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Skin Disease Detection Using Machine Learning Models

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Abstract: ***Skin diseases are one of the most common types of health illnesses faced by the people for ages. The identification of skin disease mostly relies on the expertise of the doctors and skin biopsy results, which is a time-consuming process. An automated computer based system for skin disease identification and classification through images is needed to improve the diagnostic accuracy as well as to handle the scarcity of human experts. Classification of skin disease from an image is a crucial task and highly depends on the features of the diseases considered in order to classify it correctly. Many skin diseases have highly similar visual characteristics, which add more challenges to the selection of useful features from the image. The accurate analysis of such diseases from the image would improve the diagnosis, accelerates the diagnostic time and leads to better and cost- effective treatment for patients. We developed a machine learning model to automatically detect skin disease form images. Our approach utilizing a convolution neural network (CNN), accurately distinguishes between being and malignant lesions. Through rigorous testing, our model demonstrates high accuracy and sensitivity, offering a valuable tool for early diagnosis and improved patient outcome in skin diseases detection.***

Cancer is a significant global health concern, with skin cancer being the most prevalent type, accounting for around 75% of all cancers worldwide. Skin cancer involves abnormal changes in the skin's outer layer, and although most cases are treatable, it remains a major concern due to its high incidence. Most skin cancers grow locally and invade surrounding tissues, but melanoma, the rarest type of skin cancer, can spread through the circulatory or lymphatic systems to distant parts of the body. Research has explored the use of image processing for cancer detection, with deep learning representing a significant advancement in this field's ability to address complex problems

Key Words: convolution neural network, Skin cancer

I. INTRODUCTION

The largest organ of human body is "Skin", an adult carry around 3.6 kgand 2 square meters of it. Skin acts as a waterproof, insulating shield, guarding the body against extremes of temperature, damaging UV lights, and harmful chemicals. With the rate of 10-12%, the population affected across India from skin disease is estimated at nearly 15.1 Crore in 2013 and which increases to 18.8 crores by 2015. According to statistics provided by the World Health Organization around 13 million melanoma skin cancer occurs globally each year, which shows skin diseases are growing very rapidly. There are many factors responsible for a disease to occur such as UV lights, pollution, poor immunity, and an unhealthy lifestyle. There are two major categories in which the lesions (spot) of skin disease are classified; benign and malignant skin lesions. Most of the skin lesions are benign in nature which is gentle and non-dangerous. Our proposed system builds upon recent advancements in convolutional neural network (CNN) architectures, which have demonstrated remarkable success in image classification tasks. By training our model on a diverse range of skin images annotated with corresponding diagnostic labels, we seek to enable the automated recognition and differentiation of benign and malignant lesions.The advancement of medical technology has made it possible to diagnose skin diseases much more quickly, efficiently, and accurately with lasers and photonics. However, the cost of such a diagnosis is still limited and very expensive. Therefore, we come up with an image processing-based approach using deep learning to diagnose skin diseases. This method takes the digital image of the disease affecting the skin area as input and then uses image scanning to identify the type of disease. This approach is simple, fast and, does not require expensive equipment other than a camera and a computer. We utilized a Mobile-Net convolutional neural networkpretrained on approximately 12,80,000 images from 2020 ImageNet Challenge and finetuned on HAM10000 dataset which contain 10015 dermoscopy images employing transfer learning. The Mobile-Net model classified skin lesion image with performance better or comparable to expert dermatologists for seven classes. We also conducted data-analysis on the dermoscopy images of skin cancer from HAM10000 dataset to uncover the relation of skin cancer with several parameters to strengthen the understanding of skin cancer.

Generally, there are five steps in computer-aided skin cancer diagnosis: image acquisition, pre-processing, segmentation, feature extraction, and classification. The most essential steps in computer-aided diagnosis of skin cancers are segmentation and classification. However, diagnosing skin cancer using computer-aided methods is not straightforward, and we must

consider many factors for an accurate diagnosis. For example, artifacts such as hairs, dark corners, water bubbles, marker signs, ink marks, and ruler signscan result in misclassification and inaccurate segmentation of skin lesions.
The most commonplace neoplasms in humans are skin cancers, which are mainly divided into two types: melanoma and non-melanoma. However, melanoma (the most threatening type of skin cancer) is not common compared to other malignant types, it is more likely to spread than other skin cancers. In 2020, an estimation 324,635 new registered cases of melanoma from 185 countries is diagnosed, of which 57,043 cases led to death. Non-melanoma skin cancer (NMSC) mainly consists of Basal Cell Carcinoma (BCC) and Squamous Cell Carcinoma (SCC), grouped and called “keratinocyte carcinomas” (KC) due to the formation of a type of skin cell called keratinocyte.

