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Comparative analysis of prakruti using photoplethysmography and facial aspects

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ABSTRACT

In today's modern technological era, many diagnostic equipment and procedures are used to assess the human's health state, providing a wealth of information about the human, invasively and treated with a single drug for everyone. Root causes of the disease were not thoroughly investigated using modern technology. To overcome this, traditional Ayurvedic science was combined with computer vision technology to accurately characterize an individual's prakruti, thereby identifying the root cause of disease. Major individuals' predominant prakruti might be vata, pitta, or kapha. Imbalance of vata, pitta, and kapha in human body results in disease. The work presents identification predominant prakruti's vata, pitta, and kapha of an individual using sparshana (photoplethysmography or PPG) and darshana (facial attributes) methods. Morphological attributes of PPG signal such peak, width and inter beat interval were adapted for identification of predominant prakruti in sparshana technique. Facial attributes such mouth aspect ratio, nose aspect ratio, and eye aspect ratio of darshana method were employed for identification of predominant prakruti. An accuracy of 85.7 % and 90.5% using k-nearest neighbors (KNN) was achieved with sparshana and darshana respectively. Comparative analysis of predominant prakruti using PPG of sparshana and facial aspects of darshana methods were carried out.

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1. INTRODUCTION

Ayurveda, an Indian medical science, posits that three doshas vata, pitta, and kapha, are derived from the combinations of ether, fire, water, earth, and air elements. Every individual possesses a distinct amalgamation of three dosha elements that contribute to their 'prakruti'. Prakruti regulates physiological and psychological inclinations, as well as their interactions with the surroundings. This equilibrium affects their physiological characteristics such as the texture and hue of skin, hair, and eyes, length of the fingers, shape of palm, body structure, efficiency of digestion and influences psychological traits, including introversion, extroversion, calmness, excitability, intensity, laid-backness, and response to stress. The characteristics are genetically determined during an individual's formation and remain constant throughout their lifespan. Individuals' prakruti might be vata, pitta, kapha, vata-pitta, pitta-kapha, vata-kapha, or tridosha.

Vata is responsible for biological movements in the body, pitta energizes the body, while kapha provides strength and natural tissue resistance to body. According to Ayurveda, vata predominant prakruti occur in old age, huge amount of pressure required to pump the blood from ventricular to rest of body hence high amplitude values of photoplethysmography (PPG) occurs and high heart rate range in between 80 to 100 bpm, while pitta predominant prakruti occur in adult age where PPG peak value of PPG signal greater than 750 mV and heart rate could be in between 70 to 80 bpm. Kapha predominant prakruti occur in childhood, peak value of PPG signal very low and heart rate occurs between 60 to 70 bpm. Facial attributes in subjects grow in childhood, while in adult age it's well developed and shrinks in old age. An Ayurveda practitioners evaluate an individual's prakruti by either personally assessing their physical characteristics or by examining the nature of their pulse or by response of the questionnaire. Using these methods, practitioners diagnose, prevent, and treat the condition of subjects by prescribing personalized medication. Diseases arise because of an imbalance of vata, pitta and kapha dosha in the subject. Identification and quantification of such pulse parameters and facial attributes can provide insights of individual prakruti of subject to treat or identify the root cause of the disease. Identification of prakruti was carried out by well-trained practitioners and analysis varies from practitioner to practitioner. To standard measurements of wrist pulse and facial attributes, an automation system was implemented for the identification of prakruti. This system support will be advantageous for doctors who lack training in nadi pariksha, as it will aid in the diagnosis and prognosis of cardiac-related disorders.

The work presents both wrist analysis and facial aspect for identification predominant prakruti. In the wrist pulse signal analysis with various sensors [1] with time, frequency, wavelet, multichannel feature fusion [2] and nonlinear feature extraction techniques were deployed for diagnosing cardiovascular, respiratory, and other chronic diseases were implemented with machine learning and deep learning models [3]. Flexible wearable micro-electro-mechanical system (MEMS) sensor array [4], [5], piezoelectric sensor array [6] with multiple channels were demonstrated to capture spatial variations of wrist pulse signals. Authors had emphasized different anatomical locations to extract quality PPG signal [7], [8]. CycleGAN [9], autoencoder [10], and neural networks [11] denoising techniques were adapted in wearable devices while in [12] exhibits morphological variations of PPG signals based on contact pressure on the sensors. Physiological measurements of vata, pitta, kapha and tridosha prakruti were described using ultrasound doppler pulses [13] while k-nearest neighbors (KNN) [14], artificial neural network (ANN) [15] were developed for classification of time domain features of PPG signals. Face recognition of subjects was carried based on principal component analysis, linear discriminant analysis, local binary patterns histogram, Gabor wavelets, convolutional neural network (CNN), deep learning, and multi fusion models by several researchers [16]–[23]. Phenotypic assessment was effectively demonstrated by DeFFace method [24] and 3D framework [25]. Color analysis, texture analysis, and geometric analysis were carried on tongue images for the assessment of prakruti's [26]. Prakruti analysis was carried out by statistical color features with machine learning algorithms [27]. Morphology features of PPGs were trained by ANN algorithm for the classification of vata, pitta, and kapha prakruti [15], [28].

