

AN ANDROID-BASED PATTERN RECOGNITION APPLICATION FOR THE CHARACTERIZATION OF EPIDERMAL MELANOMA

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Abstract. *Malignant melanoma is currently one of the leading cancers among white-skinned populations around the world, mainly due to the changes in life styles and the significant increase in ultraviolet radiation. Although the mortality rate due to melanomas was about 70%, forty years ago, nowadays, a survival rate of 70% is claimed, which is attributed to early diagnosis. Hence, early stage detection of melanoma is of major significance for increasing chances of long term survival of affected patients. The most effective method for early detection is skin self-examination, a procedure often underestimated by individuals, resulting in poor prognosis. Therefore, the aim of the present study is to address the need for early and accurate characterization of skin lesions through the design and implementation of an Android application that enables users identify areas on their skin that may need attention from an expert physician. The proposed application uses the phone's camera feature to take a picture of a skin lesion/mole, communicates with a remote specialized pattern recognition system, via a set of XML Web Services, and within seconds receives a risk analysis of their uploaded image being a melanoma. The proposed system was trained using an image database from New Zealand Dermatological Society, and was reviewed by an expert dermatologist.*

INTRODUCTION

Malignant melanoma is nowadays one of the leading cancers among many white-skinned populations around the world, and it has recently dramatically increased mainly due to the changes in life styles and the significant increase in ultraviolet radiation^[15]. While the mortality rate due to melanomas was about 70%, forty years ago, nowadays, a survival rate of 70% is claimed, which is attributed to early diagnosis. Therefore, early stage detection of melanoma is of major significance for increasing chances of long term survival of affected patients.

The most effective method for early detection is skin self-examination. The individual investigates skin changes, especially in moles (existing or new) and reports to the doctor when suspicious regions require consultation from the medical experts. During the first stages of the disease, complete treatment is most probable for most patients, with at least 5 year survival rates for the 95% of cases. However, it has been shown that skin self-examination is usually underestimated by individuals, resulting in poor prognosis. Melanoma detected in later stages, is extremely aggressive and deadly, resulting in patient suffering and increase mortality/morbidity. This has driven researchers to seek solutions in automated, early diagnosis of skin lesions^[1-15] and to render such procedures accessible to the general public.

Automated image analysis systems for the characterization of epidermic melanoma, based on recent technology, can be deployed as an excellent useful tool for prescreening of suspicious regions on human skin. The first studies for automated classification of pigmented skin lesion images are referred in literature from 1987^[16]. Although, those systems cannot provide a definite diagnosis, they can help physicians to focus on certain, suspicious cases, for malignant melanoma.

Recently, with the rapid development of handheld devices, such as smartphones and tablets, this need was addressed by applications that reclaim all the recent technology applied, such as the embedded camera and the fast processors^[5-8]. The Cronian Labs Corporation has already suggested the "Skin Scan" application for Apple iOS operating system using pattern recognition algorithms and

calculating several features, characterizes the melanoma in three categories (low, medium and high risk), based on growth rate. . The Health Discovery Corporation has also suggested a similar application for iOS and Android, called “MelApp” using a database of melanoma images from John Hopkins University. However, these applications are in a preliminary stage of being employed to safely characterize skin lesions as part of routine self-examination. The proposed application aims to provide self-screening of skin lesions for early and accurate detection of epidermic melanoma, by a friendly graphical user interface (GUI) that utilizes the device’s camera to photograph the suspicious region and provide a first decision.

MATERIALS AND METHODS

System Overview

The proposed system consists of three main parts developed in Java programming language: (i) a mobile application running on Android-based devices (i.e. smartphones, tablets etc.), (ii) a remote Pattern Recognition system acting as a virtual dermatologist, and (iii) a set of web services acting as an intermediate layer and providing access to the Remote PR system (see Figure 1). In a typical use case scenario, the user of the mobile application takes a photo of a suspicious skin region and marks the segment which contains the abnormality. Then, the application, seamlessly, communicates with the remote PR system and informs the user with the result.