Images are applied in three conventional modalities for skin lesions: dermoscopic, histological, and photographic images. Dermoscopy images are obtained by a specialized instrument, leading to high-resolution skin imaging with a decrease in the skin surface reflectance. Histological images are acquired via invasive biopsy and microscopy. Both dermoscopy and histological methods result in great standardized images, while simple photographic images (using smartphones and cameras) show discrepancies in the zoom, angle, and lighting and may contain irrelevant backgrounds, making automated classification significantly more challenging. To overcome this challenge, we require a data- driven approach using millions of pre-training and training images to make classification robust to photographic variability.The present analytical study aimed to introduce a new viable DL based approach for the automatic prediction of skin lesion type as a tool, which can help physicians interpret lesion images. Additionally, the proposed model used the patient data, such as the anatomical site of the lesion, age, gender, and the lesion image to predict the lesion type. Recent studies have shown that the skin cancer incidence rate increases with age and men are 10% more likely to develop melanoma skin cancer than women and are 4% more likely to die from melanoma than women. Also, a correlation between the lesion type and its anatomical site on the body has been found. These findings motivated us to investigate the impact of including this information (age, gender, and anatomical site) as the input of our automated model for skin cancer detection

II. LITERATURE SURVEY

There have been many attempts to implement traditional telemedicine across the world especially in the developing countries, but the efforts has been characterized with challenges such as high-cost of sustaining telemedicine solutions and non-availability of medical expertise. Cancerous Skin disease such as melanoma and nevi typically results from environmental factors (such as exposure to sunlight) among other causes. The necessary tools needed for early detection of these diseases are still not a reality in most African communities. In recent years, there have been high expectations for techniques such as Dermoscopy or Epiluminiscence Light Microscopy (ELM) in aiding diagnosis; however evaluation of pigmented skin lesions using ELM is not only non-affordable by most of African communities but also complex and highly subjective, thus motivating researches in diagnosis automation. A part of the system would use computational intelligence technique to analyze, process, and classify the image library data based on texture and possibly morphological features of the images. Trained medical personnel in a remote location can use mobile data acquisition devices (such as cell phone) to generate images of PSL, supply such images as input to the proposed system, which in turns should intelligently be able to specify the malignancy (lifethreatening) or benign (non- threatening) status of the imaged PSL.

Medical Imaging provide techniques and processes in creating images of human body or samples (such as blood or sputum) for clinical purposes - (medical procedures seeking to reveal, diagnose or examine disease), medical science - (study of normal anatomy and physiology) or for knowledge discovery. Digital image processing involves the screening of a region for processing and saving this region to a location (possibly a file) for processing using operations such as fractal and texture analysis.

Dermatology is a one of major session of medicine that concerned with the diagnosis and treatment of skin diseases. Skin diseases are the most common form of disease in humans. Recently, many of researchers haveadvocated and developed the imaging of human vision or in the loop approach to visual object recognition. This research paper presents a development of a skin diseases diagnosis system which allows user to identify diseases of the human skin and to provide advises or medical treatments in a very short time period. For this purpose, user will have to upload an image of skin disease to our system and answer questions based on their skin condition or symptoms This system uses technologies such as image processing and data mining for the diagnosis of the disease of the skin. The image of skin disease is taken and it must be subjected to various preprocessing for noise eliminating and enhancement of the image. Finally data mining techniques are used to identify the skin disease and to suggest medical treatments or advice for users. This expert system exhibits disease identification accuracy of 85% for Eczema, 95% for Impetigo and 85% for Melanoma.

To solve the above-discussed problem we came up with the solution of an Expert System for diagnosis the skin disease. In our solution we need to take care of that difference of pattern. Before examine the patterns the system first need to bring all the images to a certain level where the patterns are much more visible for the usage without noisy and unwanted data then we extract the certain features like area features color features that can be used for create the classification model
Melanoma has the highest mortality rate of all skin cancers, with about 220 000 cases and 37000 deaths reported annually in the USA and Europe combined.1 Early detection of melanoma and other skin tumors is the most important predictor for survival.2,3 Diagnosis of skin cancer requires sufficient expertise and proper equipment for adequate accuracy. For expert dermatologists, the accuracy of melanoma diagnosis is about 71% with naked- eye inspection, and 90% using a dermato-scope, which is a magnifying lens with either liquid emulsion or cross-polarization filters to eliminate surface reflectance of skin.4,5 However, there is a global shortage of expert dermatologists: in Spain, there are 3·27 dermatologists per 100000 citizens, 6·6 in Germany, 0·55 in the UK, and 0·33 in the USA.

