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Classification of Humans into Ayurvedic Prakruti Types using Computer Vision

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Classification of Humans into Ayurvedic Prakruti Types using Computer Vision

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Classification of Humans into Ayurvedic Prakruti Types using Computer Vision

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ABSTRACT

Ayurveda, a 5000 years old Indian medical science, believes that the universe and hence humans are made up of five elements namely ether, fire, water, earth, and air. The three Doshas (Tridosha) Vata, Pitta, and Kapha originated from the combinations of these elements. Every person has a unique combination of Tridosha elements contributing to a person's 'Prakruti'. Prakruti governs the physiological and psychological tendencies in all living beings as well as the way they interact with the environment. This balance influences their physiological features like the texture and colour of skin, hair, eyes, length of fingers, the shape of the palm, body frame, strength of digestion and many more as well as the psychological features like their nature (introverted, extroverted, calm, excitable, intense, laidback), and their reaction to stress and diseases. All these features are coded in the constituents at the time of a person's creation and do not change throughout their lifetime. Ayurvedic doctors analyze the Prakruti of a person either by assessing the physical features manually and/or by examining the nature of their heartbeat (pulse). Based on this analysis, they diagnose, prevent and cure the disease in patients by prescribing precision medicine.

This project focuses on identifying Prakruti of a person by analysing his facial features like hair, eyes, nose, lips and skin colour using facial recognition techniques in computer vision. This is the first of its kind research in this problem area that attempts to bring image processing into the domain of Ayurveda.

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1. Introduction

Ayurveda, a 5000-year-old science of healthcare, is the oldest science of healing known to the world [1], [2]. Ayurveda believes in the idea of embedding wellbeing into the human lifestyle to prevent and cure diseases. It focuses on strengthening and maintaining the balance in the body so that its natural defense system is strong enough to protect against diseases [1]. Just as every person has a unique fingerprint, every person also has unique physical, mental and emotional characteristics. These characteristics originate from a unique proportion of three principle constituents, which is determined at the conception of the living being and remain fixed throughout one's lifetime [1] . The three principle constituents are Vata, Pitta and Kapha [1]. Ayurveda believes that every element in the universe is made up of five building blocks namely, air, fire, water, space (ether) and earth [2], [3]. Vata, Pitta and Kapha originated from the combination of these elements. Vata is the energy of movement and is composed of air and space. It governs breathing, pulsation of heart, blinking, muscle and tissue movement and all the movements in the cytoplasm and cell membranes [1]. Vata promotes creativity and flexibility when in balance and fear and anxiety when out of balance. Vata people are more prone to diseases associated with the air principle, like nervous system related disorders, arthritis, emphysema, Alzheimer, etc. Pitta is the energy of digestion and metabolism which is composed of fire and water elements. It is responsible for digestion, metabolism, absorption, assimilation and the body temperature. Pitta promotes understanding and intelligence when in balance and, anger and jealousy when out of balance. Kapha is the energy of lubrication and structure which is made up of earth and water. It is responsible for forming the structure of the body by holding the cells together via bones, tendons and muscles. Kapha promotes love, calmness and forgiveness when in balance and envy and greed when out of balance.

The classification of people into the three fundamental constituents of Vata, Pitta, and Kapha is the foundation of every Ayurvedic treatment. This theory is called “Tri-dosha” in Ayurveda where ‘tri’ stands for three and ‘Dosha’ stands for constituents in Sanskrit language [4]. Tridosha are continuously formed in the human body and they are responsible for the homeostasis and metabolic activities in the human body. Tridosha influence the mind and body functions. The proportion of Tridosha constituents is unique for every person and is termed as his/her “Prakruti” where ‘pra’ means original and ‘kruti’ means creation in Sanskrit language. Prakruti determines the physiological and psychological tendencies in all living beings, influencing their physiological features like the texture and colour of the skin, hair, eyes, length of fingers, the shape of the palm, body frame, strength of digestion etc., and psychological features like their nature (introverted, extroverted, calm, excitable, intense, laid-back), including their reaction to stress. Prakruti usually does not change throughout the lifetime of a person [5] and forms the basis behind studying, how different people respond to the same environmental conditions in varied ways. It also helps to assesses the patient’s suitability for a treatment [1]. Table 1.1 depicts the 7 different types in which Prakruti can be classified. Most people will have one predominant Dosha (V, P or K), comparatively few people have two Dosha equal in proportion (VP, VK, PK) and even fewer will have all the three Doshas in equal proportion (VPK) [6].

Table 1-1 Types of Prakruti [2]:

TYPE	DESCRIPTION
V, P, K	Predominant in one Dosha

VP, VK, PV	Two relatively equal proportions with one predominating
VPK	Doshas in almost equal proportion

Dominant Dosha for Prakruti analysis can be discovered by observing physiological and psychological features of a person [6]. Table 1.2 enlists few out of the 31 special characteristics observed by Ayurvedic doctors to determine the Prakruti of people. The dominant element is the one for which majority of the characteristics match with the patient under observation.

Table 1-2 Characteristics of Tridosha [2], [6]:

NO.	OBSERVATION	TRIDOSHA		
		VATA	PITTA	KAPHA
1	Body size	Slim	Medium	Large
2	Body weight	Low	Medium	Overweight
3	Cheeks	Wrinkled/sunken	Smooth flat	Rounded, plump
4	Face shape/ chin	Thin, angular	Tapering/ triangular	Rounded, double chin
5	Eyes	Small, sunken, dry, active, black, brown, nervous	Sharp, bright, gray, green, yellow/red, sensitive to light	Big, beautiful, blue, calm, loving
6	Nose	Uneven, deviated septum	Long pointed, red nose-tip	Short rounded, button nose
7	Lips	Dry, cracked, black/brown tinge	Red, inflamed, yellowish	Smooth, oily, cool, white, pale
8	Teeth	Stick out, big, roomy, thin gums	Medium, soft, tender gums	Healthy, white, strong gums
9	Skin	Thin, dry, cold, rough, dark	Smooth, oily, warm, rosy	Thick, oily, cool, white, pale
10	Hair	Dry, brown, black, knotted, brittle, scarce	Straight, oily, blonde, gray, red, bald	Thick, curly, oily, wavy, luxuriant
11	Appetite	Irregular, scanty	Strong, unbearable	Slow but steady
12	Digestion	Irregular, forms gas	Quick, causes burning	Prolonged, forms mucous
13	Thirst	Changeable	Surplus	Sparse

14	Emotions	Anxiety, fear, uncertainty	Anger, hate, jealously	Calm, greedy, attachment
15	Mind	Restless	Impatient	Calm
16	Intellect	Quick but faulty response	Accurate response	Slow, exact
17	Speech	Rapid, unclear, talkative	Clear, sharp, penetrating	Quiet, slow, monotonous
18	Voice	Weak, hoarse	Strong tone	Deep, good tone

During the course of one’s life, a person may be exposed to various environmental conditions which result in disturbance of the Tridosha constitution resulting into the symptoms of diseases. This is called prakruti imbalance [5]. Treating the physiological or psychological disease is nothing but re-establishing the equilibrium of the Tridosha in the body. Consider an example to understand the Tridosha imbalance. If food consumed by a person causes diarrhea, surplus motion in the bowels indicate air element into play, which means Vata element has aggravated; if the person is feeling nausea immediately after food intake, meaning the metabolism (fire element) is not effective during the digestion, conveying that Kapha element has aggravated; whereas if the food caused a burning sensation near the chest indicates the increase of fire element, pointing towards Pitta aggravation [3].

