Vi-da: vitiligo diagnostic assistance mobile application

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Abstract. Vitiligo is a skin disorder in which white patches of depigmentation appear on different parts of the body. Usually, patients come to hospitals or clinics to have their vitiligo conditions assessed. This can be very tiring to the patients, as vitiligo treatments usually take a relatively long period of time, which can range from months to years. To address this challenge, we present in this paper a prototype of an Android-based mobile application called Vi-DA, which stands for Vitiligo Diagnostic Assistance. Vi-DA consists of three subsystems, which are user sign-up subsystem, camera and image analysis subsystem, and progress report subsystem. The mobile application was developed in Java programming language and uses MySQL as the database system. Vi-DA adopts a vitiligo segmentation algorithm to segment input image into normal skin area, vitiligo skin area, and non-skin area. Results showed that Vi-DA gave comparable results to the previous system implemented in Matlab. User acceptance testing results also showed that all respondents agreed on the usefulness of the system and agreed to use Vi-DA again in the future. Vi-DA benefits both dermatologists and patients as not only a computer-aided diagnosis (CAD) tool but also as a smart application that can be used for self-assessment at home.

1. Introduction
Amongst skin diseases, vitiligo is a rare skin disorder in which white patches of depigmentation appear on the skin. Vitiligo is an abnormality affecting melanocytes, which are the pigment-producing cells in the skin, where the cells are destroyed, resulting in depigmentation on different parts of the body. This pigment loss appears as brighter mottles in the skin and sometimes might also take place on the mucous membranes, retina, and hair follicles [1]. Though vitiligo patients generally do not feel ill, the disease can have profound psychological impact as the appearance of white patches can be very distressing. This emotional distress is more common in patients with darker skin tone as the white patches tend to be more noticeable. Currently there are several treatment options for vitiligo. Common treatments include topical corticosteroid, oral medication, UVB light therapy, and surgery. Due to the relatively long duration of the treatments, which may range from months to years, patients might feel discouraged. Some patients have even quitted treatments midway from not seeing any visible progress. In addition, having to physically come to the hospitals or clinics frequently to get their vitiligo conditions assessed can be very tiring.

To address this challenging situation, a prototype of a vitiligo diagnostic assistance system is proposed in this research. The system is called Vi-DA, which stands for Vitiligo Diagnostic Assistance. The mobile application was developed on Android in Java programming language and uses a MySQL database. Vi-DA automatically segments vitiligo-affected skin from the normal skin and calculates the ratio between vitiligo-affected skin area and the whole skin area for specific parts of the body, for
example face, hand, and chest. As Vi-DA provides quantitative assessment, it can help dermatologists and patients discover minor progress which might have been left unnoticed if the skin examination is performed manually. Vi-DA benefits both dermatologists and patients in two ways. Firstly, the system can be used as a computer-aided diagnosis (CAD) tool. Secondly, the mobile application can also be used by vitiligo patients to perform self-assessment at home. In addition, patients can come to the clinic less frequently as patients can capture photographs of their skin and perform analysis by using the mobile application. The data are stored in a database and can be sent to the attending dermatologists for consultations.

Today, there are many mobile applications dedicated to dermatology. These applications can generally be categorized into two types—social networking platforms [2] and computer-aided diagnostic systems [3]. The first type is usually educative in nature, and several apps provide features for consultations with dermatologists. First Derm app [4] is a mobile application with which users can take pictures of their skin problems, input descriptions of the problems, and press ‘send’. Within 24 hours, there will be a dermatologist responding with a medical opinion and suggestion for the first step treatment options and whether the problem requires an immediate visit to a doctor in-person. Vitiligo Treatment + Symptoms app [5], Vitiligo Handbook app [6], and Skin Disease and Treatment app [7] provide information about vitiligo and treatment options. Some of these apps aim to build a community and support groups for people with vitiligo. For example, Vitiligomatch app [8] provides vitiligo sufferers with a social networking platform to interact with each other.

