ARAŞTIRMA / RESEARCH

An Application for Automated Diagnosis of Facial Dermatological Diseases

Yüzdeki Dermatolojik Hastalıkların Otomatik Teşhisi İçin Bir Uygulama

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Abstract

Objective: Dermatological diseases are public health problems. Several factors including subjective diagnosis, lack of enough dermatologists, inability to go to a dermatologist due to old age, psychological problems or pandemic like coronavirus enforce to use automated techniques in dermatology. In the literature, there are many techniques on automated lesion classification to provide accurate, objective, reliable and reproducible results for the diagnosis of several dermatological diseases. However, although the techniques are promising, they become useless without a user interface for many patients or users who don't have any prior knowledge on how to choose or set appropriate parameters and how to run source codes. Therefore, the objective of this work is to develop an application with an efficient user interface for patients and dermatologists.

Material and Method: The application has been developed with Matlab (R2019) using digital photographs provided from public databases.

Results: An application with an efficient and friendly user interface has been designed and implemented for patients with dermatological diseases.

Conclusion: The application can present results of (i) lesion segmentation, (ii) image classification, and (iii) analysis according to time periods. It provides to view data easily and parametrization of the network. It can also be useful for dermatologists to analyze lesions or make decisions about diseases. Also, the application can be used for educational purpose since it provides information and tests on dermatological diseases. Therefore, it can be useful for both patients and researchers working in this area.

Keywords: Classification, deep learning, dermatological diseases, diagnosis, skin lesion.

Öz

Amaç: Dermatolojik hastalıklar halk sağlığı problemleridir. Teşhisin öznel olması, yeterli dermatolog bulunmaması, yaşlılık, psikolojik sorunlar veya koronavirüs salgını gibi nedenlerle dermatoloğa gidememek gibi çeşitli faktörler dermatolojide otomatik tekniklerin kullanılmasını zorunlu hale getirmiştir. Literatürde, çeşitli dermatolojik hastalıkların teşhisinde doğru, objektif, güvenilir ve tekrarlanabilir sonuçlar sağlamak için otomatik lezyon sınıflandırması üzerine birçok teknik vardır. Fakat bu teknikler, ümit verici olmasına rağmen, uygun parametrelerin nasıl seçileceği veya nasıl ayarlanacağı ve kaynak kodlarının nasıl çalıştırılacağı konusunda önceden bilgisi olmayan birçok hasta veya kullanıcı için, bir ara yüz olmadan faydasız hale gelmektedirler. Bu nedenle, bu çalışmanın amacı, hastalar ve dermatologlar için etkili bir kullanıcı ara yüzüne sahip bir uygulama geliştirmektir.

Gereç ve Yöntem: Uygulama genel veri tabanlarından sağlanan dijital fotoğraflar kullanılarak Matlab (R2019) ile geliştirilmiştir.

Bulgular: Dermatolojik hastalıkları olan hastalar için etkili ve kullanıcı dostu ara yüze sahip bir uygulama tasarlanmış ve geliştirilmiştir.

Sonuç: Uygulama, (i) lezyon bölütleme, (ii) görüntü sınıflandırması ve (iii) zaman periyotlarına göre analiz sonuçlarını sunmaktadır. Verilerin kolayca görüntülenmesini ve ağın parametrelendirilmesini sağlamaktadır. Dermatologlar tarafından lezyon analizinde veya karar verme aşamasında da kullanılabilir. Ayrıca uygulama, dermatolojik hastalıklar hakkında bilgi ve testler sağladığı için eğitim amaçlı da kullanılabilmektedir. Dolayısıyla bu hem hastalar hem de bu alanda çalışan araştırmacılar için faydalı olacaktır.

Anahtar Kelimeler: Sınıflandırma, derin öğrenme, dermatolojik hastalıklar, teşhis, deri lezyonu.

1. Introduction

An important part and the largest organ of our body is skin. It does not only protect our body from infections but also produces several vitamins such as the vital vitamin-D. However, various factors such as humidity, climate conditions, age, food habits, ultraviolet radiations of the sun, and genetic factors can affect skin and cause variety of dermatological diseases. Although mostly acne, rosacea, eczema, and hemangioma are known, there are more than 3000 kinds of dermatological diseases (1,2).

Dermatological diseases are known as the fourth most common of illnesses (2). Studies about burden and prevalence of the diseases are usually performed with small clinical samples or based on national researches (3). For instance, according to a study on skin disorders in the United States showed that one out of every three Americans visited a dermatologist in 2013 due to a skin ailment, and the cost for the United States' health system was $75 billion (4). Patients often do not visit a dermatologist or consult general practitioners, if there is not enough dermatologist. Therefore, the diseases are much more common than it is estimated (2).

Accurate and early diagnosis is needed to apply an appropriate and early treatment for many dermatological diseases, such as melanoma, which is a kind of skin cancer. If melanoma is detected at the early stage (zeroth or first stage), the disease is 90% curable with surgical operations. However, if the disease has progressed until the fourth stage then a median life-expectancy becomes less than 12 months (5).

