IOP Conference Series:
Materials Science and
Engineering

PAPER • **OPEN ACCESS**

Skin Disease Classification System Based on Machine Learning Technique: A Survey

To cite this article: Saja Salim Mohammed and Jamal Mustafa Al-Tuwaijari 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1076** 012045

Skin Disease Classification System Based on Machine Learning Technique: A Survey

Saja Salim mohammed[1,2] and Jamal Mustafa Al-Tuwaijari[1]

[1] Department of Computer Science, College of Science, University of Diyala, Iraq

[2] E-mail: sajasalim@sciences.uodiyala.edu.iq

Abstract: Skin diseases are a major and worrying problem in societies due to their physical and psychological effects on patients. Detecting skin diseases at an early stage has an important role in treatment. The process of diagnosing and treating skin injury is related to the skill and experience of the specialist doctor. The diagnostic process must be accurate and timely. Recently, artificial intelligence science has been used in the field of diagnosing skin diseases through the use of machine learning algorithms and the exploitation of the vast amount of data available in health centers and hospitals. In this paper, quite many previous studies related to methods of classification of skin diseases based on the principle of machine learning were collected. In a group of previous studies, the researchers used some systems, mechanisms, and algorithms. Several systems have been successful in classifying skin diseases and achieving varying diagnostic accuracy. Various systems have relied on methods of image processing and feature extraction that help predict and detect disease type. There are other systems designed to identify specific types of skin disease through clinical features and features obtained from tissue analyzes after a skin biopsy of the affected area. This survey shows that the diagnostic accuracy in image processing methods was relatively uneven, ranged between (50% to 100%). As for the methods of treating tissue features, the accuracy was of an excellent level of 94% or more. The results provide an overview of the actual relevant studies found in the literature and highlight most of which research gaps have emerged.

Keywords: Skin diseases, Artificial Intelligence, Machine Learning, Convolutional Neural Network, Classification.

1. Introduction

There are many types and forms of skin diseases and have many causes, including internal ones related to hormones and body glands such as acne, or external related to air pollution or sensitivity to sunlight such as rashes. The skin disease may be contagious, such as scabies and lice, or it may not be contagious, such as drug allergy and rosacea, or it may be chronic, such as psoriasis and atopic eczema, or it may be rare, such as sweet syndrome and ofuji disease. The outlook of society, in general, reduces the importance of skin disease when it appears and it is preferable not to visit the doctor. skin diseases contribute 1.79% of the physical disabilities of humans in all countries of the world, according to global statistics [1]. Skin problems cause suffering for about 30% to 70% of people in various countries of the world [2].

Skin cancer is an abnormal growth in skin cells that sometimes occurs as a result of a specific skin injury that is not treated at first or is often caused by the ultraviolet rays of the sun. Cancer is the second cause of human death in recent years. Approximately nine million people die annually, and 70% of these deaths are recorded in countries with low levels of living income. This is due to the delay in reviewing specialized doctors at the beginning of the disease, and thus the difficulty of treatment due to the progression of the disease and its transformation into a type of cancer and it is reaching advanced stages, causing death [3-5]. Skin diseases interact with society, and both are affected by each other. Including its relationship to the aesthetic aspect [6]. That gave it more importance and paid attention of many researchers in various countries of the world to research the automatic diagnosis of skin diseases, given the great importance of skin diseases in pathology on the one hand. On the other hand, rapid technological development and its role in all fields, the most important of which is the medical field [7].

Data extraction techniques from healthcare systems are useful in designing automated disease diagnostic tools using machine learning algorithms and deep learning algorithms. Researchers have used multiple types of artificial intelligence algorithms to train classifiers needed to perform machine diagnostics, using the principles of machine learning and deep learning. The close relationship between artificial intelligence, machine learning, and deep learning is a progressive process as well. Deep Learning comes to solve the data and create new accounts through a lot of information [8-10], this information is provided by Machine Learning and transmitted through Neural Networks. Then, when you create Machine Learning, several of them can be combined into one device to get Artificial Intelligence [11]. The medical data created in patient records can be used to research the causes of diseases and how they spread, to develop appropriate plans and policies, and to prepare and develop medicines and medical treatments [12,13]. In villages and rural areas, patients do not receive adequate health care, and there is a lack of dermatologists in those places, and the diagnosis is made by trained staff [14]. Because of the high costs of medical professionals to monitor the condition of a person with a skin disease. There must be technical systems that use images to determine the degree of patient injury [15].

Several machine learning algorithms have demonstrated high efficiency in the ability to classify skin diseases at a specific stage of the lesion's life for a group of diseases that are difficult to diagnose by image due to the presence of great similarity in their shapes, such as psoriasis, lichen planus, seborrheic dermatitis, pityriasis rosea, and chronic dermatitis, pityriasis rubra. The prediction method relies on extracting a set of clinical features and histopathological characteristics to characterize disease [16]. The expert systems technology has contributed to the diagnosis of skin diseases with outstanding accuracy and efficiency, as they simulate human behavior in prediction [17]. Skin disease symptoms are a long-term and continuously changing process, so the person diagnosing the condition must provide an assessment of the extent of the changes that have occurred since the appearance of the lesion. People are ignorant of the high risks involved in changing skin conditions. An artificial intelligence program based on self-learning and data visualization sophistication can be introduced to provide medical care that meets real-time, extensibility, and uniqueness requirements [18,19].

