



# Detection of Skin Cancer Using SVM, Random Forest and kNN Classifiers

A. Murugan<sup>1</sup> · S.Anu H. Nair<sup>2</sup> · K. P. Sanal Kumar<sup>3</sup>

Received: 6 February 2019 / Accepted: 25 June 2019 / Published online: 4 July 2019  
© Springer Science+Business Media, LLC, part of Springer Nature 2019

## Abstract

Most common and deadly type of cancer is Skin cancer. The destructive kind of cancers in skin is Melanoma as well as it can be identified at the initial stage and can be cured completely. For the diagnosis of melanoma, the identification of the melanocytes in the area of epidermis is an essential stage. In this paper the watershed segmentation method is implemented for segmentation. The extracted segments are subjected to feature extraction. The features extracted are shape, ABCD rule and GLCM. The extracted features are then used for classification. The classifiers are kNN (k Nearest Neighbor), Random Forest and SVM (Support Vector Machine). Among different classifiers, the SVM classifier provided better results for the skin lesions classification.

**Keywords** Melanoma · Segmentation · Classification · ABCD rule · Epidermis · GLCM

## Introduction

Tumors in Skin happen because of changes in metabolism of human body. Tumors on Skin may be gentle or deadly. Tumors that are lethal cause skin cancer. The major cause of cancer formation in skin is excess in exposure to ultraviolet rays occurs from sun. The more frequent types of tumors in skin are Basal carcinoma, squamous carcinoma and melanoma. In recent days, frequently appeared deadly type of skin tumor is Melanoma [1].

Very frequent type of tumors is caused in Skin. Generally it has two various tumor cells in skin is malignant melanoma,

this type is occurred at least rate and it is lethal; and non-melanoma skin cancer, this type is frequent and it is not deadly kind of tumor cells. Malignant melanoma can be sometimes indicated itself as tumor cells of skin. It is the kind of tumor cells on skin that is least common and lethal type of tumor cells of skin. This type of cancer in skin is related with 75% of deaths in United States [2]. A mole (nevus) is a benign tumor cell of skin that grows from melanocytes that are identified in epidermis layer of skin. The infected cells on skin will develop a brown pigment called melanin. Melanin provides the skin its tan or brown color. Melanomas can occur in any human body part that comprises melanocytes. Illustration study of a lesion of melanocytic is segmentation of every point in the image as part of the lesion. A lesion on skin is a part of the epidermic layer that has an abnormal development or appearance compared to skin around it. Dermatoscope is a device used to obtain the lesion on skin images. An image acquired from dermatoscope is called dermoscopic images. If melanoma is identified previously then nearly at preventable phase or else death occurs.

Tumor of Skin can be healed at higher rates with easy and cost effective remedies. For the advantage of human compete, there is a necessitate for identification of tumor on skin at an initial phase and many research authors are previously analyzing in that way by the method of implements and program enhancement by various methods. In this concern, we are assumed to utilize images of cancer infected part of skin for person being treated commonly. In detection of melanoma, the

---

This article is part of the Topical Collection on *Image & Signal Processing*

---

✉ S.Anu H. Nair  
anu\_jul@yahoo.co.in

A. Murugan  
progmurugan@gmail.com

K. P. Sanal Kumar  
sanalprabha@yahoo.co.in

- <sup>1</sup> Department of Computer and Information Sciences, Annamalai University, Chidambaram, India
- <sup>2</sup> Department of CSE, Annamalai University, Chidambaram, India
- <sup>3</sup> Department of Computer Science, R. V. Govt. Arts College, Chengalpattu, India

segmentation and recognition of the melanocytes in the epidermal layer is an essential stage previous to the analysis is finished. If the melanocytes are identified appropriately, structural and nuclear characteristics could be utilized to evaluate or conclude the disease of the skin tissue [3].

In occurrence lesions on skin, segmentation amounts for identifying the boundary that isolates the area of lesion from the skin in neighboring. When the injured part (lesion) is identified, characteristics relating the asymmetry, boundary, color, and architectures available in the lesion can be figured and utilized to instruct arithmetical techniques to recognize the analysis [4]. Consequently, acquiring a precise segmentation of the lesion is significant, particularly to calculate shape and border characteristics. To indicate the issues, a quantity of methods of dermoscopy image classification techniques has been evolved. These techniques can be generally categorized as follows: Random forest, Support Vector machine (SVM).