Because of this shortage of expertise, efforts have focused on scaling expertise by developing tools for automated assessment. The International Skin Imaging Collaboration (ISIC) Archive has collated the largest public repository of dermoscopic image datasets to support this continued research effort, facilitating 5 years of public challenges to use artificial intelligence (AI) to detect skin cancer.7–12 Several articles have reported the development of AI
Skin cancer is the most common malignancy in fair-skinned populations, and melanoma accounts for the majority of skin cancerrelated deaths world- wide. Despite special training and the use of dermo-scopes, dermatologists only rarely achieve clinical test sensitivities greater than 80%. In 2017, Esteva et al.[3] were the first to report a deep-learning convolutional neural network (CNN) image classifier that performed as well as 21 board-certified dermatologists when identifying images with malignant lesions.In this work, we trained a CNN with enhanced techniques to classify images of suspect lesions as melanoma or atypical nevi by the use of open- source images exclusively. The classification results of the CNN were compared with the efforts of 157 dermatologists from 12 German university hospitals of all levels of training including a small subsample of resident physicians.

To compare the performance of the digital automated diagnosis method with that of dermatologists, a test set with a total of 100 images of melanomas and atypical nevi was created. Using only 100 images allowed for the participation of a large number of dermatologists in the test, in light of the time required to review all the images. The chosen ratio of the classes was based on the test and training set for the International Symposium on Biomedical Imaging 2016 challenge. While this proportion does not reflect the frequency of diagnosis in clinical practice, statistical quality of the test is enhanced when a sufficient number of melanomas are in the test set In recent decades, many expert systems have been used in various branches of medicine. In fact, medicine is one of the first fields where expert systems have been used. Artificial intelligence can design decision support systems in hospitals and clinics to help professionals in making clinical decisions. These systems receive clinical information, analyze and provide conclusions as output and thereby offer the possibility to analyze and diagnose diseases and improve the quality of clinical decisions (1). MYCIN, NURSExpert, CENTAUR, DIAGNOSER, MEDI, GUIDON, MEDICS and DiagFH are some of the earliest and most successful medical expert systems (2). However, one of the major challenges facing smart systems is evaluation of their performance. Assessment is a method for analyzing data that confirms the effectiveness and efficiency of expert systems that should necessarily be applied after implementation of expert system in order to ensure the adequacy of the designed system (3). Different methods are used to evaluate the accuracy of an expert system. Sometimes, performance accuracy is measured with the gold standard (which compares the performance of a designed expert system with the specialists' function in the specified area).

A total of 600 patients were enrolled in the study. Their medical records were studied after which signs of disease and demographic characteristics were logged into the designed system. Specialists' diagnosis was compared with the expert system' diagnosis by SPSS software version 16 and STATA. The specialist's diagnosis based on clinical symptoms was considered as the gold standard. Kappa statistics, indicators of sensitivity, specificity, accuracy and confidence intervals were calculated for each disease. Expert system is a system that is trying to adopt human knowledge into a computer, so that the computer can resolve the issue as was done by experts. The purpose of this study to design an application of expert system for diagnosis the human skin diseases by using forward chaining method as one of inference technique that aims to discover symptoms of the disease that is displayed in the form of questions. The skin organ chosen because in the interaction between humans, skin is the first organ that used to shake hands, touch, kiss, etc, so that some diseases can be transmitted only through touch or by interaction of skin with skin, and many cases of skin diseases that resulted in death due to delayed handled. The expert system application design consists of seven stages: preliminary studies, data collection, data analysis, system design, system implementation, system evaluation (testing) and the last, drawing conclusions. Expert system software application built to recognize the type of skin disease after consultation by answering a few questions displayed by the system, and can infer the type of skin diseases suffered by the patient. Based on the results of black box testing, the expert system application has been running with good. Skin diseases are a group of diseases affecting people of all ages, commonly caused by fungi, bacteria, parasites, viruses, and infections. The disease's main symptoms are usually itching all over the skin. Many patients are often underestimated and embarrassed to consult directly with doctors, which in the end, ignores the symptoms of skin diseases. Since they usually have imprecision symptoms, examining skin diseases is complex and challenging. Recently, many efforts have been made to utilize artificial intelligence approaches for diagnosing various diseases based on the patient's condition. This paper aims to develop a novel fuzzy-based medical expert system based on unprecise existing symptoms. It shows that this system succeeds in all tests with an accuracy value of 95.6%.

