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Early Disease Detection Through Nail Image Processing Based On Ensemble Of KNN Classifier And Image Features

Priya Maniyan[1], B L Shivakumar[2]
[1]*HSST Junior Computer Science, Govt . H S S, Poothrikka, Kerala, India*
[2]*Principal, Sri Ramakrishna Polytechnic College, Coimbatore, India*
Corresponding Author: Priya Maniyan

Abstract: *Prediction of various diseases can be done by the close examination of Human nail. The proposed system – Nail Image Processing System using KNN (NIPS-K) helps us to create a model which can perform the analysis of human nail and thereby help us in predicting various diseases. The input to the proposed system is the Human Palm Image. The nail portion is segmented and nail color, shape and texture features are extracted and combined to form 13 features and then analysis of nail is done which will then be used for the diagnosis of various diseases. This proposed system will surely help the medical practitioners in the early diagnosis of diseases.*

Keywords: *Nail Analysis, Feature analysis, disease prediction, Supervised Learning, KNN classifier*

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I. Introduction

In a human being, various systemic and dermatological diseases can be easily diagnosed through careful examination of nails of both hand and legs. A lot of nail diseases have been found to be early signs of various underlying systemic diseases [1]-[8]. The color, texture or shape changes in nails are symptoms of various diseases primarily affecting nails.

And if we are able to use digital image processing techniques[9] for detecting such changes in the human nail, then we would be able to get more accurate results and predict various diseases easily.

The Proposed system (NIPS-K) extracts a total of 13 features of the human nail which is a combination of Nail Color, Shape and Texture Features and then they are used for disease prediction. The input to the system is the backside of the palm which is captured using a camera. Then the Region of Interest, the nail area is segmented automatically. The segmented nail area is then processed for extracting the features of nail. The extracted features are then combined to form a feature vector which are then compared with the existing datasets and the diseases are predicted using the knowledge base. Thus the proposed system will assist us in detecting various diseases in their early stage itself easily without spending much of our time and money.

II. Literature Survey

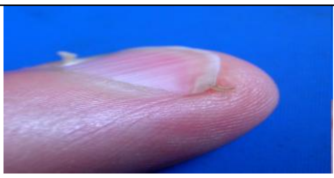
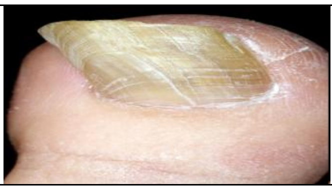
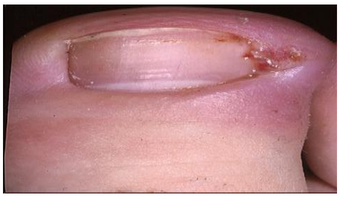
This section will give us an idea about the various diseases affecting the nail, previous work done in the area of digital image processing for disease prediction, various features extracted from nail and about a classification method – KNN.

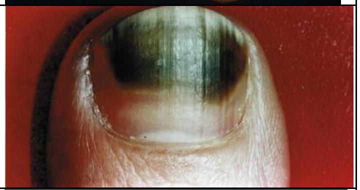
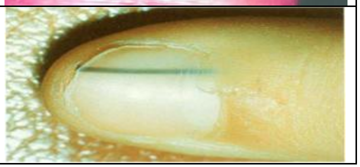
2.1 Nail Disorders

A nail disorder is a condition caused by injury to the nail or due to some diseases or imbalances in the body.

Nail Disorders can be classified into four categories – Congenital, Traumatic, Infectious, Tumors

Table I : Nail Disorders[4][6][11]

