Artificial intelligence detection of refractive eye diseases using certainty factor and image processing

Rizal Rachman[1], Sari Susanti[1], Hendi Suhendi[2], Adi Karawinata Satyanegara[2]
[1]Department of Information Systems, Faculty of Information Technology, Adhirajasa Reswara Sanjaya University (ARS University), Bandung, Indonesia
[2]Department of Informatics Engineering, Faculty of Information Technology, Adhirajasa Reswara Sanjaya University (ARS University), Bandung, Indonesia

Article Info

Article history:

Received Jun 28, 2024
Revised Aug 6, 2024
Accepted Aug 11, 2024

Keywords:

Artificial intelligence
Certainty factor
Disease detection
Eye refraction
Image processing

ABSTRACT

Refractive errors are defined as an impairment in the eye's capacity to focus light, resulting in the formation of blurred or unfocused images. These issues arise from alterations in the shape of the cornea, the length of the eyeball, or the aging of the crystalline lens. It is anticipated that the prevalence of visual impairment will increase in conjunction with global population growth. At present, a significant number of countries have not yet accorded sufficient priority to eye health within their healthcare systems. This has resulted in insufficient awareness and reluctance to seek costly specialized care. This study proposes the development of an advanced refractive eye disease detection system with the objective of improving diagnostic accuracy, disseminating disease information, and reducing financial barriers to specialist consultation. The research employs certainty factor (CF) methods and image processing with feature extraction. The initial results demonstrate the potential for identifying specific refractive eye diseases with high certainty through the analysis of symptoms and the examination of photographs of the eye. The proposed approach provides an alternative method for diagnosing refractive eye diseases, which could enhance access to refractive eye care services and reduce the economic burden on patients.

Corresponding Author:

Rizal Rachman
Department of Information Systems, Faculty of Information Technology
Adhirajasa Reswara Sanjaya University (ARS University)
40291 Bandung, West Java, Indonesia
Email: rizalrachman@ars.ac.id

1. INTRODUCTION

Refractive error is a condition characterized by an inability of the eye to focus light entering the eye, resulting in an indistinct or blurred shadow of an object. The shape of the cornea and the lens of the eye may be affected by an abnormally short or long eyeball, respectively, due to the influence of age [1]. The World Health Organization (WHO) has stated that as many as 253 million people worldwide experience visual impairment, 36 million of whom are blind and 217 million of whom have moderate to severe visual impairment. This figure demonstrates that refractive errors are a significant issue in our environment. The world report on vision has indicated that 2.2 billion individuals worldwide are affected by visual impairment, with over 1 billion of these cases potentially avoidable or curable. It is predicted that visual impairment will continue to increase in line with the growth of the ageing population. Those in developing countries are most likely to suffer from visual impairment, resulting in a reduced quality of life. Currently, most countries have not established eye health as a hallmark of their national health systems or policies [2]. It is widely acknowledged that the prevalence of refractive errors in the human population is shaped by a complex interplay of biological, environmental and behavioural factors [3]. Among the Indonesian population, the most prevalent refractive disorders are myopia, hyperopia, astigmatism, and presbyopia [4]. The American Academy of Pediatrics asserts that 75% of the learning stages in early human life depend on vision [5]. Uncorrected refractive errors have a profound impact on the economic and social aspects of an individual or community. Failure to treat this disorder promptly and effectively can result in a more severe situation [6].

The current state of affairs is that the equipment used for eye examinations is typically only available at clinics or from eye specialists. Consequently, the general public rarely has the opportunity to have their eyes examined at such facilities for a number of reasons, including the time commitment and financial costs involved [7]. It is therefore evident that artificial intelligence is required to detect refractive eye disease [8]. An intelligent system designed to emulate the problem-solving abilities of an expert, based on input statements provided to the system [9]. This intelligent system will facilitate the general public in early detection through the symptoms they experience [10]. An expert, especially a doctor, is greatly assisted by the use of this intelligent system technology, given the high workload and the variety of diseases that must be detected [11]. The application of artificial intelligence in the medical field has yielded encouraging outcomes in the performance of crucial tasks. The growth of artificial intelligence is responsible for its exceptional capacity to extract sophisticated features and previously unidentified patterns from vast data sets. These systems are capable of attaining commendable performance, even exceeding that of human judges and medical professionals in diagnostic tasks [12]. Ophthalmologists can utilize artificial intelligence to review patient images and provide remote consultations. This information is of assistance to healthcare centres in the allocation of resources for the provision of expedient treatment for patients deemed to be at high risk. Artificial intelligence can assess patient data types, medical history, genetic information, and medical imaging, to provide customized treatment recommendations [13]. While certainty factor (CF) is a method for processing symptom data with rules, values and calculations that produce the highest data value, it is not without limitations [14]. In applications for medicine, requiring photo input, optical coherence tomography (OCT) scans, visual maps, radiology reports, image processing with feature extraction can be used to produce better value performance [15].