In conventional, diagnosis is mainly provided manually by visual evaluations and examinations of lesions. However, results of the conventional approach can be unreliable, irreproducible and time-demanding outcomes. Because, the approach is subjective and based on visual perceptions and also the experience level of dermatologists (6, 7). Therefore, semi-/full-automated methods have been proposed to obtain accurate, reliable, and reproducible results in dermatology by computerized diagnosis (8-11). Computer-assisted diagnosis is also cost-effective when it is compared to the conventional diagnosis whose cost can increase nearly at every visit to dermatologists.

Deep learning-based techniques have great potential in pattern classification and they are promising for automated real-time diagnosis of dermatological diseases (12). Most of them have been developed using dermoscopy or clinical images and handled only one kind of dermatological diseases, such as skin cancer. In a few recent studies (13-15), digital photographs have been used with deep neural networks to diagnose several dermatological diseases except skin cancer. For example, AlexNet model has been applied in (13) to diagnose acne, keratosis, eczema herpeticum, and utricaria. According to the experimental results reported by the authors, the model can classify those diseases with 85.7%, 92.3%, 93.3%, and 92.8% accuracy, respectively.

The authors in (15) implemented tight versions of three models (Inception-V4, DenseNet and ResNet-18) to diagnose acne. According to their comparative evaluations, Inception-V4 provided the highest performance with 67% accuracy.

In a more recent work (14), five common dermatological diseases have been handled and a new network model based on DenseNet201 has been implemented. Also, nine widely used deep networks (VGG-16, VGG-19, GoogleNet, Xception, Inveption-V3, Inception-ResNet-V2, ResNet-18, and its deeper structures as ResNet-50 and ResNet-101) have been applied with the same image data sets to compare their performances. It has been reported that the proposed network architecture can achieve diagnosis with an average of 95.24% accuracy.

In the literature, the proposed deep learning-based methods are usually not open-source. Even if their source codes are available, they become useless for many end-users who generally do not have enough programming information to run them without a user-friendly interface. Therefore, although computerized techniques have been proposed, they may not be opened and used by dermatologists or patients.

Although, user interfaces have been proposed for different purposes such as hypertension diagnosis (16), radiological (17) and eye disease diagnosis (18), according to the best of our knowledge, there is not a user interface with the above properties in the literature. There are some smartphone applications proposed for automated classification of dermatological diseases (19-22). However, except the recent work in (22) which uses a lightweight architecture rather than a dense network structure and produces results with 94.76% accuracy, the five types of diseases handled in this work have not been handled in them. Therefore, we believe that the application will be useful for both patients and the users who are working on computer-assisted diagnosis in dermatology.

2. Materials and Methods

In this work, an application with an efficient user interface has been designed and developed for this purpose. The application can present results of (i) lesion segmentation, (ii) image classification and (iii) analysis according to time periods. It provides to view data easily and parametrization of the network. Also, the application can be used for educational purpose since it provides information and tests on dermatological diseases.

Matlab (2019) has been used to design and implement the user interface. The images used in this work are digital photographs. Because, nowadays, mobile phones are commonly used in worldwide and digital photographs having high quality can be obtained easily at anywhere/anytime by them. Public image databases (e.g., in (23,24)), have been used. Five facial diseases (seborrheic dermatitis, rosacea, hemangioma, psoriasis, acne vulgaris) have been considered in this work. Therefore, the photographs showing those five diseases have been used.

2.1. Lesion Segmentation and Classification

In this work, lesion detection and segmentation has been provided by the F-ADFD (Fully Automated Detection of Facial Disorders) method (14). The F-ADFD method detects lesions by using a k-means based clustering after noise reduction and contrast enhancement processes. Noise reduction is provided with Weiner filtering by:

$$W(\mathrm{x},\mathrm{y}) = \left[\left(\sigma^2 - k^2\right)/\sigma^2\right]\left(I(x,y) - \mu\right) + \mu \quad (1)$$

where refers to grayscale form of an input photograph, σ and μ terms refer to the variance and mean values that are computed using values of 8 pixels adjacent to each pixel. The average value of local variances is represented by k2. To provide contrast enhancement, images are converted from RGB space to La*b* space, and double-type data in the images are scaled to [0 1] rage. Contrast enhancement is applied merely for the values in the luminosity channel (i.e., a* and b* channels are kept as the same). For this purpose, merely the pixels located in the region of one percent from the bottom and top side are saturated. At the end of the enhancement step, the images are converted to RGB space.

