyp frame'. And if it is less than the threshold value, then it is classified as 'Normal Frame'. The features or the regions that satisfies the criteria in the segmented image are rounded out by a circle. The center of segmented region is calculated & rounded out by a circle. It will help to clearly display or point out the polyp area. The regions which are likely to be polyps are ball fitted.

III. Experimental Analysis

Experimental analysis is performed for the classification of polyp frame from normal frame. This section gives detailed information about binary segmentation and classifier. Polyp detection is done by frame by frame manner.

A. Database

In this work colonic frames are taken from the local hospital, which are having two different classes of database, normal frames and polyp frames. In this database polyp frames are classified using binary segmentation and geometrical processing. Following Fig. 2 shows the original colonic frame taken from the hospital.

B. Binary Segmentation & Classification

In this section, the frames are binary segmented and classified as polyp frame and normal frame. Following Fig. 2 shows the original image from the database on which further steps are applied.

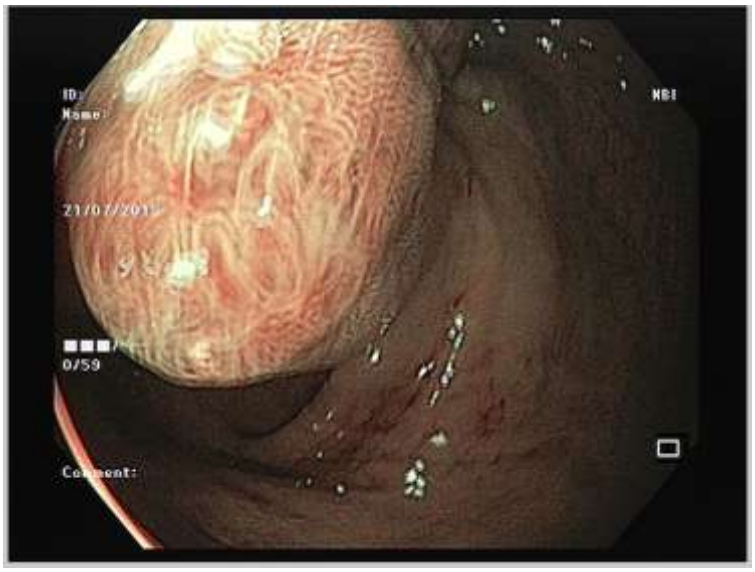

Figure 2 Original frame

After the data acquisition the frame is resized or compressed to smaller size. Fig. 3 shows the resized image. Then frame is pre-processed from three steps: Cropping, RGB to Gray and Intensity normalization and it is shown by the following Fig. 4, Fig. 5 and Fig. 6 respectively.

