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Nail Feature Analysis and Classification Techniques for Disease Detection

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Abstract**—** In the healthcare domain, various techniques available for early disease diagnosis. Nail image analysis is one of the techniques for early stage disease diagnosis. Human fingernail image analysis is procedure consists of image capturing, pre-processing of image, image segmentation, segmentation of image, feature extraction. This paper presents review based generalized model for human fingernail image processing system, different classification techniques for nail feature classification and nail features. The nail features such as color, shape and texture used to predict diseases. Color features discussed are Mean, Standard Deviation, Skewness, Kurtosis and average RGB color. Shape features discussed in this paper are area, perimeter, roundness and compactness. Texture features are entropy, energy, homogeneity, contrast and correlation. Different classification techniques such as SVM classifier, KNN classifier, ANN classification used to classify the nail database for disease prediction are discussed.

Keywords **—** image processing, feature extraction, disease detection, SVM, ANN, K-Nearest Neighbor, nail image analysis

I. INTRODUCTION

In the healthcare domain, early stage disease diagnosis is very important aspect which plays key role during the identification of the cause of a particular disease. There are different parts of human body analyzed to predict disease at the early stage of disease diagnosis by observing symptoms with respect to color or pattern or other features. The different human body parts such as eye, hair, teeth, skin, nail, breath etc. have been used for identification of the nature and the cause of disease at different stages. Medical techniques used to visualize internal structure of the human body without any surgery are Ultrasound, MRI, CT-Scan, PET Scan which provides information about the human soft tissue to help in the disease diagnosis [2]. In the traditional disease diagnosis system, Ayurveda, the disease prediction was done by observing the symptoms of eyes, hand nail and pulse rate. With this background, now images of an eye and nail are used for disease diagnosis by extracting appropriate features from image. Image processing consists of various stages such as pre-processing of image, image segmentation, segmentation of image, feature extraction. The process of receiving and analyzing visual information by digital computer is called digital image processing [1]. There are many factors which affect nails as effect of a particular disease such as iron deficiency (anemia) affect nail color, and it becomes white nail [3][5][10]. Abnormal functioning of health can be represented by the changes in the nail color or texture or shape. For example, in circulatory disorders first affect the appearance of fingernails [4], yellow nails point to conditions such as a thyroid disease, lung, diabetes, or psoriasis [7]. Different changes in nail are early symptoms of various diseases due to which the nail color, shape and texture changes have been considered for prediction of various diseases [6]. The nail image analysis is non-invasive approach for disease detection. Different nail image processing systems implemented as part of research work have been discussed and compared [10]. In this review paper, we are discussing various features which can be extracted from nail image and used for disease diagnosis. There are different nail parts which can be further explored to use for a particular disease diagnosis such as color of nail plate [3][9], shape of a nail, etc. In this paper, we will be discussing about generalized model for nail image processing system based on the existing systems discussed here, different features which can be extracted from nail image for analysis and comparison of classifiers implemented by existing nail image processing system.

II. LITREATURE SURVEY

There are different nail image processing systems implemented for disease diagnosis [10], to detect nail abnormalities [7] and to identify nail diseases [8]. Different nail features extracted from nail image for particular disease identification but here we are mainly focusing on three features color, texture and shape.

Indi et. al used nail color for disease identification in the Red-Green-Blue color model. This system uses RGB average value and j48 classifier for disease prediction. Lean et. al used color threshold and shape feature for detection of circulatory diseases. Maniyan et. al used color, shape and texture features for disease detection.

Saranya et. al presented system in which the shape attributes, area, perimeter & diameter, are calculated and the segmentation results are compared to detect nail abnormalities. Mannino et. al proposed smartphone application analyzing color and metadata of fingernail bed photos to estimate hemoglobin levels for anemia detection.

Overall features which are used in the above systems are nail color, nail shape and nail texture feature for disease diagnosis.

III. Review Based Generalized Model For Nail Image Processing System

Based on review and comparison of different nail image processing systems [10], the generalized model for nail image processing system is as shown in figure-1. The input to these systems is in various forms such as human palm backside image or human nail image in which the nail image cropped or selected or captured to get particular fingernail image for further processing. The input nail image is further divided into multiple parts for feature extraction. As shown in figure-1, the next module is nail feature extraction in which mainly three features focused in the review systems are color feature, shape feature and texture feature.