Machine Learning applications have five areas that are currently popular in dermatology: (1) Precision Medicine (2) Using clinical images to classify skin diseases (3) Using dermatopathology images to classify skin diseases (4) Classifying skin diseases using smartphone applications and monitoring devices Personal (5) scientific research facilities for highly prevalent epidemic diseases [20]. In the medical field, the classifier must be confident of its efficiency with a very high percentage when predicting the type of disease, and on the contrary, it passes the diagnosis to the doctor to avoid harming the patient's safety [21]. Internet of things technology has contributed to the development of important medical systems. Doctors are now able to use it in multiple places, with patient diagnostic capacity that can be increased without affecting subjective factors [22]. It is perfect for developing smart systems to diagnose diseases accurately like what professionals do. However, the problem of data imbalance between rare and common diseases remained an open problem for any system to be learned in an effective way to identify rare and common diseases [23].

This research paper contributed to the penetration in the field of data processing of patients with skin diseases and methods of classification of diseases after extracting a set of clinical and histological features or so-called (bioinformatics) and collecting the research conducted by researchers within this framework using different machine learning algorithms, in addition to the classification methods that It relies on computer vision to images the skin. The rest of the research includes four sections. In the first section, data set and machine learning algorithms. The second section, an overview of the literature. The third section, for the discussion, and the last section is set for the conclusion.

2. Data sets and machine learning algorithms

To build a diagnostic system for dermatological diseases firstly, the preparation of the data set, which is the basic building block of work, and can be obtained from several sources, whether it was collected from specialized hospitals and clinics, or randomly selected from electronic sites over the Internet or from official websites and approved repositories specialized in providing data sets for students and researchers. Among the most prominent sites from which the researchers took their research data set and according to previous surveys are ISIC, OLE, DermNet, PH2, DermIs, DermQuest, etc. [24-28]. Secondly, the selection of the classification algorithm from the family of supervised machine learning algorithms. supervised machine learning algorithms deal with labeled datasets and established a function that defines the inputs to the required output. It among the most important algorithms used: Artificial Neural Networks(ANN), Support Vector Machine (SVM), Convolutional Neural Networks(CNN), Decision Tree(DT), Boosted trees, K Nearest Neighbors (KNN), K-Means Clustering, Random Forest(RF), Naive Bayes(NB), Genetic algorithm(GA), Fuzzy algorithm(FA), and so on. [29,30]. Then begins the operation of processing the data and extracting the necessary features that perform a model. In any classification process using machine learning algorithms, the choice of feature to be entered is a very important and key step. It was found that in previous studies, several types of features were used, according to the specific classification algorithms. When classifying the dermatological images, several different types of texture and color features were used in conjunction with the ANN, SVM, and KNN algorithms, and they had good results with fair proportions of accuracy [31].

3. Overview of literature

This section is split into two parts:

3.1. PART A: skin diseases classification using image processing techniques

The method of classification of skin diseases through images depends mainly on the subjective features of the diseases and is extremely important for accuracy. Skin diseases can be classified in two ways. Firstly, the classification of skin disease employing the traditional approach. Secondly, Classification of Skin Disease employing Deep Learning based Approach [24].

Diagnosing skin lesions automatically by way of images remains a difficult task. An integrated diagnostic program can be offered that includes the combination of a lesion boundary segmentation step and a classification step for different skin lesions [32]. The image segmentation and classification of skin lesions need filtering to remove noise before the extraction of lesion areas [33]. There is another method for segmentation and classification of lesions that can bypass the problem of noise in the images and does not require prior treatment and is considered a technique with promising efficacy in segmenting difficult to diagnose lesions [34]. In the table below, a survey was conducted on 27 research papers from 2015 to 2020, and various algorithms were used on different data sets.

Table 1. Review of references for skin disease classification using image processing techniques

Ref.	Data set	year	No. of image	Diagnosed disease	Classifier	accuracy
[35]	DermNet	2020	174	Acne, keratosis Eczema, urticaria	CNN	98.6 to 99.04
[36]	---------	2015	426	Skin lesions	Decision forest	Sensitivity: 97.4% Specificity: 44.2%
[37]	DermIs DermQuest DermNZ	2019	1800	Eczema, Acne Psoriasis, benign Malignant melanoma	Support Vector Machine	83%
[38]	DermIs DermQuest DermNZ PH^2	2019	1800	Eczema, Acne Psoriasis, benign Malignant	Quadratic Support Vector Machine	94.74%
[39]	DermIs DermQuest DermNZ	2019	9144	Healthy, eczema, acne, benign, or malignant melanoma.	CNN-SVM	86.21%
[40]	PH^2	2017	200	classify lesions of the skin: normal, abnormal, and melanoma	ANN	92.50%
					SVM	89.50%
					KNN	82.00%
					DT	90.00%
[41]	NIH CA101639-02A2	2015	192	melanoma vs benign	Logistic regression	87.9%
[42]	ISIC	2017	___	Basal Cell Carcinoma, Skin Angioma	NN-NSGA-II	90%
[43]	DermIs DermQuest	2017	206	Melanoma Benign lesion	SVM	76.9%
[44]	DermNet	2019	102	Acne, Basal Cell Carcinoma, Atopic Dermatitis	Logistic Regression, CNN	Efficient method
[45]	MIT BMI	2016	704	Benign &Malignant Skin Cancer, Warts	SVM	96% -98%
[46]	HAM10000	2020	10000	7- categories of skin lesion	Fully Convolutional Network(FNC)	98%
[47]	Different sources	2019	12000	Acne, Angioedema, Granuloma, facial, Rosacea, Vitiligo, Blepharitis, pityriasis Alba, Actinic, and keratosis	CNN	88%
[48]	DermNet	2018		Initially diagnosis with five disease	CNN	70%
[49]	ISIC	2020	1646	Melanoma	Naïve Bayes	91.2%
				Keratosis		92.9%
				Benign		94.3%