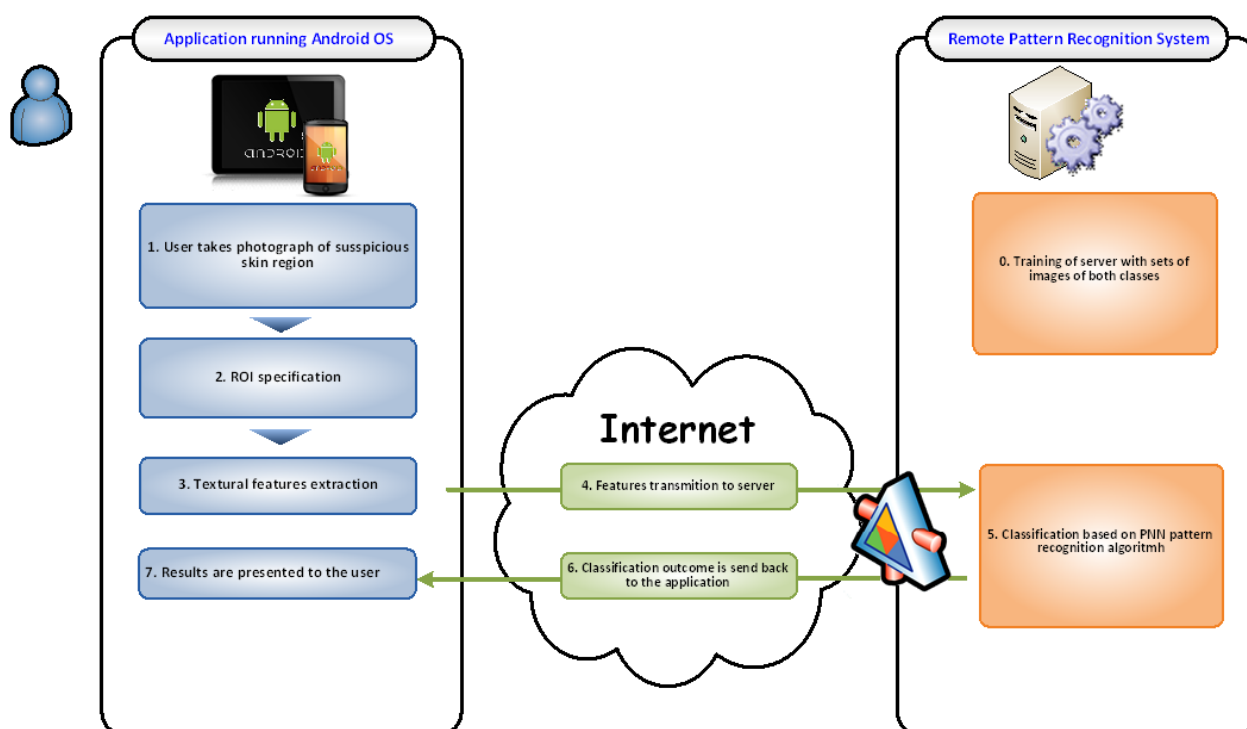


Figure 1: Graphic presentation of application's process

Android application – Client

The proposed mobile application was developed in Java programming language taking full advantage of the Android OS version 2.3 with codename “Gingerbread”, since, based on recent statistics, it is the version with the highest percentage of use among smartphone users. However, the application is compatible with later versions of Android, like the 4.0 with codename “Ice Cream Sandwich”.

The software packages used during implementation of the mobile application included the Eclipse Integrated Development Environment (IDE), the Android Development Tools (ADT) plugin for Eclipse, the Android Software Development Kit (SDK), and Java Standard Edition Development Kit (JDK).

Once started, the proposed mobile application presents the user with a simple and clean menu, giving him the choice to either use the embedded camera to capture an image of the suspicious area-lesion, or select an already saved photo from his phone gallery. In the next step, the user specifies a region of interest (ROI) within the image via the touchscreen interface (see Figure 2a) and the cropped image of the suspicious skin region is then used to extract the set of 12 textural features mentioned afore, via a custom made textural extraction algorithm developed in Java. Then, with by invoking an XML web service, the extracted set of features is transmitted to the remote PR system requesting classification of the suspicious skin area (see Figure 2b). Within a few seconds, the remote PR system responds with the result of the classification process. The latter is then presented to the user through the GUI (see Figure 2c).

