An Efficient Machine Learning Approach to Nephrology Through Iris Recognition

C D Divya
Vidyavardhaka College of Engineering
Gururaj H L (gururaj1711@vvce.ac.in)
Vidyavardhaka College of Engineering
R Rohan
Vidyavardhaka College of Engineering
V Bhagyalakshmi
Vidyavardhaka College of Engineering
H A Rashmi
Vidyavardhaka College of Engineering
A Domnick
Vidyavardhaka College of Engineering
Francesco Flammini
University of Applied Sciences and Arts of Southern

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An Efficient Machine Learning Approach to Nephrology through Iris Recognition

[*]Divya C D, [*]Gururaj H L, [*]Rohan R , [*]Bhagyalakshmi V, [*]Rashmi H A, [*]Domnick A, [+]Francesco Flammini

[*]gururaj1711@vvce.ac.in

[*]Vidyavardhaka College of Engineering, Department of Computer Science and Engineering, Gokulam 3rd stage vijaynagar, Mysuru 570002, India.
[+] University of Applied Sciences and Arts of Southern Switzerland

Abstract: Iridology is a technique in science used to analyze color, patterns, and various other properties of the iris to assess an individual's general health. Few regions in the iris are connected by nerves coming from different organs of body, this shows some special unique qualities which is advantageous along with which assist in psychological condition, particular organ conditions and construction of the body. The structural and designed patterns present on specific part of iris represent the level of intensity of disorder caused by the organs. This method of approach can be employed as reasonable and logical guidelines for the detection and identification of disorders. Therefore, after scanning the image of iris advance study of disorder can be carried out for detecting the condition of organ. Initially by the service of an adaptive histogram, the image of eye should be separated from part of the image captured. Next the images of iris are classified and recognized using machine learning algorithm Support Vector machine or Support Vector Networks. The features are extracted from images of iris using white Gaussian filters which are then used as a feature descriptor. These descriptors count the occurrences of gradient orientation and magnitude in localized portions of an image. Then convert the image of iris to a gray scaled image, final image is standardized. Next is to convert it into rectangular shape and then assembling the HMM images of eyes related to the kidney. The final level is to diagnose the edge of image of iris HMM. By analysing end results, condition of the organ can be diagnosed and results can be obtained from the iris recognition system.

Keywords: Iridology, Digital Image Processing, Edge Detection.

INTRODUCTION

Iridology is the diagnostic approach that reads the iris, the coloured part eye and to determine the condition of any part of the body. It is a science and practice, which helps to reveal the location of inflammation, weaknesses, and strength. The intensity levels or irregularities of body parts affected by illness are simultaneously stored and recorded in the iris. This can be used as guideline for diagnosing various disorders. The treatment given to the patients are quite expensive, the damage caused remains unknown for long time. By using of symptoms shown by the organs on the iris, diagnosing can be done through the iris of the eye. Any changes and imbalances found in organs of human body are stored in the iris of the eye.
In this study, the project is expected to categorize by utilizing detection of the edge and segmentation of mining.
The features are extracted from images of iris using white Gaussian filters which are then used as a feature descriptor.

These descriptors count the occurrences of gradient orientation and magnitude in localized portions of an image. When the image of the iris is obtained, firstly the image of the eye must

be separated and then changes the iris image to grey scaled image, finally the image is standardized by employing adaptive histogram. Later it is converted into rectangular shape and then assembling the HMM (Hidden Markov Module) images of eyes related to the kidneys, the final step is to diagnose the edge image of the iris HMM. Later it is converted to binary imagery for calculating the extent wound in the image of the iris HMM.

- Collecting Database of the iris-based kidney disease (Trained and Tested database).
- Image pre-processing converting the iris image from RGB to Gray.
- A Caney edge filter is used to remove the noises from the iris image.
- Image segmentation: it separates the objects from the image background.
- HMM Algorithm used to recognize the kidney disease by analysing iris patterns.

The paper consists of:

1. Survey of the kidney problem related papers and the comparison of the existing and the proposed system.
2. Methodology of the Proposed System.
3. Various algorithms used in the system.
4. Results and Conclusion.

LITERATURE SURVEY

In this literature survey we have referred ten different journal papers. The below all paragraphs will briefly describe the techniques, methodology, working principles and used algorithms.

