Red-Channel Based Iris Segmentation for Pupil Detection

S. Bhuvaneswari(✉) and P. Subashini

Department of Computer Science, Centre for Machine Learning and Intelligence (CMLI) Avinashilingam Institute, Coimbatore, India
{bhuvaneswari_cs,subashini_cs}@avinuty.ac.in

Abstract. Iridology is the science and practice that helps to learn the health status through the examination of the structural aspects of an eye. Iris segmentation is an important phase in Iridology that aids to recognize iris signs and identify aberrant organ activity. The primary elements of iris segmentation are the detections of the iris and pupil. However, iris segmentation is greatly impacted by noises and images with low quality. The proper method for iris and pupil detection supports improving the result of iris segmentation in Iridology. This study provides a computer vision-based method to segment the human eye's iris and pupil using an alternate method. The procedure is based on the red channel information of the image with various image processing operations. Iris images from the UBIRIS.v1. Dataset, which was taken in less restrictive image acquisition conditions, is used in an experiment. This method gives a unique way for iris segmentation with an accuracy of 97.49%.

Keywords: Canny edge detection · Complementary medicine technique · Contour · Iridology · Pupil detection

1 Introduction

The human iris is as distinct as the fingerprint as there are no two irises alike. Hence, most security agencies use biotechnology or eye-based personal identification as one of their methods. The eyes can also be used as a health status indicator, according to Iridology. Reading the features of an eye to assess the health status is known as the study of Iridology (pronounced as eye-rid-ology), which is an alternative medicine technique [1]. Early diagnosis is important in the field of the health sector for successful treatments and longer survival times. Iridology serves as a pre-screening method in the medical field and helps to reveal the organs' health status by interpreting the eye's image through the advancement of technology.

The Iridologist who handles the Iridology practice on the patient uses the Iridology chart [2]. The physiology of the body is located on the iridology chart using a unique code. Many Iridology charts are introduced by many practitioners based on their own experiences and observations [3]. In these chart makers' lists, Bernard Jensen's chart is popular and internationally acceptable [4] (see Fig. 1). Computer vision is used to conclude the status of the organs by interpreting the eye based on an Iridology chart.

A. E. Hassanien et al. (Eds.): AICV 2023, LNDECT 164, pp. 231–241, 2023.
https://doi.org/10.1007/978-3-031-27762-7_22

Iridology is aided by a variety of image processing algorithms in computer vision, which show its ability in understanding image better.

The following steps are considered to be effective for iris and pupil detection: 1) To detect the iris, the simple color channel slicing method is used. 2) The filter is applied to remove the noise to reduce inaccuracy in the result. 3) The Range function is used to mask the iris portion and Morphological operations [5] are used to make the objects more visible. 4) The Circle Hough Transform is used to detect the iris portion. 5) Then the lower and upper bound range is applied to mask the pupil area. 6) The Auto Canny edge detection Algorithm generates the edges for detecting the pupil using the most suitable sigma value. 7) The pupil region is detected by using the Circle Hough Transform algorithm.

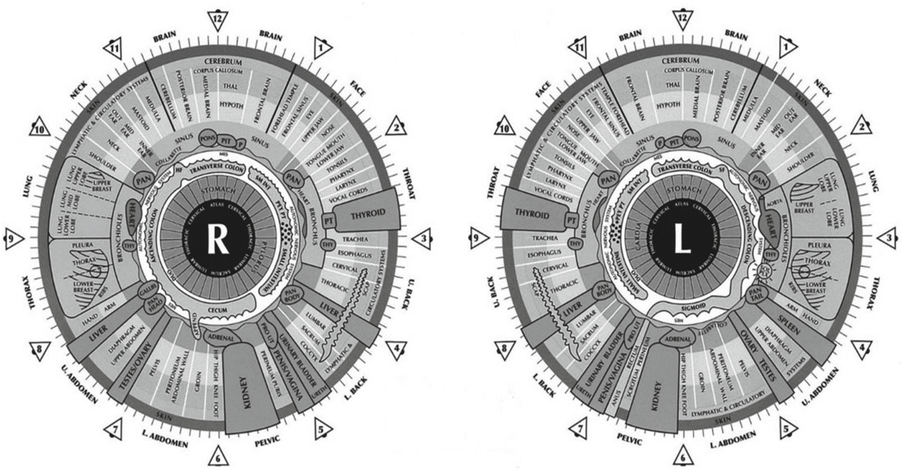

Fig. 1. Dr. Bernard Jensen's Iridology chart

The structure of this paper is as follows: Sect. 2 discusses an overview of the related work to this paper. Section 3 describes the experimental methodology for detecting the iris and pupil. The implementation's findings are presented in Sect. 4, and the conclusions are summed up in Sect. 5.