Correctly diagnosing a skin disease is essential to patient centered care. It requires knowledge and thoroughness from expert doctors, but doctors have limitations in consulting with patients because of the tight schedule and many patients. In addition, patients are sometimes embarrassed to consult directly with the Doctor. Many patients underestimate this skin disease, which in the end ignores the symptoms of skin disease. The treatment therapy given to patients is usually done by giving medicine. Providing the appropriate drugs and the proper dosage is critical for skin disease medication and requires the standard knowledge of pharmacology. Inappropriate or improper dosage would become health problems, such as increased side effects, treatment failure, and resistance

Recently, as computers have become popular, many researchers have developed technology in the form of artificial intelligence that imitates an expert's ability (based on expert knowledge) to make decisions. Expert systems use an expert's knowledge to solve some of our real-life activities, including Interpretation, Prediction, Diagnosis, Design, Planning, Monitoring, and so on [5]- [6]. In medical science, expert systems have been adopted to help doctors and specialists diagnose and get appropriate advice on several medical problems, such as Teeth and Gums, Shortness of Breath in Infants and Children, Eye Diseases, breast cancer, neck pain, and
Anemia Diseases. With this expert system, even ordinary people can solve complex issues that usually can only be solved with the help of experts.

A self-learning disease detection model will be useful for identifying skininfections in suspected individuals using skin images ofinfected patients. To detect skin diseases, some AI-based bioinspired models employ skin images. Skin infection is a common problem that is currently faced due to various reasons, such as food, water, environmental factors, and many others. Skin infections such as psoriasis, skin cancer, monkeypox, and tomato flu, among others, have a lower death rate but a significant impact on quality of life. Neural Networks (NNs) and Swarm intelligence (SI) based approaches are employed for skin disease diagnosis and classification through image processing. In this paper, the convolutional neural networks-based Cuckoo search algorithm (CNN-CS) is trained using the well-known multi-objective optimization technique cuckoo search. The performance of the suggested CNN-CS model is evaluated by comparing it with three commonly used metaheuristic-based classifiers: CNN-GA, CNN-BAT, and CNN-PSO.

Skin disease research is in the fore front and gains prominent focus of medical image processing. The two most prevalent diseases, skin cancer, and monkeypox cause millions of illnesses and deaths worldwide each year. Dermatologists are helped by machine-learning-based techniques for detection and classification of skin diseases. The procedure is speed up with use of image processing, which extracts distinguishing characteristics from the images. To enhance and boost the diagnostic performance of dermoscopy, many dermoscopy techniques have been created. Dermoscopy is a non-invasive technique for imaging the skin. The clarity of skin spots is aided by the ability to get a magnified and lit image of a particular area of skin [3]. It enhances the visual effect of a skin lesion by removing surface reflectivity.

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. 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 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

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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 of uji 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.
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

III. SYSTEM METHODOLOGIES

Skin diseases, including various types of cancer, pose significant health risks globally. Timely and accurate diagnosis is paramount for effective treatment and improved patient outcomes. With the advent of machine learning and computer vision techniques, there has been a growing interest in developing automated systems for skin disease detection, offering the potential to enhance diagnostic accuracy and efficiency. In this paper, we present a novel approach to skin disease detection leveraging previous patient image datasets. These datasets, comprising a wide array of dermatological images, serve as valuable resources for training machine learning models. By harnessing the wealth of information contained within these datasets, we aim to develop a robust and reliable automated system capable of accurately identifying various skin diseases, including but not limited to cancerous lesions. Our proposed system builds upon recent advancements in convolutional neural network (CNN) architectures, which have demonstrated remarkable success in image classification tasks. By training our model on a diverse range of skin images annotated with corresponding diagnostic labels, we seek to enable the automated recognition and differentiation of benign and malignant lesions.