[50]	Collected from Different patients	2018	310	Chronic eczema, Lichen planus, and Plaque psoriasis.	ANN LDA NB SVM	62.9% 80.9% 67.42% 81.61%
[51]	-------	2019		Acne, Melanoma, Mycosis, Papillomas, Psoriasis, Vitiligo, Warts	KNN	91.80 %
[52]	Collected from Different websites	2019	80	Melanoma, Eczema, and Psoriasis	SVM	100%
[53]	IPC and DermNetNZ	2020	187	Plaque Guttate Psoriasis	CNN	82.9% 72.4
[54]	Collected from Different patients	2018	6584 5619	Set of diseases	ANN	50.27%
[55]	PH^2 and ISBI 2017	2019	23906 200	melanoma	CNN	96.4% 94%
[56]	ISIC	2018	811	Melanoma, Nevus, and Atypical	SVM KNN ANN FFNN CNN	91.13% 87.46% 90.78% 94.11% 96.89%
[57]	ISIC	2019	4000	malignant or benign	VGG-16 CNN	97.81%
[58]	Collected from 4 hospitals	2018	49,567	onychomycosis	CNN	95%
[59]	Collected from the internet	2016	85	Eczema	SVM	93%
[60]	---------	2018	----	Acne, Psoriasis, Melanoma, Heat Rash	SVM	Good results
[61]	ISIC	2020	10015	Actinic keratosis, Basal cell carcinoma, Benign keratosis, Dermatofibroma, Melanocytic nevi, Melanoma, Vascular lesions.	CNN-SVM	98.7%

After performing several statistics on algorithms and dermatological diseases using the image processing method, as shown in Table 1, the percentage of using the convolutional neural network algorithm was the highest among the others, according to the illustrated chart in Figure 1, and the number of diseases classified reached about 67, the most common being melanoma, eczema, psoriasis, acne, rosacea, lichen planus, and keratosis.

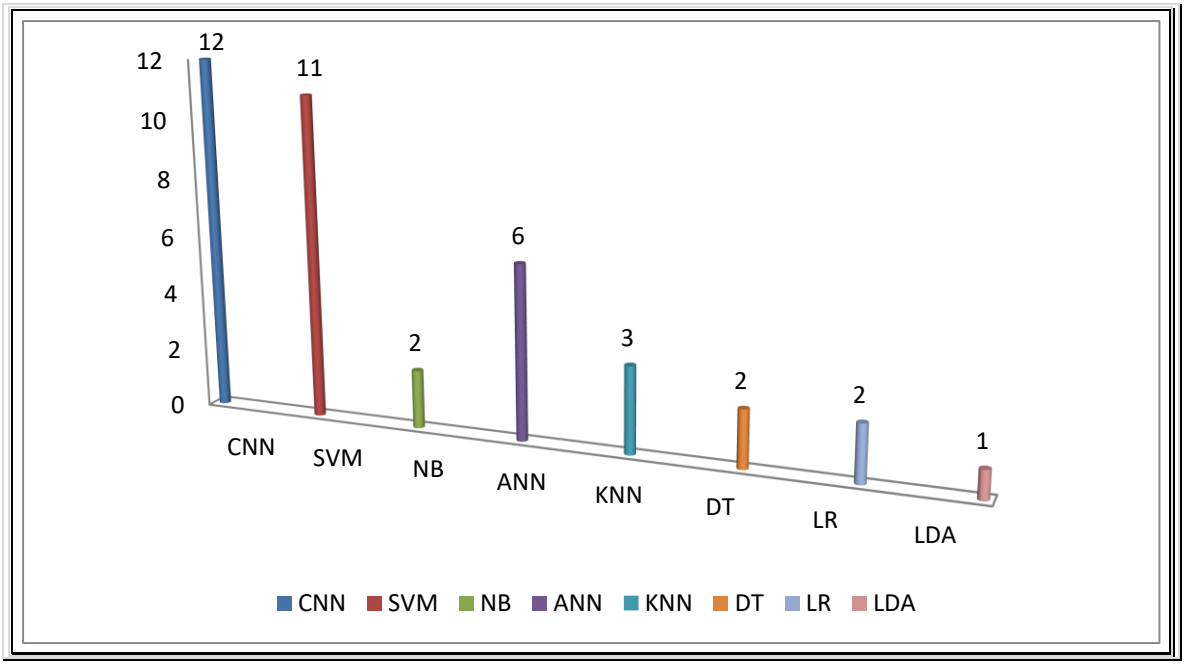

Figure 1. Distribution of models based on algorithms.

3.2. PART B: skin disease classification using analytical results of skin biopsy.

There is a group of skin diseases that posed a challenge to researchers, as they were not diagnosed by images because of the great similarity at the beginning of their appearance, and sometimes they give characteristics to another disease at a certain stage, which are six types (psoriasis, seborrheic dermatitis, lichen planus, pityriasis rosea, chronic dermatitis, pityriasis rubra pilaris). The results of a medical biopsy are used as an ideal way to diagnose any of them. A skin biopsy is easily performed by removing some cells from the affected skin area. With the use of bioinformatics analytical tools, a set of scientifically valuable basic information is obtained about tissue cells, which contributes to understanding patterns and discovering new previously unknown features about the nature of the disease. The newly discovered information is helping to add improvements to medicines and medicinal products [28].

The researchers obtained the dataset from the University of California (UCI) machine learning repository website. The dataset consists of 366 diagnostic patients and has 34 attributes of six class diseases of the skin. Since this data was available in the UCI repository in 1998, researchers have conducted numerous research. This survey has only reviewed researchs for the last ten years as shown in Table 2.

Table 2. Review of references for skin disease classification using analytical results of skin biopsy.

