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DESIGN OF A CATARACT DETECTION SYSTEM BASED ON THE CONVOLUTIONAL NEURAL NETWORK

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ABSTRACT

Cataract, a condition characterized by clouding of the eye's lens, leads to decreased vision and potentially blindness. In Indonesia, it is the predominant cause of blindness, accounting for 81.2% of cases. Given the rising life expectancy, the incidence of degenerative diseases like cataracts is expected to increase. This research aims to develop a cataract detection system capable of classifying eye images as either indicative of cataracts or normal. Utilizing Convolutional Neural Networks (CNN) and RGB-based image processing—including edge detection techniques such as Canny and Prewitt—the system identifies eye contours. This facilitates image segmentation to ascertain the eye's condition. Therefore, image collection and processing models play a crucial role in this study. The research findings indicate that the system functions effectively, with a 98% success rate in accurately processing normal eye images through the CNN model without detecting cataracts. When tested using grayscale imaging, cataract-afflicted eyes—characterized by red spots in the images—were also successfully identified by the CNN model. These test results demonstrate that the designed cataract detection system can accurately classify images into normal or cataract-afflicted eyes with high precision. This system shows promise for use in early cataract detection, potentially helping to reduce the prevalence of cataract-related blindness in Indonesia.

Keywords: cataract eye, convolutional neural network, deep learning, image processing.

I. INTRODUCTION

THE most important organ in the human body is the eye, which functions as a vision device that records images and stores their memory in the brain. Vision is considered an invaluable gift from God, and the role of the eyes is very important in daily life. Currently, there are various disorders or diseases that can affect eye health [1]. Cataract is a condition where the lens of the eye becomes cloudy, resulting in decreased vision and blindness. Cataract eye disease often goes unnoticed by sufferers until noticeable physical symptoms, such as cloudiness in the lens, develop. This underscores the need for early detection so that appropriate treatment can be administered promptly. With the advancements in technology, artificial intelligence (AI) is now being leveraged to predict and detect health conditions, including cataract eye disease. The majority of cataract cases are attributed to the aging process.

According to data available on the Ministry of Health's website in Indonesia, around 8 million people have moderate to severe visual impairment, while 1.6 million people are blind. Between 1.7% and 4.4% of the population over 50 years old experience blindness, with varying degrees of severity. East Java recorded the highest prevalence of blindness at 4.4%, while Bali had a rate of 2.0%. More than 80% of blindness cases in Indonesia are preventable, and the main cause is cataract, which accounts for 81.2%."[2] Meanwhile, the trend of life expectancy in Indonesia continues to show a significant increase. The average life expectancy increased from 63 years in 1990 to 69 years in 2017. In fact, it is estimated that by 2045, the elderly population in Indonesia will increase by around 19.9% or reach 60 million people. This increase in life expectancy has the potential to cause an increase in cases of degenerative diseases, such as cataracts and other visual impairments that are often associated with conditions such as Diabetes Mellitus. Dr. Nila Djuwita Faried Anfasa Moeloek, Sp.M(K), an

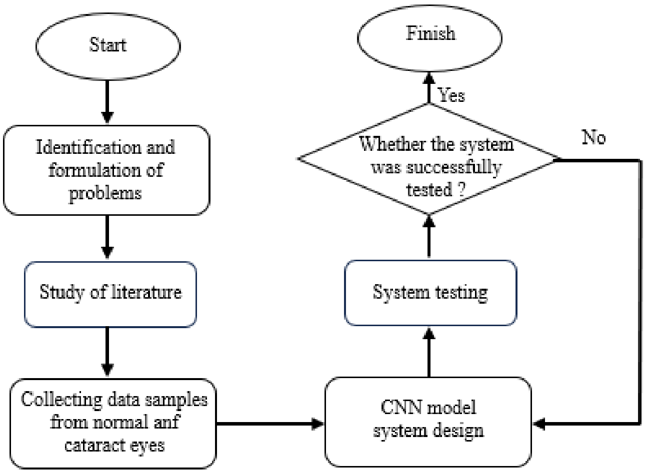


Figure 1. Research flow

ophthalmologist, says that these changes will have a significant impact on eye health, with an increase in degenerative diseases as a consequence [3]. Therefore, cataracts require early detection and understanding of the factors that can cause cataracts, to reduce the number of cataract sufferers in Indonesia.