2. METHOD

The primary emphasis is to develop complete automated system for determination of predominant prakruti using PPG signals and with face facial attributes. A total of 101 subjects of age group between 15 to 58 years underwent sparshana (wrist pulse analysis) and darshana methods with the aim of identifying predominant prakruti. As per the recommendations of Ayurvedic practitioners, it is advised that the subject should be in relaxed position for two minutes duration prior to obtaining the vata, pitta, kapha signals and face attributes. Three sensors were placed on the hollow area below the wrist to observe and assess the qualities of the pulse beneath each sensor called vata, pitta, and kapha in sparshana method. Subjects were instructed to sit down in front of the camera of the laptop at 40 to 45 cm, with an alignment of 45 to 60 degrees for the duration of 1 minute in standstill mode facing towards the camera in darshan method.

Identification predominant prakruti using sparshana and darshana methods are depicted in Figure 1. optical sensors MAX30102 sense the volumetric blood dynamics of the subject and acquire PPG signals as vata, pitta, and kapha on wrist of the subject with sampling rate of 100 Hz. 4th-order Butterworth band-pass filter of 0.5 to 5 Hz employed to remove low and high frequency noise while retaining cardiac components. The filtered vata, pitta, and kapha signals were segmented into individual pulse cycles for the detection of systolic peaks and pulse onset points. Fiducial points, pulse width, pulse duration of vata, pitta, and kapha signals were extracted to compute heart rate, inter beat interval (IBI), and to determine predominant prakruti such as vata, pitta, and kapha [29]. These prakruti are indicative of an individual's physiological and mental health condition. On other hand, face detection was carried out by histogram of oriented gradients (HOG), implemented by Dlib library. Facial attributes were extracted with 68-point landmark model as shown in

Figure 2. Aspect ratios of eyes, mouth, and nose were computed as depicted in (1) to (3) for the identification of predominant prakruti using various classifiers [30]. Predominant prakruti identified using sparshana method and darshana method were correlated.

