Classification of Cataract Slit-lamp Image Based on Machine Learning

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***Abstract*— Cataracts are diseases caused by the presence of proteins in the lens that form abnormal and gradually enlarged clumps that will interfere with vision by blocking the light entering through the lens. Identification of cataracts is done by taking the image of the eye with a slit-lamp tool from the front of the eye. Slit-lamp images can provide information about the condition of the pupils that can only be analyzed by the doctor manually based on doctor's observation and doctor's experience that can cause different analysis in determining the actual eye condition. Things that are considered by the doctor in analyzing cataracts are the level of opacity in the eyes and the area covered by the turbid. Identification and classification with slit-lamp images can be performed better and more accurately using image processing techniques. Firstly, the grayscale method, median filter method and canny method is used to preprocess the slit-lamp images. Next, the hough circular method is used to automatically segment pupil from slit-lamp images. After the segmentation process, we use pixel scanning to extract mean intensity and uniformity from the pupil image. After the feature extraction process, classification is done by single perceptron based on the extracted feature. This research is expected to help the doctor to do cataracts classification so that the classification process will be easier and more accurate. Based on the test result show that the accuracy of the system is 96.6%.**

Keywords*— *cataract; segmentation; feature extraction; machine learning

I. Introduction

Cataracts are analyzed by the doctor through slit-lamp results. The analysis is done manually based on doctor's observation and experience. This makes it possible that doctor will have multiple analyzes about classification result, making it difficult to determine the actual state of the eye. Therefore we need a system that can analyze the pupil condition accurately to perform cataract classification. [1]

According to data from the Ministry of Health of the Republic of Indonesia, Indonesia is among the countries with the highest number of blind people due to cataracts in the world, especially Southeast Asia. The latest data, 1.5 percent per two million population are cataract patients and each year 240 thousand people are threatened with blindness. The number of people with cataract disease in Indonesia is as large as the number of people in Indonesia who are elderly in the year 2000 which is estimated about 7.4% of the total population in Indonesia or about 15.3 million people who experience cataracts. The number that has been dissected in 2015 is 4,425 eyes.

In the medical world, medical imaging technology has been widely used to obtain information about the human body. Medical imaging is expected to provide a better degree of accuracy for the identification and classification of cataract disease. Medical imaging generally includes preprocessing, image segmentation, feature extraction, identification and classification. The results of the classification will be used by the physician for both patient care and surgical considerations.

Examination Slit-lamp is one way to identify cataracts by knowing the condition of the pupils in the eye. Slit-lamp is a medical device that is able to see the state of the eye with lighting lamps. The lamps facilitate examination of the anterior segment or frontal structures and posterior segments of the human eye covering the eyelids, sclera, conjunctiva, iris, lens, and cornea. In general, cataract examination is done by Slit-lamp examination and continued with physician analysis [2] based on the image of Slit-lamp. As for the classification is done based on doctor's observation on the turbid area of the pupil.

This research will be done by identification and classification of cataracts with Slit-lamp image improvement step in order to provide optimal input on identification system and classification. Followed by Hough Circular method to find the location of pupils on the eyes and continued with feature extraction Mean Intensity and Uniformity on the image to do the classification by training on features that have been extracted using Neural Network Perceptron. It is expected that this system can be used to facilitate cataract classification system.

II. METHODOLOGY

To perform the classification of cataracts performed several stages including load image to insert the image slit-lamp on the system, preprocessing to improve image quality with binarization method, median filter and edge detection method, segmentation to get the location of the pupil and crop the pupil by using hough circular method, after the segmentation process, perform feature extraction to get some information from the pupil image such as intensity information and the opacity areas in the pupil area, doing machine learning using the features available to get the weights that will be used to classify the cataracts into some classes.

Figure 1 is a procedure of the system used to classify cataracts with preprocessing stages, segmentation, feature-extraction and classification method.