Lesion detection is performed according to the intensity values. Because, lesion regions correspond to the pixels with higher intensity values when they are compared with the remaining pixel values in the images. Therefore, pixel values are clustered into clusters with k-means, and the pixels whose values are categorized in the last two clusters are chosen. For instance, the clusters are (i) background corresponding to the zero-valued pixels, (ii) gray, (iii) bright gray, (iv) brighter, and (v) the brightest gray level valued pixels in case of clustering an image into 5 clusters. Then, the pixels whose values are categorized in the fourth and fifth clusters are chosen. The number of clusters required in the k-means technique is obtained by Elbow algorithm (25). The chosen pixels are used to generate a binary image which is used to obtain the first level set function. The level set function evolves at each iteration in the segmentation step and stops when it reaches lesion boundaries (14). The images showing only lesions obtained from the segmentation step are classified in the classification step. Lesion classification is performed by using the deep network known as DenseNET201 architecture (26) which includes dense convolutional layers.

In this work, a major modification of the DenseNET201 is integration of a combined loss function instead of the standard cross-entropy. The reason is that a loss function in a deep network architecture has a major role in classification since it indicates the distinction between ground-truth and predicted output value. During the training stage, the error obtained from the loss function is minimized.

The cross-entropy is widely used in the literature due to its clear theory (27-29). However, feature discrimination is not always efficient with this loss function (26). Therefore, a loss function, which is obtained by combining mutual information and cross-entropy, is used in this work. The loss function is defined as (22):

$$Hybrid_{loss}(X,Y) = \frac{1}{4N}E(X,Y) + \frac{3}{4K}Loss_{NI}(X,Y) \quad (2)$$

In (2), the terms X and Y refer to the samples and labels, the terms K and N correspond to the number of classes and samples. The term E(X,Y) corresponds to the cross-entropy that is computed by considering the Bernoulli distribution instead of the Gaussian distribution because it is set worse than the Bernoulli distribution for a small number of data (31). The cross-entropy is computed by:

$$E(X,Y) = -\frac{1}{N}\sum_{k=1}^{K}\sum_{i=1}^{N} P_k(Y_i)\ln\left(P_k(X_i)\right) \quad (3)$$

where $P_k(Y_i)$ and $P_k(X_i)$ are ith probability values predicted for kth class. In (3), the term $Loss_{NI}(X,Y)$ refers to the loss function obtained after normalization by the harmonic mean of the coefficients of the mutual information function. The mutual information is obtained with:

$$I(X,Y) = \sum_{i=1}^{N} P(X_i,Y_i)\log\frac{P(X_i,Y_i)}{P(X_i)P(Y_i)} \quad (4)$$

2.2. Automated Diagnosis

Automated diagnosis is performed like the traditional diagnosis (22). Some questions are asked to patients by dermatologists in the traditional diagnosis approach to learn symptoms and to obtain the "first evaluation result". The questions are about age, gender, the approximate date for lesion occurrence, problems about eyes, whether there is itching, pain, fever, and whether a cream (or similar medicine) has been applied on lesions. According to the responses given to the questions, the first evaluation result showing which disease the symptoms may indicate is obtained. Similarly, the application developed in this work asks the same questions and generates the first evaluation result.

Age information is considered together with other symptoms since it is not a determining factor alone in the diagnosis of diseases. For instance, seborrheic dermatitis can be seen in people of all ages (32), even in three-month-old babies (33). A hemangioma can be congenital or can occur in the first months of infancy and can be seen in childhood until the age of about ten (34). Psoriasis is seen in people aged three years and over (35). Acne vulgaris, known as adolescent acne, is also seen in primary school children older than ten years old (36). Although rosacea is mostly seen in people over the age of thirty (37), it is also seen in people between the ages of ten and twenty and is called "Prerosacea" because it is the pre-stage of the disease (38).

Itching in lesions is an important symptom since it is present in anyone with psoriasis or seborrheic dermatitis, while it is present only in some people with rosacea or acne vulgaris.

A person's eye problem (swollen red eyelids, pink eye (also known as conjunctivitis), blood in the eyes, redness, swelling, irritation, burning, itching, dryness, or sensitivity to light) is a sign of having rosacea (39).

Gender is another information entered by the patient in the application. However, it is not used as a distinguishing feature for disease diagnosis. Because, although it is known that rosacea and psoriasis are mostly observed in women, all the diseases mentioned in this project can be seen in both women and men. Dermatologists also ask the gender of the patient in order to have an opinion on the causes of lesions. Therefore, gender information is used in the application only to inform the dermatologist who uses the application for computer-assisted diagnosis.

Also, it is asked whether the person has applied any medication (such as cream, gel, lotion, foam) on the lesion and when the lesion occurred. Because the use of wrong drugs may cause changes of the typical appearance or shape of the lesion. The answer was given to the questions of when the lesion occurred and whether any medication was used or not helps the dermatologist to decide how strong a drug should be preferred for treatment and how often it should be applied to the lesion.