Ref.	Country	Year	Classifier name	Accuracy
[62]	Turkey	2010	k-means clustering	94.22%
[63]	China	2011	SVM	98.61%
[64]	____	2012	Naive Bayes	98.9%
[65]	Iran	2013	PSO-SVM	98.91%
[66]	India	2013	SVM	96.0%
[67]	Saudi Arabia	2014	ANN-SVM	96.72%
[68]	India	2015	Bayesian technique	99.31%
[69]	Iran	2016	SVM, KNN, MLP	97.78 %

[70]	Serbia-croatia	2017	EHO-SVM	99.07%
[71]	Indonesia	2017	SVM	99.18%
[72]	Cyprus	2018	FNN	98.37%
[73]	India	2019	CART, SVMs, GBDTs, DTs, RFs	95.90 %
[74]	India	2019	PAC, LDA, ETC, RNC, BNB, NB	99.68%

The researchers used the support vector machine algorithm as a classifier of the six diseases significantly, as it proved excellent efficiency, as shown in Figure 2.

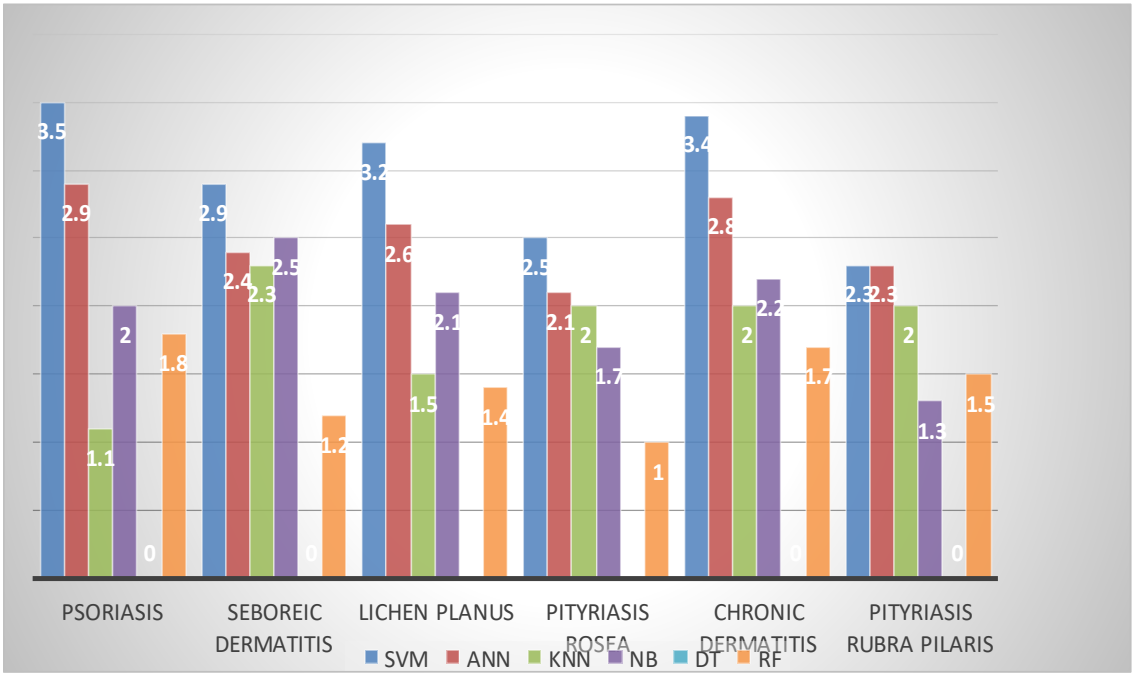

Figure 2. Distribution of diseases based on algorithms.

4. Discussion

After scanning a large number of research papers that were conducted on how to classify skin diseases using machine learning algorithms, it was found that researchers took two directions of action, one of which is the broadest and most studied is analyzing the image of the skin disease as a direct method, which is the easiest and fastest way to detect the type of disease. This classification process has been subjected to confusion due to several factors, including that the resolution of the images is low and has a large amount of noise, especially that some skin diseases have somewhat similar apparent characteristics, and that the medical diagnosis is not likely to make mistakes due to the matter of the patient's life. Most of the researchers have tended to use the convolutional neural network algorithm for its high ability to classify large groups of skin diseases and to overcome the confusing obstacles to the process and also its success in classifying the lesions into benign and malignant, but one of the disadvantages is that it takes a long time to train and process data. The artificial neural network algorithm and the support vector machine achieved high diagnostic accuracy in large data sets and diagnostic accuracy decreased when a relatively small data set was used. A Naive Bayes gave good results, whether the data set was small or large. The trait selection method affected the effectiveness of the K-nearest neighbor algorithm, confirming its sensitivity to unrelated traits.

As for the second track, it was directed towards analyzing vital information of skin tissue and training classifiers on what was deduced from data and selecting features that achieve reliable diagnostic accuracy. In general, accuracy was excellent regardless of the type of classifier used to classify

diseases of dermatitis, lichen planus, pityriasis rosea, and psoriasis. Although the second path is slower because it is restricted to a time that extends between taking the biopsy and then sending it to the specialized laboratory and waiting for the results that will be used as input to the system to identify the type of disease, theoretically and through the level of balanced accuracy that was recorded in most of the proposed systems it is considered more efficient. It is very important to realize that the high accuracy obtained in most research may not be a true measure of a model's performance if it is tested on various datasets or even real data. There are other areas of research that emerged during the survey. Some researchers presented hybrid expert systems that can classify skin diseases through images in addition to the results of pathological tests such as diagnosing arsenic disease [75].