## Literature survey

The author handles preprocessing, Segmentation and Classification in analysis images of the skin. The advanced technique utilizes CLAHE algorithm for the preprocessing of image subsequence by bilateral filtering. The primary segmentation is attained between Fuzzy C-Means algorithm and a limited area recursive algorithm is executed for the concluding segmentation outcome. Elliptical descriptor is utilized to attain area ellipticity and limited model features to differentiate the melanocytes from the applicant nucleus area [3].

In D.C. Li, C.W. Liu, et al. (2011) [5] a three-step algorithm was suggested. Initially non-linear transformation techniques on basis of fuzzy logic to enlarge classification associated data from the new data quality principles for a little data set. Next, on basis of the novel distorted data set, requests principal component analysis (PCA) to remove the best separation of characteristics. Lastly, researchers utilized the distorted data with these most favorable characteristics as the input data for a learning tool, a support vector machine. The maximum description accuracy of the technique was 96.35% on WBCDD.

Techniques of image segmentation have been evolved on basis of numerous methods to help the analysis of lesions on skin from images (Oliveira et al., 2016) [6]. From these, algorithms on basis of threshold have been extensively used, mostly due to their ease. Thus, thresholding techniques, such as the Otsu (Schaefer, 2013) [7], type-2 fuzzy logic (Yüksel & Borlu, 2009) [8] and the Renyi entropy technique (Beuren et al., 2012) [9], intend to create the threshold rates that split the regions of interest (ROIs) in the input images. Though, these methods might disclose various difficulties; for example the lesions that are segmented influence to be slighter than their actual dimension, and the segmentation method can direct to extremely asymmetrical lesion boundaries.

Barata [10] presented substitute method for melanoma recognition through dermoscopy images, on basis of exterior appearance and shade of color characteristic extraction. Texture and color were contrasted in execution in their study, with the latter verifying further efficient in separation. It must be recognized that the technique is however acquired active consequences in terms of classification precision. The disadvantages of these schemes were the incapability to control on a real-time analysis application or develop any image captivating operations obtainable.

Sadeghi et al. [11] proposed a graph-based technique to categorize and visualize pigment system. They authenticate the technique by calculating its capability to organize and picture the actual dermoscopic images. The precision of the scheme was 92.6% in dividing images to two classes of absent and present.

Glaister et al. [12] projected a novel multistep clarification modeling technique to proper clarification difference in comprehensive images. This technique initially resolves a non statistical technique of the elucidation by utilizing a Monte Carlo sampling technique. Then, a statistical polynomial plane model is utilized to resolve the concluding elucidation evaluation. Lastly, the brightness-rectified image is acquired by utilizing the observance factor calculated since the last predictable elucidation.

ANN Classifier is simulated in MATLAB software for tumor on skin recognition. Initial step in the tumor on skin recognition scheme is the input image. Dermoscopic image in digital system is known as input to the structure. Dermoscopic image in digital scheme is known as input to the scheme. Then step is the noise elimination. The image comprises hairs and other noises. These noises create inaccuracy in classification. The noises are neglected by filtering. Filtering technique executed at this point is the Median Filtering [13].

This paper [14] proposes an easy so far efficient and incorporated computer vision algorithm utilized for identifying and analyzing the initial step of melanoma. The structure is developed on basis of three stages in incorporated varied characteristic technique: segmentation, filtering and localization steps. In the initial stage, user can choose numerous color spaces and appeal learning and non-learning techniques to divide the entity. In the filtering stage, morphological filter has been correlated for image noise elimination. In the localization stage, associated constituent classifying and K-means method are used for classification of materials. Kind of tumor melanoma is driven on basis of a score designed from ABCD features. Research has been regulated effectively by tumor images of skin are obtained from internet. This consequence justified that the improved structure can be utilized for sustaining the premature recognition of tumor. In common, this study can provide to the computer science knowledge particularly in domain of computer vision.