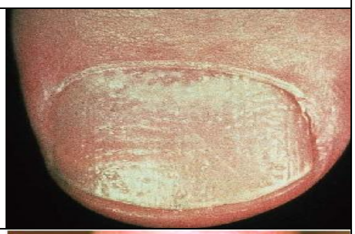
Si.No	Type of Nail Disorder	Disease Name	Associated Systemic Conditions	Figure
1	Congenital Disorder	**Anonychia[13]**	i.Severe congenital ectodermal defect ii.Ichthyosis, trauma iii.Raynaud phenomenon iv.epidermolysis bullosa v.Lichen planus or severe exfoliative diseases	
2		**Nail patella syndrome[9]**	I.Kidney issues may arise such as proteinuria and nephritis. ii.Hypothyroidism,irritable bowel syndrome iii.Attention deficit hyperactivity disorder (ADHD) iv.Thin tooth enamel	
3		**Pachyonychia congenita**	i.Hyperhidrosis ii.Hyperkeratosis,warts iii. Skin lesions on the limbs iv. Lustreless and kinky scalp hair is also seen.	
4	Traumatic Disorder	**Onychophagia[10]**	i.Various types of viral and microbial infections are seen ii. Skin picking, skin biting, iii.Urge to pull out hair disorders.	
5		**Hangnail**	Paronchyia	
6		**Onychogryphosis**	Most commonly seen in the older people. Later on it becomes necessary to remove the nail and matrix surgically.	
7		**Onychocryptosis**	Bacterial Infection	

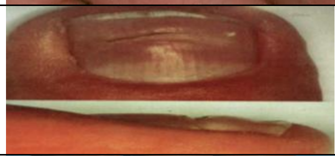
8		**Paronychia**	The affected area often appears erythematous and swollen. Pus collects under the skin of the nail.	
9		**Pseudomonas infection[3]**	i.Onycholysis ii.nail psoriasis iii.fungal nail infections.	
10	Tumors	**Glomus tumour [13]**	Usually associated with severe pain, which may be spontaneous or resulting due to mild trauma or changes in temperature	
11		**Melanocy-tic nevi[11]**	Abnormal skin pigmentation in some areas of the body	

2.2 Nail Abnormalities in Systemic Diseases

Nail Abnormalities can also be classified into following three categories based on changes in shape [1] [8], surface [11][14] and color of the nails. They are:

Table II: Nail Abnormalities [4] [6] [11]

Si.No	Type of Nail Disorder	Nail Findings	Disease Indication	Image
1	Dermatosis	**Onycholysis**	i.Psoriasis ii.Amyloidosis iii.Hyperthyroidism ivSarcoidosis v.Infection vi.Trauma viiConnective tissue disorders	
2		**Splinter Hemorrhage**		
3		**Darier's Disease**	i. Epilepsy ii. Depression	
4		**Alopecia areata**	Hair Loss	

5		**Eczema**	Skin Inflammation	
6	Nail Shape Changes	**Clubbing**	i.Inflammatory bowel disease ii.Chronic bronchitis iii.Cirrhosis iv.Congenital heart disease v.Atrioventricular malformations	
7		**Koilonychia**	i.Anaemic iiTrauma,nail-patella syndrome iii.Hemochromatosis iv.Raynaud's disease	
8	Nail Surface Changes	**Beau's Lines**	i.Pemphigus ii.Trauma iii.Raynaud's disease iv.Diabetes v.Hypocalcaemia	
9		**Muehrck-e's Lines**	i.Liver disease ii.Hypoalbuminemia(nephrotic syndrome) iii.Malnutrition	
10		**Leukony-chia**	i.Random and minor trauma to the proximal region of the nail bed	
11	Nail Color Changes	**Terry's nails**	i.Hepatic failure, ii.Diabetes mellitus iii.CHF iii.Cirrhosis iv.Hyperthyroidism v.Malnutrition	
12		**Yellow Nail Syndrome**	i.Rheumatoid arthritis ii.Lymphedema iiiImmunodeficiency iv.Bronchiectasis v.Pleural effusion vi.sinusitis vii.Nephrotic syndrome viii.Thyroiditis, ix.Tuberculosis	
13		**Half and Half Nails (Lindsay's nails)**	i.Specific for renal failure. ii.Hemodialysis iii. HIV patients	
14		**Red Lunula**	i.Collagen vascular disease and alopecia areata. ii.Rheumatoid arthritis, iii.Cardiac failure iv.COPD, v.Cirrhosis vi.,Chronic urticaria vii.Psoriasis	

15		**Splinter hemorrhage**	i.Ulcer ii.Oral contraceptive use iii.Endocarditis iv.Rheumatoid arthritis v.Pregnancy, vi.Psoriasis, vii. Trauma	

2.3 Survey of the Model for Nail Analysis

In this section a survey of the existing model for nail analysis that has been applied is presented.

