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Analysis of dermoscopy images by using ABCD rule for early detection of skin cancer

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ABSTRACT

Melanoma is the most deadly type of skin cancer in humans. Which occurs as a result of a change in the pigment of the skin, which is known as pigment cells. Which produces a pigment known as melanin. Which appear in multiple colors. And asymmetry from one part to another. Its borders are irregular. And grow continuously. This disease can be treated and cured if there is an early diagnosis of the disease. Effective techniques are required for early detection using a Computer-Aided Diagnosis (CAD). In this paper ABCD rules have applied for automatic detecting skin cancer. In order to test the proposed system PH2 standard dataset has used, PH2 contains three types of skin diseases namely Atypical Nevi, Melanoma and Common Nevus. The propose system is divided into two stages: the first stage: pre-processing stage use to enhance the quality of image, the Gaussian filter method is employed to enhance the images and remove unwanted pixels. For extracting the Region of Interest (RoI) from dermoscopy images the contour method has been applied. Furthermore, Morphology method is considered for increasing the quality of skin lesions. The second stage: ABCD (Asymmetry, Border, Color and Diameter) rules have implemented to extract appropriate features. The obtaining features are processed by using Total Dermoscopic Score (TDS) for detection benign and malignant. Standard performance measures namely, Accuracy, Specificity and Sensitivity are used to calculate the results of proposed system. It is observed that the results of proposed system is satisfactory.

1. Introduction

Skin cancer is one of the types of cancers that infect humans and is arising from abnormal cells. It has the ability to spread in the parts of the body if there is no early diagnosis in time [1]. Melanoma study conducted by Cascinelli et al. in 1987 [2] it was of one of the first works that focused on the Computer Aided Diagnosis (CAD) [3,4] by using automatic methods for early detection of skin lesion. The authors explained their interest in analyzing images by focusing on color, shape, and structure. Since the segmentation of the lesion area is done correctly, which aims to separate the lesion area from the rest of the image [5]. This is to ensure that the features in the next steps are extracted correctly. The segmentation of images, has been still an important research area. Green et al. [6] proved in 1994 that the segmentation by using statistical analysis, progresses quickly and efficiently, reaching 83.8%. And in 2007 Mendonça et al. [7], they compared performance in many segmentation algorithms. The results were evaluated with a dermatologist, which was a score of 83.3% and 97.9%. For extracting features from the lesion area correctly, that helps and lead to a correct classification. Their development was slow, making it difficult to implement algorithms that extract the features correctly. Most automatic detection systems rely on ABCD rule. Ganster et al. in 2001 [8] are the first to work with the four features of this method which includes 122 parameters. The skin cancer is divided into three types there are; squamous-cell carcinoma (SCC), basal-cell carcinoma (BCC) and melanoma [9]. The first two types are less common in skin cancer and known as the nonmelanoma skin cancer, Basal cell carcinoma, growth is slow, and may damage the tissues surrounding it. But it does not lead to death and is more present in the nose [10,11]. Squamous-cell skin cancer is present as hard lump with a scaly top with scaly crusts and may form an ulcer [12]. Melanoma is the most aggressive form of skin cancer and leads to spread in the parts of the body and lead to death if there is no diagnosis and treatment in the early stages of its appearance. Common signs of melanoma are asymmetry, border irregularity, multi-color and dermoscopic structure [13], according to the ABCD rule.

2. Related works

(Nayara Moura, et al.,.2018) This work presented, a computational method assists dermatologists in diagnosing skin lesions as malignant or benign. They use 406 dermoscopic images from two public databases.

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Their proposal aims to classify skin lesions using hybrid descriptors obtained by combining the features of shape, texture, color and Convolutional Neural Networks (CNN) before training. These attributes are used as input to Multi Layer Perceptron classifier. The accuracy of their proposal was 92.1% [14].

(Kasmi, Reda, et al.,.2016) In this study, The ABCD rule was used to diagnose malignant melanoma and benign lesions. They were based on pre-processing method to enhance images using a median filter to remove noise such as bubbles and thin hair using Gabor filters. Based on the hair mask, the images are repaired using linear interpolation method. The GAC method is used to segment the lesions. Extracting the features based on the ABCD rule using calculate values in A, B, C and D by using specific weights for the diagnosis of the lesion. Their results in the set of 200 dermoscopy images, where 120 are benign and 80 are melanomas. They have obtained the accuracy of 94% [15].