2 Related Work

Many algorithms and methods have been developed and used for human iris and pupil detection. These include traditional image processing methods, as well as deep learning.

Principal Component Analysis (PCA) was used by L. I. Permatasari et al. [6] to minimize the size of the feature extraction and to optimize the amount of information from the selected characteristics from the interior area of the iris. When compared to the original features, the PCA may miss some information, which is one of its current drawbacks. R. F. Lestari et al. [7] focused on the diagnosis of liver illness utilizing the Extended Center Symmetric Local Binary Pattern (XCS-LBP) approach to derive the feature from the iris and classify the data in addition to the K-Nearest Neighbor method. However, the cropping process was done manually. M. U. Rehman et al. [8] proposed the Ensemble learning method based on iris features. The author extracted the iris features from the Region of Interest (ROI) using Statistical Features, Gray-Level Co-Occurrence Matrix (GLCM), and Gray-Level Run Length (GLRL) Matrix to estimate the liver functionality.

Using Newton's interpolation method, F. Hernandez et al. [9] experimented to predict the early stages of Alzheimer's by examining the region of the brain represented by the structure of an iris. The Hough Transform technique was used in this investigation to find the iris and pupil, and the afflicted area was enhanced using the Logarithmic Intensity Transformation. D. C. Adelina et al. [10] suggested the GLCM for feature extraction and neural network backpropagation for classification to assess iridology and ascertain the condition of the pancreas organ. For segmenting the iris from the whole image, the author used the Hough Circle Transform method. However, the CHT failed to detect an iris portion due to excessive or inadequate light exposure. S. H. Putri et al. [11] developed a system to diagnose cholesterol by analyzing the Low-Density Lipoprotein (LDL) level. The researcher used Image processing techniques for preprocessing and a Convolution neural network for classification. To localize the iris province on the image, the Circle Hough Transform is used. However, there is a need for some restrictions to isolate the iris due to the greyish-white colored ring (Cholesterol ring) which is surrounded by the iris region. Onal M.N. et al. [12] proposed a hybrid method which is incorporating image processing and deep learning to diagnose diabetes based on iris images. The author used Daugman's Integro-Differential Operator (IDO) technique to distinguish the iris from the rest of the image and to locate the pancreatic region using the Iridology chart [13]. After segmenting, the entire iris area, the cropped ROI, is categorized by various deep-learning networks, and performances are assessed separately.

The primary goal of all previous techniques was to identify specific body organ malfunctions. In this study, the results of an iris detection are evaluated using a standard grayscale image and a different approach that uses red-channel information of an image.

3 Experimental Methodology

This study tries to provide an alternate method for segmenting the iris. Lately, most experiments have been made using Near Infrared Images (NIR) as input. Because the pupil is not stimulated by NIR illumination. Therefore, during image acquisition, pupil dynamics do not significantly affect the texture of the iris. Moreover, in contrast to the color irises, the texture of dark-colored irises is more discernible in the Infrared spectrum [14]. NIR camera help to obtain a clear image of the iris, thus the pupil and iris can be seen with great contrast in NIR images [15, 16]. As a result, pupil detection in NIR images is straightforward. However, when compared to NIR images, color images are noticeably noisier. [17]. Thus, segmenting the iris in color images is not an easy task.

The human iris has various iris colors, patterns, and pigments. In addition, the brightness of the light will dilate or shrink pupil size [18]. Thus, iris recognition will be impacted by differences in iris structure, iris color, and pupil dilation or contraction. The study represents a single-color spectrum approach based on the red-channel information of an image during iris localization to improve its efficiency. Figure 2 depicts a red channel-based iris detection workflow.

