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Detection of Diseases using Nail Image Processing Based on Multiclass SVM Classifier Method

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Abstract:
Human nail can be used for the prediction of various systemic and dermatological diseases. The proposed system – Nail Image Processing System using Multiclass SVM (NIPS-McS) 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 taken together to form a feature vector and then analysis of nail is done which is used for the diagnosis of various diseases. This proposed system will help the doctors in the early diagnosis of diseases.

Keywords: Binary classification, digital image processing, disease prediction, feature vector, Multiclass SVM, Nail Analysis, SVM

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-McS) extracts a total of 13 features of the human nail 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 like nail color, shape and texture. The extracted features are then taken together to form a feature vector which is 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 – Multiclass SVM.

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 congenital [10]**	i.Hyperhidrosis ii.Hyperkeratosis, warts iii. Skin lesions on the limbs iv. Lustreless and kinky scalp hair is also seen.	
4	Traumatic Disorder	**Onychophagia**	i.Various types of viraland icrobial in fections are seen ii. Skin picking, skinbiting, iii.Urgeto 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	

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.2. Nail Abnormalities [4] [6] [11]

Si. No	Type of Nail Disorder	Nail Findings	Disease Indication	Image
1		**Onycholysis**	i.Psoriasis ii.Amyloidosis iii.Hyperthyroidism ivSarcoidosis v.Infection vi.Trauma viiConnective tissue disorders	
2		**Splinter Hemorrhage**		
3	Dermatosis	**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		**Beau's Lines**	i.Pemphigus ii.Trauma iii.Raynaud's disease iv.Diabetes v.Hypocalcaemia	
9	Nail Surface Changes	**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		**Terry's nails**	i.Hepatic failure, ii.Diabetes mellitus iii.CHF iii.Cirrhosis iv.Hyperthyroidism v.Malnutrition	
12	Nail Color Changes	**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	

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 is successful in predicting 23 diseases by combining the nail color, shape and texture features together and then using the classification method multiclass SVM for prediction.

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.3. 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	$\sigma = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(P_{ij}-\mu)^2}$
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.4. 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 fromeach 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.5. 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.

Support Vector Machine (SVM)

In machine learning, SVM is a supervised learning method which gives machines the ability to learn without being explicitly programmed. It has evolved from the computational theory of AI. In supervised learning each example is a pair consisting of input object (vector) and a desired output (supervisory signal). The supervised learning algorithm produces an inferred function or program which can be used for mapping new examples. An optimal scenario will help the algorithm to determine the class labels for unseen instances. This requires the learning algorithm to generalize from training data to unseen situations. A supervised learning algorithm works on the principle:
Given a set of N Training examples of the form:
$\{(x_1,y_1),(x_2,y_2),\ldots\ldots\ldots,(x_N,y_N)\}$ such that x_i is the feature vector of the i^{th} example and y_i is its label(class), a learning algorithm seeks a function

$$g: X \rightarrow Y$$

where X is the input space, Y is the output space and g is called the hypothesis space Support Vector Machine (SVM) is a classification and regression prediction tool that uses machine learning theory to maximize the accuracy of prediction while automatically avoids the over-fitting to the data. The foundation of Support Vector Machines (SVM) was developed by Vapnik [26] and it gained popularity due to its many features such as better empirical performance. The idea of support vector machine is to create a hyper plane in between data sets to indicate which class it belongs to. The challenge is to train the machine to understand structure from data and mapping with the right class label, for the best result, the hyper plane has the largest distance to the nearest training data points of any class. There are many linear classifiers (hyper planes) that separate the data. However only one of these achieves maximum separation which is illustrated below in Fig 1. Now we will try to express the SVM mathematically and here we have used a linear SVM. The goals of SVM are separating the data with hyper plane and extend this to non-linear boundaries using **kernel trick**. For calculating the SVM we see that the goal is to correctly classify all the data. For mathematical calculations we have,

[a] If $Y_i = +1$; $wx_i + b \geq 1$

[b] If $Y_i = -1$; $wx_i + b \leq 1$

[c] For all i; $y_i(w_i + b) \geq 1$

In this equation x is a vector point and w is weight and is also a vector. So to separate the data [a] should always be greater than zero. Among all possible hyper planes, SVM selects the one where the distance of hyper plane is as large as possible. If the training data is good and every test vector is located in radius r from training vector. Now if the chosen hyper plane is located at the farthest possible from the data. This desired hyper plane which maximizes the margin also bisects the lines between closest points on convex hull of the two datasets as shown in Fig 2. Thus we have [a], [b] & [c].

