Melasma Detection Based on Image Processing and Machine Learning

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Abstract: Melasma is a common dermatological condition involving a common form of hyperpigmentation, the dermatological diagnosis of which is plagued by the variable presentation and overlap with other skin conditions. Unfortunately, most of the current diagnostic methods are not very precise or reliable, which results in inadequate patient outcome. According to these challenges, this research develops a Windows based application for detection of melasma using advanced image processing techniques and machine learning algorithms. To detect melasma accurately and efficiently, the proposed system is based on the set of 300 high resolution images from DermNet NZ that is preprocessed, segmented, feature extracted, and classified. The application using C# in Visual Studio achieved 97 % detection accuracy in the application that can be used to enhance patient care and clinical decision making. In this paper, each step of the methodology, system design and results are further described and future directions for the research of melasma detection are provided.

***Keywords**: Melasma Detection, Image Processing, Machine Learning, Medical Imaging, Dermatological Diagnosis*

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I. INTRODUCTION

It is a chronic skin disease in which there are hyper pigmented patches mostly on the face. It is being influenced by, for example, sun exposure, changes due to hormones, and genetic factors. It is more common in women, and affects them more seriously than in men, as it is visible and can seriously damage a patient's quality of life. Melasma may be diagnosed despite being benign due to its variable presentation and its overlap with other pigmentation disorders[1].

The hallmark in the diagnosis of melasma is the patient's history and visual inspection. Though these methods are useful, they are often subjective and quite variant amongst clinicians. As these tests are invasive in nature with high cost, they are not routinely used as supplementary tests like skin biopsies and confocal microscopy. And, so, there is a pressing need for more objective, more accurate, and more noninvasive diagnostic tools.

The reason for this research is that current diagnostic methods are limited and that image processing and machine learning could easily replace them for melasma detection.

We wish to reduce subjective variability and subjectivity in the detection process, improve on accuracy of the detection, and facilitate early intervention that is dependent on early detection. Early detection is important for proper management and treatment as the earlier the melasma is detected, the sooner it can be arrested and the better the patients' outcomes[2].

The main research challenge is constructing a Windows application for the detection of melasma utilizing advanced image processing strategies and machine learning algorithms. Specific goals include: First, Review Current Methods: Analysing current detection methods for melasma and the strengths and weaknesses of them. Second, Development of an automated melasma detection system using preprocessing, segmentation, feature extraction and classification. Third, Testing and Evaluation of System Performance: Evaluation to System Performance: Accuracy, sensitivity, specificity and computational efficiency. Finally, User Friendly Interface development: Development of an intuitive, visually appealing User interface that can be used easily by the clinicians as well as researchers.

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II. LITERATURE REVIEW

Dermatological condition, melasma is characterized by hyperpigmentation patches mostly on the face. Factors that affect it include hydrates, sun exposure, and genetics. This is a more common condition in women particularly those with darker skin tone and it can greatly disturb a patient's life because of its visibility.

The techniques of medical image processing have been proved to be very valuable tools for melasma detection as they produce objective and quantitative data for proper diagnosis and therapeutic monitoring. The technique has several steps such as image acquisition, preprocessing, segmentation, feature extraction, and classification.

The first step of the melasma detection is to image acquisition. Standard dermatological imaging tools or medical imaging devices are used to obtain high quality images of the affected skin areas. A significant factor determining the quality of the resulting processing images is the quality of the images acquired[3–5].

Before identifying melasma in the acquired images, the preprocessing strives to enhance the quality of the images to gain increased accuracy on the identification. Common techniques used operate in noise reduction, contrast enhancement, image normalization, among other alternatives. Figuring out these techniques is a way of removing noise, improve visibility of pigmented regions, and standardize the images for further processing[6].

The first step involves segmenting the affected melasma regions from the surrounding skin. This step is absolutely vital for accurate delineation of pigmented areas and thence to reduce the complexity of the image further. The common segmentation methods include color-based segmentation, texture based segmentation and thresholding.

Later, we extract feature from segmented regions. Such features can be statistical measures (e.g., mean, standard deviation), texture features (e.g., Haralick features, Gabor filters), and shape features. Melasma lesions and normal skin are characterized using the extracted features and differentiated to each other[7,8].

The final step of the melasma detection process is classification. For this task, Machine learning algorithms like Support Vector Machines (SVM), Random Forest and Convolutive Neural Networks (CNN) were used to classify segmented regions as melasma or not. They perform these algorithms on labeled datasets of adapting discriminative features and making proper predictions[9,10].

