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Detection and classification of eczema on the skin using Image processing and machine learning

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ABSTRACT

Eczema is a chronic skin disease that when left untreated may lead to major health consequences if not detected and controlled early. Early detection and seeking out medical attention early may help prevent the skin from worsening. However, diagnosis of eczema is time consuming and costly. This paper aims to detect and classify eczema on the skin using modern image processing techniques and machine learning algorithms. In this paper, two methods of comparison are used to detect and classify the skin disease namely non-segmented and segmented methods. The non-segmented method achieves an accuracy score 59% while segmented method achieves an accuracy score of 52%. The results on which method is more suitable are skewed towards non-segmented methods.

1. INTRODUCTION

Eczema is a chronic skin disease that cannot be cured, it is one of the most widely known skin diseases. 31.6 million of the population of the US are affected by some form of Eczema [1], which amounts to more than 10% of the population in the US. Eczema, also known as Atopic Dermatitis (AD) is a condition that makes your skin red and itchy. Infection of Eczema can occur on any part of the body like face, neck, feet, etc. By using modern image processing techniques, the Eczema region can be easily identified and proper measures can be taken. A lot of research has been done on skin diseases using image processing techniques. However, most of the attention is towards skin cancer which is more dominant in terms of popularity. Nonetheless, Eczema is still a major health problem and deserves more attention. There is not enough research done in the case of Eczema disease and existing research did not show any outperformance in terms of accurately detecting infected regions. The Eczema region started small initially, but as time went by, the region may lead to major consequences like impairment. At this rate the cost and cure time will also increase following the severity of the Eczema. Most people don't understand the nature of this disease and didn't take note of it in the early stages. This causes them to miss the time frame to get the necessary treatment to cure Eczema successfully. Therefore, early detection and treatment is the most reliable way to prevent Eczema from taking a turn for the worse.

In this paper, we did the Eczema classification using the Support Vector Machine method. Before the actual classification, multiple stages of image pre-processing and feature extraction were conducted on the raw image. The image pre-processing includes occlusion removal, LUV color space, morphology, thresholding, median filters, and Contrast-Limited Adaptive Histogram Equalization. After image pre-processing, image segmentation was performed to segment between the skin and background before moving on to the features extraction. The feature extraction extracts the color feature to use for classification. Finally, the classification was conducted on two different datas, one for non-segmented data while the other segmented data. This is to see which situation does the classification perform better. The classification classifies the image into acute and chronic.

There are multiple sections in this paper. Section 2 is the literature review of the research papers. Section 3 describes the architecture and methodology used. Section 4 is the results of our research. Section 5 is the evaluation. Section 6 and 7 are discussion and limitation. Finally Section 8 and 9 are the conclusion and reference respectively.

2. LITERATURE REVIEW

There are many different detection and classification of eczema on the skin using image processing and machine learning. In this literature review we will look into some of the other research done by others.

In the paper [2], the researcher proposed using noise reduction, resizing images, and contrast enhancement which will prove useful later in our project. This is because all this technique will help to improve the images so that all the information we need from the images can be obtained better during the feature extraction. In this paper, different segmentation techniques are used to find out which segmentation techniques are the most suitable to detect skin diseases. K-means clustering shows the best result when applied on Eczema diseases. However, the segmentation procedure could be more efficient if coupled with the classification of the disease.

A paper written by Masum Shah Junayed et al, 2020 [3], aims to classify five different classes of Eczema in their dataset. They did a data augmentation on the images which consist of rotation, flipping, shading, translation, and shearing. Then it is normalized before the training. The proposed model achieved an accuracy of 96.2%, which exceeded the performance of the state of the arts. But their proposed model showed over fitting in classifying results which can produce false-positive in real application, hence inaccuracy in outputs.

