



ABCD rule based automatic computer-aided skin cancer detection using MATLAB®

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Abstract

Detection of skin cancer in the earlier stage is very critical and this paper proposes and explains the implementation of automatic detection and analysis Skin Cancer from given photograph of patient's cancer affected area. The proposed scheme is using Watershed Segmentation for image segmentation, border detection & decision related with structural nature of lesion, Wavelet Transformation and decomposition for image improvement, de-noising, histogram analysis & for calculating diameter of lesion and mamdani based Fuzzy Inference System color based skin classification based on the pixel color severity. We are using worldwide recognized ABCD rule of cancer diagnostic. We are calculating TDS Index for differentiating and making final decision of non-cancerous (benign), suspicious and cancerous (melanoma) image, which will help patients/doctors/dermatologist/clinicians for taking further medical treatment, which will ultimately saves patients valuable time, money and life.

Presently there is a greater need of automatic diagnosis of skin cancer for masses at an early stage. In this direction, we are explaining you our implemented automation skin cancer diagnosis system. For this we are using images of cancer affected skin of patients. The basic aim of this “automatic cancer detection system” implementation paper is, to have a simple, efficient and automatic skin cancer, detection and diagnosis system with the use of commonly available software for non-experts/clinicians/doctors. This explained automatic skin cancer diagnosis system is implemented in commonly available software - MATLAB® 2009b. We are using watershed segmentation, Wavelet Transformation & decomposition and Fuzzy Inference System for the qualitative (Structural nature of lesion, Nature of Skin, Nature of cancer) and quantitative (% affected skin, diameter of lesion, A-B-C-D factors and TDS Index) analysis of skin cancer images.

1. Introduction

Skin cancer is a malignant tumor which grows in skin cells. It is one of the most common of all cancer which affects human beings and accounts for more than 50% of all types of cancers around the world. Skin cancer is skin's unwanted growth with differing causes and varying degrees of malignancies. It can spread very fast to all organs/parts of human body through lymphatic system or blood. The incidences of melanoma - the deadliest form of skin cancer has been on rise at an alarming rate of 3% per year [1]. Detection of malignant melanoma in its early stages considerably reduces morbidity and mortality. Skin cancer can be cured at very high rates with simple and economical treatments [2, 4, 5, 6], if detected at its earlier stages.

This paper is organized as follows: Techniques & Tools used in this implementation for image processing and analysis are discussed briefly in Section 2. Overview of ABCD rule based skin Cancer diagnosis is explained in Section 3. Our methodology is given in Section 4. Implementation of the methodology using MATLAB® 2009b is presented in Section 5, Experimentation result are given in section 6 and lastly, we conclude in Section 7.



2. Available Techniques & Tools

In Automatic computer-aided skin cancer detection/diagnosis systems, the aim is to detect potentially malignant lesions from the given images. Mostly this is performed in a three-stage system, viz., identification of potentially unhealthy regions of interest, computation of descriptive features and labelling by a classifier.

2.1. Image Pre-processing Techniques

The acquisition of the digital image of affected skin is the first and primary step in image processing. We are using images taken from commercially available digital camera or from Epiluminescence microscopy (ELM or Dermoscopy).

Once image is acquired, then it goes for pre-processing. In first part of preprocessing digital images of skin cancer, collected in Bitmap or JPEG format from different sources are converted to indexed images. It converts the ordinary image to first RGB then grayscale and at the end binary. It makes an image suitable for a particular application. The second part of pre-processing involves enhancement of image (edge highlighting, sharpening, deblurring, brightening, change in contrast, masking, hair removal, cropping or resizing and/or noise removal). For border detection of skin lesion we are using Canny Edge Detection technique.

2.2. Segmentation Techniques

Image segmentation involves image partitioning into multiple segments or regions of interest. It helps in to grouping similar characteristics regions. It is a process of extracting and representing information from the image to group pixels together with region of similarity. The aim of segmentation is converting the image representation into a meaningful one for simplification in image analysis. In this process a label is assigned to each pixel, such that pixels with same labels share common visual characteristics. Image segmentation is used to locate skin lesions and their boundaries. We are using Watershed segmentation, because of its popularity due to generation of less complex computational results.

