Automated Detection of Cholesterol Presence using Iris Recognition Algorithm

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ABSTRACT
Arcus senilis is a grayish or whitish bow shaped or ring-shaped deposit in the cornea. It is associated with coronary heart disease (CHD). It is also recognized as a sign of hyperlipidemia. Iridology is an alternative medicine to detect diseases using iris's pattern observation. Iridologists believe that the grayish or whitish deposit on the iris is sign of presence of cholesterol or Arcus senilis disease. The simple and non-invasive automation system is developed to detect cholesterol presence using iris recognition algorithm in image processing. This study applies iris recognition method to segment out the iris area, normalization process and lastly determines the cholesterol presence using OTSU's thresholding method and histogram to determine the optimum threshold value. The result showed that the presence of cholesterol was high when the eigenvalue exceeds an optimum threshold value.

Keywords
Biometric-Identification, Iris recognition, OTSU's Algorithm, Arcus Senilis, Cholesterol Detection.

1. INTRODUCTION
The objective of study is to explain how the presence of cholesterol in blood vessel of human being can be detected by applying iris recognition algorithm. Iris recognition is the today's most widely implemented biometric systems in use. John Daugman has developed the most widely used algorithms and most efficient techniques for iris recognition, but there have been many new methods and algorithms available today [1]. In reference [2], stated the uniqueness and stability of human iris patterns and an open source iris recognition system. Cholesterol or Hypercholesterolemia is a high level of lipid or cholesterol in the blood causes a significant threat to a person's health. It is a sign of elevated high cholesterol. This may lead to cardiovascular diseases. It is caused by extracellular cholesterol deposition in the peripheral cornea, with the deposits consisting of cholesterol, triglyceride cholesterol esters, and phospholipids [3].

The current techniques for measuring the cholesterol level in the human body are by doing blood tests and the test is referred as lipoprotein profile. The lipoprotein profile is an intrusive method which causes discomfort amongst many patients. A laser based technology as non-intrusive technique to measure blood cholesterol or lipid through the skin. This technique proposed infrared (IR) absorption spectroscopic as the characterization of cholesterol or lipid in the skin. Based on [4], generally skin contains approximately 11 percent by weight of all body cholesterol and when several coronary artery diseases are present, the numerical values that acquired with the skin cholesterol test increases. Therefore, the palm test is not useful in identifying coronary artery disease and it is not intended to be used as a screening tool to determine the risk for several coronary artery diseases in general persons.

Iridology is one of the alternatives to the medicines, which claims that the iris pattern could reflect one's health and expose the state of change of individual organ. According to Iridology chart [8], cholesterol in the human body can be detected if there is a "sodium ring" present in the patient's eyes. In order to have a simple and noninvasive means to be as a testing tool to detect cholesterol, we found that high cholesterol or lipid can be detected from the changes in iris pattern and they are referred Arcus Lipoides (Arcus Senilis or Arcus Juvenilis). The Arcus senilis is a grayish arc or circle visible around the peripheral part of the cornea in older adults [5]. Lipid or cholesterol deposits cause Arcus senilis in the deep layer of the surrounding cornea and similar discoloration in the eyes of younger adults (Arcus juvenilis) is often concerned with high blood cholesterol [6]. This statement claims that iris pattern can be analyzed and used as another way to detect the cholesterol presence in the human body.

2. INTRODUCTION EYE IMAGE
Iris is a pigmented, rounded, contractile membrane of the eye, placed between the lens and cornea and in the hole filled by the pupil. Iris regulates and controls the amount of light entering the eye [7]. According to [8], the eyes are connected and continuous with the brain's Dura mater through the fibrous sheath of the optic nerves, and they are associated directly with the spinal cord and sympathetic nervous system. The optic tract extended to the thalamus area of the brain. This results with a close link with the hypothalamus and pituitary glands and pineal glands. These endocrine glands are present within the brain and are the major control and it is the processing centers of the entire body. Because of this anatomy and physiology, we can conclude the eyes are having direct interaction with the biochemical, hormonal, structural and the metabolic process of the human body.