The scanned images are obtained from CT scanner is used for detecting and identifying the damage in the kidney. These results come up with an accurate detail regarding the amount of damage in their positions in various medical proposals. The tests which are conducted manually and traditionally for the medical purpose are more time consuming and also it increases labour cost. In recent days, diagnosing the damages using CT scan as become a most main task for clinical diagnosis. For the development and improving efficiency of medical of medical testing, CADD (Computer Aided Diagnosis) is required. By combining four IOU thresholds of cascade RCNN, they implemented the two convolution of morphology and they changed the feature pyramid network in rapid RCNN. [1]

Chronic kidney disease (CKD) is recognized as a global health problem because of its high mortality rate which include other disorders. There are no symptoms found in the early stage of CKD. Therefore, patients are ignorant of this disease. It diminishes the progression of this disease, in case patient can obtain time to time treatment from early diagnosis of CKD. Machine learning models, are efficiently benefits the medicos achieve their goal because of its speedy and precise recognition performance. For detecting CKD, a machine learning model was proposed. The incomplete values and missing values can be filled by using the KNN algorithm. The six machine learning algorithms can be applied, once the missing datasets are filled efficiently. [2]

It is possible to know the condition of inner organs by scanning the iris such as kidneys, heart and other organs by looking at the iris tissue [2, 3, 5, 6, and 7]. They referred a chart that was introduced by the Dr. Bernard Jensen. The chart contains various broken tissue pattern with abnormal organ conditions. Since various nerves are connected to iris from various organs of body broken tissue in the iris represents the condition of specific organ in the human body. This broken tissue is represented by a pattern or mark or just changing the color of the iris. The one who had kidney problem or lost the kidney prior to this examination, did not exhibit any broken tissue in the respective iris was one of drawback from this research. [3]

In the eye, numerous nerves are connected to iris from various organs of body. Each and every part of the body is connected with iris of eye. By examining region of interest (ROI) on the iris, shows which part of the body is facing problems. Iridology has become the main framework in the body, because of its attributes present in the iris. Excluding rest part of the eyes, the whole iris is considered to this study. The images are classified based on broken tissue, colour gradation and few other qualities. Patients diagnosed having broken tissue, to draw out the properties Watershed technique is utilized. Since Coronae has straight forwardness qualities, any video or photographic equipment can be used to capture the iris image. In order to detect the image of the iris whether it has broken tissue or any other properties on the ROI of iris, supervised machine learning algorithm (SVM) is utilized to detection. [4]

When the kidney functionalities get lost after several months or years due to CKD, Chronic Kidney Disease (CKD) gradually gets progressed. It cannot be able to detect, unless Kidney losses its functionalities up to twenty-five percent. Since there is no symptom are shown initially, the patient cannot be able to recognize his renal or kidney failure. CKD data sets are built by utilizing wrapper and filter techniques. This method has their own evaluator individually. To perform filter technique, CFsSubsetEval and FilterSubsetsEval a good search engine is utilized". For wrapper technique, among ClassifierSubsetsEval and WrapperSubsetEval a good search engine is utilized. [5]

The convenient diagnosis system cannot be able to replace by iris diagnosis system, however, it utilized as screening level diagnosis, and it helps the medicos. Since image acquisition is first stage the iris diagnosis, the image quality, accuracy, illumination, duration needed for image capturing and diagnosis of iris system are all depending on it. The important step of iris diagnosis system localization technique. The localization procedure takes more time when compared to other procedures. By resizing and reducing the size of the image are made to control the localization time. [6]

In this approach, cropping of the iris image is required. To get accurate results and successful cutting, capture of higher clarity image of iris is required. Here, the very first step is Converting RGB to Gray image, then this image is being filtered to remove the noise in the image. Next step is feature extracting, where the pupil part of the eye is being removed from iris. In the third step the image is being converted into rectangular image and the rectangular image is being converted into a binary image. At the end the image is being compared with the Iridology chart

to detect the disease. [7]

The condition of internal organs of human body is predicted using human iris. On recognizing color of the iris and its patterns, then it is compared with the Iridology chart. The Iridology chart, divide the iris plane into several segments, where each segment is connected to an internal organ. This approach is depending on three procedures: 1. Iris recognition, 2. Extraction, 3.dark/white regional localization. By comparing the iris pattern with the Iridology chart, it is possible to generate the diagnosis. [8]