2.3. Wavelet Transformation & Decomposition Techniques

Wavelets are used for decomposing the skin lesion image in order to utilize wavelet coefficients for its characterization. They are an extension Fourier analysis. Wavelets are hierarchically decomposing given images in the frequency domain by preserving the spatial domain. This is very useful in noisy images analysis as it separates them from the background and from other objects. Also wavelets can be used for analyzing functions at various scales as it stores

versions of an image at various resolutions, which is very similar the working of human eyes.

The noisy properties can be efficiently separated and characterized with the techniques of Wavelet Decomposition. Wavelets decomposes an image into orthogonal sub bands with low-low (LL), low-high (LH), high-low (HL), and high-high (HH) components which correspond to approximation, horizontal, vertical and diagonal respectively. The LL sub-band is further decomposed into another four sub-bands; horizontal, vertical and diagonal respectively. The LL sub-band is further decomposed into another four sub-bands; and the Low-low-low-low (LLLL) component, which represents the image approximation at this level, is decomposed once again.

After decomposition, we reconstruct the image by using reconstruction function, which computes the matrix of reconstructed coefficients of level N, based on the wavelet decomposition Structure. Computation of Single-level inverse discrete 2D wavelet transform can be done using the inverse function. After getting the reconstructed image, we smoothens the image by using different windowing filtering techniques. We can also convert the processed image into binary image for further analysis.

2.4. Fuzzy Inference Techniques

The Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. In the Fuzzy Inference System, skin color as input variable is fuzzified by applying membership function to it. It is a skin classifier based on skin color intensities. We are using MATLAB[®]'s Fuzzy toolbox with mamdani system. It classifies skin into Healthy, Rash and/or Cancerous skin.

3. ABCD Rule of skin Cancer detection

In order to educate the masses to recognize melanoma in its early stages in 1985, group from New York University [3] devised the ABCD acronym (Asymmetry, Border irregularity, Color variegation, Diameter > 6mm). It is one of the easiest guides to the most common signs of melanoma. Further, Stolz, W. [7] established this diagnosis scheme for dermatoscopic images known as the ABCD rule of dermatoscopy. The characteristics needed to diagnose a melanoma as malignant are

(A) Asymmetry - Cancerous lesions are checked for symmetry. If the lesion is Symmetric (0 value) then it is benign (non-cancerous). For Cancerous cases asymmetry in zero, one (value 1)), or two orthogonal axes (value 2) are considered.

(B) Border irregularity - Most of the cancerous lesions edges are ragged, notched or blurred. Its value ranges 0 to 8.

(C) Color – Cancerous skin lesion’s pigmentation is not uniform. The presence of up to six known colors must be detected - white, red, light brown, dark brown, slate blue, and black. Its value ranges 0 to 6.

(D) Diameter – Cancerous lesions are greater than 6mm wide. Differential structures with at least five patterns are relevant for specific types of lesions. Any growth of a mole should be of concern. Its value ranges 0 to 5.

Some melanomas do not fit the ABCD rule described above, so it is important for us to notice changes in skin markings or new spots on our skin.

TDS (Total Dermatoscopy Score) Index [8] is an important tool used in the diagnosis of melanoma. Calculation of the TDS Index is based on Asymmetry, Border, Color and Diameter of the skin lesion. Asymmetry or A-factor has three values (symmetry – 0, 1-axis asymmetry – 1, 2-axis asymmetry – 2). Border or B-factor has 0 to 8 values. Color or C-factor has six values (Red, Blue, White, Black, light brown, dark brown). Presence of each color in the image leads to addition of value 1. Diameter or D-factor has 0 to 5 values. Any skin lesion with diameter greater than 6mm will be equal to value 5.

