EasyChair Preprint

№ 6320

Properties of Telemedicine While Using Ultraviolet Dermatoscopy

Olha Isaieva and Oleh Avrunin

August 17, 2021

PROPERTIES OF TELEMEDICINE WHILE USING ULTRAVIOLET DERMATOSCOPY

Olha Isaieva
Biomedical Engineering
Kharkiv National University of Radioelectronics
Kharkiv, Ukraine
olha.isaieva@nure.ua

Oleh Avrunin
Biomedical Engineering
Kharkiv National University of Radioelectronics
Kharkiv, Ukraine
oleh.avrunin@nure.ua

The paper presents the main method for examining the skin - ultraviolet dermatoscopy (UV-dermoscopy). The main modules and components of the system for skin research are considered. Skin types are discussed, as well as how a skin disease or skin type can be identified using UV dermoscopy. In addition, the segmentation process is being studied. Also, the main aspects about telemedicine are described. The novelty lies in the fact that telemedicine services can be used to study dermatological diseases, which greatly simplifies the situation during a pandemic.

Keywords—UV-dermoscope, skinscope, image processing, telemedicine, RGB

I. INTRODUCTION (*HEADING 1*)

Currently, one of the primary methods of examination in the diagnosis of skin diseases is video dermatoscopy [1]. The method allows using special optical devices of video dermatoscopes to visually assess the condition of the skin and to examine tumors at a magnification of tens to hundreds of times with different depth of field [2] – [5]. The color and shape of the tumor can determine its nature and the risk of recurrence into a malignant form [6], [7]. To date, along with standard dermatoscopy, there is another non-invasive method for the diagnosis of skin diseases - ultraviolet video dermatoscopy - UV video dermatoscopy. This method of luminescent diagnostics is based on the fact that in the ultraviolet spectrum high-energy photons can convert atoms of many organic and inorganic compounds into an excited state and thus cause the phenomenon of luminescence or non-thermal glow, and in the visible range, which are traditional for visualization [8]. For UV-video dermatoscopy lamps of "soft" long-wave ultraviolet UVA in the range of wavelengths of 350-400 nm are used. With the help of long-wave UVA ultraviolet light, it is possible to detect a pathological process occurring on the skin surface at the initial stage of development, often not yet visible with standard video dermatoscopic devices [9]. The effectiveness of such diagnostics is directly related to the fact that the products of life of microorganisms are able to fluoresce under the action of ultraviolet radiation, while healthy skin in long-wave ultraviolet radiation does not fluoresce [10]. Weak blue glow, for example, is caused by molecules of elastin, aromatic amino acids and metabolites of melanin, which can be used in aesthetic medicine to determine skin aging, dryness, moisture or oiliness of skin, pore size, pigmentation, vascular disorders. You can also diagnose the presence of dermatoses, fungal skin lesions, candidiasis, microsporia, trichophytia and some other pathological conditions caused by pathogenic microorganisms [11].

Knowing that visualization by UV video dermatoscopy is performed in the visible range, as well as the presence of clear differential criteria for staining different affected areas depending on the condition, it is advisable to register the resulting fluorescent image and its automated analysis [12]. Thus, the paper considers aspects of automated image processing in UV - video dermatoscopy. Modern research methods require fast and reliable analysis of digitized video information. At the same time, there is a tendency to increase the degree of automation in the processing of incoming research results. The literature widely covers the issues of pre-computer processing of digitized images of medical images [13]. Numerous universal and specialized software tools have been developed to improve the quality characteristics of images. However, the processing of different types of information requires a comprehensive approach aimed at developing complete specialized diagnostic systems, taking into account the specifics of a particular area and the nature of the images obtained [14] – [17]. Taking into account the personalized approach when prescribing therapy, at the current stage of development of skin research methods it is advisable to use modern technical base and image processing tools for individual selection of cosmetics based on ultraviolet video dermatoscopy [18].

Due to the continuing Pandemic of COVID-19, the huge increase in morbidity, quarantine measures and the introduction of self-insulation, telemedicine technologies get widespread introduction [19]. The relevance of this issue is extremely high to perform inspections, or holding consultations in online mode. This approach avoids extra contact with possible carriers of this virus in medical facilities [20].