The Iris is the greenish-yellow area around the pupil. The outer white area is called the sclera and the central clear part is known as the cornea. Iris is a component of the nervous system and the combined cluster of millions of nerve endings and impulses. The overall process is carried out to get the correct approximate of disease by analysing the iris image. A Gabor filler algorithm is needed in feature extraction. All the features which are required should be extracted, checked clearly. [9]

Kidney disease is an issue in society because of its increasing in levels of morbidity and mortality. Through clinical analysis potential discovery of kidney disease or its absence is needed for clinical trials and medical studies. One of the hurdles is to store samples from patients with the known conditions related to the kidney in medical bio repositories. Combination of pathological results with the description of discharge summaries and billing codes. [10]

Author	Approach	Description
HUI ZHANG, YURONG CHEN, YANAN SONG ZHENLIN XIONG, YIMIN YANG, Q.M. JONATHAN WU	Phonology cascade vortex neural networks for detecting Kidney lesion.	They introduced a device which detects wound using multi-IOU (Intersection Over Union) based on the Convolutional Neural Network. Small wound in the kidney can be found out using deep learning algorithm (RCNN).
JIONGNIMG QIN, LIN CHEN, YUHUA LIU, CHUANJUN LIU, CHANGHAO FENG, BIN CHEN	Detection of Kidney problems using Machine Learning.	In this approach, they are collecting the data from the University, where it has a large number of missing data / values. It is difficult to get accurate results due to missing values. To fill these values, they used KNN (K-Nearest Neighbour) imputation method. After the missing values filled, Machine Learning algorithms: 1.Random forest algorithm 2.Logistic Regression algorithm 3.SVM algorithm 4.K-Nearest neighbour (KNN) 5.Naïve Bayes Classifier

		6. Feed forward Neural Network, were used to complete this approach.
MAYA ARMYS ROMA SITORUS, ADHI WIBAWA, MAURIDHI HERY PURNOMO	Detection of Chronic renal failure through a watershed algorithm by analysing the iris image.	They classified the iris of image of patients suffering from chronic renal failure to various stages based on the region of interest of the eye. By analyzing the iris, it is possible to know the condition of the inner organ. They referred a chart that was introduced by the Dr. Bernard Jensen. The chart contains various broken tissue pattern with abnormal organ conditions.
Sandhya Kumari, Bhagwate Dhiraj	Kidney disease detection through Iris Image.	They proposed a technique is based on finding the core of iris along with, they analyze the abnormalities in the iris of patient that compare to the kidneys to find the wounds or problems in the Kidney.
Hsueyin Polat, Homay Danaei Mehr, Aydin Cetin	Using Support Vector Machine by feature selection method for detecting Chronic Kidney Conditions.	They used two methods to find Kidney problem 1. Wrapper and 2. Filter For Filter they used a greedy search engine cfsSubsetEval and best first search engine FilterSubsetEval. The greedy stepwise search engine was used for wrapper. Search engine used are: ClassifiersSubsetEval WrapperSubsetEval
Sandeep Panwar Jogi, Bharat Sharma	Strategy for inspecting iris image for clinical check-up.	They extract the clinical data like unusual colors, spots, marks. After analyzing the iris, the iris image is being compared with the Iridology chart. Localization of the image is the important process and this takes a lot of time. By changing the size of the iris image, Localization time can be reduced.
Lavanya R, Sakana G, Praveen kumar E, Gowdhani D, Sivasaravanababu S	Early Stage Diagnosis of Disease in All Parts of Body using Iris Image	They proposed a computerized ideological system for detecting abnormal conditions in the body with the help of image processing through several stages.

Adrina Lodin, Sorina Demea	Iris design based on the clinical recognition approach	In this approach patient can receive the correct treatments based their iris tissues information. This approach is mainly depending on the three important procedures: 1.Iris Recognition 2.Extraction 3. Dark or white region Localization. They generate diagnosis based on Iridology chart.
Jyoti Prasad, Divya Patel, Megha Jadhav, Prof.Rupali Deshmukh	Iris Based Medical Analysis by Geometric Deformation Feature.	They used Gabor filter algorithm for feature extraction, which is the most important process. By comparing the normal eye with diseased eye, they can find the abnormalities that were present in the diseased eye.
Christoph Weber, Lema Roschke, Luise Modernsohn, Christina Lohr, Tobias Kolditz, Udo Hahn, Danny Ammon, Boris Betz, and Michael Kiehntopf	Enhanced detection of high-level Chronic Kidney Disease and its absence by merging various electronic health data by using machine learning strategy.	In this approach they are merged information from different resources like EHR (Electronic Health Record) to identify the kidney diseases. Also, they are comprising laboratory values, and other components. Various classification models were used, they are AUROC and AUCPR.