In cholesterol detection process the sample of the eye is important because the actual analysis is based on the feature extracted from human eyes. This extracted iris image is then used in this system to check the presence of cholesterol. Thus, it is vital to segment out this part, i.e. iris from the whole unnecessary part of the eye image sample. This isolation or segmentation is the process of removing the outer part of the eye, i.e. outside the iris circle, to get an exact iris image that is useful for localization of the cholesterol or lipid. The quality of the images is very important to get the accurate result, thus the images should not have impurities that can lead to wrong location of iris area. These impurities include the light reflection, as well as angle of image acquisition. [12]

In this work, the real eye image samples are collected from patients at the local ophthalmology clinic at Aurangabad. Since the various cases of eye disease are reported in this clinic that later can be referred to Arcus Senilis problems. The iris image is captured from a patient eye sample for labeled dataset. Along with the eye image samples, the blood test reports of lipoprotein profile were also collected for all the patients in the dataset. In this work, images can be used obtained from iris database sources, which can be freely available online. Such as CASIA, UBIRIS, MMU etc.

3. SEGMENTATION

The process of segmentation (localization) is to search for the center coordinates and the radius of the pupil and iris. These coordinates can be marked as c_i , c_p where c_i represented as the parameters $[x_c, y_c, r]$ of the limbic and iris boundary and c_p represented as the parameters $[x_c, y_c, r]$of the pupil boundary. It makes use of [9] to select the possible center coordinates first. The method consist of threshold followed by checking if the selected points (by threshold) correspond to a local minimum in their immediate neighborhood, these points serve as the possible center coordinates for the iris.

The segmentation algorithm is based on the Circular Hough transform is employed [10]. Initially, an edge map is created by calculating the first derivatives of the intensity values of an eye image and then set the threshold value based on the result. After from this edge map, values are passed in Hough space for the parameters of circles passing through each point in the edge map. These parameters will be considered as the center coordinates and radius, that are able to define a circle according to the following equation:

$$x_c^2 + y_c^2 + r^2 = 0 \qquad (1)$$

These radius values were set manually; the input to this function is the image to be segmented and the input parameters in this function, including roaming and rmax (the minimum and maximum values of the iris radius). The range of radius values to search for was set manually, depending on the database used. The output of this function will be the value of c_i , c_p which is the value of $[x_c, y_c, r]$ for the pupilary boundary and the limbic/iris boundary and also the segmented image. For all the above process the use of the Hough Transform is made.

The Hough transform [10] is a standard computer algorithm that can be used to determine the parameters of the simple geometrical shapes, which can be detected in an image, for e.g., lines and circles, etc. The circular Hough transform can be employed to reduce the radius and the center coordinates of the pupil and iris regions. A maximum point in the Hough space will match to the radius and center coordinates of the circle best which can be defined by edge points in the edge map. We can also make use of the parabolic Hough transform to find the eyelids from eye image, by approximating the lower and upper eyelids with parabolic arcs, which are given as following equation;

$$\left(\left(-x - h_j\right) \operatorname{Sin} \theta_j + \left(y - k_j\right) \operatorname{Cos} \theta_j\right)^2 = a_j((x - h_j) \operatorname{Cos} \theta_j + \left(-y - k_j\right) \operatorname{Sin} \theta_j) \qquad (2)$$

The parabolic Hough transform controls the curvature, which is the peak of parabola and it is the angle of rotation relative to the x-axis. According to reference [9], in edge detection step, we take the partial derivatives with respect to the x axis (horizontal direction) for detecting the outline of the eyelids; whereas again we take the partial derivatives with respect to the y axis (vertical direction). It is used for detecting the outer circular boundary of the iris. Reason behind this is, the eyelids are usually positioned in horizontal alignment, and also the eyelid edge maps will impress the circular boundary of the iris edge map if using all incline data. Only the vertical pitch are considered for the iris boundary location and it will diminish the influence of the eyelids while performing the circular Hough transform, and all edge pixels in the edge map, defining the circle are not required for successful localization. These claims more proficient and perfect circle localization, because there are few edge points in the edge map required to cast votes in the Hough space. However, the Segmentation process was not able to perfectly reconstruct the same pattern from images with varying amounts of pupil dilation, as the deformation of an iris results in small changes of its surface patterns.

4. NORMALIZATION

After the process of iris segmentation, the next step is normalization. From the process of normalization, the segmented image of the eye will give the value radius pupil and the iris. This image will be cropped base on the value of iris radius, so that the unwanted area will be removed (e.g. Sclera and limbic), Arcus senilis is described[3] as a yellowish white ring around the cornea that is separated from the limbus by a clear zone 0.3 to 1 mm in width. Normally the area of white ring (Arcus Senilis), occurs from the sclera/iris up to 20 to 30 percent toward to pupil, thus this is the only important area that has to be analyzed.