II. THEORY PART

A. Explanation of UV dermatoscopy

Ultraviolet dermatoscopy is a method of modern real-time diagnosis of the skin using black ultraviolet. This method allows using special optical devices - dermatoscopes to visually assess the condition of the skin and perform examination of tumors at magnification from tens to hundreds of times with different depth of field, with different types of lighting and the use of optical filtering. The dermatoscope consists of a light source and can be polarized or non-polarized, as well as with a magnifying glass and additional elements. The method is non-invasive and allows the color and shape of the skin to determine its nature and the risk of recurrence into a malignant form [21] – [23].

The use of digital technologies in dermatoscopy significantly expands the diagnostic capabilities of this method and allows the registration of visual information, storage and further processing of data, as well as simplifies remote counseling with modern telemedicine services. The greatest diagnostic capabilities of digital video dermatoscopy are manifested using automated systems for processing and analysis of skin images [24] – [28].

B. The principle of operation of the black light lamp

A black light lamp or an ultraviolet lamp is a lamp that emits almost exclusively in the longest wavelength ("soft") part of the ultraviolet range and, unlike a quartz lamp, has a relatively weak visible glow. Such lamps are in SkinScope apparatus on Fig. 1.

Figure 1 – Inside view of the apparatus

Lamps are made on the same principles as ordinary fluorescent lamps, with the only difference that a special phosphor is used in the production of black light lamps and instead of a transparent glass bulb a bulb made of very dark, almost black, blue-violet violet glass with cobalt oxide additives is used. or nickel. This glass is called Wood's glass. It practically does not transmit visible light with a wavelength of more than 400 nm [14] – [16].

The black light lamp can be made without the use of special phosphors. In this case, the bulb is a light filter or a light filter is installed in it, which transmits mainly ultraviolet radiation. Wood glass is usually used for the light filter [17].

Radiation generated by the discharge in mercury vapor with wavelengths of 365.0153 nm, 398.3931 nm, 404.6563 nm and 407.783 nm also passes through such a light filter. This is the design of the first black light lamps [19].

Wood's lamp is used in dermatology to diagnose skin diseases, in particular in the detection of fungal lesions and hair loss (trichophytia) [9]. A special magnifying glass with ultraviolet illumination in combination with the table (Fig. 2) allows you to determine the data on the condition of the skin by its glow.

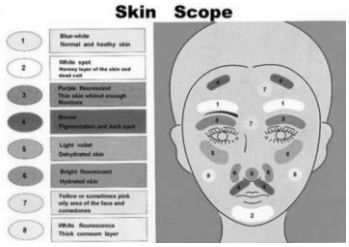

Figure 2 – The table of the ratio of color and pathology

III. Materials and Methods

Before using the method of UV-dermatoskopy, we should know the components of such system.

A. The device which is used to do research of skin

A clear example of a device that uses black ultraviolet light is the Skin Scope (Fig. 3). An innovative hardware diagnostic method that allows you to detect all the features and the smallest changes in the skin to accurately select the optimal care [10]. Thanks to the examination on the SkinScope device, you can make the correct diagnosis, choose the necessary means for skin care and track changes in the condition of the epidermis [1].

Figure 3 – Skin Scope

After hardware diagnostics, professional cosmetologists select a care program - determine the necessary drugs and techniques to address the identified problems (dehydration, pigmentation, acne, hyperkeratosis, etc.) [21].

During the diagnosis, it is possible to photograph the patient through an eyepiece using a smartphone or camera [4] – [6]. After that, it is necessary to transfer the image to a medium that will have special software where it is possible to process and segment the dermatoscopic image, and further, to diagnose [10]. The advantages of this method are that the procedure can be done in real time and immediately find skin imperfections [7].

B. Installation for the study of the skin

The Sony DSC QX-100 camera is mounted to the dermatoscope eyepiece in afocal projection. With this camera, we could see an enlarged clear image, which was instantly transmitted to the mobile application Imaging Edge Mobile (Fig. 4).

Identify applicable sponsor/s here. If no sponsors, delete this text box (*sponsors*).