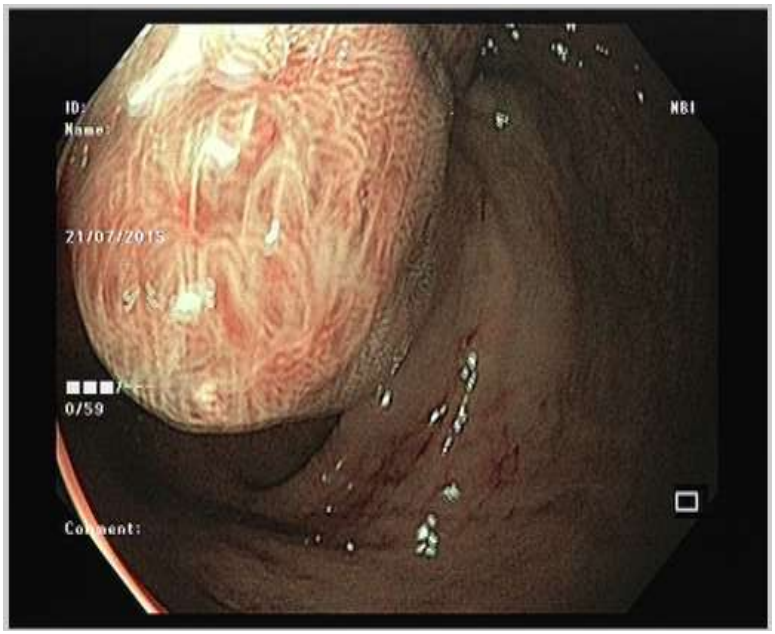

Figure 3 Resized frame

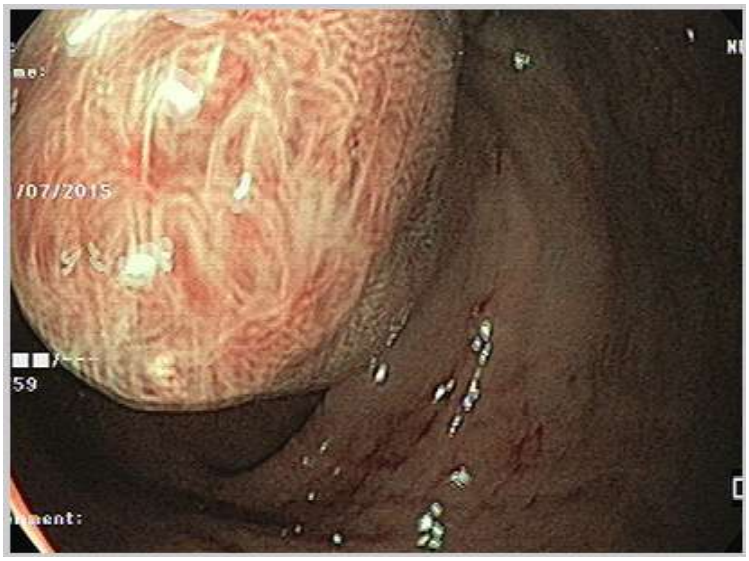

Figure 4 Cropped frame

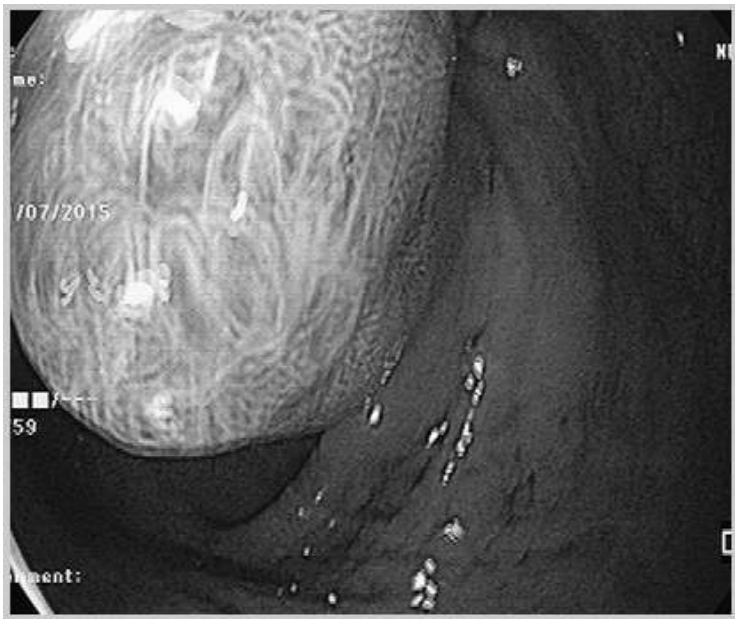

Figure 5 RGB to gray

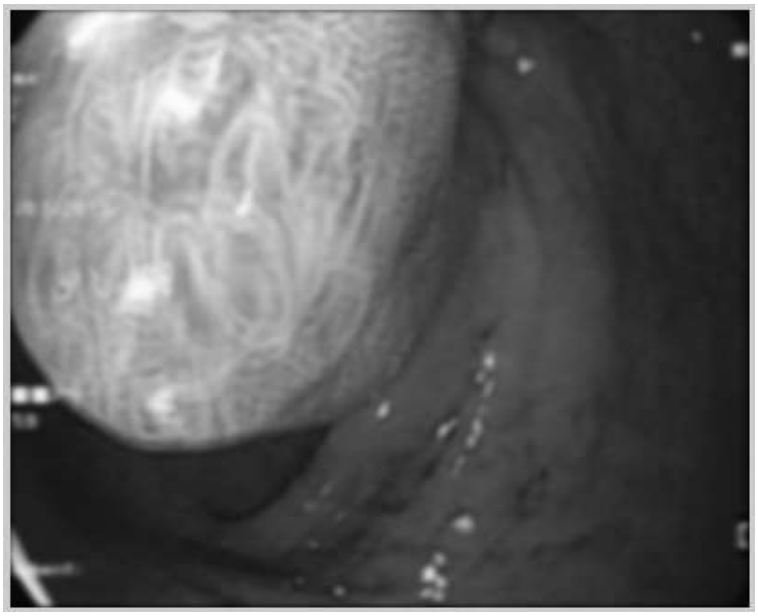

Figure 6 Intensity normalized frame

After the intensity normalization, texture analysis is performed. Texture analysis will give the information about the texture. That means it will give the texture information of bumpy area on flattered portion. Polyps are like mushrooms with stalk or without stalk on flat surface. So, it will have a different texture from the surrounding area. Following Fig. 7 shows the texture analyzed frame. Using Fig. 7 segmentation is performed. From the texture information the image is binary segmented showing the connected regions with white area separated from background area with black color. Using geometrical processing the centroid of the segmented region is calculated and the polyp area is rounded out by a circle. Fig. 8 shows the segmented image with ball fitting around the polyp area. Fig. 9 shows the original frame with ball fitting around the polyp area.