Table 1: Comparison Analytics

METHODOLOGY

In the methodology, we have described the working flow of the project, the methodology contains the conversion of the image from .jpg, .png format to PGM (Portable Gray Map) to get more information about the image. And next to the image is converted to a grayscale image, and then the image goes under the filtering process so that the unwanted noises could remove, these noises may occur during capturing the image or while transferring from one device to another. After that, the edges are marked using the canny edge detection method and finally, the HMM (Hidden Markov Model) algorithm is used to obtain the results.

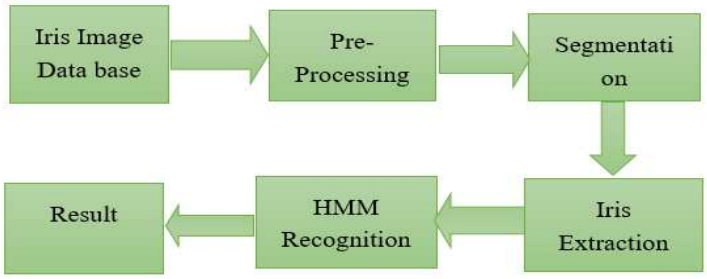


Fig. 1: Methodology

Through the process of checking the iris pattern it is possible to know the condition of the kidney. The main concept is to combine the process of image manipulation and irido diagnosis and, in order to create a new medical operative method. This method is created by manipulating the image, where features extraction plays a major role. The image of iris is uploaded for pre-processing, where image quality is enhanced.

A. Iris Image Database: The trained data & tested data is stored in a database file, which is an iris image data base. The model (e.g., a neural net or a naive Bayes classifier) is trained on the training dataset using a supervised learning method. In practice, the training dataset often consists of pairs of an input vector (or scalar) and the corresponding output vector (or scalar), which is commonly denoted as the *target* (or *label*). The current model is run with the training dataset and produces a result, which is then compared with the *target*, for each input vector in the training dataset. Finally, the test dataset is a dataset used to provide an unbiased evaluation of a *final* model fit on the training dataset.

B. Image Pre-Processing: Discovering an iris in the data set, location of iris is found out using object detector. Cascade entity is a MATLAB method used for detecting the iris.

C. RGB to Grey Image: The iris images which are colored are taken from train and test database. These images are changed to Grey level to reduce to the price of calculation and storage space. Grayscale ranges as monochromatic shades from black to white. Therefore, a grayscale image contains only shades of gray and no other colours. By converting a colored image into grey image, we get only two-colour combination i.e., black and white, so that it is easy to such images for further stages.

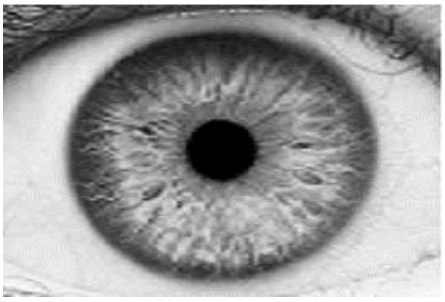


Fig. 2: Gray converted image

D. Grayscale Adjusted Image: In the normalization process, the image resolution is decrease in order to complete the operation. The unwanted part of the image that is generated is removed and quality of the image is increased to meet the specified resolution. Histogram equalization is used for optimizing the diversity of the picture.

Fig. 3: Gray scale adjusted image

E. Edge Detection Image: To get the inner and outer plane of the iris edge detection operation is used. Here canny edge detector algorithm is used, which gives the boundaries of the iris image.

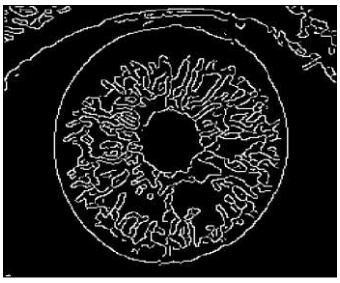


Fig. 4: Gray scale adjusted image

Canny edge detection is a multi-step algorithm that can detect edges with noise supressed at the same time.