Doctors usually observe the color, texture, shape of human nails (finger and toe) to get assistance in predicting various diseases as mentioned above. We know that when we go to a hospital, we need to spend a lot of money on various tests like Blood, Urine, TFT, LFT, etc. for diagnosing a disease. If an efficient model for doing the analysis of nail using Digital Image Processing is developed, then it would be a big boon for the Medical Practitioners to predict the diseases more accurately, easily and at a cheaper cost. In recent years, various number of research work has been carried out for predicting diseases using Nail Analysis.

The First model [15][16] was proposed by Hardik Pandit et. al. The working of the model and its advantages and disadvantages are mentioned in my survey paper [17]. In this model, the authors compared the user's input nail color with the reference colors. And if a match is found then it will predict the type of disease the user has been diagnosed for. This model analyses only the color of finger nails and it detects only six diseases.

In the second model proposed by Trupti S Indi et. al [18], the authors have predicted various diseases using nail color by finding the average of RGB color of ROI of nail image. And then disease prediction was done by building a decision tree.

In the third model proposed by Vipra Sharma and et.al [19], the authors have predicted diseases using nail color and texture analysis. But the model has a lot of constraints and is able to detect only two or three diseases by analyzing the texture.

In all the above models we have been able to overcome the constraints of human eye like subjectivity and resolution power and predict diseases easily and at a lower cost. But the first two models analyze only the color of finger nails and even though the third model has been successful in analyzing the texture but with a lot of constraints for detecting the texture of two or three diseases. The first three models are able to detect only five or six diseases. But the model proposed has been successful in predicting more diseases but the performance can be improved by choosing other classifier methods.

2.4 Feature Extraction in Nail

The Nail regions are segmented, and various features of the nail like **color, shape and texture** are extracted and recorded.

Out of the many feature extraction techniques, **color** is considered the most dominant and distinguishing visual feature. A mix of **Histogram** and **Statistical based feature extraction method** for extracting the Color feature is used as it has high accuracy [20][21][22] . Histogram is used as a model of probability distribution of intensity level and Statistical features provide information about the characteristics of intensity level distribution for the image. The various statistical features used are **Mean or Median, Standard Deviation, Skewness and Kurtosis**.

Table III presents the equations for calculating the mean, standard deviation, kurtosis and skewness of the color channels, where M and N denotes the dimension and total number of pixels in the image, P_{ij} denotes the color value of i^{th} column and j^{th} row.

Table III: Color Features

Si.No	Feature Name	Feature Calculation
1	Mean	$\mu = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} P_{ij}$
2	Standard Deviation	$\sigma = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(P_{ij}-\mu\right)^2}$

3	Skewness	$\theta = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(P_{ij}-\mu)^3}{MN\sigma^3}$
4	Kurtosis	$\gamma = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(P_{ij}-\mu)^4}{MN\sigma^4}$

Besides the color features, **shape features** also provide useful information for retrieval of information about images. The shape of an object is a binary image representing the extent of the object. Shape features can be categorized as boundary-based and region-based. The former extracts features based on the outer boundary of the region while the latter extracts features based on the entire region [23]. Feature vectors extracted from boundary-based representations provide a richer description of the shape and for this reason, boundary based shape features are extracted from the various regions of an image. Features like **area, perimeter, compactness, eccentricity** are extracted.

Table IV: Shape Features

Si.No	Feature Name	Feature Calculation
1	Area	It is the number of pixels in the region described by the shape. It is measured as the count of the internal pixels
2	Perimeter	It is the number of pixels in the boundary of the shape
3	Compactness	It is a measure of how closely packed is the shape. $\text{Compactness} = \frac{(\text{region border length})^2}{\text{area}}$
4	Eccentricity (Roundness)	It is the ratio of the longest chord of a shaped object to longest chord perpendicular to it. Eccentricity is a measure of how circular a shape is.