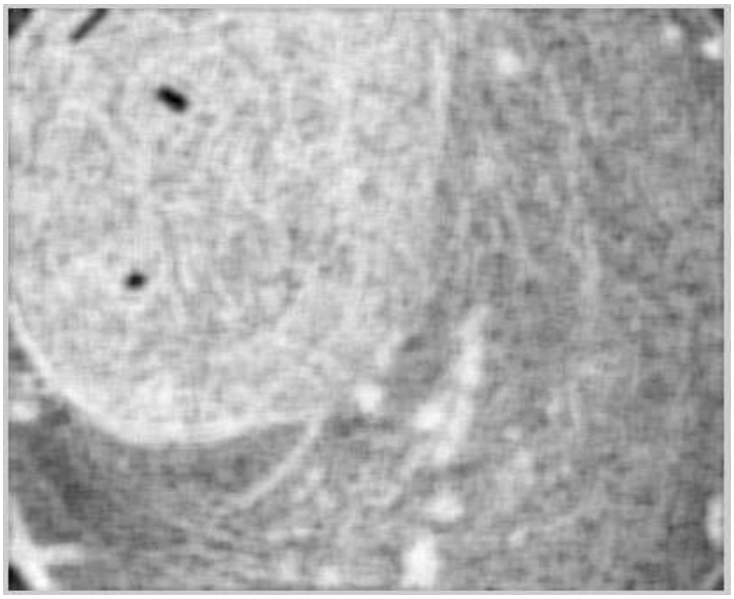

Figure 7 Texture analysis frame

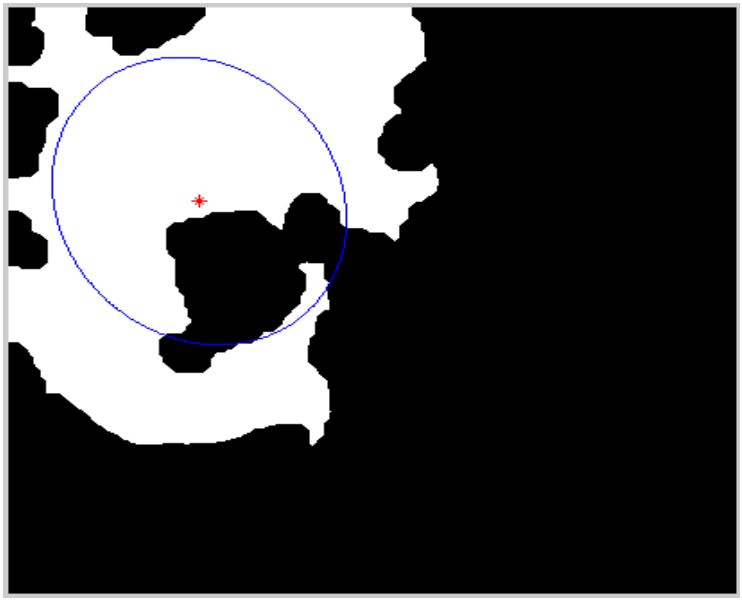

Figure 8 Segmentation with ball fitting

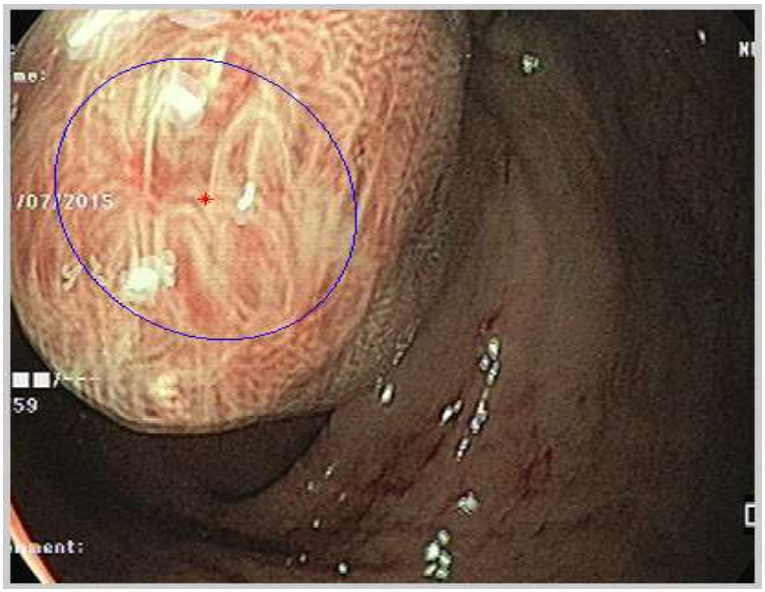

Figure 9 Original Frame with ball fitted to polyp area.

IV. Conclusion

In this work rather than considering full frame the cropped frame is taken to avoid discontinuity along the edges. Then the gray image is taken and processed for texture analysis. From the texture information binary segmentation is performed. The segmented area is passed through geometrical processing which will calculate the centroid of the area. The segmented area is likely to be polyp is ball fitted. Here, the texture information is the major step of the algorithm. But, sometimes because of the thrash, liquids or bubbles presents in the path it gives false positive results. Therefore, it needs future research for more accurate results.

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