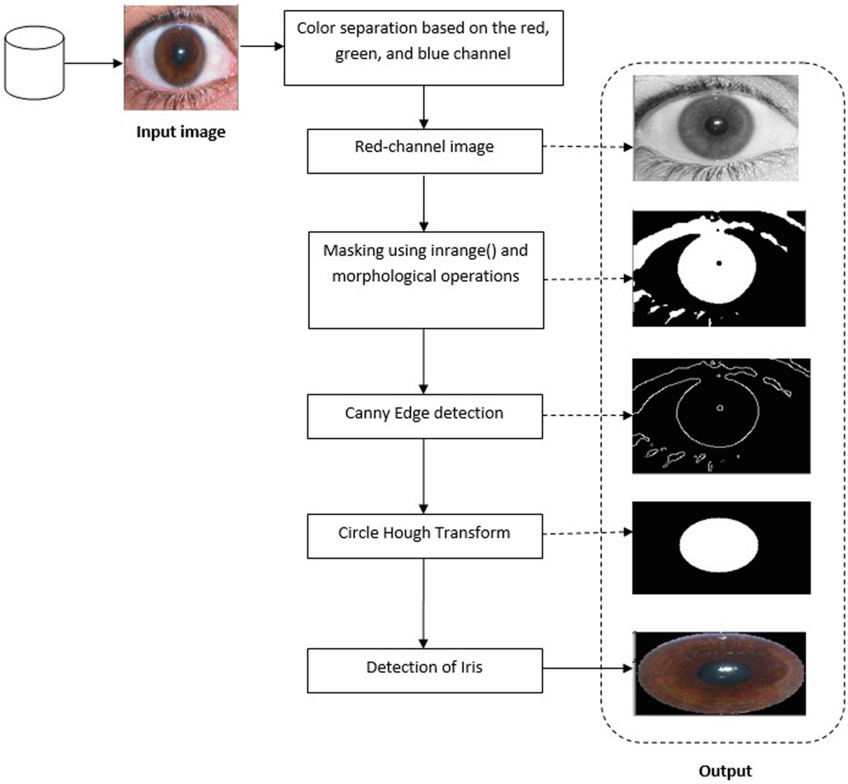

Fig. 2. Workflow for iris recognition using red-channel image

3.1 Iris Localization

In the human eye, the common feature is pupil color. The pupil color is always dark in the eye, unlike the iris. Hence, the authors initially try to detect the pupil from the human eye, though the illumination or an uncontrolled environment will affect the pupil's darkness. It will make difficulties in pupil detection. Hence, this study aims to locate the iris of an eye before detecting the pupil region.

3.1.1 Pre-processing

Color Conversion

With data collected from the UBIRIS.v1 database, the method was evaluated. The dataset contained RGB-formatted images that could be accessed [19]. So, the Color conversion will help to read more details about the input data. The human iris is differentiated by its various color. It needs some common color conversion method that is suitable for research work. Grayscale image conversion is the most popular technique due to its range of color, and low computation power. Apart from the NIR input image, in iris recognition most of the authors prefer the grayscale image for iris detection and pupil detection, to make the complex task simple. The Grayscale image range comes under three categories; one is black, the second is white, final is a gradient between black and white. Those ranges will help to detect or separate the required region of the input image.

In the RGB image, each pixel represents three channels. The color of the pixel is decided by the combination of red, green, and blue colors. An area that contributes more red color in the original image produces more brightness in the red channel image, if not look darker. This applies to the remaining two channels. So, the separated color channel images will look like the grayscale image, for the reason the pixel of these images has only one channel like the grayscale image. This study used red channel-based color images to evaluate and compare the outcomes of iris segmentation with conventional grayscale images.

Noise Removal

The acquired input data may be affected by the noise. The noise filtering techniques help to reduce the noise, and the filtered results aid to increase accuracy (see Fig. 3). The median filter aids to remove the impulse noise from an input image. Therefore, a median filter is a feasible option for reducing noise from the input image of the human eye without degrading the sharpness of the image [20].

Fig. 3. a) Input image b) Before noise reduction c) After noise reduction.

3.1.2 Edge Detection

In the eye, the pupil represents the prominent level of black color, and the sclera represents the major level of white or bright color. The colored area of the eye is termed as iris. These distinctions aid in separating an iris from the eye. The inRange function of thresholding is used to increase the visibility of the iris part. The inRange function detects the region, based on the pixel values. It returns the number of elements that lies between the given upper and lower bounds.