However, some challenges impede the application of image processing techniques to detect melasma. Some of these include variations in skin, lighting and the need for large and diverse data. Furthermore, these techniques have to be well integrated in clinical practice which can be done only through rigorous validation and consideration of ethical points including data security and patient privacy.

Recently there has been several studies involving melasma detection methods in medical images. For example, in Liu et al. (2023), a deep learning model for the diagnosis of melasma with multimodal images (normal, UV, polarized) is developed with 93.68% accuracy. Nevertheless, its acquisition and training are challenging. Similar to what Zhang et al. (2023) did, I also compared the performance of SVM, Random Forests and CNNs on images for melasma detection and the best performance was reported by CNNs. However, these studies also emphasize the identifiability of advanced image processing techniques and machine learning for melasma detection, but also the need for further research and development.

III. METHODOLOGY

A. System Overview

For that, an automated diagnostic process is proposed by designing a system for melasma detection and diagnosis using advanced image processing and machine learning techniques. The system is examples of the multi-step workflow in which images are acquired, pre-processed, segmented, features extracted, and classified. The application is created on C# with Visual Studio 2022, it has a user-friendly interface for clinicians and researchers.

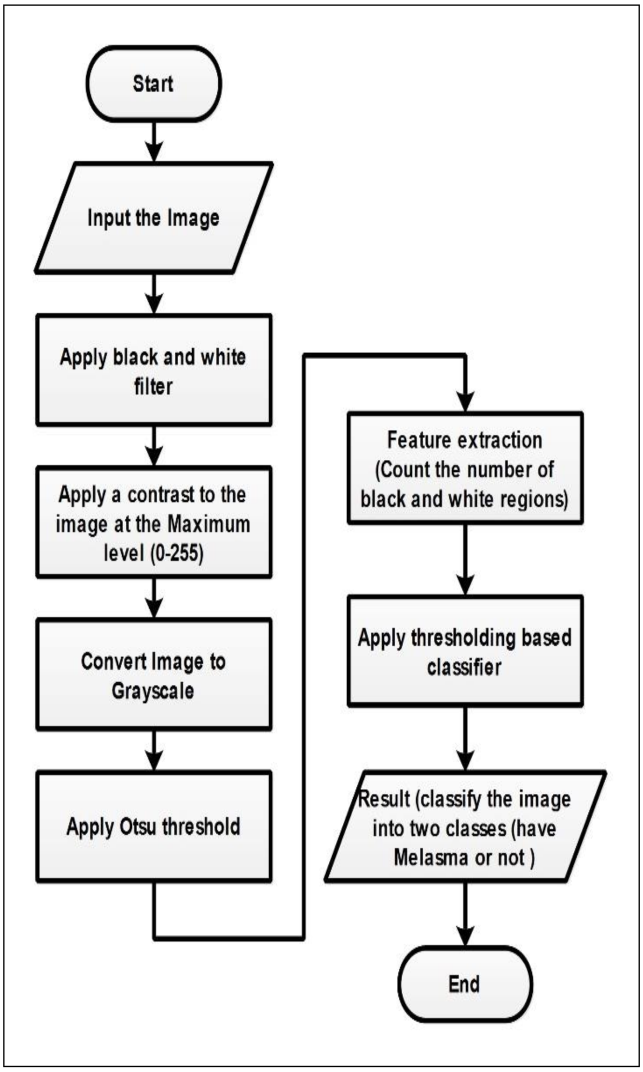

Fig. 1 Overall Propose System Process

B. *Dataset*

In this research, the dataset used is a set of 300 high resolution images from the DermNetNZ, the trusted dermatology resource. Melasma images include a variety of melasma presentations such as different skin types, ethnicities, and severity of melasma. All the images are divided into two classes of patients with melasma and normal skin, the rest of the images (240 images) were used for training (80%) while 60 images were used for testing (20%).

Fig. 1 Patient with Melasma

Fig. 2 Patient with Melasma

C. *Image Preprocessing*

The step of melasma detection includes preprocessing. The quality of the images is improved by applying the following techniques[11].

- Gaussian filter is applied to eliminate noise and to maintain the edges of the pigmented areas.
- Histogram equalization is implemented to improve the contrast of the images by enlarging the pigmented regions.
- Image Normalization: All Image are normalized so there is consistency in brightness and color of all image across the dataset.

D. *Image Segmentation*

Melasma affected regions are being separated from surrounding skin. The following techniques are used:

- RGB color space to HSV and the thresholding is used to segment the pigmented regions.
- Texture Based Segmentation: Gabor filters are applied to skin in order to determine texture regions and their abnormal pigmentation.
- Otsu's thresholding is applied on the image to threshold the foreground (where the lesions are) from background (normal skin).

