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Human Skin Tone Detection using Unsupervised Machine Learning

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***Abstract*:** Researchers have been working on an effective skin detection technology for decades. Current methods, on the other hand, have not been able to overcome substantial constraints. To address these restrictions, a clustering and efficient optimization strategy is given. These strategies, when combined with sufficient understanding, result in a more successful algorithm. The idea is to be able to dynamically define the number of clusters in a collection of pixels structured as an image. The number of clusters in clustering for most problem areas is defined a priori and thus does not perform well across a wide range of data contents. As a result, this study developed a skin detection approach that confirmed the previous findings. This method uses the K-means algorithm along with the Particle swarm optimization method for the efficient working of the ML model and to obtain an accurate output. It also consists of a UI framework for the people less equipped with the coding part.

IndexTerms—Machine Learning, Particle Swarm Optimization, K-means clustering, User Interface.

I. INTRODUCTION

Skin detection is a primary stage in a variety of applications that use photos with human content. The process of distinguishing human skin pixels from non-skin pixels in an image is known as skin detection [1]. In image processing, human skin detection is an extensively used primitive. The biggest issue in detecting human skin is the huge variations in human look when compared to other items. Furthermore, skin detection is complicated by a number of reasons. Variations in illumination is one of the most remarkable. Machine learning technology has been utilized by firms all over the world to construct predictive models that use a big set of data to anticipate the results of various operations in recent years [2]. Developing such models makes human labor easier and cuts down on the time it takes to predict events. It also produces trustworthy and error-free results. The goal of this project is to assist police departments and national security organizations with biometric identification. It will make security professionals' task easier when it comes to suspect profiling. The website has been designed in such a way that it does not complicate the identification procedure and can be used by someone with little computer experience. The user has to just upload an image on the website from their local computer and click on the result to identify the skin tone of the image.

The primary contributions of the research are:

- Using the vast spectrum of the LAB color space, the luminance of skin color was separated from skin tone. For skin detection, the suggested technique solely evaluates A and B components. It ensures that the pixels' properties are not influenced by the luminance (lightness/darkness) value of an image.
- The biggest problem in using an unsupervised technique is determining the number of clusters to use. Because image features are unpredictably variable, the number of clusters should be dynamically determined. The technique for dynamic cluster allocation based on individual picture attributes was proposed and confirmed in this study.

II. RELATED WORKS

The goal of this project is to determine the skin tone hue of an image submitted via the device or from the URL of an image published on a website. Although several works on face detection and recognition have been offered in the past, the idea of identifying the skin tone of an image given to us is relatively new in literature. To acquire an overview of the existing literature in the given problem area, we explore some of the existing methodologies related to human attribute manipulation below. We also go through some of the existing skin/non-skin segmentation techniques. Earlier methods looked at how to change the appearance of human faces in photos, such as altering the beard to no beard, changing the hair color or pattern, changing the smiling to nonsmiling face, and so on. If a component contains at least one skin pixel, all candidate pixels are classed as skin pixels. Methods based on color model-specific criteria (e.g., RGB, HSV, Ybor) have been proposed in[3]. However, in some circumstances, color model-based techniques that do not include context may result in inaccurate classification, for example, clothing portions with hues that are similar to skin color may be identified as skin. For skin detection, Zou et al. suggested a deep neural network-based technique.

III. AIM AND METHODOLOGY USED

1 - The project is intended to find out the skin tone of a person and then classify them into different categories like 'fair', 'mild', or 'dark [4].

2 - This project is intended to be used by Police Departments and national security agencies for biometric identification.

3 - It will ease the work of security professionals in suspect profiling.

4 - Creating such models eases the human work and greatly reduces the time involved in predicting outcomes.

5 - This project uses a dataset of images for the testing and
training of the machine learning model. It deploys the machine learning model using image processing to train the model using one part of the dataset and use the other part of the dataset for the testing.

6 - The project also involves web development to create a website on which the user can upload the images either by uploading a file from the local computer, or just by using the URL of the image.

7 - The frontend part of the web development involves the creation of a website with a home page, Image Upload page and a contact us page.

8 - The backend involves the code which merges the machine learning technology with the web development.