When creating the first evaluation result, the distinguishing symptoms (age, itching, eye-related problem) are taken into consideration in the classification of diseases and the algorithm given in Figure 1 is used. In this algorithm, pain and fever (burning sensation) symptoms are not used in the classification of diseases other than hemangioma, since they are not distinctive features. The two symptoms are present in patients with rosacea (38-43) or acne vulgaris (40-42), if the lesion is pus and blisters. They are also present in some patients with psoriasis (44-47) or seborrheic dermatitis (48). When deciding on the drug and treatment method to be recommended, the dermatologist also takes into account the presence of pain or fever. Therefore, the responses given by the user for the two symptoms in the application are used to inform the dermatologist.

Figure 1. The first examination algorithm

1. If age>10
   1.a. If there is itching and no problems with the eye, the result is psoriasis, seborrheic dermatitis, rosacea or acne vulgaris.
   1.b. If there is no itching and no eye problems, the result is rosacea or acne vulgaris
   1.c. If the symptoms do not comply with the statements in (1.a) or (1.b), the result is rosacea
2. If age≤10
   2 a. If other symptoms are absent, the result is hemangioma
   2.b. If there is itching and there is no eye problem, the result is psoriasis or seborrheic dermatitis.
   2.c. If the symptoms do not comply with the statements in (2.a) or (2.b), the result is consulting a dermatologist

When dermatologists make a decision for the diagnosis of the disease, the difference in lesion appearances is the determining factor. For this reason, dermatologists take into account their decisions based on the appearance of lesions when they diagnose. The first evaluation result is supportive information for diagnosis. The application has been developed in this direction. It has been designed in such a way that if the first evaluation result is the same as the result of the classification of the lesion image, the result is shown to the user as diagnostic information. If none of the diseases determined as a result of the first evaluation are the same as the result of the classification of the lesion image, the application shows a warning message that the user should contact a dermatologist due to this difference. Similarly, if the probability value obtained from the classification stage in the application is lower than 85%, the user is informed that a dermatologist should be contacted.

3. Results

The application can be used easily with its user interface. A user should enter his/her identification number and password to use the application once the interface launched (Figure 2). If the user does not have an account, he/she can click the "sign up" button to open the registration window (Figure 3). The user should enter identity number, name, surname, email, password information and then save them on this window for registration.

Figure 2. Sign-in window

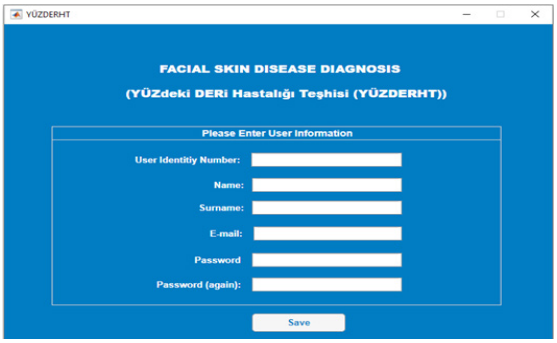
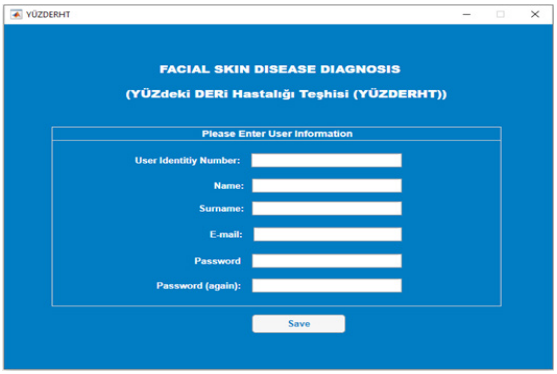
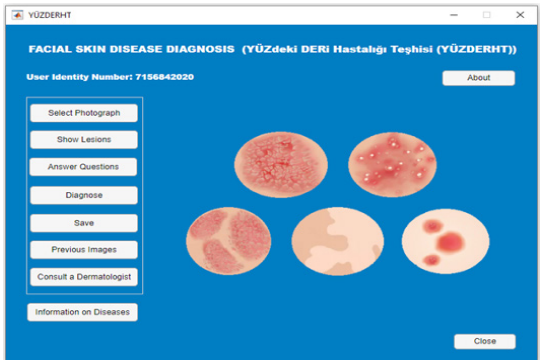


Figure 3. Sign-up window



After entering to the system, the user can see main window (Figure 4) with the user identity number at the left up-corner. The "About" button is appeared at the right up-corner to give a short information about the program. After clicking on this button, a message box with the message; "This system has been developed to diagnose these 5 facial skin diseases: acne vulgaris, rosacea, hemangioma, psoriasis, seborrheic dermatitis" is shown. Synthetic images to show some example skin lesions as symbolic are appeared on the same window. Also, other buttons to make operations are listed at the left-hand side on the same window.

Figure 4. Main window



The first button at the left-hand side is "Select Photograph", which enables users to browse and select a photograph from any folder. Once a photograph is selected, it is loaded and visualized on the main window (Figure 5).