F. **Grayscale Images:** A grayscale image is a matrix of data whose values represented intensities within a certain scope. In MATLAB unique matrix is used to store a Grayscale image, where each unique value of the matrix corresponds to one pixel in the image.

G. **Iris detection and segmentation:** Data is used to detect iris and is segmented by applying feature extraction. When the iris is recognized it gets the form of the face by applying hog and Gabor filters. This percolate used boundary detection and direction values to obtain the facial structure by scanning the image

H. **Feature extraction:** Firstly, upload all the training picture and change every the RGB color to grayscale to get one sample in every single pixel. The white Gaussian filter is used as a feature descriptor which can be used to obtain features from images.

I. **SVM Classification:** Supervised learning model in machine learning, firstly train a support vector machine, and then cross validate the classifier. Use the trained machine to classify (predict) new data. In addition, to obtain satisfactory predictive accuracy in trained model.

J. **HMM Recognition:** Hidden Markov Model is a learning algorithm that inspect information used for separating and regression inspection. HMM is defined by a separating hyper plane. This Algorithm is the most important algorithm in the system. By analysing the size and shape of the iris image and by applying HMM algorithm it is possible to get the result of kidney condition. Train, and optionally cross validate, an HMM

classifier using fitcHMM. The most common syntax is:

HMMModel=fitcHMM(X, Y, 'KernelFunction', 'rbf',...

'Standardize', true, 'ClassNames',{'negClass', 'posClass'});

The inputs are:

X — Matrix of predictor data, where each row is one observation, and each column is one predictor.

Y — Array of class labels with each row corresponding to the value of the corresponding row in X. Y can be a categorical, character, or string array, a logical or numeric vector, or a cell array of character vectors.

KernelFunction — The default value is 'linear' for two-class learning, which separates the data by a hyperplane. The value 'gaussian' (or 'rbf') is the default for one-class learning, and specifies to use the Gaussian (or radial basis function) kernel. An important step to successfully train an HMM classifier is to choose an appropriate kernel function.

Standardize — Flag indicating whether the software should standardize the predictors before training the classifier.

ClassNames — Distinguishes between the negative and positive classes, or specifies which classes to include in the data. The negative class is the first element (or row of a character array), e.g., 'negClass', and the positive class is the second element (or row of a character array), e.g., 'posClass'. ClassNames must be the same data type as Y. It is good practice to specify the class names, especially if you are comparing the performance of different classifiers.

The resulting, trained model (HMMModel) contains the optimized parameters from the HMM algorithm, enabling you to classify new data.

1. Gaussian Filter

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Equation 1: Gaussian Filter

The Gaussian Filter is used to remove the noises in the iris image.

2. Canny Edge Detection

BW = edge (I, 'canny');

Equation 2: Canny Edge Detection

The Canny edge detection is used to select the outer line of the iris image.

3. HMM (Hidden Markov Model)

I. Transition Probability:

$$P(y) = P((start) \times \prod_{i=1}^{L-1} P(y_i) \times P(y_L)$$

Equation 3: Transition Probability

Transition Probability occurs within the Hidden Markov Model (HMM). It actually represents the probabilities of a specific state transition.

II. Emission Probability:

$$P(y) = \prod_{i=1}^{L} P(y_i)$$

Equation 4: Emission Probability

Emission Probabilities are the probabilities of an observation accurately representing the internal Hidden state of the model for that specific state transition. The Hidden Markov Model (HMM) is used to recognise the kidney condition by analysing the iris pattern of the eyes.

RESULT ANALYSIS

An Efficient Approach to Nephrology through IRIS Recognition will detect the diseases that are related to kidney by considering the shape, size and patterns of the iris image and analysing presence of broken tissue, colour degradation of iris of eye. The approximate accuracy of the system is around 80%.

We have taken 100 different types of eye images where, 20 images are Diabetic related images, 20 images are stone kidney related images, 20 images are kidney fail related images, 20 images are chronic kidney failure related images and 20 images are normal eye images.