9 – The front-end part makes sure that the feature of image uploading or providing the URL of image is easily visible by using the HTML and CSS language.

10 - Creating Machine Learning models ease the human work and greatly reduces the time involved in predicting outcomes.

11 – The overall model will ease the work of security professionals in suspect profiling.

I. FLOWCHART AND STEPS FOLLOWED

A. Flowchart (Machine Learrning)

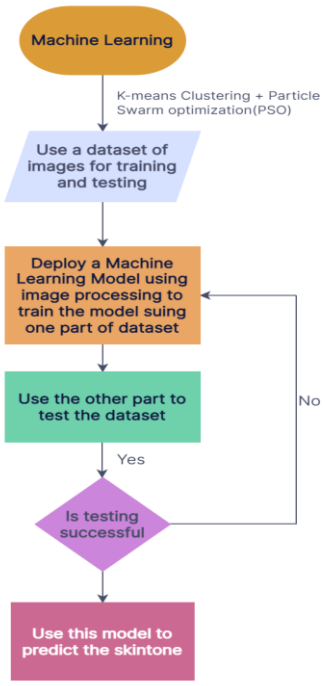

Fig. 1- Flowchart of Machine Learning

B. Steps Followed in Machine Learning

1- Machine Learning

- Importing of dataset of images and using them for training and testing.
- Deploying a machine learning model using image processing to train the model using one part of dataset.
- Using the other part to test the dataset.
- If testing is successful then using this model to predict the skin tone.

C. Flowchart (Web Design)

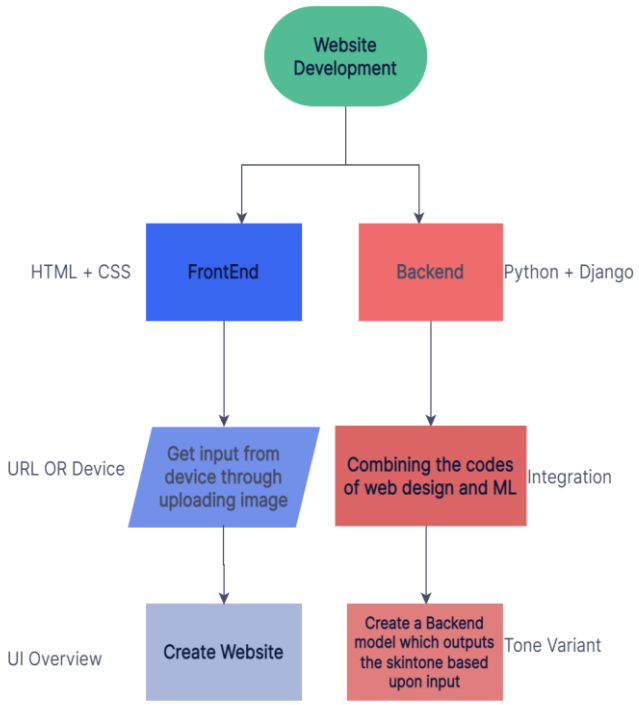

Fig. 2- Flowchart of Web Design

D. Steps followed in Web Design

1 – Frontend

- Creation of website.
- Get the input from device through uploading the image or by obtaining the URL of the image.

2 – Backend

- Combining the codes of web design and Machine Learning.
- Creation of a backend model which outputs the skin tone according to the given input.
- Use for various Database transactions.

II. DATASET/ DATABASE SPECIFICATION

E. Dataset

- The skin dataset is collected by randomly sampling B, G, R values from face images of various groups.
- Total learning sample size is 245057; out of which 50859 is the skin samples and 194198 is non-skin samples.
- Dataset has been obtained from ics/ uci website [5].

III. TECHNIQUES/ ALGORITHMS USED

1 – Machine Learning

- Machine learning is used in internet search engines, email filters to sort out spam, websites to make personalized recommendations, banking software to detect unusual transactions, and lots of apps on our phones such as voice recognition. [6]
- Clustering is one of the most common exploratory data analysis techniques used to get an intuition about the structure of the data.
- K-means algorithm is an iterative algorithm that tries to partition the dataset into K pre-defined distinct non-overlapping subgroups (clusters) where each data point belongs to only one group
- The Machine Learning algorithm used in our project is the K-means clustering.
- To make the project standout one and more efficient we have used Particle swarm optimization (PSO) in our project.
- Particle swarm optimization (PSO) is a basic algorithm that searches the solution space for the best solution. It differs from other optimization techniques in that it simply requires the objective function and is unaffected by the gradient or any differential form of the objective.