Using the statistical based feature extraction method, color features extracted are mean, standard, skewness and kurtosis of color channels. Also, color threshold and RGB color average is used to derive color feature. The shape features have been extracted are area, perimeter, roundness, and compactness. The texture features have been extracted are entropy, energy, contrast, homogeneity and correlation.

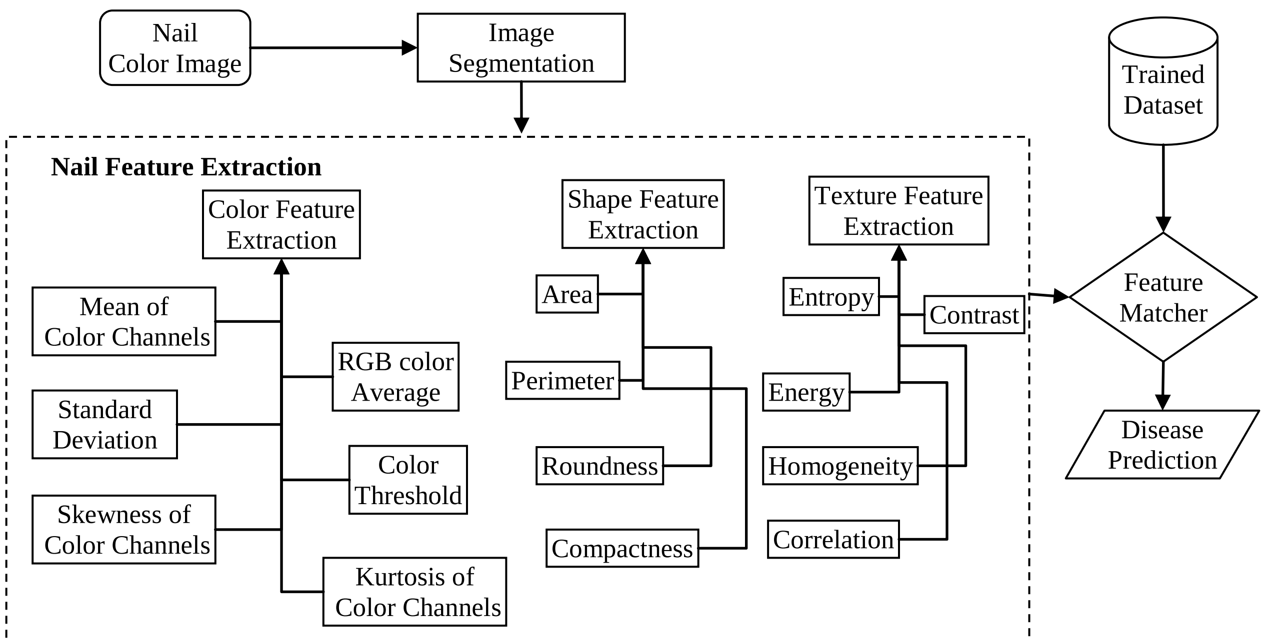

Figure 1: Generalized Model for Nail Image Processing System

A. Nail Features:

Maniyan et. al implemented nail image processing system (refer as system-1) in which 13 features created with the help of three nail features color, shape & texture, here using color value four features derived are Mean, Standard Deviation, Skewness and Kurtosis. Four boundary based shape features are area, perimeter, compactness, and roundness. A combination of histogram and statistical based feature extraction method is used for color feature extraction. The Gray Level Co-occurrence Matrix (GLCM) approach used to extract five texture features like entropy, energy, contrast, homogeneity & correlation.

Lean et. al implemented nail image processing system (refer as system-2) in which RGB values extracted as nail color features and roundness of the fingernails extracted as nail shape feature. Nijhawan et. al implemented nail image processing system (refer as system-3) using a hybrid of 3 different CNN's for capturing the different aspects of the human nail and stored in a vector, 3 such vectors obtained from each CNN were combined forming the final feature vector. In Indi et. al implemented nail image processing system (refer as system-4) in which only RGB color average value is used as nail color feature.