In the projected technique [15], an advanced clustering technique has been determined which efficiently separates borders of lesion by graph of spectral dividing technique in a suitable color space, regarding particular distinctiveness of dermoscopy images. The projected segmentation technique has been useful to 170 dermoscopic images and estimated through two metrics, through the segmentation results contributed by a qualified dermatologist as the ground certainty The simulation outcomes of this methods show that, complex contours are differentiated properly as demanding characteristics of lesions in skin such as feature alterations, weak or false contours, and irregularity in color and figure are managed as may be predictable when contrasted to four stage of the ability techniques.

### Proposed system

Initially an image is transmitted to the system, the image will be preprocessed using median filtering method. The preprocessed image will be segmented using watershed algorithm. Then, the segmented images are subjected to feature extraction by using ABCD rule, GLCM feature method and shape feature. Lastly classification techniques are used; there are three types of classification used to find the optimal results. Figure 1 depicts the proposed architecture of our research work.

### Preprocessing

In primary stage pre-processing is made using median filter. Median filter is used to get rid of unnecessary

hair, bubbles along with noise from the images. The skin cancer image typically comprises fine hair, noise and bubbles. These are not the cancer factor so these are removing using median filter. Median filter are utilized to conserve the amplitude and location of edges. Median filter minimizes the variance of the intensities in the image that means median filter smoothers the image by utilizing the median of the neighborhood.

### Median filter

The median channel is usually utilized to decrease disorder in an image, parallel to the mean channel. For two descriptions, median channel can be distinct as in equation

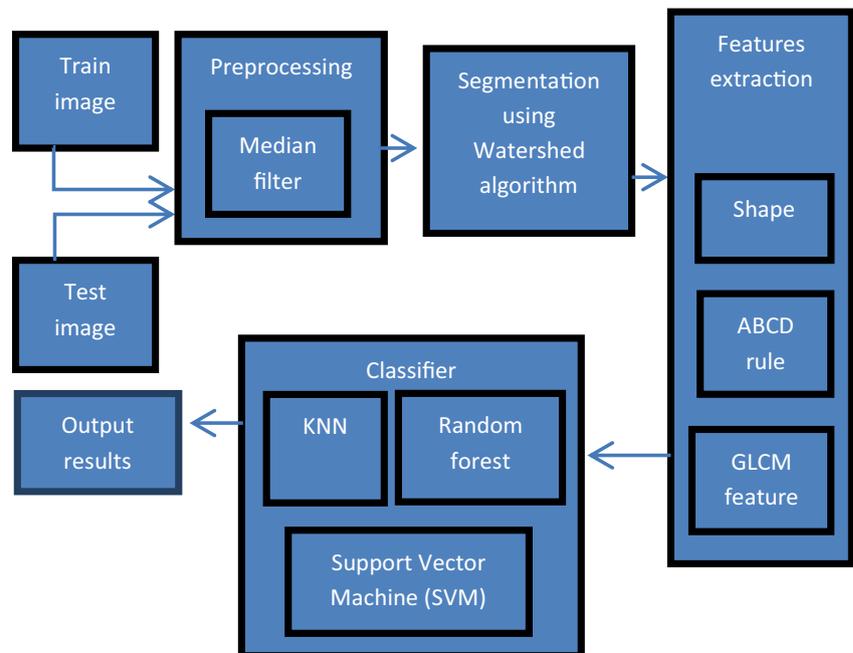
$$median [S(x) + A(x)] \neq median S(x) + median A(x) \quad (1)$$

S(x) and A(x) are the operations of two images. The particular channels even the statistics as possessing the minute and pointed details. The median is only the center significance of all the standards of the pixels in the surroundings. Median filtering is extremely feasible at neglecting different varieties of commotion.

### Segmentation

The segmentation can be made for the preprocessed image. The preprocessed image can be fed as an input to the segmentation stage. The watershed segmentation is used to evaluate the ridges and the last result is visualized.