The TDC Index is computed using following formula. It is also known as ABCD formula.

$$TDS = 1.3A + 0.1B + 0.5C + 0.5D$$

If the TDS Index is less than 4.75, it is benign (non-cancerous) skin lesion. If TDS Index is greater than 4.75 and less than 5.45, it is suspicious case of skin lesion. If TDS Index is greater than 5.45, it is malignant melanoma (cancerous) skin lesion.

ABCD rule has proven more accurate and effectiveness in clinical practice with 76% diagnostic accuracy [9]. The ABCD rule is also used by the American Cancer Society, American Academy of Dermatology and others worldwide to provide simple parameters for evaluation and identification of pigmented lesions that may need further examination. But all melanomas do not have all four ABCD features. It is the combination of features (e.g., A+B, A+C, B+C, A+B+C, etc.) that render some lesions most suspicious for early melanoma.

4. Methodology

The aim of automatic computer-aided skin cancer detection/diagnosis system is to detect potentially malignant lesions in the given/acquired images of affected skin. The processing consists of extracting the useful and desired information of the skin lesion.

The main objectives of this proposed skin cancer diagnosis system are

1. To get proper information about cancer (such as Boundary, Size and distinct frequency based features) for different types of skin cancer detection.

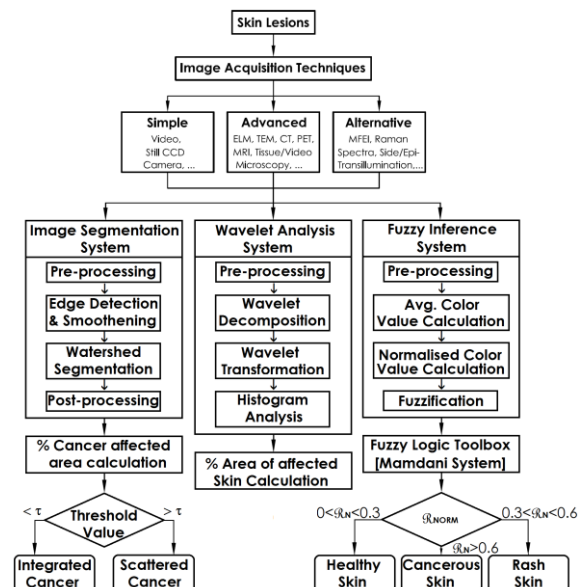
We use following techniques:

- Edge Detection
- Watershed segmentation and
- Wavelet Transformation

2. To get skin color and to decide about the nature of skin based on color pigmentation severity.

- We use fuzzy logic for quantification of cancer severity

The proposed methodology of skin cancer detection and diagnosis are shown in **Figure 1**.



Φιγυρε 1. Προποσεδ Μετηοδολογη

We are using generally available formulas of different Indexes to calculate A, B, C and D factors.

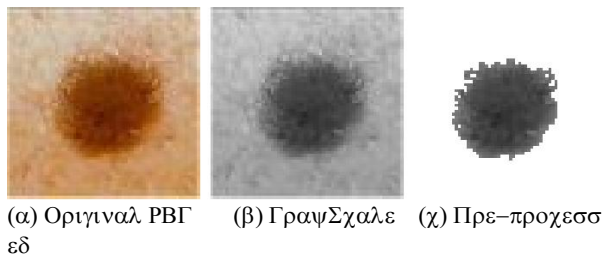
There are three modules in this system as shown in **Figure 1**. Each module is doing its own image pre-processing. It also extracts useful information for the processed images. In image Segmentation system, we are calculating A and B factors using asymmetry and irregularity indexes. In wavelet Analysis System, we are calculating percentage area of affected skin and diameter of skin lesion and subsequently D-factor. In Fuzzy Inference System, we are calculating C-factor.