Figure 4 – The installation to study skin

C. *UV-dermatoscopy for different types of skin*

There are different types of skin, respectively, each of the types is determined differently by ultraviolet dermatoscopy. With the help of dermatoscopy, it is possible to find out what type of skin the patient has. If there are no spots, pigmentation, or colored areas, then we can say that this is a normal skin type [17].

By this term we mean that the skin is balanced and healthy. Normal-skin is velvety, with no acne and even in color A person with normal skin type has no problems with acne, blackheads, irritation and peeling. Normal skin type is most common in children and only 7% of adults [13]. Normal-skin is velvety, with no acne and even in color It is almost invisible pores and wrinkles appear quite late. Despite such characteristics of this skin type, due attention should be paid, without it the skin can change its type or acquire unwanted defects [1].

To maintain a normal skin type throughout life, it is necessary to use cleansers, toners and moisturizers. Gels, foams and hydrophilic oils can act as such means. Such products must be used both day and night.

While talking about oily skin, then, using the method of video dermatoscopy, you can find out the red and yellow spots on the face [13]. In this case, skin care products will be aimed at removing oily shine. It is necessary to regularly use such cosmetics for cleaning as gels, and also to do de-make-up. Keep in mind that the use of alcohol for this skin type is not required, so the tone should be used without alcohol. You can also use products such as serums and scrubs to narrow pores and remove dirt. It was found that cosmetics for oily skin should contain components such as zinc, glycerin, salicylic acid. Plant extracts help to matte oily skin [1].

Most people have dry skin, which is determined by white spots on video dermatoscopy. To combat this type of skin, it is necessary to use such cosmetics as hyaluronic acid, glycerin, plant oils and squalane - an oil-based product. Only foams can be used for cleaning [18].

Combination skin can be determined by the principle of dry and oily skin. So, there will be both yellow spots and white spots that indicate dryness. Combination skin is the most popular among the population and the most difficult to fight, because this type of skin requires careful care. On the one hand - it should be care for dry skin, and on the other - for oily skin. Usually, it is not very economical, so there is an option for choosing cosmetics for this skin type. Zone U, which acts as dry skin on the face, should be moisturized with masks, Zone T, which is an oily area, should be matted with clay masks. It is important to remember that the eyes need care, which will involve applying patches [1], [12].

IV. RESULTS OF THE RESEARCH

To analyze the dermatoscopic images it should be used the segmentation and image processing. In addition to the fact that dermatoscopy is applied to a decent contact with the doctor, it can also be noted that it is possible to explore the skin and remotely [8].

This approach avoids extra contact with possible carriers of this virus in medical facilities.

Telemedicine technologies are already used in different fields of medicine, for example, when testing the shallow motility of hands, in otorinolaryngology, when analyzing the data of radiation research methods. With the advent of such an approach and the relevant technologies, dermatologists can expand access to medical care, shorting the time for traditional outpatient reception. Dermatological telemedicine services offer a reduced waiting time, increased graph flexibility and sufficient patient satisfaction [2, 3].

At the moment, it is known that telemedicine can be applied to implement remote consultations and observations in the dynamics of such dermatological diseases such as angry rash, pigment lesions, atopic dermatitis, skin neoplasms. At the same time, timely diagnosis of these diseases is very important [10]. Of course, the effectiveness of traditional interaction with the doctor remains more accurate, but in self-insulation, technical means help to provide registration and analysis of diagnostic information on the removal and provision of high-quality and secure consultations [8].

A. *Telemedicine mechanism*

The Telemedicine system should necessarily include a digital videomatoscope, which will allow register diagnostic images with an adjustable optical increase from 10 to 200 times and a resolution of at least 5 megapixels in the sizes of a matrix at least 1 / 2.5 inches to provide an acceptable dynamic range, as well as a built-in lighting unit. . An example of a digital dermatoscope can serve as a video armatoscope UM039 [2].

The device must be able to record digital images to a memory card and transmit them using telemedicine services for analysis, for example, to a computer or smartphone. A feature is to obtain images in formats (for example, TIFF), deprived of specific artifacts from image compression leading to distortion of diagnostic information. A specialist must have a specialized software for storing and processing obtained diagnostic images, taking into account the analysis of the color component of areas of interest specific for diagnosed pathologies [26]. At the same time, issues of processing of registered dermatoscopic images and the use of existing approaches to their analysis.