Fig. 1 Proposed architecture



### Watershed segmentation

The watershed segmentation is an image segmentation technique on basis of the hypothesis of arithmetical system. The watershed technique uses a topographical demonstration on basis of intensity in which the luminous pixels characterize elevated distance or the ‘hills’ with the unilluminated pixels correlate to the ‘valleys,’ which permits for the verification of the passage that a falling raindrop would track. Watershed edges are the partition edges of ‘provinces of attraction’ of water drops (or the limitations of catchment basins). The flooding alteration of the watershed technique is equivalent to captivation of the assistance in a lake flooded from minimum holes. This modification is further capable than the unique falling raindrop technique for various applications.

The watershed algorithm uses topographical depiction on basis of intensity, in which the luminous pixels symbolize elevated distance or the ‘hills’ and the unluminous pixels correlate to the ‘valleys,’ which permits for the verification of the passage that a falling raindrop would track. Lines of Watershed are the separate lines of ‘realm of captivation of water drops. The flooding variation of the watershed technique is equivalent to concentration of the release in a lake flooded from minimum space. The flooding variation is further capable than the unique falling raindrop method for many applications. The fundamental watershed rainfall features execution is utilized to attain the minimum region by subsequent the raindrop passage, through these fundamental stages

1. These minimum region turn into the streaming initial positions. We utilize the similar brand for the pixels in the rainfall passage and the minimum region.
2. Replicate the rainfall model on all adjacent pixels to observe either there is one more position that might attain the similar decreased region. Spot every the pixels with the similar brand while the minimum region is attained; or else, a novel streaming method will initiate with a minimum region planned for the subsequently streaming.
3. When the diverse brands of waterhole are concerning to combine, a ‘dam’ is developed to avoid the integration. The dam limitations are lastly developed while the streaming process attains the inclusive limit. The barrier limitations at this point are mentioned to as lines of watershed.

### Feature extraction

The feature extraction is the subsequent segment of the recognition and classification method. The features are separated by the segmented image and then the feature extraction is made by integrating the GLCM and ABCD Rule technique.

### ABCD rule

ABCD rule based recognition utilize ABCD rule for extracting the skin lesion. Feature extraction is performed on the pre-processed image where the four features - Asymmetry (A), Border (B), Color(C), and D (Diameter) are extracted in the subsequent way. Feature extraction is made using the properties called ABCD in computerized analysis of skin cancer.

- 1) **Asymmetry** – Melanoma lesions are asymmetric in character. Asymmetry index is used for influential the level of symmetry of the entity. This is made by separating the image parallel or upright.
- 2) **Border** - In case of melanoma the boundary is uneven, torn, and unclear. The compactness index is used to conclude the boundary abnormality.
- 3) **Color** – Melanoma are not consistent in color dissimilar the benign mole. Normalized Euclidean distance among each pixel is used to establish the color consistency.
- 4) **Diameter** - The melanoma lesion has superior than 6 mm. The diameter in the image is found out and compared to 6 mm measurement.

### Grey level co-occurrence matrix feature

Gray Level Co-occurrence Matrix (GLCM) examines through arithmetical method by considering the dimensional association of pixels. The gray level co-occurrence matrix is also called as gray-level spatial dependence matrix. The combo of pixels with definite principles and in a particular dimensional association occurring in image is calculated by GLCM. These figures afford data regarding the surface of an image. The subsequent equations list the statistics.

Statistic	Description
difference	It computes the local variation in the GLCM. $Contrast = \sum_{k=0}^{N-1} k^2 \sum_{a=0}^{N-1} \sum_{b=0}^{N-1} (f(a, b))$
Connection	Computes the combined probability rate of the particular pixel pairs. $Correlation = \sum_{a=1}^{N-1} \sum_{b=1}^{N-1} (a-\mu)^2 f(a, b)$
Energy	Presents the computation of squared constituents in the GLCM. As well known as equivalence or the angular second moment. $Energy = \sum_{a=0}^{N-1} \sum_{b=0}^{N-1} f(a, b)^2$
Homogeneity	computes the proximity of the allocation of essentials in the GLCM to the GLCM diagonal $Homogeneity = \sum_{a=0}^{N-1} \sum_{b=0}^{N-1} \{f(a, b)\}^2$

## Shape feature

The shape characteristics are irregularity index, abnormality index, and distance that evaluate from lesion in binary image.