(Qaisar Abbas, et al.,.2013) In this proposed, a novel melanoma recognition system (MRS) using the ABCD rule to extract the features from lesions. MRS consists of six steps: convert to the CIEL*a*b* color space, preprocessing to enhance the area of interest, the hair removal and black-frame, the segmentation to identify the skin lesion using skin tumor area extraction (STEA) algorithm. After the determining of the lesion, the characteristics are extracted within the lesion area using the ABCD rule. The features selected for good diagnosis between the malignant and benign are using SFFS method (Sequential Forward Selection). The classification of this study they use SVM technique. The proposed system for testing 120 dermoscopic images achieved the accuracy 80% [16].

(Roberta B. Oliveira, et al.,2016) This paper presented anisotropic diffusion filter to enhance the images pre-processing, in their proposal, they introduced chan-vese's method to separate the lesion area from the image, then they used morphological method to enhance the accuracy in the segmented region. Then The feature extraction by new computational method to extract the features from the interest of region is based on border, color and texture. They used SVM technique for classifying image [17].

(M. Monisha, et al.,.2018) In their study they used several methods to extract the features and then all the features extracted from each method are combined to diagnose the skin lesion whether it is malignant or benign. The preprocessing method uses a medium filter to enhance the image. The segmentation method uses the threshold method to separate the lesion area from the rest of the image. They used several methods such as ABCD rule, LBP and GLCM to extract features. All features are combined and compared with features stored in a database to diagnose the lesions. Classification used by ANN-BPN techniques aims to classify input images whether they are benign or malignant depending on the collected features in previous step. Accuracy in their proposal has reached 95% and sensitivity 90% [18].

(Pablo G. Cavalcanti, et al.,.2013) Their paper presents a new method using a standard camera to calculate features of the classification based on estimation of eumelanin and pheomelanin containing the lesion area. These features are used in two stages of classification, first stage begin with discrimination based on ABCD rule for extracting features (Asymmetry, border, color and diameter). The second stage is based on different features of melanin variation to enhance accuracy and sensitivity. The proposal is relied on the images at different stages of lesions development. The study combined between features obtained from ABCD rule and melanin to classify correctly, which produce high accuracy close to 100% [19].

(Catarina Barata, et al.,.2014) In this study, the proposed algorithm for the detection of colors in lesions dermoscopy images is using Gaussian mixtures method. The dermatologists when diagnosing dermoscopy images by using key in ABCD rule, they claimed that the colors are more common in melanomas than in benign lesions such as black, blue, gray, white, and red. And in Computer Aided Diagnosis (CAD) systems is based on the discovery of blue-whitish veil to classify the lesion as malignant or benign. The result achieved when integrating the information of the HSV and La*b* color spaces is 78.8% [20].

(J. Jaworek-Korjakowska, et al.,.2014) In this study, a method was introduced for the detection and classification of skin lesions at irregular boundaries using the ABCD rule. Preprocessing for enhancing images to remove hair and bubbles visible in the images uses the Gaussian filter method. Segmentation is based on seeded region-growing algorithm for separating the lesion area from the healthy skin. Border irregularity detection is implemented in four steps. Firstly, calculating a bounding box in the segmented lesion area. Secondly, finding the border pixels associated with the center of the mass with the vertices. Next Step Finds the distance between the edges of the image and the border. Result get a function with reflection of the irregularities of border. To assess the lesion area is by dividing it into eight similar parts and shape, abrupt cut-off in each part represents score of 1. If the lesion is irregular, max border score is 8. If the lesion is regular, it min border score of 0. As in the benign lesion is very low, the score is 0 and in melanomas is between 4 and 8 [21].

(Nidhal K. EL Abbadi, et al.,.2017) In this study. Diagnosis of skin lesions is based on ABCD rule. Pre-processing for removal of hair, bubbles and different effect of illumination is using median filter. Segmentation is based on several steps: Firstly, median filter for removing noise and hair. Secondly, Markov and Laplace filter is used to edges detection. Thirdly, convert the image color to YUV color space. Fourth, finding the value of the threshold based on Otsu's thresholding to separate the lesion area from the healthy skin. Fifthly, morphology process to enhance the segmented image and fill holes and remove unwanted objects. Extracting features is used by means of ABCD rule. Asymmetry, the lesion divided into two parts vertical and horizontal axes $A = 0$ when the lesion is symmetry in tow axes, $A = 1$ when the lesion is symmetry in one axis, $A = 2$ when the lesion is asymmetry in tow axes. The irregular boundary B is between zero and eight. Colors are of six various types used of to distinguish between the lesion of malignant or benign These colors are red, light-brown, dark-brown, dark-blue, black and white. Diameter when the diameter of the lesion is greater than 6 mm and grows continuously, it is malignant, diameter less than 6 mm is a benign lesion [22].