The image pixels are stored as a dependent variable while the target label is stored as an independent feature. The data is divided into train and test split and it is reshaped to handle the imbalance issues (it can only be handled if the data is 2 Dimensional), after which Random Over sampler does the job of handling the imbalance. The data is fit on the train set and the new shape is checked, following which it is reshaped again to 3 Dimension in order to train the Convolutional Neural Network. After checking if the shape is acceptable, the Convolutional Neural Network model is defined and subsequently the first layer of the CNN is plotted. Max pooling is used to select the maximum features as identified by the convolutional filter. After this, Batch Normalization does the job of making the Artificial Neural Network faster and more stable by normalization of the layer's inputs through re-scaling and re-centering. Skin cancer is one the most dangerous types of cancer and is one of the primary causes of death worldwide. The number of deaths can be reduced if skin cancer is diagnosed early. Skin cancer is mostly diagnosed using visual inspection, which is less accurate. Deep-learning-based methods have been proposed to assist dermatologists in the early and accurate diagnosis of skin cancers. This survey reviewed the most recent research articles on skin cancer classification using deep learning methods. We also provided an overview of the most common deep- learning models and datasets used for skin cancer classification.

Generally, there are five steps in computer-aided skin cancer diagnosis: image acquisition, pre-processing, segmentation, feature extraction, and classification. The most essential steps in computer-aided diagnosis of skin cancers are segmentation and classification. However, diagnosing skin cancer using computer-aided methods is not straightforward, and we must consider many factors for an accurate diagnosis. For example, artifacts such as hairs, dark corners, water bubbles, marker signs, ink marks, and ruler signs can result in misclassification and inaccurate segmentation of skin lesions.

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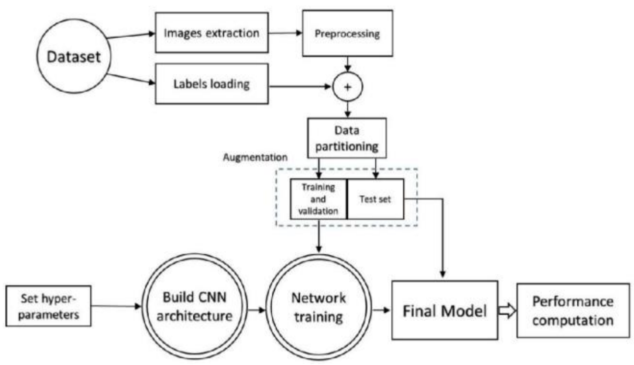
Data Collection:
Image Acquisition: Dermatological images can be obtained through various sources such as digital cameras, smartphones, dermatoscopes, or medical imaging devices. Data Annotation: Dermatologists or trained annotators label images with corresponding disease categories, providing ground truth for supervised learning algorithms.

Preprocessing:
Image Cleaning: Remove noise, artifacts, or irrelevant information from images to improve the quality of input data. Normalization: Standardize images to a common scale, resolution, or color space to ensure consistency across the dataset. Augmentation: Increase the diversity of the dataset through techniques like rotation, scaling, flipping, and adding noise, helping improve model generalization

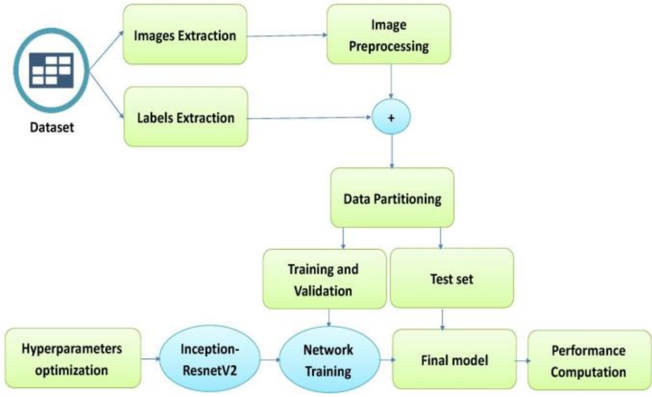


Feature Extraction:

Handcrafted Features: Extract meaningful features from images, such as color histograms, texture descriptors, shape characteristics, and gradient features. Deep Features: Utilize pre-trained convolutional neural networks (CNNs) to automatically learn hierarchical representations from raw pixel data, capturing intricate patterns relevant to skin diseases

Model Development:

Machine Learning Models: Train classifiers like support vector machines (SVM), random forests, or logistic regression on extracted features to classify skin diseases. Deep Learning Models: Utilize CNN architectures such as VGG, ResNet, or Inception, either from scratch or through transfer learning, to learn discriminative features directly from images for disease classification. Hybrid Models: Combine the strengths of traditional machine learning approaches and deep learning models to improve performance and interpretability.