### Irregularity

Irregularity is a significant feature of structure perceptive is proportion, which is extremely functional in prototype study. For a proportionate prototype, one desires merely single division of the model with the centre of proportion. If a division of the model is lost or noisy, with the assist of equilibrium one can finish the model or clear the model of noisy. Lesions on Skin that are Malignant be liable to comprise proportionate form but benign lesions are liable to possess irregular form. If the form is entirely proportioned, the ratio is 1. As the irregularity enhanced the ratio processed nearer to 0.

Irregularity Index is calculated with the subsequent eq. (2).

$$Assy = \frac{\Delta A}{A} * 100 \quad (2)$$

### Abnormality

Malignant lesions on skin are liable to have asymmetrical limitations with pointed boundaries and notches. Benign lesions are liable to have even limitations. If the figure is entirely proportionate, the ratio is 1, also the ratio processed nearer to 0. Abnormality index is a utility of area (A) and perimeter (P), considered with the subsequent eq. (3):

$$Irreg = \frac{4\pi A}{P^2} \quad (3)$$

For an ideal loop, the abnormality index is 1. As the boundary turns to more asymmetrical, the index attains 0.

### Distance

Malignant melanoma is liable to develop superior than benign melanoma, and particularly the distance of 6 mm, to locate the distance, computes the distance among every couple of points. The increase of these diameters is the distance. Algorithm explains the stages of shape characteristics technique.

---

### *Algorithm: calculate the shape characteristics*

**Input:** Binary image which consequent from segmentation stage subsequent to relate morphological process.

**Output:** Shape characteristics vector.

**Step 1:** Calculate the region of the entire Image.

**Step 2:** Calculate the region of lesion.

**Step 3:** Calculate the region distinction among entire image and region of lesion.

**Step 4:** Calculate irregularity index from equation (2).

**Step 5:** Discover the external borders of substance, along with borders of space within these substances, in the binary image.

**Step 6:** Calculate the pixels of the edge.

**Step 7:** Calculate the boundary of the Lesion.

**Step 8:** Calculate the region of the Lesion.

**Step 9:** Calculate edge abnormality index by using the equation (3).

**Step 10:** Compute the correlates (x, y) of every pixel of the lesion boundary.

**Step 11:** Compute the diameter among every join up of points.

**Step 12:** The outcome from this algorithm is a vector of characteristics, which has three elements irregularity, regularity and distance.

Here, the extracted features are provided as input to various classifiers such as SVM, Random Forest and kNN for classification of lesions.

## Classification

The classification is the final phase which categorizes into benign or melanoma image. Benign meaning a regular image and melanoma is the tumor image. Two schemes are obtainable to utilize one is Support Vector Machine (SVM) and Random Forest method.

## Support vector machines

For both classification and regression challenges, supervised machine learning algorithm Support Vector Machine (SVM) is used. Though, it is frequently used in issues of classification. In this algorithm, design all data point as a position in n-structural hole (where n is numeral of features possessed) with the significance of every characteristic being the value of an explicit correlates. Support Vectors are merely the correlates of separate examination. Support Vector Machine is a front line which finest separates the two classes (hyper-plane/contour).