(P G Scholar, et al.,.2017) In this paper, presented a more accurate way for the recognition of the skin lesion using ABCD rule (asymmetry (A), irregular borders (B), notched edges, and variations of colors(c)). Work used a PH2 dermoscopy images dataset. Preprocessing method is used to enhance images from impurities. Segmentation methods to identify area of the lesion uses a multi-level threshold method. Non-invasive Real-Time Automated Skin Lesion Analysis System melanoma tumors are asymmetrical, irregular borders, and multiple color. This system consists of two phases: Firstly, real-time alert to help prevent skin burn caused by the sunlight, secondly, the model of the analysis of the lesion automatically, which includes the enhancement of image, segmentation, extraction of features and classification [23].

In the system proposed by Chatterjee, S. et al. (2020), dermoscopy image diagnosis system using an ABCD rule through the spatial features of the lesion region. They used a median filter to remove noise due to illuminating, and also applied a morphological bottom-hat filter to remove hair. The lesion area was segmented and separated from healthy skin by using lesion segmentation module (LSM). Their system reached their system diagnostic accuracy of 97.86%, sensitivity of 97.69%, and specificity of 97.97% [24].

Singh, L., et al. (2020), a PH2 dataset diagnostic system. They applied a thresholding method to determine the area of interest, then extract the features using the ABCD rule. The performance of the proposed system was evaluated using the SVM algorithm, and the accuracy of the system reached 92.5% [25].

Mabrouk, M. S., et al. (2020), dermoscopy images diagnostic system by SVM, ANN and TDS classifiers. Images were resized and contrast adjusted in the pre-processing step. The ABCD rule was applied to extract

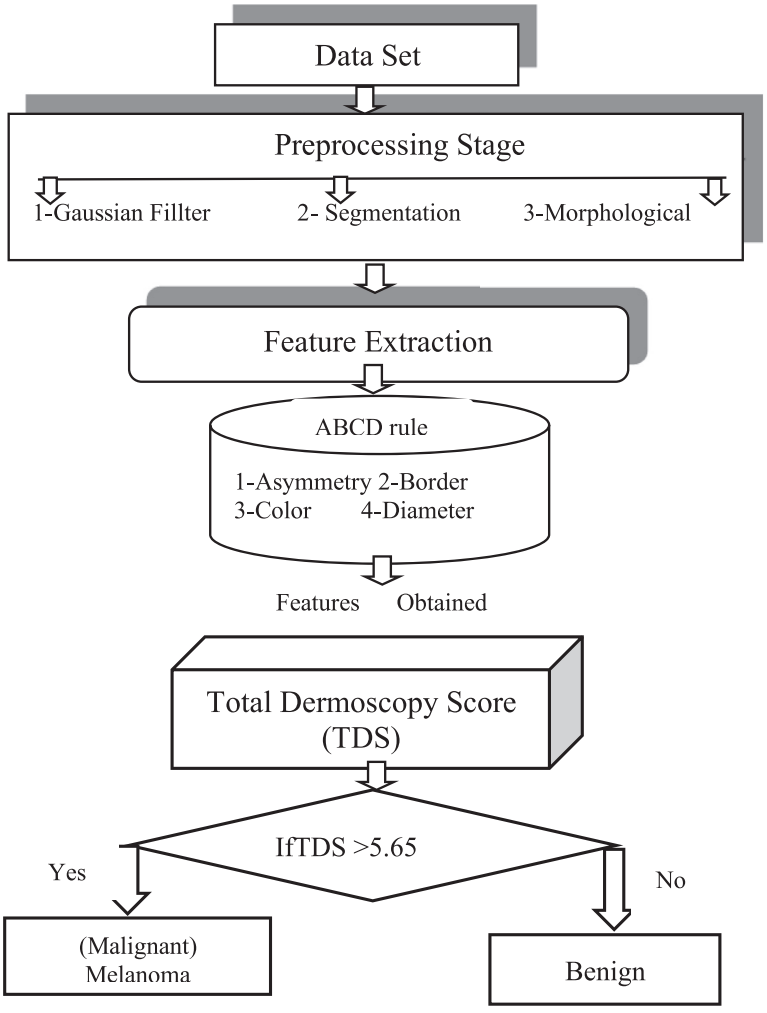

Fig. 1. Flow diagram of the proposed system.

the asymmetry, border regularity, color and D parameters from each image. Their proposed system achieved an accuracy of 98.75%, 95% and 98.1% for the SVM, ANN and TDS classifiers respectively [26].