Test case 1:

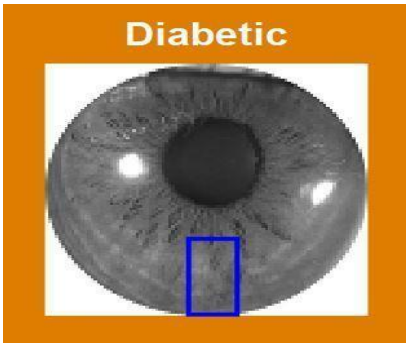
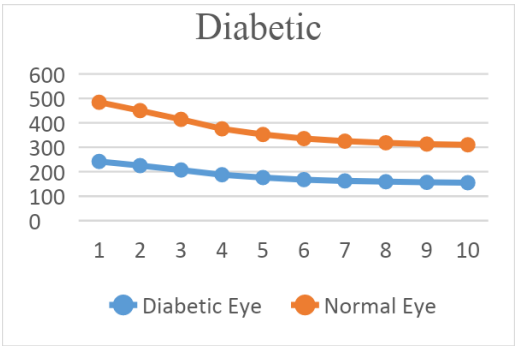
Image	Graph
	 Graph 1: Diabetics Graph

Table 2 : Diabetics versus Normal Iris Graph

In the above test iris image, the bottom part of the iris, which indicates the kidney section, shows some broken tissue on it. Since it is not broken completely, but there are some broken lines in the iris. For those patients who have this kind of iris, their kidney problem condition is in the early stage. Hence it is diagnosed as diabetes.

Test case 2:

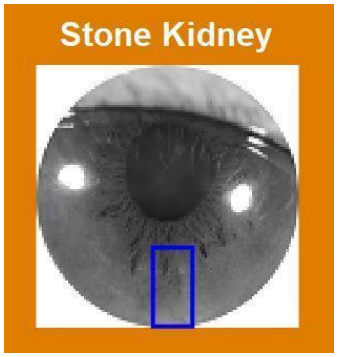
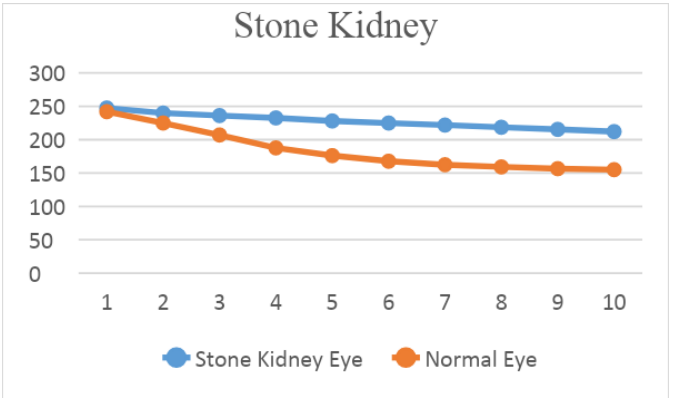
Image	Graph
	 Graph 2: Kidney Stone Graph

Table 3: Kidney Stone versus Normal Iris Graph

Table 3:

In the above test iris image, the bottom part of the iris, which indicates the kidney section, shows some broken tissue on it. In this type, the kidney section part is damaged almost half of the part. Those patients who have this kind of iris, their kidney problem condition is in the middle stage. They might have stones in their kidney.

Test case 3:

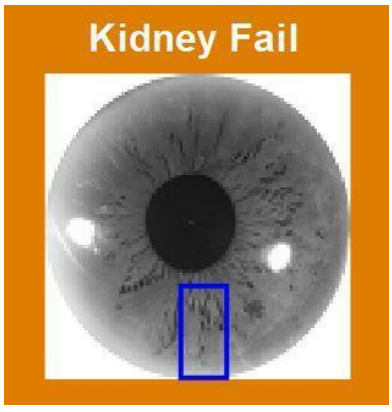
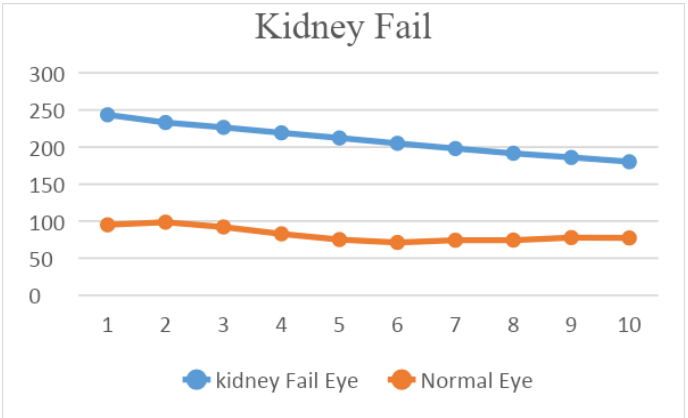
Image	Graph
	 Graph 3: Kidney Fail Graph

Table 4: Kidney fail versus Normal Iris Graph

In the above test eye image, the bottom part of the iris, which means the kidney section that is

damaged. In this type, the kidney section part is totally damaged. For those patients who have this kind of iris, their kidney problem condition is in the final stage. This kind of patient has kidney failure.