The test results indicate that a number of different methods can be employed as a means of diagnosing refractive disease [16], [17]. The prevalence of refractive errors is influenced by a number of factors, including community-based activities. It is possible for individuals to save their consultation data as a guide for the next consultation. The novelty of the model is well demonstrated in the performance of the CF method in generating classification pattern rules. The CF firmly gives certainty to each classification indicator used [18], [19]. Therefore, artificial intelligence research on eye refraction disease detection using CF and image processing with feature extraction will develop from previous research, by conducting further analysis based on data sources, data processing and methods used.

In light of the aforementioned research gap, the author proposes the creation of artificial intelligence capable of detecting refractive eye diseases through the use of a CF and image processing with feature extraction. The initial phase of this process will entail conducting interviews with experts and conducting observations at eye clinics. Additionally, primary data will be collected through social media and literature studies. Once this data has been gathered, it will be meticulously managed and analyzed. The methodology will be evaluated to ascertain its efficacy in detecting eye refraction. Subsequently, the outcomes of these techniques will be assessed and validated.

2. LITERATURE REVIEW

In this research, the CF method and image processing with feature extraction were selected based on their capacity to process and analyse symptom data, value data and image data. Some of the algorithms employed include those which have successfully diagnosed symptoms using the CF method, with a decision value of 97.6% [20] and an average accuracy of 88% [21]. Furthermore, it has been demonstrated to achieve 90% accuracy in diagnosing glaucoma, retinal image objects exhibit discernible patterns [22], and artificial intelligence has the potential to enhance the efficiency, accuracy, and accessibility of healthcare [23], Additionally, the management of retinal images has been shown to be a promising area of research [24]-[27]. The model achieved a validation set accuracy of 0.90, indicating a high degree of generalisation ability. There is a clear need for further model improvement with respect to eye objects, as evidenced by the findings of [28], [29]. Image processing with feature extraction has been shown to produce high accuracy when combined with feature selection methods, demonstrating a strong ability to capture intrinsic features [30], [31].

The histogram of oriented gradients (HOG) is a frequently employed feature extraction algorithm in the field of computer vision, particularly for the purpose of object detection in images. The principal function of HOG is to capture the edge pattern and local gradient orientation distribution in the image, which is highly effective in recognising the shape and structure of objects [32]. The hu invariant moment (HIM) algorithm plays a significant role in the field of image recognition and processing due to its capacity to extract features that are invariant to geometric transformations, including translation, rotation, and scale. The algorithm employs seven invariant moments, calculated from the intensity distribution of pixels in the image, to provide a distinctive and stable representation of the shape and structure of objects within the image. The invariant nature of Hu moments renders it highly efficient and straightforward in terms of calculation [33]. Haralick features are employed for the extraction of textural information from images, through the analysis of the spatial relationships between pixels. These features are calculated using a grey-level co-occurrence matrix (GLCM). By measuring various aspects of texture, such as contrast, homogeneity, energy, and entropy, Haralick features provide a comprehensive representation of the pattern and structure of texture in an image. These features are valuable as they can capture subtle variations in retinal texture that may indicate the presence of disease symptoms, such as hard exudates and vascular changes. This allows for the early detection and more accurate diagnosis of such symptoms [34].

3. METHOD

This research employs an ophthalmologist interview as the primary data collection method, along with the CF method and image processing with feature extraction. The main tools used are Google Form, Microsoft Excel, RapidMiner, and the Python programming language. In experimental research, it is necessary to define clear stages that will be applied in the research process. The following section will explain the scope of the research, previous research, and the methodology that will be employed. The research flow diagram, which will be used as a stage of the research process to achieve the desired results, is presented in Figure 1.