In rectangular shape analyze can be done either from top to bottom or from bottom to top. (J. Daugman, 2004)[1] describes details on algorithms used in iris recognition. He has introduced the Rubber Sheet Model that transforms the eye from the circular shape into rectangular form and it is shown in Fig.1.

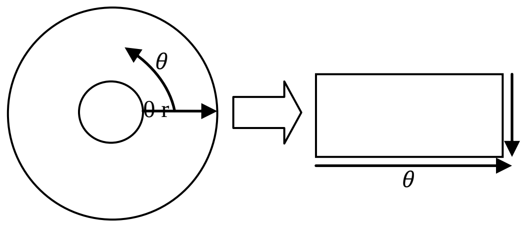

Figure 1: Rubber Sheet Model for iris Normalization

This model remap all points within an iris region to a pair of polar coordinates (r, θ) where θ the angle is [0, 2π]

and *r* is in the interval [0, 1]. The remapping of the iris image I (x, y) from the Cartesian coordinates to polar coordinates can be achieved by

$$I\big(x(r,\theta), y(r,\theta)\big) \rightarrow I(r,\theta) \qquad (3)$$

With

$$x(r,\theta) = (1-r)x_p(\theta) + rx_1(\theta)$$

$$y(r,\theta) = (1-r)y_p(\theta) + ry_1(\theta)$$

Where I(x, y) is the iris region image, (x, y) are the original Cartesian coordinates, (r,θ) are the corresponding normalized polar coordinates, and x_p,y_p Andx_1, y_1 Are the coordinate of the pupil and iris boundaries in the θ direction.

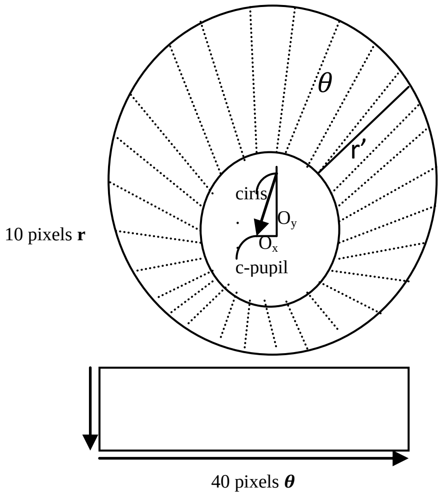

Figure 2: Outline of the normalization process with radial resolution of 10 pixels and Vertical resolution of 40 pixels.

Since the pupil can be non-matching with the iris therefore it needs to remap to recall the points depending on the angle around the pupil and iris. This formula is given by:

$$r' = \sqrt{\alpha\beta} \pm \sqrt{\alpha\beta^2 - \alpha - r_1^2} \qquad (4)$$

With $\alpha = o_x^2 + o_y^2$

$$\beta = \cos(\pi - \arctan\left[\frac{o_y}{o_x}\right] - \theta)$$

The shift of the center of the pupil relative to the iris center, this given by o_x, o_y and r' is the distance between the edge of pupil and edge of the iris at the angle θ around the region, and is the radius of the iris [11]. Whereas the remaining formula gives the radius of the iris region 'doughnut' as a function of the angle θ. A constant number of points are chosen along each radial line, hence a constant number of radial data points are considered, irrespective of thinness or wideness radius is at a particular angle.

The normalized pattern was created by backtracking to find the Cartesian coordinates of data points from the radial and angular position in the normalized pattern. From the 'doughnut' iris region, the normalization generates a 2D array with horizontal dimensions of angular resolution and vertical dimensions of radial resolution. It is difficult to do the analysis if the image is in the original form; therefore the image needs to be wrapped to transform the nature from circle to rectangular shape.

5. CHOLESTEROL DETECTION SYSTEM

The process starts with obtaining a number of normal eyes and cholesterol affected eye images (Arcus senilis). The next step is to segment out the actual iris region in a digital eye image.