The vast number of modern medical treatments offered today, are based on the “One drug fits all” phenomena [7]. However, it is observed that the same medication used to address the same diseases elicit a varied response from different people. Here, Prakruti plays a vital role in preventing and treating diseases. Ayurvedic philosophy claims that no two persons suffer from apparently similar disease, therefore, all the treatments are highly individualized according to one’s Prakruti. There are, in all, 80 types of Vata-borne, 40 types of Pitta-borne and 20 Kapha-borne diseases. For example, a person of Vata Prakruti is prone to diseases like rheumatism and nervous system related disorders. Hence the preventive measures will consist of avoiding Vata aggravating foods and activities. A person of Pitta Prakruti will inherently have high heat levels, hence cooling medicines will typically by a part of his treatment. Likewise, a Kapha Prakruti person is prone to obesity and will be administered with heat increasing medicine because his body has a cool nature due to dominant Kapha element [3]. Drugs also have different effects on different Prakruti types; Pitta Prakruti type people are fast drug metabolizer since they have greater energy and heat production while Kapha type people are weak metabolizers, therefore requiring smaller dosage than the prior [8].

Diseases are caused due to imbalance i.e. increase or decrease in any of the Tridosha. It has been observed that the Tridosha of non-healthy persons displayed more erratic behavior than that of a healthy person [10]. Therefore, Prakruti analysis is the first and the foremost step performed by Ayurvedic doctors to evaluate which of the Doshas are out of balance. The analysis is performed in 3 ways to find the dominant Dosha determining one’s Prakruti [9]:

1. Sparshanam (Touch based): Analysis of pulse rate and body temperature.
2. Prashna (Question based): Analysis based on a questionnaire, consisting of questions related to background of the disease and lifestyle of the person, patterns related to sleep, dreams, appetite, energy levels, kind of voice, etc.
3. Darshana (Visual based): Analysis of physiological features like body frame, weight, height, skin and hair, eyes and teeth.

The most stable factors of a person’s nature reveal the Prakruti of the patient. The physical structure of a patient gives the greatest clue toward constitutional tendencies and is more reliable than functional indicators like pattern in appetite, digestion, sleep, voice, etc. This is because it is least likely to change, even during Prakruti imbalance, except for the body weight. Functional indicators, however, are still useful since they indicate lifelong patterns [5].

Unfortunately, Prakruti determination using modern technology tools of visual analysis has had limited investigation. Pulse diagnosis and questionnaire in the textual format are the only methods used by many researchers to automate Prakruti analysis [9][10][11]. The Tridosha analysis has been performed using the pulse diagnosis method by deploying pressure sensors [10], [12] and optical sensors [9] to capture the pulse waves. Machine learning algorithms like the neural networks and decision tree [9], LASSO, Elastic Net, random forest clustering [11] algorithms have been applied to this data to classify the Prakruti of the patient. All the research performed in this area focuses on using questionnaires to cover the darshana (visual based) phase described above. Thus, this indicates that more research is required in exploring the problem of Prakruti determination using visual analysis of physical features (Table 1.2). I hypothesize that if computer vision techniques were to be applied to traditional textual and manual analysis approaches, the automation of Prakruti identification and classification could be further improved. One of the ways to achieve this is to leverage facial recognition applications of computer vision.

Today, due to a lot of demand in security and other commercial applications, one of the most successful domains of computer vision in image analysis is facial recognition. Availability of efficient hardware systems has resulted in technical advancement of facial recognition applications. Facial recognition problem can be described as identification or verification of a given person in a still image or a video [13]. This task further involves: (1) segmentation of faces (face detection) from cluttered backgrounds and lighting conditions, (2) feature extraction from the face regions and (3) recognition, or verification (Fig. 1). Research in facial recognition systems has been focused on developing fully automatic system by first solving the lower level problems like localization of a face in a given image, extraction of features such as skin, eyes, mouth, etc. Each of the above subtask has been extensively explored to achieve the final goal of facial recognition. These three subtasks are handled differently according to the nature of the application.

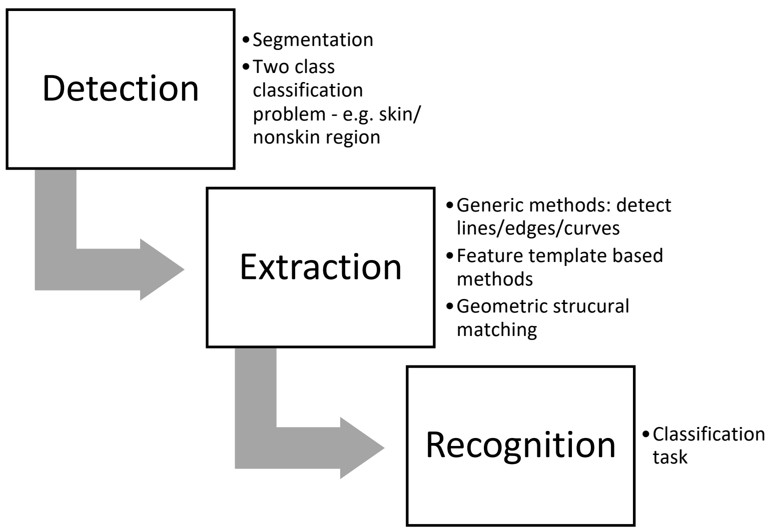

Figure 1-1 Configuration of generic feature recognition system [13]

The features defining a face which play a significant role in facial recognition are hair, face outline, eyes, and mouth [14]. These facial features are also being used in the Prakruti determination as depicted in Table 1.2. Hence, it can be hypothesized that facial recognition approaches can be applied to the problem of automating Prakruti determination. A subset of the physical characteristics observed by Ayurvedic doctors, as enlisted in Table 1.3, can be utilized to achieve this goal. The properties of each feature, such as size, colour and texture, will help in classifying the people into different Prakruti types [15]. Detailed analysis of each of the facial features listed above, is in itself a vast research area in the computer vision domain.

Table 1-3 Subset of physical features used for prakruti determination

NO.	OBSERVATION	TRIDOSHA		
		VATA	PITTA	KAPHA
1	Skin colour	Dark, grayish black	Rosy (pinkish), whitish, yellowish	White, pale, light brown (wheatish)
2	Hair texture and colour	Dry, scarce, dry curly, dark gray	Straight, bald, blonde, tawny, brownish red	Thick, soft curly, wavy, black, blackish blue
3	Face shape/ chin	Thin, angular	Tapering/ triangular	Rounded, double chin
4	Eyes	Small, gray	Green, blue, hazel yellow/red	Big, black, blue

There are two kinds of approaches followed in previous literature for solving the facial recognition tasks as depicted in Fig. 2. Traditionally, the feature segmentation and extraction algorithms involved usage of geometric shaped models like the elliptical boundary model or the parametric classifiers like Gaussian Mixture Models (GMM), Gaussian clusters, Bayes Network, Naïve Bayes, random forest etc. With the support of high computational power and a lot of data, the use of neural networks in computer vision applications has grown tremendously in the recent years, which forms the basis of the second approach. We will be reviewing these two approaches while analyzing how each of the feature mentioned in Table 1.3 can be extracted for determining the Prakruti type.