The nail features used in the systems 1, 2, 3 & 4 are color features, shape features, texture features and feature vectors. The details of nail feature given in the figure-2. There are other parts of nail, visible and non-visible, from which features can be derived for disease diagnosis such as nail plate, nail lanula, nail root, nail sinus, nail hyponychium and nail margin [30].

The nail features used by various systems are - system-1 using nail color, shape and texture whereas a system-2 using nail color & shape and system-4 using only nail color.

The number of target diseases diagnosed by these systems, in system-1 targeted 24 diseases, system-2 targeted 4 circulatory diseases, system-3 targeted 11 nail diseases and system-4 targeted 4 diseases.

Color Features:

Color feature is an important and widely used visual feature in image processing and analysis which plays an important role in the human visual perception mechanism. Image color is invariant with respect to the size of image, translation and rotation of image. The different methods used to extract color feature from image are histogram method, statistical method, and color model. The number of pixel of given color is calculated in color histogram method. In the color model method, each color is represented by the single point where in the color space every color has its color coordinates. RGB model, CMY model, HSV model these are some majorly used color models [11][12]. The statistical model is the one used in syetem-1 to extract color feature. The statistical methods classified as a first order (one pixel), second order (pair of pixels) and higher order (three or more pixels) statistics. First order histogram statistics are mean, variance, skewness and kurtosis [15]. Color moment have the highest precision to extract color feature. For any color model (RGB, CMYK) color moments can be calculated whereas the three color moments are computed per color channel therefore 9 color moments for RGB model, and 12 color moments for CMYK model [16].

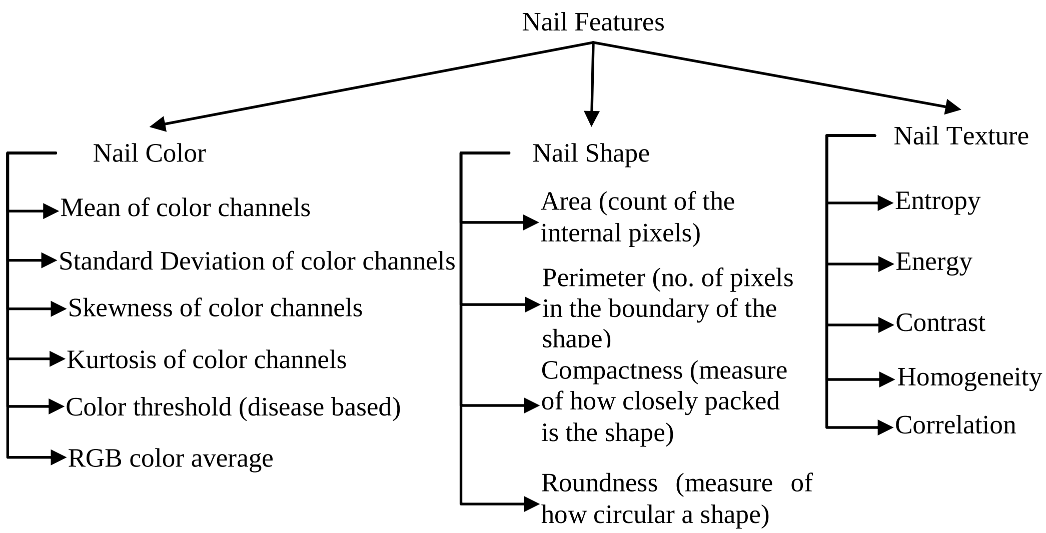

Figure 2: Nail Features (Color Features, Shape Features and Texture Features)

Mean of Color Channels: First color moment is an average color in the image [16].

Table 1: Mean Feature Calculation

Mean – First Order Color Moment [13]	$$E_i = \frac{1}{N}\sum_{j=1}^{N} P_{ij}$$ … eq(1)

Mean Feature Calculation in System-1	$$E_i = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} P_{ij}$$ … eq(2)

N = total number of pixels in the image
M = dimension of the image
Pij = value of the j-th pixel of the image at the i-th color channel.

Standard Deviation of Color Channels: Second color moment is obtained by taking the square root of the variance of the color distribution [16].

