Colonoscopic Image Polyp Classification Using Texture Features

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Abstract. Colonoscopic polyps, which may lead to cancer in the later stage has been claiming lots of lives worldwide. So, an early detection and classification system for such polyps has become crucial for timely diagnosis. Many features learning based classification frameworks have been proposed in the literature. Extreme difficulties have been faced in this field are due to lack of sufficient data set, feature similarity among different classes of polyps and so on. In this paper, a two class classification of polyps namely benign and malignant has been devised. The proposed method uses multi directions and multi frequency texture analysis. Gabor filter banks are used in the initial stage followed by discrete cosine transform (DCT) upon the sub-bands. Local binary pattern (LBP) as texture features is also used. Since malignant polyp generally oozes blood on its surface, color features is also considered. The square of the DCT coefficients calculated on all the sub-bands of the Gabor filter are considered as the energy. The DCT co-efficients derived from all the sub-bands are fused to form the feature vector. Along with these features, LBP features and color features are also added to form the final feature vector. SVM is used as the classifier which performs $k-$fold validation on the data set. The proposed method gives competitive results with recent state-of-the-art methods of colonoscopic polyp classification.

Keywords: Colonoscopic polyps · Gabor filters · DCT · LBP · SVM

1 Introduction

Colonoscopic cancer is becoming a potential threat to the mankind globally. Early detection of such cancer can reduce the mortality rate to a large extent.

One such technique is endoscopy, which is used to investigate the conditions of the Gastro-intestinal (GI) tract. For this approach, we are concentrating only on colonic polyp analysis as it is the most common pathological finding of colonoscopy. Polyp generally describes an unnatural growth of mass of tissue protruding into the lumen of the bowel [7]. According to the WHO, a patient with colonic polyp should undergo colonoscopic examination every three years [3]. During this procedure, a device called endoscope is used to scan the entire colon of the patient body from rectum to cecum. When the endoscopists find any abnormal region seeming to be polyp region, they perform visual inspection and/or histological examination to identify the presence of an anomaly. The procedure may be followed by biopsy of the tissue samples to determine the actual nature of the anomaly. Manual categorization of polyp is not an ideal approach due to constraints like observer bias, textural similarity as perceived by human eyes. For this study, automated feature analysis is performed for two classes, i.e. Neoplastic (Malignant) and Non-Neoplastic (Benign) polyp.

During the examination of polyps, the endoscopist looks into the shape, size, presence of blood debris, boundary (smooth or wobble like) and textures of the polyp region. The micro textures on the surface of polyps can be studied to classify such polyps into Benign and Malignant. Since, such texture features can't easily be visualized by naked eye, it is very difficult for the doctor to arrive to any conclusion. Nevertheless, there is minute difference in the textural pattern between the polyps from both the classes. In this work, we are trying to quantify these features using some advanced image processing and machine learning techniques which can represent texture and color features efficiently.

In the proposed work, the Discrete cosine transform (DCT) coefficients of the sub-bands taken from the Gabor filter response are used to form the feature vector. Here, the square of the DCT co-efficients are treated as the energy quantity. Since, malignant polyps have high textural pattern, it is expected to have high energy than the benign polyps. The Local binary pattern (LBP) as the texture feature is also considered here. The S component of the HSV color space is taken as the color feature. All the features are then concatenated to form the final feature representation of the polyps. Finally, classification is performed based on four measures viz. accuracy, recall, precision and f-score using SVM. To avoid over-fitting, four-fold cross-validation technique is used for assessments. Experiments show that the proposed method outperforms some of the existing approaches for Colonic polyp detection. Also, to verify the consistency of the proposed work, the experiments have been performed on the database annotated by an endoscopist.

Rest of the paper is organized as follows - Sect. 2 will give some light on the existing works in this domain, Sect. 3 will portray an overview of the proposed work and explanations on methodologies. Result and discussions are explained in Sect. 4. Finally, conclusions are drawn in Sect. 5.