$$EAR = (||p_2 - p_6|| + ||p_3 - p_5||)/(2||p_1 - p_4||) \quad (1)$$

$$MAR = \frac{||p_{52} - p_{58}||}{||p_{49} - p_{55}||} \quad (2)$$

$$NAR = \frac{||p_{28} - p_{34}||}{||p_{32} - p_{36}||} \quad (3)$$

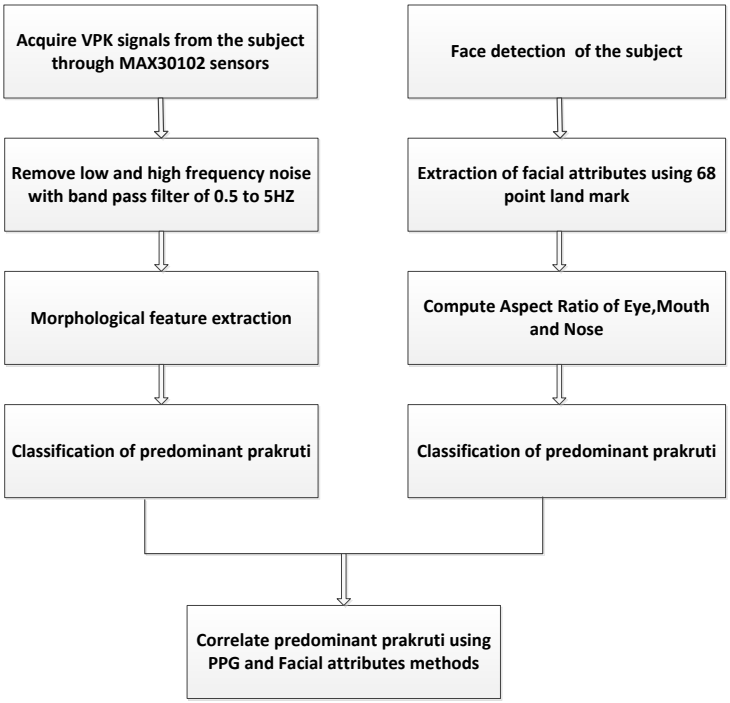


Figure 1. Automation system for identification predominant prakruti

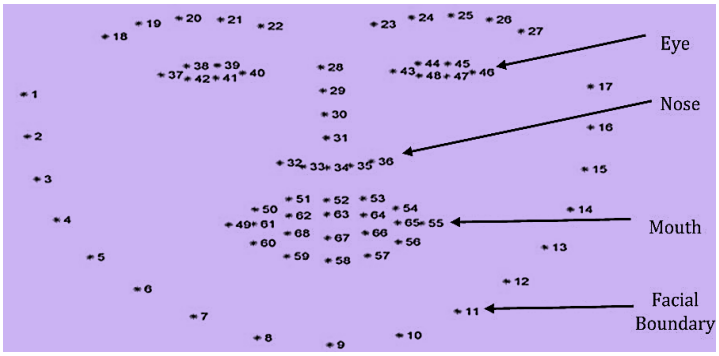


Figure 2. 68 points facial landmark image

3. RESULTS AND DISCUSSION

Sparshana and darshan approaches have been carried out on 101 subjects. Sparshana approach includes analysis of wrist pulse parameters while darshan approach includes facial features. These Ayurvedic techniques were used to identify predominant prakruti of the subjects.

3.1. Sparshana method

Statistical analysis of pulse-wave characteristics heart rate, IBI, and pulse amplitude was carried out for the subject of sample size of 101 individuals. The one-way analysis of variance (ANOVA) test was performed to study the statistical significance of all the parameters at each stage of the experimental protocol. All the data were represented as mean ± SD. The present study involved the collection of vata, pitta, and kapha wrist pulse and identifying predominant. Predominant prakruti of an individual was carried out on the amplitude, heart rate and IBI of PPG signal and classify the same with various classifiers. Heart rate and IBI of the subjects were measured for predominant prakruti and recorded in Table 1.

Table 1. Measurements of BPM and IBI of the subject of various prakruti

Prakruti / parameters	Mean ± SD	
	Heart rate (bpm)	IBI (ms)
Kapha	76 ± 6.6	771.8 ± 51
Pitta	69 ± 7.6	877.7 ± 90
Vata	76.5 ± 10.3	797 ± 112

IBI specifies the heart rate variability, varies from subject to subject and reveals physical, emotional, stress, and psychology of an individual. If IBI is high, it indicates an individual with high tolerance of stress and relaxing from stress whereas lower the IBI value indicates high stressful, emotional person. IBI indicates health disorders such cardiac disorders and mental illness. IBI values of kapha, pitta, and vata are 771.8 ± 51, 877.7 ± 90, and 797 ± 112, in milliseconds respectively ($p < 0.0241$). All the predominant prakruti 's IBI is within 1000 milliseconds and pitta individuals have low heart rate and high IBI indicating their health status with high metabolism, digestion and high persistency. According to Ayurvedic science, kapha individuals with 50 to 60 bpm, while pitta 70 to 80 bpm, and vata with 80 to 90 bpm. In the analysis kapha individual have 76 ± 6.6 bpm slight great values of 10 to 20 bpm, while pitta individual has 69 ± 7.6 bpm is coinciding with reference values and vata individual have 76.5 ± 10.3 are almost closer to reference value with significant parameter ($p < 0.001$).

Amplitude of kapha, pitta, and vata were measured at different points of the wrist of every individual to estimate the predominant prakruti and tabulated in Table 2. It was found that amplitudes mean ± SD of predominant prakruti kapha, pitta, and vata wrist pulses of the dataset are 776 ± 137, 874 ± 103, and 977 ± 14 in millivolts respectively were statistically significant ($p < 0.0001$). In childhood kapha is predominant; in adult age pitta is predominant and in old age vata is predominant. Vata controls body movements and commences approximately at the age of 50 or 60 years. As the level of vata in body constitution rises, an individual undergoes physical and mental transformations. Though dataset consideration for study was under age 15 to 54 years, vata prakruti has been dominant in most individuals rather pitta prakruti. Results could be based on their adapted lifestyle, physical activities, mental stress, lack of physical activities, and food habits. Huge amount of pressure required to pump the blood from ventricular to rest of body hence high amplitude values of PPG and high IBIs. Most vata dominant individuals have higher IBI values signify the aging of heart muscles. Morphological features of PPG signals were trained and test in ratio of 80:20 using KNN, decision tree, and suppot vector machine (SVM) algorithms and their performance metrics as shown in Table 3. Synthetic minority over-sampling technique (SMOTE) analysis was carried out to balance the dataset.