To increase the efficiency of the program, five new buttons are shown automatically at the right-hand side over the photograph on the interface. The five buttons, which are shown in the red circle in Figure 6, are appeared when the mouse is over the photograph. The buttons enable the user to perform these operations: (1) to zoom in (using), (2) to zoom out (using), (3) to slide the image in the frame (using), which is needed if lesions are distributed and can not be seen in the frame after zoom in, (4) to show with original sizes (using), (5) to save the image with different extensions (e.g., jpeg, tiff, png) into another folder and to save it as vector graphic form (using) to be able to use in different programs.

Figure 5. Program after selecting a photograph

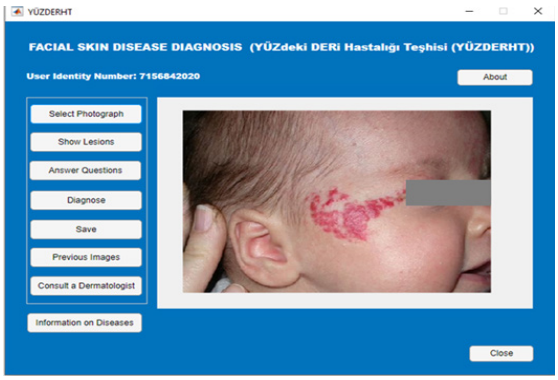
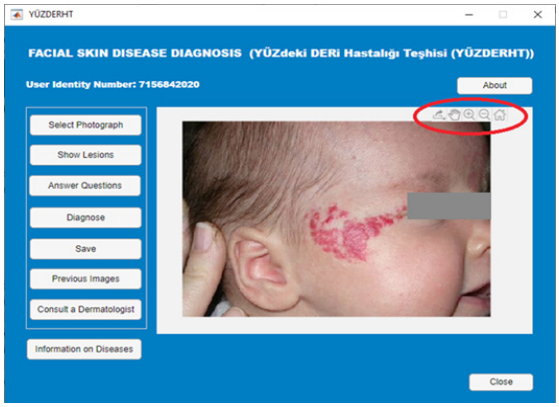


Figure 6. Buttons created automatically over the photograph



The second button on the main window is "Show Lesions" which enables users to see lesions after segmentation. Lesion boundaries are shown with red color on the image (Figure 7).

The third button is "Answer Questions" which enables users to see the questions asked by dermatologists to learn symptoms and to obtain the first evaluation result indicating which diseases the symptoms can be a sign (Figure 8).

The fourth button in the main window is "Diagnosis". After clicking on this button, segmented lesion images are categorized by using the deep network-based method (Section 2), and the result of the classification with its probability value is shown under the photograph (Figure 9). Also, total lesion area and number information are presented under the classification result.

Figure 7. Lesion boundaries after segmentation

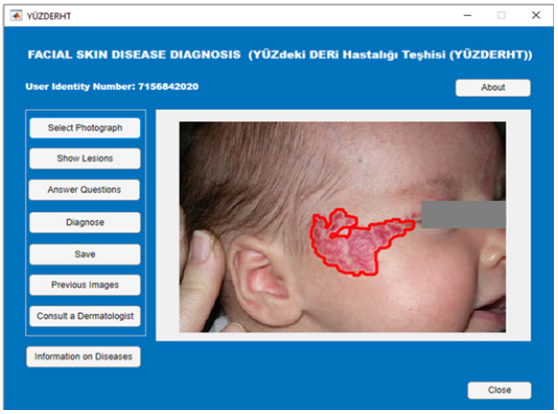


Figure 8. Questions asked to patients

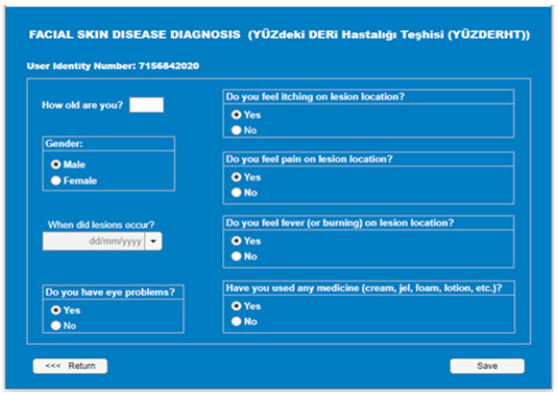
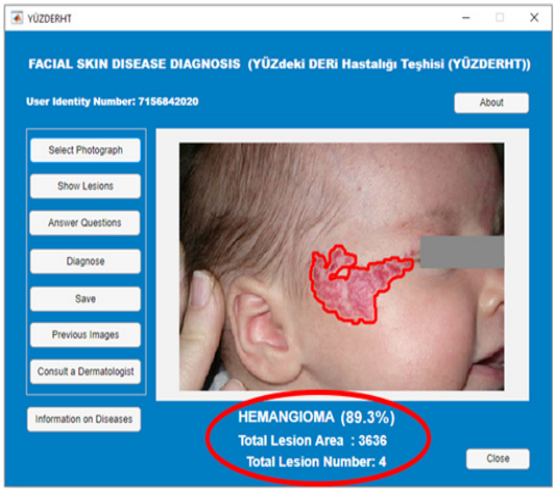