2   Related Works

From the last many year's researchers have been working on colonoscopy images. Though a lot of work has been done in this domain, still this area is open and needs to be explored. Some have worked on polyp detection and segmentation, and other's work may include only feature extraction, video tracking for best frame selection, and classification using conventional classifiers or deep networks. Since, we are only concentrating on feature extraction, selection and classification, that is why only the concerned literature's in this particular domain are explored.

Hafner *et al.* [5] proposed a method to describe local texture properties within color images with the aim of automated classification of endoscopic images. They suggested a color vector field from an image, then computes the similarity between neighboring pixels. The resulting image descriptor is a compact 1D-histogram which is used for classification using the k-nearest neighbors classifier. Mesejo *et al.* [6] worked on a generated database and try to compute 2D texture features using Invariant gabor texture, rotational invariant LBP; 2D color features using color naming, discriminative color, hue, opponent and color GLCM, and 3D shape features using shape-DNA and kernel-PCA. Color-GLM using SVM classifier is explored by Engelhardt *et al.* [4]. Bag of words descriptors with spatial pyramid matching is done in ref [2]. Muhammad *et al.* [8] proposed to describe the image features using gabor filter and DCT in application to image forgery.

3   Methodology

In the first stage, an RGB endoscopic image is converted into HSV color space. Malignant polyp surface generally contains blood debris *i.e.,* it is highly saturated. So, S component is taken as the color feature.

In the next step, the Gabor filters are applied to the grey images. Gabor filter banks with varied orientation and frequency are used to capture the micro textures in the polyp surface. This transform is a decomposition technique with multi-scale and multi-orientation properties. The mathematical formulation of a 2-dimensional Gabor filter is represented as follows:

$$g(x,y) = \frac{1}{2\pi\sigma_x\sigma_y}\exp\left[-0.5\left(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2}\right)\right]\exp\left(2\pi jWx\right) \tag{1}$$

Where, σ_x and σ_y defines the width of the gaussian function, W is the central frequency of the sinusoid. This frequency component is called the orientation (rotation angle) of the gaussian envelope. To extract the texture features of an image, Gabor filter bank can be formed with different scale and orientation to encapsulate features in different sub-bands.

In this method, we use Gabor transform with varied scales and orientations. The scales are 1, 2, and 3, and 0, $\pi/4$, $\pi/2$, and $3\pi/4$ are chosen as the rotational angles.

The second step accentuates the textures of the polyps at different sub-bands. To encapsulate such features, DCT is used. Unlike discrete fourier transform (DFT), DCT uses real valued cosine functions as the basis functions for the transformation. An image can be represented as the sum of cosine of different frequencies [1] by the help of DCT. It transforms the image from spatial domain to frequency domain (set of frequency coefficients). In our experiments, we extracted all the DCT coefficients for each subbands. In the fourth step, Local binary pattern (LBP) of each pixel is calculated. LBP is a type of visual descriptor used for classification. The window size of 32×32 is taken to form the feature vector. For classification, SVM with RBF kernel is used. With other kernels the results are not satisfactory as with RBF kernel. Performance analysis is done with 4-fold cross validation method. The overall process is given in the Fig. 1.
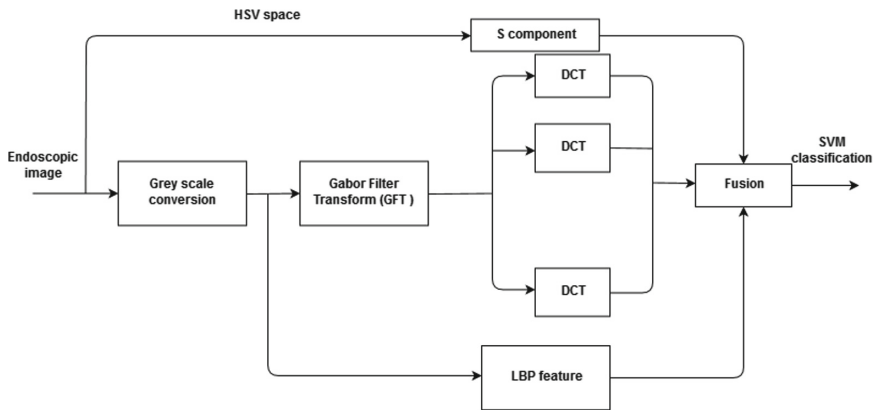

Fig. 1. Block diagram of the proposed method.