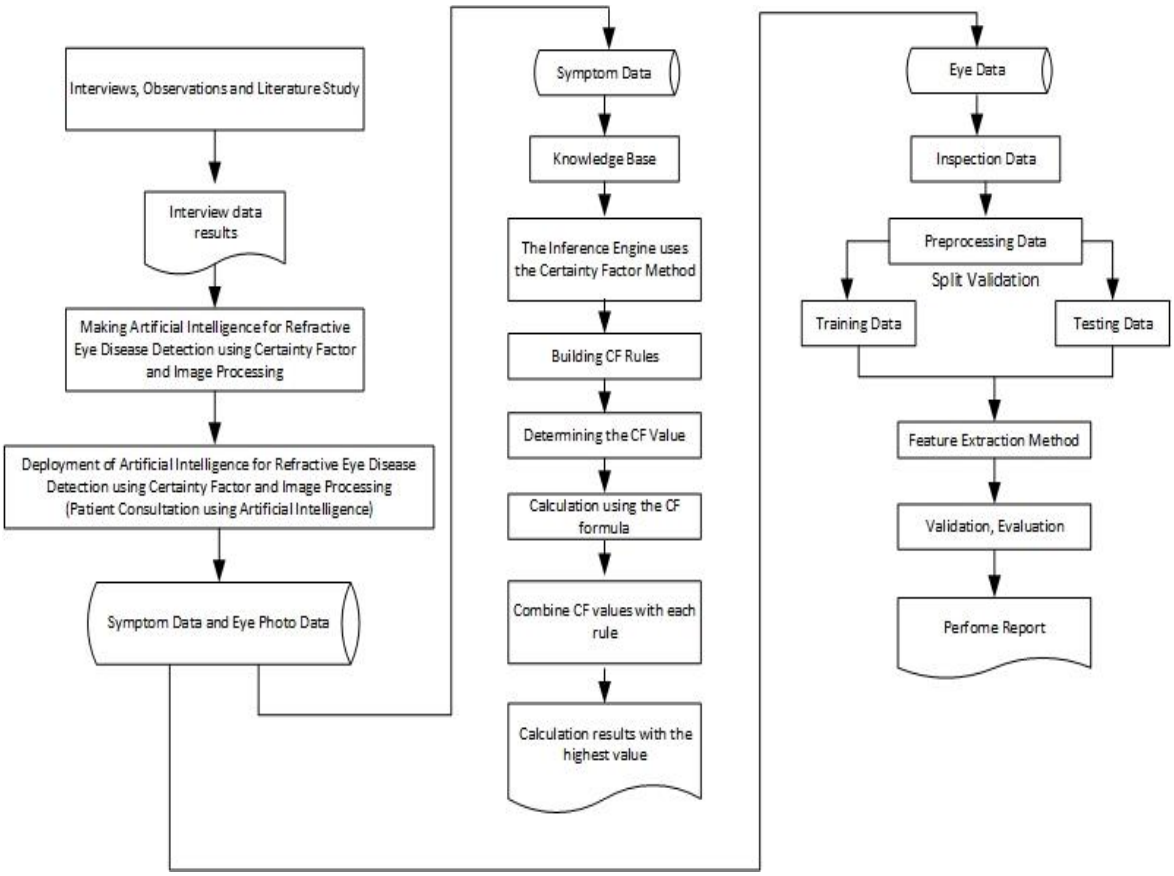


Figure 1. Research flow diagram

Explanation of research flow diagram from Figure 1:
- A number of ophthalmologists were directly interviewed, and clinics or hospitals were observed. Additionally, literature studies were conducted, drawing on books and the internet, to gain insight into eye refraction.
- The findings of the interviews, observations and literature studies will be documented in the form of symptom data, eye photographs and threshold values for refractive eye disease.
- The development of an intelligent system application to detect refractive eye disease based on the website is underway. Once the application has been created, it will be made available to the general public via social media. Individuals will be requested to complete a questionnaire comprising symptoms and eye photographs.
- The data to be utilised in this study comprise two data sets: symptom data and eye image data.
- The symptom data will be analysed using the CF method, while the image data will be processed using image processing techniques with feature extraction.
- The CF method is a method that defines confidence in a fact or rule based on the confidence level of an expert. The CF method employs a calculation process whereby the user’s CF value is multiplied by the expert’s CF value, resulting in a combined CF value. This value represents the final outcome of the CF method calculation. The following is the basic formulation of the CF:

$$CF[H.E] = MB[H,E] - MD[H,E] \quad (1)$$

Description:
CF=certainty factor in hypothesis H affected by fact E.
MB=measure of belief, is an incremental measure of the confidence of hypothesis H affected by fact E.
MD=measure of disbelief, is the confidence of the disbelief of the hypothesis affected by fact E.
E=evidence (event or fact)
H=hypothesis (conjecture)