This research focuses on the second type, which is as a computer-aided diagnosis (CAD) system. To the best of our knowledge, there is still no Android application for vitiligo image analysis. However, there are existing mobile applications embedded with image analysis algorithms which are targeted to other skin diseases. Molexplore [9], Skin Vision [10], Miiskin - Melanoma Skin Cancer [11], and UM Skin Check [12] analyze skin lesions for skin cancer detection. If the lesion is categorized as suspicious or at a risky level, the user is recommended to follow up with a dermatologist. The Molexplore Melanoma Skin Cancer app [9] allows users to perform a comprehensive monitoring of moles on different parts of the body. The app also includes an approximation of the UV index at user’s location. The Skin Vision app [10] automatically assesses the risk level of a mole through its camera algorithm. It also provides expert review which refers to assessments given by dermatologists. The Miiskin app [11] focuses on mole tracking. The UM Skin Check app [12] provides several functions in the app, including guidance for self-exam, full-body survey, lesion tracker and sun safety information. In general, all these apps have image capture and analysis capability. Some of the apps focus on quantitative analysis, while some others focus on telemedicine practice by providing consultations with dermatologist through the apps.

2. System Design & Implementation

The overall system architecture is illustrated in Fig. 1. The mobile app was developed using Android Studio 2.1 in Java programming language with a MySQL database [13,14]. The system was developed using the waterfall approach. The main functions of Vi-DA include: 1) user account creation and login, 2) user profile management, 3) image capture and retrieval, 4) image analysis (which includes skin segmentation and vitiligo area percentage calculation), and 5) data visualization.

![Figure 1. Vi-DA app System Architecture](image-url)

This application needs the user to register to access the content. Username and password are required to login to the system, and for a new user, who does not have an account yet, he/she will be directed to
the user registration screen which requires user to enter username, password and other basic information. Successful authentication will bring the user to the home screen which shows a list of photographs which have been analyzed and the corresponding analysis dates and results. User can access his/her profile and change his/her particulars and login information.

Figure 2. User Interface design for Vi-DA app: (a) image analysis progress, (b) image analysis result, (c) progress visualization, (d) record history.

There are two sources for image analysis: from the device’s photo gallery through the image retrieval function in Android or from device’s camera by using the photo capture function in Android. The photograph is further processed by performing skin segmentation followed by vitiligo segmentation using an algorithm developed by Nurhudatiana [15]. The ratio between vitiligo segment and whole skin segment is then calculated (Fig. 2(a)). The segmentation algorithm uses the Fuzzy C-Means (FCM) clustering algorithm to segment input image into three clusters (i.e., background/non-skin, normal skin, and vitiligo skin), followed by vitiligo percentage calculation by taking the ratio between the total number of vitiligo skin pixels and the total number of skin pixels [15]. The algorithm was originally written in Matlab and was rewritten in Java for the Android app. The algorithm is described in detail as follow:

Step 1: Read the input RGB image as Bitmap file.

Step 2: Convert the RGB image into YCbCr image using the formula:

\[
Y = 0.299*R + 0.587*G + 0.114*B \\
C_b = -0.1687*R - 0.3313*G + 0.5*B + 128 \\
C_r = 0.5*R - 0.4187*G - 0.0813*B + 128
\]

(1)

Step 3: Extract the Cr channel from the YCbCr image.

Step 4: Apply FCM algorithm onto the Cr channel (grayscale image) obtained from Step 3. The algorithm segments the Cr image into two clusters - background area (darker region) and skin area (brighter region). The skin cluster is represented by higher intensity values, whose indexes are then stored into skin index array S.

Step 5: Extract the Blue channel from the original RGB image given in Step 1.

Step 6: Apply FCM algorithm for the second time onto the Blue channel (grayscale image) obtained from Step 5 by taking only the pixels included in S. In this round, the pixels are further separated into two clusters - normal skin area (darker region) and vitiligo area (brighter region).