### SVM Algorithm

**Algorithm:** Generate SVM

**Input:** Trained Data, Tested Data

**Output:** Classified Data

**Step 1:** Dataset given to system

**Step 2:** Features and attributes are classified based on the labeled class.

**Step 3:** Candidate Support Value Estimation

**Step 4:** While the instances value is not equal to null

Repeat the following steps for all instances

**Step 4:** Support Value is equal to Similarity between each instance in the attribute

Find Total Error Value

**Step 5:** If any instance is less than 0 then Estimate the decision value

Decision value = Support Value/Total Error

Repeat the above steps until empty

End If

## Random forest

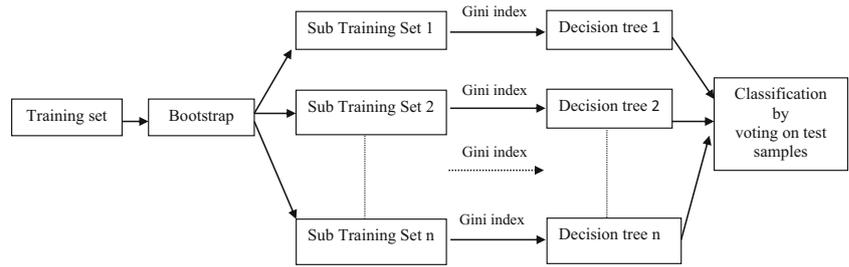
An RF is established with a numeral of decision trees, and every tree acquires its position arrangement effect by utilizing dissimilar classification. This method permits the evaluation of the sampling allocation utilizing the random sampling technique, also particularly appropriate for some minute models. Essential procedure of classification on basis of RF is as follows. Figure 2 depicts the flowchart for Random Forest.

1. The unique training illustration set is developed, in which the amount of cases is X also the

amount of contribution character is Y. This illustration will be the training set for increasing the tree.

2. A secondary training set is arbitrarily created by sampling with the substitution bootstrap technique for n tree times; hence, the subordinate training set for the RF with numeral n tree is created.
3. Ahead of choosing the characters (features) for every non leaf node (internal node), this technique at random chooses a definite number of characteristics from all distinctiveness, utilizes

**Fig. 2** RF classification algorithm Flowchart



them as divide characteristics of the existing decision tree, and chooses the optimal one to divide the nodes. The amount of characters tried at every division is indicated by  $m_{try}$ ,  $m_{try} \leq M$ .

4. Expect pruning, the tree expansion is increased.
5. The created trees are joint with RF. every tree in the RF transmit an entity choice for the mainly accepted group, and the classifier result is resolute by a mass choice of the trees
6. . Considering that set S comprises k sorts of attribute principles and every kind of attribute principle creates one subnode,  $Gini(i)$ , the Gini coordinates of node i is calculated as

$$Gini(i) = 1 - \sum_{j=1}^h [p(j/i)]^2$$

where h is the amount of categories of node i and  $p(j/i)$  is the comparative frequency of form no. j on node i. The infection must be zero [i.e.,  $Gini(i)$  is 0] if the node is every one class, which illustrates that the major data or entropy is used.  $Gini(i)$  should be elevated when a node is evenly parted between every classes, which is known that the divided utilizes the slightest valuable information.

7. The part index of set S is

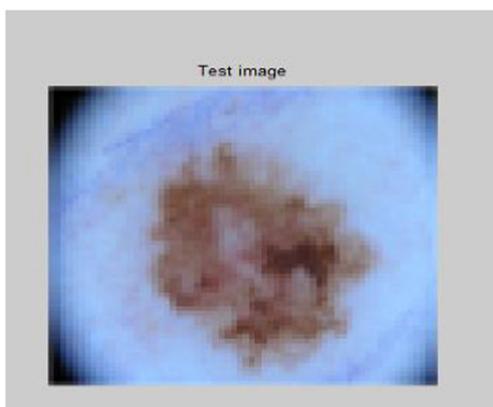
$$Gini_{split}(S) = \sum_{i=1}^r \frac{S_i}{S} Gini(i) \tag{4}$$

where  $Gini_{split}$  is the split index of set S, r is the record type within set S,  $s_i$  is the record number on node i, and s is the total record number of set S.

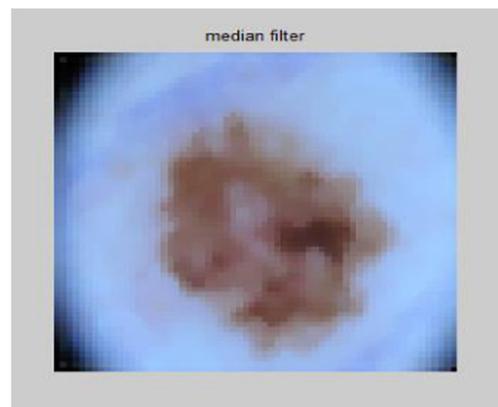
**kNN classifier**

Skin cancer classification can be done with the identification of his algorithm such that the test samples and the training samples are loaded in the databases. Samples are categorized by evaluating the nearest diameter to the preparation case. Its part then concludes the categorization of the sample. kNN classifier expands this suggestion by captivating the k adjacent position with proclaiming the indication of the mainstream. It is unique to choose k values.