Test case 4:

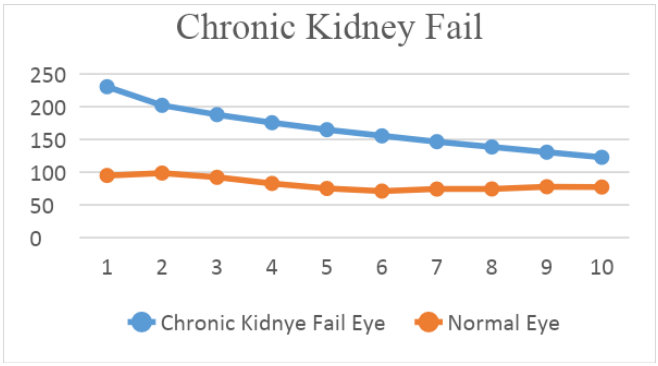
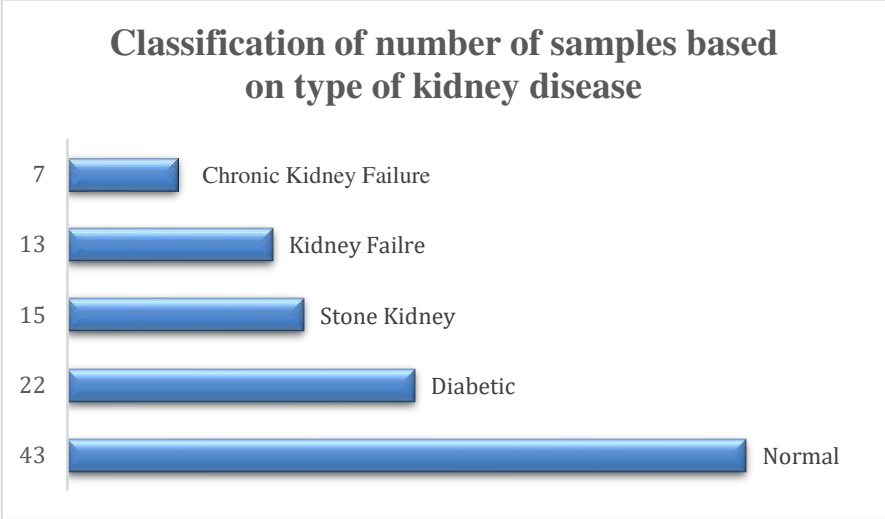
Image	Graph
	 Graph 4: Chronic Kidney Fail Graph

Table 5: Chronic Kidney Fail versus Normal Iris Graph

In the above test iris image, in the bottom region of the iris, in this case the nerve which is connected from the kidney to the eye has damage at the eye end.



Graph 5: Classification of Number of Samples Based on Type of Disease

The above graph shows the classification of Iris images for the above test cases.100 test samples were classified where 43are Normal, 22 are Diabetic, 15 are stone kidney, and 13 are Kidney Failure and 7 are Chronic Kidney Failure

CONCLUSION AND FUTURE WORK

In this system, kidney problems are being detected by analysing the patterns of the iris in the eyes. Each and every nerve that connected to the inner organ are also has a connection to the eyes. Therefore, it is possible to understand the inner organ condition only by analysing the human eyes. Here, the nerve that is connected to the eyes and kidney is considered for the detection of kidney problems. The lower left side nerve for the left eye and the lower right side nerve for the right eye is considered to test the condition of the kidney. The HMM (Hidden Markov Model) is the main algorithm that helps to detect kidney problems. The future work is to implement this model to detect the other inner organ problems. Such as Condition of Stomach, heart state, Liver condition, Lung's condition, Condition of the throat, thyroid problem, Small intestine, descend.

An Efficient Approach to Nephrology through IRIS Recognition will implement using Machine Learning and MATLAB. It is used to detect the various kidney problem by checking the iris image. Hence it is used as a real-world criterion for scanning kidney diseases based on iris images. Further study about the condition of the organ is done by checking out the iris images. The program is able to perform the process of classification of five samples of 100 data like Diabetic kidney recognition, stone kidney recognition, kidney failure, kidney chronic failure and kidney normal state.

