Smart-Dermo: A computerize tool for classification of skin cancer using smartphone through Image Processing and Fuzzy logic

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Summary

A smartphone-based android application is developed to classify skin lesions using dermoscopic images (Smart-Dermo) in this paper for helping poor person in remote areas due to high expense of pre-screening process. In practice, many studies of health service outcomes found teledermatology reduced waiting times and could result in earlier assessment and treatment. Accordingly, the Smart-Demo application is very helpful to diagnose the skin cancer to detect effective features and classify them by fuzzy-logic derived from artificial intelligence platform. The Smart-Demo helps a patient to diagnosis the skin cancer once in a week to keep track his medical state. In the traditional way, diagnose of skin cancer is very expensive, time-consuming and tedious task. Therefore, the main objective of this paper is to develop an android-based Smart-Demo application that detects the type of skin cancer like melanoma versus non-melanoma and save the time for both the patients and the clinical experts. To develop Smart-Demo application, the image processing techniques, and the fuzzy logic are used to solve this problem through ABCD clinical rule for differentiation among skin tumors. The experimental results on 2200 dermoscopic images indicate that the Smart-Demo application achieved high classification accuracy 92% to detect melanoma in a fast and effective way compare to state-of-the-art methods. As a result, this Smart-Demo application may assist dermatologists to better recognize pigmented skin lesions (PSLs).

Key words:

Skin cancer, digital dermoscopy, malignant melanoma, image processing, fuzzy logic, android application

1. Introduction

Teledermatology is widely used nowadays [1] to detect skin cancer in remote areas, where there is difficult to provide dermatologist experts and medical facilities. However, some studies informed that skin cancer diagnosis through teledermatology has high accuracy. In past years, the skin cancer is most common form of cancer and it is widely spread throughout the world. In general, skin cancer has two main types of pigmented skin lesions (PSLs) such as malignant melanoma (MM) and benign tumors when diagnosis through digital dermoscopy. Nowadays, the rapid increased of malignant melanomas [2] have high incident rate. Another study suggested that the malignant melanomas are deadliest type of skin cancer that caused 70% of deaths [3]. Due to popularity of MM PSLs, many scientists have developed various intelligence or computational techniques to early diagnosis of PSLs [4]. As a result, many clinical experts have received considerable awareness about MM PSLs but this knowledge is limited to modern cities. However, many remote areas are still unreachable due to expensive diagnosis of PSLs lesions.

Several mobile-phone or smartphone based technologies were developed [5] in the past to automatically diagnosis PSLs through teledermatology without physical presence of the dermatologists in remote areas. Compare to desktop-based computerize systems, the researchers are trying to develop an effective computer algorithms in the smartphone environment. These algorithms are easily transported and portable in the smartphone environment. In fact, the smartphone-based recognition of PSLs were provided very flexible and effective environment to develop computer algorithms [6]. If smartphone-based application was developed to diagnosis PSLs then it will save time, cost and provided reliable treatment.

Currently, smartphone devices are having reliable features compare to last generation cell phones in terms of computational power, advanced operation system and memory. These advanced devices [6, 7] have been utilized on several criteria in evaluating computer programs on which they operate as in terms of reliability, time complexity and error rate. Commonly, there are many people in the world who have smartphones compare to expensive laptops. Hence, the progress in smartphones has improved health sciences and awareness on the significance of a healthy lifestyle [8]. Smartphone-based applications access camera features for diagnosis of PSLs have been incorporated into low-priced cell phones. This intelligent setup allows the smartphone [9] to help poor people to diagnosis and analyze skin lesions. As a result, the images captured by smartphone cameras are analyzed and evaluated based on accuracy, computation time and error rate [8, 10]. These images are received by intelligent application running in smartphone to classify the PSLs [11] into malignant melanoma and benign tumors. Therefore in this paper, a smartphone-based app is developed to recognize PSLs.