With the development of technology, it is possible to recognize cataracts using digital images. The field of image processing deals with image transformation. Image processing aims to improve image quality. One of the first steps in the process is edge detection. The development of digital image processing techniques led to computer vision, a discipline that uses image processing to make decisions based on visual information from sensors. Its function parallels that of human vision, interpreting spatial data indexed in more than one dimension. Computer vision techniques can accurately mimic the function of the human eye and improve the human vision system [4]. This study employs various image processing methods, including the RGB method and edge detection, to detect cataract eyes. The RGB color space, commonly used in CRT monitors and many computer graphics systems, comprises three primary colors: red (R), green (G), and blue (B) [5]. Edge detection, a crucial technique in image segmentation, helps identify object outlines within an image, enhancing image details through processes such as gray level conversion, resizing, and thresholding. Image segmentation, another significant image processing technique, aims to separate an object from its background, facilitating easier object analysis and recognition, which often involves aspects of visual perception [6].

In our approach to detecting cataract eyes, we utilize the RGB method along with Canny and Prewitt edge detection methods to delineate the eye's contours. Following this, the image is segmented to determine whether the eye condition is normal or indicative of cataracts. This process involves collecting image data that will be integrated into the image processing model.

II. RESEARCH METHOD

This section discusses the Convolutional Neural Network (CNN), a branch of artificial intelligence within the field of Deep Learning. CNNs are commonly used for pattern recognition in images, virtual image processing, image extraction, and classification [7]. In the medical domain, CNNs are often utilized to modify image sizes of disease-related images, as well as to identify and annotate specific regions based on the disease imagery provided [8]. One of the key advantages of the CNN method is its efficiency in terms of cost and time. CNNs can detect diseases faster than other methods by classifying disease image data that has previously been fed into the model. Additionally, developing CNN technology is relatively economical as it primarily relies on knowledge and programming skills. This cost-effectiveness presents an opportunity for further development of CNN technology, potentially enhancing the accuracy and classification of patterns and images, especially in resource-limited research settings.

The research method of this study encompasses five stages, starting with problem identification and formulation, followed by a literature review, collection of data samples from both normal and cataract-afflicted eyes, system design utilizing the CNN model, and finally, system testing. A detailed description of these steps is presented in the form of a flowchart, as depicted in Figure 1. The following is an explanation regarding the research flow formed in the flowchart.

A. Problem Identification and Formulation

Problem identification involves formulating a problem based on the background presented in Chapter 1. This formulation is substantiated by proposing a solution that validates the research findings through the application of image data processing in a CNN model. This model is used for the detection and classification of image patterns in normal and cataract-afflicted eyes.

In this research, the problem formulation has been effectively addressed and verified through the development of a detection and classification system for normal and cataract eyes, utilizing the architecture of the CNN model.

B. Study of Literature

Subsequent steps involve conducting research and gathering information from various electronic and print media sources. In this study, literature reviews were sourced from multiple platforms to identify diverse reading materials that could inspire and inform the research, particularly those related to Deep Learning.

Deep Learning, a subset of machine learning, involves modeling data through a series of nonlinear transformation functions within highly layered structures [9]. Common applications of Deep Learning include image and sound recognition, as well as classification tasks [10].

Additionally, Deep Learning encompasses a technique known as transfer learning, which is notable for its ability to update models based on previously processed data. This facilitates faster data processing, as it allows for the incremental addition of data in manageable sizes. Transfer learning requires fewer training datasets and achieves greater accuracy through comprehensive and independent feature extraction. This adaptability is particularly advantageous in computing environments where data volume and complexity are significant factors [11]. The process of data handling in Deep Learning is illustrated in Figure 2.