In addition, it is possible to develop specialized certified equipment and allocated communication channels for rapid and secure transmission of not only diagnostic images, but also the necessary medical information (data of the history, sanitary and hygienic characteristics of workplaces, etc.), which allows a highly qualified specialist with telemedicine consultations. monitor the process of treating a patient with dermatological diseases [10] – [11]. These systems have become particularly relevant in a pandemic of COVID-19 virus, forced quarantine and self-insulation, when visiting the diagnostic centers for planned treatment is undesirable.

The study is subject to the accuracy of diagnostics [2, 3] of various dermatological diseases based on data video productoscopy in the conditions of telemedicine and observations of the condition of the skin by the patient in dynamics using telemedicine services.

B. Segmentation of dermatoscopic images

While talking about segmentation, it is appropriate to say about the subsystem of data analysis [1].

The data analysis subsystem is implemented on a graphical workstation and consists of the following modules:

- image pre-processing, which includes methods for suppressing noise components and histogram correction of the brightness and contrast of the input image;

Features of video dermatoscopic image processing are a comprehensive analysis of color [28] and morphological characteristics of the studied areas.

A color model is a way of describing a color with quantitative characteristics. Color model usually means a term that refers to an abstract model to describe color images in the form of three- or four-digit numbers, called color components (sometimes color coordinates) [8]. The color model is used to describe the radiated and reflected colors. Together with the method of interpretation of these data, many colors of the color model determine the color space [1].

RGB is a color model named after the three capital letters of the underlying color names: Red, Green, and Blue. The same colors form all the intermediates. Scientific name - additive model. Used to display images on monitors and other electronic devices. It has an excellent color coating [5].

There is also an HSV system, which is characterized as:

- Hue is a color tone (such as red, green, or blue). It ranges from 0 ° to 360 °, but sometimes decreases to the range from 0 to 100 or from 0 to 1.

- Saturation - saturation. It ranges from 0 to 100 or from 0 to 1. The larger this parameter, the "purer" color, so this parameter is sometimes called color purity. And the closer this parameter is to zero, the closer the color is to neutral gray.

- Value or brightness. Also specified in the range from 0 to 100 or from 0 to 1.

As a result of the study it becomes clear that in the method of ultraviolet dermatoscopy it is advisable to switch from the RGB system to the HSV system, because the HSV system uses the characteristics of colors, rather than the colors themselves, as the RGB system [19]. It should also be noted that the RGB system is focused on the technical device, while the HSV system is focused on the person and will continue to help doctors make an accurate diagnosis [12] – [15].

To analyze the image, it is advisable to switch to the color model HSV by formulas (1 - 3) and determine the values of brightness channels from the data obtained by RGB characteristics [6].

$$V \leftarrow \max(R, G, B) \tag{1}$$

$$S \leftarrow \begin{cases} \dfrac{V - \min(R, G, B)}{V}, if V \neq 0 \\ 0, else \end{cases} \tag{2}$$

$$H \leftarrow \begin{cases} \dfrac{60(G - B)}{S}, if V = R \\ 120 + \dfrac{60(B - G)}{S}, if V = G \\ 240 + \dfrac{60(R - G)}{S}, if V = B \\ if\ H < 0, \quad then\ H = H + 360 \end{cases} \tag{3}$$

The next module is image segmentation, which consists in constructing a characteristic image function that highlights homogeneous areas of objects and background [4] - [7]. In the general case, the process of image segmentation is divided into 2 stages:

- separation of areas of objects from the background, which is the construction of a binary characteristic function of the image, which takes the value:

$$f(i, j) = \begin{cases} 1; f(i, j) \in D_O, \\ 0; f(i, j) \in D_B, \end{cases} \tag{4}$$

where D_o and D_B are areas belonging to objects and background, respectively;

- image markup, which leads to the construction of multivalued characteristic function of the species:

$$F(i, j) = \begin{cases} k; f(i, j) \in D_{O_k}, \\ 0; f(i, j) \in D_B, \end{cases} \tag{5}$$

where D_{0_k} is the area belonging to the *k*-th object.