5. Conclusion

Detecting skin disease from its inception helps facilitate treatment and increase the patient's chances of recovery and survival. Any wrong diagnosis that leads to improper treatment may harm the patient's health. The use of different combinations of computer technologies and computer vision can reliable skin disease classification. Image processing techniques have contributed to the establishment of automated screening systems for most skin diseases. Two methods were adopted to classify the skin disease using images, namely, the traditional machine learning approach and the Deep Learning Approach. process of segmentation is an important step to recognize the disease area and skin area but sometimes it can be surpassed. Image features extraction plays a fundamental role in the way of classification. The accuracy of any model can be negatively affected by irrelevant features such as linear algorithms and the reason for low accuracy of classification is the large feature dimension. The results obtained after skin biopsy, laboratory analysis, and discovery of tissue characteristics have proven effective in predicting many diseases. Using modern algorithms in machine learning provides a quantum leap for achieving high-precision predictive ratios in the field of dermatology. Some researchers used a single algorithm, and other researchers used more than one algorithm. Systems that used more than one algorithm and hybridization method in classifying dermatological diseases demonstrated higher diagnostic accuracy. It is hoped that machine learning will have a promising role for real-time diagnostics of dermatology by assisting clinicians in extensive screening using either endoscopic or clinical images or by examinations tissues.

References

[1] [N. Hameed, A. M. Shabut, M. K. Ghosh, and M. A. Hossain, “Multi-class multi-level classification algorithm for skin lesions classification using machine learning techniques,” Expert Syst. Appl., vol. 141, p. 112961, 2020, doi: 10.1016/j.eswa.2019.112961.

[2] [J. Yang, X. Sun, J. Liang, and P. L. Rosin, “Clinical Skin Lesion Diagnosis using Representations Inspired by Dermatologist Criteria,” 2018 IEEE/CVF Conf. Comput. Vis. Pattern Recognit., pp. 1258–1266, 2018, doi: 10.1109/CVPR.2018.00137.

[3] T. Y. Tan, L. Zhang, and C. P. Lim, “Intelligent skin cancer diagnosis using improved particle swarm optimization and deep learning models,” Appl. Soft Comput. J., vol. 84, p. 105725, 2019, doi: 10.1016/j.asoc.2019.105725.

[4] S. Chatterjee, D. Dey, and S. Munshi, “Integration of morphological preprocessing and fractal based feature extraction with recursive feature elimination for skin lesion types classification,” Comput. Methods Programs Biomed., vol. 178, pp. 201–218, 2019, doi: 10.1016/j.cmpb.2019.06.018.

[5] S. Lima, L. Teran, and E. Portmann, “A Proposal for an Explainable Fuzzy-based Deep Learning System for Skin Cancer Prediction,” 2020 7th Int. Conf. eDemocracy eGovernment, ICEDEG 2020, pp. 29–35, 2020, doi: 10.1109/ICEDEG48599.2020.9096799.

[6] M. Preethi and K. Sathiyakumari, “Analyzing Human Skin Texture using Machine Learning Approaches,” Int. J. Comput. Appl., vol. 136, no. 1, pp. 5–8, 2016, doi: 10.5120/ijca2016908313.

[7] S. Bhadula, S. Sharma, P. Juyal, and C. Kulshrestha, “Machine Learning Algorithms based Skin