Table 2. Measurements of amplitudes of predominant prakruti

Predominant prakruti	Kapha (mV)	Pitta (mV)	Vata (mV)
Kapha	776 ± 137	523 ± 136	623 ± 205
Pitta	339 ±138	874 ±103	582 ± 229
Vata	406 ± 115	533 ± 145	977 ± 14

Table 3. Performance metric of prakruti identification using sparshana

Metrics	KNN (%)	Decision tree (%)	SVM (%)
Precision	82.20	87.50	74.30
Sensitivity	83.90	91.70	75.60
Specificity	92.20	93.70	84.30
F1-score	82.40	87.50	74.20
Accuracy	85.70	85.70	71.40

Figure 3 shows the confusion matrices of the Sparshana method with three classification models: KNN as in Figure 3(a), decision tree as in Figure 3(b), and SVM as in Figure 3(c). All models have perfectly classified kapha prakruti subjects. Precision of KNN is better compared to other models. Pearson r = 0.80 indicating high correlation between automated score and practitioner analysis in KNN algorithm for vata predominant prakruti. Sensitivity, specificity, and F1-score of decision tree outperformed with SVM and KNN (N = 3). KNN and decision tree showed same accuracy for dataset.

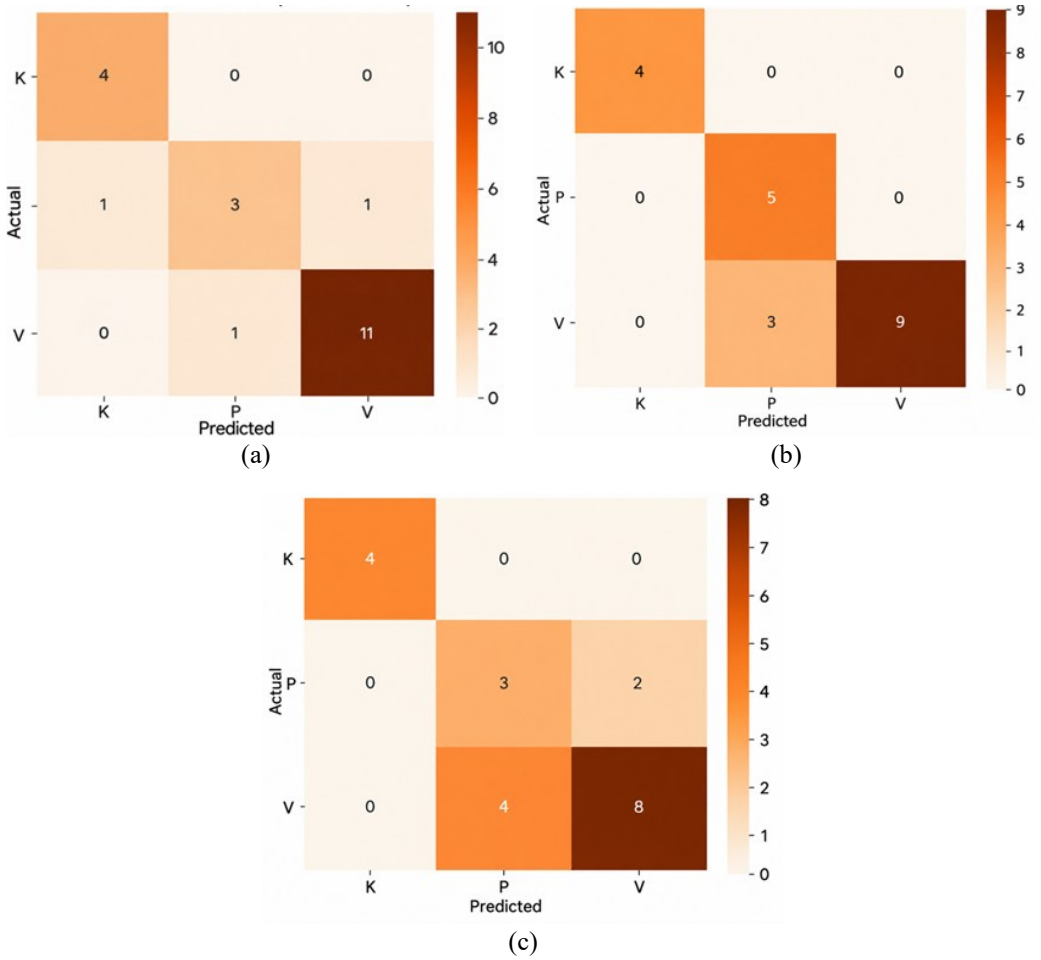


Figure 3. Sparshana method confusion matrix of (a) KNN, (b) decision tree, and (c) SVM

3.2. Darshan method

In darshan method, subjects were directed to position to acquire image and superimposed onto a 68-point facial landmark model to extract the face attributes. An Ayurveda practitioner uses an analytical approach to ascertain the dosha by examining the length, height, and proportions of the mouth, ear, and nose. The dominant constitution of an individual is mostly determined by their genetic, environmental factors, and lifestyle choices.