The main limitation is the condition of non-overlapping segmented objects:

$$D_{O_k} \cap D_{O_m} = \varnothing \quad , \text{при } k \neq m. \tag{6}$$

Otherwise, the objects cannot be separated during the analysis, which will contribute to the appearance of distorted information in skin formations [18] - [20]. Given the specifics of dermatoscopic images containing moles and pigment spots, it is advisable to segment images by the method of boundary separations by intensity or color characteristics of the image, which are chosen based on a

priori information [21] - [24]. The following information consists of:

- image description - obtaining geometric and optical characteristics of objects segmented in the previous module. Such characteristics are usually color coordinates and area, perimeter, coefficients of shape of the analyzed objects [14] – [17].

- module for forming a diagnostic solution, which classifies the characteristics of the analyzed objects, as which are most often chosen their color and geometric characteristics, taking into account the a priori and additional transmission of diagnostic information about the patient. It should be noted that in this module is the formation of not a final but a preliminary diagnostic solution, which helps the doctor to make a final diagnosis [10] - [11].

C. The analizing of dermatoscopic images

Consider dermatoscopic images obtained by the method of ultraviolet dermatoscopy. To find out the pathologies that are present in these images, let's look at the ratio between color and pathology.

So, if we have coral spots it means that skin is oily. When we see white spots then it’s dry skin. Some dark fields on the skin means pigmentation [11].

The first patient has a big number of pigment spots around her nose and forehead (fig 5 a, b). Pigment spots are accompanied by the fact that the patient is often exposed to ultraviolet rays, the sun, or age-related changes [15].

a b

Figure 5

Let's analyze the condition of the skin of another patient (Fig. 6 a, b). Dehydration of the skin can be seen in the nasolabial region, which means that the patient does not have proper skin care or does not moisturize his skin [16].

Comparing the original image and the segmented one, you can see that with the processed image, problem areas on the face are noticeable better than on the original [11].

a b

Figure 6

V. CONCLUSION

In the tasks of automated image processing and analysis of luminescent video dermatoscopy, a priori information about the studied image always plays a significant role. The process of segmentation is to build a characteristic function of the image that highlights the problem areas of the skin [22].

As a criterion of homogeneity in segmentation, it is advisable to choose statistical indicators of characteristic areas of the image, the coordinates of which are indicated interactively. Errors that occur in the analysis of UV-video dermatoscopic images associated with inhomogeneity of lighting, which may be caused by improper placement of the patient inside the diagnostic device, or errors in the coordination of the optical path visualizes eyepiece - camera lens, the presence of local obstacles, overlapping areas changes and their high variability. Therefore, it is necessary to form statistical data on the visualization of specific conditions of the skin, taking into account the hardware features of the system of ultraviolet video dermatoscopy [23] – [26].

This allows the use of modern technical base and image processing tools for individual selection of cosmetics based on ultraviolet video dermatoscopy and increase the effectiveness of treatment based on personalized approaches to diagnosis and therapy.

In modern conditions, the advantages of the use of telemedicine services for primary diagnosis and control of the treatment of some dermatological diseases are obvious. The capabilities of mobile televisermatology make it possible to reduce the costs of time, reduce contact with carriers of diseases and reduce the financial costs in the process of monitoring a number of chronic skin diseases [27] – [28].

The prospect of the work is to increase the efficiency of the developed approach to processing and analysis of video dermatoscopic images based on methods of ensuring high stability and repeatability of diagnostic results, as well as preliminary clinical trials of the complete system for ultraviolet video dermatoscopy [25].