5. Implementation in MATLAB®

Skin cancer is a malignant tumor which grows in skin cells. It is one of the most common of all cancer which affects human beings and accounts for more than 50% of all types of cancers around the world. Skin cancer is skin’s unwanted growth with differing causes and varying degrees of malignancies. It can spread very fast to all organs/parts of human body through lymphatic system or blood. The incidences of “melanoma - the deadliest form of skin cancer has been on rise at an alarming rate of 3% per year [1]. Detection of malignant melanoma in its early stages considerably reduces morbidity and mortality. Skin cancer can be cured at very high rates with simple and economical treatments [2, 4, 5, 6].

5.1. Image Preparation

In image preparation, the ordinary images acquired from other sources are processed as shown in Figure 2.

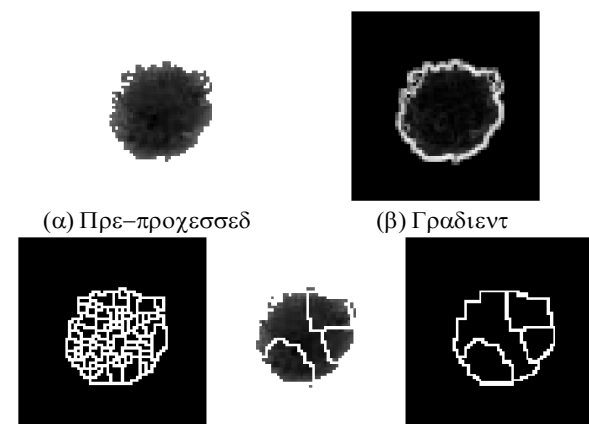


(α) Οριγινάλ ΡΒΓ (β) ΓραψΣχαλε (γ) Πρε-προχεσσεδ

Φιγυρε 2. Ιμαγε Πρε-προχεσσιγγ

5.2. Image Segmentation System

Pre-processed image is segmented using Watershed Segmentation as shown in Figure 3.



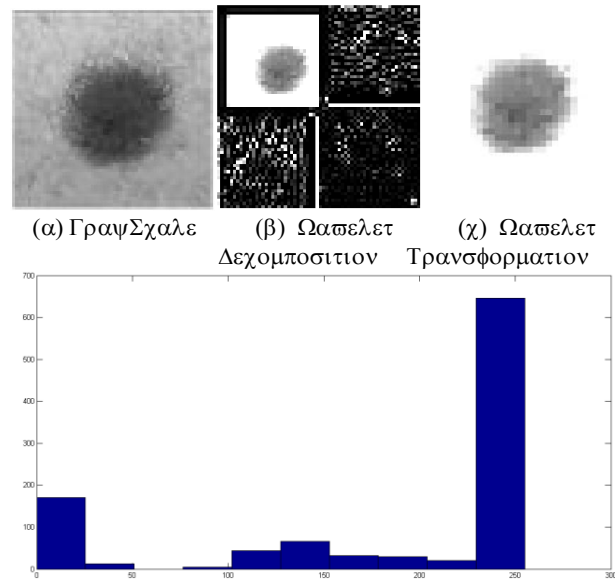
(α) Πρε-προχεσσεδ (β) Γραδιεντ (γ) Ριδγε Λινεσ (δ) Σεγμεντεδ & Σμοοτηνεδ (ε) Ωατερσηεδ Σεγμεντεδ

Φιγυρε 3. Ιμαγε Σεγμεντατιον

5.3. Wavelet Analysis System

Features of interest and noise properties of given pre-processed image is efficiently and separately

characterized with the techniques of Wavelet Decomposition as shown in Figure 4.



