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EXPLORING TECHNIQUES FOR SKIN CANCER DETECTION USING IMAGE PROCESSING:A SYSTEMATIC REVIEW

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ABSTRACT

This literature review explores the technological advancements supporting the development of automated skin cancer detection systems using image processing techniques. The study examines various methodologies that integrate digital dermoscopy, machine learning, and deep learning algorithms for enhanced diagnostic accuracy. Key technologies discussed include preprocessing techniques for noise reduction and artifact removal, segmentation methods such as thresholding, clustering, and edge-based approaches for precise lesion isolation, and feature extraction techniques focusing on color, shape, and texture analysis. Additionally, the role of convolutional neural networks (CNNs) in enabling real-time, high-accuracy classification of skin lesions is highlighted, along with the use of publicly available datasets like ISIC for model training and validation. Cloud-based platforms and computational frameworks that support large-scale image analysis and remote diagnostic services are also reviewed. Challenges such as dataset imbalance, varying skin tones, image quality inconsistencies, and the need for clinically explainable outputs are critically analyzed. The paper emphasizes how these emerging technologies can bridge existing gaps in early melanoma detection, ultimately improving clinical workflows, reducing diagnostic delays, and supporting tele-dermatology applications. Future research directions focusing on multi-modal imaging, AI-driven diagnostic assistance, and improved generalization across diverse populations are also outlined.

Keywords: Skin Cancer Detection, Image Processing, Dermoscopy, Deep Learning, Machine Learning, CNN, Segmentation, Feature Extraction, Melanoma Detection, Medical Imaging, Computer-Aided Diagnosis.

1. INTRODUCTION

Skin cancer is one of the most prevalent and fastest-growing cancers across the world, affecting millions of people annually. It primarily develops due to abnormal and uncontrolled growth of skin cells, often triggered by excessive exposure to ultraviolet (UV) radiation from the sun or artificial sources. Among the various types, melanoma is considered the most dangerous because of its high tendency to spread to other organs if not identified at an early stage. Although early diagnosis significantly increases the chances of successful treatment, many cases remain undetected due to lack of awareness, limited access to dermatologists, and the subjective nature of visual inspections. Traditional diagnostic procedures such as dermoscopic examination and biopsy are accurate but depend heavily on expert interpretation, making them time-consuming, expensive, and not always feasible in rural or resource-limited settings.

Advancements in digital imaging and computational techniques have opened new possibilities for automated skin cancer detection. Image processing plays a crucial role in this domain by enabling computers to analyze dermoscopic images and identify patterns that may not be easily recognized by the human eye. Through steps such as image enhancement, noise removal, segmentation, and feature extraction, image processing algorithms help isolate the lesion region and highlight important characteristics related to shape, color, borders, and texture features that are commonly used to distinguish benign lesions from malignant ones. These processed features can be further analyzed using machine learning or deep learning models, particularly convolutional neural networks (CNNs), which can learn complex patterns from large datasets and classify skin lesions with high accuracy.

The increasing availability of annotated databases like ISIC (International Skin Imaging Collaboration) has accelerated research in this field by providing thousands of dermoscopic images for training and validation. These datasets, combined with powerful computational frameworks, allow the development of reliable models capable of assisting dermatologists in early detection. However, challenges still exist, including variations in skin tones, inconsistent image quality, presence of artifacts such as hair and reflections, and the need for clinically explainable AI methods. Addressing these challenges is vital to ensure that automated systems can perform consistently across diverse populations and real-world environments.

This project aims to design and implement an automated skin cancer detection system using image processing techniques to support early diagnosis and improve clinical efficiency. By integrating preprocessing, segmentation, feature extraction, and classification within a systematic workflow, the system seeks to reduce dependency on manual examination and provide a more accurate, faster, and accessible diagnostic solution. Ultimately, such technology has the potential to enhance tele-dermatology services, assist medical professionals, and contribute to reducing the mortality rate associated with late-stage skin cancer detection.