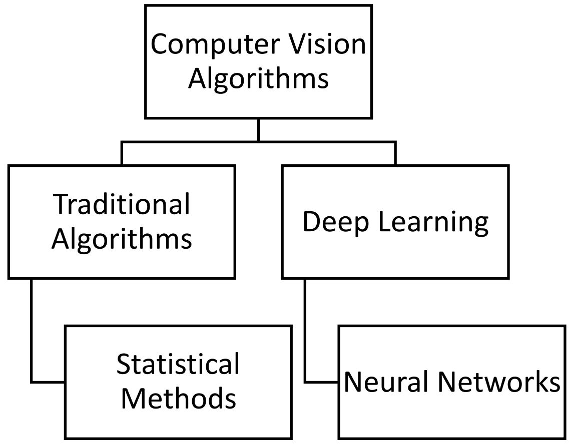

Figure 1-2 Type of Approaches

A. Skin Analysis

Skin detection is considered as a challenging problem in image processing because there exists disparate variations in the images like the lighting conditions, presence of skin colour-like background, variations in skin colour of people belonging to different ethnicities and variations due to makeup [16]. The unique combination of Tridosha in Prakruti defines the skin colour of an individual [2], [6]. Following are the prominent characteristics of skin according to different Prakrutis (Table 1.3):

- Vata – Thin, dry, rough, dark, grayish black, dark brown
- Pitta – Smooth, oily, warm, rosy (pinkish), whitish, yellowish
- Kapha – Thick, oily, cool, white, pale, wheatish

Colour is a feature which can be extracted easily using the RGB value of pixels. Hence, skin colour will be a prominent feature in the Prakruti determination problem.

The skin colour detection is approached in the previous researches as pixel labelling problem of first detecting the skin and non-skin regions in the image. Various algorithms like Bayesian classifier with histogram technique, multi-layered perceptron and the Gaussian classifier [17] or other statistical based machine learning approaches like random forest [18] are applied. K-means clustering is one of the widely used algorithm because of its speed and simplicity [19]. Bayesian classifier with the histogram based technique are found to have higher classification rates even when there was less data but were less effective when the skin and non-skin regions overlapped to a greater degree [20].

Multi-layer perceptron (MLP), fully connected convolutional neural networks are also used in the skin segmentation tasks. However, it was observed that due to the inability of CNN and MLP to establish a relationship between pixels and its neighbors, recurrent neural networks (RNN) in conjunction with the fully CNN (FCN) were developed [21]. The datasets used for this task are COMPAQ [17] and ECU [22] which contain heterogenous images of people belonging to different ethnicity, gender and age. The neural network models are robust and performed better classification in comparison the statistical approaches by successfully identifying the skin regions and rejecting the skin-like background regions. The pretrained models like VGG can also be used as one of the many layers in the CNNs [16].

After the skin regions have been classified, pixel values of the clusters are evaluated using the YCbCr or the RGB colour space to identify the human skin colour. This can be utilized further to classify into the aforementioned three Prakruti types.

B. Hair Analysis

Hair analysis is another important and challenging problem in computer vision [23]–[25] used for facial recognition tasks. Hair analysis plays a vital role in the study of Prakruti identification. The hair characteristics differs with respect to a person's Prakruti [15]. Following are the prominent hair characteristics according to different Prakrutis (Table 1.3):

- Vata – Thin, dry, curly, sparse
- Pitta – Thin, soft, straight, blonde, tawny, brownish red, bald, receding hairline
- Kapha –Thick, oily, shiny-curly, black, blackish blue

The hair features mainly analyzed using computer vision are forehead and outer hairline, length, volume, density, colour, baldness and texture [23]. The problem of hair analysis can be approached by dividing it in three sub-problems [24]:

- Detection: Hair and non-hair region in the image
- Segmentation: Label the central pixels where hair presence is uncertain
- Classification: Wavy, straight, kinky, curly

Vata Pitta Kapha

Figure 1-3 Hair texture according to Prakuti [25]

Support vector machines (SVM) and random forest are the optimal machine learning techniques used to separate the hair region and non-hair region in the images [24], [25]. Linear

Ternary Pattern (LTP) is another method used to extract texture features for the hair, used in conjunction with statistical methods. The effect of the different dimensions of hair like hairline, texture, colour, volume, length, split has also been analyzed by applying the techniques of principle component analysis and eigenfaces [23]. Along with simple convolutional neural networks, variations in CNN have been developed like heuristically trained neural network [26], CNN with deep features from pretrained CNN models like VGG-VD, CaffeNet for hair detection [24]. The neural network algorithms are observed to perform better than the current state-of-the art classifiers for hair classification.

Thus, the final classification from hair analysis gives us the information about the person's Prakruti, kinky and curly signifying Vata, straight signifying Pitta, and wavy and signifying Kapha. Hair colour information can also be extracted by defining the boundaries for each colour using the YCbCr or RGB colour space while segmenting the hair pixels [27], which will in turn help us to assign a Prakruti label to the person.

C. Face Shape Analysis

The shape of an object is described by the object's geometric structure and appearance. A person's face shape is an important feature used in facial recognition tasks. In Prakruti analysis, the face shape points towards the dominant Tridosha in the person's body, Vata people having angular shape with defined cheek bones, Pitta signifying pointed/ tapering chin and Kapha signifying rounded face.

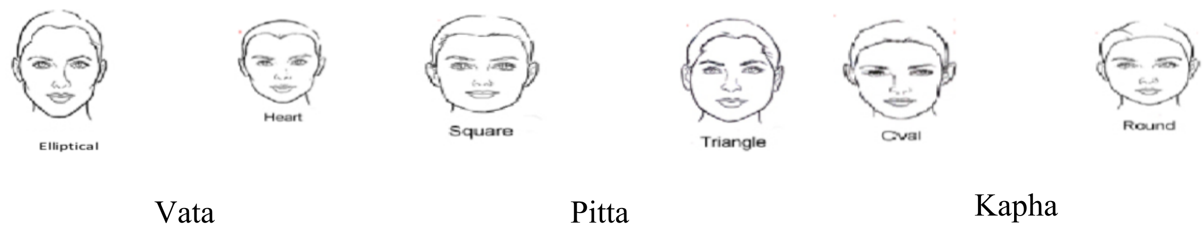

Figure 1-4 Face shapes [28] classified according to Prakruti

Active shape model has been widely used for face shape classification by localizing the eyes and the mouth. Geometric shapes like ellipse, square, triangle, etc. are used to calculate its similarity with the detected face [28] using region similarity, correlation coefficient and fractal dimensions. Most the algorithms [29][30] detect the boundary of the face but do not classify them in the shapes required for Prakruti determination. However, the edge boundaries detected using these algorithms can be fed to another model to detect its resemblance to a the geometric shape [31][32].