The inRange emphasizes the iris portion. To improve this result, the erosion operation is applied to the result of inRange method. One of the techniques used in morphological operations is erosion. It will compare the kernel against the matrix of the input image. If there is a perfect match, it assigns the binary value 1(bright), else assigns the value

0(black). As a result, the increased black will make the necessary part of an image more visible and reduce reflection. The final image makes it simpler to see the edges. For better edge identification erosion operations are used in conjunction with thresholding operations using the inRange. The edges in the resulting binary image are identified using the Canny edge detection method. To identify the strong edges in the input image, the Canny edge detection technique performs the five steps as follows: 1) With the use of a Gaussian filter, the Canny edge detection technique smooths and eliminates distortion from the input image to generate strong edge pixels. 2) Identifies the horizontal, vertical, and diagonal edges in the blurred image by detecting the intensity gradient of the image. 3) Then it applies the edge thinning technique to find the sharpest changes in intensity value locations. 4) After applying the non-maximum suppression even though the resultant image may contain thin edge pixels due to the noise and color variation. To suppress this weak edge, the Canny algorithm applies the double threshold. 5) Finally strong edge pixels by using hysteresis are traced.

To do noise reduction, the Canny edge algorithm uses a Gaussian kernel (3x3, 5x5, 7x7, 9x9, etc.) to perform the Convolution technique on the image. The kernel size depends on the required blur range.

A Gaussian filter kernel size's equation is,

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

The following equation is used by the Canny edge algorithm to calculate the gradient value after the image has been smoothed:

$$\left|G\right| = \sqrt{G_x^2 + G_y^2} \tag{2}$$

$$\theta(x, y) = arctan\left(\frac{G_y}{G_x}\right) \tag{3}$$

3.1.3 Circle Hough Transform (CHT)

Different kinds of object detection and recognition algorithms are dealt with in image processing. The iris looks in the shape of an ellipse. Additionally, CHT is the widely used computer vision algorithm for locating the circle's center coordinate values [21, 22]. Thus, CHT is the desired method to detect an iris.

To detect the circle, three parameters (a, b, R) are required mathematically. The circle's center points are a and b, and its radius is r. It will produce the edges $[(X_1, Y_1), (X_2, Y_2), \ldots\ldots\ldots.(X_n, Y_n)]$ using these three parameters around the given center point. The following three parameters can be used to define a circle:

$$X = a + R\cos(\theta) \tag{4}$$

$$Y = b + R\sin(\theta) \tag{5}$$

This is the principle upon which the Circle Hough Transform (CHT) operates. When a circle's center point is uncertain, the radius is taken into account and generates a circle on the edge which is given by the Canny edge detection algorithm. The CHT algorithm moves along the strong edge (x, y) and plots the circles, then compute the coordinates of the center of all the circles. It considers the high voting feature point from the accumulator array as the center point of the circle (see Fig. 4).

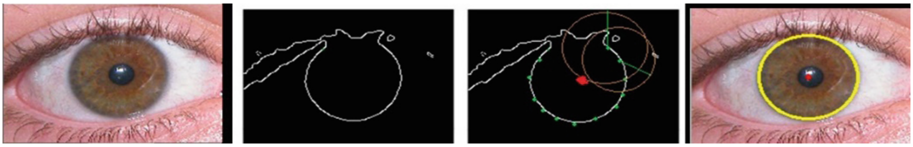

Fig. 4. Iris identification. a) Input image b) Edges of an image c) Plotting circles along edges with predefined radius d) Outcome with a high voted center point

3.2 Pupil Detection

Iris detection makes pupil detection simpler. When the iris pigments are dispersed across the pupil boundary in grayscale images, the threshold value occasionally impacts the iris area (see Fig. 5). The pupil was therefore identified in this analysis using RGB images. In comparison to a grayscale image, it produces better outcomes.

