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Detection of Kidney Condition Using Hidden Markov Models Based on Singular Value Decomposition

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Abstract

The frequencies of chronic kidney disease are likely to continue to increase worldwide. So people need to take a precaution, which is by maintaining kidney health and early detection of renal impairment by analyzing the composition of the iris is known as iridology. This paper presents a novel approach using a one-dimensional discrete Hidden Markov Model (HMM) classifier and coefficients Singular Value Decomposition (SVD) as a feature for image recognition iris to indicate normal or abnormal kidney. To accelerate algorithms and reduce computational complexity and memory consumption in hardware implementations, we used a number of SVD small coefficients and 7-state HMM for the image of the model configuration. The system has been examined on 200 iris images. The total images of the abnormal kidney condition were 100 images and those for the normal kidney condition were 100 images. The system showed a classification rate up to 100% using total of image for training and testing the system unspecified, resize iris image 56x46 pixels, coefficients of singular values consists of orthogonal matrix is (1,1) and diagonal matrices are (1,1) and (2,2), quantized values [18 10 7], and classify by 7-state HMM with .pgm format database.

Keywords: iridology, SVD, HMM

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1. Introduction

One part of the human bodies that are unique and can be used as the system identifier is iris of the human eye. The condition of the organ or the level of a person's health can be known through the iris based iridology. Iridology is a science that studies signs contained in the network structure of the iris as a reflection of the condition and various organs and systems in the body.

The frequencies of chronic kidney disease are likely to continue to increase worldwide. In response to this, PERNEFRI (Society of Nephrology Indonesia) appealed to the public to take precautionary action by maintaining kidney health and early detection of renal impairment [1]. Therefore, we chose to make a system for early detection the kidney condition through the iris image.

This paper presents a novel approach using a one-dimensional discrete HMM (Hidden Markov Model) as a classifier and coefficients SVD (Singular Value Decomposition) as a feature for image recognition iris. We used the 7-state HMM for the image of the model configuration. To accelerate algorithms and reduce computational complexity and memory consumption in hardware implementations, image format segmentation kidney area on the iris image in .jpeg with different sizes changed format and size become .pgm and 56x46pixels which is then used in a number of SVD small coefficients. Results of calculation of SVD coefficients are then used as input to the HMM.

Previous research on detection of kidney condition has been done. The classification uses edge detection and segmentation floating with 20 images iris tested reached 95% [2]. Research using Neural Networks Learning Vector Quantization has training accuracy 100% and testing accuracy 93.75% [3].

Previous research on image recognition with SVD method and HMM already been done. Retina recognition, design of blood disease recognition, and ABO blood types recognition using HMM method have an accuracy rate of up to 100% [4-6]. Face recognition system using HMM achieve recognition accuracy rate of 84.28%, with a database of 70 images of 10

individuals with each individual having 7 different variations of expression [7]. Face recognition using SVM and HMM method has an accuracy rate of 97.78% for the ratio of 50:50 training data image and 100% for the ratio 60:40 training data image [8]. Therefore we design a system to detect the kidney condition through iris image using HMM based on SVD as features extraction method. Where the SVD will be used to extract iris image features and HMM will be used for iris image classification showed kidneys in normal or abnormal conditions. With the combining of SVD and HMM, the detection results obtained will be more accurate.

2. Research Method

2.1. Iridology

Iridology is the science of analyzing signs such as color, and structure of the iris to obtain important information about the **status** of person's health. Iris is a circular disc-shaped tissue located in front of the lens. Iris has specific advantages, which can record all state organs, body construction, as well as **psychological condition**. Trace recordings relating to levels of intensity or deviation organs caused by disease recorded in a systematic and patterned on surrounding area of iris. It can be used as a practical guide to diagnosis of various diseases.

The kidney is one of organ that is located in both irises. Iris map is divided into sectors and each sector is associated with certain body parts. Kidney area in the iris of the left eye is located at 6 and 7 o'clock, while the **right eye iris** located at 5 and 6 o'clock. Figure 1 shows a map of the right and left eye by Dr. Bernard Jensen, D.C.