In a paper titled “On using Support Vector Machines for the Detection and Quantification of Hand Eczema” [4]. This research mainly focuses on Hand Eczema, they devised an image processing method for segmentation based on Support Vector Machines. They use F1 score as their primary measuring method. The final evaluation achieves a F1 score of 58.6% for the front sides of the hands and 43.8% for the back sides. The problem with this paper is that it lacks versatility since it only focuses on Hand Eczema.

3. METHODOLOGY

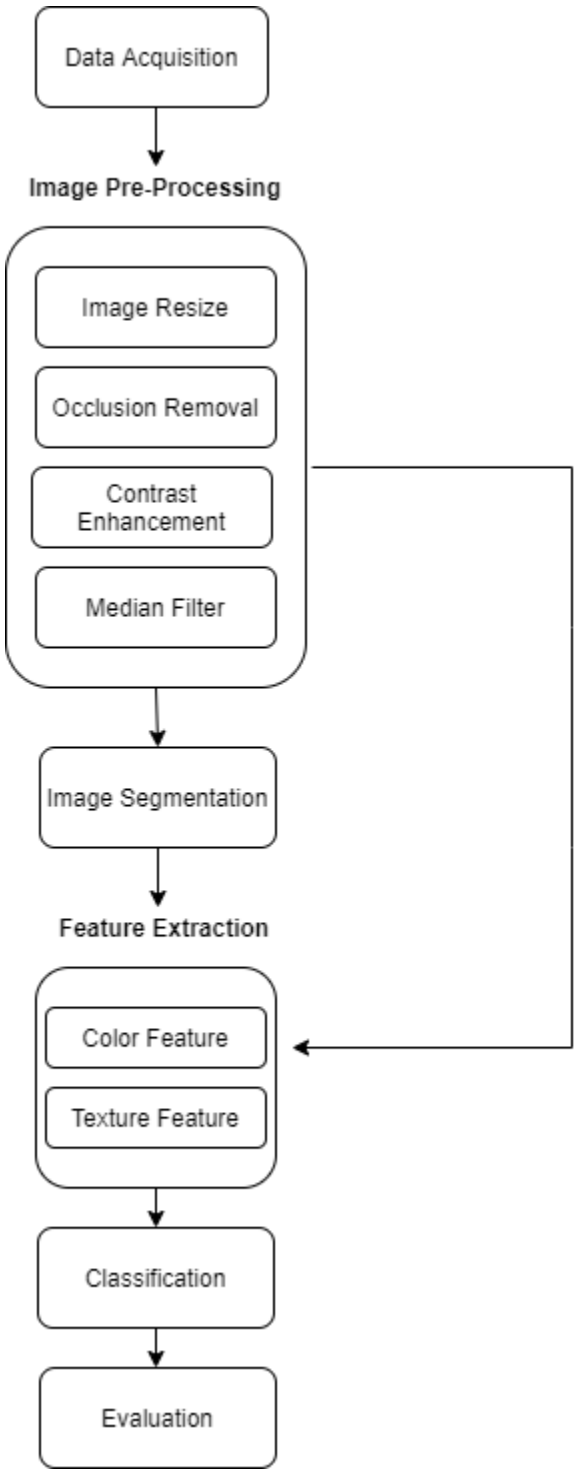

Fig. 1: Flowchart of Methodology

Data acquisition: The data is collected from kaggle (https://www.kaggle.com/ismailpromus/skin-diseases-image-dataset). This dataset contains 1744 images of patient's infected with eczema. The data was not labelled by the severity of diseases. This is why we manually labelled the data into two dataset, named "Acute" and 'Chronic'. Here, Acute denotes eczema with mild severity and 'Chronic' denotes extreme severity.