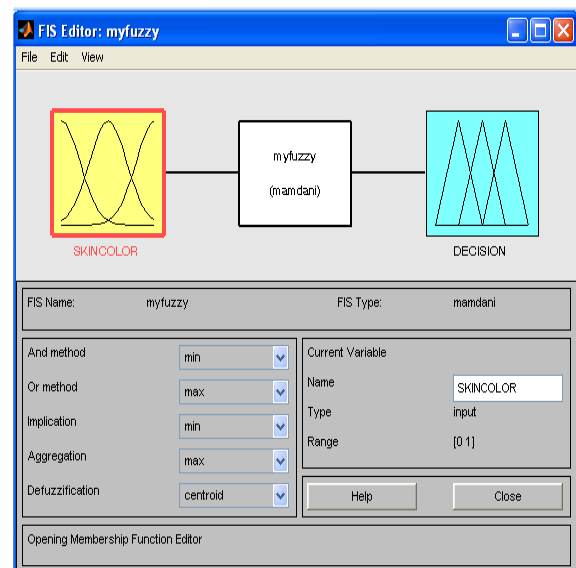
(α) ΓραψΣχαλε (β) Ωαπελετ Δεχομοποσιτιον (γ) Ωαπελετ Τρανσφορματιον

(δ) Ηιστογραμ οφ Προχεσσεδ Ιμαγε

Φιγυρε 4. Ωαπελετ Δεχομοποσιτιον ανδ Τρανσφορματιον

5.4. Fuzzy Inference System

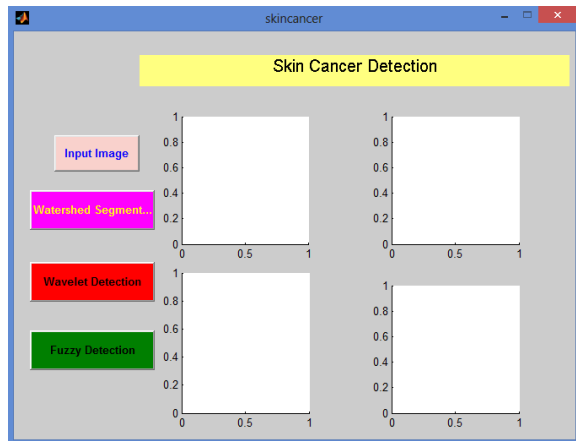
In fuzzy Inference system given color image is classified as light red, medium red and dark red using a skin classifier, which defines a decision boundary of the skin color class in color space based on a fuzzified skin-colored pixels & severity of cancerous cell. The output of Fuzzy Inference system is in terms of a decision related with the type of skin as healthy, Rash or cancer skin is shown in Figure 5.



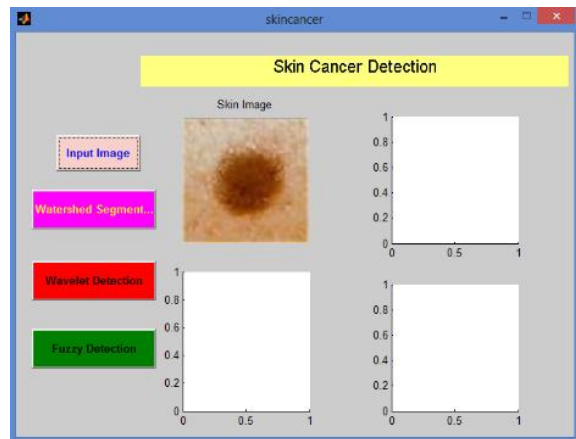
Φιγυρε 5. ΦΙΣ Εδιτορ- Φυζζψ Ινφερενχε Σψστεμ

5.5. Automatic Skin Cancer Diagnosis System

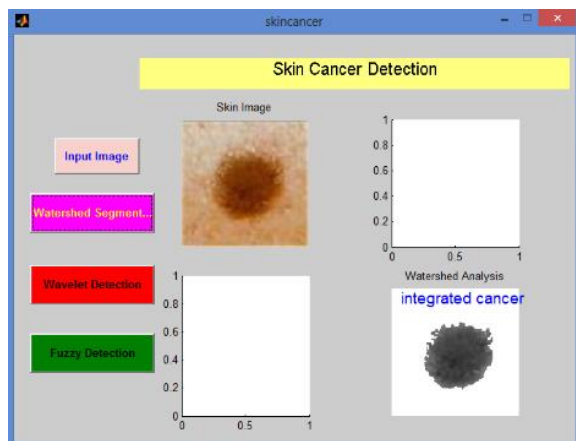
The skin cancer diagnosis system's graphic user interface, which can be used by anybody with general knowledge of computers, is shown in **Figure 8** along with other inputs and outputs for decision based on three outputs; viz., Segmentation, Wavelet Analysis & Fuzzy Analysis.