Another important feature that has been proved to be important and useful in the area of computer vision and image analysis is Texture. An image texture feature is a set of metrics calculated to provide information about the spatial arrangement of color or intensities in an image or selected region of an image [24]. Texture features can be extracted using either statistical approaches or transformation approaches. Statistical approaches can be divided into two areas which are the spatial domain approach and the frequency domain approach. The spatial domain approach, are more powerful than frequency domain approach [25]. One of the most widely used approaches to texture analysis, the Gray Level Co-occurrence Matrix (GLCM) approach. The proposed system has used 14 texture features that utilize the spatial relationship amongst gray level values of pixels with in a region.

The GLCM is a tabulation of how often different combinations of pixel brightness values (grey levels) occur in an image. Various texture features like entropy, energy, contrast, homogeneity and correlation are extracted from each sub band. And various Tamura features like coarseness, contrast, directionality, line-likeness, regularity and roughness are also extracted from each sub band. These texture features are calculated as shown in Table V, where P_{ij} is the probabilities calculated for values in GLCM and N is the size of GLCM.

Table V: Texture Features

Si.No	Feature Name	Feature Calculation
1	Entropy	$\sum_{i,j=0}^{N-1} P_{i,j}(-\ln P_{i,j})$
2	Energy	$\sqrt{\sum_{i,j=0}^{N\ 1} P_{i,j}^{\ 2}}$
3	Contrast	$\sum_{i,j=0}^{N-1} P_{i,j}(i-j)^2$
4	Homogeneity	$\sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1+(i-j)^2}$

5	Correlation	$f = \sum_{i=0}^{N_g-1} \sum_{j=0}^{N_g-1} p_{d,\theta}(i,j) \frac{(i-\mu_x)(j-\mu_y)}{\sigma_x \sigma_y}$

Coarseness has a direct relationship to scale and repetition rates and an image will contain textures at several scales. Coarseness aims to identify the largest size at which a texture exists, even where a smaller micro texture exists. Contrast aims to capture the dynamic range of grey levels in an image, together with the polarization of the distribution of black and white. Degree of Directionality is a global property over a region. The feature described does not aim to differentiate between different orientations or patterns, but measures the total degree of directionality. It is measured using the frequency distribution of oriented local edges against their directional angles.

2.5 Supervised Learning

Supervised or machine learning is a multidisciplinary field of study which is mainly concerned with the design of algorithms which will allow the computers to learn. In machine or supervised learning, classification, is a task of identifying, to which class the new observation belongs. An algorithm which implements the classification is mainly called as the classifier.

2.5.1 K-Nearest Neighbor Classifier

Data mining techniques are widely used for mining knowledgeable information from the medical data sets. K-Nearest Neighbor (KNN) is a very simple, highly efficient and effective algorithm for pattern recognition. In KNN, samples are classified based on the class of their nearest neighbor.

KNN is frequently used in many studies, especially when there are only few or no information about the data distribution. KNN is a non-parametric algorithm, i.e.; it does not make presumptions about distribution of data used in analysis. KNN is also called as a lazy algorithm as it only uses quick training phase. KNN does not make generalization which implies that KNN maintains all training data [26].

2.5.2 Classification using KNN

K-nearest neighbor algorithm is a technique for classifying data based on the closest training examples in the feature space.

The algorithm for KNN classifier is as follows:

a. First the dataset is divided into a testing set and training set.
b. For each row in the testing set, the "K" nearest training set objects is found, and the classification of test data is determined by majority vote with ties are broken at random. If there are ties for the K^{th} nearest vector then all the instances are included in the vote [27].
c. Calculating the distances between the testing data vector and all of the training vectors using a particular distance calculation methodology which is given as follows: Considering the case of two input variable; the Euclidean distance between two input vectors p and q is computed as the magnitude of difference in vectors i.e. p - q , Where both the data are having "m" dimensions i.e. p= (p_1, p_2… p_m) and q= (q_1, q_2,…,q_m).