Figure 2 illustrates that the Deep Learning structure incorporates multiple layers, which enhances its flexibility in updating data from previous processing efforts without needing to start from scratch. This attribute is particularly advantageous for handling big data, as Deep Learning processes data more rapidly than traditional machine learning methods. The layers within the Deep Learning architecture include [12]:

1. Input Layer: This layer consists of neurons that receive data inputs. In the illustration shown in Figure 2, there are three parts of neurons receiving inputs; each neuron in the neural network architecture serves as a node.
2. Hidden Layer: Acting as an intermediary, this layer consists of neurons that receive data from the input layer, process it, and then transmit it to the output layer.
3. Output Layer: This is where the final result of the processed input is displayed.

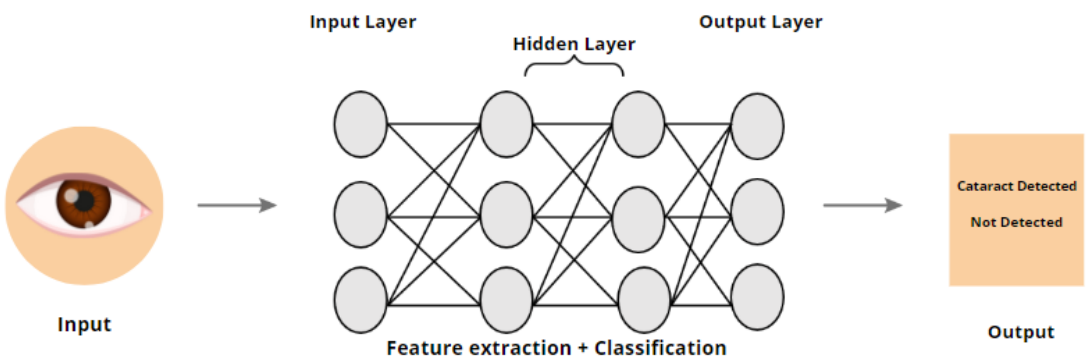


Figure 2. Deep Learning Structure

C. Data Sample Collection

In this research, data samples were obtained from the internet, namely two image data of normal eyes and cataracts, to be used as testing samples and training data in the research. Data samples from normal eyes and eyes diagnosed with cataracts are needed to prove that the designed system can function well in detecting whether the image of the eye is a normal eye or a cataract.

D. CNN Model System Design

The system design involves creating a framework using a Convolutional Neural Network (CNN) model. To start, source code is referenced to establish the model framework. This is followed by the integration of libraries and the importation of image data via links, which are incorporated into the system as test samples. The architecture of the CNN model includes several layers: input, convolution, pooling, fully connected, and output layers. This architecture is employed in deep learning for pattern recognition within visual data [13]. The specific arrangement and structure of the CNN architecture are designed to identify unique characteristics in visual data, as illustrated in Figure 3 [14].

In Figure 3, the distinctive characteristic of the CNN architecture is highlighted by a hidden layer that connects only to a subset of neurons from the preceding layer [15]. This selective connectivity allows CNNs to implicitly learn features [16]. Moreover, the CNN architecture facilitates hierarchical feature extraction. For instance, the initial layer primarily identifies shapes within an image, the subsequent layer focuses on colors, and deeper layers discern various other aspects of image objects, culminating in the final layer which recognizes objects. The components of the CNN structure are as follows [17].

1. Input Layer: This layer receives visual data such as images and videos. Unlike subsequent layers, it does not have neurons; instead, the pixel intensities of the input image act as the neurons.
2. Convolution Layer: This layer extracts local features from the visual data by recognizing specific aspects like corners, edges, and textures.
3. Pooling Layer: This layer reduces the dimensionality of the data, facilitating the processing of higher-resolution images and videos.
4. Fully Connected Layer: Every neuron in this layer is interconnected, processing inputs into outputs from the visual data received.
5. Output Layer: This is the final layer where the processed visual data is outputted as results.

E. System Testing

After designing and creating the system, it is essential to conduct initial testing to assess the system's effectiveness based on the design. Furthermore, the final step involves performing an image classification test to distinguish between normal eyes and those with cataracts using the imported eye image data. The aim is to ensure that the test can accurately identify whether an eye is affected by cataracts. This process facilitates an easy diagnosis of cataracts for observers, simply by inputting images into the system.