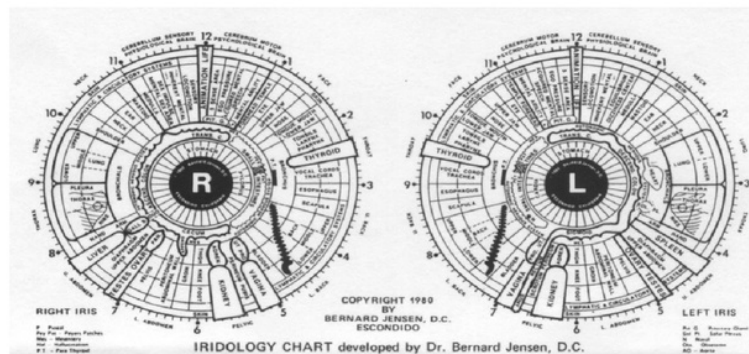


Figure 1. Iridology Chart developed by Dr. Bernard Jensen, D.C. [9]

2.2. Data Sets and Image Pre-processing

For this study, 200 iris images consist of kidney condition types (abnormal and normal) was prepared from 20 persons. There are 10 images per person. So the image dataset of the abnormal kidney condition is 100 images and for the normal kidney condition is 100 images. Every person were taken at different times, varying the lighting, eyes expressions (eyes opened perfectly or slightly closed), and pupil image detail (shrink and swell due to camera flash light). The images are in .jpeg format. The size of each image is 2592x1944 pixels.

For the first step, image dataset is divided in two parts per person. So the total image for training is 100 images and for testing are 100 images. Next step, SVD is used to extract features from iris images and HMM is used to build the classification model. HMM is trained with extracted features from five iris images and tested with five iris images that different with the images used in training. The model returns probabilities of how likely the iris images recognized as abnormal kidney condition and normal kidney condition.

This system using the data input from the colour iris image RGB transformed into a grayscale image [10]. Before it can be used for further image processing, part of the iris image on all parts of the eye is separated through the first iris image localization process. Results of the iris image segmentation still have a low level of contrast and iris fibres image detail is less

clear that produce low accuracy. Therefore, the image of the iris contrast enhanced using Adaptive Histogram Equalization [11]. This method aims to obtain images with good contrast but will not damage the overall image quality. The image then resized to 56x46 pixels as represented on Figure 2(c). In order to balance the flash effect and reduce the noise, a minimum order nonlinear-static filter is used. The filter gives smoothing effect and reduces the image noise. An example result of the applied filter is presented on Figure 2(d).

2.3. Selection of Region of Interest (ROI)

ROI is the area used to extract features. For this research, the ROIs are the kidney organ on the iris images. All ROIs are manually selected from the image by a well-trained operator and confirmed by iridologist. A ROI of many size pixels was extracted with a mass centred in the window [12]. Figure 2(a) and 2(b) represents the ROI of iris image to get kidney organ. The flowchart of kidney organ condition classification using HMM is presented in Figure 3.

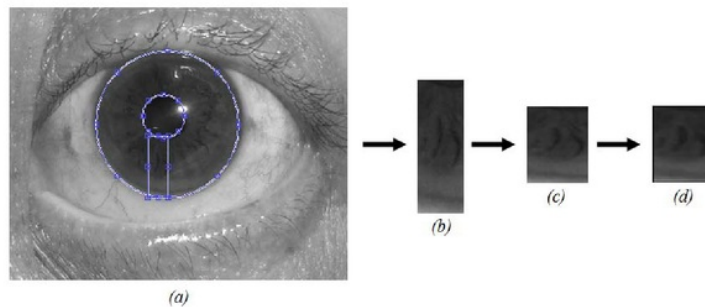


Figure 2. (a) The selected ROI of image; (b) The ROI of Iris for Kidney Organ; (c) The resized iris images to 56x46 pixels; (d) The effect of the smoothing filter

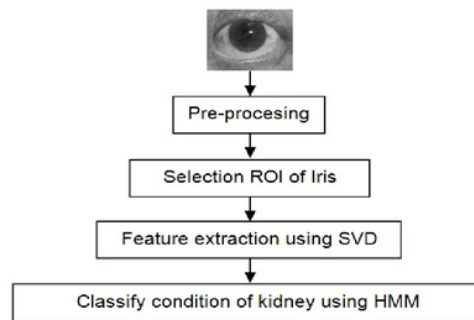


Figure 3. Stage of the kidney organ condition classification method

2.4. SVD for Feature Extraction and Quantization

SVD is a tool often used in signal processing and statistical data analysis. Singular values from given data matrix contain the information about noise levels, energy, rank of matrix, etc. Singular vectors of matrix are the span bases of matrix, and orthogonally normal, they can show few features of the patterns in the signal. SVD gives a different way to extract algebraic features from an image vector. SVD from $m \times n$ matrix X is defining by:

$$X_{min} = U_{min} * \Sigma_{min} * (V_{min})^T \quad (1)$$

Where U and V are orthogonal matrices and Σ is a diagonal matrix of singular values [13]. Coefficients $U(1,1)$, $\Sigma(1,1)$ and $\Sigma(2,2)$ are chosen by trial and error as the most relevant features of the image [8]. Each block is represented by a vector of observation with n elements:

$$C = \text{coeff}_1, \text{coeff}_2, \dots, \text{coeff}_n \quad (2)$$

Every element of (2) is quantized into D_i distinct levels. The difference between two quantized values is:

$$\gamma_i = \frac{\text{coeff}_{imax} - \text{coeff}_{imin}}{D_i} \quad (3)$$

Where coeff_{imax} and coeff_{imin} are maximum and minimum of the coefficients in all observation vectors. Every element of vector C is replaced with its value that has been quantized:

$$qt_i = \left\lceil \frac{\text{coeff}_i - \text{coeff}_{imin}}{\gamma_i} \right\rceil \quad (4)$$

Distinct (D_i) values used in (4) to quantize coefficients $U(1,1)$, $\Sigma(1,1)$, $\Sigma(2,2)$ are 18, 10, and 7. These values are chosen based on the experimental results in [8]. Next step is to represent each block by one discrete value named *label*:

$$\text{label} = qt_1 * 10 * 7 + qt_2 * 7 + qt_3 + 1 \quad (5)$$

Where qt_1 , qt_2 and qt_3 are the quantized values. If the coefficients (2) are all zero, the *label* value is one and if quantized the first feature $U(1,1)$ into 18 levels, the second feature $\Sigma(1,1)$ into 10, and the third feature $\Sigma(2,2)$ into 7, leaving 1260 possible distinct vectors. So the *label* will be given the maximum value 1260. As the result, each iris image is represented by an observation sequences with 52 or 60 observed states, equivalent to blocks number. The 7-state HMM model use these observation vectors as input.

2.5. HMM for Training and Classification

HMM is modeling the probability of a system to look for parameters Markov (hidden), which is not known to acquire the systems analysis. HMM is able to handle the change statistics of the image by modeling the elements using probabilities. HMMs are usually used to model one dimensional data. HMM also be used for temporal pattern classification system. For example, voice recognition, handwriting, gestures, bio informatics, sentence compression, etc. Every HMM is associated with hidden states and observable sequence, generated by the hidden states individually.

Classification process is based on frontal iris view. From top to bottom the iris image can be divided into seven regions which each is assigned to a state in a left to right one dimensional HMM. Figure 4 show the seven iris regions. Figure 5 shows equivalent one-dimensional HMM model for a divided image into seven distinct regions as seen in Figure 4.



Figure 4. Iris regions from top to bottom

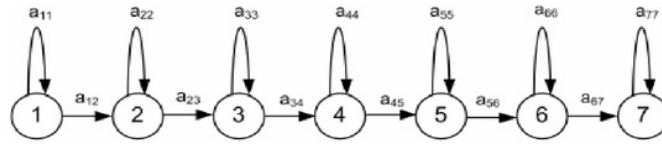


Figure 5. A one dimensional HMM model with 7-states for an iris image by seven regions

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The fundamental factors to build a HMM model are as follows:

- a) $N=|S|$ is the number of states in HMM model, where $S = \{s_1, s_2, \dots, s_N\}$ is number of all possible states. The state model at any random time t is given by $q_t \in S, 1 \leq t \leq T$ where T is the observation sequence lengths.
- b) $M=|V|$ is the number of symbols of different vector observations, where $V = \{v_1, v_2, \dots, v_N\}$ is number of all possible vector feature v_i . The feature vector at any random time t is given by $o_t \in V$.
- c) 'A' is the probability of state transition matrix which given by $A = \{a_{i,j}\}$ where

$$a_{i,j} = P[q_{t+1} = s_j | q_t = s_i], 1 \leq i, j \leq N, 0 \leq a_{ij} \leq 1 \tag{6}$$

$$\sum_{j=1}^N a_{ij} = 1, 1 \leq i \leq N \tag{7}$$

So the transition matrix A as shown below on Table 1.