2. LITERATURE SURVEY

Sooyong Chae, Tongyu Huang, Omar Rodríguez-Núñez , Théotim Lucas, Jean-Charles Vanel, Jérémy Vizet, Angelo Pierangelo , Gennadii Piavchenko , Tsanislava Genova , Ajmal Ajmal, Jessica C. Ramella-Roman, Alexander Doronin , Hui Ma, and Tatiana Novikova , [1], This paper discuss that the translation of imaging Mueller polarimetry to clinical practice is often hindered by large footprint and relatively slow acquisition speed of the existing instruments. Using polarization-sensitive camera as a detector may reduce instrument dimensions and allow data streaming at video rate. However, only the first three rows of a complete 4×4 Mueller matrix can be measured. To overcome this hurdle we developed a machine learning approach using sequential neural network algorithm for the reconstruction of missing elements of a Mueller matrix from the measured elements of the first three rows. The algorithm was trained and tested on the dataset of polarimetric images of various excised human tissues (uterine cervix, colon, skin, brain) acquired with two different imaging Mueller polarimeters operating in either reflection (wide-field imaging system) or transmission (microscope) configurations at different wavelengths of 550 nm and 385 nm, respectively. Reconstruction performance was evaluated using various error metrics, all of which confirmed low error values. The reconstruction of full images of the fourth row of Mueller matrix with GPU parallelization and increasing batch size took less than 50 milliseconds. It suggests that a machine learning approach with parallel processing of all image pixels combined with the partial Mueller polarimeter operating at video rate can effectively substitute for the complete Mueller polarimeter and produce accurate maps of depolarization, linear retardance and orientation of the optical axis of biological tissues, which can be used for medical diagnosis in clinical settings.

Syed Akbar Raza Naqvi, Ahmed Toaha Mobashsher, Beadaa Mohammed, Damien Foong, and Amin Abbosh [2], This paper aims to characterize Non-Melanoma malignancies and their corresponding benign conditions in ex-vivo/in-vivo tissue environments to study the feasibility of microwave techniques for skin cancer detection. Methods: The dielectric dataset is developed across the frequency band 1 to 14 GHz using Keysight slim-form and RG405 probe characterization systems. The acquired reflection data captured by the systems is converted to dielectric values using the Open-Water- Short and Open-Water-Liquid calibration methods, respectively. Furthermore, the impact of anaesthesia application during skin excision procedure on ex-vivo dielectric data is investigated. Results: The observations suggest that the dielectric properties (DPs) of excised skin lesions may not accurately represent actual tissue properties as they vary significantly ($\Delta\epsilon'$ =30.7%, $\Delta\epsilon''$ =66.6%) compared to pre- excision conditions. In-vivo dielectric data analysis indicates that when compared to healthy skin, malignant Basal Cell Carcinoma presents increased DPs (dielectric constant & loss factor) of (24.8 & 38.6%), respectively. On the other hand, for malignant Squamous Cell Carcinoma and pre-malignant Actinic Keratosis, the measured results show decreased DPs (dielectric constant & loss factor) accordingly by (19.4 & 18.2%) and (19.2 & 27.9%). The corresponding benign lesions have less than 13% dielectric contrast compared to healthy skin across the tested band. Conclusion: The significant contrasts between in-vivo healthy and cancerous skin DPs strongly suggest the viability of the microwave band for skin cancer detection. Significance: The research finding of this study would be critical in developing a portable electromagnetic system for skin cancer detection.

Hailong He , Johannes C. Paetzold , Nils Börner , Erik Riedel, Stefan Gerl , Simon Schneider , Chiara Fisher , Ivan Ezhov , Suprosanna Shit , Hongwei Li , Daniel Rückert , Juan Aguirre , Tilo Biedermann , Ulf Darsow, Bjoern Menze , and Vasilis Ntziachristos [3], —This paper discusses that the Ultra-wideband raster-scan optoacoustic mesoscopy (RSOM) is a novel modality that has demonstrated unprecedented ability to visualize epidermal and dermal structures in-vivo. However, an automatic and quantitative analysis of three-dimensional RSOM datasets remains unexplored. In this work we present our framework: Deep Learning RSOM Analysis Pipeline (DeepRAP), to analyze and quantify morphological skin features recorded by RSOM and extract imaging biomarkers for disease characterization. DeepRAP uses a multi-network segmentation strategy based on convolutional neural networks with transfer learning. This strategy enabled the automatic recognition of skin layers and subsequent segmentation of dermal microvasculature with an accuracy equivalent to human assessment. DeepRAP was validated against manual segmentation on 25 psoriasis patients under treatment and our biomarker extraction was shown to characterize disease severity and progression well with a strong correlation to physician evaluation and histology. In a unique validation experiment, we applied DeepRAP in a time series sequence of occlusion-induced hyperemia from 10 healthy volunteers. We observe how the biomarkers decrease and recover during the occlusion and release process, demonstrating accurate performance and reproducibility of DeepRAP. Furthermore, we analyzed a cohort of 75 volunteers and defined a relationship between aging and microvascular features in-vivo.
More precisely, this study revealed that fine microvascular features in the dermal layer have the strongest correlation to age. The ability of our newly developed framework to enable the rapid study of human skin morphology and microvasculature in-vivo promises to replace biopsy studies, increasing the translational potential of RSOM.