Figure 9. Lesion classification result

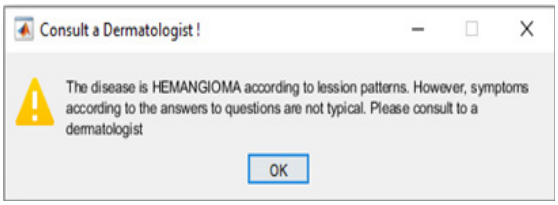


If the first evaluation result is the same as the result of the classification of the lesion image, this result is shown to the user as diagnostic information. If none of the diseases determined as a result of the first evaluation are the same as the result of the classification of the lesion image, the system shows a warning message that the user should contact a dermatologist due to this difference.

For example, if the result of classification according to lesion appearance is Hemangioma, and if the first evaluation result is a different disease, the following warning message is displayed (Figure 10): "The disease is hemangioma according to lesion patterns. However,

symptoms according to the answers to questions are not typical. Please consult to a dermatologist". Similarly, if the probability value obtained from the classification stage in the application is lower than 85%, the user is informed that a dermatologist should be contacted.

Figure 10. Example of message shown when the result of classification according to lesion appearance (here Hemangioma) and first evaluation result are different

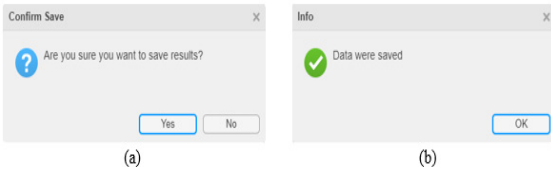


In the developed system, a confirmation message is shown when the "Save" button on the user panel is clicked (Figure 11.a). If the user approves, the diagnostic result and numerical information about the lesion are recorded in the database, and the information that the operation has been successfully performed is presented to the user (Figure 11.b).

The fifth button on the main window is "Previous Images" (Figure 9). When the users click on this button, they can see the photographs previously saved to the system in a new window (Figure 12). In addition, when they hover the cursor on a photograph, they can see the date and time information of the photograph as shown in Figure 12.

When the "Analysis" button is clicked on the window shown in Figure 12, the results obtained by analysis of the previous photographs based on time and lesion area are presented graphically. With this graphic, the healing process of the disease can be followed according to the change in the lesion area and it can be evaluated whether the drug applied for treatment is effective or not.

Figure 11. Confirmation to save results (a); Information message on saving process (b)

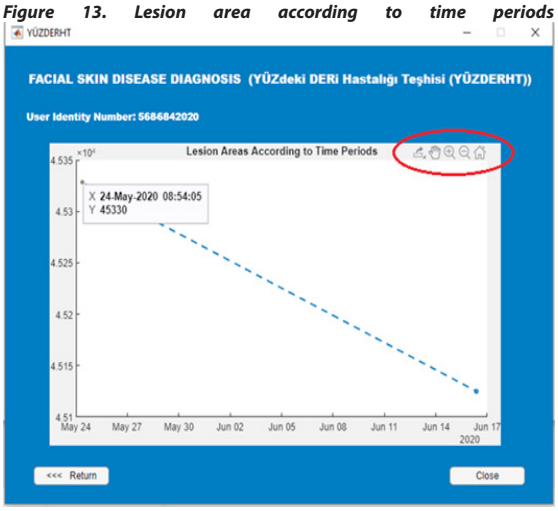


(a) (b)

Figure 12. Previous images with date and time information

For example, in Figure 13, the decrease in the lesion area between two date intervals is shown for the two different photographs shown in Figure 12. In the graph, the vertical axis shows the lesion area and the horizontal axis shows the time information. When the user moves the cursor to the first point on the left of the graph, he/she can see the numerical information (as X: 24-May-2020 08:54:05, Y: 45330) for the first photograph in the small box. When it comes to the other point, the numerical information for the other photograph can be seen in the box (as X: 16-June-2020 12:24:15, Y: 45125). In addition, if the date intervals are too long, the tools (marked with red color in Figure 13) in the upper right corner of the graphic can be used to analyze the numerical information of the photographs uploaded to the system. With the tools, graphics can be saved in different file types (pdf, png, tif, jpg), they can be enlarged or shrunk at the desired point or shifted right-left-up-down.