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To develop this android-based application (Smart-Dermo), an image processing and fuzzy logic based computational techniques are utilized to classify skin lesions. This Smart-Dermo app is directed to people who can't visit the specialist because of their distance from the specialized clinics and also expensive diagnosis of skin cancer, through the use of modern technology will shorten the time to detect the skin cancer in its early stages. Moreover, it provides a cheap way to diagnosis skin cancer and easy to use. As always, anyone who wants to diagnose a disease goes to a specialist doctor for this. This traditional method takes time, effort and money so we decided to help them by use technology to be able to provide the whole process themselves. The patients that are present in the town or village may take more benefit compared to people in cities because it is difficult for them to visit the doctor constantly. Furthermore, Smart-Dermo application helps the researches to find a better cure for the skin cancer by studying the previous pathological cases.

Smart-Dermo application to recognize skin cancer facilitates the diagnosis of the disease by taking a picture of the skin. The ABC (asymmetry, border irregularity, and color) sign parameters are mostly used to detect skin cancer because it is one of the most accurate methods. This technique is used in comparing images taken by the patient to his skin, to give us the smallest details of the affected area. Technology got great care in the health sector in recent year. Some hospitals and clinics have adopted the basic technical means to obtain the services they provide. Most of the medical services provided by the hospitals do not need to visit Doctors, only exceptional cases. It has become an urgent need to develop an application that Provides diagnostic and detection services as efficiently as possible to those who need them. Hospitals and clinics continue to rely on the traditional way of diagnosing cancer by taking a scan of the skin and then analyzing it by the competent body and the doctor analyze it. The person who is injured often cannot come to the clinic constantly to keep track of his / her health and often takes time to detect cancer. Cancer may be detected at a later stage, leading to difficulty in treatment.

The difficulty of visiting the doctor constantly to follow the current health of the patient, especially for those living in remote areas such as the village and small cities. It will increase the time and effort. The cancer detection in later stages makes treatment difficult. Therefore, this Smart-Dermo came to solve all these problems and reduce the time and effort to all users by using this application. The application of smart phone technology provides a possible solution to these problems. It is trying to reduce process cycle time; reduce consumption and more time in the diagnostic process. The proposed program can provide a means to monitor and evaluate the quality of cancer screening services. It can provide accurate and accessible data to track the patient's health status and provide treatment as soon as possible. The main objective of this paper is to develop a program to detect skin cancer to facilitate and speed the knowledge of cancer in its advanced stages while saving time and effort as all the necessary information will be stored to be ready for the patient to track his health status.

2. Related Work

Several Smart-phone based applications have been developed in the past to diagnosis skin cancer. They utilized ABCDE (A: asymmetry, B: Border, C: Color variation, D: Diameter > 6mm, E: Evolving or changing size, shape or color) rule to describe general information about the classification of skin cancer and the reason of getting the skin cancer. This ABCDE rule strategy was used to classify cancer and then a similar approach is used in this paper to develop Smart-Dermo application with good accuracy. These smartphone based applications are described below.

In paper [12], the authors developed melanoma recognition system through android smart phone. The authors in this paper [12] proposed a system based on lesion segmentation, extraction of features and recognition steps. The authors claimed that this mobile application to detect skin lesion can run on mobile device with a camera and also on tablet PC. The authors first try to convert color image into monochrome image for detection skin tumor region. Afterwards, the authors used only color and shape features to define patterns of skin lesions. Finally, they used a KNN classifier to recognition these features. On average, the authors reported 67.8% of classification accuracy on detection of malignant melanomas.

Another mobile application was developed in [13] to recognize melanoma using enable health care system. The authors proposed a smartphone based application through digital image processing and computer vision techniques to build this system. In the first step, the authors removed noise by applying Gaussian filtering technique. Next, Graph cut algorithm was used to detect the region of skin lesions. After detecting tumor region, the authors extracted features like area, perimeter and eccentricity. Those features are submitted to support vector machine (SVM) machine learning algorithm to classify melanoma versus nevus skin lesions. The authors named this system as m-skin. On average, the m-skin achieved classification accuracy of 80% and average time is 14938 milliseconds.