D. Eyes Analysis

Human eye information is crucial to gain deeper understanding of one’s physiological and psychological conditions, thus, finding its applications in the domains like facial recognition, medical diagnosis, facial expression recognition, auxiliary driving, drowsiness detection and psychological analysis. This emphasizes the need for an accurate and efficient eye detector [33] [34] [35]. The main aim of this line of research is to extract eye components and its characteristics like the iris, pupil, eyelids along with its geometric shape [36]. Extracting the eye colour after localizing eyes in an image will also help in the problem of Prakruti determination, brown/black tones of iris signifying Vata, gray/green signifying Pitta and blue signifying Kapha Prakruti of the person.

Vata Pitta Kapha

Figure 1-5 Characteristics of eyes according to Prakruti [37]

Many machine learning techniques like Support vector machines (SVM) and random forest have been proposed for feature extraction in noisy conditions. However, deep learning methods like deep neural networks and deep convolutional neural network have proven to work better in analyzing eyes even in noisy conditions. Facial area in the image is localized using Viola-Jones face detector [33] [35] and then segmented using AdaBoost algorithm [33]. Eye patches are extracted from facial regions which are then fed to the neural network [35]. Few approaches also involve localization of iris center of the eyes considering the circularity score by taking into account the symmetry of pixels at radius [33]. After localizing eyes, eye colour information can be extracted by defining the boundaries for each colour using the YCbCr or RGB colour space, in turn assigning a Prakruti label to the person.

By classifying each of the aforementioned features into Vata, Pitta and Kapha type, we can determine one's Prakruti by adding up the score for each type. The final Prakruti will be the one having the majority score [6]. This appears to be a completely novel solution, with no previous mention in the literature. Here I report promising results of applying computer vision to Prakruti determination which serve as the first step for future research and opens up new possibilities for possibly curing and preventing diseases.

2. METHODS

A. Dataset Collection

Prakruti analysis using computer vision is concerned with automating the physical feature analysis to gain the visual understanding of a person's Tridosha elemental constitution.

Variability present in human faces due to race, age, gender, pose, facial expressions and presence of facial hair, along with the varying aspects of an image like different lighting conditions and image resolution, face detection in images is considered as a challenging task in computer vision.

In order to do an effective Prakruti analysis using computer vision, capturing all the physical features is essential. All the physical features of a person can be captured in whole body and frontal face images where details like the body structure, type (built), facial features, hair type, etc. are effectively visible and comparable to observation performed with a naked eye. Analyzing the complete body frame to classify whether a person is skinny (Vata), broad (Kapha), medium (Pitta) [2], [6] is a complex task considering the different clothing worn by a person, the relative camera distance from which the image is captured, varying lighting conditions, image resolution etc., which makes the person appear different from different angles. Therefore, this experiment focuses on analyzing the front facial features (Table 1.3) from the head up to the shoulders to classify persons into their Prakruti.

Since the problem of Ayurvedic Prakruti analysis using image processing had not be been attempted at the time of this research, there was no labelled dataset readily available for classifying images of people into 7 Ayurvedic Prakruti categories of Kapha, Pitta, Vata, Kapha-Pitta, Vata-Kapha, Pitta-Vata, and Vata-Pitta-Kapha.

i. Manual Collection and Labelling

Dataset of around 36 images was collected using Google Form containing the frontal face photos of people along with their age, height and weight. The parameters age, height and weight were also captured since these fields are used by an Ayurvedic doctor for assessing the body frame. Since the no. of images in this manually collected dataset were not sufficient for solving the Prakruti analysis problem, other frontal face image datasets like Labeled Faces in the Wild [38], 10k US Adult Faces Database [39] and Celebrity-Face-Recognition [40] were explored.

ii. Labelled Faces in the Wild

Labeled Faces in the Wild (LFW) dataset consists of 13,000 images of faces collected from the web mainly used for facial recognition tasks. Each image is approximately of size 15 KB having dimensions 250 x 250. On processing few of the images from this dataset, it was observed that these images did not have enough clarity to accurately analyze the intricate feature information like eye and lip colour, making it difficult to label the persons into target Prakruti categories. Hence this database was removed from consideration.

iii. 10k US Adult Faces Database

In an attempt to find the suitable dataset having clear facial features to analyze the colour and type of eyes, skin and hair, the authors of 10k US Adult Faces Database[39] were contacted. On receiving access to the database and its annotations, it was observed that the images of this database had only visible facial area, with minimum exposure to the person's the hair. Initial experiments on this dataset revealed incorrect results for feature recognition. Since hair analysis is also an important part for classifying Prakruti, this dataset was not used further.

iv. Celebrity-Face-Recognition-Dataset

This dataset consists of 800K images of around 1100 Famous Celebrities. All the images have been scraped from Google and is licensed under the Creative Commons Attribution 4.0 International. The dataset consists of celebrities from different background ethnicity, gender and age. 800 photos of each celebrity are present in this dataset. Since the images present in this dataset had enough clarity and also contained images covering the head to shoulder regions of the people, this dataset was finalized for Prakruti analysis. Around 400 unique images of celebrities were manually selected from a pool of 800 images per celebrity.

v. Finalized dataset

300 images were manually selected from the Celebrity Face Recognition dataset having the following properties:

1. Image covering the head to shoulder region
2. Format .jpg with size greater than 700 KB size
3. Good lighting condition
4. Photos with minimum makeup
5. Front facing orientation
6. Only one person per image
7. No eye ware, hats and other accessories obscuring the visibility of the natural facial features
8. Preferably smiling without teeth visible
9. Eye pupils not dilated

Combining with the 34 manually collected images, the final dataset consists of 334 images. These images were hand labelled into the 7 categories of Prakruti namely Kapha, Pitta, Vata, Kapha-Pitta, Vata-Pitta, Vata-Kapha and Vata-Pitta-Kapha, with the help of an Ayurvedic doctor with more than 20 years of experience. The doctor performed the analysis using Ayurvedic principles for physical examination of features to classify people into the aforementioned categories.

vi. Figaro1k Dataset

Hair texture analysis is a challenging problem for analysis and is an important feature for Prakruti determination. Figaro 1k dataset [24] contains 1050 unconstrained images of persons with different hair types, subdivided into seven different hairstyle classes (straight, wavy, curly, kinky, braids, dreadlocks, short). For the purpose of hair type analysis, a subset of 648 images, relevant to the finalized dataset were chosen and manually labelled into Kapha, Pitta and Vata categories.