Disease Detection," no. 2, pp. 4044–4049, 2019, doi: 10.35940/ijitee.B7686.129219.
[8] Y. Liu et al., "A deep learning system for differential diagnosis of skin diseases," Nat. Med., vol. 26, no. 6, pp. 900–908, 2020, doi: 10.1038/s41591-020-0842-3.
[9] H. Liao, "A deep learning approach to universal skin disease classification," Univ. Rochester Dep. Comput. Sci. CSC, 2016.
[10] H. Liao, Y. Li, and J. Luo, "Skin disease classification versus skin lesion characterization: Achieving robust diagnosis using multi-label deep neural networks," Proc. - Int. Conf. Pattern Recognit., vol. 0, pp. 355–360, 2016, doi: 10.1109/ICPR.2016.7899659.
[11] A. Becker, "Artificial intelligence in medicine : What is it doing for us today ? ☆ Early work," Heal. Policy Technol., vol. 8, no. 2, pp. 198–205, 2019, doi: 10.1016/j.hlpt.2019.03.004.
[12] D. D. Miller, C. M. Facp, and E. W. Brown, "Artificial Intelligence in Medical Practice : The Question to the Answer ?," Am. J. Med., vol. 131, no. 2, pp. 129–133, 2018, doi: 10.1016/j.amjmed.2017.10.035.
[13] M. R. Wehner, K. A. Levandoski, M. Kulldorff, and M. M. Asgari, "Research Techniques Made Simple: An Introduction to Use and Analysis of Big Data in Dermatology," J. Invest. Dermatol., vol. 137, no. 8, pp. e153–e158, 2017, doi: 10.1016/j.jid.2017.04.019.
[14] K. S. Parikh and T. P. Shah, "Support Vector Machine – A Large Margin Classifier to Diagnose Skin Illnesses," Procedia Technol., vol. 23, pp. 369–375, 2016, doi: 10.1016/j.protcy.2016.03.039.
[15] S. Kolkur and D. R. Kalbande, "Survey of texture based feature extraction for skin disease detection," Proc. 2016 Int. Conf. ICT Business, Ind. Gov. ICTBIG 2016, 2017, doi: 10.1109/ICTBIG.2016.7892649.
[16] A. K. Verma, S. Pal, and S. Kumar, "Comparison of skin disease prediction by feature selection using ensemble data mining techniques," Informatics Med. Unlocked, vol. 16, no. April, p. 100202, 2019, doi: 10.1016/j.imu.2019.100202.
[17] M. Z. K. Patricia, V. Z. E. Santiago, and M. Y. F. Javier, "Expert System for the Pre-diagnosis of Skin Diseases," Int. J. Mach. Learn. Comput., vol. 10, no. 1, pp. 81–86, 2020, doi: 10.18178/ijmlc.2020.10.1.902.
[18] M. Chen, P. Zhou, D. Wu, L. Hu, M. M. Hassan, and A. Alamri, "AI-Skin: Skin disease recognition based on self-learning and wide data collection through a closed-loop framework," Inf. Fusion, vol. 54, pp. 1–9, 2020, doi: 10.1016/j.inffus.2019.06.005.
[19] N. I. A. Dabowsa, N. M. Amaitik, A. M. Maatuk, and S. A. Aljawarneh, "A hybrid intelligent system for skin disease diagnosis," Proc. 2017 Int. Conf. Eng. Technol. ICET 2017, vol. 2018-Janua, pp. 1–6, 2018, doi: 10.1109/ICEngTechnol.2017.8308157.
[20] S. Chan, V. Reddy, B. Myers, Q. Thibodeaux, N. Brownstone, and W. Liao, "Machine Learning in Dermatology: Current Applications, Opportunities, and Limitations," Dermatol. Ther. (Heidelb)., vol. 10, no. 3, pp. 365–386, 2020, doi: 10.1007/s13555-020-00372-0.
[21] A. Mobiny, A. Singh, and H. Van Nguyen, "Risk-Aware Machine Learning Classifier for Skin Lesion Diagnosis," J. Clin. Med., vol. 8, no. 8, p. 1241, 2019, doi: 10.3390/jcm8081241.
[22] D. de A. Rodrigues, R. F. Ivo, S. C. Satapathy, S. Wang, J. Hemanth, and P. P. R. Filho, "A new approach for classification skin lesion based on transfer learning, deep learning, and IoT system," Pattern Recognit. Lett., vol. 136, pp. 8–15, 2020, doi: 10.1016/j.patrec.2020.05.019.
[23] W. Lei, R. Zhang, Y. Yang, R. Wang, and W. S. Zheng, "Class-Center Involved Triplet Loss for Skin Disease Classification on Imbalanced Data," Proc. - Int. Symp. Biomed. Imaging, vol. 2020-April, pp. 16–20, 2020, doi: 10.1109/ISBI45749.2020.9098718.
[24] T. Goswami, V. K. Dabhi, and H. B. Prajapati, "Skin Disease Classification from Image - A Survey," 2020 6th Int. Conf. Adv. Comput. Commun. Syst. ICACCS 2020, pp. 599–605, 2020, doi: 10.1109/ICACCS48705.2020.9074232.
[25] G. A. Zakhem, J. W. Fakhoury, C. C. Motosko, and R. S. Ho, "Characterizing the role of dermatologists in developing artificial intelligence for assessment of skin cancer: A systematic review," J. Am. Acad. Dermatol., 2020, doi: 10.1016/j.jaad.2020.01.028.

[26] A. Marka, J. B. Carter, E. Toto, and S. Hassanpour, "Automated detection of nonmelanoma skin cancer using digital images: A systematic review," BMC Med. Imaging, vol. 19, no. 1, 2019, doi: 10.1186/s12880-019-0307-7.
[27] L. T. N. Ngoc, D. Park, Y. Lee, and Y. C. Lee, "Systematic review and meta-analysis of human skin diseases due to particulate matter," Int. J. Environ. Res. Public Health, vol. 14, no. 12, 2017, doi: 10.3390/ijerph14121458.
[28] J. Schwingen, M. Kaplan, and F. C. Kurschus, "Review — Current Concepts in Inflammatory Skin Diseases Evolved by Transcriptome Analysis : In-Depth Analysis of Atopic Dermatitis and Psoriasis," 2020, doi: 10.3390/ijms21030699.
[29] O. F.Y, A. J.E.T, A. O, H. J. O, O. O, and A. J, "Supervised Machine Learning Algorithms: Classification and Comparison," Int. J. Comput. Trends Technol., vol. 48, no. 3, pp. 128–138, 2017, doi: 10.14445/22312803/ijctt-v48p126.
[30] M. Oyedere and K. Gray, "ROP and TOB optimization using machine learning classification algorithms," J. Nat. Gas Sci. Eng., vol. 77, no. February, p. 103230, 2020, doi: 10.1016/j.jngse.2020.103230.
[31] B. J. Erickson, P. Korfiatis, Z. Akkus, and T. L. Kline, "Machine learning for medical imaging," Radiographics, vol. 37, no. 2, pp. 505–515, 2017, doi: 10.1148/rg.2017160130.
[32] M. A. Al-masni, D. Kim, and T. Kim, "Computer Methods and Programs in Biomedicine Multiple skin lesions diagnostics via integrated deep convolutional networks for segmentation and classification," Comput. Methods Programs Biomed., vol. 190, p. 105351, 2020, doi: 10.1016/j.cmpb.2020.105351.
[33] R. Sumithra, M. Suhil, and D. S. Guru, "Segmentation and classification of skin lesions for disease diagnosis," Procedia Comput. Sci., vol. 45, no. C, pp. 76–85, 2015, doi: 10.1016/j.procs.2015.03.090.
[34] N. Moradi and N. Mahdavi-amiri, "Computer Methods and Programs in Biomedicine Kernel sparse representation based model for skin lesions segmentation and classification," Comput. Methods Programs Biomed., vol. 182, p. 105038, 2019, doi: 10.1016/j.cmpb.2019.105038.
[35] T. Shanthi, R. S. Sabeenian, and R. Anand, "Automatic diagnosis of skin diseases using convolution neural network," Microprocess. Microsyst., vol. 76, p. 103074, 2020, doi: 10.1016/j.micpro.2020.103074.
[36] L. K. Ferris et al., "Computer-aided classification of melanocytic lesions using dermoscopic images," J. Am. Acad. Dermatol., vol. 73, no. 5, pp. 769–776, 2015, doi: 10.1016/j.jaad.2015.07.028.
[37] N. Hameed, A. Shabut, and M. A. Hossain, "A Computer-Aided diagnosis system for classifying prominent skin lesions using machine learning," 2018 10th Comput. Sci. Electron. Eng. Conf. CEEC 2018 - Proc., pp. 186–191, 2019, doi: 10.1109/CEEC.2018.8674183.
[38] C. Multiple and S. Lesions, "An Intelligent Computer-Aided Scheme for," pp. 1–12.
[39] N. Hameed, A. M. Shabut, and M. A. Hossain, "Multi-Class Skin Diseases Classification Using Deep Convolutional Neural Network and Support Vector Machine," Int. Conf. Software, Knowl. Information, Ind. Manag. Appl. Ski., vol. 2018-Decem, pp. 1–7, 2019, doi: 10.1109/SKIMA.2018.8631525.
[40] M. Koklu and I. A. Ozkan, "Skin Lesion Classification using Machine Learning Algorithms," Int. J. Intell. Syst. Appl. Eng., vol. 4, no. 5, pp. 285–289, 2017, doi: 10.18201/ijisae.2017534420.
[41] R. Kaur et al., "Real-time supervised detection of pink areas in dermoscopic images of melanoma: Importance of color shades, texture and location," Ski. Res. Technol., vol. 21, no. 4, pp. 466–473, 2015, doi: 10.1111/srt.12216.
[42] S. Chakraborty et al., "Image based skin disease detection using hybrid neural network coupled bag-of-features," 2017 IEEE 8th Annu. Ubiquitous Comput. Electron. Mob. Commun. Conf. UEMCON 2017, vol. 2018-Janua, pp. 242–246, 2017, doi: 10.1109/UEMCON.2017.8249038.
[43] W. Abbes and D. Sellami, "Automatic Skin Lesions Classification Using Ontology-Based