The segmentation process needs to be done to segment the outer boundary for the iris and the inner boundary for the pupil. This can only be done by searching the center point of the pupil given by x and y axis as proposed by [10]. Hough transform is implemented to detect edges of the iris and pupil circle [10]. The algorithm processes the image with the Matlab software; the image from the database gives a wrong detection on pupil boundary because segmentation on a pupil is on the illumination light rather than segmenting the pupil boundary. This will fail to determine the edge of the pupil, but it will detect the edge of the impurity illumination light, which will affect the segmentation quality of eye image, cause imperfection in detecting the iris and pupil boundary region of the eyes.

But luckily the significant area of white ring (Arcus Senilis) position at the boundary of the sclera or iris up to the pupil, so as long as the segmentation done correctly on the iris it can considered succeed. In this process of segmentation, image will be crop based on the value of iris's radius.

Even though the pupil boundary is not accurately detected in this segmentation process, these images still can be accepted since the presence of cholesterol normally occur from limbic up to the pupil which is 30 percent of the overall normalization image. Therefore, for this kind of segmentation, we consider the correct segmentation of iris boundary rather than pupil boundary segmentation. (The border of the iris) so this result can be used.

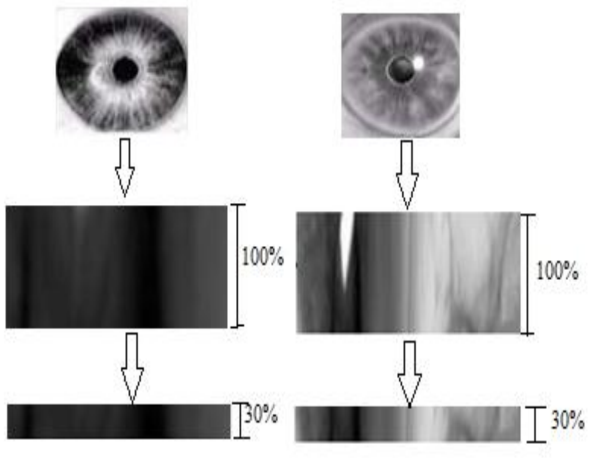

Figure 3: Illustration of normalization and cropping process on normal eye and cholesterol affected eye.

Next, the image has to be analyzed and this can only be done if it is transformed to normalized polar coordinates using Rubber Model [1]. Since the "sodium ring", terminology given in Iridology, or Arcus senilis for the grayish or whitish arc in the iris are only available at the bottom of this coordinate, thus only 30% of the iris part is considered in the normalization.

Lastly, to determine whether the eye has the ring, and image histogram has to be plotted .The OTSU's algorithm assumes the image contains two classes of pixels that is foreground and background and finds the optimum threshold separating these two classes so that their combined spread within-class variance is minimal [13].

6. RESULTS

A clear view for this automated detection of cholesterol presence system shows the entire process of the cholesterol detection system using iris recognition and image processing algorithm.

This process comprises the following procedures step by step:

a) Eye images acquired from a database or from digital camera.

b) Process of the pupil and iris localization and segmentation, for extracting the required iris region.

c) Attain normalization process on the segmented iris from the circular shape to rectangular shape with full image.

d) Crop the resulting iris image obtained from the process of normalization to 30% of full image from the top or bottom as required.

e) Analyze the iris image after cropping to get the histogram value.

f) The histogram for normal image the values are concentrated near the lowest intensity level (near to 0) and for the image having cholesterol ring is having the more values concentrating in the area of higher intensity (near to 255).

g) Results "Sodium ring detected and Arcus Senilis Positive" or "Sodium ring not detected and Arcus Senilis Negative" will be displayed in MATLAB window.

Here, sodium ring refers to the cholesterol ring.

The result is based on the eigenvalue obtained in the automated detection of cholesterol presence system. The algorithm output will be either "sodium ring is detected" or "sodium ring is not detected" depend on the sampling eye images processed by the automated detection of cholesterol presence system.

By using this cholesterol detection system will determine either someone have the symptom of the cholesterol presence at higher level (that is Arcus senilis positive) or not. The result is displayed in the command window, yet the result is displayed in the command window, yet the program can be executed and display using a Graphic User Interface (GUI), where MATLAB has the tools to perform it.