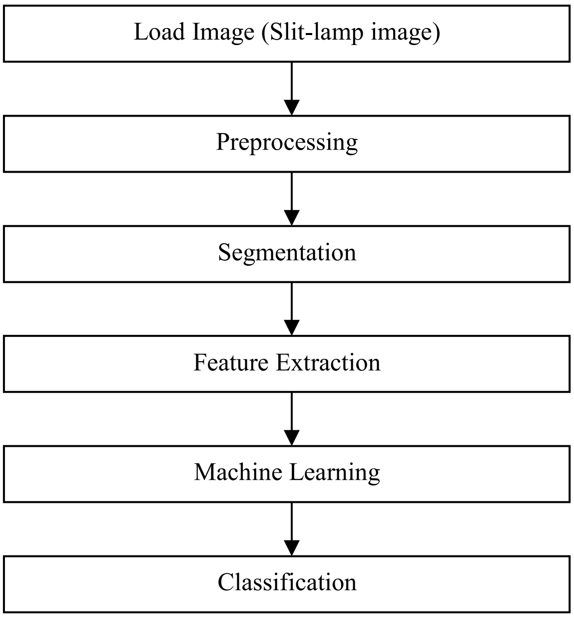


Fig. 1. System Diagram

A. *Load Image*

The input used in this system is a Slit-lamp image. Slit-lamp images will be obtained from Dr. Sjamsu Clinic in Surabaya. Image retrieval is done by observing light on the Slit-lamp device so that light does not affect the pupil area of the eye. Slit-Lamp light should be placed or positioned outside the pupil area by adjusting the image taking position. The image is taken with JPG extension and will be resized according to system requirement. Figure 2 is the result of a slit-lamp examination.

Fig. 2. Slit-lamp image

B. *Preprocessing*

Preprocessing is used to reduce noise, improve lighting effects and sharpen the edges of images. These are some preprocessing stages:

1) *Grayscaling*

The image input obtained from the Slit-lamp capture is an image with RGB specification. While to process the image in the segmentation and feature extraction required image with a specification of grayscale value 0-255 [3] so that in accordance with the needs of the next process. The grayscaling formula can be represented as :

$$Gray\ [i] = \frac{R[i]+G[i]+B[i]}{3}$$

Result of *grayscaling* [4] process can be seen in a Figure 3.

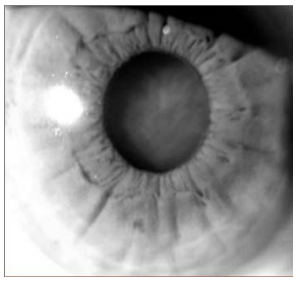


Fig. 3. Grayscale image

2) *Median Filtering*

Median Filtering is a non linier method that effective to reduce the noise. Median Filtering moving through pixel by pixel in an image, replacing each value with the median value of neighboring pixels. Median filtering is calculated by first sorting all pixel values from window to numerical sequence, and then replacing pixels with pixel middle values. The median filtering formula can be representated as:

$$f(x,y) = median_{(s,t)\in S_{xy}} \{g(s,t)\} \qquad (1)$$

Result of *median filtering* process can be seen in a Figure 4.

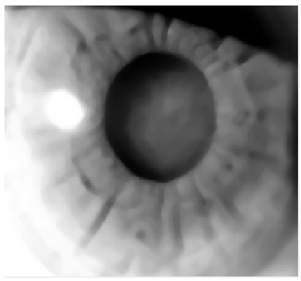


Fig. 4. Median filter image

C. *Segmentation*

Classification of cataracts can be done by considering the condition of pupils in the eye so that required segmentation process to separate the pupil with the whole image. This is preprocessing stage:

1) *Hough Circular*

Hough Transform is an image transformation technique that can be used to isolate or in other words acquire features of an image. Since the purpose of a transformation is to acquire a more specific feature, Classical Hough Transform [5] is the most commonly used technique for detecting curved objects such as lines, circles, ellipses and parabolas. The main advantage of the Hough transform is that it can detect a edge with a gap at the feature boundary and quickly without being unaffected by noise. If the object is a circle, then the Hough circle is used. The procedure used in detecting a circle is the same as the Hough transformation of the line object [6], but it is done on a more complex dimensional space that is in the 3D space parameter (Xo, Yo, R). Where Xo and Yo are the central coordinates of the circle and r is the radius of the circle. Here is the equation of the hough circular method:

$$(x - x_0)^2 + (y - y_0)^2 = r^2 \qquad (2)$$

Result of segmentation [7] process can be seen in a Figure 5.