Image Pre-processing: The collected images of eczema are not suitable for performing classification algorithms. These images are very raw which may possibly decrease the quality of the classification algorithm. It is observed that these images contain different noise such as fine hair, air bubbles, watermark, spots etc. This is why it is necessary to apply subjective preprocessing methods on images to obtain better results in classification mode. After analyzing different previous research , we noticed that the research applied various image processing methods to clean images : for example: median filter to denoise skin images , contrast enhancement to increase the quality of images , unsharp masking and so on. In this section, we will discuss the applied image processing techniques which are used in this project:

- **Image resizing**: To work with classification algorithms, the features and dimensions of the designated subject must be union and the same. Thus, the collected images of eczema must have a uniform size. For this project, we're using 400x300 as the dimensions for all the images.

- **Occlusion Removal:** Occlusion removal is a very comprehensive application for Image enhancement. The main reason behind occlusion removal is making the image more compatible with analysis. The output is shown in figure: 2. It helps to remove fine hair, any spot, bubbles and water marks. The applied process are explained below:

    1. **Luv color space**: In color space, Luv has both Chroma and saturation value. It also behaves to be more suitable in this attribute. This is why in this section, we will first convert the image into LUV space where, L, represents luminance, U and V represents chromaticity of color images. Here, we take the luminance which is represented by the L channel and pass this channel for hysteresis Thresholding to generate the mask.

    2. **Morphology**: This operation is a collection of non-linear methods related to the morphology of features in a grayscale or binary image. It filters the image with a structuring element having shape like reactance, ellipse or cross. In this section we applied a morphological closing method which consists of a dilation followed by an erosion method. This tends to close up dark gaps between bright regions. We used a kernel with size 8 as a structure element in ellipse shape.

    3. **Thresholding:** This is a type of image segmentation technique which aims to change the pixels of an image to make the image easier to analyze. We applied the mask which was obtained from Luv color space to do the Thresholding, which helps to extract the targeted pixels.

- **Median filte**r: This is a filter of nonlinear digital filtering technique used to remove noise from an image. To improve the result of any kind of segmentation or feature extraction, median filter is widely used and helps to denoise the image. A structuring element with a shape of square is applied on each pixel of an image. Pixels under the kernel are replaced with the mean of neighborhood pixels. In our analysis we use a kernel shape of square for applying a median filter on the image. The resulted data shown in Fig:2

- **Contrast-Limited Adaptive Histogram Equalization (CLAHE):** This algorithm uses histogram computed over different regions of the image for local image contrast enhancement. It transforms its every pixel based on the histogram of a square surrounding pixels. However, unlike the ordinary histogram equalization which usually tends to oversimplify the contrast in neighborhood contrast of image, here CLAHE tends to limit the contrast amplification by clipping the histogram at a predefined value. Before generating the

cumulative distribution function. In our methodology, during the CLAHE method, we convert the image into Lab's color space and create clahe with grid size 8. The resulted data shown in Fig. 2

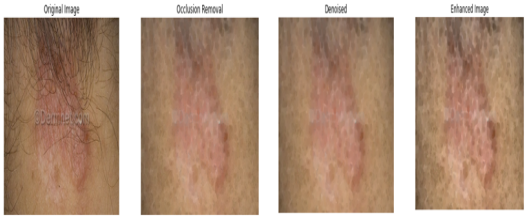

Fig. 2: Image Processing by steps

Segmentation: The aim of this process is to distinguish between background/non skin region and skin region. Segmentation in image processing is very important as it tends to extract the objects of interest, for further processing such as segmenting the region of interest. It isolates the desired area or object from the image in order to perform analysis of the isolated region as shown in figure 3. In our analysis, the segmentation process contain in the following process:

- **Color space based masking:** The main motive of this step is segmenting images with color space value as a mask and applied Thresholding. We used two types of color space value: HSV and YCrCb. We pick these two colors as they are more robust towards the chromaticity and colorfulness of images. We created a mask within the range of hsv color [0, 0, 0] (lower) and [60,255,255] (upper) and for YCrCb color [0, 138, 67] (lower) and [255,173,133] (upper). Then the mask undergoes the morphology operation and extracts the pixel values within the range of color space value.