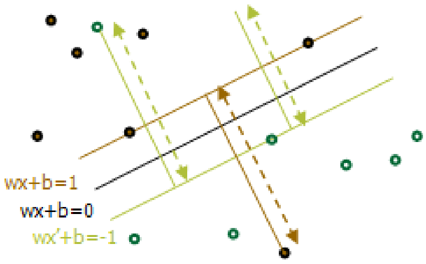


Figure.1. Representation of Hyperplanes

Expression for Maximum margin is given as:

$$\text{margin} \equiv \arg\min_{\mathbf{x}\in D} d(\mathbf{x}) = \arg\min_{\mathbf{x}\in D} \frac{|\mathbf{x}\cdot\mathbf{w}+b|}{\sqrt{\sum_{i=1}^{d} w_i^2}}$$

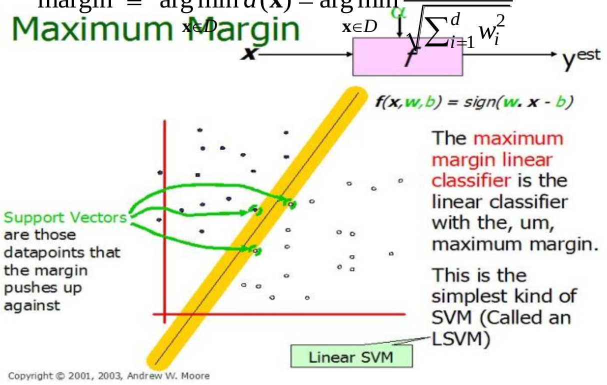


Figure.2. Linear SVM Classifier

Classification using SVM

SVM is one of the useful techniques for data classification. Even though it's considered that Neural Networks are easier to use than this, however, sometimes unsatisfactory results are obtained. A classification task usually involves training and testing data which consist of some data instances. Each instance in the training set contains a target value and several other attributes. The aim of SVM is to produce a model which will predict the target value of data instances in the testing set. SVM classification involves the identification of datasets which are closely connected to the known classes. This is called feature selection or feature extraction. Feature selection and SVM classification are used for predicting unknown samples. They can be used to identify key sets which are involved in all the processes which distinguish the different classes.

Multiclass SVM

Support vector machine (SVM) originally separates the binary classes (k = 2) with a maximized margin. However, real-world problems often require the discrimination for more than two categories. Thus, the multi-class pattern recognition can be used. The multi-class classification problems (k > 2) are commonly decomposed into a series of binary problems such that the standard SVM can be directly applied. Two representative ensemble schemes are one-versus-rest (1VR) [27] and one-versus-one (1V1) [28] approaches.

Classification using Multiclass SVM

Multiclass SVM models combines multiple binary-class optimization problems into one single objective function and simultaneously achieves classification of multiple classes. The one-versus-rest (1VR) approach [27] constructs k separate binary classifiers for k-class classification. The m-th binary classifier is trained using the data from the m-th class as positive examples and the remaining k − 1 classes as negative examples. During test, the class label is determined by the binary classifier that gives maximum output value. Another classical approach for multi-class classification is the one-versus-one (1V1) or pairwise decomposition [29]. It evaluates all possible pairwise classifiers and thus induces k (k − 1)/2 individual binary classifiers. Applying each classifier to a test example would give one vote to the winning class. A test example is labeled to the class with the most votes.

III.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-McS 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 are then compared with the existing database of diseased and normal nail. The proposed system uses Multiclass SVM Classification Method for classification and prediction of diseases.

