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Automated POLYP Detection in Colon Capsule Endoscopy using SVM Classifiers

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Abstract: Acolorectal polyp is an initial stage that develops into a colon cancer, which is a major threat to health. One investigation method involves a small capsule ingested by the patient and images of intestine being recorded continuously by a digital camera in the form of a video sequence. This colon capsule endoscopy is a harmless and minimally invasive examination procedure. The video sequence is then analysed for the presence of polyps. A computer-aided method is proposed to analyze the frames in the video sequence by pre-scanning it, which minimises the labour of a human operator. The algorithm uses Support Vector Machine for classification, which labels the frame as either containing polyps or not, based on the geometrical analysis and the texture content of the frame. The algorithm achieves 95% accuracy and on an average, with a video sequence length of 259 frames, only 5 false positive frames need to be inspected by an operator.

Index terms: Colorectal polyps, Colon cancer, SVM, Geometrical analysis

1. INTRODUCTION

An abnormal growth of tissue projecting from a mucous membrane is known as a polyp. In this paper, polyp in the colon is considered, which is the second most common cause of cancer in women and the third most common cause in men [1], with the mortality reaching to about 50% of the incidence. Colon Capsule Endoscopy (CCE) [2]-[10] is an alternative method to conventional examination methods, such as the Colonoscopy or Computed Tomography (CT) Colonography [11].

In CCE, a capsule (small imaging device), is ingested by the patient. As the capsule passes through the patient's gastrointestinal tract, it records the digital images of the surroundings by means of an on-board camera (or multiple cameras). The recorded images are transmitted wirelessly to a recording device. Depending on the model of the capsule and its principle of operation, the images are captured at a rate of 2 to 30 or more frames per second. After the recording of the video sequence, is analyzed for the presence of polyps. Since the video sequence of a single patient may contain thousands of frames, it is difficult for manual analysis. In this paper, a computer-aided method is used to analyze and reduce the time required for complete screening of the video. The idea is that if the system detects polyps, the physician will focus on the signaled portions of the video with urgency. The portions of the video where polyps are not detected will be left for later processing by the physician.

The paper is organized as follows. The existing approaches are discussed in Section 2 and the proposed method is given in Section 3. Results are discussed in Section 4 and the conclusions are drawn in section 5.

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2. EXISTING METHODS

In CT Colonography and in the conventional Colonoscopy videos [12], [13], [14], [15], [16] the polyps were characterized as protrusions from the surrounding mucosal tissue [17], [18], [19]–[21] based on geometrical information solely.Choice of a measure of protrusion is also of crucial importance. Common methods used included curvatures and the shape index and curvedness [22], or the Gaussian and mean curvatures [17]. Polyp characterization based on geometrical information solely led to issues in distinguishing protrusions that are polyps from the numerous folds of healthy mucosal tissue.The curvatures are computed based on differentiation of the image, which must be approximated by finite differences. These computations are rather unstable in the presence of noise.

3. PROPOSED METHOD

In the proposed method texture information present in the frame along with geometrical information is used for characterization of polyps. Support Vector Machine (SVM) classifier is best suited for high dimensional videos and it is used for the classification of frames as either normal or as containing polyp [23]. The proposed method is shown in fig.1. Since the capsule endoscope can operate in an absence of ambient light, an on-board light source is used to capture the images. Due to the directional nature of the light source and the optical properties of the camera's lens, the captured frames are subjected to an artifact called vignetting, which refers to the fall-off of intensity of the captured frame away from its center. As a first step of frame pre-processing, the normalization of intensity using the vignetting correction algorithm is performed.

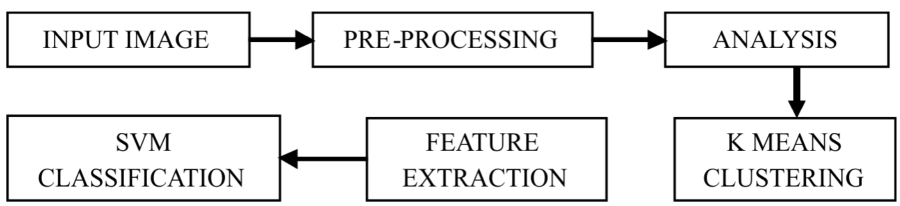

Figure 1.Proposed method

The images acquired by the Endoscope are of circular in shape and bilinear interpolation is used for zooming out of the frame in both x & y directions. The movement of the capsule via the colon may be susceptible to random noise during video recording. Thus noise removal is adopted as the next step using a filter. The performance of the filters is assessed using Peak Signal to Noise Ratio (PSNR) and Root Mean Square Error (RMSE). The values suggest that out of the compared filters like wiener, median and average filters stood the best amongst others with lower RMSE and higher PSNR values. The RMSE and PSNR value obtained for the detected 20 frames is discussed in Section 3. The surface of polyps is often highly textured, so it makes sense to discard the frames with too little texture content in them. This leads to an increased number of false positives. Thus, in order to avoid both the situations mentioned above, a pre-selection procedure is applied that discards the frames with too much or too little texture content. The range filters are used to separate the polyps based on the texture.

