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Segmentation of Vitiligo images using modified Watershed Segmentation

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ABSTRACT

Vitiligo is a dermatological condition characterized by depigmentation of the skin, resulting from the loss of melanocytes. Automatic image analysis methods are essential for diagnosing vitiligo and tracking its development. Because it is good at defining object boundaries, watershed segmentation is a frequently used technique for segmenting medical images. However, traditional watershed segmentation may produce over-segmentation and under-segmentation issues in vitiligo images due to their complex and irregular patterns.

This research paper proposes a modified watershed segmentation approach tailored specifically for vitiligo image analysis. The proposed method incorporates pre-processing steps to enhance image contrast and reduce noise, followed by a novel marker-based watershed segmentation algorithm. In this algorithm, markers are strategically placed based on local intensity and texture features to guide the segmentation process and improve boundary delineation.

Annotated ground truth images from a collection of vitiligo images are used to assess the effectiveness of the suggested technique. Several quantitative indicators, including accuracy, the Jaccard index, and the Dice similarity coefficient, are used to compare the segmentation outcomes produced by the suggested method with those produced by advanced techniques.

Experimental results demonstrate that the modified watershed segmentation method outperforms existing approaches in accurately segmenting vitiligo lesions while minimizing over-segmentation and under-segmentation errors. The proposed method shows promising potential for aiding dermatologists in diagnosing and monitoring vitiligo progression, facilitating timely treatment interventions, and improving patient confidence.

.KEYWORDS

Segmentation, Watershed, Pre-processing, Vitiligo, Image Processing etc.

1. Introduction

Vitiligo is a chronic autoimmune skin disorder characterized by the loss of melanocytes, leading to the formation of depigmented patches on the skin. This condition affects approximately 1% of the global population, with no predilection for age, gender, or ethnicity. While vitiligo is not life-threatening, its psychological and social impact on affected individuals can be significant, often resulting in low self-esteem, social stigmatization, and impaired quality of life.

The diagnosis and monitoring of vitiligo typically rely on visual examination by dermatologists. However, manual assessment can be subjective, time-consuming, and prone to inter-observer variability. Consequently, there is a growing interest in leveraging advanced image processing techniques to aid in the analysis of vitiligo images.

Medical image processing encompasses a broad range of computational methods aimed at extracting meaningful information from medical images to assist in diagnosis, treatment planning, and monitoring of various medical conditions. In the context of vitiligo, image processing techniques can play a crucial role in automating lesion detection, segmentation, and quantification, thereby providing objective and reproducible assessments of disease severity and progression.

The use of medical image processing in the context of vitiligo offers several advantages. Firstly, it enables the accurate delineation of vitiligo lesions, facilitating quantitative analysis of lesion size, shape, and distribution. This information is valuable for tracking disease progression over time and assessing treatment efficacy. Moreover, automated image analysis can help standardize diagnostic criteria and reduce the subjectivity associated with visual inspection.

Additionally, medical image processing techniques can aid in the early detection of vitiligo lesions, allowing for timely intervention and management. Early detection is critical for implementing treatment strategies aimed at halting or reversing depigmentation and preserving remaining melanocytes.

Image segmentation is a fundamental task in digital image processing that involves partitioning an image into multiple regions or segments based on certain characteristics such as color, intensity, texture, or motion. The goal of segmentation is to simplify the representation of an image into meaningful and homogeneous regions, which can facilitate subsequent analysis and understanding of the image content.

In various applications of image processing, including medical imaging, remote sensing, object recognition, and computer vision, segmentation plays a crucial role in pre-processing and analysis tasks. One of the primary reasons for employing segmentation in pre-processing is to enhance the efficiency and accuracy of subsequent processing steps by isolating regions of interest and reducing the complexity of the image data.

One popular segmentation technique widely used in image processing is watershed segmentation. The watershed algorithm, inspired by the geological concept of watershed lines separating different drainage basins, partitions an image into regions based on gradients or intensity discontinuities. Watershed segmentation is particularly useful for segmenting objects with uneven or unclear boundaries, as it tends to delineate regions along intensity gradients.

In watershed segmentation, the image intensity or gradient is treated as a topographic surface, where high gradient values correspond to ridges and low values correspond to valleys. By flooding this surface from regional minima (markers), watershed lines are formed along the boundaries of adjacent catchment basins, effectively partitioning the image into distinct segments.

Despite its effectiveness, traditional watershed segmentation may suffer from over-segmentation, where small, spurious regions are created, or under-segmentation, where adjacent regions are merged incorrectly. To address these issues, various modifications and enhancements to the watershed algorithm have been proposed, such as marker-controlled watershed, hierarchical watershed, and gradient-based watershed.