Table 1: Accuracy (%) of Classifiers used for Automated Detection of Cholesterol Presence

No. of training iris image samples	Accuracy of classifiers (%)			
	Multilayer Perceptron	Naïve Bayes	ADTree	Zero R
20	90	90	95	90
25	92	92	96	92
30	96.67	90	96.67	90
35	97.14	91.43	97.14	88.5714
40	95	92.5	97.5	87.5
46	97.83	93.48	97.83	82.61

The above table shows the accuracy of four different classifiers in percentage obtained after applying classifiers on automated detection of cholesterol presence system for several training data sets containing both cholesterol affected as well as normal eye images. Two observations can be made from the above table. First is the ADTree Classifier is the most suitable classifier for automated detection of cholesterol presence system in terms of getting higher percentages of accuracy for 10 cross validations.

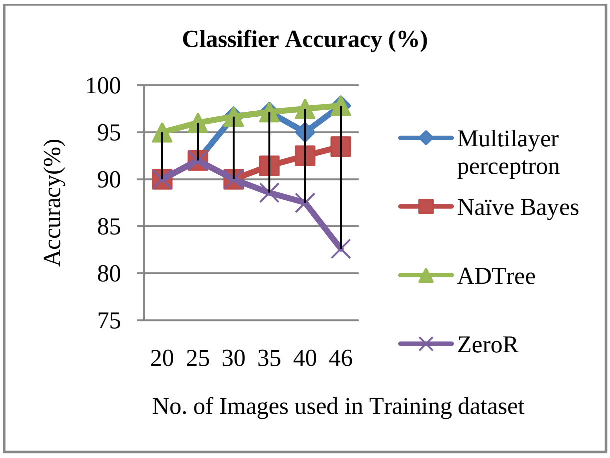

Figure 4: Graphical Representation of Classifier Accuracy.

An alternating decision tree is a collection of decision nodes and prediction nodes. Decision nodes denote a predicate condition. Prediction nodes hold a single number. The prediction nodes can be present in an ADTrees as both root node and leaf node.

An instance is classified by an ADTree by traversing all paths for which predicate conditions in all decision nodes are satisfied as true and summing any prediction nodes that are navigated. This classifier is different from binary classification trees such as Classification and regression tree (CART) or C4.5 in which an instance follows only one path through the tree.

The ADTree classifier supports two-class problems. The number of boosting iterations needs to be manually adjusted to suit the dataset and the desired complexity and accuracy tradeoff.

Table 2: Confusion matrix of ADTree Classifier

No. of training iris image samples	Confusion matrix of ADTree Classifier			
	TP	TN	FP	FN
20	1	18	0	1
25	1	23	0	1
30	2	27	0	1
35	3	31	0	1
40	4	35	0	1
46	7	38	0	1

Table 2 shows the confusion matrix for ADTree classifier when it is implemented for ADCP for several training data sets. The observation can be made from the above table is we are getting higher accuracy as we are increasing the number of training samples in the dataset.

Table 3: ADTree Classification Performance Evaluation

No. of training iris image samples	ADTree classifier performance			
	Accuracy (%)	Specificity (%)	Error rate (%)	Precision (%)
20	95	50	5	100
25	96	50	4	100
30	96.67	66.67	3.33	100
35	97.14	75	2.86	100
40	97.5	80	2.5	100
46	97.83	87.5	2.17	100

Table 3 shows the performance evaluation of ADTree classifier applied on ADCP for the different training data set. Here we are interested in the accuracy, precision, Specificity as well as precision.

7. CONCLUSION

This study introduces a non-invasive method using iris recognition algorithms to detect the presence of cholesterol level in the human body by the sign of existence Arcus senilis in iris pigmented. It can prove an advantageous method for the cholesterol detection than the available techniques for measuring the cholesterol level in the human body. Similar opinion support by Iridology practitioner call this symptom as sodium ring refers to Arcus senilis signs of cardio heart diseases (CHD). The algorithm had been tested on more than 70 samples of normal and abnormal eye images.

The entire process of automated detection of cholesterol presence system, developed using MATLAB coding refers to Mr. Libor Masek's work for iris recognition algorithm. However this work uses only a single method to determine the arcus senilis i.e. the sign of cholesterol presence which is using OTSU method with histogram analysis.The improvement can be done for detecting the stages of cholesterol presence and to determine the eye problem due to other type of eye diseases such as cataract, glaucoma, diabetic, tumor etcetera. Other method can be used for determines the arcus senilis region such as using nntool for neural network in MATLAB for detecting either normal or diseases eye (arcus Senilis).

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