The statistical analysis was performed on nose aspect ratio, mouth aspect ratio, and ear aspect ratio of predominant prakruti of the subjects. The comparison of nose aspect ratio among the predominant prakruti is presented in Figure 4. Noise aspect ratio of predominant prakruti kapha, pitta, and vata are 0.90 ± 0.03, 0.97 ± 0.05, and 0.86 ± 0.06 respectively. Nose aspect ratio of pitta individuals was higher than kapha and vata individuals significantly with $p < 0.0001$ as delved in Figures 4(a) and 4(b). While, comparing nose aspect ratio of kapha with vata individual's, kapha individuals have higher value than that of vata individuals, significantly with $p = 0.0135$ as delved in Figure 4(c). Paired t-test of mouth aspect ratio of kapha, pitta, and vata predominant prakruti are 0.52 ± 0.03, 0.53 ± 0.03, and 0.51 ± 0.02, respectively. Statistical analysis of mouth aspect ratio was carried out to verify the significant between predominant prakruti's as delved in Figure 5. It was found that there is no significance between kapha and pitta as shown in Figure 5(a) and vata and pitta as shown in Figure 5(b); and most significant changes between kapha and vata as shown in Figure 5(c).

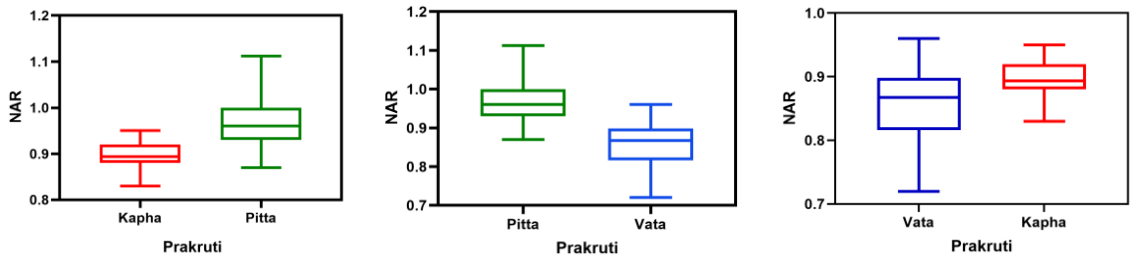


Figure 4. Comparison of nose aspect ratio of predominant prakruti: (a) kapha vs. pitta (b) pitta vs. vata, and (c) vata vs. kapha

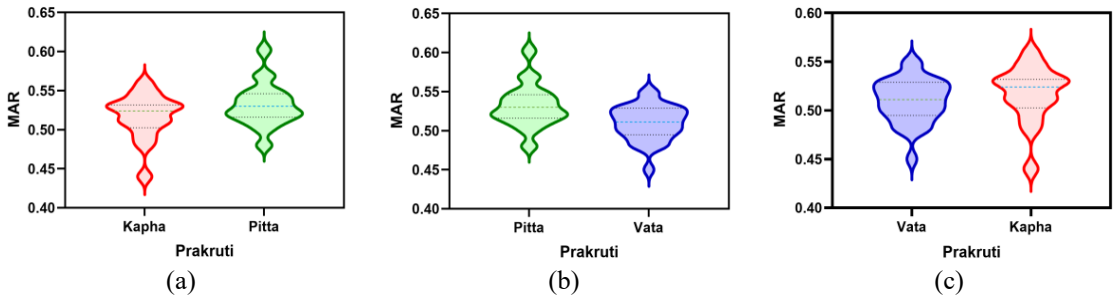


Figure 5. Comparison of mouth aspect ratio of predominant prakruti: (a) kapha vs. pitta (b) pitta vs. vata, and (c) vata vs. kapha