The Euclidean distance between "p" and "q" is found to be :

$$D(p,q) = |p - q|$$
$$= \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2 + \ldots + (p_m - q_m)^2}$$

d. Then take the test instance "x" and find the K-nearest neighbors in the training data
e. Assign "x" to the class occurring with the most among the K neighbors.

Proposed System

Medical Practitioners have been using nail color, shape and texture changes for prediction of various diseases because the changes in nail are early symptoms of various diseases. The proposed model will surely help doctors to predict diseases automatically, easily, cost effectively and with great precision.

We all know that for diagnosis of a disease we need to do various tests like blood, urine, LFT, TFT, Urea, CBC, etc. All these tests would cost around Rs.300 – Rs.600. For these tests the patient has to go personally to the Lab. But by using the proposed system, the patient can himself by sitting at home know about the disease he has been diagnosed with. And the proposed system will surely be an aid to Medical Practitioners for the detection of earlier symptoms of various diseases.

The input to the proposed system NIPS-K is the backside of the palm on a white background. Then from the palm image using Canny's edge detection method and segmentation process, the Region of Interest (ROI), the nail region is extracted. Then the nail color, shape and texture are extracted and combined together to form a feature vector which is then compared with the existing database of diseased and normal nail. The proposed system uses K Nearest Neighbor (KNN) Classification Method for classification and prediction of diseases.

3.1 Block Diagram of the Proposed Model

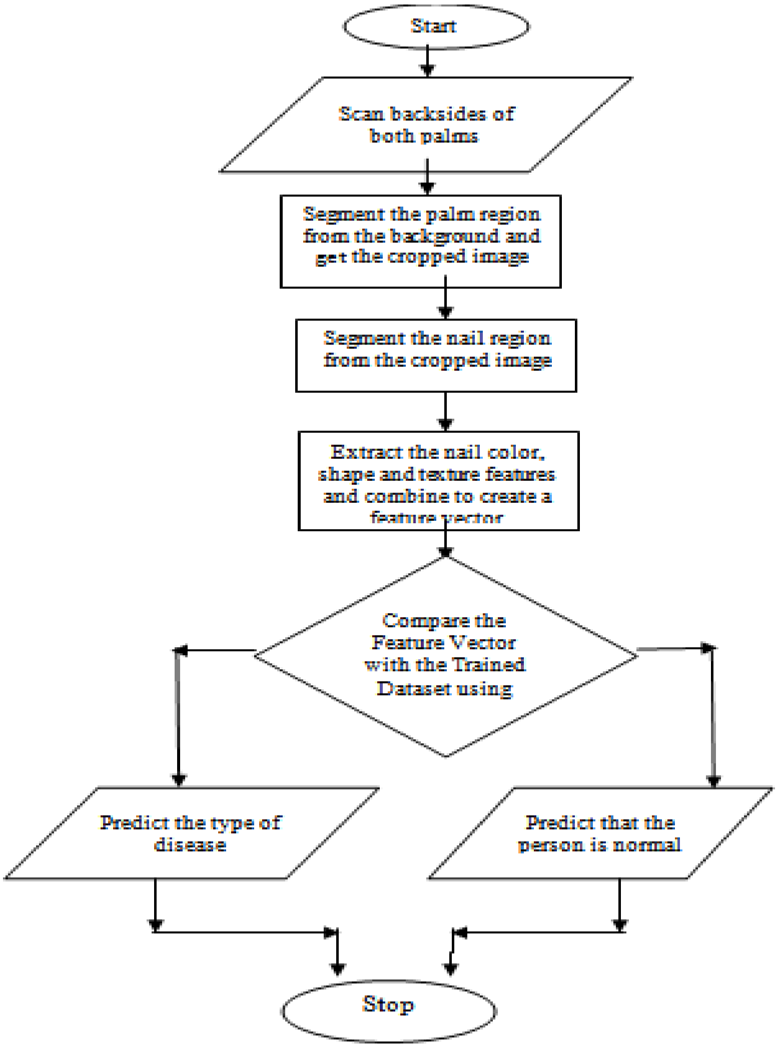


Fig 1: Flow Chart for NIPS-K

3.2 Methodology of the Proposed System

(i) Scanning back sides of both the palms

The back sides of both the left and right palms are scanned using a good camera with proper light. The palm has to be placed on a white background with minimum distance between the fingers. The fingers should not be nail-polished.