REFERENCES

[1] Olha A. Isaieva, Oleg G. Avrunin, Irina I. Moroz, Olena V. Stoliarenko, Roman B. Akselrod, Volodymyr S. Kylyvnyk, Konrad Gromaszek, Aigul Iskakova, Saule Rakhmetullina, and Ainur Kozbakova "Features of image analysis under UV-video dermoscopy", Proc. SPIE 11456, Optical Fibers and Their Applications 2020, 114560H (12 June 2020); https://doi.org/10.1117/12.2569774

[2] Avrunin, O., Kolisnyk, K., Nosova, Y., Tomashevskyi, R., & Shushliapina, N. (2020). Improving the methods for visualization of middle ear pathologies based on telemedicine services in remote treatment. Paper presented at the *2020 IEEE KhPI Week on Advanced Technology, KhPI Week 2020 - Conference Proceedings*, 347-350. doi:10.1109/KhPIWeek51551.2020.9250090

[3] Kolisnyk, K., Deineko, D., Sokol, T., Kutsevlyak, S., & Avrunin, O. (2019). Application of modern internet technologies in telemedicine screening of patient conditions. Paper presented at the *2019 IEEE International Scientific-Practical Conference: Problems of Infocommunications Science and Technology, PIC S and T 2019 - Proceedings*, 459-464. doi:10.1109/PICST47496.2019.9061252

[4] Avrunin, O., Tymkovych, M., & Drauil, J. (2015). Automatized technique for three-dimensional reconstruction of cranial implant based on symmetry. Paper presented at the 2015 Information Technologies in Innovation Business Conference, ITIB 2015 - Proceedings, 39-42. doi:10.1109/ITIB.2015.7355070

[5] Avrunin, O. G., Nosova, Y. V., Abdelhamid, I. Y., Pavlov, S. V., Shushliapina, N. O., Wójcik, W., . . . Kalizhanova, A. (2021). Possibilities of automated diagnostics of odontogenic sinusitis according to the computer tomography data. Sensors (Switzerland), 21(4), 1-22. doi:10.3390/s2104119

[6] Avrunin, O. G., Tymkovych, M. Y., Moskovko, S. P., Romanyuk, S. O., Kotyra, A., & Smailova, S. (2017). Using a priori data for segmentation anatomical structures of the brain. Przeglad Elektrotechniczny, 93(5), 102-105. doi:10.15199/48.2017.05.20

[7] Rashkevych, Y., Peleshko, D., Vynokurova, O., Izonin, I., & Lotoshynska, N. (2017). Single-frame image super-resolution based on singular square matrix operator. Paper presented at the 2017 IEEE 1st Ukraine Conference on Electrical and Computer Engineering, UKRCON 2017 - Proceedings, 944-948. doi:10.1109/UKRCON.2017.8100390

[8] Rajpara SM, Botello AP, Townend J, Ormerod AD. Systematic review of dermoscopy and digital dermoscopy/ artificial intelligence for the diagnosis of melanoma. Br J Dermatol. 2009 Sep;161(3):591-604. doi: 10.1111/j.1365-2133.2009.09093.x.Epub 2009 Mar 19.

[9] MacKie R.M., Hauschild A., Eggermont A.M. Epidemiology of invasive cutaneous melanoma // Ann. Oncol. 2009. Vol. 20, Suppl. 6. P. 1–7. doi: 10.1093/annonc/mdp252

[10] Meyle K.D., Guldberg P. Genetic risk factors for melanoma // Hum. Genet. 2009. Vol. 126, No. 4. P. 499–510. doi: 10.1007/s00439-009-0715-9

[11] Mistry M., Parkin D.M., Ahmad A.S., Sasieni P. Cancer incidence in the United Kingdom: projections to the year 2030 // Br. J. Cancer. 2011. Vol. 105, No. 11. P. 1795–1803. doi: 10.1038/bjc.2011.430

[12] Vestergaard M.E., Macaskill P., Holt P.E., Menzies S.W. Dermoscopy compared with naked eye examination for the diagnosis of primary melanoma: a meta-analysis of studies performed in a clinical setting // Br. J. Dermatol. 2008. Vol. 159, No. 3. P. 669–676. doi: 10.1111/j.1365-2133.2008.08713.x

[13] Argenziano G., Ferrara G., Francione S., et al. Dermoscopy – the ultimate tool for melanoma diagnosis // Semin. Cutan. Med. Surg. 2009. Vol. 28, No. 3. P. 142–148. doi: 10.1016/j.sder.2009.06.001

[14] Giuseppe Argenziano, H Peter Soyer. Dermoscopy of pigmented skin lesions – a valuable tool for early // The Lancet Oncology. — 2001-07. — Т. 2, вып. 7. — С. 443–449. — ISSN 1470-2045. — doi:10.1016/s1470-2045(00)00422-8.