The comparison of eye aspect ratio among the predominant prakruti is presented in Figure 6. Eye aspect ratio of kapha, pitta, and vata predominant prakruti are 0.16 ± 0.02, 0.17 ± 0.02, and 0.14 ± 0.02, respectively. Statistical analysis of eye aspect ratio was carried out and showed no significance between kapha and pitta as depicted in Figure 6(a). While comparing vata, kapha and pitta, vata showed more significance, indicating eye stagnant in old age when vata prakruti is dominant in the body depicted in Figures 6(b) and 6(c). The aspect ratio of the nose, eyes, and mouth tends to be slightly larger in adulthood compared to childhood. In childhood, facial attributes undergo growth, remain stable during adulthood, and then diminish in size at old age. The aspect ratio of predominant facial attributes remains relatively constant throughout childhood, adulthood, and old age due to the proportional changes in the width and height of these characteristics as one age. Biological rationale of vata prakruti correlates with ectomorph, pitta correlates to mesomorphic and kapha to endomorph. The retrieved attributes were trained with distinct classifiers and accomplished the accuracy levels indicated in Figure 7. Figure 7(a) shows the confusion matrix of KNN. Figure 7(b) shows the confusion matrix of the decision tree, while Figure 7(c) shows the confusion matrix of SVM. Features nose aspect ratio and eye aspect ratio have correlation of r = 0.67 while mouth aspect ratio and nose aspect ratio features are independent features. KNN algorithm performance metrics are better compared to other algorithms as depicted in Table 4 and Figure 7. Pitta classification is accurate in decision tree.

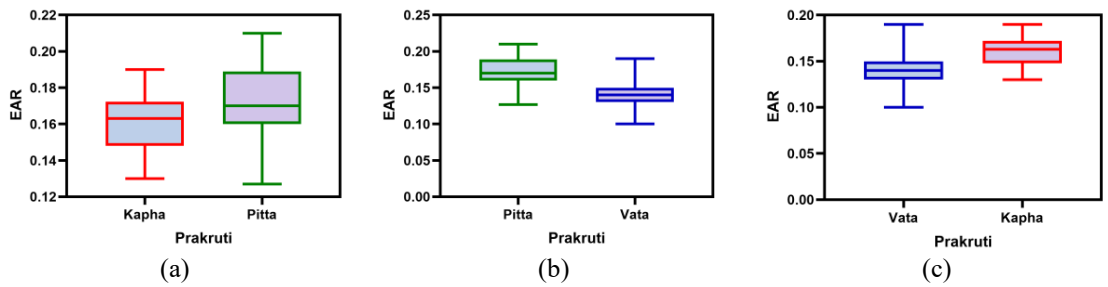
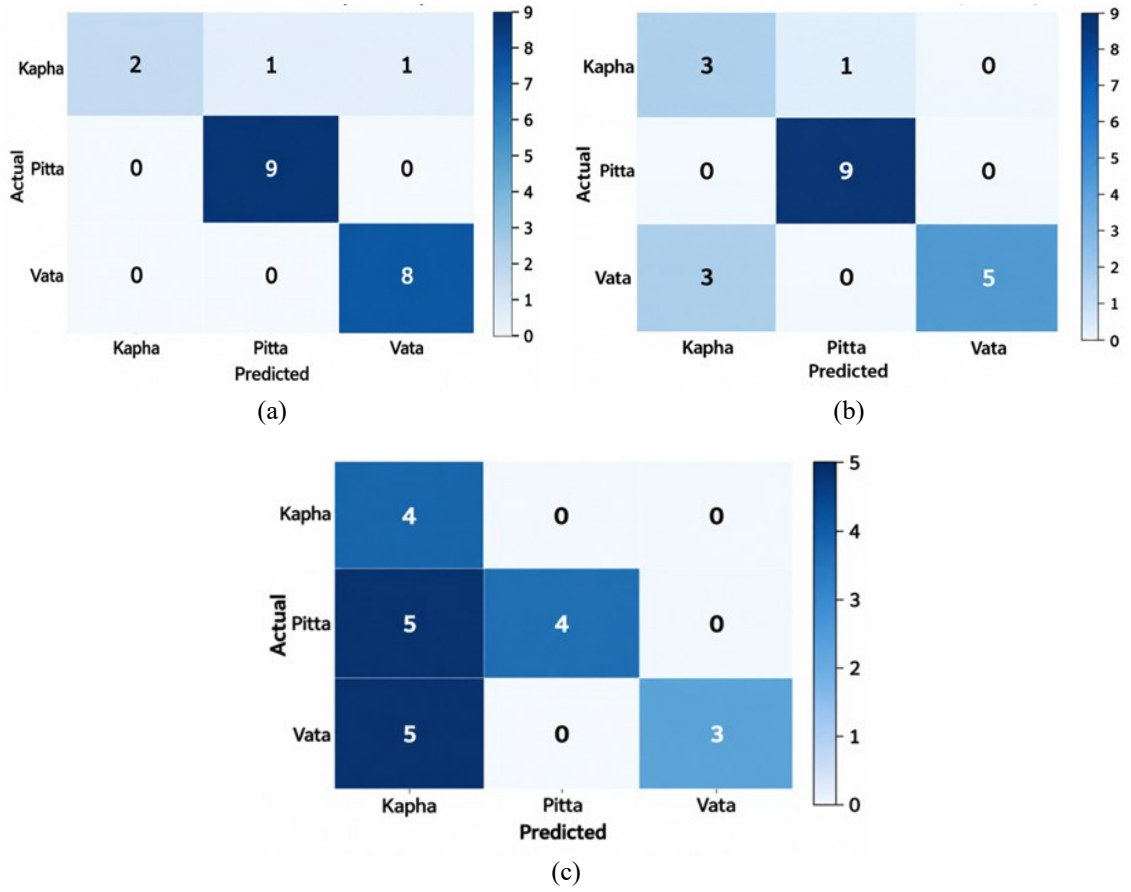