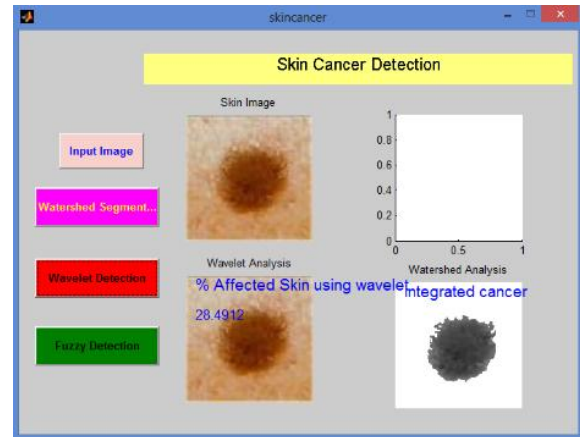
(α) Σκιν Χανχερ Διαγνωσις Συστημ ΓΥΙ



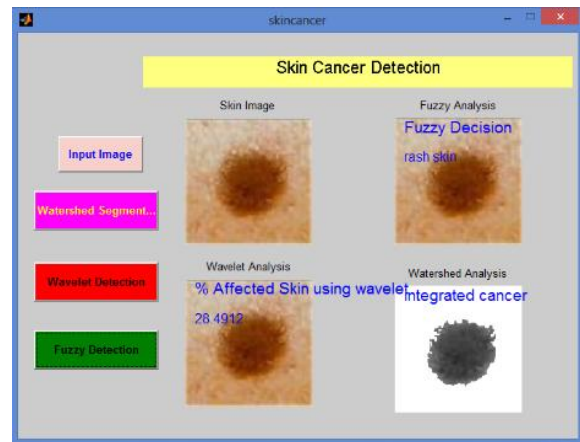
(β) Ιντυτ Ιμαγε φορ Διαγνωσις



(γ) Ωατερσηεδ Σεγμεντατιον Ρεσυλτ



(δ) Ωαπελετ Αναλψσις Ρεσυλτ



(ε) Φυζζψ Αναλψσις Ρεσυλτ

Φιγυρε 8. Σκιν Χανχερ Διαγνωσις Συστημ

On the front-end we are extracting different data from the input image and at the same time calculating and presenting the nature of skin lesion, nature of skin and percentage of cancer affected skin patch. Whereas on the back-end we are calculating A, B, C and D factors to calculate the TDS value or Index to decide, whether the skin lesion in the input image is cancerous, suspicious or non-cancerous.

6. Experimentation

This diagnosis system is evaluated using a database of cancerous and non-cancerous images. We have analysed all the input images given to us with our developed skin cancer diagnosis system. This system is giving results at the two fronts, viz., front-end and backend. It is found to be working satisfactorily with considerable detection accuracy. Sample of input images are shown in **Table 1** (Numbered as Image-column). The experimentation results are shown in **Table 2**.