Model Evaluation:

Cross-Validation: Divide the dataset into training and validation sets, iteratively training the model on subsets and evaluating performance to assess generalization capability. Performance Metrics: Measure model performance using metrics like accuracy, precision, recall, F1-score, and area under the ROC curve (AUC) to quantify classification performance.

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Confusion Matrix Analysis: Examine the distribution of true positive, true negative, false positive, and false negative predictions to identify model strengths and weaknesses.

Model Optimization:

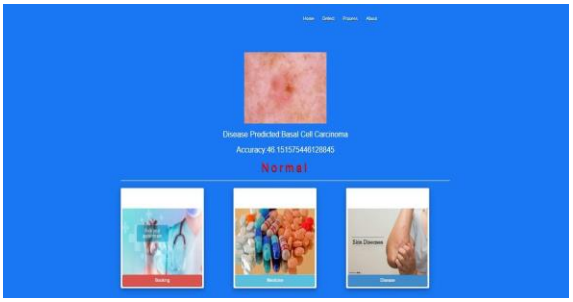
Hyper parameter Tuning: Fine-tune model parameters (e.g., learning rate, regularization strength) using techniques like grid search or random search to optimize performance. Ensemble Methods: Combine multiple models (e.g., bagging, boosting) to improve robustness and mitigate over fitting, leveraging diverse perspectives for decision-making.

Deployment and Integration:

Integration with Clinical Systems: Integrate the developed model into clinical workflows or electronic health record systems for seamless adoption by healthcare providers. User Interface Development: Design user-friendly interfaces for dermatologists or healthcare professionals to interact with the system, providing insights and recommendations based on model predictions. Continuous Monitoring and Updating: Regularly monitor model performance in real-worldsettings and update the system with new data or improved algorithms to ensure continued effectiveness and relevance.

IV. EXPERIMENTAL RESULTS

Diseases Prediction



Prediction and Recommendation

Medications for Cancer

Other names: Carcinoma; Malignant Disease; Malignant Tumor

Cancer is a malignant growth or tumour resulting from an uncontrolled growth of abnormal cells

Drugs used to treat Cancer

The medications listed below are related to or used in the treatment of this condition.

All drug classes   Filter

Drug name	Rating	Reviews	Activity	Rx/OTC	Preg	CSA	Alcohol
carboplatin	1.0	2 reviews		Rx	D	N	
fluorouracil	Rate	Add review		Rx	D	N	
doxorubicin	10	1 review		Rx	D	N	
etoposide	Rate	Add review		Rx	D	N	

V. CONCLUSION

In conclusion, our exploration into skin disease prediction reaffirms the pivotal role of data in achieving accurate and reliable outcomes. Through the analysis of extensive datasets, we have demonstrated the potential to predict skin diseases with a considerable degree of success. However, it is evident that the predictive power of our models is intricately linked to the richness and diversity of the training data. Our findings underscore the importance of having a substantial volume of high-quality images encompassing a wide spectrum of skin conditions. With a larger and more diverse dataset, our models can learn intricate patterns and variations inherent in different skin diseases, thus enhancing their predictive accuracy. Moreover, our research highlights the significance of ongoing efforts to expand and enrich existing datasets. By continually augmenting our database with new images and cases, we can improve the generalizability and robustness of our predictive models. This iterative process is essential for staying abreast of evolving medical knowledge and ensuring the efficacy of our predictive systems in real- world clinical settings. Looking ahead, the quest for greater accuracy in skin disease prediction will undoubtedly hinge on our ability to access and leverage large-scale datasets. By harnessing the collective power of data-driven approaches and advanced machine learning techniques, we can pave the way for more precise and effective diagnosis and treatment of skin conditions, ultimately enhancing patient outcomes and advancing the field of dermatology

FUTURE ENHANCEMENT

Deep learning algorithm-based algorithms are developed to assist dermatologists in the timely and accurate diagnosis of skin cancers with the end goal of developing an AI-powered device that can detect skin cancers in real time. We discussed different deep learning architectures used for the detection of skin cancers, and we specifically focused on skin cancer classification using deep learning algorithms.. The size of the datasets limits the performance of deep learning algorithms in skin cancer detection; we do not have large skin lesion datasets. Moreover, most skin lesion datasets have white skin images; the deep learning algorithms' accuracy will decrease when we test the deep learning models on different skin colors. In the future, data can be collected with varying colors of skin to address the color bias in skin lesion datasets. Moreover, to assist the dermatologist in real-time, there is a need to work on the hardware implementation of deep learning algorithms.

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