Values which are greater in the value of k help in reducing the effects of noisy levels in the pixels rate inside the training data set and opt the value of k is frequently executed during cross-validation. Here the several methods obtainable for this problem is to select



**Fig. 3** Input image



**Fig. 4** Preprocessed image using Median Filter



**Fig. 5** Segmented image using Watershed Algorithm

a subset of the training data such that classification by the 1-NN rule using the values of many subsets.

## Performance analysis

The proposed technique is to identify and categorize the skin cancer images are discussed in this section. The dataset used here is International Skin Imaging Collaboration (ISIC). Here 1000 samples were taken. 10 cross fold validation is used where all samples were trained and tested.

Figure 3 shows the input cancerous image to detect the skin cancer. Figure 4 depicts preprocessed image using median filter.

The fig. 5 shows output result of the segmented image, the watershed segmentation technique is used for segmenting the required area for classification.

Table 1 shows the classification performance analysis for various classifiers using ABCD rule feature for classifying the melanoma. The performance analysis of the feature extraction of ABCD rule with SVM method is best when compared to other classifier technique.

Table 2 shows the classification performance analysis for various classifiers using GLCM feature for classifying the melanoma. The performance analysis of the feature extraction

**Table 1** Performance analysis of various classifiers for ABCD rule

Parameters	Classifiers		
	SVM	Random forest	KNN
Accuracy (%)	89.43	76.87	69.54
Sensitivity (%)	91.15	78.43	71.32
Specificity (%)	87.71	75.31	67.76

**Table 2** Performance analysis of various classifiers for GLCM feature

Parameters	Classifiers		
	SVM	Random forest	KNN
Accuracy (%)	85.72	74.32	65.39
Sensitivity (%)	87.68	76.85	68.27
Specificity (%)	83.76	71.79	62.51

of GLCM with SVM method is best when compared to other classifier technique.

Table 3 shows the classification performance analysis for various classifiers using shape feature for classifying the melanoma. The performance analysis of the feature extraction of GLCM with SVM method is best when compared to other classifier technique.

Figure 6 shows that SVM classifier outperformed the best for ABCD rule than other classifiers.

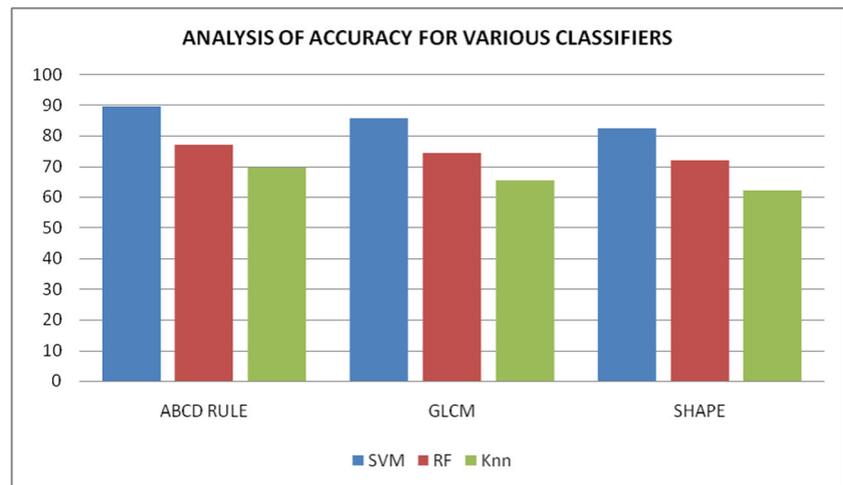
## Conclusion

This research article discusses a segmentation method and classification method for skin cancer. Segmentation is the classification of the input image into skin. The watershed techniques can section lesions on skin through increase in precision. The simulation of SVM for ABCD rule presents the increased stage evaluated with new classifiers technique. The proposed methodology concentrates on comparing the SVM, Random forest and kNN and SVM provided better results than other classifiers. SVM provides advantages like it is accurate and robust even if the training sample shows some bias. It provides unique solution since the optimality problem is convex. SVMs provide a good out-of-sample generalization. SVMs gain flexibility in the choice of the form of the threshold separating solvent from insolvent companies, which needs not be linear and even needs not have the same functional form for all data, since its function is non-parametric and operates locally.