Semantic Analysis of Optical Standard Images," Procedia Comput. Sci., vol. 112, pp. 2096–2105, 2017, doi: 10.1016/j.procs.2017.08.226.
[44] R. Bhavani, V. Prakash, R. V. Kumaresh, and R. Sundra Srinivasan, "Vision-based skin disease identification using deep learning," Int. J. Eng. Adv. Technol., vol. 8, no. 6, pp. 3784–3788, 2019, doi: 10.35940/ijeat.F9391.088619.
[45] M. S. Manerkar, U. Snekhalatha, S. Harsh, J. Saxena, S. P. Sarma, and M. Anburajan, "Automated skin disease segmentation and classification using multi-class SVM classifier," IET Conf. Publ., vol. 2016, no. CP739, 2016, doi: 10.1049/cp.2016.1528.
[46] A. A. Adegun and S. Viriri, "FCN-Based DenseNet Framework for Automated Detection and Classification of Skin Lesions in Dermoscopy Images," IEEE Access, vol. 8, pp. 150377–150396, 2020, doi: 10.1109/ACCESS.2020.3016651.
[47] R. El Saleh, S. Bakhshi, and A. Nait-Ali, "Deep convolutional neural network for face skin diseases identification," Int. Conf. Adv. Biomed. Eng. ICABME, vol. 2019-Octob, pp. 1–4, 2019, doi: 10.1109/ICABME47164.2019.8940336.
[48] J. Rathod, V. Wazhmode, A. Sodha, and P. Bhavathankar, "Diagnosis of skin diseases using Convolutional Neural Networks," Proc. 2nd Int. Conf. Electron. Commun. Aerosp. Technol. ICECA 2018, no. Iceca, pp. 1048–1051, 2018, doi: 10.1109/ICECA.2018.8474593.
[49] V. R. Balaji, S. T. Suganthi, R. Rajadevi, V. Krishna Kumar, B. Saravana Balaji, and S. Pandiyan, "Skin disease detection and segmentation using dynamic graph cut algorithm and classification through Naive Bayes classifier," Meas. J. Int. Meas. Confed., vol. 163, p. 107922, 2020, doi: 10.1016/j.measurement.2020.107922.
[50] P. R. Hegde, M. M. Shenoy, and B. H. Shekar, "Comparison of Machine Learning Algorithms for Skin Disease Classification Using Color and Texture Features," 2018 Int. Conf. Adv. Comput. Commun. Informatics, ICACCI 2018, pp. 1825–1828, 2018, doi: 10.1109/ICACCI.2018.8554512.
[51] A. V Ubale and P. L. Paikrao, "Detection and Classification of Skin Diseases using Different Color Phase Models," no. July, pp. 1331–1335, 2019.
[52] N. S. Alkolifi Alenezi, "A Method of Skin Disease Detection Using Image Processing and Machine Learning," Procedia Comput. Sci., vol. 163, pp. 85–92, 2019, doi: 10.1016/j.procs.2019.12.090.
[53] R. Roslan, I. Najwa, M. Razly, N. Sabri, and Z. Ibrahim, "Evaluation of psoriasis skin disease classification using convolutional neural network," vol. 9, no. 2, pp. 349–355, 2020, doi: 10.11591/ijai.v9.i2.pp349-355.
[54] X. Zhang, S. Wang, J. Liu, and C. Tao, "Towards improving diagnosis of skin diseases by combining deep neural network and human knowledge," BMC Med. Inform. Decis. Mak., vol. 18, no. Suppl 2, 2018, doi: 10.1186/s12911-018-0631-9.
[55] H. M. Ünver and E. Ayan, "Skin lesion segmentation in dermoscopic images with combination of yolo and grabcut algorithm," Diagnostics, vol. 9, no. 3, 2019, doi: 10.3390/diagnostics9030072.
[56] S. Albawi, Y. A. Abbas, and Y. Almadany, "Robust skin diseases detection and classification using deep neural networks," vol. 7, no. 4, pp. 6473–6480, 2018, doi: 10.14419/ijet.v7i4.24178.
[57] S. Garg, H. Garg, V. Tripathi, B. Pant, and K. Pant, "An Efficient Framework using Deep Learning for Skin Cancer Classification," Int. J. Innov. Technol. Explor. Eng., vol. 9, no. 2, pp. 1947–1951, 2019, doi: 10.35940/ijitee.b7854.129219.
[58] S. S. Han et al., "Deep neural networks show an equivalent and often superior performance to dermatologists in onychomycosis diagnosis: Automatic construction of onychomycosis datasets by region-based convolutional deep neural network," PLoS One, vol. 13, no. 1, pp. 1–14, 2018, doi: 10.1371/journal.pone.0191493.
[59] N. Alam et al., "Automatic Detection and Severity Measurement of Eczema Using Image Processing," pp. 1365–1368, 2016.
[60] A. Haddad, "Image Analysis Model For Skin Disease Detection : Framework," 2018 7th Int.