In paper [14], the authors developed an application that utilized electronic devices for patients to seek medical advice. The authors in this paper were simply trying to develop a mobile application to handle and teach medical doctors about skin lesions where there is difficult to get medical assistance. Also in [15], the authors utilized mobile technology to detect pigmented skin lesions (PLSs) through teledermoscopy technique. The authors advised to put magnifying glass with polarized light to capture skin tumor details on mobile phone so that the recognition step is became very easy. They used IOS platform to deploy their application. They developed this application by adding image and send to teledermatologist for detail review about lesion. To develop this application, the authors used the asymmetry-color (AC) rule. On average, the authors reported that they have achieved 94% of sensitivity and 62% of specificity for melanoma identification.

The authors were developed a smartphone based application to recognition skin lesions in paper [16, 17] through spectrometer. The spectrometers are low-cost devices that utilize the camera of the mobile phone to take image. Moreover, the authors in [18] developed another smartphone based application to handle the problem of skin lesions classification.

The classification of skin cancer is one of biggest problem in the world that is focus on saving the human life. Same as in many different Healthcare applications, they give the patient's information about their conditions. However, Smart-Dermo method will keep track and give delay information of the state on the cancer in the healing process. One of the most widely spread cancer in the world is skin cancer. Moreover, it represented 40% from the cancer case of the world [19], and it infected the white people more than other [20]. Since one of five people get the cancer and causes death, early discovers helps to limit to spreading the cancer in the human body and reduce the number of death and early cure, we can classify the skin cancer throws ABC rule.

Application medical phone become widely spread in the last period, application skin cancer is often used by Dermatology to know the prevalence of the skin cancer in the human body by certain strategy called ABCDE rule which is take a picture to a particular pieces of skin and examined by ABCDE rule, Which A refer to "Asymmetrical" , search for area that are Irregular, and B refer to "borders" search for area that have irregular edges , and c refer to "color" the color will be different and strange , and D refer to "diameter" bigger than 6 mm, and refer to "evolving" try to find anything new for the area[21]. Skin cancer like any other Diseases which is having many reasons, the most important reasons are excessive exposure to the sun's rays [22], other reason is smoking and effected with HPV [23] virus, and use drugs that reduce the immune like "Cyclosporine A" Which increases the danger of having skin cancer 200 time [24]. DERMA/Care: An Advanced Image-Processing Mobile Application for Monitoring Skin Cancer used software to exam the skin by using a device is not expensive like a microscope and Smartphone which is enough to take a picture for the skin and used to discover cancer, Improve the efficiency of cancer discovery by image processing the picture which has cancer and the main goal of them is to use them in remote areas that lack resources [25].

Smartphone applications for melanoma detection by community, patient and generalist clinician users, the using of Smartphone is not limited to the entertainment and communication, now in this day we use Smartphone constantly such as an app for monitoring the weight and practicing sport. In the medical field, most of the doctor using Smartphone in their line of their work, such as using the technology to do an application to find cancer [26], This kind of application is used to improve the performance of the doctors and help them to evaluation the patient carefully, this kind of application do not prevent patient to go the doctor [27]. Skin cancer application is correct more than other application [28].

3. Methodology

The Smart-Dermo system is proposed in this paper by using image procesing and apply clinical rule using ABC clinical technique. The visual representation of proposed Smart-Dermo system is displayed in Fig.1. The development of Smart-Dermo steps is explained in the subsequent paragraphs.

3.1 Dataset Acquisition

The dataset is acquired from three difference sources on total 2200 dermoscopy images including 1100 malignant melanomas (MM) and 1100 of benign tumors. This dataset of 2200 dermoscopy images are used for developing Smart-Dermo application and it is also used to compare with two different state-of-the-art mobile applications. This pigmented skin lesions (PSLs) are obtained from different public and private sources. The first 1300 dermoscopy images were obtained from EDRA-CDROM [29] including 800 of MM and 500 of benign skin lesions. Next, 400 of dermoscopy images are obtained from ISIC [30] dataset online including 100 MM and 300 benign skin lesions.

Furthermore, the third type of dataset is obtained from DermNet [31]. On total, the 300 of MM and 300 of bengin tumors are obtained with different sizes. Finally, the last dataset is acquired from the Department of Dermatology, University of Auckland. Whereas the Ph2-dataset [32] contains a total of 200 dermoscopic images including 80 common nevi, 80 atypical nevi, and 40 melanomas with a resolution of 768 x 560 pixels. From Ph2-dataset, the 30 melanoma and 70 nevus skin lesions are selected to test the performance.