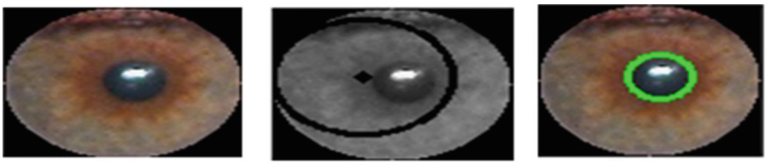

Fig. 5. Pupil detection. a) Input image b) Grayscale image c) RGB image

In this method, the binary representation of an image is changed by selecting and masking the pupil ranges. Then the Morphological closing operation is applied to the masked regions. The reflection noise in the iris images can be removed through morphological processing [23]. The Morphological closing operation helps to smooth boundaries and fill small holes or small black points on objects. Later, the contour method is applied to the result of the Morphological operation. Then the edge detection using Canny is then applied to the generated image.

The Canny edge detector finds the sudden intensity change's edges. It helps to improve the outcome of the Circle Hough Transform. It can be difficult to determine the best value for the lower and upper thresholds in the Canny edge detection algorithm when images are taken in various lighting situations. The auto canny detecting technique is applied to make it effective. The mean value of the binary images that have been masked is used along with the sigma value that works best for all the images. The manual tweaking that depends on the images is avoided by the auto Canny detector. In order to find the pupil, the Circle Hough Transform is applied to the images after creating the edges.

4 Results and Analysis

4.1 Dataset

Images from the UBIRIS.v1 dataset were used as input to assess its performance. The UBIRIS.v1 database encompasses a collection of 1877 images that were captured from 241 various populations using a Nikon E5700 camera. The major purpose of this approach is to detect the pupil through iris segmentation. This study analyzes the two distinct types of input images: 1) Grayscale image and 2) Single color spectrum based on red-channel information of an image which is suggested by this paper.

4.2 Iris Localization

The results are good for both the standard and red channel images. However, the red channel-based images still provide the optimum solution. To evaluate the effectiveness of iris segmentation in both conventional grayscale and red channel images, the dataset's input images are chosen at random (see Fig. 6(a)). The results of an iris localization analysis for the red-channel image and the typical grayscale image are exhibited in Figs. 6(b) and 6(c), correspondingly.

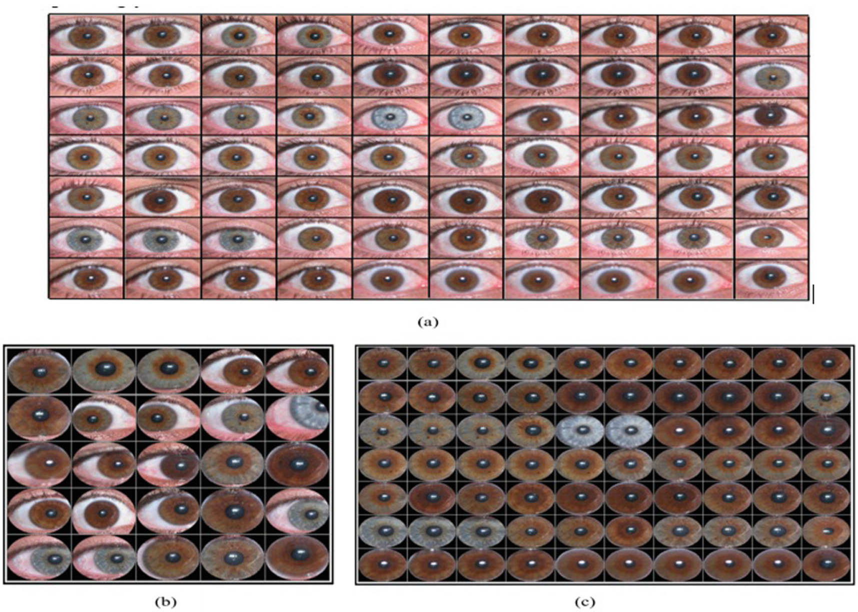

Fig. 6. Iris detection. a) Input image b) Grayscale image c) Red-channel image

The results of the iris's segmentation accuracy using grayscale and red-channel images are shown in Table 1. The images with the red channel exhibit the highest accuracy when compared to grayscale images. Through this experiment, it was determined that red channel information may more accurately segment the iris than grayscale images.