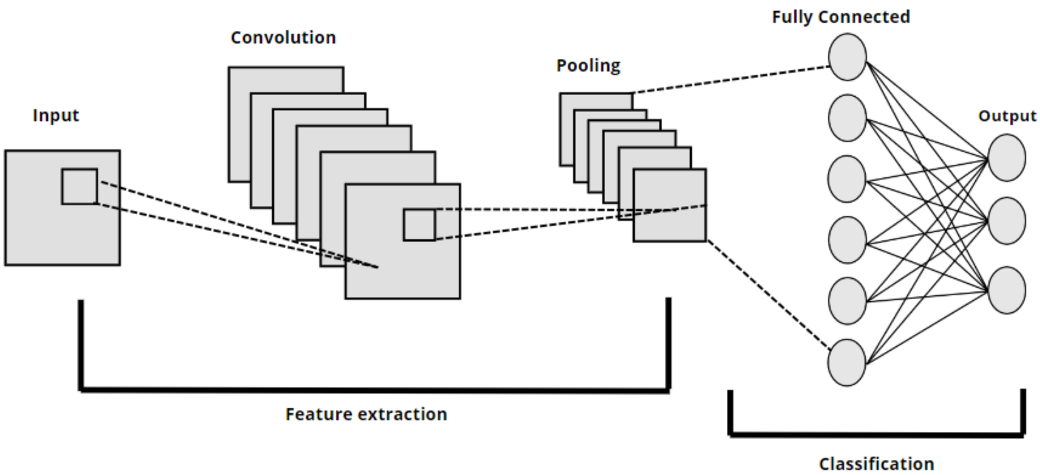
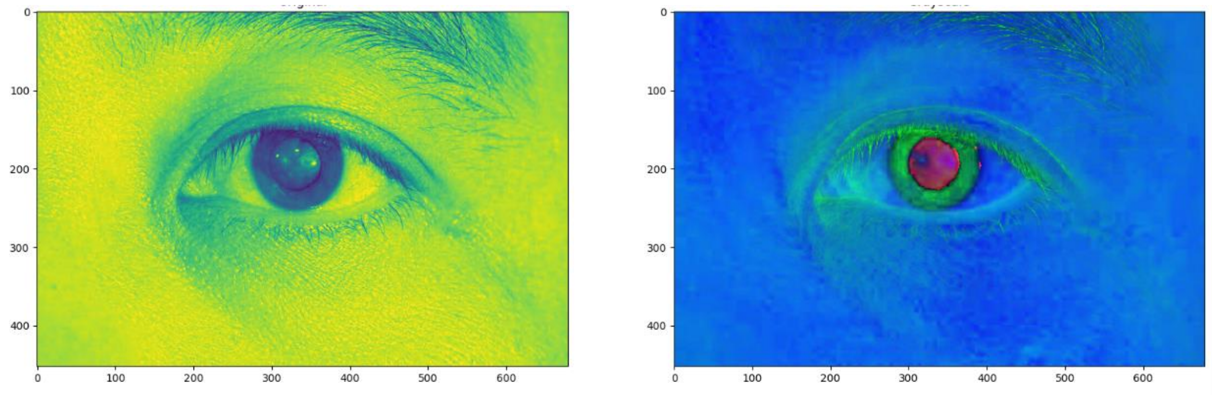
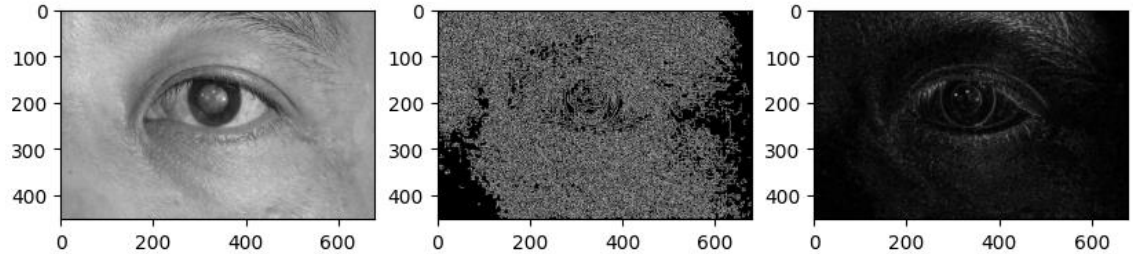