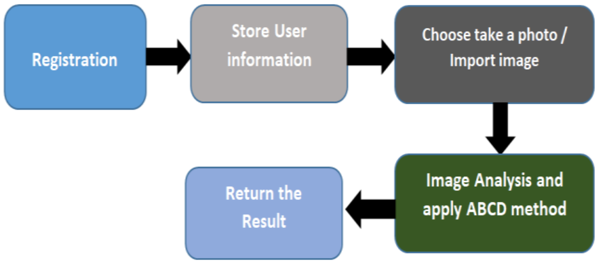


Fig. 1 Systematic flow diagram of Smart-Dermo proposed skin cancer classification system through smartphone-based application

3.2 Proposed Application Development

Classification of skin cancer through Smart-Dermo application is shown in Figure 1. The registration is the first step in the application. The person's information is then stored in the data. Afterwards, the person to the page in Smart-Dermo that makes him chooses to take the picture or lift it from the gallery. After the image is lifted for affected areas of skin, the image is analyzed and the (ABC) matched will apply in all respects. At last, the overall image analysis is returned the result; finally this result will be stored to facilitate patient health tracking. The system architecture of the Smart-Dermo and then user interface design steps are explained in the subsequent paragraphs. Afterwards, the proposed approach in the application is explained and the methodology that have been used to calculate relative risk by apply (ABC) rule. Moreover, the steps are mentioned in details that have been used to build Smart-Dermo application. The detailed steps are visually displayed in Fig.2

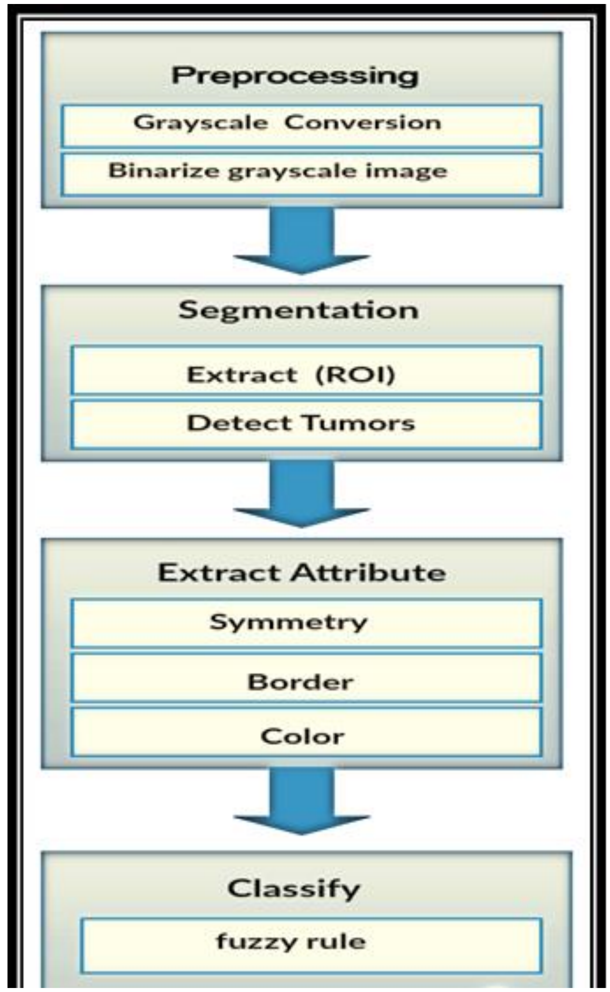


Fig. 2 Methodological development steps for classification of skin lesions using Smart-Dermo smartphone-based application.

3.2.1 Gray-scale conversion

Image capture from digital camera is RGB color image so to perform image processing task, it is required to convert it into grayscale. The grayscale is convert image to value between black and white colors by using a RGB to mat2gray in Matlab as shown in the figure 3(a).