- **Watershed:** This algorithm is used for image segmentation, which is for separating different regions or objects in an image. The main motivation behind watershed is that an image can be viewed as a surface white high intensity denotes peaks and hills while low denotes valleys. We applied watershed on the obtained pixels from color space masking.

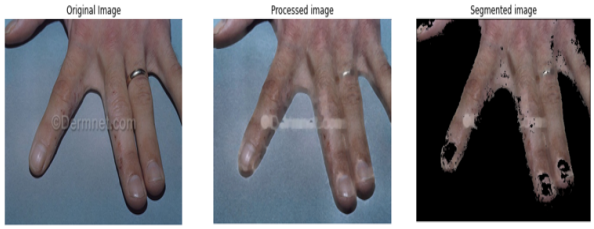

Fig. 3: Image after Segmentation

Feature Extraction: After performing all image processing methods, the images are still not suitable enough for classification purposes. This is why we did feature extraction on the images to extract only the relevant features. The main motivation of this step is to extract meaningful features of the eczema images which can help in identifying and evaluating the disease state. In our analysis, the feature extraction process contain in the following process:

- **Color Features:** This is a very used feature in terms of extracting color based features where it keep counts of several color channels in different measurements such as standard deviation , average , kurtosis, skewness etc. In our color features , used color channels are Red, Green, Blue, Hue, Value, Saturation , luminance , Cb and Cr chromaticity and the used color moments are standard deviation , mean , skewness, entropy and kurtosis calculation. In this work, we extract 30 color features description for the eczema area.

- **Texture Features**: We applied Gray Level Co-occurrence Matrix of gray scale image .This texture based analysis basically follows how often combination of pixel with specific brightness level of skin images in specific spatial direction occurred. The features which are extracted from the GLCM matrix are used to describe the area from contrast, dissimilarity, correlation, homogeneity. In total we get 3 features from here. Overall after applying the feature extraction, each image left with a vector of 81 feature values.

Classification: We applied a support vector machine to do the classification on data. Support Vector Machine is a supervised nonlinear classifier which generates an optimal n-dimensional hyperplane to separate all the data points into two categories. While training, SVM aims to maximize the distance of both the classes from separating the hyperplane. We did a grid search method to find the best parameter for our classification model. From the grid search the best obtained parameter is SVC(C=100.0, class_weight='balanced', gamma=0.0005).

Evaluation Metric: Performance of classification is evaluated against accuracy, precision, recall and confusion metrics. Accuracy represents how accurate the whole model is where in our context it represents the number of images that are correctly classified among all the text images. Precision represents the ability of the classifier to skip false positives whereas recall represents the ability of the classifier to avoid false negatives. We have also generated confusion metrics to generate the proportionality of true labels of classes (Acute and chronic) and Predicted labels of classes (Acute and chronic).

4. RESULT

The highest accuracy achieved is 59%. Using the produced model, a few testing were performed. Fig 4 below shows the example of the model successfully classifying the test images into their respective class. The first image shows a slight eczema on the fingertip of the skin. The eczema severity shown in the picture is acute, which is not critical. The model predicts it correctly by classifying the image as acute. For the second image, the eczema present on the knees area of the skin. The eczema severity shown in the picture is chronic, which is in bad condition. The model classifies the image as chronic, which is correct.

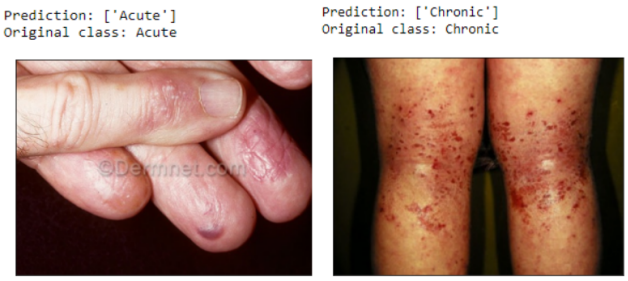

Fig. 4: Example of classification on test images

There are also a lot of miss classifications made by the models. Fig. 5 shows the example of misclassification by the model. The eczema present in the image is mild around the chin and mouth area. Thus, the image is supposed to be classified as acute and not in critical condition. But the model predicted the image to have chronic eczema severity. This is definitely a misclassification from the model.