Block Diagram of the Proposed Model

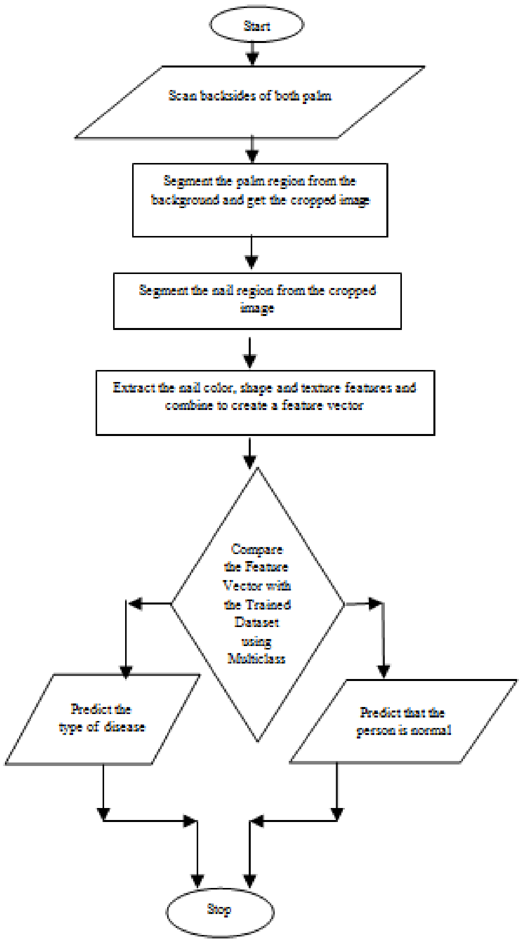


Figure.3. Flow Chart for NIPS-McS

IV.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 and recorded together to form a feature vector[30]-[33]. In the proposed system, NIPS-McS, 13 features of nail color, shape and texture were extracted to form a feature vector. The various features are as follows:

a) Color features : Mean/Median
Standard Deviation
Skewness
Kurtosis

b) Shape features : Area
Perimeter
Compactness
Eccentricity

c) Texture features : Energy
Entropy
Contrast
Correlation
Homogenity

(iv) Disease Prediction

The extracted features which are stored in a vector are compared with the existing trained dataset and the diseases are predicted using the Multiclass SVM classification method. In the Multiclass SVM method, the one-versus-rest approach is used. Here we have used classes for different diseases and one class for healthy nails. In the proposed model- NIPS-McS, binary classifiers were trained up, for example, Darier's versus not-Dariers, Psoriasis versus not-Psoriasis, Beau's Lines versus not-Beau's Lines,……………., Healthy versus not-Healthy. Then, either the positive class that's "best" (e.g., furthest from the margin across all 25 runs) is selected. Or if none of the classifications are positive (i.e., they're all not-X), the "opposite" of class that's worst (e.g., closest to the margin) is selected.