Figure 6. Comparison of eye aspect ratio of predominant prakruti: (a) kapha vs. pitta (b) pitta vs. vata, and (c) vata vs. kapha

Table 4. Performance metric of prakruti identification using darshana method

Metrics	KNN (k = 3) (%)	Decision tree (%)	SVM (Linear) (%)
Precision	93.00	80.00	76.20
Sensitivity	83.30	79.20	60.60
Specificity	94.70	91.30	80.40
F1-Score	85.20	77.20	53.50
Accuracy	90.50	81.00	52.40



(a) (b)

(c)

Figure 7. Darshan method confusion matrix of (a) KNN, (b) decision tree, and (c) SVM

3.3. Correlating sparshana and darshana methods

Sparshana method was carried out on wrist pulses while, darshana method on facial aspects. Both methods data were trained and tested in ratio of 80:20 with KNN, decision tree, and SVM (linear). The comparative classification performance of the sparshana and darshana methods is presented in Figure 8, where Figure 8(a) shows the results obtained using KNN, Figure 8(b) presents the results of the decision tree, and Figure 8(c) illustrates the results obtained using the SVM classifier. KNN outperformed in both wrist pulse analysis and facial analysis while in SVM hyperplane failed to be categorized predominant prakruti as depicted in Figures 8(a) and 8(c). Performance of the KNN model is high in darshana technique compared to sparshana technique; this could be accurate extraction features and clustering. Sparshana data as better performance compared to darshana data in decision tree model as depicted in Figure 8(b). To achieve high performance large amounts of dataset are required to learn the edge case, high precision sensors are required. The deviation between sparshana and darshana methods was approximately 5% with KNN and decision tree, while in SVM its 19% in terms of accuracy. There are various potential causes that have deviated the results such as position and precision of the sensors, body motions, distance between the camera and subjects, and intensity of the light. The experimental findings were observed and analyzed by Ayurvedic practitioners, and concluded experimental results were 85% to 90% accurate. Proposed for the inclusion of a questionnaire in conjunction with vata, pitta, and kapha acquisition and facial aspects to enhance the accuracy of predicting an individual's prakruti. Table 5 depicts the comparative analysis of various methods and their performance with the proposed work.