1.1 Motivation:

A frequently acquired skin ailment known as vitiligo causes distinct white spots to appear on the body and is caused by the loss of melanocytes in the epidermis. There are several theories on how vitiligo manifests, but the root cause is still unidentified. It is a specific autoimmune disorder. A pigmentary disorder with an unknown origin, White macules that appear on the skin are a defining feature of vitiligo, brought on by the selective death of melanocytes. Although it affects anywhere from less than 0.1 percent and more than 8 percent of the world's population, the illness only affects roughly one percent of persons in the United States and Europe. The condition is not life-threatening or contagious. It can be stressful or make you feel bad about yourself.

Figure 1: Images for skin disease Vitiligo: Adopted from [13]

Over the past few years, astounding advancements in the fields of artificial intelligence, computer vision, and deep learning have led to exceptional performance in tasks involving image categorization and perception. Image recognition is the process of identifying photos and classifying them into one of several distinct categories (or image classification).

To diagnose cancer, a variety of variables including shape, size, color, and texture are extracted using traditional computer vision techniques as a classifier. Artificial intelligence (AI) has now the capability to deal with these issues. The most reputable deep-learning architectures, including recurrent neural networks (RNN), deep neural networks (DNN), and convolutional neural networks (CNN), are used in the medical industry to identify cancer cells.

1.2. Contribution:

The following is a description of our paper's primary contribution:

• We suggest a segmentation technique that uses a modified watershed algorithm to segment the Vitiligo images even in patients with the earliest stages.

• Our proposed segmentation model outperforms other segmentation models in terms of accuracy.

• On the same dataset, various segmentation models are also assessed to compare our suggested model, and eventually, our proposed model provides the best segmentation accuracy.

1.3. Organization:

The remainder of this paper is illustrated as follows: Introduction to segmentation techniques is presented in Section 2; related work is represented in Section 3. Data collection and methodology are discussed in Section 4 along with our suggested segmentation model in Section 5. Results and discussion are presented in Section 6, and the conclusion and recommendations for further study are outlined in Section 7.

2. Related Work:

First, terminology and key difficulties related to image segmentation are introduced. Next, an overview of current segmentation techniques is given, focusing on the benefits and drawbacks of these techniques for medical imaging applications [1]. The author describes a segmentation method that uses curvatures and is based on the geometric morphological aspects of the "landscape." Precise seeds that retain the original cell form are generated by computing the curvatures as the eigenvalues of the form matrix [2]. Here, the Author creates a materials image segmentation propagation framework, in which every propagation is stated as an optimal labeling issue, which can be addressed effectively with the graph-cut technique [3]. Researchers address segmentation in this work by using the subsequent three-step protocol. We start by reducing the hyperspectral images' dimensionality.

Next, utilize a classical segmentation algorithm. Lastly, employed a region merging process based on priority queues to solve the over-segmentation issue [4]. This paper suggests the simultaneous implementation of a watershed algorithm. The algorithm uses a single program multiple data (SPMD) approach and is developed for a ring architecture with distributed memory and a shared memory piece [5]. This work presents a quick and adaptable approach for calculating watersheds in grayscale digital images. The current approach is built on an analogy of the immersion process, where a queue of pixels is effectively used to replicate the flooding of the water in the image [6]. The author describes a new implementation of a rainfalling watershed algorithm based on floating points in this paper [7]. In this work, new watershed algorithms are derived by revisiting the old shortest routes methods of graph theory [8]. Four processes make up ASLM approaches for segmenting melanoma photos [9]. A survey of different segmentation approaches was given by Gurusamy [10]. In a different study, CNN using the watershed method and U Net architecture was utilized to automatically segment vitiligo images [11]. Previously, image segmentation was accomplished by the use of morphological operations, canny-based edge detection, and image painting [12].

3. Data Description:

To create our dataset, we gathered photos from the web database Dermnet that are particular to skin conditions as well as from the Ayurvedic clinic Viswam Ayurveda. 150 photos of vitiligo and 120 images of other diseases are included in the database. The clinic provided 79 photographs, and a total of 71 Vitiligo images were downloaded. A total of 120 photos of different skin conditions, such as actinic cheilitis-sq-cell-lip, acne-pitted scars, and atypical mycobacterium, were retrieved. In the suggested work, 270 images altogether were used.

4. Methodology

In the proposed model hybrid Preprocessing and segmentation techniques were developed. The process of image preprocessing and Segmentation is explained in detail in the below sections.