A. K-means clustering algorithm

- The K-means approach, which uses an explicit distance metric to partition the data set into clusters, is the most extensively used clustering algorithm [7].
- The algorithm operates by doing several iterations of the same basic process.
- The cluster centers are set up by selecting k training instances at random, where k is the desired number of clusters.
- In terms of quality of outcomes, the K-means algorithm usually compares favorably to more sophisticated and computationally expensive clustering algorithms.

B. Particle Swarm Optimization (PSO)
- Particle swarm optimization (PSO) is a bio-inspired algorithm that searches for the best solution in the solution space in a straightforward way.
- It differs from other optimization techniques in that it simply requires the objective function and is unaffected by the gradient or any differential form of the objective.
- It also has a small number of hyperparameters.
- A basic variation of the PSO algorithm employs a population of candidate solutions (referred to as a swarm) (called particles).
- A few simple equations are used to move these particles about in the search space.
- The particles' movements are governed by their individual best-known position in the search space, as well as the best-known position of the entire swarm.
- When better positions are located, they will be used to steer the swarm's movements.
- The procedure is repeated in the hopes that a satisfactory answer will be found someday, but this is not guaranteed.
- Let f: Rn -> R be the cost function that needs to be minimized. The function accepts a candidate solution as an argument in the form of a vector of real numbers and outputs a real number that represents the candidate solution's objective function value.
- It is unknown what f's gradient is. The goal is to discover a solution a where f(a) <= f(b) for all b in the search space, indicating that an is the global minimum.

2 – Front-end Development
- The most common language used for describing the layout of the webpage is the Hypertext Markup Language (HTML). It consists of a series of elements.
- "HTML is usually stored in files that use the .htm or .html extension. A website can include hundreds or even thousands of these HTML files kept in various directories." [8]
- HTML uses a combination of various IDs and classes that helps for making the styling easier and more efficient using CSS.
- The styling of the layout of the webpage provided to us using the HTML can be done through the Cascading Style Sheets (CSS).
- CSS provides a gentle and more attractive layout to our web pages. CSS provides us an easy way to create dynamic web pages.
- Font, font-size, color, margin, padding, border, width, height are the common attributes used by us for styling purposes.

A. HTML
- Hyper Text Markup Language is the abbreviation for Hyper Text Markup Language. It is the most widely used markup language for building websites.[9]
- It describes a Web page's structure. It is made up of a number of components.
- HTML makes use of a variety of different IDs and classes to make CSS styling easier and more efficient.
- HTML is made up of a number of different elements. HTML components specify how the content should be displayed in the browser.
- The root element of an HTML page is the <html> element.

B. CSS
- Cascading Style Sheets (CSS) is an acronym for Cascading Style Sheets. It specifies how HTML elements should appear on a screen, in print, or in other media. It saves a lot of time and effort. It has the ability to control the layout of numerous web pages at the same time. CSS files contain external stylesheets.
- CSS gives our web pages a softer, more appealing appearance. CSS makes it simple to construct dynamic web pages.
- We employ font, font-size, color, margin, padding, border, width, and height as common stylistic characteristics.

3 – Backend Development
- Invented in 1992, the python language provides us with the most efficient way to start with our backend implementation. It is an object-oriented programming language.
- Python is the best language that can be used for the rapid development of our project.
- Django is the high-level python web framework that enables rapid development of secure websites and is developed by the very experienced developers.