(ii) Palm region extracted from the background

The palm can be segmented manually and automatically from the background image using the imcrop ( ) function in MATLAB. As we make use of the skin color, it is invariant to scaling or rotation. And then after the palm region is segmented , all the other pixels of the background is set to the same color, so that it does not cause any confusions for further processing and finally the palm is cropped.

(iii) Segmentation of Nail region and Extraction of Features of Nail like Color, Shape and Texture

The Nail regions are segmented, and various features of the nail like color, shape and texture are extracted, taken together and recorded. In the proposed system, NIPS-K, 13 features were extracted. The various features are as follows:

a) Color features: Mean/Median
   Standard Deviation
   Skewness
   Kurtosis
b) Shape features: AreaS
   Perimeter
   Compactness
   Eccentricity
c) Texture features: Energy
   Entropy
   Contrast
   Correlation
   Homogenity

(iv) Disease Prediction

The extracted textures which are stored in a vector are compared with the existing trained dataset and the diseases are predicted using the KNN Classification method. The KNN algorithm involves the following steps:

a. A training set is prepared which contains the features of 25 different diseased and healthy nails. The images of different diseased and healthy nails were also given for the training set to the MATLAB function KNNClassification.fit( ).
b. Then, a testset was prepared which contained the 13 features of the image to be tested
c. The Trainedset and Testset was given to the function predict( ) for prediction of various diseases belonging to 25 different classes[1 2 3 4 …….25].