Fig. 5: Example of misclassification

Using the model generated, a few testing outside of the present dataset is conducted. A random sample of eczema images is taken to test the model on real time performance. From Fig. 6, the first image shows a slight redness and eczema on the skin. The model predicts the first image as acute. While the second picture shows a big portion of redness on the back area of skin. The model classifies the image to be a chronic state.

Fig. 6: Real time testing of the model.

5. EVALUATION

Evaluating the machine learning algorithm is an essential part of any project that correlates with machine learning.

5.1. Accuracy score

$$\text{Accuracy} = \frac{(TP + TN)}{(TP + FP + TN + FN)}$$

Fig. 7: Accuracy formula

Classification Accuracy is what we usually mean, when we use the term accuracy. It is the ratio of the number of correct predictions. Accuracy is defined as the percentage of correct predictions for the test data. It can be calculated easily by dividing the number of correct predictions by the number of total predictions.

```
Test Accuracy:  0.59

Confusion Matrix
[[32 47]
 [18 62]]
              precision    recall  f1-score   support

       Acute       0.64      0.41      0.50        79
     Chronic       0.57      0.78      0.66        80

    accuracy                           0.59       159
   macro avg       0.60      0.59      0.58       159
weighted avg       0.60      0.59      0.58       159
```

Fig. 8: Metrics for non-segmented method

There are 2 main methods of comparison, non-segmented and segmented methods. For the non-segmented method, the highest mean accuracy achieved by the model is 59%. The model is able to predict 32 numbers of class acute correctly and 62 numbers of chronic class correctly.

```
Test Accuracy:  0.52

Confusion Matrix
[[35 44]
 [32 48]]
              precision    recall  f1-score   support

       Acute       0.52      0.44      0.48        79
     Chronic       0.52      0.60      0.56        80

    accuracy                           0.52       159
   macro avg       0.52      0.52      0.52       159
weighted avg       0.52      0.52      0.52       159
```

Fig. 7:: Metrics for segmented method

The 2nd method to compare is segmented method. In this method, the eczema images are segmented using colour thresholding and watershed before feature extraction. The accuracy is slightly lower than the previous method.

5.2. Confusion matrix

A confusion matrix helps us gain an insight into how correct our predictions were and how they hold up against the actual values.

5.2.1. Precision

$$Precision = \frac{True\ Positive(TP)}{True\ Positive(TP) + False\ Positive(FP)}$$

Fig. 8: Precision formula

Precision is the ratio between the True Positives and all the Positives.