Figure 2 shows the schematic diagram of the implemented scheme. Here, the modified watershed algorithm was used to extract the interested region from the input image. RGB images were taken as input and after preprocessing morphological operator was used along with Otsu Thresholding. Then obtained gradient image was used as input for the watershed algorithm.

To handle the issue of different image sizes in the database, an input image is either resized or cropped. By standardizing the image size, every image will yield the same number of features. Additionally, by cutting down on processing time, downsizing the image accelerates the system. Input images were collected and resized to 224x224.

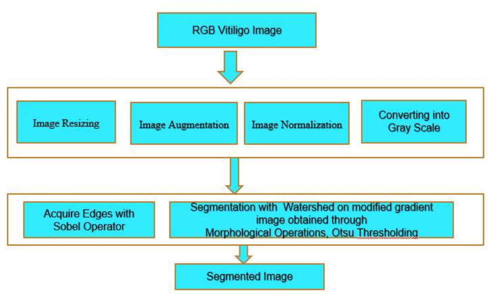

Figure 2: Schematic diagram of the implemented Proposed System

The process of adding marginally altered versions of existing data without actually gathering new information from previously collected training data is known as data augmentation. By data warping or oversampling, the training dataset size can be purposefully expanded. Alternatively, by addressing the root cause of the problem, the training dataset size can assist prevent the over-fitting of the model. We increased the amount of data using a range of augmentation parameters, including rotation, random cropping, and mirroring, to prevent this over-fitting. The parameters we used for the data augmentation of our dataset are shown in Table 1.

SN	Parameter	Parameter Value	Action
1	Rotation Range	40	picture rotation from -40 to 40 to produce input
2	Width Shift Range	0.2	The image is moved by 0.2 pixels in the horizontal direction.
3	Height Shift Range	0.2	The image is moved by 0.2 pixels in the vertical direction.
4	Shear Range	0.2	Increase the image's slant angle by 0.2 degrees.
5	Zoom Range	0.2	zoom in or out by 0.2 from the middle
6	Horizontal Flip	True	Randomly reverses the horizontal direction of the images.

Table 1: Augmentation Parameters

Image normalization and image normalization are essential steps in both traditional machine learning and deep learning. Images were normalized and converted into grayscale images.

In image processing and computer vision, the Sobel operator—also known as the Sobel–Feldman operator or the Sobel filter—is utilized, especially in edge detection techniques that emphasize edges in the image.
In the proposed work sobel operator was used to obtain the edges of the image.

A wide range of image processing techniques known as morphology analyze pictures according to their shapes. By applying a structuring element to an input image, morphological procedures yield an identically sized output image. There are two types of Morphological operations Dilation and Erosion.
Dilation: In this process, the maximum value of every pixel in the neighborhood makes up the value of the output pixel. Morphological dilatation fills up small gaps in objects and increases their visibility. Shapes that are filled in seem larger and lines appear thicker.
Erosion: In this process output pixel's value is the lowest value of all the nearby pixels. Morphological erosion

eliminates tiny lines and floating pixels, leaving only substantial objects in place. Shapes appear smaller and the remaining lines appear thinner.
Opening & Closing Operator:
Opening: Using the same structural element for both operations, the opening operation first erodes an image and then dilates the eroded image.
The shape and size of larger things in a picture can be preserved while tiny objects and thin lines are removed using morphological openings.
Closing: The closure operation uses the same structural element for both operations: it dilates an image and then erodes the dilated image. When filling in small holes in an image, morphological closing helps to maintain the size and shape of larger holes and objects in the image.
Otsu Thresholding: Gradient Even after morphological processes, several tiny dots unrelated to the target item remain in the image. The segmentation results showed a lot of nonsensical areas as a result. To acquire the points that belong to the target of interest, the threshold approach is employed to extract marks from the pictures that have been reconstructed using a morphological gradient. In the traditional procedure, the threshold value is often manually specified. A threshold value that is too high makes it challenging to remove the soft edge and causes the catchment basin with shallow depth to disappear rapidly. Strong textural noise is difficult to remove if the threshold setting is set too low. To determine the threshold value, OTSU uses the minimum intra-class variance approach, also known as the maximum inter-class variance algorithm.
Watershed Segmentation: The watershed transformation locates the lines that run along the tops of ridges by treating the image it works on as a topographic map, where each point's brightness represents its height (Watersheds). Catchment basins are the areas of land that are surrounded by watersheds and drain into rivers, basins, or reservoirs. Its limitation is over-segmentation. To overcome this limitation after pre-processing the image an edge detector was applied. Then series of morphological operations were performed to get the gradient image. Once a gradient image was obtained otsu thresholding was used to remove small unwanted points and regions. In the final image watershed segmentation algorithm was applied to get the final segmented image.