V.RESULT AND ANALYSIS

A. Graphical User Interfaces

(i) Nail Segmentation

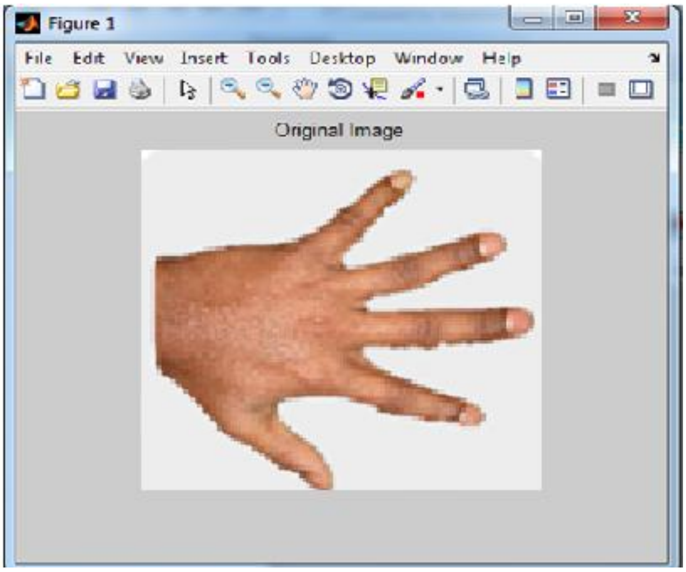


Figure.4. Original Palm Image

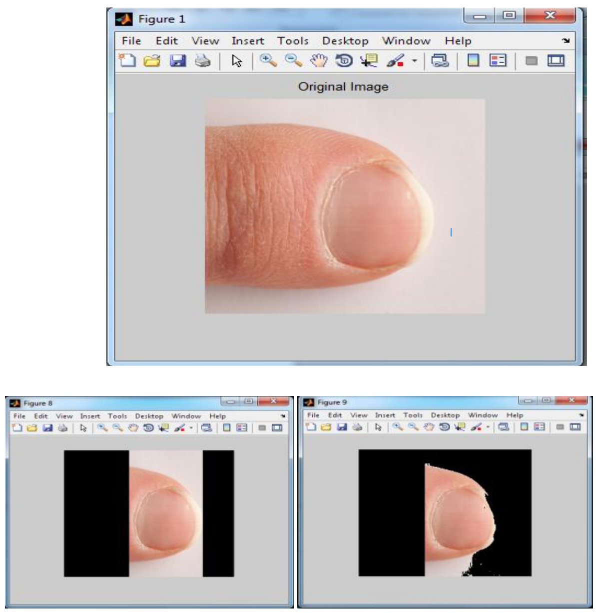


Figure.5. Nail Segmentation

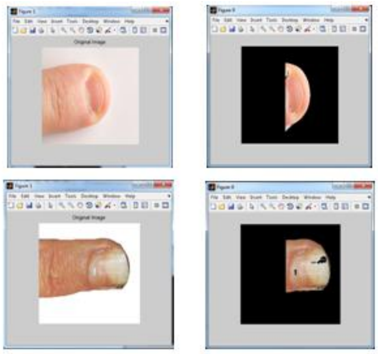
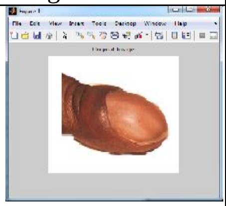
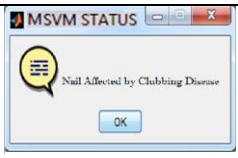
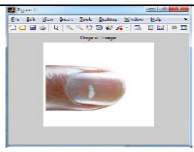
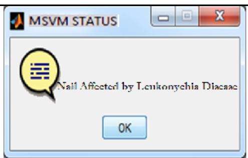
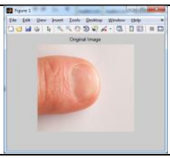


Figure.6. Other Dataset Images

(ii) Disease Prediction

Table.6. Output Result

Si. No	Original Input Image	Disease Prediction Output
1		
2		
3		

B. Test Cases

The proposed system, NIPS-McS tested more than 200 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 200 image samples, 15 samples each of 24 diseases and 40 samples of healthy persons were taken. The performance analysis of NIPS-McS was done using the statistical measures for Binary Classification like Sensitivity, Specificity and Accuracy. 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-McS.

Table.7. Performance analysis

Si. No	Disease	Specificity (%)	Sensitivity (%)	Accuracy (%)
1	Darier's Disease	75.76	96.45	90.56
2	Psoriasis	76.45	97.45	90.56
3	Beau Lines	75.67	97.89	90.67
4	Eczema	75.98	97.45	89.56
5	Lindsays	75.67	98.5	89.23
6	Melanonychia	76.78	96.45	90.56
7	Muehrckes Lines	75.56	96.12	90.45
8	Nail Patella	75.45	97.56	89.98
9	Onchocryptosis	75.34	97.56	90.56
10	Onchophagia	74.67	97.34	89.45
11	Pachyonychia	76.45	97.56	90.65
12	Terrys Disease	76.12	97.12	89.56
13	Alopecia Areata	75.78	97.89	89.67
14	Anonychia	75.89	97.67	90.02
15	Clubbing	75.67	97.45	89.12
16	Glomustumor	74.35	98.5	89.23
17	Hang Nail	75.45	96.45	90.12
18	Koilonychia	76.57	98.45	90.45
19	Leukonychia	78.56	97.56	90.34
20	Paronychia	76.98	97.78	89.56
21	Pseudomonas	76.89	97.34	89.56
22	Red Lunalla	76.34	97.25	89.96
23	Splinter Hemorrhage	76.04	97.56	89.67
24	Yellow Nail Disease	75.03	97.67	89.89
25	Healthy	74.65	97.67	88.95
	Average (%)	75.924	97.4676	89.9332

VI.CONCLUSION AND FUTURE WORK

The ability to detect various diseases in their early stages is a very useful work for the society. The proposed system NIPS-McS is based on Digital Image Processing, Combining features of Nail color, shape, texture for forming a feature vector and then doing the nail analysis and prediction using a classifier – Multiclass SVM. 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, the one-versus-rest(1VR) method for Multiclass SVM is used, but its training time is longer compared to one-versus one(1V1) method, but 1VR's performance is better than 1V1. 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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