3. Methodology

Image processing is a technique used to extract information from images. Fig. 1 shows the analysis of the skin lesion using the ABCD rule in proposed system. The first stage is pre-processing which includes three steps. The first one is the Gaussian filter method which is used to remove certain features such as noise, hair and air bubbles that negatively affect the information in the images. The second one is the segmentation method which is to determine the area of the skin lesion by separating the skin lesion from the healthy skin. The third step is the morphological method which is to enhance the digital image obtained from the segmentation method and production of enhanced digital image. The second stage is to extract the features from the lesion area, using the ABCD rule and the diagnosis of the lesion.

3.1. Data set

Increased skin cancer deaths have encouraged many research centers to create databases. A PH2 database was created to assist researchers. It consists of 200 images divided into three types of diseases: 80 Benign, 80 Atypical Nevi and 40 Melanomas. PH2 images have a resolution of 768 * 560 pixels in RGB color space. The PH2 database was created through research collaboration between the Dermatology service of Hospital Pedro Hispano in Matosinhos, Portugal and the Universidade do Porto, ecnico Lisboa. All images in dermoscopy images were obtained in the same conditions and contain high resolution of 768×560 pixels in RGB color system. The PH2 contains 200 dermoscopic images, divided to three types. The first type is 40 Melanomas. The second type is 80 Common Nevi. The third type is 80 Atypical Nevi. All images are either skin type II or III according to the classification of skin types of Fitzpatrick. Therefore, the colors of the skin vary in the database. The images were carefully selected, taking into consideration their accuracy, quality and dermoscopic features. All images in PH2 were evaluated by dermatologists according to the following criteria:

* Determination of the lesion area using manual segmentation.
* Histological and Clinical diagnosis (when available).
* Dermoscopic parameters (Asymmetry; Border; Colors; Internal structure; Pigment network).

The image acquired from dermatoscopy is called dermoscopy image.

3.2. Pre-processing

The artifacts and noise as air bubbles and hair are present in the images. So we need to remove all unwanted pixels and enhance the images. The pre-processing methods are used to ensure the segmentation of the lesion area and extract the features correctly which leads to high accuracy in diagnosis. In proposed system, the pre-processing methods included three steps. Gaussian filter method is used to smooth the images. The segmentation method is used to determine the area of interest

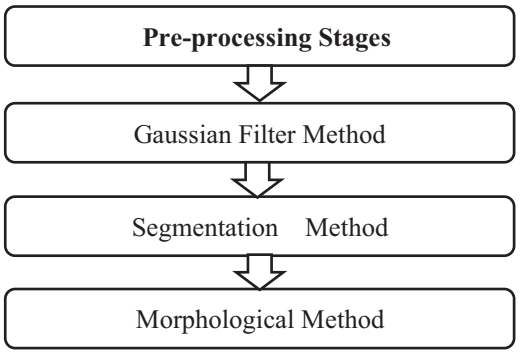

Fig. 2. flowchart for pre- processing stages.

by the separation of the skin lesion from the rest of the image. And the morphological method is used to enhance the area of the lesion after the process of segmentation, which helps to extract the features clearly. as shown in Fig. 2.

3.2.1. Gaussian filter method

Artefacts and noise are typical noise caused by natural factors, such as hair, air bubbles or external factors such as illumination, shadows and different capture devices. This noise is present in medical images. Gaussian filter is applied to remove unwanted pixels from images. In this method, unwanted pixels are replaced by calculating the average value of the adjacent or surrounding pixels of the unwanted pixels, which depend on the Gaussian distribution. The Gaussian filter belongs to a linear filter. It is used to reduce or eliminate noise and enhance images. Smoothing images by the use of the Gaussian method produces a blurry image. The degree of smoothing is determined by the standard deviation in Gaussian. In proposed system, we used PH2 dermoscopy images for 200 images. Due to the large image size that contains high resolution of 768 * 560 pixels in RGB color system. We worked on resizing the images to a resolution of 52 * 52 pixels for fast computation, with preserving the important areas. We used the Gaussian filter with the new image size. The Gaussian filter is used to remove unwanted pixels such as hair and air bubbles by replacing unwanted pixels by averaging the pixels of the adjacent pixels.