Abdul Rahman Dira, Hazlina Hamdan , Alfian Abdul Halin ,and Noridayu Manshor [4], Deep Learning (DL) techniques have significantly improved the diagnostic accuracy in healthcare, particularly for detecting and classifying skin cancer. Such technological advancements will assist healthcare professionals in delivering more accurate, efficient, and timely diagnoses, ultimately improving patient outcomes and facilitating early detection and treatment. Medical imaging technologies such as magnetic resonance imaging (MRI) and computed tomography (CT) are critical for diagnosing dermatological conditions. However, interpreting these images can be challenging due to overlapping structures and varying image quality. This study explores the application of DL in skin cancer diagnosis, focusing on advances in image segmentation and classification. DL-based models are reviewed specifically by convolutional neural networks (CNNs), and evaluations on their effectiveness for skin lesion detection are provided. This study also examines the critical challenges of deploying DL models in clinical practice, covering issues including dataset diversity, model interpretability, and real-world implementation feasibility. It further explores the selection of network architectures and data preprocessing techniques, emphasizing their influence on model performance. In summary, this study identifies research gaps and suggests future directions for enhancing DL models for dermatological applications.

Ryan A. L. Schoop , Lotte M. de Roode , Lisanne L. de Boer, and Behdad Dashtbozorg [5], Multi-modality image registration is an important task in medical imaging because it allows for information from different domains to be correlated. Histopathology plays a crucial role in oncologic surgery as it is the gold standard for investigating tissue composition from surgically excised specimens. Research studies are increasingly focused on registering medical imaging modalities such as white light cameras, magnetic resonance imaging, computed tomography, and ultrasound to pathology images. The main challenge in registration tasks involving pathology images comes from addressing the considerable amount of deformation present. This work provides a framework for deep learning-based multi-modality registration of microscopic pathology images to another imaging modality. The proposed framework is validated on the registration of prostate ex-vivo white light camera snapshot images to pathology hematoxylin-eosin images of the same specimen. A pipeline is presented detailing data acquisition, protocol considerations, image dissimilarity, training experiments, and validation. A comprehensive analysis is done on the impact of pre-processing, data augmentation, loss functions, and regularization. This analysis is supplemented by clinically motivated evaluation metrics to avoid the pitfalls of only using ubiquitous image comparison metrics. Consequently, a robust training configuration capable of performing the desired registration task is found. Utilizing the proposed approach, we achieved a dice similarity coefficient of 0.96, a mutual information score of 0.54, a target registration error of 2.4 mm, and a regional dice similarity coefficient of 0.70.

3. COMPARITIVE ANALYSIS OF LITERATURE REVIEWS

Table1:Comparison Study of Papers

Paper Title	Authors	Comparative Study
Machine Learning Approach to 3 × 4 Mueller Polarimetry for Complete Reconstruction of Diagnostic Polarimetric Images of Biological Tissues	Sooyong Chae, Tongyu Huang, Omar Rodríguez-Núñez , Théotim Lucas, Jean-Charles Vanel, Jérémy Vizet, Angelo Pierangelo , Gennadii Piavchenko , Tsanislava Genova , Ajmal Ajmal, Jessica C. Ramella-Roman, Alexander Doronin , Hui Ma, and Tatiana Novikova	The study compares complete Mueller polarimetry with partial 3×4 polarimetry and shows that machine learning can effectively bridge the missing information. The IMP1 system, operating in reflection on bulk cervical tissue, provides wide-field data but is affected by surface variations, while the IMP2 transmission microscope delivers high-resolution images of thin brain, skin, and colon tissues with distinct polarization patterns. Model I, trained only on IMP1 data, works well for cervical tissue but fails to generalize to other tissues or configurations. In contrast, Model II, trained on combined IMP1 and IMP2 datasets, achieves high accuracy, strong robustness, and excellent structural similarity between reconstructed and true Mueller matrices. Overall, the comparison shows that integrating diverse datasets makes machine learning capable of accurately reconstructing full Mueller matrices, enabling fast, clinically useful polarimetric imaging.