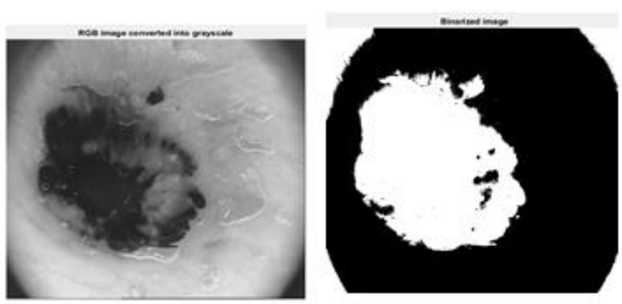
3.2.2 Generate binarize image

After transforming RGB color image into grayscale then image binarize step is performed to develop Smart-Dermo application. The binarize the grayscale image using Otsu's method witch detect the darker spots in the border, Appling graythresh library witch select the largest region in the tumor and ignore the noise also choose the threshold to minimize the color to the black and white pixels. After that we converted the image to binary image, based on threshold as shown in the figure 3(b).

Although Thresholding separates the background pixels from object pixels, but the separated objects are not clear to understand for further processing on these objects (or objects pixels). Since image Thresholding converts grey image into binary image which has only black and white pixels. So, the Threshold image may have very small areas of black pixels (object pixels). These pixels do not form an object. And also the Threshold image may have small area with white pixels within objects (i.e., objects can have gaps of white pixels in them). Image segmentation using mean-shift can be used to fix these problems. So, to remove small areas of black pixels that do not form objects, and to fill gaps within objects, I have used Image Segmentation using mean shift.

3.2.3. Segmentation of skin lesions

Segmentation will be performed after we apply preprocessing, which is extract ROI, and detect tumor. ROI is a way to remove small region in the tumor and focus on the bigger region and libeling it by function call (bwlabel) library, which is libel every region on the tumor and delete the small region. Shown on the figure.13, we try to determine the CenterPoint of the tumor by making the image in the standard form the height and the width are the same size then we use function call (regionprops) this function will calculate everything related with the tumor, it will calculate the centroid, shown in the figure 4.



(a) **(b)**

Fig. 3 Pre-processing step to initial segment tumor region where figure (a) shows the gray-scale converted image and figure (b) represents binary image

3.2.4. Detection of tumors

The detection step for boundary in the tumor is obtained by apply a function call (edge) this function. This step is used to detect the edges of the tumor and draw the boundary as shown in the figure 5.