Step 7: Calculate the depigmentation percentage:
The analysis result is displayed as depigmentation percentage (see Fig. 2(b)). User is allowed to type additional information related to the analyzed image in text form including caption (e.g., after first treatment), description, and the body part category from which the image was captured (e.g., right arm). When the save button is clicked, the system automatically saves the data and timestamp. Fig. 2(c) shows the progress tracking visualization screen, which shows the depigmentation percentage values from time to time in the form of a scatter plot diagram. Each data point is linked to the photograph and the corresponding analysis. Finally, Fig. 2(d) shows record history screen categorized by body part.

3. Results
Because Vi-DA app was developed using an algorithm previously written in a different programming language and environment, two results are reported here: 1) the performance of the image analysis algorithm embedded in the Android app compared with the performance of the previous Matlab implementation, and 2) the result of user acceptance testing (UAT) involving vitiligo patients in a dermatology clinic in North Jakarta, Indonesia. A questionnaire-based survey based on the information systems success model was distributed to the respondents to collect UAT results [16].

3.1. Algorithm result
The comparison result in Fig. 3 shows that in general, the percentage difference between the Matlab implementation and the Vi-DA app is small, except that for the arm body part, noise was observed at the arm boundary for the Matlab implementation.

Figure 3. Comparison of the segmentation output given by previous Matlab implementation [15] and Vi-DA app.
It can be observed that both implementations give consistent performance. In addition, the weakness of the previous Matlab implementation could be handled well by the Vi-DA app. The Matlab implementation produced rough edges at the arm boundary and the middle part of the palm was wrongly segmented as background. The Vi-DA app fixed the problem and gave smoother segmentation output for all four different body parts.

3.2. User Acceptance Testing (UAT) Result

To test system usability, user acceptance testing (UAT) was conducted. The UAT involved three patients in the clinic who were diagnosed with vitiligo and were undergoing treatments. These respondents were asked to use Vi-DA app for a day and surveyed regarding their uses of the app through questionnaires. The questionnaires consisted of ten questions and used 5-scale Likert scale to indicate each respondent’s level of agreement with the statements provided in the questionnaire. The respondents collected were “1” for strongly disagree, “2” for disagree, “3” for neutral, “4” for agree, and “5” for strongly agree. As the app was still in prototype phase, the respondents were also asked to provide input on how to improve the system. The responses are provided in Fig. 4.

Figure 4. Responses obtained from user acceptance testing (UAT)

All respondents strongly agreed that the Vi-DA app is useful for them. They also agreed that the app was helpful as self-diagnosis assistance. However, these respondents generally disagreed on the responsiveness of the app. This is because it could take up to 60 seconds to process a single image. This was considered too slow for them and requires improvement. When these respondents were asked whether they would like to use Vi-DA in the future, all of them agreed to use this app and they would choose to use Vi-DA over conventional visit to the clinic.

4. Conclusion & Future Work

As reported in the UAT survey results, some improvements need to be made to the system. The first priority is to reduce the processing speed. In average, a photograph requires a minute to process, and this can be a problem since user generally expects to wait for 5-10 seconds for a live (real-time) processing. One way to reduce the time consumption for image analysis is by reducing the number of iterations in the clustering process during the image segmentation. However, further experiment is required to determine the proper number of iterations to achieve optimum segmentation output. Another way is to further reduce the image size to be processed, and further experiment is required to determine the optimum image size which will not compromise the segmentation output quality.

There are also several variability factors during the image acquisition stage which could affect the calculation of the results. Those factors include illumination, distance, and viewpoint differences. These
inconsistencies could result in high variability in the depigmentation percentage. To overcome the problem, a preprocessing module will be added to the system before the image segmentation module. This preprocessing step will help to normalize the lighting/color in the image before analysis. In addition, a functionality to guide the image capture process in terms of lighting (e.g., white light and not yellow light), viewpoint (e.g., straight pose), and distance (e.g., to meet certain value for face-to-frame ratio) will be added so that the variability can be further minimized.

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