Table 2: Standard Deviation Feature Calculation

Standard Deviation – Second Order Color Moment [13][14]	$\sigma_i = \sqrt{\frac{1}{N}\sum_{j=1}^{N}(P_{ij} - E_i)^2}$ … eq(3)
Standard Deviation Feature Calculation in System-1	$\sigma_i = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(P_{ij} - E_i)^2}$ … eq(4)

Ei = mean value for the ith color channel of the image

Skweness of Color Channels: Third color moment gives information about the shape of the color distribution which measures how asymmetric the color distribution [16].

Table 3: Skweness Feature Calculation

Skweness – Third Order Color Moment [13][14]	$s_i = \sqrt[3]{\frac{1}{N}\sum_{j=1}^{N}(P_{ij} - E_i)^3}$ … eq(5)
Skweness Feature Calculation in System-1	$s_i = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(P_{ij} - E_i)^3}{MN\sigma^3}$ … eq(6)

Kurtosis of Color Channels: Fourth color moment is a measure of how flat or tall the distribution is in comparison to normal distribution [16].

Table 4: Kurtosis Feature Calculation

Kurtosis – Fourth Order Color Moment [13][14]	$k_i = \sqrt[4]{\frac{1}{N}\sum_{j=1}^{N}(P_{ij} - E_i)^4}$ …. eq(7)
Kurtosis Feature Calculation in System-1	$ki = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(P_{ij} - E_i)^4}{MN\sigma^4}$ …. eq(8)

Shape Features:

Shape of an object in an image is an important feature used to identify or recognize an object in an image. Shape features are classified based on the boundary information of the shape or the region covered by the shape. The boundary-based and region-based approaches are further classified as structural and global based on shape information represented as complete or in sub-parts [17].

Area: It is simple and majorly used feature of shape. It is a region-based global feature which is measured as the total number of pixels covered in the region [4][17].

Perimeter: It is a boundary-based global feature which is measured as the number of pixels in the boundary of the shape [4][17].

$$perimeter = \sum_{i=1}^{N-1} d_i = \sum_{i=1}^{N-1} |X_i - X_{i+1}| \quad \text{… eq(9)}$$

Compactness: It is a boundary-based global feature and a numerical quantity tells the degree to which a shape is compact.

$$Compactness = \frac{(region\ border\ length)^2}{area} \quad \text{… eq(10)}$$

Eccentricity: It represents roundness of an object. It is the ratio of the length of major axis (straight line segment joining the two points of a shaped object) to the length of minor axis (line segment perpendicular to the major axis). Eccentricity value is between 0 and 1. Eccentricity can be calculated by using following methods: (i) Principal axes method and (ii) Minimum bounding rectangle method [3][18][19].

$$E = a/b \quad \text{… eq(11)}$$

where, a = length of major axis and b = length of minor axis

(i) *Principal axes method*: In this method, two segments of lines which cross each other perpendicularly through the centroid of the shape define the principal axes of a given shape. It represents the directions with a cross correlation.

Eccentricity can be calculated,

$$E = \lambda_2 / \lambda_1 \text{… eq(12)}$$

Eigenvalues are λ_1 and λ_2 which calculated as given below:

$$\lambda_1 = \frac{1}{2}\left[C_{xx} + C_{yy} + \sqrt{\left(C_{xx} + C_{yy}\right)^2 - 4\left(C_{xx}C_{yy} - {C_{xy}}^2\right)}\right] \quad \text{… eq(13)}$$

$$\lambda_1 = \frac{1}{2}\left[C_{xx} + C_{yy} - \sqrt{\left(C_{xx} + C_{yy}\right)^2 - 4\left(C_{xx}C_{yy} - {C_{xy}}^2\right)}\right] \quad \text{… eq(14)}$$

Covariance Matrix C of a shape:

$$C = \frac{1}{N}\sum_{i=0}^{N-1}\begin{pmatrix} x_i - g_x \\ y_i - g_y \end{pmatrix}\begin{pmatrix} x_i - g_x \\ y_i - g_y \end{pmatrix}^T = \begin{pmatrix} c_{xx} & c_{xy} \\ c_{yx} & c_{yy} \end{pmatrix}$$

… eq(15)

where,

$$c_{xx} = \frac{1}{N}\sum_{i=0}^{N-1}(x_i - g_x)^2$$

… eq(16)

$$c_{xy} = \frac{1}{N}\sum_{i=0}^{N-1}(x_i - g_x)(y_i - g_y)$$

… eq(17)

$$c_{yx} = \frac{1}{N}\sum_{i=0}^{N-1}(y_i - g_y)(x_i - g_x)$$

… eq(18)

$$c_{yy} = \frac{1}{N}\sum_{i=0}^{N-1}(y_i - g_y)^2$$

… eq(19)

$G(g_x, g_y)$ is the centroid of the shape, here $c_{xy} = c_{yx}$

Lengths of the two principal axes equal the eigenvalues λ_1 and λ_2 of the covariance matrix C of a shape respectively [18].