IV. Result and Analysis

4.1 Graphical User Interfaces

(i) Nail Segmentation

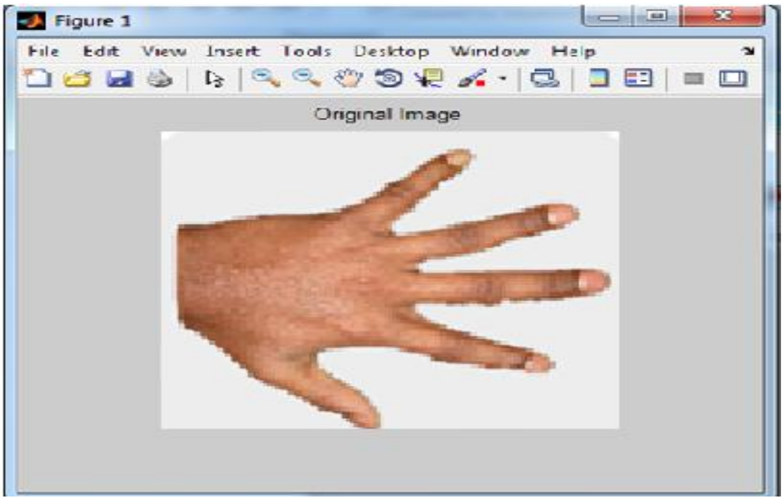


Fig 2: Original Palm Image

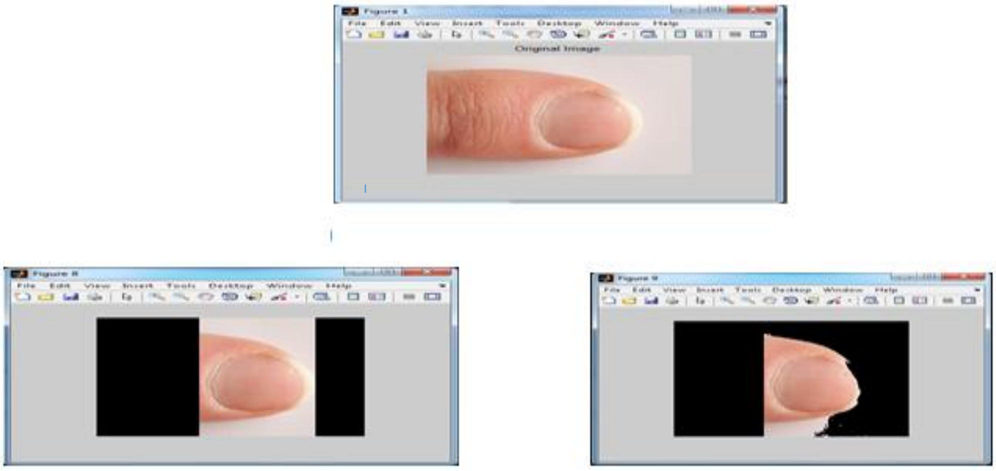


Fig 3: Nail Segmentation

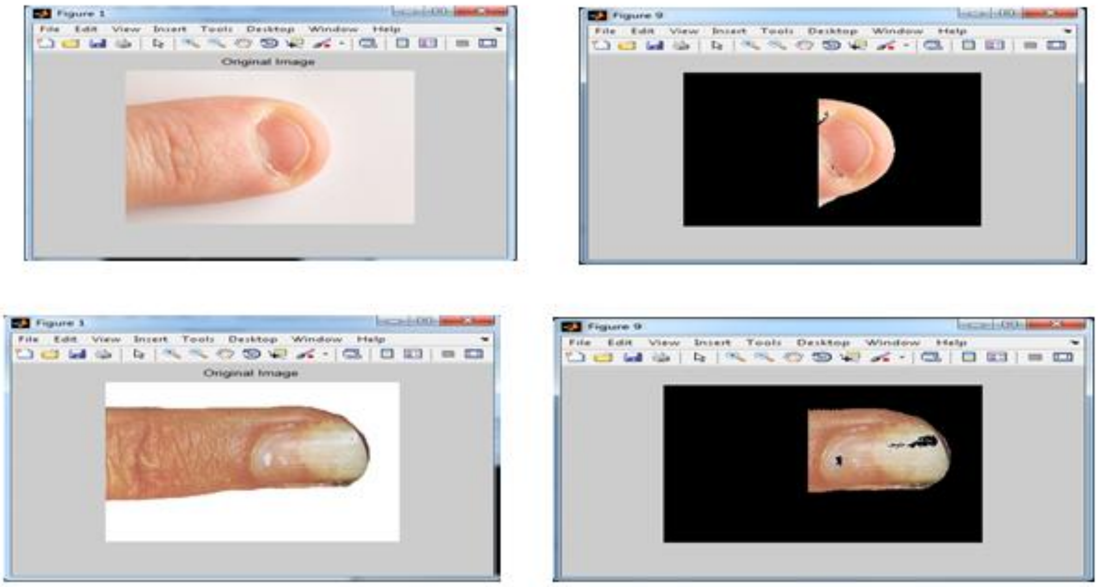
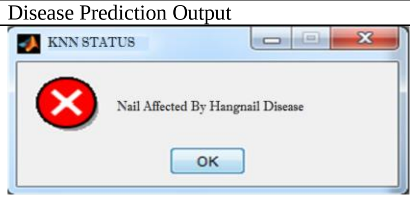
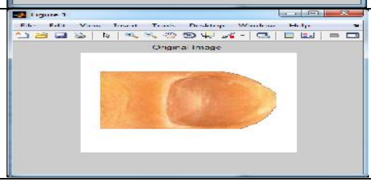
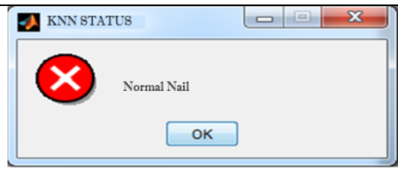


Fig 4: Other Dataset Images

(ii) Disease Prediction

Table VI : Output Result

Si.No	Original Input Image	Disease Prediction Output
1		
2		

3		

4.2 Test Cases and Evaluation Measures

The proposed system, NIPS-K tested 483 image samples of palm of 40 persons which were captured using a digital camera. Five images per person were taken. Some of the nail images and their outputs are shown in Table VI. Out of the 483 image samples, 15 samples each of 24 diseases and 123 samples of healthy persons were taken. For the TrainingSet of KNN, 13 Features of 24 diseases and normal nail were used. And out of the total 360 diseased images, 240 images were used for training and 120 images were used for TestSet. From the samples of healthy nail, 86 images were used for TrainingSet and 41 images were used for TestSet.