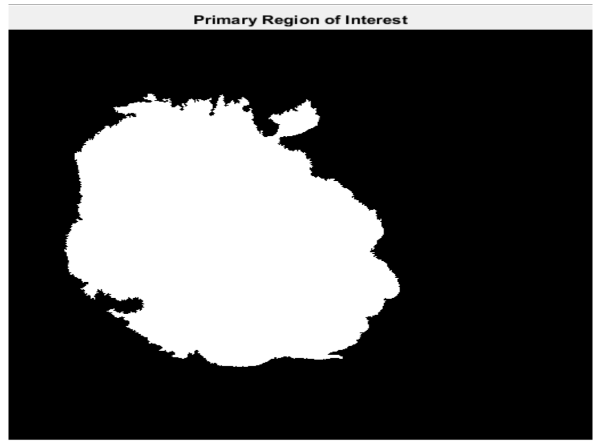


Fig. 4 Tumor region segmentation using simple

Otsu's thresholding technique

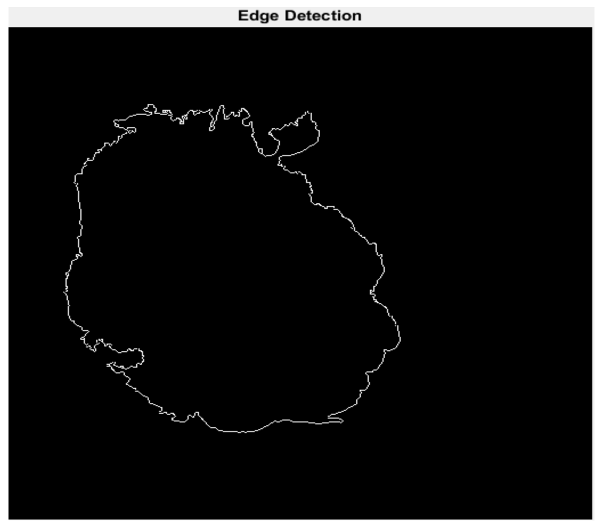


Fig. 5 Tumor region detection by proposed Smart-Dermo application

3.2.5. Detection features from segmented Tumor region

After segmenting tumor region from the background step as a preprocessing step. Next step is to be used to analyze the tumor regions by means the characteristics of the individual. These characteristics are noun as ABC, the self-examination of the skin. This feature is known as asymmetry (A), border (B) and color (c). It is also known as ABC clinical rule to determine the difference between benign and malignant lesions. These features are extracted and defined from the following sub-sections.

a) Asymmetry

In the figure 6, it is observed that how vast difference between misleading area and the surrounding area is the biggest region from the image has been taking, and shows a total inconsistency between the tumor and the other region.

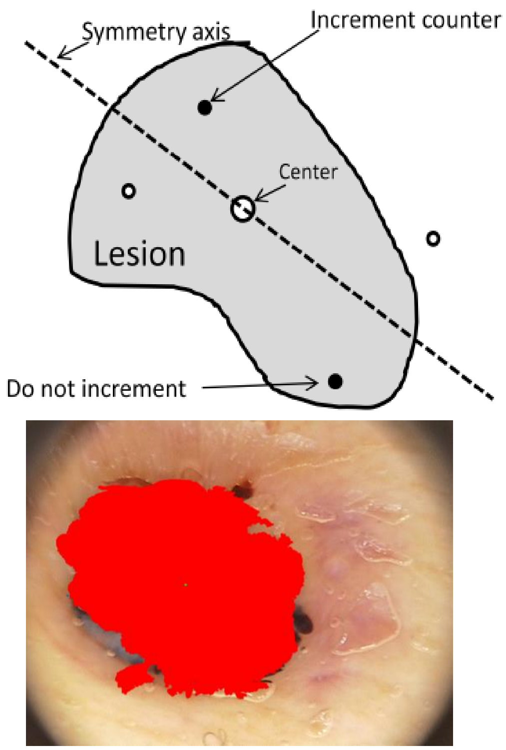


Fig. 6 Calculate asymmetry of tumor region to define "A" attribute of clinical expert formula used in the development of Smart-Dermo application

b) Border

We use Gaussian filter to analyze the mean variation inside the border and measure the pattern and remove the noise inside the tumor by apply the formula

$g(x) = \sqrt{\frac{a}{x}} \cdot e^{-a \cdot x^2}$, as shown in figure 7.

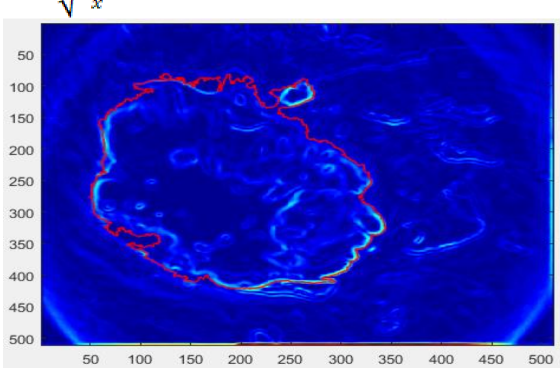
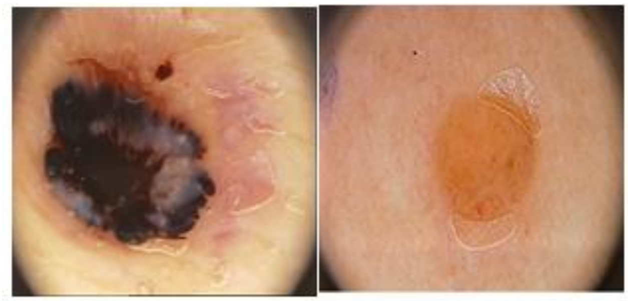


Fig. 7 Calculate border region of tumor region to define "B" attribute of clinical expert formula used in the development of Smart-Dermo application

c) Color



(a) Malignant **(b) Benign**

Fig. 8 Calculate color variation region of tumor region to define "C" attribute of clinical expert formula used in the development of Smart-Dermo application

In the figure 8, the possibility of the image will be melanoma if it have big different in color between area and increase the possibility if the color is darker. In figure 9, it was observed that the degree of color is not darker and that prove there is low possibility if there is melanoma and that call benign.