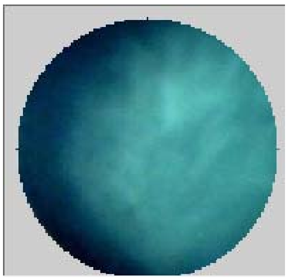


Fig. 5. Pupil image

D. Feature Extraction

Feature extraction is performed to find the mean intensity and uniformity values in the pupil image. These features are obtained by looking at the histogram value of the pupil area. The histogram used is a gray histogram where the gray histogram contains the gray pixel value in an image that has a range of 0-255 on each pixel. Here are the features that will be extracted on feature extraction [8]:

1) Mean Intensity

Mean intensity is the average intensity of gray values present in the pupil area. Mean intensity can be calculated by summing all the gray values in the pupil area then divided by the number of pixels in the pupil area like the following mathematical equations:

$$m = \sum_{i=0}^{L-1} \left(\frac{I(i)}{N}\right) \qquad (3)$$

Here 'm' is the average intensity, 'I' is the possible intensity, 'N' is the number of pixels in the image, and 'L' is the value of the possible intensity level. Mean Intensity indicates a turbidity area in the pupil or indicates cataract.

2) Uniformity

Uniformity is the value of the similarity of pixels present in the pupil. Uniformity can be calculated using the same gray value in one area like the following mathematical equations:

$$U = \sum_{i=0}^{L-1} \left(\frac{H(i)}{N}\right)^2 \qquad (4)$$

Here 'U' is a measure of uniformity, 'H' is the probability histogram of the intensity level in the drawing region, and 'N' is the number of pixels in the drawing area, the index used is the index 0 to L - 1 into the corresponding histogram, and 'L 'is the value of the possible intensity.

Result of feature extraction process can be seen in a Figure 6.

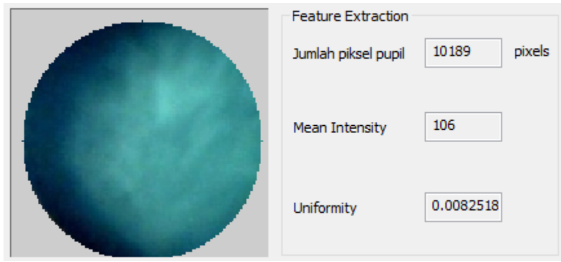


Fig. 5. Feature Extraction

E. Machine Learning

Machine learning is used to classify cataracts into several classes. Machine learning is done by using training data that has been classified by the doctor as a reference in doing cataract classification. Here are the method used to do system training:

1) Single Perceptron

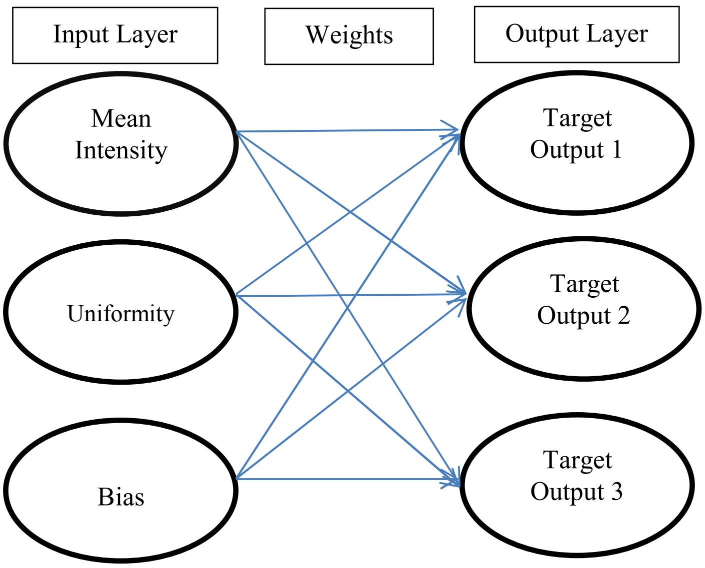


Fig. 6. Single Perceptron Training Model

In Figure 6, it can be seen that there are 9 weights that will be trained based on mean intensity, uniformity and bias. This training process will produce 3 outputs that match the targets that have been determined in the training process. The training process will succeed if the error value in the training process reaches 0. These trained weights will be used to classify independently in the classification process. In perceptron training there is normalization done so that the mean intensity and uniformity feature is worth between 0-1. The target of the training process is normal (1.0.0), mild-cataract (0,1,0), severe-cataract (0,0,1).

F. Classification

Classification is done by entering data testing on the classification system that has been established in the previous training system. The results of the classification include normal, mild, severe and unidentified / unknown. Based on the features of training data drawn from Dr. Sjamsu Clinic in September-October 2017 and based on figure 6 can be seen that the difference between normal eye, mild cataract, severe cataract is in pupil color. In image processing, the average value of intensity will be different for each class. In normal eyes the intensity will tend to be small due to the color on the pupils which tend to be dark and the uniformity value of pixels / uniformity will tend to close to 1 because the pixels in the eye are almost uniform at the same intensity value. In the eyes of mild cataract and severe cataract the intensity value will tend to be larger because there is a lighter intensity on the pupil area by the turbidity area of the pupil and the pixel uniformity value will be smaller because the intensity value contained in the pupil tends to have different values. The mean value of intensity and uniformity of each class can be separated so well that no multi-layer is required in the classification model. So mean intensity and uniformity can be written as follows [9]:

Mean Intensity: Normal <Mild <Severe
Uniformity: Normal> Mild> Severe

Neural network single layer perceptron can provide fast learning time but requires separate feature distribution between one class and another or there are no overlapping features.

G. Graphical User Interface

Graphical User Interface is used to facilitate medical personnel in using cataract classification system that will be done at Dr. Sjamsu Clinic. Here is a graphical user interface used for cataract classification in this research:

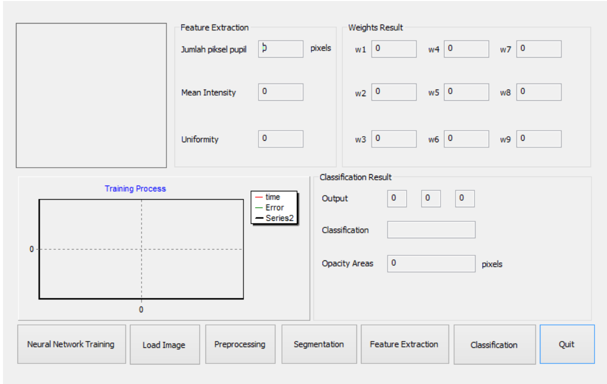
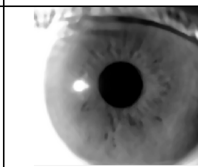
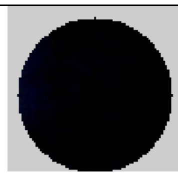
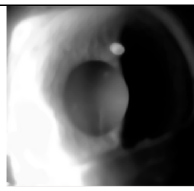
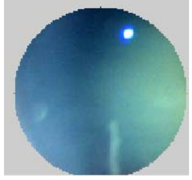
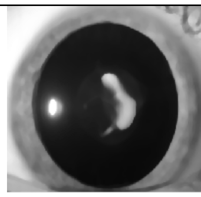
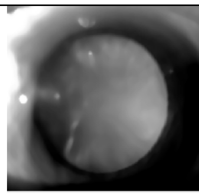
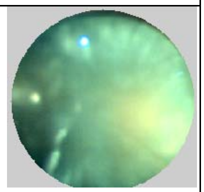
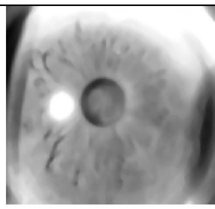
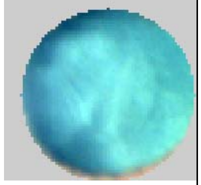


