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An Enhancement of Computer Aided Approach for Colon Cancer Detection in WCE Images Using ROI Based Color Histogram and SVM2

P. Shanmuga Sundaram [1] · N. Santhiyakumari [1]

Abstract

The colon cancer is formed by uncontrollable growth of abnormal cells in large intestine or colon that can affect both men and women and it is third cancer disease in the world. At present, Wireless Capsule Endoscopy (WCE) screening method is utilized to identify colon cancer tumor at early stage to save the patient life who affected by the colon cancer. In this CTC method, the radiologist needs to analyze the colon polyps in digital image using computer aided approach with accurate automatic tumor classification to detect the cancer tumor at early stage. This kind of computer aided approach can operate as an intermediate between input digital image and radiologist. Therefore, in this paper, a novel computer aided approach is presented with ROI based color histogram and SVM2 to find the cancer tumor in WCE image. In this method, the digital WCE image can be preprocessed using filtering and ROI based color histogram depending on the salient region in colon. In common, the salient region can be distinctive because of low redundancy. Hence, the saliency is estimated by ROI based color histogram on the basis of color and structure contrast in given colon image for the further process of clustering and tumor classification in WCE image. The K-means clustering can be employed to cluster the preprocessed digital image to discover the tumor of colon. Subsequently, the features are extracted from the image in terms of contrast, correlation, energy and homogeneity by applying SGLDM method. The SVM2 classifier as input to classify the tumor is normal or malignancy using selected feature vectors. Here, the extracted features can also being combined to enhance the hybrid feature vector for the accurate tumor classification. Experimental results of proposed method can show that this presented technique can executes can tumor detection in colon image accurately reaching almost 95% in evaluation with existing algorithms.

Keywords Colon cancer · Computer aided approach · ROI extraction · Image clustering · Feature extraction · SVM2 classifier

Introduction

Colon cancer can be one kind of cancers that is occurred on the colon walls' inner side of large intestine. In this colon cancer, uncontrollable growth of abnormal cells is produced in colon continuously that can be known as polyp. It also called as colorectal cancer and it is second directing to cancer in industrial western countries and the mainly third diagnosed cancer in world-wide often. Many cancer tumors can be started as polyp in the colon surface in intestine of patient and it can take 10 years approximately to develop into a colon cancer and cancer development is based on the polyp's size. The colon cancer may lead to cause of patient death. If it is detected at early stages, then this colon cancer can be preventable and curable by giving the correct treatment [1–3]. Therefore, we need to find the malignant tumor and to examine molecular modifications in colon at early stage for the treatment of cancer to save the patient life. At present, many screening methods are used to detect the colon cancer tumor such as colonoscopy, upper gastrointestinal endoscopy to analyze and examine the large intestine for diagnosis. Nevertheless, this kind of screening method having many procedures as they need to treat the patient and it can also be painful. In addition, the small intestinal parts are taking surgery for observation. Hence, WCE is used to overcome the above problems. WCE is an invasive process that can

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✉ P. Shanmuga Sundaram
   psece@kiot.ac.in

[1] Department of Electronics and Communication Engineering, Knowledge Institute of Technology, Salem, Tamil Nadu, India

obtain digital images from the gastrointestinal tract of patient straightly. The patient's lower gastrointestinal tract also been viewed by this method. Figure 1 shows the structure of WCE [4, 5].

The WCE is pill shaped device that having visual dome, CMOS image sensor, two batteries, two LEDs and ASIC transmitter. The length of WCE device can be 26 mm and breadth is 11 mm. This type of device can be swallowed by the patient for 12 h. This small WCE device pushed by peristalsis of gastrointestinal tract can be started to operate and record the digital images at 2 frames per second whilst moving onward all along the gastrointestinal tract. 50,000 screen shorts are taken in patient's large intestine part by the WCE device and it is transmitted into wearable receiver wirelessly [6, 7]. Then, the procedure can be ended and videos or the digital images are uploaded to a workplace for additional assessment and physicians need to recognize and classify the abnormalities and gastrointestinal diseases such as ulcers, blood-based abnormalities and tumors or polyps. But, this method has taking more time to analyze the tumor or other disease because of high amount of images that having 50, 000 digital images for each inspection. And some of WCE images are blurred images due to the high ratio of compression. Therefore, we necessary to develop the image quality and computer aided detection method to reduce the time complexity. In this paper, filtering method and color histogram can be exploited to improve the WCE image quality by removing the noises, and enhance the contrast and color of image. The novel method ROI based color histogram with SVM2 is presented to enhance the computer aided approach for the physicians to analyze the colon cancer tumor easily without time complexity and errors [8].