B. Feature Engineering

To implement the algorithm for Prakruti Analysis, the below 7 facial features are extracted:

Table 2-1 Facial features for prakruti determination

NO.	FEATURE	KAPHA	PITTA	VATA
1.	Skin colour	Wheatish	Fair	Brown
2.	Hair colour	Black, Brown	Light Brown, Blonde	Gray
3.	Hair Type	Thick, smooth, wavy	Shiny, straight, bald	Scarce, dry curly
4.	Eye colour	Black, Brown	Blue, Green, Light Brown	Gray
5.	Eye size	Large	Medium	Small
6.	Lip colour	Pale Pink	Pink, Red	Brown
7.	Lip size	Large	Medium	Small
8.	Nose size	Large	Medium	Small

The following subsections describe in detail about the steps followed to extract each of the above features.

i. Skin Region Segmentation

The goal of this step is to extract the dominant colour of the skin tone of a person in an image. This can be achieved in three steps:

a. Reading the Image – The input image is read in the form of a NumPy array provided by the NumPy library, which is a three-dimensional matrix representing the three channels for Red, Green and Blue colours respectively.
b. Thresholding – This is the process of creating a binary image by filtering out the pixels which do not fit in a given range. A lower and upper limit is defined which represent the skin colour range [41]. OpenCV [42] library's .inRange() function is used to create a binary image using the lower and upper thresholds. This process is also called as masking. Once a skin mask is generated, we use the GaussianBlur function, a linear filter provided by OpenCV used for removing noise from the image while preserving the edges in the image. This technique is also termed as Gaussian smoothing and often used as a pre-processing step in computer vision applications.
c. Clustering – The final step of skin segmentation is grouping the similar pixels together in order to extract the dominant colours present in an image. Kmeans clustering, provided by the Scikit-learn package [43] is used for this purpose. Fig. 2.1 shows the skin segmentation process and the clustered colours represented in the form a colour bar.

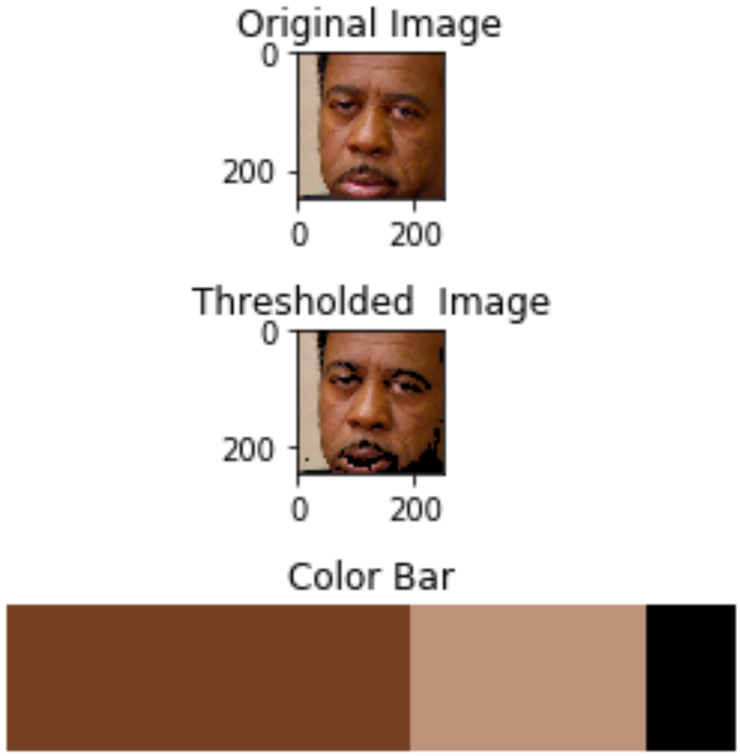

Figure 2-1 Skin colour extraction and colour bar of clustered colour shades

ii. Dlib's HoG based face detector

The first step in detecting the facial features is locating the face in a given image. Haar and Histogram Oriented Gradients (HoG) are few of the widely used facial detection models in computer vision which help in this task. Haar Cascade based Face Detector was introduced by Viola and Jones which was considered to be the state-of-the-art model in face detection before deep learning and other advanced machine learning based models were introduced. OpenCV package provides Haar based models for frontal face detection, lower and upper body, eye detection, etc. On experimenting with this model, it was observed that though this model performs well on a CPU, it does not work well on slight pose variations and gives false predictions for face detection.

HoG face descriptor has the distributions (histograms) of the gradient directions as features. Magnitude of the gradients is large around the edges and the corners in the image. HoG based face detector is provided by the computer vision library dlib [44] , which helps to find frontal human faces in an image returning 68 landmarks. These 68 landmarks represent the points on the faces such as corner of mouth, eyebrows, eyes and the jaw line. The face shape predictor is trained using 2825 images and is available in the form of a .dat file. This face detector performs well on a CPU and is a light weight model compared to deep neural networks and Haar Cascade based facial detection models [45]. Therefore, is the best choice for facial detection step for this research's system configuration. Fig. 2.2 shows an image passed through HoG face detection. This algorithm returns the coordinates of the rectangles surrounding the facial features like nose, left eye, right eye, mouth, left and right eye brows.

Using the coordinates returned by the face detector for eye brows, the x and y coordinates can be adjusted in the opposite direction in order to locate the hair region of a person in the image for the purpose of extracting the hair colour.