3.2.6. Classification

We classify a fuzzy rule which is clinical condition to determine the image if it melanoma or non-melanoma aby comparing the result of asymmetry, border, color with the standard measurement of many experiment, shown in figure.20 a result of melanoma and in figure.21the result of non-melanoma.

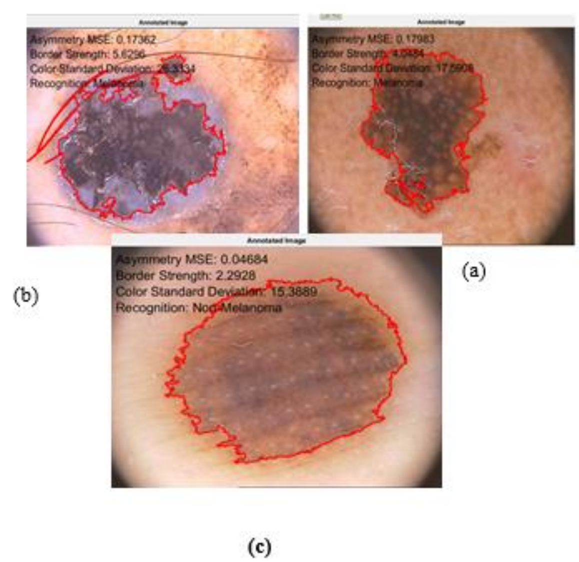


Fig. 9 Classification result obtained by Smart-Dermo application where figures (a, b) represent malignant tumors and figure (c) shows benign lesion.

4. Experimental Results and Discussion

This smart-dermo is implemented on Intel core I7 CPU, 16 GB of RAM, Windows operating system and python language. To test and compare the results with state-of-the-art smart-dermo systems, statistical measures were used as described in the sub-sequent sections. For the testing purpose of skin tumor Recognition, here I will test it with different images (having more than one tumor) to recognize lesions. The purpose of doing this is to check how much the software is accurate.

In this section, a description of implementation is described. First of all, the hardware and software specification details are given to build this tool that have been used to build and operate the application, and then we will describe the implementation tool after that we will include some of the implementation code with details.

4.1 Software and hardware

The following table shows the computer software requirements to run the system. From Table 1 to Table 4, this information is detailed describe including mobile specification that is minimum required to run Smart-Dermo application. It has been built and tested on Android platform.

Table 1: Software requirements to deploy Smart-Dermo application

No	*Items*	*Software Specification*
1	Operating System	Windows 10 Professional Edition
2	Web Server	PHP server
3	Platform	Android Studio

The following table shows the computer hardware requirements to run the proposed Smart-Dermo system.

Table 2: Hardware requirements to deploy Smart-Dermo application

No	*Items*	*Software*
1	CPU	Intel Core i5 3.10GHz
2	Screen Resolution	1280 X 960
3	Network	Ethernet Network Driver
4	Hard Disk	250 GB
5	Time Zone	Arab Standard Time
6	Firewall	Windows Defender

The Classification of Skin Cancer will support any mobile that have an android system version 6 and above. To more precise we will mention the most specifications that must be there in the mobile phone so the application will work.

Table 3: Mobile Environment requirements to deploy Smart-Dermo application

No	*Items*	*Software*
1	Operating System	Android Platform
2	Version	6.1.0
3	Edition	Marshmallow

The hardware specification of mobile devices is given at the minimum standard to run Smart-Dermo application.