Related works

An algorithm has been enhanced in [9] for automated recognition of polyps in the digital images that are captured by a WCE and a arithmetical performance assessment of this method on a data set containing about18900 frames from 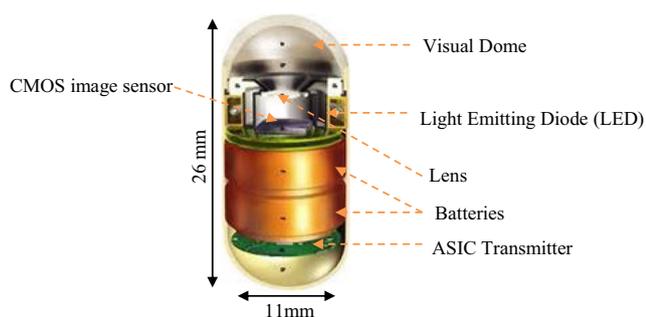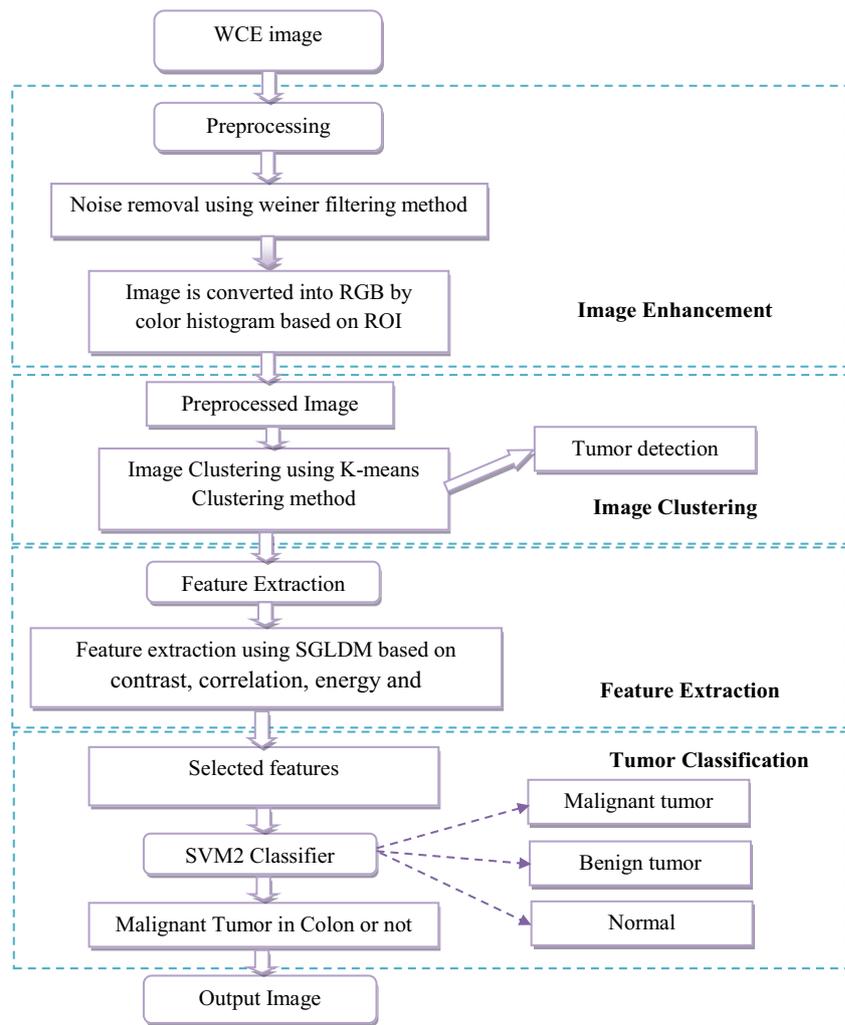the capsule endoscopic video. The methods were classified in [10–15] on the base of the implemented method and primary data set, and complete description of system of colon cancer recognition has been given in all category. Furthermore, comparison of colon cancer detection methods is given in this study. The value of capsule endoscopy has been estimated in [16] in terms of categorization of patients with Crohn's sickness. This kind of examination was tested on 52 patients with known Crohn's disease. Little bowel follow-through discovering have been compared with capsule endoscopic discoverings. A Neighboring Ensemble Predictor (NEP) coupled with CNN has also been introduced to more exactly expect the class label of recognized cell nuclei. The computer-aided-diagnosis and analysis of colon polyp cancer was examined, and CAD method's importance and different techniques has been presented with comparison in [6, 10, 17, 18].