A. PYTHON
- Python is a high-level (easier for humans to grasp) object-oriented (data-driven) programming language. It was first released in 1992 and is designed to be relatively easy to write and understand. As a result, it's an excellent coding language for individuals that wish to develop quickly. [10]
- Python can be used to construct web applications on a server.
- Python may be used to develop workflows in conjunction with other software.
- Python has the ability to connect to database systems. It also has the ability to read and change files.
- Python may be used to work with large amounts of data and execute complex calculations.
- Python may be used for rapid prototyping as well as creation of production-ready software.
- Python may be used on a variety of platforms (Windows, Mac, Linux, Raspberry Pi, etc.).
- Python's syntax enables programmers to write programs in less lines than other programming languages.
- Python can be approached in three ways: procedural, object-oriented, and functional.

B. DJANGO

- Django is a high-level Python web framework for creating secure and maintainable websites quickly. Django is a web development framework built by professional developers that takes care of a lot of the heavy lifting so you can focus on developing your app instead of reinventing the wheel.
- Data from the database is provided by the model.
- The data is given as an Object Relational Mapping (ORM) in Django, which is a mechanism for making database operations easier.
- SQL is the most frequent method for extracting data from a database. One issue with SQL is that it necessitates a thorough understanding of the database structure in order to use it.
- Django's ORM allows you to interface with your database without having to write sophisticated SQL statements.

IV. RESULT AND ANALYSIS

In order to generate the result of the proposed method-

- We are uploading a jpeg file from our system or the link of the image file for which we want to predict the skin tone color.
- To obtain the URL for the image uploaded using the URL we are adding our own ProtocolName + HostName + PortNumber along with the filepathName
- To visualize the given dataset, we are using SQLyog by writing the different SQL queries.

Method	Accuracy	FPR
Rudra P K Poudel (SuperPixel Only)	91.46	13.75
Rudra P K Poudel (SuperPixel +CRF)	91.79	13.14
Jedynak et al., 03	82.95	10
Proposed Method	92.06	5.99

For performance evaluation of our method and comparing it with the other method we have included the following parameters-

1. **True Positive Rate (TPR)**

   It's the percentage of accurately classified positive instances (i.e., harmful programmed features vectors):

   TPR = TP / (TP + FN)

   where TP denotes the number of properly categorised positive instances and FN denotes the number of incorrectly classified positive instances.

2. **False Negative Rate (FNR)**

   False Negatives (FN) are negative outcomes predicted inaccurately by the model. This is sometimes referred to as a Type II mistake.

   FNR = FN / (TP + FN)

   where TP denotes the number of properly categorised positive instances and FN denotes the number of incorrectly classified positive instances.

3. **True Negative Rate (TNR)**

   Interpretation: As you predicted, the outcome is bad.

   TNR = TN / (TN + FP)

   where *FP* is the number of negative instances incorrectly classified and *TN* is the number of negative instances correctly classified.

4. **False Positive Rate (FPR)**

   It is the proportion of wrongly categorized negative cases (i.e., feature vectors of benign applications):

   FPR = FP / (TN + FP)

   where *FP* is the number of negative instances incorrectly classified and *TN* is the number of negative instances correctly classified

5. **Accuracy**

   The accuracy of a machine learning model is a metric for determining which model is the best at recognising relationships and patterns between variables in a dataset based on the input, or training, data. The stronger a model's generalisation to 'unseen' data is, the better predictions and insights it can generate, and thus the more business value it can deliver.

   ACC = ((TP + TN) / (P + N))

6. **Precision**

   It is equal to the number of real positives divided by the total number of components classified as positive.

   PREC = TP/ (TP + FP)

7. **F Score (0.5)**

The F-score or F-measure is a measure of a test's accuracy in binary classification statistical analysis. It is calculated using the test's precision and recall, with precision equalling the number of true positive results divided by the total number of positive results, including those that were incorrectly identified, and recall equalling the number of true positive results divided by the total number of samples that should have been identified as positive. In diagnostic binary classification, precision is also known as positive predictive value, while recall is also known as sensitivity.