Fig. 3 shows the process for enhancement images by the use of Gaussian filter method. We choose three images of the benign lesions and three of the malignant. In Eq. (1) known as the Gaussian equation to enhancing images by remove noise and unwanted artefacts.

$$h(x,y) = \frac{1}{2\pi\sigma^2} e \frac{x^2 - y^2}{2\sigma^2} \quad (1)$$

Where x is the distance from the origin in the horizontal axis, y is the distance from the origin in the vertical axis, and σ is the standard deviation of the Gaussian distribution.

3.3. Segmentation method

Segmentation is one of the basic parts of image processing. It is used for the purpose of separating part of the image to be processed. Segmentation is essential in image analysis because it facilitates the methods processing of the next steps. In the analysis of medical images, the segmentation is necessary. If segmentation is effective, the next steps in image processing are more accurate and efficient. Medical image analysis requires segmentation of images in the areas of interest. With the correct segmentation process, the correct results are obtained from the interest pixels. There are many methods and algorithms for image segmentation. In proposed system we used the Active Contour Technique (ACT) for images segmentation, which is a good method to analyze medical images. This technique determines the lesion of the skin by separating the skin lesion from the healthy skin. The efficient in the process of segmentation is important and helps to extract features correctly.

Fig. 4 shows the process for Images segmentation by the use of active contour method, Separation of the skin lesion area from the healthy skin.

3.4. Morphological method

Morphology is one of the processes of images processing in the pre-processing stages, which processes images based on shapes. The number of pixels removed or added from images depends on the shape and size of the structure element. Morphological operators often deal with a digital image and a structuring element as input parameters and process them by using some operators as (union, intersection, complement and inclusion). Then it returns an enhanced digital image. The operator manipulates the objects in the input image based on attribute of its shape. When performing the segmentation method, it produces a digital image that contains very small holes. These holes need to be enhanced to get proper features. In proposed system, we used the morphology method to remove the very small objects from the entered digital images, and to obtain enhanced digital images, with preserving the size and shape of object in dermoscopy images. Fig. 5 shows, before and after the morphological method of enhancing digital images after segmenting the lesion. It returns an enhanced digital image.

3.5. Feature extraction

Feature extraction is the procedure used for extracting meaningful features from dermoscopy images. The aim of this feature extraction through Computer-Aided Diagnosis (CAD) systems is to extract various features from a given dermoscopy images which can discriminate between benign or malignant. The methodology for extracting the feature in many early detection systems for the skin lesion has been based on ABCD rule of dermoscopy images because of its effectiveness, efficiency and simplicity of performance and implementation. The effectiveness of ABCD rule in extracting important features of the malignant lesion such as asymmetry, border irregularity, color and diameter can be measured by means of using computer algorithms. This section explains some of the features of melanoma recognition. After taking a score to each of the four criteria called (A_{score}, B_{score}, C_{score} and D_{score}), the Total Dermoscopy Score (TDS) is calculated as the equation:

$$TDS = [(A_{score} * 1.3) + (B_{score} * 0.1) + (C_{score} * 0.5) + (D_{score} * 0.5)]$$

If TDS< 5.65 then the lesion is Benign.
If TDS>= 5.65 then the lesion is Melanoma.

3.5.1. Asymmetry

To extract the features based on of asymmetry, the lesion area is divided into two sub-regions (R_1, R_2) on the basis of the longest diagonal axis d, defined by the Euclidean distance [27], as by formula 2.

$$D_{(P,q)} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (2)$$

Where (x_1, y_1) and (x_2, y_2) the coordinates of the boundary pixels represent p and q along the lesion. All lesion *1*border pixels are analyzed, to find which pairs have the largest distance $D_{(p,q)}$. The similarities between the two sub-regions of the lesion are then analyzed by computing the perpendicular lines in the boundary pixel marriage having a distance greater than d. Perpendicular lines differ from image to image according to the size of the diagonal. Therefore, the formula $N = T / P$ to define the perpendicular lines for all the images to be classified, where T represents the total vertical lines along the diagonal axis, and P is a constant number of the expected perpendicular lines. Where $D_{(p,q)}$ is computed for each perpendicular of both sub-regions (R_1, R_2) where p represents the diagonal pixel and q represents the edge pixels. The determination of whether a lesion is symmetric or asymmetric is determined according to the ratio between the semi-lines.