The process of WCE images have been atomized in [19] for the abnormalities detection by introducing a novel texture extraction method for polyp, pathological inflammation in WCE images. A method has been presented in [20] for bleeding region recognition at super-pixel level for WCE digital images. In this method, the pixels were grouped adaptively depending on the location and color throughout super-pixel segmentation. A methodology has been introduced in [21] that generate 3-D surfaced video interpolated WCE frames for diagnosis. As a result, a real digestive tract 3-D representation is practicable during the utilization of tiny WCE devices that available in the market presently. A detection method was presented in [22] for polyp recognition in examinations of video endoscopic WCE has been enhanced by employing boosting-based method and geometric and textural features were combined by the whole recognition chain for polyp description. An approach was introduced in [23] depending on the textural analysis of the various color channels, exploiting the wavelet transform to choose the bands with the most important texture data. Detection technique was proposed in [24–27] to recognize peptic ulcers in the small intestine mechanically. The color transformation has been executed in first into the HSV color space. The log Gabor filters were exploited to discover meaningful regions in digestive system.

Proposed methodology

In this paper, four steps are suggested to detect and classify the colon tumor in WCE digital image with effective computer aided approach to detect the colon cancer at early stage for survival of patient who affected by the colon cancer. The overall process of our proposed method has been established in Fig. 2. In first step, unwanted noises and background parts are removed from the given WCE wiener filtering method is called smoothing process to improve the image quality that can be used to further process such as clustering and classification. After that, the smoothed image can be

Fig. 1 Structure of WCE

Fig. 2 Overall process of
proposed method

WCE image

Preprocessing

Noise removal using weiner filtering method

Image is converted into RGB by
color histogram based on ROI

Image Enhancement

Preprocessed Image

Image Clustering using K-means
Clustering method

Tumor detection

Image Clustering

Feature Extraction

Feature extraction using SGLDM based on
contrast, correlation, energy and

Feature Extraction

Tumor Classification

Selected features

Malignant tumor

SVM2 Classifier

Benign tumor

Malignant Tumor in Colon or not

Normal

Output Image

converted into RGB color by applying color histogram with
ROI. In this image enhancement, salient regions are convert-
ed as RGB color using ROI extraction. In second step, the
K-means clustering algorithm is applied to cluster the WCE
image to detect the tumor in colon. Afterward, the features
are extracted in third step using SGLDM method from the
image depending on the contrast, correlation, energy and
homogeneity in terms of shape, tumor structured and place
of tumor in WCE image. Consequently, the features can be
selected based on the tumor characteristics that containing
cancer tumor and normal tumor uniqueness. These selected
features can improve the performance of SVM2 classifier. In
final step, the selected features are given to the SVM2 clas-
sifier to classify the tumor in colon into benign, malignant or
normal. This proposed system can help to enhance the com-
puter aided approach to detect the cancer tumor with low
time complexity.