F (0.5) = ((1.25 x PREC x REC)/ (0.25 x PREC + REC))

Dataset Experimental Results-

Method	TP (Recall)	FN	TN	FP	Accuracy	Precision	F(0.5) score
Adaboost Baseline	0.6713	0.3334	0.9478	0.0532	0.8072	0.9265	0.8502
AdaBoost Canny	0.4749	0.5288	0.9645	0.0362	0.7196	0.9291	0.7883
AdaBoost Sobel	0.2414	0.7633	0.9722	0.0278	0.7519	0.8948	0.584
RGB	0.532	0.472	0.867	0.148	0.684	0.7813	0.7084
HSV	0.616	0.409	0.695	0.321	0.641	0.6549	0.6426
ER/GH	0.354	0.672	0.917	0.087	0.628	0.8033	0.6317
CMYK(base)	0.77	0.27	0.765	0.252	0.751	0.7522	0.7525
CMYK(ROC)	0.77	0.27	0.782	0.248	0.754	0.7568	0.7565
CMYK(blue)	**0.959**	**0.091**	0.49	0.57	0.697	0.6371	0.683
CMYK(Cascade)	0.77	0.25	0.78	0.28	0.75	0.75	0.79
YCbCr	0.484	0.572	0.872	0.144	0.68	0.7821	0.5384
Proposed	**0.825**	**0.19**	**0.978**	**0.028**	**0.929**	**0.9342**	**0.8708**

Figure 5.1: Comparison of experimental results

Poud Al presented a segmentation method based on super-pixels, which combine colour pixels of the same hue together. These regions are classed as skin or non-skin instead of individual pixels. Skin detection based on regions performs better than skin detection based on pixels. Nonetheless, the proposed strategy has a 0.6 percent higher accuracy and a nearly 3% lower false-positive rate. To demonstrate the comparisons, some experimental findings are provided [11].

Figure 5.2: Region based skin detection results for dataset

Fig. 3- Overview of About Page

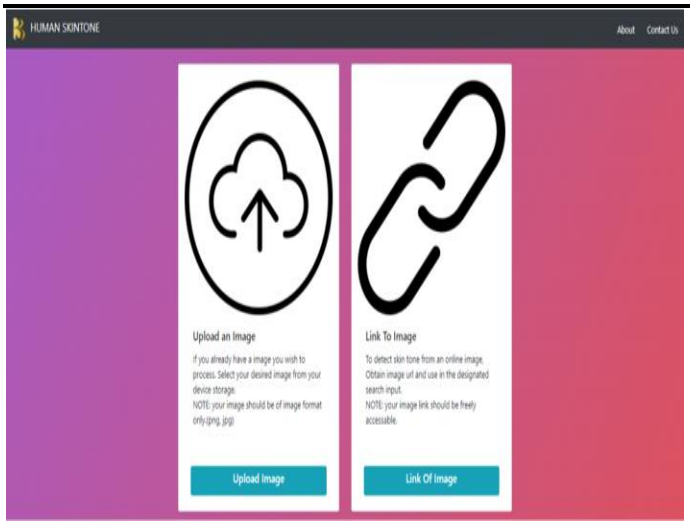

Fig. 4- Overview of Home Page

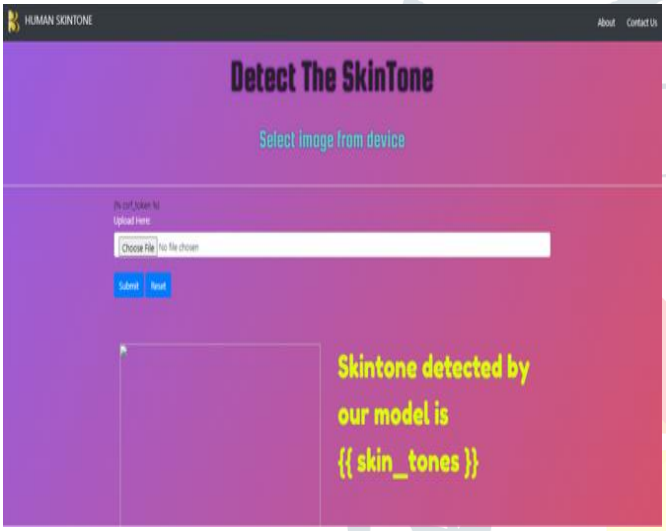

Fig. 5- Overview of Upload Picture from Device

Fig. 6- Overview of Upload Picture using URL

The result for the all three types of skin colors, ‘fair’, ‘mild’ and ‘dark’ has been shown below [12]: -