**Table 3** Performance analysis of various classifiers for shape feature

Parameters	Classifiers		
	SVM	Random forest	KNN
Accuracy (%)	82.31	71.97	62.19
Sensitivity (%)	87.76	74.75	65.72
Specificity (%)	78.86	69.19	58.66

**Fig. 6** Analysis of accuracies for various classifiers



## Compliance with Ethical Standards

**Conflict of Interest** The authors have no conflict of interests and the paper has not been submitted elsewhere.

**Research Involving Human Participants and/or Animals** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed Consent** The work does not involve any human or animal participants. The datasets used in the work are taken from free online sources.

## References

- Hemalatha, R. J., Babu, B., Josephin Arockia Dhivya, A., Thamizhvani, T.R., Chandrasekaran, J. E. J. R., A Comparison of Filtering and Enhancement Methods in Malignant Melanoma Images, IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), 2017.
- Revathi, V. L., and Chithra, A. S., A Review on Segmentation Techniques in Lesion on skinImages. International Research Journal of Engineering and Technology (IRJET) 02(09), 2015.
- Ray, P. J., Priya, S., Ashok Kumar, T., Nuclear Segmentation For Skin Cancer Diagnosis From Histopathological Images, IEEE Proceedings of 2015 Global Conference on Communication Technologies (GCCT), 2015.
- Ma, L., and Staunton, R. C., Analysis of the contour structural irregularity of skin lesions using wavelet decomposition. Pattern Recogn. 46:98–106, 2013.
- Li, D.-C., Liu, C.-W., and Hu, S. C., A fuzzy-based data transformation for feature extraction to increase classification performance with small medical data sets. Artif. Intell. Med. 52:45–52, 2011.
- Oliveira, R. B., Filho, M. E., Ma, Z., Papa, J. P., Pereira, A. S., and Tavares, J. M. R. S., Computational methods for the image segmentation of pigmented skin lesions: A review. Comput. Methods Prog. Biomed. 131:127–141, 2016.
- Scharcanski, J., and Celebi, M. E., Computer vision techniques for the diagnosis of skin cancer. Berlin Heidelberg: Springer-Verlag, 2013.
- Yuksel, M. E., and Borlu, M., Accurate segmentation of dermoscopic images by image thresholding based on type-2 fuzzy logic. IEEE Trans. Fuzzy Syst. 17:976–982, 2009.
- Beuren, A. T., Janasievicz, R., Pinheiro, G., Grando, N., and Facon, J., Skin melanoma segmentation by morphological approach. In: International conference on advances in computing, communications and informatics. Chennai: ACM, 2012, 972–978.
- Barata, C., Ruela, M., Francisco, M., Mendonça, T., and Marques, J. S., Two systems for the detection of melanomas in dermoscopy images using texture and color features. Systems Journal, IEEE 8: 965–979, 2014.
- Sadeghi, M., Razmara, M., Ester, M., Lee, T. K., and Atkins, M. S., Graph-based pigment network detection in skin images. Proc. SPIE 7623:762312, 2010.
- Glaister, J., Amelard, R., Wong, A., and Clausi, D., MSIM: multi-stage illumination modeling of dermatological photographs for illumination-corrected lesion on skinanalysis. IEEE Trans. Biomed. Eng. 60:1873–1883, 2013.
- Dumitrache, I., Sultana, A. E., and Dogaru, R., Automatic detection of skin melanoma from images using natural computing approaches. 2014 10th International Conference on Communications (COMM), 2014.
- Hadi, S., Tumbelaka, B. Y., Irawan, B., and Rosadi, R., “Implementing DEWA Framework for Early Diagnosis of Melanoma” International Conference on Computer Science and Computational Intelligence (ICCSCI 2015). Procedia Computer Science 59:410–418, 2015.
- Saleh, F. S., Azmi, R., Automated Lesion Border Detection of Dermoscopy Images Using Spectral Clustering, 2015 2nd International Conference on Pattern Recognition and Image Analysis (IPRIA 2015), 2015.

**Publisher’s Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.