Ταβλε 1. Ιντυτ Ιμαγες φορ Διαγνοσις



Ταβλε 2. Διαγνοσις Εξπεριμεντατιον Ρεσυλτς

Input Image	Segmentation Result	Wavelet Result, %	Fuzzy Result	A-factor	B-factor	C-factor	D-factor	TDS	Conclusion	Result
Img-11	integrated	11.7432	cancerous	0.4793	0.2854	4.3693	5	5.3363	Suspecious	Right
Img-12	integrated	9.6191	cancerous	0	0.0774	4.3504	4.5810	4.4735	Non-Cancerous	Right
Img-13	integrated	10.2539	cancerous	0	0.0774	4.3128	4.7298	4.5290	Non-Cancerous	Right
Img-14	integrated	11.0596	cancerous	0.0941	0.1046	4.5253	4.9121	4.8515	Suspecious	Right
Img-15	integrated	11.0107	cancerous	0.3119	0.2029	4.0536	4.9012	4.9032	Suspecious	Right
Img-16	integrated	15.0391	cancerous	0.4310	0.2960	4.2104	5	5.1951	Suspecious	Right
Img-17	integrated	13.8916	cancerous	0.3606	0.2473	4.1902	5	5.0886	Suspecious	Right
Img-18	scattered	36.5234	cancerous	1.6011	1.9900	3.9568	5	6.7588	Cancerous	Right
Img-19	integrated	10.7666	cancerous	0.0962	0.0979	3.6062	4.8466	4.361	Non-Cancerous	Right
Img-20	integrated	17.3584	cancerous	0.5778	0.4174	3.8843	5	5.2351	Suspecious	Right
Img-21	integrated	11.5723	cancerous	0.1106	0.1064	3.7640	5	4.5364	Non-Cancerous	Right
Img-22	scattered	98.5840	cancerous	4.0658	11.2313	3.9162	5	10.8667	Cancerous	Wrong
Img-23	integrated	10.0098	cancerous	0	0.0774	4.1686	4.6731	4.4286	Non-Cancerous	Right
Img-24	scattered	28.1494	healthy	0.8309	0.7125	1.4236	5	4.3632	Non-Cancerous	Right
Img-25	integrated	23.8281	healthy	0.6204	0.4822	1.2706	5	3.9900	Non-Cancerous	Right
Img-26	scattered	47.5342	healthy	1.5974	1.9249	1.7886	5	5.6635	Cancerous	Right
Img-27	integrated	20.3125	rash	0.5953	0.4512	3.0530	5	4.8455	Suspecious	Right
Img-28	scattered	21.9482	rash	0.9290	1.0937	2.7000	5	5.1670	Suspecious	Right
Img-29	integrated	10.0342	rash	0	0.0774	2.7569	4.6788	3.7256	Non-Cancerous	Right
Img-30	scattered	46.0449	rash	1.8853	3.2904	2.7000	5	6.6300	Cancerous	Right
Img-31	integrated	15.8203	rash	0.3883	0.2636	2.7000	5	4.3811	Non-Cancerous	Right
Img-32	scattered	41.3818	rash	1.7477	2.1215	2.2944	5	6.1314	Cancerous	Right
Img-33	scattered	53.3447	rash	1.5402	1.8416	2.4372	5	5.9050	Cancerous	Right
Img-34	scattered	79.4189	rash	4.0390	10.9931	2.7000	5	10.2000	Cancerous	Wrong
Img-35	scattered	38.2324	rash	2.0944	3.9036	2.7000	5	6.9630	Cancerous	Wrong
Img-36	scattered	18.335	rash	0.8018	0.6363	3.3039	5	5.2579	Suspecious	Right
Img-37	scattered	42.0654	rash	1.8238	2.3684	2.7000	5	6.4577	Cancerous	Right
Img-38	scattered	24.8779	rash	1.5172	2.3141	3.2704	5	6.3389	Cancerous	Right
Img-39	scattered	37.8174	rash	1.3195	1.4455	2.7000	5	5.7100	Cancerous	Right
Img-40	scattered	23.6328	rash	1.5840	1.9243	3.1951	5	6.3492	Cancerous	Right



7. Conclusion

This diagnosis system is evaluated using a database of 30 cancerous and non-cancerous images. It is found to be working satisfactorily with a detection accuracy of about 90%. Most of the cancerous skin lesion are found to be from scattered lesions and rash skins types. This system seem to be very usefulness to Dermatologists, Doctors, Clinicians and Masses for early detection of skin cancer for further treatment. We are getting wrong results due to spread of cancer in complete image, which gives us overestimated A-B-C-D factors during backend calculations. This system is simple, easy-to-use, intuitive, cheap, fast and an accurate tool. This system will be a great help in early detection of malignant melanomas for faster, cheaper and efficient treatment.

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