[15] Benvenuto-Andrade C., Dusza S.W., Agero A.L., et al. Differences between polarized light dermoscopy and immersion contact dermoscopy for the evaluation of skin lesions // Arch. Dermatol. 2007. Vol. 143, No. 3. P. 329–338. doi: 10.1001/archderm.143.3.329

[16] Sergeev Yu.Yu., Sergeev V.Yu., Mordovtseva V.V. Follow-up of melanocytic lesions with use of dermoscopy (literature review). Medical alphabet. 2020;(6):66-71. (In Russ.) https://doi.org/10.33667/2078-5631-2020-6-66-71

[17] Czajkowska, J., Korzekwa, S., & Pietka, E. (2020). Computer aided diagnosis of atopic dermatitis. Computerized Medical Imaging and Graphics, 79 doi:10.1016/j.compmedimag.2019.101676

[18] Hornstein, O. P. (1986). Definition and classification of eczemas. A pertinent challenge to dermatologists. Journal of Dermatology, 13(2), 81-91. doi:10.1111/j.1346-8138.1986.tb02906.x

[19] Czajkowska, J., Badura, P., Korzekwa, S., & Płatkowska-Szczerek, A. (2021). Deep learning approach to skin layers segmentation in inflammatory dermatoses. Ultrasonics, 114 doi:10.1016/j.ultras.2021.106412

[20] Genzel, I., Jansen, W., Bertram, G., & Wienert, V. (1996). Measurements of capillary resistance in atopic dermatitis. [KAPILLARRESISTOMETRISCHE BEFUNDE BEI ATOPISCHER DERMATITIS] Hautarzt, 47(4), 276-280. doi:10.1007/s001050050414

[21] Guimarães, P., Batista, A., Zieger, M., Kaatz, M., & Koenig, K. (2020). Artificial intelligence in multiphoton tomography: Atopic dermatitis diagnosis. Scientific Reports, 10(1) doi:10.1038/s41598-020-64937-x

[22] Hsiao, Y. -., Wang, H. -., Chen, S. -., Tsai, C. -., & Yang, J. -. (2015). Identified early stage mycosis fungoides from psoriasis and atopic dermatitis using non-invasive color contrast enhancement by LEDs lighting. Optical and Quantum Electronics, 47(7), 1599-1611. doi:10.1007/s11082-014-0017-x

[23] Pietka, E., & Gertych, A. (2021). Advances in biomedical image processing. Computerized Medical Imaging and Graphics, 89 doi:10.1016/j.compmedimag.2021.101891

[24] Son, S. W., Park, S. Y., Ha, S. H., Park, G. M., Kim, M. G., Moon, J. S., . . . Oh, C. H. (2005). Objective evaluation for severity of atopic dermatitis by morphologic study of skin surface contours. Skin Research and Technology, 11(4), 272-280. doi:10.1111/j.0909-725X.2005.00124.x

[25] Thomsen, K., Christensen, A. L., Iversen, L., Lomholt, H. B., & Winther, O. (2020). Deep learning for diagnostic binary classification of multiple-lesion skin diseases. Frontiers in Medicine, 7 doi:10.3389/fmed.2020.574329

[26] Sroka-Tomaszewska, J., & Trzeciak, M. (2021). Molecular mechanisms of atopic dermatitis pathogenesis. International Journal of Molecular Sciences, 22(8) doi:10.3390/ijms22084130

[27] Tamagawa-Mineoka, R., & Katoh, N. (2020). Atopic dermatitis: Identification and management of complicating factors. International Journal of Molecular Sciences, 21(8) doi:10.3390/ijms21082671

[28] Yang, G., Seok, J. K., Kang, H. C., Cho, Y. -., Lee, H. S., & Lee, J. Y. (2020). Skin barrier abnormalities and immune dysfunction in atopic dermatitis. International Journal of Molecular Sciences, 21(8) doi:10.3390/ijms21082867