3.1. Segmentation

Segmentation is accomplished using K-means clustering algorithm and connected component analysis. K-means clustering method initially takes the number of components of the given data equal to the final required number of clusters. Each component in the given data is assigned to one of the clusters depending on the minimum distance. When a component is added to the cluster the centroid position is recalculated every time and this continues until all the components are grouped into the final required number of clusters. Connected component labelling is used to detect connected regions in data with higher dimensionality.

3.2. Feature Extraction

A feature extraction method selects a subset of meaningful dimensions specific for the application from the original set of dimensions. Using feature subset extraction techniques, redundant and irrelevant features can be omitted to reduce the amount of data during run time. Fuzzy entropy technique is used for classification. In this technique, the entire dataset is classified according to the number of clusters in the dataset and then the proposed entropy fuzzy measures are calculated. Next a feature subset that meets the boundaries giving a high accuracy degree is found. The proposed method is tested on different datasets and the features such as area, major axis length, minor axis length, eccentricity, centroid and equivdiameter of the segmented output are extracted. Based on the entropy values for low-mid-high intensity, the minimum value is taken as the output.

3.3. Support Vector Machine (SVM) Classifier

The final step of the algorithm is classification of high dimensional data set. SVM classifier with radial basis function kernel is used for the final stage classification of polyps from the colon capsule endoscopy videos. The classifier is a separating hyperplane. The important training points are support vectors that define the hyperplane. SVM classifiers find the best hyperplane in the input space and computes largest distance hyperplane to the nearest data point of any class.

4. RESULTS AND DISCUSSION

The proposed algorithm is implemented in MATLAB and a video data set of length 10 sec is used for testing. The frame rate is 25 frames /sec and the size of the video is 876 kb. The total number frames are 250 out of which 235 frames are normal and 15 frames contained polyp. The videos are captured with PillCam COLON capsule in the native resolution of 480 x 480 pixels and are down sampled before processing. The down sampling is performed to reduce the processing time for each frame. Fig. 2. shows the input video used for the study shows the input video used for the study. Fig. 3. shows the results of pre-processing stage on one polyp-containing frame.

Fig.4. shows the segmented and classifier output for a polyp containing frame. The accuracy of the frames is calculated as in the equation (1)

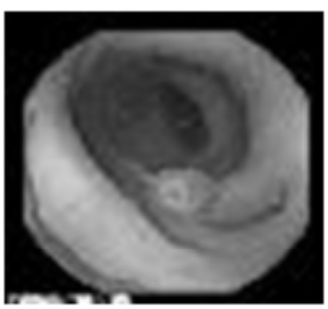

Figure 2: Input video

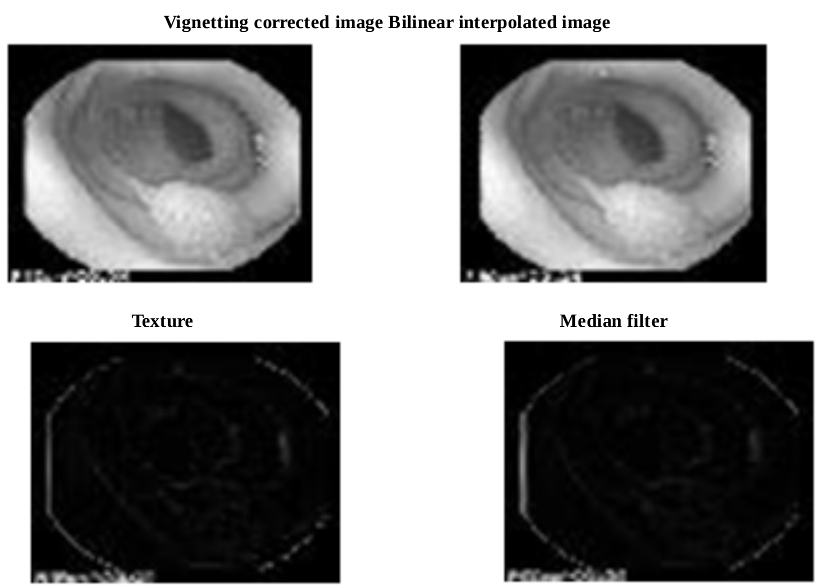

Figure 3: Pre-processing Stage Output-Polyp containing frame

Figure 4: Segmentation and Classifier Output-Polyp containing frame

$$((tp + tn) / (tp + tn + fp + fn))*100 \tag{1}$$

where,

tp-true positive tn-true negative

fp-false positive fn-false negative

A classification accuracy of 95% was obtained using SVM for the overall frames detected. 20 frames were analysed. Among these 20, 15 were detected with polyps. The effectiveness is confirmed using the Receiver Operating Characteristics (ROC). Fig.5. shows the ROC plot for the classifier.