This proposed methodology contains following steps to
detect the cancer tumor of colon using WCE image

- Image enhancement using weiner filtering method and
  ROI based color histogram
- WCE image clustering using K-means clustering method
- Feature extraction from WCE image using SGLDM
  method
- Colon Tumor Classification using SVM2 classifier

Image enhancement using weiner filtering method and ROI based color histogram

In this process of image enhancement, firstly, the unnecessary
noises and background parts are removed from the WCE im-
age to give the smoothing for further process. Here, the weiner
filtering method is applied to remove the noise. In this process,
an optimal estimation of given WCE image is constructed by
implementing a minimum mean square error constraint be-
tween estimation and WCE image using weiner filtering
method. Overall mean square error of given image can be

reduced and noises are also be reduced by this filter to give the WCE image quality. Noises and degradation functions are managed by weiner filter. The error between input WCE image $F(a, b)$ and the estimated image $F(p, q)$ can be calculated in degradation model using following Eq. (1).

$$Error(E) = F(a, b) - F(p, q) \tag{1}$$

And the square error can be calculated using following Eq. (2)

$$square\ error = [F(a, b) - F(p, q)]^2 \tag{2}$$

Finally the mean square error is calculated as

$$MSE = E\left\{ [F(a, b) - F(p, q)]^2 \right\} \tag{3}$$

Hence, given input WCE image is smoothed by weiner filtering method.

After that, the color histogram is applied based on the ROI extraction on smoothed image to improve the WCE image quality. In this preprocessing, the ROI can provide the coding in a salient regions of given WCE image to give suggestions for color histogram method. In WCE image, the saliency region can be distinctive due to the low reduncy value. Thus, the ROI extraction is employed with process of color histogram. The color histogram is designed in WCE image depending on the salient area in colon by counting the number of pixels of every color in smoothed image. Saliency region can be estimated by ROI based color histogram depending on the color. The color histogram is calculated as

$$H_{P,Q,R}(p, q, r) = n\Big(P(P = p, Q = q, R = r)\Big) \tag{4}$$

In Eq. (4), the histogram of color H in WCE image generates the three color channels P, Q, R such as Red, Green, Blue (RGB) based on the n number of pixels that are presented in the image. Thus, the number of pixels of every color in WCE image has been counted and it converts the image into RGB color image for further process.

Image clustering using K-Means clustering algorithm

From the WCE image, RGB color space can be clustered using K-means clustering. The better cluster center is discovered by the K-Means algorithm. RGB color WCE image can be clustered into three parts such as nuclei, lumen and polyp to detect the tumor in colon.

Figure 3 shows the K-Means clustering algorithm for WCE image clustering. In this method, the RGB color can be converted into CIELab color planes (L*a*b*). L * represents the Luminosity layer, a* and b* denotes the chromaticity layers. a* containing red-green axis and b* containing the green-blue axis. Tri-stimulus coefficients are calculated by using following Eqs. (5), (6) and (7)
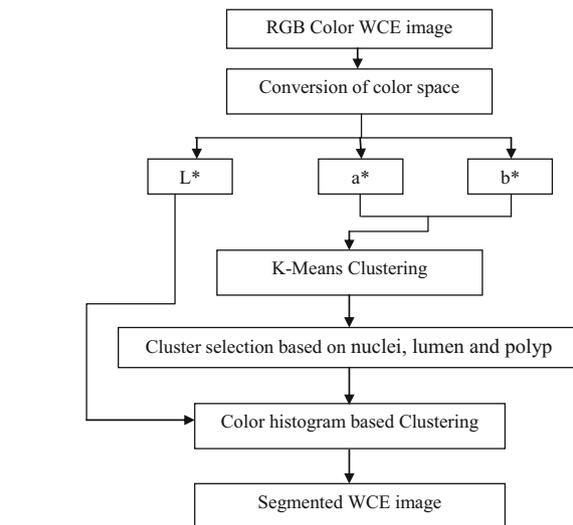