The performance analysis of NIPS-K was done using the statistical measures for Binary Classification like Sensitivity, Specificity and Accuracy. The performance analysis was done using different values of k=1, 3 and 5. And it was found that with k=5, the performance was very high

Sensitivity measures how well a particular test predicts one category from another. Specificity measures how well a particular test predicts the other category and Accuracy measures how well the test predicts both the categories. The equations are given below:

$$\text{Sensitivity} = \frac{True\ Positive}{True\ Positive + False\ Negative}$$

$$\text{Specificity} = \frac{True\ Negative}{True\ Negative + False\ Positive}$$

$$\text{Accuracy} = \frac{True\ Positive + True\ Negative}{True\ Positive + False\ Positive + True\ Negative + False\ Negative}$$

Here,
True Positive - means the total number of diseased images correctly identified by the algorithm
True Negative - means the total number of diseased images mistakenly identified by the algorithm
False Positive - means the total number of diseased images correctly rejected by the algorithm
False Negative - means the total number of diseased images mistakenly rejected by the algorithm
The Following Table VII shows Sensitivity, Specificity and Accuracy for the different diseases that were generated by NIPS-K.

Table VII: Performance analysis

Si.No	Disease	Specificity (%)	Sensitivity (%)	Accuracy (%)
1	Darier’s Disease	87.45	99.78	93.67
2	Psoriasis	88.56	100	94.34
3	Beau Lines	88.12	99.5	93.67
4	Eczema	87.56	99.67	93.62
5	Lindsays	87.45	98.5	94.45
6	Melanonychia	88.34	99.12	95.12
7	Muehrckes Lines	87.45	100	94.23
8	Nail Patella	88.45	99.12	93.56
9	Onchocryptosis	87.89	99.89	93.78
10	Onchophagia	88.42	99.78	93.67
11	Pachyonychia	87.45	100	93.34
12	Terrys Disease	88.56	99.5	93.34
13	Alopecia Areata	88.12	98.45	93.62
14	Anonychia	87.56	98.5	93.12
15	Clubbing	87.45	99.67	93.23
16	Glomustumor	87.26	100	93.12
17	Hang Nail	87.05	99.12	93.45
18	Koilonychia	88.45	99.89	93.78
19	Leukonychia	87.15	99.56	93.12
20	Paronychia	87.56	100	93.14
21	Pseudomonas	87.45	99.12	93.02
22	Red Lunalla	87.12	99.89	93.67
23	Splinter Hemorrhage	87.45	99.12	94.34

24	Yellow Nail Disease	88.45	99.89	93.23
25	Healthy	87.12	99.89	93.34
	Average (%)	87.7556	99.5184	93.6388

V. Conclusion and Future work

The ability to detect various diseases in their early stages is a very useful work for the society. Through the proposed system NIPS-K which is based on Digital Image Processing, Nail color, shape, texture analysis and KNN classifier has been designed and it helps in recognizing various diseases. This model gives more accurate results than human vision, because it overcomes the limitations of human eye like subjectivity and resolution power. The detection system makes easy for doctors to give correct treatment to patients.

In the proposed system, NIPS-K, 13 features of diseased and normal nails were extracted and the system was trained with these. The system was able to achieve good performance and accuracy. By varying the Image processing techniques and Classifiers, the precision can be improved for this system. Despite having some difficulty, these techniques are very helpful in medical science. The data we have collected will be helpful in medical field. Moreover in the proposed system only the images of nails of fingers and toenail have been used for classifying the diseases, but in future we can combine other features of human body and predict various diseases based on the symptoms of patient and hence would be able to detect a lot of diseases with good precision and accuracy.

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