(ii) *Minimum bounding rectangle*: In this method, minimum bounding rectangle is the smallest rectangle which contains every point in the shape and eccentricity is measured as the ratio of the length L and width W of minimal bounding rectangle of the shape at some set of orientations [18].

Based on eccentricity other term Elongation, *Elo*, can be calculated as:

$$Elo = 1 - {}^{W}\!/_{L}$$

… eq(20)

Elo is a measure that takes values in the range [0, 1]. An elongation value will be zero for circle or square shapes which are symmetrical shapes in all axes and elongation value will be closed to 1 for shapes with large aspect rations [18].

Texture Features:

Texture feature in an image is measured to provide information about the spatial arrangement of colors or intensities [3]. Texture refers to texels, repetition of basic texture elements which contains several pixels, whose placement could be periodic or deterministic (artificial textures) or random (natural textures) [17]. The texture feature extraction methods classified in different classes [20] but mainly it is classified into statistical approaches and structural approaches [3][17][20]. Statistical features extracted from statistical distributions of pixels and are first order statistics (one pixel), second order statistics (two pixel), higher order statistics (one or more pixels) [21]. In an image, texture of regions described through higher-order moments of their grayscale histograms referred as statistical texture analysis.

Statistical approach further classified into spatial domain and frequency domain approaches. In spatial domain approach, Gray Level Co-occurrence Matrix (GLCM) approach is used in system-1 for texture feature extraction. A gray level co-occurrence matrix (GLCM) is most commonly used method for texture analysis in which various textural features extracted from a gray level co-occurrence matrix [21]. GLCM concept is also referred as a spatial grey level dependence matrix (SGLDM) [20] which is a tabulation of how often different combinations of pixel brightness values (grey levels) occur in an image [3]. In this, co-occurrence matrices are used which relate the relative frequencies P (i, j | d, Θ) that two pixels at constant vector distance (d, Θ) from each other. The two pixels have intensity (i, j), in the GLCM P (i, j | d, Θ), the (i, j)th entry of the matrix, represents the number of occurrences of a pixel having the intensity value i that is separated from another pixel with intensity value j at a distance d in the direction Θ [20].

Entropy: It measures the disorder of the GLCM [20].

$$Entropy = -\sum_{i=0}^{G-1}\sum_{j=0}^{G-1} P(i,j|d,\Theta)\log_2\big(P(i,j|d,\Theta)\big)$$

… eq(21)

Energy: The probabilities of the grey level pairs are similar then it represents low values else high values [20].

$$Energy = \sum_{i=0}^{G-1}\sum_{j=0}^{G-1} P(i,j|d,\Theta)^2$$

… eq(16)

Contrast: Also referred as inertia. It quantifies local variations present in the image [20].

$$Inertia = \sum_{i=0}^{G-1}\sum_{j=0}^{G-1}(i-j)^2 P(i,j|d,\Theta)$$

… eq(22)

Homogeneity: Also referred as inverse difference moment. When the same pairs of pixels are found then it represents high value [20].

$$Homogeneity = \sum_{i=0}^{G-1}\sum_{j=0}^{G-1}\frac{P(i,j|d,\Theta)}{1+(i-j)^2}$$

… eq(23)

Correlation: At specified positions, the grey level linear dependence between pixels is measured. When the values are uniformly distributed in the GLCM then it represents high value else low values [20].

B. Classifiers:

System-1 implemented for disease prediction three classifier techniques - SVM, Multiclass SVM and KNN classifier. The system-2 implemented Artificial Neural Network (ANN) classifier. The system-3 implemented deep neural network for classification and the system-4 implemented j48 decision tree for classification.