Fig. 3 K-Means clustering process

$$a = 0.3201R + 0.2652G + 0.1582B \tag{5}$$

$$b = 0.2106R + 0.6472G + 0.0624B \tag{6}$$

$$c = 0.0202R + 0.1472G + 0.8473B \tag{7}$$

The CIELab color planes are given by

$$L^* = 115\left(h\left(\frac{b}{b_s} \right) \right) - 15 \tag{8}$$

$$a^* = 500\left(h\left(\frac{a}{a_s} \right) - h\left(\frac{b}{b_s} \right) \right) \tag{9}$$

$$b^* = 300\left(h\left(\frac{b}{b_s} \right) - h\left(\frac{c}{c_s} \right) \right) \tag{10}$$

Where a_s, b_s, and c_s can be the standard stimulus coefficients of color image and a* and b* containing all colors of WCE image.

The cost minimization is calculated as

$$Cost(S) = \sum_{p \in S} \sum_{i \in C_i} ||p - i|| \tag{11}$$

In Eq. (11), S denotes the set of samples, p represents the sample of S, i can be the cluster center C and C_i denotes the set of cluster centers. Here, the K-means clustering method is evaluated depending on the initial cluster center. The centers of clusters have been chosen randomly at every various labels are allocated to similar region of WCE image. Hence, nuclei, lumen and polyp are clustered from the WCE image to detect the tumor in colon.

Feature extraction from WCE image using SGLDM method

After the image clustering, we extract the features from the WCE image using SGLDM (Spatial gray level

dependence matrices) method to enhance the classification accuracy. The better suggestion can be provided to the classifier by this process to classify the image and tumor in WCE image. The dimensionality reduction is also happened to simple the image classification. Before the image and tumor classification, features are extracted based on the shape, structure, surface and place of tumor in given input image. In this process, the clustered image can be converted into gray level image by SGLDM method.

The SGLDM method is applied on WCE image to extract the features of tumor in colon. The co-occurrence matrices are built by SGLDM in given image to distribute the gray levels depending on the region of interest. The second order statistical texture features are calculated from the WCE image for the feature extraction. The features are extracted in image after the estimation by the SGLDM process. The density probability functions of statistical textures features are represented by $f(p, q, d, \theta)$. An element at SGLDM matrix location (p,q) can indicates the probability. θ represents the particular orientation from the vertical, horizontal and two diagonal and the distance is noted as 'd' that containing gray level values of WCE image p and q. The distance d and angle θ can be described to estimation the co-occurrence matrix. In the given sample WCE image, the statistical data will be extracted by co-occurrence matrix that is generated by the SGLDM according to the pixels pairs' sharing. By giving angle θ and distance d, pixels pairs in WCE image is evaluated. The pixel pairs in given image is separated by distance d while executing the feature extraction process. Depending on the gray level values of given WCE image, the pixels' pairs are counted to extract the specified features. Angle θ may be in the values of 0°, 45°, 90° and 135°. The features have been extracted from the WCE image depending on the color, correlation, energy and homogeneity. These four features are calculated as in (12), (13), (14) and (15).

In contrast, the local variations of gray levels between reference pixel and its neighbor are estimated in the WCE image using Eq. (12).

$$contrast = \sum_p \sum_q (p-q)^2 f(p,q) \qquad (12)$$

where, $f(p, q)$ denotes the co-occurrence matrix's elements that can be the likelihood of moving from a pixel with gray level values p to q.

WCE image's local homogeneity can be estimated using following Eq. (13) and lager values have been assigned to differences of gray levels within the pairs of pixel in image.

$$homogenity = \sum_{p,q} \frac{1}{1+(p-q)^2} f(p,q) \qquad (13)$$

Pixel-pair repetitions in WCE image are calculated by Eq. (14)

$$energy = \sum_p \sum_q f((p-q))^2 \qquad (14)$$

The correlation of given input image is calculated using the following Eq. (15)

$$Correlation = \sum_a \sum_b f(a,b) log(f(a,b)) \qquad (15)$$

Hence, features are extracted from the clustered WCE image. Subsequently, the features will be chosen depending on the tumor features to SVM2 Classifier.