. The full algorithm is described below:

- Resize, Augment, and normalize the image.
- Apply Sobel edge detector.
- Apply Morphological Operations to construct the gradient map
    - Opening & Closing
- Use Otsu-based threshold to define the threshold for unrelated points to target
    - Interclass variance for calculating threshold to remove the points unrelated to the target point.
    - To avoid the over-segmentation problem of the Watershed Algorithm
- Apply watershed segmentation on the reconstructed Gradient **Image.**
    - Watershed Algorithm on reconstructed gradient image.

5. Result and Discussion

The system is implemented in Python using Keras, Numpy, and Matplotlib. We ran the experiment in this study using our suggested Segmentation model. The results of different segmentation models are displayed in Table 1. We made use of a setup with a 2.10 GHz Intel Core i3 processor and 4 GB of RAM. Initially, the input images are pre-processed, and segmentation is performed using the model constructed above. After training, the model's 93.5 % accuracy was achieved. In this study, 270 skin images from the Internet were also used by several individuals with dermatological diseases. The system is efficient. Additionally, early discovery of vitiligo skin growth, particularly in individuals who are not accepted by doctors, can greatly motivate them to receive treatment on time.

Here the above image represents the original image segmented by several methods. The above image is an enlarged view of an image. From the result, we can observe that the modified watershed segments with gradient images perform well. Finally, our proposed method gave superior results when compared to the other methods.

Name of the Techniques	Jaccard Coefficient (JC)	Dice Similarity Coefficient (DSC)	Average Precision (AP)	Accuracy (ACC)
Multi OTSU	70	82.3	75.3	82.1
Quick Shift	79.5	88.5	88.7	91.6
SLIC (K-Means-based image segmentation)	76.3	86.6	84.5	87.7
RAG (Region Adjacency Graph)	58.3	73.6	68.1	70.4
Watershed with a modified gradient image	82.4	91.2	94.1	93.5

Table 2 shows the Jaccard Coefficient comparison of the various approaches. The Jaccard Coefficient for the modified watershed algorithm with gradient image is 82.4%. Whereas Multi OTSU gave an accuracy of 70%, Quick Shift's accuracy was 79.5%, SLIC was 76.3% and RAG had 58.3% accuracy. The Dice Similarity Coefficient for the modified watershed algorithm with gradient image is 91.2%. Whereas Multi OTSU gave an accuracy of 82.3%, Quick Shift's accuracy was 88.5%, SLIC was 86.6% and RAG was 73.6.% accuracy. The average Precision for the modified watershed algorithm with gradient image is 94.1%. Whereas Multi OTSU gave an accuracy of 75.3%, Quick Shift's accuracy was 88.7%, SLIC was 84.5% and RAG was 68.1.% accuracy. The accuracy for the modified watershed algorithm with a gradient image is 93.5%. Whereas Multi OTSU gave an accuracy of 82.1%, Quick Shift's accuracy was 91.6%, SLIC was 87.7% and RAG is 70.% accuracy.

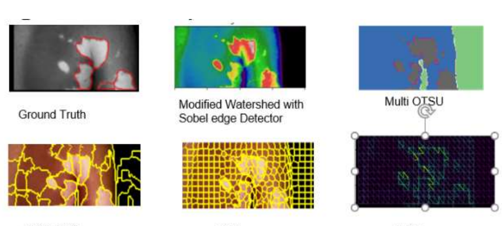

Figure 3: Ground Truth image and images obtained through different segmentation techniques.

6. Conclusion & Future Work

In conclusion, the application of modified watershed segmentation for the segmentation of vitiligo demonstrates promising results in accurately delineating the affected areas from normal skin. The method offers advantages such as simplicity, computational efficiency, and adaptability to varying image qualities. By incorporating modifications such as gradient-based pre-processing and marker initialization, the segmentation performance has been enhanced, leading to improved accuracy and reduced over-segmentation. However, it is essential to acknowledge certain limitations, including sensitivity to parameter settings, potential under-segmentation in regions with low contrast, and the need for manual intervention in marker selection. Despite these challenges, the modified watershed segmentation presents a valuable tool for clinicians and researchers in analyzing vitiligo images, facilitating precise quantification of lesion characteristics and aiding in treatment monitoring and evaluation."

With the use of this model, other skin diseases kinds can be segmented in the future. In the future, it may be possible to segment additional skin conditions.

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