Table 4: Mobile Environment requirements to deploy Smart-Dermo application

No	*Items*	*Specifications*
1	CPU	core 2.7 Snapdragon 805
2	RAM	4 GB
3	Digital Camera	16 Mega Pixels
4	Network	GSM / HSPA / LTE/ 5G
5	Memory	16 GB

To perform state-of-the-art comparisons, two other mobile applications are used mobile-skin [11] and m-skin [12]. The experiments are performed on 2200 dermoscopy images including 1100 of malignant melanomas and 1100 of benign skin lesions. The table 5 represents the comparisons result obtained by Smart-Dermo compare to two other studies such as mobile-skin and m-skin in terms of accuracy and time complexity. The visual interface of proposed Smart-Dermo is displayed in Fig.10. From table 5, it is noticed that mobile-skin obtained 78% of accuracy and response time of application is 20s. Whereas, the m-skin achieved 81% of classification accuracy but response time of this application is very higher. It almost reaches to 50s when tested on this dataset. Compare to these two mobile-skin and m-skin, the proposed Smart-Dermo is outperformed in terms of accuracy and time complexity. The proposed Smart-Dermo achieved 992% of classification accuracy to make difference between malignant melanomas and benign tumors along with time taken 15s (seconds).

Table 5: State-of-the-art Comparison on 2200 both malignant melanoma and benign tumors

No	*Methodology*	*Accuracy*	*Time (seconds)*
1	Mobile-Skin[11]	78%	20s
2	m-skin [12]	81%	50s
3	Proposed Smart-Dermo	92%	15s

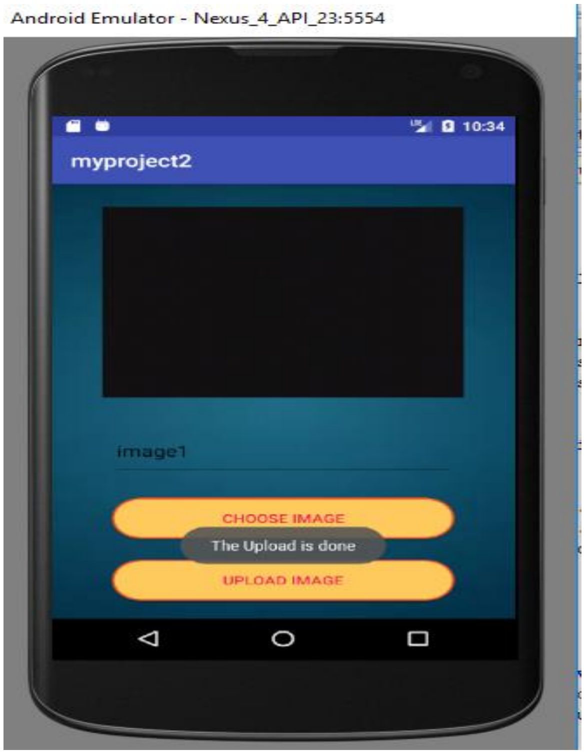


Fig. 10 A graphical user interface (GUI) mobile inter develop as Smart-Dermo application

5. Conclusions

A smartphone-based android application is developed to classify skin lesions using dermoscopic images (Smart-Dermo) is developed in this paper for helping poor person in remote areas due to high expense of pre-screening process. In practice, many studies of health service outcomes found teledermatology reduced waiting times and could result in earlier assessment and treatment. Accordingly, the Smart-Demo application is very helpful to diagnose the skin cancer to detect effective features and classify them by fuzzy-logic derived from artificial intelligence platform. The Smart-Demo helps a patient to diagnosis the skin cancer once in a week to keep track his medical state. In the traditional way, diagnose of skin cancer is very expensive, time-consuming and tedious task. Therefore, the main objective of this paper is to develop an android-based Smart-Demo application that detects the type of skin cancer like melanoma versus non-melanoma and save the time for both the patients and the clinical experts. To develop Smart-Demo application, the image processing techniques, and the fuzzy logic are used to solve this problem through ABCD clinical rule for differentiation among skin tumors. The experimental results on 2200 dermoscopic images indicate that the Smart-Demo application achieved high classification accuracy 92% to detect melanoma in a fast and effective way compare to state-of-the-art methods. As a result, this Smart-Demo application may assist dermatologists to better recognize pigmented skin lesions (PSLs).

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