Table 1 and Table 2 lists the PSNR and RMSE values of the wiener and median filters. From the results, it is observed that the performance of the median filter is better than the wiener filter

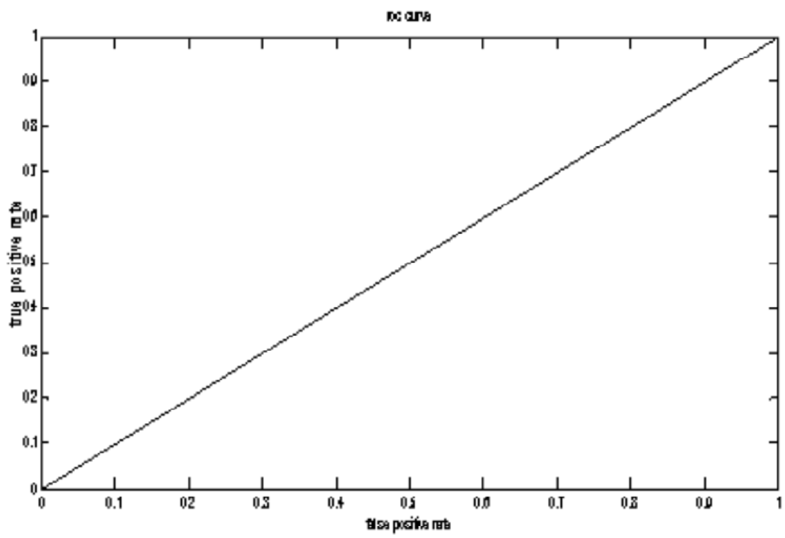

Figure 5: Receiver Operating Characteristics

Table 1
PSNR values for analyzed frame

Frame Number	*Wiener*	*Median*
1	5.4169	1.6706
2	5.4169	1.6702
3	5.4168	1.6701
4	5.4167	1.6700
5	5.4172	1.6699
6	5.2125	1.6027
7	5.2089	1.6054
8	5.2090	1.6052
9	5.2092	1.6049
10	5.2090	1.6171
11	5.0532	1.6000
12	5.0544	1.6003
13	5.0542	1.6007
14	5.0539	1.6003
15	5.0538	1.6004
16	5.0755	1.5778
17	5.0755	1.5776
18	5.0733	1.5775
19	5.0732	1.5773
20	5.0731	1.5777

Table 2
RMSE values for analyzed frames

Frame Number	*Wiener*	*Median*
1	21.8367	33.4557
2	21.8378	33.4558
3	21.8381	33.4559
4	21.8382	33.4562
5	21.8384	33.4554
6	22.0169	33.7899
7	22.0095	33.7959
8	22.0101	33.7957
9	22.0108	33.7953
10	22.9779	33.7957
11	22.0241	34.0595
12	22.0235	34.0574
13	22.0223	34.0577
14	22.0234	34.0583
15	22.0230	34.0584
16	22.0848	34.0212
17	22.0855	34.0212
18	22.0858	34.0251
19	22.0862	34.0251
20	22.0852	34.0254

5. CONCLUSION

The polyp detection is quite perplexing due to a multitude of factors like the presence of trash liquids and bubbles, vignetting due to the use of a non-uniform light source, high variability of possible polyp shapes and the absence of a clear cut between the polyps and the folds of a healthy mucosal tissue. A computer-aided method that reduces the labour of a human operator in analyzing the video frames obtained in CCE is proposed. In the course of work, the above listed issues were mitigated by the various pre-processing steps. This included pre-processing of the input video frame obtained from CCE followed by texture analysis of the frames along with image normalization. Segmentation is done with K-means clustering and connected component analysis methods. The segmented frames were further processed for feature extraction based on geometrical classification followed by feature selection using the fuzzy entropy technique. Finally the video frames were classified as either containing polyps or not, using SVM classifier technique. A classification accuracy of 95% is obtained for the proposed method. The ROC curve of the classifier shows a linear measure between the true positive detection and false positive detection. Thus the proposed computer aided method could reduce the time required for manual inspection of the frames in CCE.

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