Conf. Comput. Commun. Eng., no. c, pp. 1–4, 2018.
[61] Z. Qin, Z. Liu, P. Zhu, and Y. Xue, "A GAN-based image synthesis method for skin lesion classification," Comput. Methods Programs Biomed., vol. 195, p. 105568, 2020, doi: 10.1016/j.cmpb.2020.105568.
[62] E. D. Übeyli and E. Doğdu, "Automatic detection of erythemato-squamous diseases using κ-means clustering," J. Med. Syst., vol. 34, no. 2, pp. 179–184, 2010, doi: 10.1007/s10916-008-9229-6.
[63] J. Xie and C. Wang, "Using support vector machines with a novel hybrid feature selection method for diagnosis of erythemato-squamous diseases," Expert Syst. Appl., vol. 38, no. 5, pp. 5809–5815, 2011, doi: 10.1016/j.eswa.2010.10.050.
[64] S. Aruna, L. V. Nandakishore, and S. P. Rajagopalan, "A Hybrid Feature Selection Method based on IGSBFS and Naive Bayes for the Diagnosis of Erythemato - Squamous Diseases," Int. J. Comput. Appl., vol. 41, no. 7, pp. 13–18, 2012, doi: 10.5120/5552-7623.
[65] M. J. Abdi and D. Giveki, "Automatic detection of erythemato-squamous diseases using PSO-SVM based on association rules," Eng. Appl. Artif. Intell., vol. 26, no. 1, pp. 603–608, 2013, doi: 10.1016/j.engappai.2012.01.017.
[66] N. Rajkumar and P. Jaganathan, "A new RBF kernel based learning method applied to multiclass dermatology diseases classification," 2013 IEEE Conf. Inf. Commun. Technol. ICT 2013, no. Ict, pp. 551–556, 2013, doi: 10.1109/CICT.2013.6558156.
[67] M. El Bachir Menai and N. Altayash, "Differential diagnosis of erythemato-squamous diseases using ensemble of decision trees," Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics), vol. 8482 LNAI, no. PART 2, pp. 369–377, 2014, doi: 10.1007/978-3-319-07467-2_39.
[68] W. Deepanker and N. Pathak, "Classification of Dermatology Diseases through Bayes net and Best First Search," vol. 4, no. 5, pp. 116–119, 2015, doi: 10.17148/IJARCCE.2015.4526.
[69] B. Lahijanian, F. V. Farahani, and M. H. F. Zarandi, "A New Multiple Classifier System for Diagnosis of Erythemato-Squamous Diseases Based on Rough Set Feature Selection," pp. 2309–2316, 2016.
[70] E. Tuba, I. Ribic, R. Capor-hrosik, and M. Tuba, "Support Vector Machine Optimized by Elephant Herding Algorithm for Erythemato-Squamous Diseases Detection Support Vector Machine Optimized by Elephant Herding Support Vector Machine Optimized by Elephant Herding Algorithm for Erythemato-Squamous Diseases ," Procedia Comput. Sci., vol. 122, pp. 916–923, 2017, doi: 10.1016/j.procs.2017.11.455.
[71] Maryam, N. A. Setiawan, and O. Wahyunggoro, "A hybrid feature selection method using multiclass SVM for diagnosis of erythemato-squamous disease," AIP Conf. Proc., vol. 1867, no. August, 2017, doi: 10.1063/1.4994451.
[72] J. B. Idoko, M. Arslan, and R. Abiyev, "Fuzzy Neural System Application to Differential Diagnosis of Erythemato-Squamous Diseases," Cyprus J. Med. Sci., pp. 90–97, 2018, doi: 10.5152/cjms.2018.576.
[73] A. K. Verma, S. Pal, and S. Kumar, "Classification of skin disease using ensemble data mining techniques," Asian Pacific J. Cancer Prev., vol. 20, no. 6, pp. 1887–1894, 2019, doi: 10.31557/APJCP.2019.20.6.1887.
[74] A. K. Verma and S. Pal, "Prediction of Skin Disease Using Ensemble Data Mining Techniques and Feature Selection Method — a Comparative Study," 2019.
[75] M. A. Islam and M. S. Arefin, "A framework for detecting arsenic disease," 2016 3rd Int. Conf. Electr. Eng. Inf. Commun. Technol. iCEEiCT 2016, 2017, doi: 10.1109/CEEICT.2016.7873149.