Tumor classification using SVM2 classifier

After the feature extraction, the selected features are given to the SVM (SVM1, SVM2) classifier to classify the WCE image and tumor. Initially, SVM1 classifier is utilized to classify the WCE image into normal or abnormal WCE image and SVM2 classifier can be employed to classify the tumor into benign, malignant or normal. SVM classifier is supervised learning algorithm with high classification accuracy by making the good decision plans. In this decision planes, the unequal class memberships are separated. In this method, two steps are used in SVM for the purpose of classification such as training and testing. The WCE image and colon tumor classification has been established in Fig. 4. From the Fig. 4, the selected feature vectors are given to the SVM classifier in which SVM1 and SVM2 classifiers are used. Firstly, the SVM1 is trained and tested using feature vectors on polyp features. If SVM1 classifiers find the polyp or tumor in WCE images, then it classify the image as abnormal and SVM1 classifiers classify the WCM image as normal when it has no polyp or tumor features. The SVM2 classifier is executed when the WCE image is classified as abnormal. Then, the SVM2 classifier is exploited on abnormal WCE image to classify the colon tumor. The SVM2 classifier is trained and tested by the selected tumor features. Hence, the colon tumor is classified by SVM2 into benign, malignant or normal.
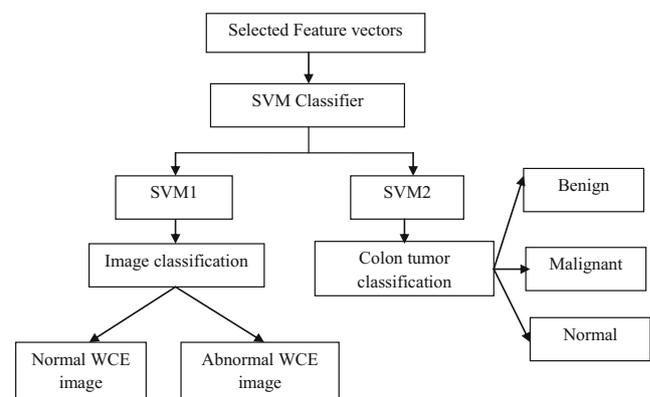
Fig. 4 WCE image and colon tumor classification

Table 1 Performance analysis of proposed and existing methods

Parameters	Proposed method (%)	Binary classifier (%) [1]	Boosting-based olyp classication (%) [8]	Fuzzy Region segmentation (%) [10]
Sensitivity	96.0	81.2	91	75
Specificity	95.4	90.2	95.2	73.3
Accuracy	95.7	85.7	93.1	74.15

Results and discussions

In this section, the performance proposed computer aided approach of colon cancer detection can be estimated and compared with the existing methods in terms of sensitivity, specificity, accuracy, error rate that can be utilized in WCE image and colon tumor classification and it calculated using following Eqs. (16–18)

$$Sensitivity = \frac{TP}{TP + FN} \tag{16}$$

$$Specificity = \frac{TN}{TN + FP} \tag{17}$$

$$Accuracy = \frac{TP + TN}{TP + FN + TN + FP} \tag{18}$$

From the above Eqs. (16–18), TP represents the True Positive, TN is the True Negative, FP denotes the False Positive and FN can be the False Negative. Number of correctly detected and classified colon cancer tumor pixels is defined by the TP and number of incorrectly detected and classified cancer tumor pixels in WCE image is defined by the TN. FP defines the number of incorrectly recognized and classified cancer tumor pixels in WCE image and FN describes the number of incorrectly discovered and classified non-cancer tumor pixels in given image.

The performance comparison of proposed and existing methods has shown in Table 1. From the above table, the proposed method has taken 96 percentage of sensitivity, 95.4
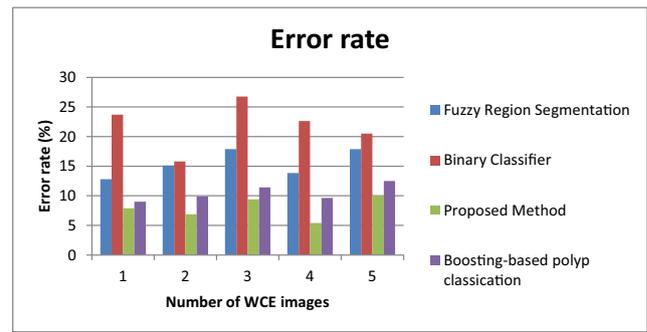

Fig. 6 Error rate of proposed and existing methods

percentage of the specificity and 95.7 percentage of the accuracy than the existing methods binary classifier, boosting-based polyp classification and fuzzy region segmentation. Consequently, our proposed method having high percentage of sensitivity, specificity and accuracy for the colon tumor detection and classification compared to existing methods.