Table 1. Accuracy of different methods in detection on the same dataset

Total images	Red-channel image		Grayscale image	
	Detected	Poor Detection	Detected	Poor Detection
205 (Controlled Environment images)	202	3	140	65
34 (Less controlled Environment images)	31	3	27	7
239	233	6	167	72
Accuracy	**97.49%**		69.87%	

4.3 Pupil Detection

The pupil detection is achieved using RGB images. The pupil area is masked using the minimum and greatest range of pupil intensity values. However, the reflection makes pupil detection difficult. In order to identify the reflection area, the threshold operation is used. It is found that the reflection range exceeds 200 after considering the various input images. The inpaint approach is used to provide a solution to fill the reflection area after the reflection portion has been identified. However, it creates a watermark in the painted area. These marks will make edge detection more challenging (see Fig. 7). Therefore, to solve this issue, Morphological operations are used. As a result, the experiment uses the Morphological closing operation along with the filling contour method to reduce reflection.

Fig. 7. Marks after reflection removal

In terms of object detection and segmentation, the contour performs well. It defines the area of the image that is within the specified intensity range. This concept is utilized in the filling contour approach for reflection removal. Thus, the contour area is detected and filled or painted by the bright intensity value. The reflection area and the pupil area can be integrated, according to this conception. It will help to improve the pupil region's detection (see Fig. 8).

The results of the segmented iris images are randomly chosen to test the effectiveness of pupil detection using the filling contour approach. The outcome of pupil detection is displayed in Fig. 9. In contrast to a technique without a contour method, the filling contour method offers the best result.

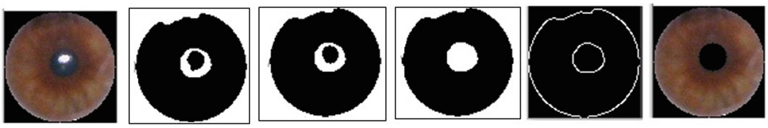

Fig. 8. Pupil detection using the filling contour method

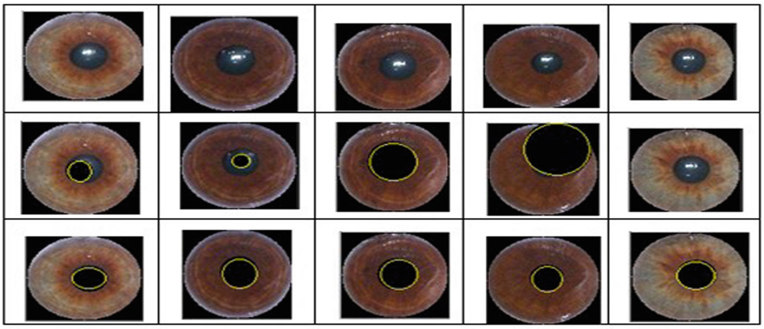

Fig. 9. Pupil detection. Top row: Segmented Iris images. Middle row: Output images obtained by the non-contour method. Bottom row: Output images obtained by the filling contour method

5 Conclusion

This study provides an alternative approach to segmenting the iris and pupil in Iridology. The input image of the eye is subjected to various types of image processing algorithms based on red channel information in order to identify the pupil. The filling contour method is applied to minimize the reflection during pupil detection. This study experimented with color images, which are useful for analyzing visible wavelength images. Thus, this distinctive and useful method will be advantageous for color images taken with smartphones. This work also provides a useful analysis of the grayscale images and red channel images as part of the iris segmentation procedure. In this paper's experimental study, only publicly accessible iris images were used. Future research will therefore concentrate on real-time images with improved versions of various types of algorithms and classification techniques in an effort to further reduce mistake rates.

Acknowledgment. This work has been supported by the Centre for Machine Learning and Intelligence (CMLI) funded by the Department of Science and Technology (DST-CURIE).

References

1. Jensen, B.: Visions of Health: Understanding Iridology. Penguin, New York (1991)
2. Iridology Chart: https://myinfiniteiris.com/product/updated-wallet-size-iridology-chart/
3. Pau, G.: The Foundations of Iridology: The Eyes as the Key to Your Genetic Health Profile. Simon and Schuster, New York (2019)