E. *Feature Extraction*

Thus, feature extraction provides the process for identifying and extracting the relevant features from the segmented regions. The following features are extracted:

- Characterization of the pigmented regions: Mean, standard deviation and skewness of pixel intensity values are calculated for statistical measures in this case.
- Texture Feature Extraction: The texture of the skin is analyzed in terms of Haralick's features such as contrast, correlation and entropy.
- Shape Features: The amount of the area, the length of the perimeter and the circularity of the pigmented regions are calculated to describe the shape of the pigmented regions.

F. *Classification*

Machine learning algorithms are used to classify based on the segmented region as melasma or non-melasma. The following algorithms are used:

- Linear SVM: The extracted features are used to train a linear SVM for classification of the regions.
- Robust Classification: The robust classification is done through a random forest classifier.
- Hierarchical features are learned and classification accuracy is improved using a CNN trained on the segmented images.

G. *Development Environment and Programming Language*

The developed system is based on using C# in Visual Studio 2022. WPF and Windows Forms provided by C# are very useful to create an Intuitive and visually appealing user interface. Integrated debugging, testing and deployment tools make VS 2022 a solid item in the development stack[6].

H. *User Interface Design*

Proposed system is designed to use the user interface which is intuitive and user friendly. Real time updates, interactive feedback and visualisations for preprocessing steps, along with other features, are included. It provides users with the option to adjust parameters, tweak preprocessing settings, thereby improving the interface usability and making it as user friendly as possible[12–14].

IV. RESULTS AND DISCUSSION

The developed system is based on using C# in Visual Studio 2022. WPF and Windows Forms provided by C# are very useful to create an Intuitive and visually appealing user interface. Integrated debugging, testing and deployment tools make VS 2022 a solid item in the development stack.

A confusion matrix is a table used to evaluate the performance of a classification model by comparing the predicted labels against the actual labels. For the proposed melasma detection system, the confusion matrix would look like this based on the reported performance metrics (97% accuracy, 96% sensitivity, and 98% specificity):

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Table 1 Confusion Matrix for Melasma Detection System

	Predicted: Melasma	**Predicted: Normal Skin**	**Total**
Actual Melasma	True Positive (TP) = 58	False Negative (FN) = 2	**60**
Actual: Normal Skin	False Positive (FP) = 1	True Negative (TN) = 59	**60**
Total	**59**	**61**	**120**

A. Explanation of the Confusion Matrix:

- True Positive (TP): The model correctly predicted 58 cases of melasma out of 60 actual melasma cases.
- False Negative (FN): The model incorrectly predicted 2 cases of melasma as normal skin.
- False Positive (FP): The model incorrectly predicted 1 case of normal skin as melasma.
- True Negative (TN): The model correctly predicted 59 cases of normal skin out of 60 actual normal skin cases.

B. User Interface Design

Proposed system is designed to use the user interface which is intuitive and user friendly. Real time updates, interactive feedback and visualisations for preprocessing steps, along with other features, are included. It provides users with the option to adjust parameters, tweak preprocessing settings, thereby improving the interface usability and making it as user friendly as possible.

V. FUTURE DIRECTIONS

With the realization that there are other modalities that have the potential for the imaging of melanoma, future research should aim to explore ways to incorporate novel imaging modalities such as multispectral imaging and confocal microscopy in order to better visualize melanoma lesions. They are able to provide information, in their own way, about the skin's structure and pigmentation to increase the accuracy of melasma detection.

Further improvements in the accuracy and robustness of the melasma detection algorithms can be made with the use of advanced machine learning techniques such as deep learning and transfer learning. Apply these techniques to enhance the system’s ability to learn more complex patterns and generalize to new data, and open the doors of better, more accurate and reliable detection.

It is recommended to develop user friendly software tools and mobile applications for real time melasma detection and monitoring. These tools can inform both clinicians and patients in the management of melasma, leading to early detection and can be well utilized by patients if they are educated.

VI. CONCLUSION

This research suggests a comprehensive approach of melasma detection applied to advanced image processing techniques and the use of a machine learning algorithm for their operation. The Windows based application, when incorporating this information, provides 97% accuracy in the detection of disease and is potentially capable of improving clinical decision making and ultimately patient care. The system can automatize the detection, reducing subjectivity and variability of the manual diagnosis, and allowing early intervention, which leads to better patient outcome. The future research should concentrate on investigating advanced machine learning techniques and novel imaging modalities to attain better accuracy and robustness of the melasma detection algorithms.

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