The classification algorithm contains two phases: training phase and testing phase. In the training phase, training instances is constructed whereas in testing phase; label is assigned to an unlabeled test instance [23]. The classifiers, as shown in table-5, used in nail image processing systems compared based on the basic idea of the technique, purpose, classification metric, parameter estimation of an algorithm and performance. Support Vector Machine (SVM) classifier works on the basic principle that separate the data in two groups using hyperlane [24]. The basic idea of K-Nearest Neighbor classifier is classify the samples based on their nearest neighbour from the training instances [27]. Artificial Neural Network (ANN) consists three layers of neurons - input, output and hidden where information is constantly "fed forward" from one layer to the next [31]. Decision Tree classifier tree data structure used in which every interior node contains a decision criteria depending only on one feature whereas in Random Forest Classifier several decision trees are created and merged for stable prediction [28]. SVM classifier is more reliable but computationally more intensive [26]. K-Nearest Neighbor classifier is computationally less intensive and slow in performance [24]. Combination of classifier models with all the three features produces the better output [6] than single classifier model.

Table 5: Review Based Comparison of Various Classifiers used in different Nail Image Processing Systems

Classifier	Basic Idea	Purpose	Classification Metric	Parameter Estimation Algorithm	Performance
SVM / Multi-class SVM	Separate the data into two groups using hyperplane [24] Multi-class SVM: Combination of multiple binary-class optimization problems into one single objective function and classification of multiple classes [1]	Pattern classification (linear and non-linear) [25] and classification and regression analysis [26] Multi-class SVM: One classifier per class (One-vs-one) and one classifier per pair of classes (One-vs-all) Classification [1] [24]	Requires a proper phase of training and for new unlabelled data, predict classes [26]	Solve quadratic program to find boundary that maximizes margin hyper plane [25]	Computationally more intensive, More reliable [26]
K-Nearest Neighbor	samples are classified based on the class of their nearest neighbor from the training instances [1] [27]	Pattern Recognition [1] and instance-based learning algorithm [27]	distance metric: distance metric is calculated each time [26]	Store all training data to classify new points. Choose K using cross validation [3].	Computationally less intensive [26], Lazy Learner and slow performance [24]
Artificial Neural Network (ANN)	Three layers of neurons input, output and hidden. Information is constantly "fed forward" from one layer to the next [4]	To solve a binary classification problem [29]	Network is attuned until the network output matches the target (based on the comparison of the output and the	Artificial Neural Network Fitting algorithm [4]	Neural network can learn more complicated tree boundaries and its training time is very large [31]

	[31].		target) [4]		
Random Forest Classifier	For stable prediction, several decision trees are created and merged [28]	To solve classification and regression problems and to overcome the drawbacks associated with single decision trees [28]	calculates a response variable by creating many different decision trees [28]	Response is calculated based on the outcome of all of the decision trees [28]	Depends on the outcome of all the decision trees [28]
Decision Tree	a data structure in form of a tree in which every interior node contains a decision criteria depending only on one feature [27]	Statistical classification [7]	features' relevance for classification is determined by entropy reduction	Algorithms: ID3, CART,C4.5	Highly Complex if depth of tree is higher [24]

IV. CONCLUSION AND FUTURE SCOPE

An existing nail image processing systems using various nail features such as nail color, nail shape & nail texture used to analyze nail image and to identify disease. The color feature can be measured as mean of color channels, standard deviation of color channels, skewness of color channels, Kurtosis of color channels, color threshold (disease based) and RGB color average. The shape feature can be measured as area (count of the internal pixels), perimeter (number of pixels in the boundary of the shape), compactness (measure of how closely packed is the shape) and roundness (measure of how circular a shape). The texture feature can be extracted as entropy, energy, contrast, homogeneity and correlation. The classification techniques used by an existing nail image processing systems are SVM / Multi-class SVM, K-Nearest Neighbor, Artificial Neural Network (ANN), Random Forest Classifier and Decision Tree.

Other features of human body can be combined to predict various diseases based on the symptoms identified during first level investigation of patient. There are various non-invasive methods to diagnose the diseases such as breath analysis, hair testing, eye image processing, saliva testing etc. The hybrid model with these non-invasive approaches for disease diagnosis will enhance the overall early stage disease diagnosis and health monitoring process.

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