Table 1. Transition Matrix A-7 state[14]

a_{ij}	1	2	3	4	5	6	7
1	0,5	0,5	0	0	0	0	0
2	0	0,5	0,5	0	0	0	0
3	0	0	0,5	0,5	0	0	0
4	0	0	0	0,5	0,5	0	0
5	0	0	0	0	0,5	0,5	0
6	0	0	0	0	0	0,5	0,5
7	0	0	0	0	0	0	1

2

- d) 'B' is the probability of the observational vector matrix which given by $A = \{b_j, k\}$ where

$$b_j(k) = P[o_t = v_k | q_t = s_j], 1 \leq j \leq N, 1 \leq k \leq M \tag{8}$$

1

And the emission matrix B is:

1 2 ... 1260

$$B = \begin{bmatrix} 1 & 1 & \dots & 1 \\ 1 & 1 & \dots & 1 \\ \vdots & \vdots & \ddots & \vdots \\ 1 & 1 & \dots & 1 \end{bmatrix} / 1260$$

- e) ' π ' is the distribution of the initial state, i.e $\pi = \{\pi_i\}$ where

$$\pi_i = P[q_1 = s_i], 1 \leq i \leq N \tag{9}$$

Assuming that a block moves from top to bottom of the iris images and in any time that block shows one of the seven regions. The block is shifting consequently and cannot miss a state. For example, a block in the state "s₂", the next state cannot be "s₁", but will always at the

state "s₃". Thus the probability of moving from one state to the next state is 50% and remain in the current state is 50%. Initial state of the system is "s₁" with a probability of 1. And the final state of the system is always "s₇". So the π matrix is:

$$\pi = \begin{matrix} s_1 s_2 s_3 s_4 s_5 s_6 s_7 \\ [1 & 0 & 0 & 0 & 0 & 0 & 0] \end{matrix}$$

In short notation HMM is defined as follows:

$$\lambda = (A, B, \pi) \quad (10)$$

π , A and B matrices define the iris model that is trained with the dataset.

3. Results and Analysis

3.1. Comparing Results for Different Total and Size of Training Image

The classification system was tested on a machine with Core i3 CPU 1.80 GHz, 3.89 GB Ram and 64-bit operating system. The best results are shown on Table 2. Based on the total of image for training and testing, image with sized 56x46 pixels gives better classification result rate up to 100%. The intuition behind this result is that total of image for training and small iris image details are not important and may even worsen the classification.

Table 2. Comparing Results for Different Total and Size of Training Image

Total of Image For Training	Total of Image For Testing	Classification Rate	
		For 56x46 pixels	For 64x64 pixels
100	100	100%	15%
120	80	100%	15%
140	60	100%	15%
160	40	100%	15%
180	20	100%	15%

3.2. Classifications Rate For Different Features

Selection and arrangement of the SVD features is crucial for the performance of the HMM system as it's presented on Table 3. Coefficients $U(1,1)$, $\Sigma(1,1)$ and $\Sigma(2,2)$ are chosen by trial and error as the most relevant features from images and gives better classification rate up to 100%.

Table 3. Classifications Rate for Different Features

1st	Used Values		Classification Rate
	2nd	3rd	
$U(1,1)$	$\Sigma(1,1)$	$\Sigma(2,2)$	100%
$\Sigma(3,3)$	$\Sigma(1,1)$	$\Sigma(2,2)$	20%
$U(1,1)$	$\Sigma(1,1)$	$V(1,1)$	10%
$U(2,2)$	$\Sigma(1,1)$	$\Sigma(2,2)$	60%
$U(1,1)$	$\Sigma(1,1)$	$V(2,2)$	5%
$\Sigma(1,1)$	$\Sigma(2,2)$	$\Sigma(3,3)$	5%

3.3. Classification Rate For Different Quantized Values

The quantization levels 18, 10 and 7 helps make the algorithm faster, but with lower image resolution. With that such quantization levels it will be difficult or impossible to classify iris images with bad quality. On Table 4 we can see that the quantization levels [18 10 7], [7 7 7] and [18 18 18] gives better classification rate up to 100%. While quantization levels [32 32 32] and [64 64 64] occurs computation problem because those values can't using in HMM training process where value of sequence must consist of integers between 1 and 1260.

Table 4. Classifications Ratefor Different Quantized Values

1st	Quantized Values		Possible Combinations	Classification Rate
	2nd	3rd		
18	10	7	$18 \times 10 \times 7 = 1260$	100%
7	7	7	$7 \times 7 \times 7 = 343$	100%
18	18	18	$18 \times 18 \times 18 = 5832$	100%
32	32	32		computation problem
64	64	64		computation problem

4. Conclusion

Detection of kidney condition through the iris image can be done by using SVD as a feature extraction and HMM as a classifier. The experiments showed a classification rate up to 100% by using total of image for training and testing the system unspecified, resize iris image 56x46 pixels, coefficient values $U(1,1)$, $\Sigma(1,1)$ and $\Sigma(2,2)$, quantized values [18 10 7], and classify by 7-state HMM with .pgm format database. These classification results are obtained using chosen optimized system parameters after a comprehensive study about their affect discussed in this paper.

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