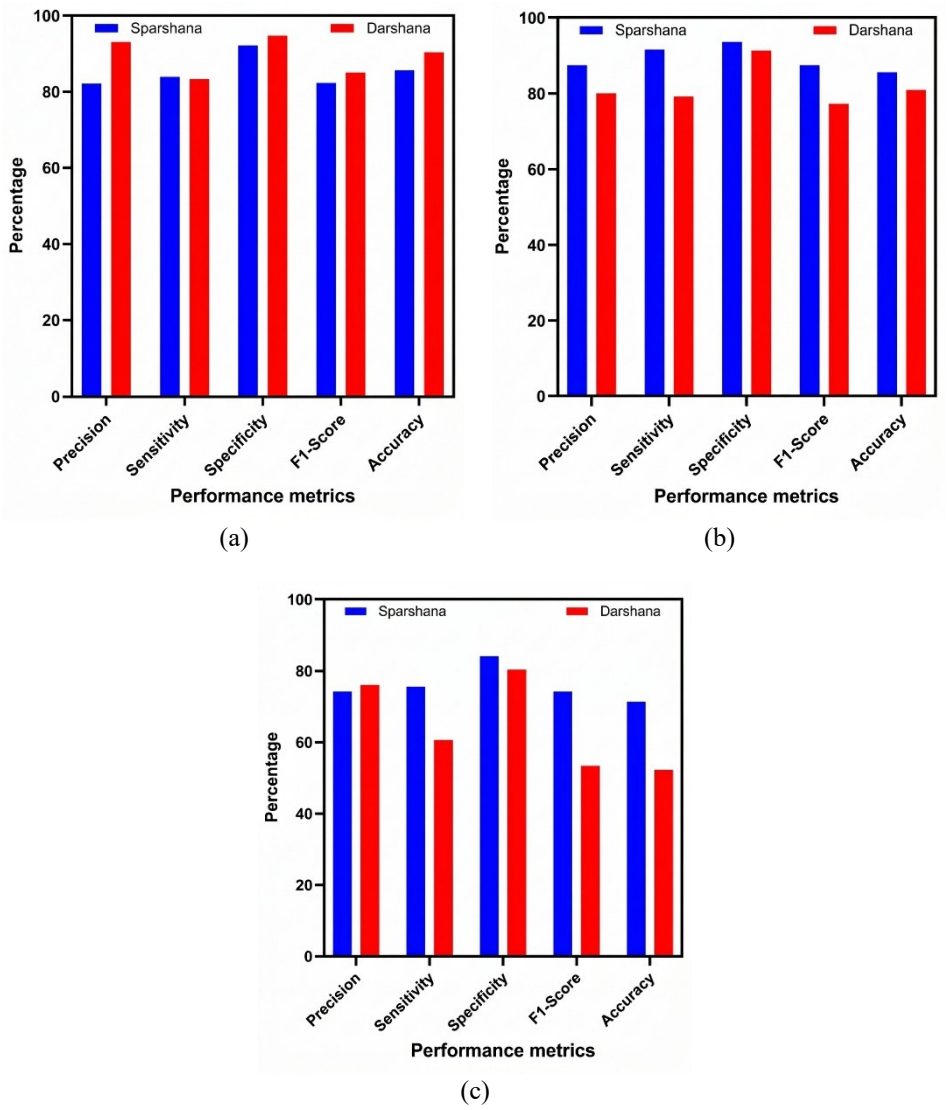


Figure 8. Comparative metric analysis of sparshana and darshana methods with (a) KNN, (b) decision tree, and (c) SVM

Table 5. Comparative analysis of existing Prakruti identification methods and the proposed work

Reference	Method	Prakruti estimated	Performance
Rajasekar *et al.* [31]	Questionnaire-based phenotypic feature	Vata, pitta, kapha	Ensemble classifiers outperformed individual classifiers; improved classification accuracy of 94%
Gupta *et al.* [32]	Conversational artificial intelligence + digital nadi pariksha (PPG/pulse analysis) + machine learning	Prakriti and vikriti	Demonstrated automated Prakriti assessment using pulse analysis; qualitative performance reported, detailed numerical metrics not extensively presented.
Trivedi and Patel [27]	Skin color extraction	Vata, vata - pitta	Random forest: 92%, KNN: 92%, linear SVM: 90%, Gaussian SVM: 90%, sigmoid SVM: 16%.
Suguna and Veerabhadrappa [30]	Facial feature extraction	Vata, pitta, kapha	SVM accuracy 87.5%
Proposed work	Facial features + PPG	Vata, pitta, kapha	KNN and decision tree with an accuracy of 95%

4. CONCLUSION

The work focused on estimate predominant prakruti of an individual, using sparshana approach and darshana approach. In sparshana approach morphological features of vata, pitta, and kapha signals were

extracted for classification of predominant prakruti. The statistical validation of amplitude and heart rate associated with vata wrist pulse signal has achieved significant difference among all other predominant prakruti's. Darshan method of predominant prakruti was employed using facial aspect such as eye aspect ratio, mouth aspect ratio, and nose aspect ratio. Nose aspect ratio of pitta individuals found to higher, while mouth aspect ratio found more significant in kapha predominant prakruti's, and eye aspect ratio of kapha and pitta found to higher indicating eye develop in childhood and adult age. Estimation of predominant prakruti was carried out using KNN, decision tree, and SVM algorithms for both sparshana approach and darshana approach. KNN outperformed in sparshana approach and darshana approach with an accuracy of 85.7% and 90.5%, respectively. Combination of sparshana and darshan approaches provides an aiding tool for Ayurvedic doctors. Identification of predominant prakruti using PPG and face recognition system were correlated with an accuracy of about 95% using KNN and decision tree. An attempt has been accomplished in establishing the correlation between PPG signal processing techniques and face recognition technique for identification of predominant prakruti.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

Informed consent was obtained from all study participants prior to data collection. Ethical approval was obtained from the appropriate institutional authority at JSS Academy of Technical Education, as the study participants were recruited from the institution.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author, [SGC], upon reasonable request. The data were collected from participants at JSS Academy of Technical Education, with their informed consent.

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