Figure 3. Convolutional Neural Network Architecture



(a) Original Image (b) Grayscale Image

Figure 4. Image is the result of an image processed with image processing RGB method



(a) Original Image (b) Canny Image (c) Prewitt Image

Figure 5. Image is the result of image processing edge detection

III. Results and Discussion

In this study, several methods are employed to detect cataracts in eyes, one of which involves image processing using edge detection techniques. The edge detection methods utilized include the RGB, Canny, and Prewitt methods. These methods focus on identifying the contours of the eye's core and then segmenting the image to determine whether the eye is affected by cataracts or is normal. The images used in this study are sourced from Google Images and encompass a variety of conditions, including normal, irritated, and cataracted eyes.

A. Experiments using the RGB Method

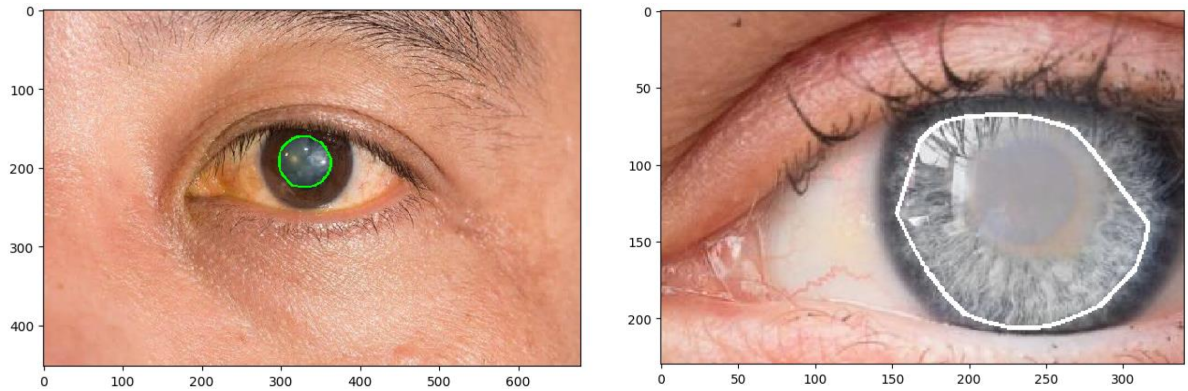
In the research experiments using the RGB method, code will be developed for HSV (Hue, Saturation, Brightness) to handle images. Additionally, a specific segment of the code will adjust the brightness level, referred to as the "hue image" code. This code will also generate image coordinates and display them on the model. The display will feature two types of images: the original image, labeled "Original", and the processed image, which utilizes the RGB method and is labeled "Grayscale".

From Figure 4, the original image depicts a normal eye, which contrasts with the grayscale image. The grayscale image appears brighter because it has been processed with high HSV (Hue, Saturation, Brightness) settings. As a result, the edges of the eyeball are more illuminated, and the core of the eyeball is also clearly visible.