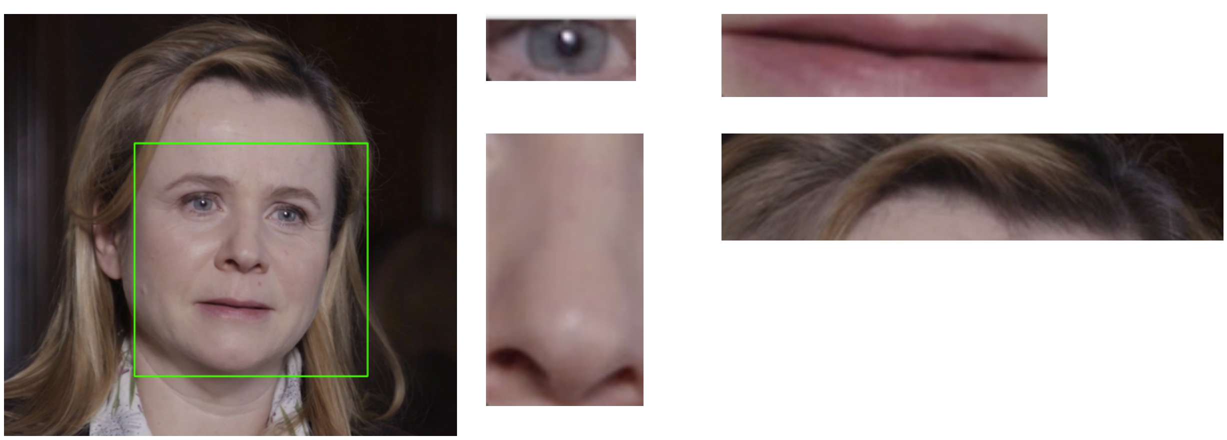

Figure 2-2 Facial Detection using HoG based face detector

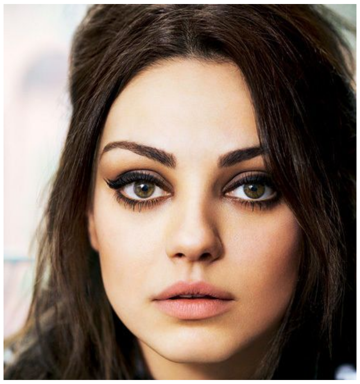

Image of a person with large eyes

Ratio of Area of Eye / Area of face = 0.015

Image of a person with small eyes

Ratio of Area of Eye / Area of face = 0.011

Figure 2-3 Example of feature size estimation for eyes

iii. Feature Size Calculation

On localizing the feature coordinates, the next step is to estimate the size of a feature and mark it as Large (L), Medium (M) or Small (S) where the size indicates the Kapha, Pitta and Vata categorization respectively. HoG based face detector returns the coordinates of the facial features. The size of the feature is relative to the size of the human face. Hence, the size is determined applying a simple method of counting the pixels covered by each feature with respect to the total number of pixels covered by the face. The bounding box coordinates returned by the HoG based face detector contain the width and the height information which is used to calculate the area of each feature. Manual observation of the images was used for benchmarking the range of large, medium and small sizes. Fig. 2.3 explains how the feature size analysis was performed. The image of a human with large, medium, small eyes were used to define the size thresholds. Similar thresholds were determined for nose and lips areas as well.

iv. Colour Detection

Colour plays a very important role in determining the Prakruti type of a person. The first step in colour detection is extracting the dominant colours in the given area of an image (Fig. 2.4). To achieve this, Kmeans clustering algorithm is used to group similar pixels together. The best no. of clusters turns out to be 5 which was defined after experimentation with various values for different features. After getting the 5 dominant colours the one, the colour with maximum occurrence percentage is used for further analysis. This process is performed for all the regions of interest for the extracted features. The next step after extracting colours is determining to which category it belongs to.

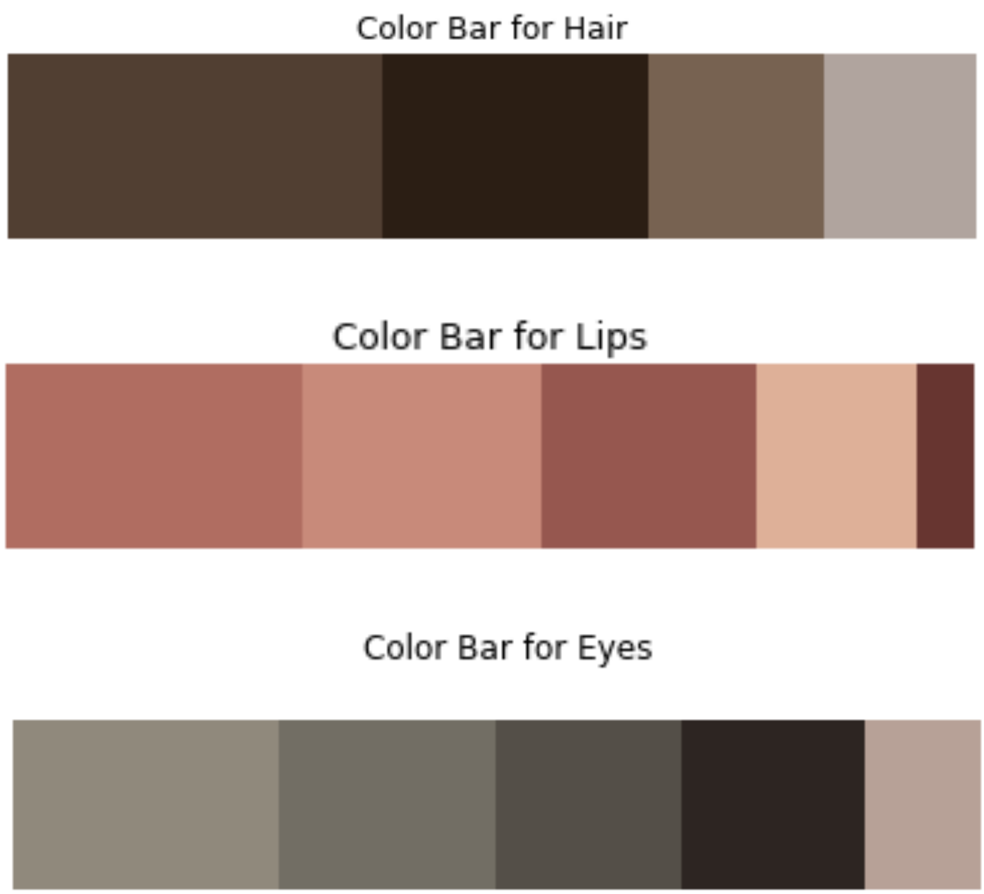

Figure 2-4 Colour bars generated for Hair, Lips and Eye

```
DICT_SKIN_COLORS = {
    "Fair" : [ "bisque2","bisque3","AntiqueWhite","AntiqueWhite2","PeachPuff2","PeachPuff3","PeachPuff1",
              "NavajoWhite2", "RosyBrown2", "MistyRose2","MistyRose3","PaleVioletRed4","bisque1","snow3",
              "BlanchedAlmond","burlywood","burlywood2","LightPink1","LightPink2","LightPink3" ],
    "Wheatish": ["salmon2","LightSalmon2","LightSalmon3","DarkSalmon","burlywood3","NavajoWhite3",
                 "RosyBrown","RosyBrown2","RosyBrown3", "wheat3","MistyRose4",
                 "tan","tan2","tan3","bisque3","coral3"],
    "Brown": ["salmon3","salmon4","tomato4","PeachPuff4","LightSalmon4","burlywood4","sienna4","gray21","gray25"]
        }
```

Figure 2-5 Dictionary for skin colours

Human analysis is required for categorizing skin tones into fair, wheatish or brown, iris shades into gray, blue, yellow, brown, and lip colour shades into pale pink, pink and brown. Because of the diversity present in humans all around the world and the vast colour space consisting of more than 16 million colours [46], choosing the exact subset for categorizing these colours is a challenging task. Defining each colour in English readable names for its different shades, from its RGB values and mapping it to the aforementioned colour tones for each feature is a tedious task. Using a simple Euclidean distance measure to categorize a new colour did not yield good results. The authors of [47] have defined an optimized approach to classify colours and returning English like names using kd-tree algorithm for finding the nearest neighbour of a given colour. The space of 568 different RGB colours is used for this purpose. This approach helped in binning the subset of colours for into the necessary groups for skin, hair, iris and the lip regions. A dictionary of colours was developed for features skin, hair, eyes and lip colour after processing around 100 images from the dataset. As shown in Fig. 2.5. the dictionary key represents the target categories and the values represent the list of possible shades falling into it. For the feature eyes, the detected region using HoG based algorithm, returned a bounding box around the eyes, resulting in capturing the skin pixels. Colour extraction using clustering often returned skin colour to be the dominant colour, failing to return the true colour of iris. To solve this problem, the region of interest for an eye was further cropped which returned the true iris colour successfully.

v. Hair Texture Analysis

Hair texture plays an important part for the Prakruti classification problem. Hair of medium thickness, silky smooth straight hair indicates Pitta Prakruti, sparse, dry and /or wavy hair indicate Vata and thick, dark hair define Kapha Prakruti present in a person. In spite of its importance, hair texture analysis is not a well explored problem because of many challenges like presence of wide number of variations in hairstyles, colour and dye, limited exposure in the images, variations in visual appearance depending on the head-tilt angle; possible presence of complex backgrounds, etc. [24]. Since the texture analysis is a complex problem to attempt using machine learning, deep learning comes to rescue. Deep learning is a subset of machine learning where the model learns the patterns from the input images without requiring manual feature extraction. Considering that the total no. of the images in the research dataset (300) are less compared to the thousands of images usually used for training a deep learning model, transfer learning is implemented.