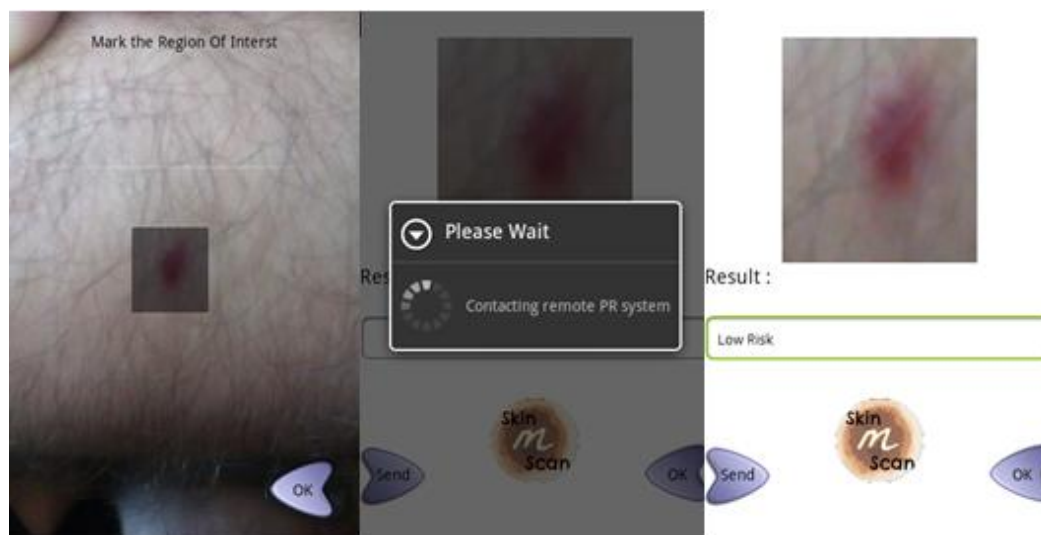


Figure 2: (a) ROI selection, (b) Communication with remote PR system, (c) Result of processing

Remote Pattern Recognition System

The proposed PR system played the role of a remote, virtual dermatologist and was based on the Probabilistic Neural Network (PNN) Classifier. Design of the classifier was accomplished using textural features extracted from a set of 130 images describing skin lesions from the database of New Zealand Dermatological Society. Both malignant (88) and benign (42) melanoma cases were histologically verified.

Access to the remote PR system is accomplished through a set of web services that enable the mobile application to send features extracted from a skin image and receive the result of the classification. The implemented XML Web Services were based on the JAX-WS model and relied on the SOAP protocol for message exchange. The software packages used for their implementation and deployment included the NetBeans IDE, the Java JDK, and Glashfish Application Server.

The hardware chosen for deployment of the remote PR system was a typical desktop personal computer, featuring an Intel Core i5 processor at 3.33 MHz, 4.00GB RAM, with Microsoft Windows 7.

Textural Feature Extraction

Texture, as depicted on images, may be described qualitatively (fine, smooth, coarse, rippled, mottled, irregular or lineated) for diagnosis^[17], or it may be quantified for use in image analysis software. Texture quantification may be achieved by means of the pixel-matrix: histogram, co-occurrence matrix, and run-length matrix. For the training of our backend system we implemented 12 features, the first three were calculated from the first order statistics (mean value, standard deviation, skewness and kurtosis)^[17], and the remaining 8 were calculated from Grey Level Co-occurrence Matrix (GLCM). The co-occurrence matrix describes the number of times (frequency) that two adjacent greylevels of the image matrix appear. From GLCM we can calculate the angular second-moment (ASM) feature, a measure of homogeneity of the image, the contrast feature, which is a measure of contrast or the amount of local variations present in an image, and the correlation feature, which represents a measure of gray-tone linear-dependencies in the image^[17]. All features used in this study are shown on Table 1. Hence, each segmented ROI was represented by a 12 feature vector. Thus, two features-classes were formed, malignant and benign.

A/A	Feature	A/A	Feature
1	Mean Value	7	Mean Correlation
2	Standard Deviation	8	Correlation Range
3	Skewness	9	Mean ASM
4	Kurtosis	10	ASM Range
5	Mean Contrast	11	Mean Homogeneity
6	Contrast Range	12	Homogeneity Range

Table 1: Complete list of extracted features

Classification

For classification of the investigating, unknown pattern, to one of two available classes, the Probabilistic Neural Network (PNN) classifier was used. PNN is a Bayes-Parzen classifier^[18]. The PNN was first introduced in 1989^[19], and was shown how the Bayes-Parzen classifier could be broken up into a large number of simple processes implemented in a multilayer neural network each of which could be run independently in parallel^[20].