5.2.2. Recall

$$Recall = \frac{True\ Positive(TP)}{True\ Positive(TP) + False\ Negative(FN)}$$

Fig. 9: Recall formula

Recall is the measure of our model correctly identifying True Positives

5.2.2. Precision - recall results

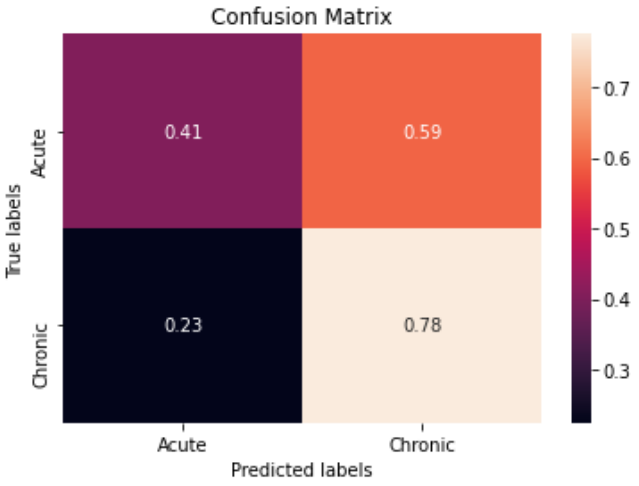

Fig. 10: Confusion matrix visualization for non-segmented method

For method 1 which is the non-segmented method. The precision for the acute class is more than half, meaning the model predicts more to be an acute class than the other category, in this case chronic. But the recall is definitely lower than half which is 0.41, which means the model predicts a lot of acute class wrong. On the other hand, the model has slightly lower precision in detecting chronic class with 0.57 precision score. But the recall is much higher compared to the acute class with 0.78 recall score. This means that the model successfully predicts the chronic class much better than acute.

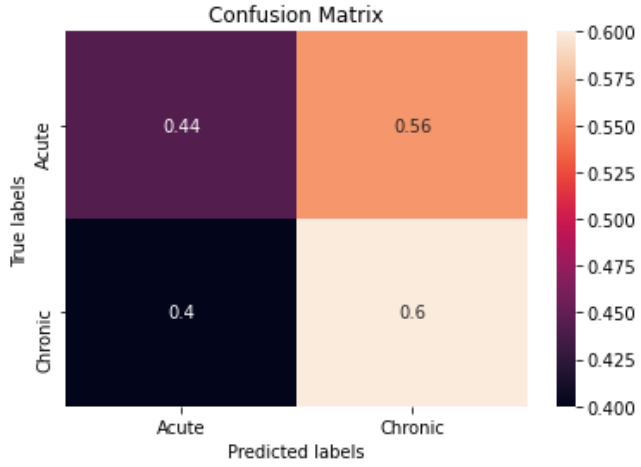

Fig. 11: Confusion matrix visualization for non-segmented method

However for the segmented method, looking at the precision and recall, there's a slight increase in recall on acute class than the previous method. Thus this method has a slightly better classification for acute class. Other than that, the model generated by the segmented method definitely performs worse than the non-segmented model in other metrics.

6. DISCUSSION

The project definitely does cater the objectives as it was stated in the proposal, which is where the initial expectation and hypothesis were formed. Looking back at the result, there were a lot of other improvisations that could be done.

80% of the data that was used in the project has a watermark on the image. Removing the watermark logo might destroy some of the details that were presented in the original image. Thus, it might affect the accuracy of the model by catering with edge and colour features. A much more refined method and approach should have been used to remove the watermarks while preserving the details of the image.

Low precision and recall of an acute class that can be seen in the previous section might be because of the low number of data present in the research. Having a low number of data of each class can make classification less accurate. Increasing the number of data might help the model to train better and to achieve much better results.

The model performance quality generated by the machine learning techniques is low with 59%. This might be

due to the machine learning approach being too linear and too rigged. A slight flexible approach should have been tested and adopted. Using deep learning techniques such as CNN might increase the accuracy of the classification.

7. LIMITATIONS

There are quite a few drawbacks and limitations for the project. Mainly lack of medical expert involvement to help with the information to set the foundation for the classification and detection. A lot of the methods that were referred to in the process of literature reviewing uses an expert to validate the data. Not having one for the project definitely set us back a few steps behind.Beside that ,the model could be trained on large data which potentially can give better model accuracy.

Image processing is a heavy task, a lot of heavy computation is needed to generate the model. Not having a strong computation device might cause a lot of delay and stretch the progress of the project. Mainly when fitting the training set onto the machine learning model.

8. CONCLUSION

In conclusion, this research aims to detect and classify the eczema on skin using image processing and machine learning. Multiple image processing techniques like morphology, median filters, Contrast-Limited Adaptive Histogram Equalization (CLAHE), etc. are used in image pre-processing and Support vector machine techniques are used for classification.

In this paper we compared two datas, one for non-segmented regions while the other for segmented regions. The accuracy turns out to be in favor for non-segmented with a 59% accuracy score versus a 52% accuracy score for the segmented region.

9. REFERENCES

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