In order to combine two or more rules, a knowledge-based system with multiple rules is required, each of which yields the same conclusion but different uncertainty factors. Each rule can be presented as a piece of evidence supporting the shared conclusion. In order to calculate the CF (confidence) of the conclusion, the combining evidence is required as follows:

$$CF\ (R1, R2) = CF\ (R1) + [CF\ (R2)]\ x\ [1 - CF(R1)] \quad (2)$$

If we were to consider the CFs of R1 and R2 in isolation, it would be reasonable to posit that the certainty of the combination would exceed one. However, it is possible to modify this figure by adding the second CF and multiplying it by (1 minus the first certainty factor). Consequently, the greater the initial CF, the smaller the certainty of the subsequent addition. Nevertheless, the addition factor always contributes to an increase in certainty. In order to apply the third rule, the following rule can be employed:

$$CF\ (R1, R2, R3) = CF\ (R1, R2) + [CF\ (R3)]\ [1 - CF(R1, R2)] = CF\ (R1, R2) + CF\ (R3) - [CF(R1, R2)].[CF(R3) \quad (3)$$

For solutions with more rules, we can employ a nested equation, as exemplified by the one above.
- The data inspection stage is the phase of data analysis during which the data is observed and the most appropriate data processing stages for the data used in the research are determined.
- The data preprocessing stage is a crucial preliminary step preceding the classification stage. In this stage, the data undergoes processing to facilitate the subsequent analysis process.
- The data division stage utilises the Split validation method with the objective of obtaining more detailed information regarding the determination of the optimal quantity of training and testing data for the data in question, such as in the context of research.
- The process of completing image processing with the test feature extraction method is carried out with a statistical approach to texture analysis based on the statistical properties of the intensity histogram, moment statistic, histogram of intensity levels in the region, number of intensity levels, mean (average) intensity, variance, uniformity measure, entropy measure of randomness to produce the optimal performance value.

$$mean = \mu = \sum_{i=0}^{L-1} z_i \, p(z_i) \quad (4)$$

$$Standard\ deviation = \sigma = \sqrt{\mu_2(z)} = \sqrt{\sigma^2} \quad (5)$$

$$Smoothness = R = 1 - 1/(1 + \sigma^2) \quad (6)$$

$$Uniformity = U = \sum_{i=0}^{L-1} p^2(z_i) \quad (7)$$

$$Entropy = e = -\sum_{i=0}^{L-1} p\,(z_i)\, log_2\, p\,(z_i) \quad (8)$$

– The subsequent stage is the evaluation and validation of the results using performance metrics in the form of recall, f-measure and accuracy, as previously outlined in the research.

4. RESULTS AND DISCUSSION

From the interviews and observations, it was explained that refraction is a component of eye disease. Refraction can affect anyone and at any time, without any age limit. Refraction is also a health problem that arises frequently in the present era, due to the use of gadgets and numerous other factors, especially in the lifestyle and diet of people today who desire convenience. Experts advise that prevention is preferable to cure, particularly given that the eye is an important organ in the body.

The algorithm, which will be implemented by researchers in this intelligent system, begins with the presentation of questions and the selection of symptoms. Following this, the user inputs the chosen symptoms, which are then evaluated to ascertain a potential diagnosis and associated options. The final stage is the presentation of the diagnosis and its associated percentage.

In developing an intelligent system for eye refractive diseases, it is important to consider the four main types of eye refractive diseases and the twenty physical symptoms that can be experienced by individuals with eye refractive diseases. The following data provides an overview of eye refractive diseases and their associated symptoms.

In the context of refractive diseases, there are a number of symptoms that can be used to diagnose and direct towards the specific refraction that is being suffered. It is important to note that there are a number of diseases that present with similar symptoms. For further detailed information, please refer to Table 1.

Table 1. List of disease

Code	Disease name
K01	Myopia
K02	Hypermetropia
K03	Astigmatism
K04	Presbyopia

In the context of eye diseases, the researcher selected four specific conditions that pertain exclusively to eye refraction. A total of 20 physical symptoms have been identified for the four diseases. The following symptom data, accompanied by the relevant symptom code, can be found in Table 2.