Transfer learning is a method where a pre-trained weights of a deep learning model, trained on millions of images are used to classify images belonging to new classes for a new problem. The ResNet50 model provided by Keras [48] is used in this implementation. ResNet50 is a deep convolutional neural network model is trained on ImageNet [49] dataset consisting of more than 14 million images belonging to approximately 20,000 classes. The hair type recognition model uses the weights of ResNet50 by replacing the last layer with the configuration relevant to the Prakruti classification task.

Transfer learning model using ResNet50 was trained with the Figaro1k dataset consisting of 648 images and three class labels namely Kapha, Pitta and Vata. The trained model is then used to predict classes for the Prakruti dataset. The result of this classification is combined with the feature classification result to determine the final Prakruti classes for an image.

vi. Feature Classification

Using the feature data extracted from the image, the final step is to classify the image, and hence the person into one of the Prakruti categories. A simplistic approach for Prakruti classification is used where the most dominant Dosha, i.e. the Dosha whose qualities are exhibited the most, is used as a final class. There are in all 7 features extracted per image as enlisted in Table 2.1. As observed in this table, each facial feature is a result of the property of one of the Tridosha i.e. Kapha, Pitta or Vata. Hence, each feature corresponds to one class. The final classification is decided based on the summation of score for each class and choosing the classes with maximum score. Fig. 2.6 gives an example of the extracted features for a given image and its corresponding Prakruti classes. The skin and the hair colour have more weightage (2 points each) compared to the other features (1 point each). Hence, the result of scores for the below example is 3 for Kapha, 5 for Pitta and 1 for Vata. Hence the resultant class for the person in the image is Kapha-Pitta, considering the top 2 scores, where Kapha is the first dominant and Pitta being the second dominant Prakruti. Identifying the cases of extreme Prakruti, where the person belongs to only one class i.e. either Kapha or Pitta or Vata, was achieved by setting a score threshold (6 in this case). If the score of that class exceeds this threshold, the person is assigned that one class label.

FEATURE	VALUE	CLASS
Skin Colour	Wheatish	Kapha
Lip Colour	Pink	Pitta
Lip Size	Large	Kapha
Eye Colour	YellowishGray	Pitta
Eye Size	Medium	Pitta
Nose Size	Small	Vata
Hair Colour	Brown	Pitta

Figure 2-6 Features extracted for one image. Prakruti classification is Kapha-Pitta

C. *Experiment Setup*

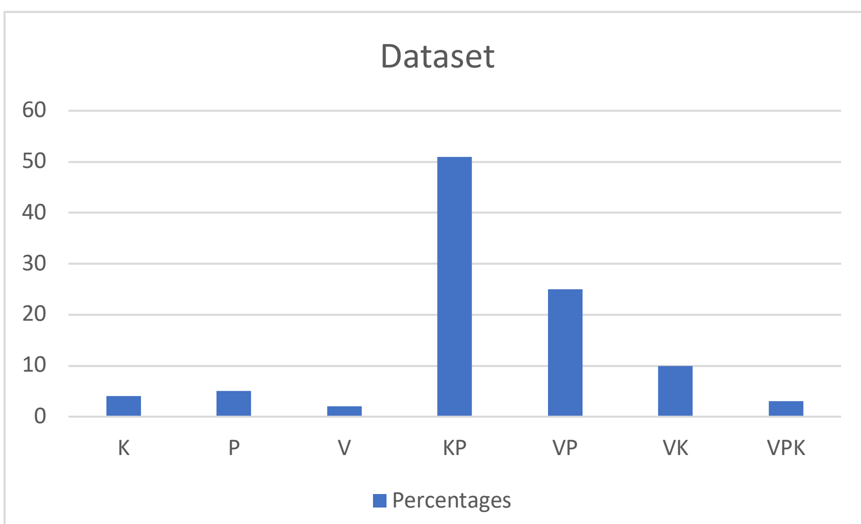

Figure 2-7 Distribution of dataset across 7 classes

The dataset used for the research contains 330 images of people belong to 7 different categories. The above figure shows the distribution of labelled dataset for the experiment set up. Majority of the people belong to Kapha-Pitta and Vata-Pitta categories.

Below is the hardware and software setup used for the analysis.

i. Hardware configuration:
   - Processor: 2.5 GHz Intel Core i5
   - RAM: 16 GB
   - OS: MacOS Mojave 10.14.3

ii. Software configuration:
   - Anaconda Navigator version 1.9.6
   - Jupyter Notebook version 5.7.4
   - Programming Language: Python 3.7.1

iii. Cloud configuration
   - Google colab notebook
   - Keras Package preinstalled in Google colab

Machine learning and computer vision image processing packages used are listed in Table 2.1.

Table 2-2 Locally Installed Packages

PACKAGE	VERSION
NumPy [50]	1.15.4
Pandas [51]	0.23.4
CV2 [42, p. 2]	3.4.2
Dlib [44]	19.16.0
Sklearn [43, p.]	0.20.1
Imutils [52]	0.5.2
Matplotlib [53]	3.0.2

3. RESULTS

A. Hair Type Classification

The training accuracy of the deep learning model for hair type classification using ResNet50 transfer learning is 96%. The testing accuracy on the Prakruti dataset is 85%. It was observed that this model did perform well in identifying the colour and the texture of hair i.e. straight, curly wavy and bald. However, the factors like quantity of the hair determining whether scalp has thick or scarce hair, or the dry or oily nature of hair was not captured.

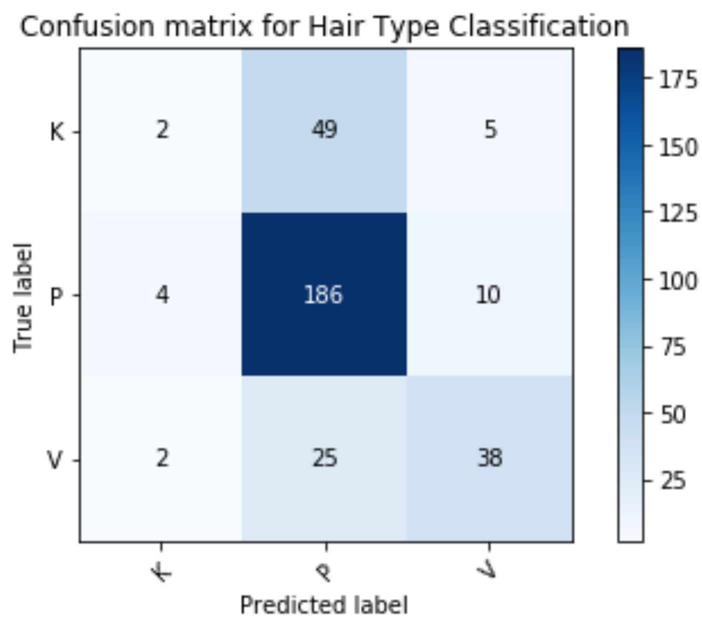

Figure 3-1 Confusion Matrix for Hair Type Classification

As depicted in the Fig 3.1, since majority of the people in the dataset have straight hair, the Pitta category which depicts straight hair, has the maximum no. of records. Adding the output of this classifier as a feature to the final set of extracted features helped to improve the overall accuracy of the Prakruti classification model.