B. Experiments using the Edge Detection Method

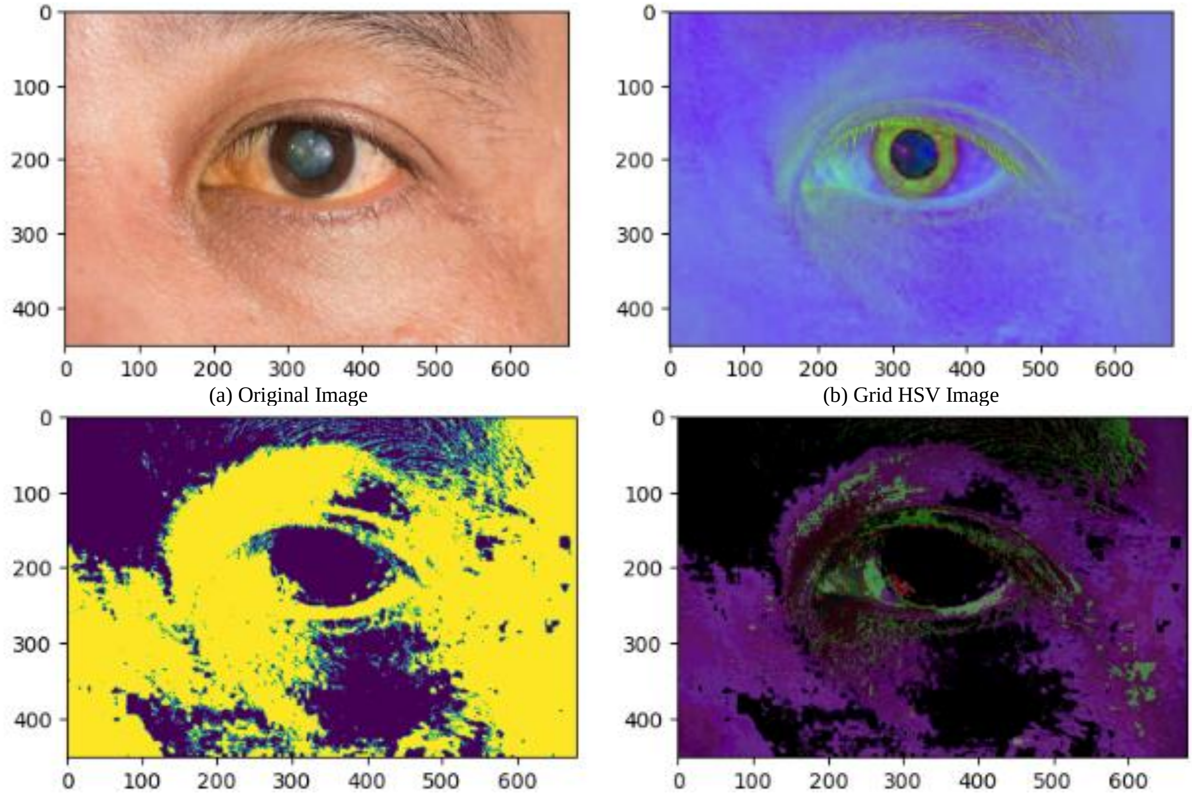
In this research experiment, computer vision techniques are employed for image processing. Initially, the model image is converted into grayscale. Subsequently, edge detection is performed using the Canny method, followed by the Robert and Prewitt methods. The code then generates the coordinates for each processed image, and labels are added to each resulting image for identification.

From the image processing results presented in Figure 5, the Original Image does not display any edges. The image processed with the Canny method appears unclear. In contrast, the image processed using the Prewitt method clearly shows the edges, including those around the core of the eye.