Benign and Malignant Skin Lesions: Dielectric Characterization, Modelling and Analysis in Frequency Band 1 to 14 GHz	Syed Akbar Raza Naqvi, Ahmed Toaha Mobashsher, Beadaa Mohammed, Damien Foong, and Amin Abbosh	The paper compares the dielectric properties of benign, pre-malignant, and malignant skin lesions in both in-vivo and ex-vivo conditions across 1–14 GHz. Malignant lesions, especially BCC, show strong dielectric contrast from healthy skin, while benign lesions show minimal differences, making malignancies easier to distinguish. A key comparison reveals that ex-vivo measurements are highly altered by anaesthesia and temperature changes, unlike in-vivo data, which more accurately reflects true tissue behaviour. Overall, the study demonstrates that in-vivo microwave dielectric characterization is more reliable and provides clearer separation between malignant and benign lesions.

Machine Learning Analysis of Human Skin by Optoacoustic Mesoscopy for Automated Extraction of Psoriasis and Aging Biomarkers	Hailong He , Johannes C. Paetzold , Nils Börner , Erik Riedel, Stefan Gerl , Simon Schneider , Chiara Fisher , Ivan Ezhov , Suprosanna Shit , Hongwei Li , Daniel Rückert , Juan Aguirre , Tilo Biedermann , Ulf Darsow, Bjoern Menze , and Vasilis Ntziachristos	DeepRAP outperforms traditional skin-analysis methods by providing automated, accurate 3D segmentation of skin layers and microvasculature using RSOM imaging. Unlike manual or threshold-based approaches—which are slow, inconsistent, and prone to errors—DeepRAP handles artifacts better, captures fine vessels more clearly, and achieves human-level accuracy. It also surpasses other non-invasive tools like dermoscopy, confocal microscopy, and OCT by offering deeper penetration and richer vascular detail, making it more effective for monitoring psoriasis, vascular function, and aging.
Segmentation and Classification of Skin Cancer Diseases Based on Deep Learning: Challenges and Future Directions	Abdul Rahman Dira Khalaf, Hazlina Hamdan , Alfian Abdul Halin ,and Noridayu Manshor	The paper compares CNN- and U-Net– based models with newer attention and transformer methods for skin cancer detection. CNN and U-Net models give strong, reliable segmentation, while advanced hybrids improve feature accuracy but require more computation. It also contrasts datasets like ISIC and HAM10000, showing issues such as imbalance and limited skin-tone diversity. Overall, newer models perform better, but data limitations and clinical deployment challenges remain.

Framework for Deep Learning Based Multi-Modality Image Registration of Snapshot and Pathology Images	Ryan A. L. Schoop , Lotte M. de Roode , Lisanne L. de Boer, and Behdad Dashtbozorg	The paper compares traditional image-registration methods—which fail due to large tissue deformation and limited landmarks—with a deep-learning VoxelMorph framework designed for snapshot-to-pathology alignment. While classical feature- and intensity-based approaches struggle with mismatched modalities, the proposed model, supported by tailored pre-processing and optimized loss functions, achieves far better overlap and clinically reliable alignment. The combined MSE + No-Background MI loss with strong regularization outperforms other configurations, resulting in superior TRE and regional DSC compared to conventional techniques.

4. Conclusion

This review report examined a broad spectrum of emerging technologies in medical imaging and skin related diagnostics, including Mueller polarimetry reconstruction, microwave dielectric characterization, optoacoustic mesoscopy, deep-learning-based skin cancer segmentation, and multi modality image registration. The analysis highlighted how each technology, powered by machine learning, contributes to faster, more accurate, and non-invasive assessment of biological tissues. From reconstructing missing polarimetric data to reliably distinguishing malignant skin lesions, automating vascular biomarker extraction, improving lesion segmentation, and aligning pathology images with macroscopic snapshots, these advancements collectively demonstrate the growing impact of AI-integrated imaging systems in clinical workflows.The findings emphasize that combining modern sensing methods with deep learning enables richer diagnostic information, reduces manual effort, and enhances the precision of medical decision-making. While challenges such as dataset limitations, high computational requirements, and imaging variability persist, the ongoing progress in AI, sensor design, and multi-modal data fusion is rapidly overcoming these barriers. Overall, this review underscores the transformative potential of intelligent, data-driven imaging technologies to deliver more reliable, scalable, and clinically meaningful tools for early detection, disease monitoring, and improved patient outcomes across dermatology and medical imaging applications.

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