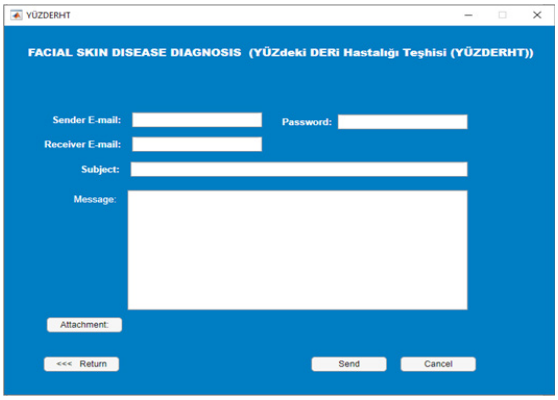
Figure 13. Lesion area according to time periods



Another button on the main window is "Consult a Dermatologist" which enables users to consult a dermatologist by sending email over a form (Figure 14). In this form, users can enter their email address, password, receiver email address, subject, and message. They can also attach files or images to their messages.

The final button on the main window is "Information on Diseases". After clicking on this button, users can get information about the diseases presented in a new window (Figure 15).

Figure 14. Form to send email



Tests have been prepared and added into the developed system to enable the user to evaluate his/her knowledge about the diseases. Test questions and answer options are recorded in the database. Explanations and three buttons for each test are presented in a window shown in Figure 16. When the user starts to answer the test questions, the starting time is recorded automatically and the time when the test will end is computed and presented in the upper right corner as shown in Figure 17.

Figure 15. Information on diseases

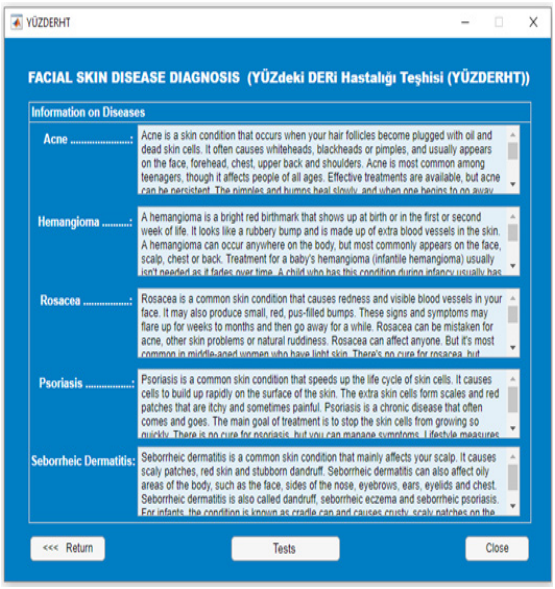


Figure 16. Explanations about tests

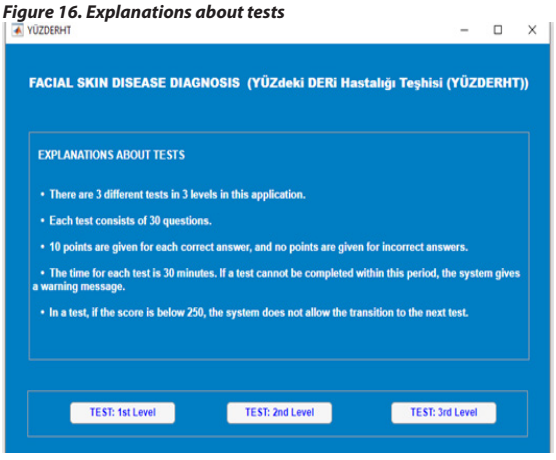
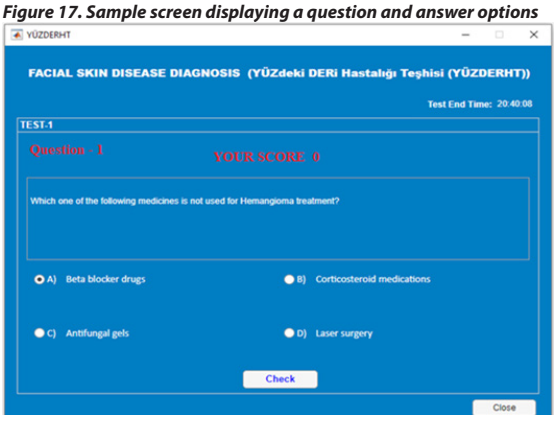


Figure 17. Sample screen displaying a question and answer options



Questions, answer options, and score change dynamically on the same window. When the user selects one of the answer options and clicks the "Check" button, if the answer is correct, the total score in the "Your Score" field increases. If the answer is incorrect then a warning message is displayed, and the next question is shown on the same window. Figure 18 shows an example warning message presented if the question is answered incorrectly. In the warning message, it is also presented which option is the correct answer for the question. Figure 19 shows an example screenshot which has been taken when the user answered the question correctly. It is also shown on the screen that the user gets 10 points for the correct answer given by the user.