4. Esteves, R.B., Morero, J.A., Pereira, S.D., Mendes, K.D., Hegadoren, K.M., Cardoso, L.: Parameters to increase the quality of iridology studies: a scoping review. Eur. J. Integr. Med. **43**, 101311 (2021)
5. Huda, A.L.: Iris detection using morphology. J. Univ. Babylon **22**(9), 2277–2282 (2014)
6. Permatasari, L.I., Novianty, A., Purboyo, T.W.: Heart disorder detection based on computerized iridology using support vector machine. In: 2016 International Conference on Control, Electronics, Renewable Energy and Communications (ICCEREC), pp. 157–161 (2016)
7. Lestari, R.F., Nugroho, H.A., Ardiyanto, I.: Liver detection based on iridology using local binary pattern extraction. In: 2019 2nd International Conference on Bioinformatics, Biotechnology and Biomedical Engineering (BioMIC) - Bioinformatics and Biomedical Engineering. no. 1, pp. 1–6 (2019)
8. Rehman, M.U., Najam, S., Khalid, S., et al.: Infrared sensing based non-invasive initial diagnosis of chronic liver disease using ensemble learning. IEEE Sens. J. **21**, 19395–19406 (2021)
9. Hernandez, F., Vega, R., Tapia, F., Morocho, D., Fuertes, W.: Early detection of Alzheimer's using digital image processing through iridology, an alternative method. In: 2018 13th Iberian Conference on Information Systems and Technologies (CISTI), pp. 1–7. IEEE (2018)
10. Adelina, D.C., Sigit, R., Harsono, T., Rochmad, M.: Identification of diabetes in pancreatic organs using iridology. In: 2017 International Electronics Symposium on Knowledge Creation and Intelligent Computing (IES-KCIC), pp. 114–119 (2017)
11. Putri, S.H., Saputro, A.H.: Design of convolutional neural network modeling for low-density lipoprotein (LDL) levels measurement based on iridology. In: 2020 4th International Conference on Informatics and Computational Sciences (ICICoS), pp. 1–5 (2020)
12. Onal, M.N., Guraksin, G.E., Duman, R.: Convolutional neural network-based diabetes diagnostic system via iridology technique. Multimedia Tools Appl. **82**(1), 173–194 (2023)
13. Daugman, J.G.: How iris recognition works. IEEE Trans. Circuits Syst. Video Technol. **14**, 21–30 (2004)
14. Bobeldyk, D., Ross, A.A.: Predicting eye color from near infrared iris images. In: 2018 International Conference on Biometrics (ICB), pp. 104–110 (2018)
15. Lee, M.B., Kang, J.K., Yoon, H.S., Park, K.R.: Enhanced Iris recognition method by generative adversarial network-based image reconstruction. IEEE Access **9**, 10120–10135 (2021)
16. Wang, Q., Zhipeng, L., Tong, S., Yang, Y., Zhang, X.: Efficient iris localization via optimization model. Math. Probl. Eng. **2017**, 1–9 (2017)
17. Hu, Y., Sirlantzis, K., Howells, G.: Improving colour iris segmentation using a model selection technique. Pattern Recognit. Lett. **57**, 24–32 (2015)
18. Mathot, S.: Pupillometry: psychology, physiology, and function. J. Cogn. **1**(1), 16 (2018)
19. Proença, H., Alexandre, L.A.: UBIRIS: a noisy iris image database. In: Roli, F., Vitulano, S. (eds.) Image Analysis and Processing – ICIAP 2005. Lecture Notes in Computer Science, vol. 3617, pp. 970–977. Springer, Heidelberg (2005). https://doi.org/10.1007/11553595_119
20. Gangwar, A.K., Joshi, A., Singh, A., Alonso-Fernandez, F., Bigun, J.: IrisSeg: a fast and robust iris segmentation framework for non-ideal iris images. In: 2016 International Conference on Biometrics (ICB), pp. 1–8 (2016)
21. Samant, P., Agarwal, R.: Comparative analysis of classification-based algorithms for diabetes diagnosis using iris images. J. Med. Eng. Technol. **42**, 35–42 (2018)
22. Jesus, R.J., Maximo, L., Pinto Elías, R., Gabriel, G.: Methodology for Iris scanning through smartphones. In: 2016 International Conference on Computational Science and Computational Intelligence (CSCI), pp. 861–864 (2016)
23. Malgheet, J.R., Manshor, N.B., Affendey, L.S.: Iris recognition development techniques: a comprehensive review. Complexity **2021**, 1–32 (2021)