Fig. 7. Graphical User Interface

III. EXPERIMENTAL RESULT

In this section, will be explained about the final result of the system. Input data gathered from Dr. Sjamsu Clinic Surabaya. Table I show several data training preprocessing and segmentation result.

TABLE I. Preprocessing and Segmentation Result

No	Input Image	Preprocessing	Segmentation
1			
2			
3			
4			
5			

From table 1 it can be seen that preprocessing has been able to improve the image quality and segmentation process has been able to take the pupil part of the whole image.

Table II show data training feature extraction result. Here is a weight training on Neural Network Perceptron with 11 data (5 Normal, 3 Mild, 3 Severe) with the following features:

TABLE II. Feature Extraction Result

No.	Mean Intensity	Uniformity
1.	5	0.52
2.	6	0.42
3.	0	0.78
4.	4	0.87
5	0	0.98
6	126	0.008
7	55	0.016
8	125	0.0103
9	161	0.0065
10	183	0.00105
11	203	0.00136

Based on the features contained in table 2, the training process is done by Single Perceptron method to produce trained weights that are used for classification. After the training is done, the error graph appears as in Figure 8 below:

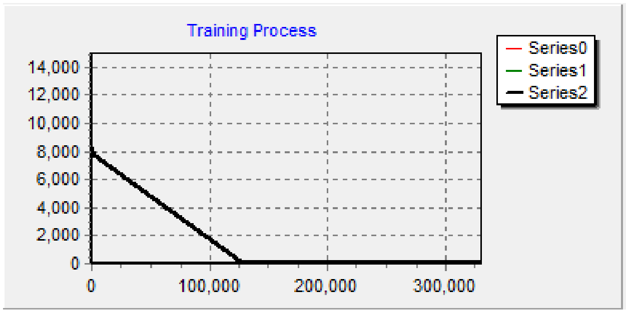


Fig. 8. Training Error Graph

Based on the graph in picture 8 the training process has been successfully done because the error in the training process has reached 0.

Table III shows the results of classification on 30 data. Classification is done by referring to the previous training process.

TABLE III. Feature Extraction Result

No	Medical Result	System's Output
1	Normal	Normal
2	Normal	Normal
3	Normal	Normal
4	Normal	Normal
5	Normal	Normal
6	Normal	Normal
7	Normal	Normal
8	Normal	Normal
9	Normal	Normal
10	Normal	Normal
11	Mild	Mild
12	Mild	Mild
13	Mild	Mild
14	Mild	Mild
15	Mild	Mild
16	Mild	Mild
17	Mild	Mild
18	Mild	Mild
19	Mild	Unidentified
20	Mild	Mild
21	Severe	Severe
22	Severe	Severe
23	Severe	Severe
24	Severe	Severe
25	Severe	Severe
26	Severe	Severe
27	Severe	Severe
28	Severe	Severe
29	Severe	Severe
30	Severe	Severe

Based on the 30 data testing, this system can classify 29 of 30 data correctly. It means that this system has 96.6 % of accuracy on 30 data test.

IV. CONCLUSION

The purposed of making this system is to do a cataract classification. Preprocessing has been successful in improving the image and segmentation has been successful in taking pupils from the entire image. The features of the pupils have been extracted and the classification training has been done successfully. The classification has been done on 30 data and has 3.33% of errors.

V. FUTURE WORK

This research can be improved by adding features that affect the classification of cataracts but the addition of features may cause overlapping features so that it will require additional layers on the neural network perceptron.

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