Figure 18. Warning message sample shown if the question is answered incorrectly

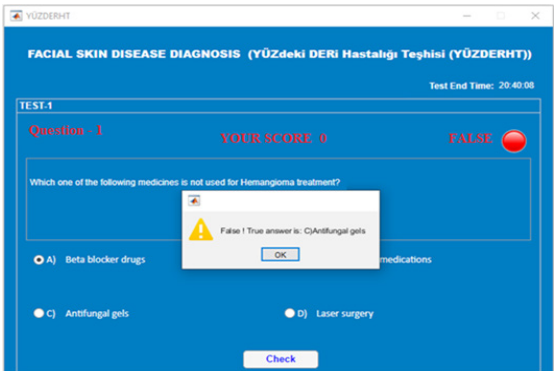
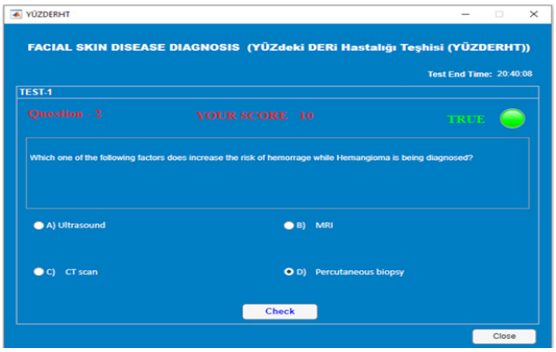


Figure 19. An example of screenshot if the user answered the question correctly



Experimental results have been evaluated in terms of accuracy. Also, to evaluate the efficiency of the combined loss function, the application has been run with the combined loss function and with the traditional cross-entropy loss function separately. The accuracy was obtained as 72.29% in the testing stage and 88.01% in the training stage when the cross-entropy was implemented. When the combined loss was applied, the accuracy was obtained as 96.01% in the testing stage and 97.44% in the training stage.

Performance evaluations for the application have also been performed by using F1 score, specificity and sensitivity metrics. It has been observed that the application produces results with 96.28% specificity, 96.42% F1 score and 98.84% sensitivity. Ground truth data provided by dermatologists have been used as references in this work.

4. Discussion

Quantitative values indicate that the proposed deep network-based technique has potential in the classification of skin lesions. The high accuracy in classification has been provided with the feature discrimination ability of the combined loss function that has both the cross-entropy and mutual information advantages.

The application produces results from the images showing hemangioma with the highest performance (accuracy:99.05%, specificity:99.36%, sensitivity:99.86%, F1 score:99.68%). The second highest performance (accuracy:98.52%, specificity:95.86%, sensitivity:96.87%, F1 score:98.89%) is obtained from the images showing psoriasis. The performance values (accuracy:96.73%, specificity:94.42%, sensitivity:88.71%, F1 score:97.89%) from the images showing seborrheic dermatitis are very close to the values (accuracy:96.11%, specificity:95.42%, sensitivity:99.81%, F1 score:98.87%) obtained from the images showing acne vulgaris. The lowest performance is obtained from the images showing rosacea (accuracy:89.62%, specificity:96.34%, sensitivity:96.86%, F1 score:98.88%).

In the literature, results are given in terms of accuracy, specificity and sensitivity. Therefore, comparative evaluations in this work are performed with these parameter values. It is observed that the proposed method produces better results when compared to the results of similar methods (Section 1). For example, a method with AlexNet model applied in (13) can classify four diseases with an average of 91,02% accuracy. In (15), tight versions of three models (Inception-V4, DenseNet, and ResNet-18) have been applied to classify images showing acne and the highest accuracy has been obtained as 67% from Inception-V4. In a more recent work presented in [14], a method with DenseNet201 has been applied to classify five diseases and the results have been obtained with an average of 95.24% accuracy, while the proposed method in this work can classify five diseases with an average of 96.01% accuracy.

A limitation of the application is that the deep network has been trained with the images showing lesions of five types of dermatological diseases. Therefore, the application can be used only for the diseases.

5. Conclusion and Recommendations

In this work, an application with an efficient and friendly user interface has been designed and developed for the patients with dermatological diseases. It can also help dermatologists in analyzing lesions or making their decisions for the disorders considered in this work. It is recommended as an extension of this work that the application can be updated to include more dermatological diseases.

6. Contribution to the Field

The main contribution of this work is a new application to diagnose dermatological diseases. The program can,

(i) allow users to select a photograph from any directory with any extension, such as png, jpg, or tiff,

(ii) show lesions after segmentation with a deterministic approach based on active contours,

(iii) classify lesions with a deep learning-based technique,

(iv) allow users to see their previous images and changes on lesion area according to time periods,

(v) be used to consult a dermatologist by sending emails,

(vi) present information on diseases and allows users to evaluate their information with the tests at different levels.

Ethical Aspect of the Research

The study was approved by the "Akdeniz University Clinical Research Ethics Committee" (70904504/301).

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Conflict of Interest

This article did not receive any financial fund. There is no conflict of interest regarding any person and/or institution.

Authorship Contribution

Concept: EG; **Design:** EG; **Supervision:** EG **Funding:** EG ; **Materials:** EG ; **Data Collection/ Processing:** EG; **Analysis/Interpretation:** EG; **Literature Review:** EG; **Manuscript Writing:** EG; **Critical Review:** EG.

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