Disease	Number of Datasets	Number of Correct Prediction	Accuracy
Normal	20	18	90%
Diabetic	20	16	80%
Kidney Stone	20	17	85%
Kidney Failure	20	15	75%
Chronic Kidney Failure	20	19	95%

Table 6: Accuracy of the model for different types of kidney diseases

Data Availability Statement:

The datasets generated during and/or analysed during the current study are available in the High-Resolution Fundus(HRF) Dataset and DIARETDB0 & DIARETDB1 Standard Diabetic Retinopathy Database.

REFERENCES

[1] R. Rohan, V Bhagyalakshmi, H A Rashmi, A Domnick, C D Divya, H L Gururaj “An efficient approach to Nephrology through Iris Recognition” 27 Apr 2021

[2] J. Jiang, P. Trundle, and J. Ren, ``Medical image analysis with arti- _cial neural networks," *Compute. Med. Image. Graph.* vol. 34, no. 8, pp. 617_631, Dec. 2010.

[3] L. Zhang et al., “Prevalence of chronic kidney disease in china: a cross-sectional survey,” Lancet, vol. 379, pp. 815-822, Aug. 2012.

[4] M. Noll, X. Li, and S.Wesarg, ``Automated kidney detection and segmentation in 3D ultrasound," in *Proc. Workshop Clin. Image-Based Procedures*, Sep. 2014, pp. 83_90.

[5] A. M. Cueto-Manzano et al., “Prevalence of chronic kidney disease in an adult population,” Arch. Med. Res., vol. 45, no. 6, pp. 507-513, Aug. 2014.

[6] A. Singh et al., “Incorporating temporal EHR data in predictive models for risk stratification of renal function deterioration,” J. Biomed. Inform. vol. 53, pp. 220-228, Feb. 2015.

[7] M. Zhang, T. Wu, and K. M. Bennett, ``A novel Hessian based algorithm for rat kidney glomerulus detection in 3D MRI," *Proc. SPIE, Med. Imag., Image Process. Int. Soc. Opt. Photon.*, vol. 9413, Mar. 2015, Art. no. 94132N9.

[8] Z. Chen et al., “Diagnosis of patients with chronic kidney disease by using two fuzzy classifiers,” Chemometr. Intell. Lab., vol. 153, pp. 140-145, Apr. 2016.

[9] H. Polat, H.D. Mehr, A. Cetin, “Diagnosis of chronic kidney disease based on support vector machine by feature selection methods,” J. Med. Syst., vol. 41, no. 4, Apr. 2017.

[10] P. T. Akkasaligar and S. Biradar, ``Diagnosis of renal calculus disease in medical ultrasound images," in *Proc. IEEE Int. Conf. Comput. Intell. Comput. Res. (ICCIC)*, Dec. 2017, pp. 1_5.

[12 A. Subasi, E. Alickovic, J. Kevric, “Diagnosis of chronic kidney disease by using random forest,” in Proc. Int. Conf. Medical and Biological Engineering, Mar. 2017, pp. 589-594.

[13] Y. Xie, B. Bowe, and H. A. Mokdad, H. Xian, Y. Yan, T. Li, G. Maddukuri, C. Tsai, T. Floyd, and Z. Al-Aly, ``Analysis of the global burden of disease study highlights the global, regional, and national trends of chronic kidney disease epidemiology from 1990 to 2016," *Kidney Int.*, vol. 94, no. 3, pp. 567_581, Sep. 2018.

[14] M. Shehata, F. Khalifa, A. Soliman, M. Ghazal, F. Taher, M. A. El-Ghar, A. C. Dwyer, G. Gimel'farb, R. S. Keynton, and A. El-Baz, ``Computeraided diagnostic system for early detection of acute renal transplant rejection using diffusion-weighted MRI," *IEEE Trans. Biomed. Eng.*, vol. 66, no. 2, pp. 539_552, Feb. 2019.

[15] Optimized Identification of Advanced Chronic Kidney Disease and Absence of Kidney Disease by Combining Different Electronic Health Data Resources and by Applying Machine Learning Strategies, June 2020.

Dat4abase links:

[1] https://www5.cs.fau.de/research/data/fundus-images/

[2] DIARETDB0 and DIARETDB1

[3] IStockphoto.com