(a) Normal Eye Image (b) Cataract Eye Image

Figure 6. Image is the result of the hull contour



(a) Original Image (b) Grid HSV Image

(c) Mask Image (d) Result Image

Figure 7. Image is the result of segmentation in normal eyes

C. Experiments to detect the Core Area of the Eye with Thresholding

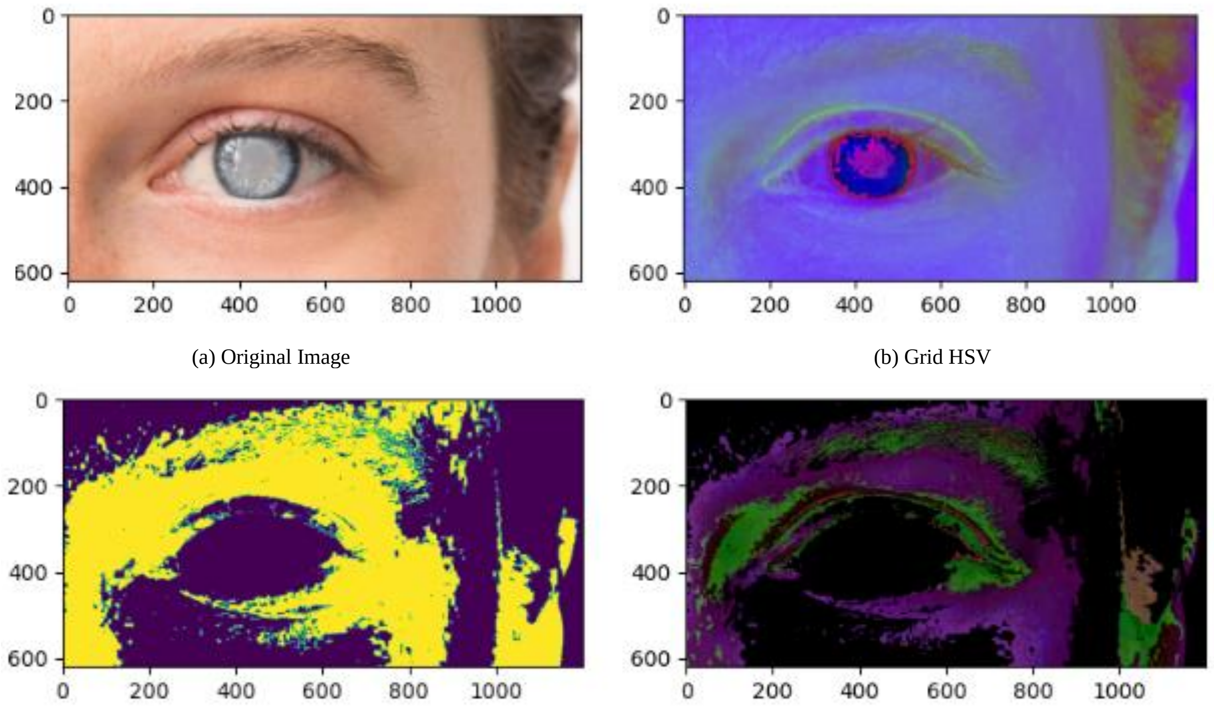
In this experiment, the model applies a thresholding technique to determine contours and sort the image or specific image areas. During this process, the model eliminates the thickest or largest frame by assessing the size of the area and its contours. Additionally, the model utilizes a "hull" method, which outlines the contours on the image.

The resulting image in Figure 6 demonstrates the core area outlined by the hull. This hull effectively highlights the spherical area at the core of the eye.

D. Segmentation Experiment to Determine Normal or Cataract Eyes

In this experiment, the model creates an HSV grid to convert colors from BGR to HSV format. It then establishes upper and lower limits, which facilitate the segmentation of the image within the model. This process enables the model to output an image showing the results of cataract eye detection.

In Figure 7, the original image remains unsegmented and is thus indistinguishable. The "Grid_HSV" image displays the segmentation results, clearly showing the shape and core of the eye. In contrast, the "Image Range" and "Image Bitwise" are segmented images that fail to clearly depict the shape and



(a) Original Image (b) Grid HSV

(c) Mask Image (d) Result

Figure 8. Image is the result of segmentation in cataract eyes

sphere of the eye. Therefore, the "Grid_HSV" image is used for cataract detection because it not only distinctly shows the shape and core of the eye but also indicates, based on color, that the core of the eye is spot-free, suggesting a normal eye condition. The image processing results reveal that the edges are not visible in the Original Image. The image processed with the Canny method appears unclear, while the image using the Prewitt method clearly shows both the edges and the core of the eye.

In Figure 8, the original image is undistinguished because it has not been segmented. The "Grid_HSV" image, however, represents the results of segmentation on the model and clearly shows the shape and core of the eye. Conversely, the "Image Range" and "Image Bitwise" are segmented images that fail to clearly depict the shape and sphere of the eye. Therefore, for cataract eye detection, the "Grid_HSV" image is utilized because it clearly displays the eye's shape and core. Notably, this image reveals a spot in the core of the eye, indicating the presence of a cataract.

IV. Conclusion

Cataracts are a condition in which the lens of the eye becomes cloudy, leading to decreased vision and potentially blindness. In Indonesia, cataracts account for 81.2% of blindness cases. The objective of this research is to develop a cataract detection system capable of classifying eye image data to determine whether eyes are cataract-affected or normal. The findings from this study indicate that the system is 98% effective. Specifically, normal eye image data processed through the CNN model did not indicate the presence of cataracts when tested using grayscale. Conversely, cataract eye image data, when processed, successfully identified signs of cataracts, including the appearance of red spots in the grayscale images.

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