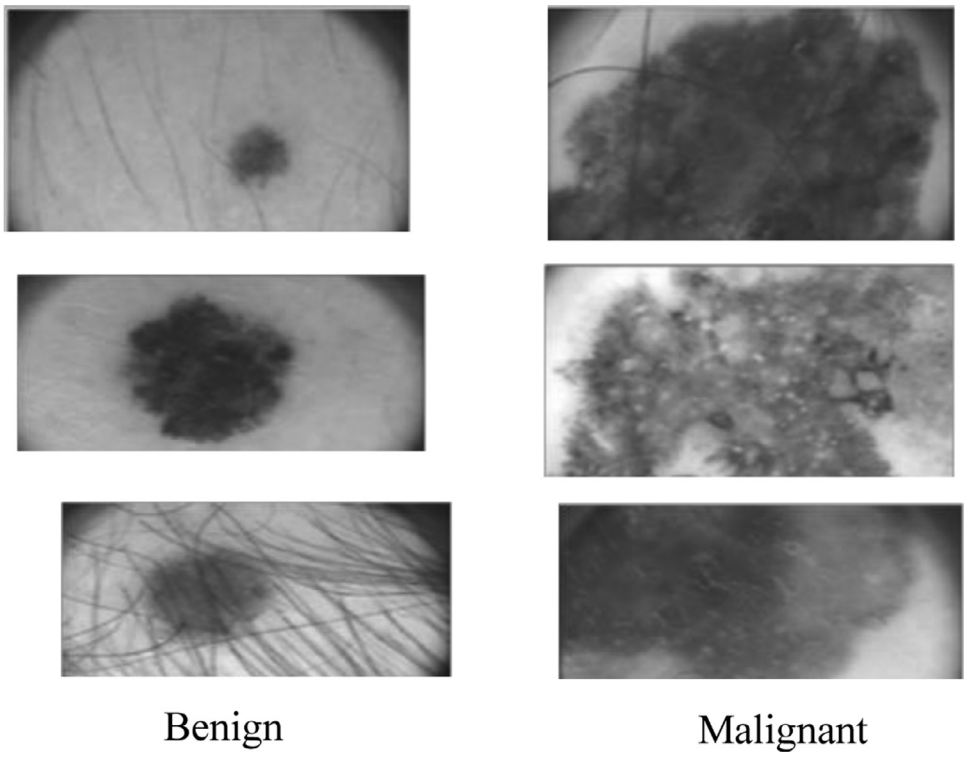

Fig. 3. Images after gaussian filter.