B. Final Prakruti Classification

Overall accuracy of the algorithm is 50%. Below is the confusion matrix for the result of all classes. It appears that the Kapha-Pitta category's detection accuracy is 69% and due to availability of less features captured for the Vata category, using computer vision methods, the accuracy of the classes involving the Vata element is comparatively low.

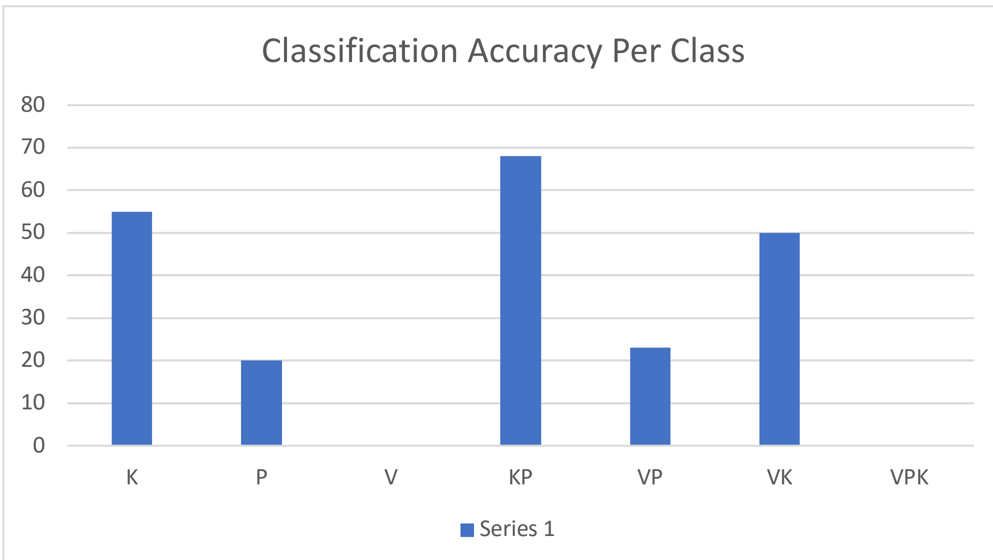

Figure 3-2 Plot for analyzing accuracy

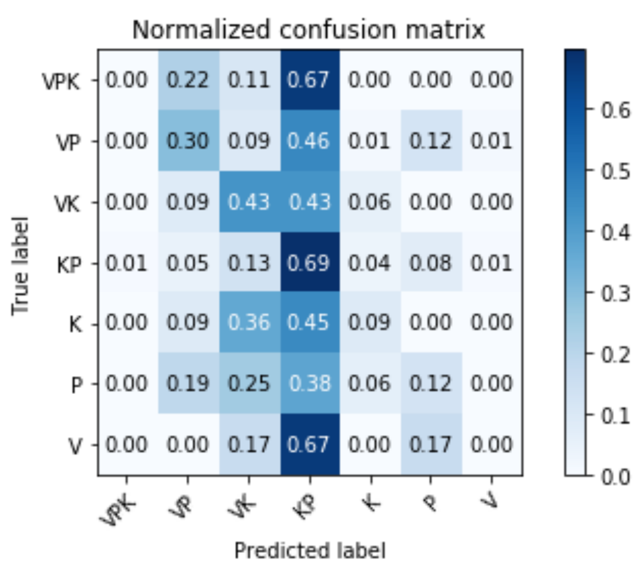

Figure 3-3 Prakruti Classification Confusion Matrix

4. DISCUSSION

Prakruti of a person is based on the geographic region of their birth place, season of conception and birth, and the Prakruti of their biological parents. The subjects included in the dataset belong to different geographic and climatic regions and it observed that the dataset has a higher no. of subjects having Kapha and Pitta as major constituents. The individuals originating from coastal regions show a high percentage of the Kapha (earth and water) component because of the dominance of water element, while in the dry regions Vata Prakruti is more dominant in correlation to the air element [54]. African continent has people belonging majorly to Vata and Vata-Kapha categories, North America and European regions have people belonging to Kapha-Pitta and Vata-Pitta categories, while Eastern regions like China and Japan have Pitta and Vata as dominant categories. From the total subjects included in this study, it was observed that 51% belonged to Kapha-Pitta and 25 % belonging to Vata-Pitta. Another important observation is that since a person's constitution is made up of all the three Doshas, no person in the dataset had a nil or 100% score of any one the Prakruti class. Also, it is to be noted that the two-Dosha Prakruti (Kapha-Pitta, Vata-Pitta, Vata-Kapha) is more prevalent in the world as compared to single Dosha Prakruti (Vata, Pitta, Kapha) or three-Dosha Prakruti (Vata-Pitta-Kapha).

An Ayurvedic doctor determines the Prakruti of a patient by asking around 35 questions which include his food preferences, sleeping habits, kind of dreams, behavioral aspects like ways of expression of feelings, general physical structure and gait, childhood nature, and other lifestyle related questions. Observing a patient in person and observing a photograph makes a lot of difference in assessing the Prakruti, since the photograph is affected by multiple conditions like lighting, distance and angle from which the photo is captured, etc. Considering the limited data available in an image (from head to the shoulder region), this research experiment performed well and exceeds the expectations in determining the seven Prakruti categories.

I conclude that applying computer vision to capture and analyze the physical features is an effective approach considering the complexity of the problem. Future research with the help of advanced computer science techniques and more data to analyze the intricate properties of thin, thick, dry, oily texture of skin and hair, symmetry of facial features and the complete body frame, will definitely turn out to be more accurate. This experiment served as a new starting point for applying visual technologies to the Ayurvedic assessment task, that has been manual for thousands of years. Combining this analysis with the existing methods of pulse-based analysis will provide superior results for the Prakruti classification and aid the Ayurvedic doctors.

Prakruti determination is critical to Ayurveda which directed Ayurveda doctors to develop methodologies like a questionnaire or pulse-based tools to capture the psychological and physiological traits. This research not only helped to contribute the first ever image dataset of people categorized into the Prakruti classes but also conceptualized as a diagnostic tool for the betterment of mankind for preventing and curing diseases and maintaining good health. Therefore, this research is an important step, not only to the Ayurvedic doctors but also to a common man helping him live in a healthy way by customizing his lifestyle.

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