The most important advantage of the PNN is that its training is very easy and fast. Other advantages of the PNN are^[19]: (i) The shape of the decision surfaces can be made as complex as necessary, or as simple as desired, (ii) The decision surfaces can approach Bayes optimal, (iii) Erroneous samples are tolerated, (iv) Sparse samples are adequate for network performance, (v) For time-varying statistics, old patterns can be overwritten with new patterns.

Equation 1 presents the discriminant function of a PNN classifier. Hence for class j :

$$g_j(\mathbf{x}) = \frac{1}{(2\pi)^{p/2} \sigma^{pN_j}} \sum_{i=1}^{N_j} w(y_i) \quad (1)$$

where $w(y_i)$ is a function of:

$$y_i = \frac{\sqrt{\|\mathbf{x} - \mathbf{x}_i\|^2}}{\sigma} \quad (2)$$

In case

$$w(y) = \frac{1}{1+y^2} \quad (3)$$

which leads to a discriminant function with a Reciprocal kernel:

$$g_j(\mathbf{x}) = \frac{1}{(2\pi)^{p/2} \sigma^{pN_j}} \sum_{i=1}^{N_j} \frac{1}{1 + \|\mathbf{x} - \mathbf{x}_i\|^2 / \sigma^2} \quad (4)$$

where \mathbf{x} denotes the test pattern vector to be classified, \mathbf{x}_i the i -th training pattern vector, N_j the number of patterns in class j , σ a smoothing parameter, and p is the dimensionality of the feature vector. The test pattern \mathbf{x} is then classified under the class with the larger discriminant function value.

Feature reduction and system evaluation

Feature selection was performed by means of the leave-one-out method^[21], whereby all possible feature combinations were used to design and evaluate the system. The classifier was evaluated using features considering melanoma images. The feature combination that was selected, provided a balance between sensitivity and specificity values, although with a lower than best possible overall success. The chosen feature combination included skewness, standard deviation and mean contrast.

RESULTS

The proposed solution was reviewed by an expert and achieved positive remarks in terms of usability, stability and performance and was found to be a useful self-examination tool. The GUI was

found to be simple and intuitive, providing a pleasant and rich user experience, even to users unfamiliar with smartphone and tablet based applications.

The proposed application achieved 67.4% accuracy in discriminating benign cases, and 70.5% in discriminating malignant cases, resulting in overall accuracy of 69.5%, as illustrated in the Table 2.

The application's response time fell within acceptable limits, varying from 10 to 15 seconds, depending on the server's hardware configuration and on the type (Wi-Fi, 3G, etc.) and the congestion state of the network used.

	Classified as Benign	Classified as Malignant	Sensitivity	Specificity	Overall Accuracy
Benign Cases	29	14	70.5%	67.4%	69.5%
Malignant Cases	26	62			

Table 2: Truth Table of the proposed PR system

DISCUSSION

The combination of modern and powerful handheld devices, such as smartphones and tablets, and recent operating systems, could lead to providing user-friendly medical applications for everyday use.

The score of the proposed system is lower compared to this of "Skin Scan" application, which achieves 83.76% overall success, 80.76% sensitivity and 85.57% specificity^[22]. The main reason behind these results is the set of images used for the training of the classifier. The latter included images taken under different shooting conditions, such as focus, exposure, brightness and distance from the mole, and therefore, introducing high degree of heterogeneity. Thus, a more close collaboration with physicians and dermatologists could lead to better results.

Additionally, in order to boost the achieved accuracy, more sophisticated PR methods and features have to be incorporated. The proposed system design, featuring remote processing capabilities, enables even computationally demanding algorithms to be easily integrated.

Furthermore, the use of XML Web Services promoted the system's interoperability, providing the grounds for easier development of similar applications for other platforms, i.e. Apple's iOS, Microsoft's Windows Phone.

Finally, the proposed system can further benefit from the relentless evolution of modern smartphones that promise more powerful processors and cameras with higher resolution.

CONCLUSION

By exploiting state-of-art technology, an Android-based pattern recognition platform was designed and achieved acceptable accuracy in discriminating malignant from benign cases.

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