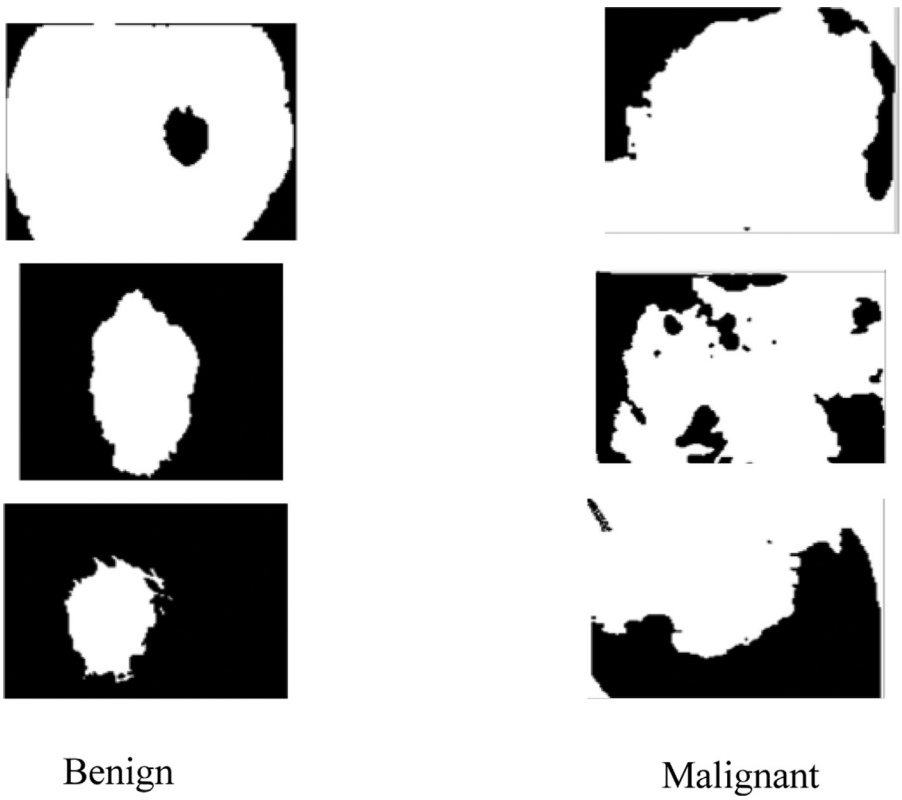

Fig. 4. Segmentation.

3.5.2. Border

The borders are represented by the edge pixels of the lesion, obtained as a result of segmentation of the lesion. The lesion area is divided into eight equal parts, and the portions with an abrupt cut are calculated. The degree of border ranges from 0 to 8. The regular part gives the value of zero and the irregular part gives the value one. The degree of melanoma varies between 3 and 8. Vectors product and inflexion point descriptors are used to extract the number of peaks, valleys, and straight lines at lesion edges [28]. Small irregular boundaries are measured by the inflexion point descriptor. Whereas clear irregular boundaries are measured by vector product descriptor. Inflexion Point Descriptor work to analyze pixel boundaries to identify which pixels exhibit a change

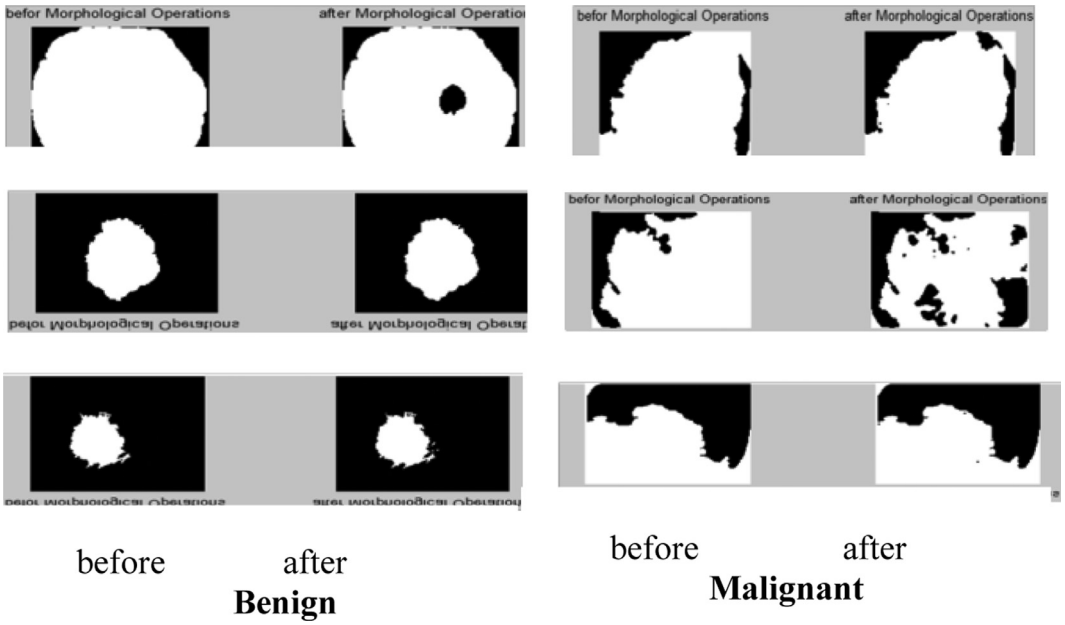

Fig. 5. Before and after morphology.

Table 1
The accuracy results obtained from the proposed method.