F. Result for skintone colour 'fair'

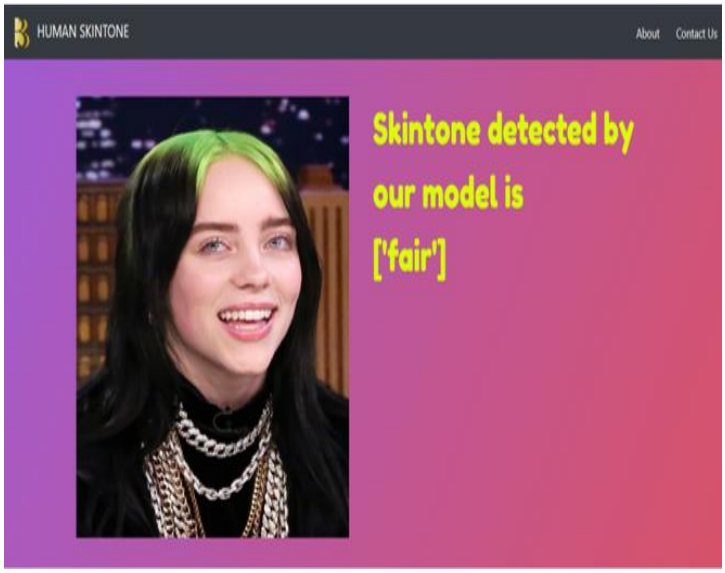

Fig. 7- Result for skin tone color 'fair'

G. Result for skintone colour 'mild'

Fig. 8- Result for skin tone color 'mild'

H. Result for skintone colour 'dark'

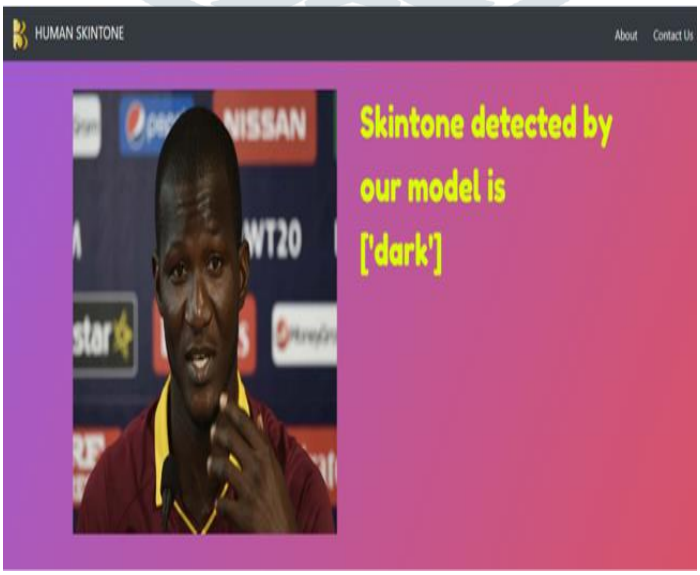

Fig. 9- Result for skin tone color 'dark'

V. CONCLUSION

This research proposed and verified a clustering-based skin tone detection algorithm along with particle swarm optimization method. The experimental findings were compared to a number of previously published research studies and our method was the most accurate one. This project plays a significant role while describing a person's physical appearance as it tells us about the skin tone color of an individual. Concludingly, the Machine Learning model to predict the skin tone of a person has been successfully created using the K Means Algorithm. The proposed algorithm shows promising results but there is always a room for improvement. In addition, a website to upload the user image or to insert the image URL has also been successfully created using CSS, HTML, Django. Furthermore, the UI too is user friendly where the user just needs to present the required image, may it be a .jpeg file or an online link and get the desired output with either of the one among Fair, Mild or Dark.

VI. FUTURE ENHANCEMENT

Use of Deep Convolution and Neural Networks for better efficiency of ML model. Addition of High-Quality web camera for uploading of images and detection of skin tone colour with much ease and in a short span of time. Use of more dynamic and efficient language such as ReactJS for creation of front-end web pages. Use of SpringBoot and Hibernate for backend implementation so as to make backend connections and database transactions much easier and faster. A broader way classification of skin tone colours such as "very fair, fair, dark, mild, very dark".

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