4   Results and Discussions

4.1   Data-Set Details

Own database is generated at the Department of Gastroenterology, Aichi Medical University, Nagakute, Japan under the supervision of Konio Kasugai. He has selected only those frames where the polyp is properly visible. Database details are available in Fig. 2. The dataset is composed of colonoscopy videos recorded with Narrow-band Imaging (NBI), White Light (WL) and dye. This database contains 208 benign and malignant images. Ground truths of all the images are verified by doctors. Here in this paper, we are concentrating only on feature analysis and classification. Experiments are performed on 2D images obtained after manual best frame selection by doctors where polyp region is properly visible. Video frame extraction and polyp tracking is not of concern as these are a totally different topic.
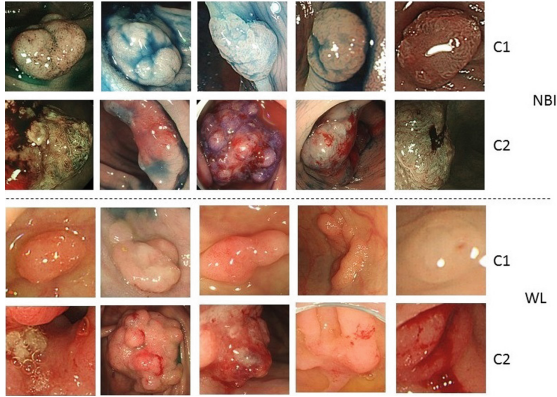
Fig. 2. Data-set details with sample images (C1: Non-neoplastic and C2: Neoplastic samples)

4.2   Comparison

Comparing with existing work is very challenging due to many reasons namely unavailability of generated databases and codes, the differences in problem statements. So for comparing our study, we have to select only those existing works that mainly concentrated on the classification of polyp using some features. Also, only two level of classification (Neoplastic and Non-neoplastic) have been performed for comparison. We have selected two existing works for comparison. The comparative results are listed in Table 1. Approach 1 [4] focused on color GLCM with kNN as classifier. In Approach 2 [2], Bag of Words descriptors with Spatial Pyramid matching were applied. It can be observed for the Table 1 that the proposed work outperform the existing works establishing the fact that the methods used for feature extraction, selection and classification are giving competitive results for colonic polyp classification.

Table 1. Comparison with existing work

	Accuracy	Precision	Recall	F-Score
Proposed	74.035	84.32	85.71	85.00
Approach 1	64.47	75.93	74.55	75.23
Approach 2	73.68	73.97	98.18	84.38

5   Conclusion

In this work, we have tried to quantify texture and color features which help in identifying the dysplasia in a polyp. In doing so, texture features were extracted

using DCT upon different sub-bands found using Gabor filter transform (GFT). Another visual descriptor used was LBP features. Final assessment using four different measures was performed to establish the efficiency of the proposed work. Also, the experiments were performed on the dataset provided by Aichi medical and hospital, Aichi, Japan. Also from comparison statistics, it can be concluded that the present work outperforms some of the existing ones establishing the claim made by us. NBI endoscopic images are generally studied as it gives better classification accuracy. In this method images taken from all the three modalities discussed above have been used.

Since this work has done only on single frames selected by doctors so in future we would like to integrate it with video tracking and automated frame selection. Also, future work includes the study of other texture features of the polyp.

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