	Classified as Benign	Classified as Melanoma	Specificity	Sensitivity	Accuracy
Benign (160)	TN = 145	FN = 15	89.50%	60.50%	84%
Melanoma(40)	FP = 17	TP = 23			

in direction. On the other hand, the vector product descriptor analyzes the edge pixels to determine the highly irregular peaks and valleys. The vector product is calculated as with Formula 3.

$$V_i = (x_2 - x_1)(y_3 - y_1)(y_2 - y_1)(x_3 - x_1) \quad (3)$$

(x_1, y_1), (x_2, y_2) and (x_3, y_3) represent whether the segment belongs to peaks, valleys, or straight lines. When $V_i > 0$ the segment is a peak, when $V_i < 0$ the segment is a valley, when $V_i = 0$ the segment is a straight line.

Six of the features are extracted from the borders, as follows:

- Extraction of three features from peaks, valleys, and straight lines according to small irregular borders by the inflexion point descriptor.
- Extraction of three features from peaks, valleys and straight lines according to highly irregular borders by the vector product descriptor.

3.5.3. Colours

color is considered one of the most important features that are used to diagnose skin diseases [29]. The colours in the lesion area are represented by six colours: white, red, black, light brown, dark brown, and blue-gray. A point is assigned to each color if found in the lesion area and then it is summed and multiplied by a weight factor 0.5 as equation: [(white + red + black + light brown + dark brown + blue-gray) * 0.5]. The maximum score is 3 when the lesion contains six colors. Melanoma disease includes at least three colors. Statistical measures are applied to represent the colors in the area of interest. The values, contrast, standard deviation, and mean for each channel in the RGB color system were extracted to extract nine features for each lesion. These features allow the lesions to be diagnosed correctly.

3.5.4. Diameter

Diameter is one of the features of identifying and diagnosing a skin lesion. In ABCD rule, the diameter is one of the features that takes the weight 0.5 as (0.5 * diameter). If the diameter is greater than 6 mm, it is malignant. If its diameter is less than 6 mm, it is benign. Formula 4 for calculating the lesion diameter.

$$D = \sqrt{\frac{4LA}{\pi}} \quad (4)$$

4. Results

Performance testing in the proposed diagnostic method. The proposed system tested all images in the PH^2 database. 200 images divided into 160 Benign images and 40 Melanomas images. After the morphological process and calculated the TDS for each image, obtained from the ABCD rule. Images diagnosis was in accordance with the standard In proposed system TDS= 5.65. Due to the high resolution of the images, the accuracy of the diagnosis reached 84%. We calculated specificity, sensitivity, and accuracy according to Eqs. (5, 6, 7) respectively. The results are shown in Table 1.

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} * 100\% \quad (5)$$

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} * 100\% \quad (6)$$

$$\text{Accuracy} = \frac{\text{TN} + \text{TP}}{\text{TN} + \text{TP} + \text{FN} + \text{FP}} * 100\% \quad (7)$$

TN number of benign images that have been correctly diagnosed. TP number of malignant images that have been correctly diagnosed. FN number of malignant images that have been diagnosed as benign. FP number of benign images that have been diagnosed as malignant. Where (TP) True Positive, (TN) True Negative, (FP) False Positive, (FN) False Negative.

Conclusion

In proposed system, we used all the images in the PH^2 database, divided into 160 benign images and 40 malignant images. Our goal is

to detect early lesions by using the ABCD rule to avoid and prevent skin cancer. Proposed system was divided into two stages: the first pre-processing stage use to enhance the quality of image, it is necessary for accurate diagnosis the Gaussian filter method is employed to enhance the images and remove unwanted pixels. For identifying the Region of Interest (RoI) from dermosopy images, and separate the skin lesion from the healthy skin, the contour method has been applied. Furthermore, Morphology method is considered to increase quality in the region of interest (skin lesions). Second stage: Extracting the features by using ABCD rule technique. It is based on four basic features in each image, asymmetry, irregular border, color and diameter. Although the proposed system was applied to all images in the PH2 database without selecting some images. The result in the proposed system is 89.5%, 60.5%, 84% with respect to Specificity, Sensitivity and Accuracy respectively. In the future we will enhance accuracy and apply the proposed system to another database.

The process of extracting the comprehensive features of a classification has practical limitations. Nevertheless, the results of our work to detect skin lesions from the dermoscopy images showed an outperformance over the classification performance of experienced dermatologists. Moreover, applying the ABCD rule may not be able to detect melanoma of homogeneous color and regular shape. These limitations are challenges that must be explored, and future work continues to find more effective advantages.

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