Time complexity

Figure 5 shows the comparison chart of time complexity. The colon tumor classification time is the total time to process the classification of tumor cells in WCE images. The time for finding and categorization of colon tumor has been executed in milliseconds. From the above chart 5, it is analyzed that proposed method ROI based color histogram with SVM2 classifier has taken small amount of time to execute the tumor detection and tumor classification. Hence, proposed method has taken less time to detect and classify the tumor from the WCE images compared to existing methods binary classifier, boosting-based polyp classification and fuzzy region segmentation. Thus, the proposed method has the low time complexity than the existing methods.

Error rate

The proposed and existing computer aided algorithms' error rate is established in Fig. 6 for tumor detection in WCE

Fig. 5 Colon Tumor Classification time
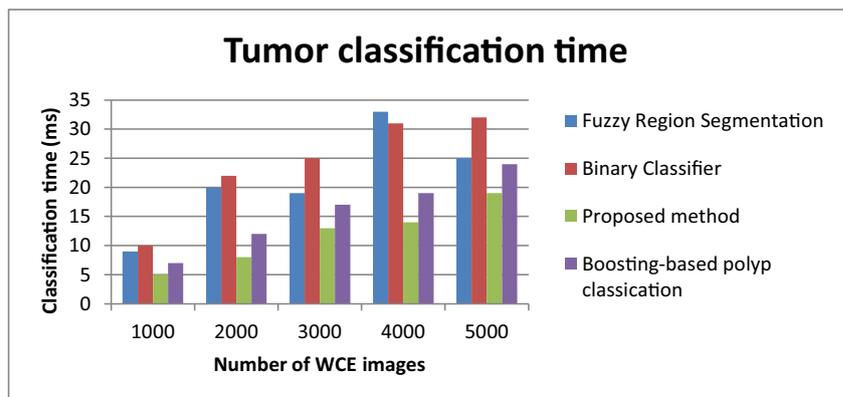
images. An error rate for the colon tumor detection system in WCE images has been evaluated depending on the inaccurately classified tumor cells from the sample WCE images. From the above chart 6, the proposed computer aided approach for colon cancer detection contains low error rate in all WCE images compared with the existing methods binary classifier, boosting-based polyp classification and fuzzy region segmentation. Therefore, proposed methods can detect and classify colon tumor in WCE image efficiently than the present methods with low error rate.

Conclusion

In this paper, a novel computer aided approach has been enhanced to the early detection colon cancer using WCE images. The WCE image has been preprocessed with the assist of weiner filter and color histogram. The ROI was utilized to extract the salient areas from the WCE image for the color histogram process. Image quality has been improved in this process by all noises and errors are filtered using weiner filtering method. Then, the image was clustered in terms, nuclei, lumen and polyp using RGB color based system of color histogram that can be assists to detect the tumor in colon from the WCE image. The features were extracted from the clustered image using the SGLDM method. This SGLDM method used the co-occurrence matrices of pixels to extract the features. After that, the features are chosen from the extracted features. The WCE image was classified into normal or abnormal image by SVM1 based on the selected feature vectors. Finally, tumor has been classified by SVM2 classifier in abnormal WCE image into benign, normal or benign. This proposed approach will be used to enhance the computer aided approach with low time complexity and it is able to detect the colon tumor at early stage for the survival of patient.

Compliance with Ethical Standards

Conflict of Interest   The author's has no conflict of interest in submitting the manuscript to this journal.

Ethical Approval   This article does not contain any studies with human participants performed by any of the authors.

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