Table 2. List of symptoms

Code	Symptom name	Code	Symptom name
D01	Blurred vision when looking at objects	D11	Hot and itchy eyes
D02	Frequent squinting	D12	Vision distortion
D03	Headache	D13	Blurred vision
D04	Eye fatigue	D14	Difficulty seeing at night
D05	Frequent eye rubbing	D15	Eyes are often tense and tire easily
D06	Excessive frequency of blinking	D16	Sensitivity to bright lights
D07	Seeing distant objects clearly	D17	Difficulty distinguishing similar colours
D08	Seeing close objects blurry	D18	Double vision
D09	Squinting to see objects clearly	D19	Needs more light when reading
D10	Difficulty reading	D20	Difficulty reading small fonts

The initial condition under consideration is myopia, more commonly referred to as nearsightedness. This is characterized by five distinct physical symptoms: D01 (blurred vision when looking at objects), D03 (headache), D05 (frequent eye rubbing), D06 (excessive frequency of blinking), and D04 (eye fatigue). Hypermetropia, or farsightedness, manifests through six identifiable physical symptoms: D11 (ocular discomfort), D07 (visual acuity), D03 (headache), D09 (ocular convergence), D08 (visual acuity), and D10 (reading difficulties). Astigmatism, also known as a cylinder eye, exhibits eight physical symptoms: D12 (vision distortion), D13 (blurred vision), D14 (difficulty seeing at night), D15 (eyes are often tense and tire easily), D03 (headache), D18 (double vision), D02 (frequent squinting), and D16 (sensitivity to bright lights) are the physical symptoms of presbyopia. D02 (frequent squinting), D03 (headache), D15 (eyes are often tense and tire easily), D20 (difficulty reading small fonts), D01 (blurred vision when looking at objects), D17 (difficulty distinguishing similar colours), and D19 (requirement for increased light when reading). The results of interviews with several doctors or experts are presented below. The certainty value MB and uncertainty MD of the problem characteristics are as shown in Table 3.

Table 3. Associations of refractive eye disease and symptoms with certainty and uncertainty values

Disease name	Symptom name	Certainty value (MB)	Uncertainty value (MD)
Myopia	Blurred vision when looking at objects	0.7	0.4
	Headache	0.5	0.4
	Frequent eye rubbing	0.8	0.4
	Excessive blinking frequency	0.7	0.3
	Eye fatigue	0.8	0.4
Hypermetropia	Eyes feel hot and itchy	0.7	0.3
	Seeing distant objects clearly	0.8	0.2
	Headache	0.6	0.3
	Squinting to see objects clearly	0.7	0.2
	Seeing close objects blurry	0.6	0.4
	Difficulty reading	0.6	0.2
Astigmatism	Vision distortion	0.8	0.2
	Blurred vision	0.7	0.4
	Difficulty seeing at night	0.5	0.3
	Eyes are often tense and easily tired	0.9	0.3
	Headache	0.8	0.3
	Double vision	0.7	0.3
	Frequent squinting	0.9	0.4
	Sensitive to bright lights	0.7	0.3
Presbyopia	Frequent squinting	0.5	0.4
	Headache	0.7	0.3
	Eyes are often tense and easily tired	0.6	0.3
	Difficulty reading small fonts	0.7	0.2
	Blurred vision when looking at objects	0.8	0.2
	Difficulty distinguishing similar colours	0.7	0.2
	Needs more light when reading	0.7	0.3

A consultation option was made available as a potential response, with each option being assigned a specific weighting value, as detailed in Table 4. This table categorizes the user responses into six distinct levels of confidence, each associated with a corresponding numerical value.

Table 4. User size

No	Description	User value
1	No	0
2	Don’t know	0.2
3	Slightly confident	0.4
4	Fairly sure	0.6
5	Sure	0.8
6	Very sure	1

The user interface is employed to facilitate an overview of the system’s interface. Upon initial access to the system application, the user is directed to the home page, as illustrated in Figure 2. Subsequently, the consultation page, depicted in Figure 3, is presented. In Figure 4, the consultation results pertaining to the potential ailments that may be encountered are displayed in Figure 4(a). Finally, an explanation of the disease in question is provided in Figure 4(b).

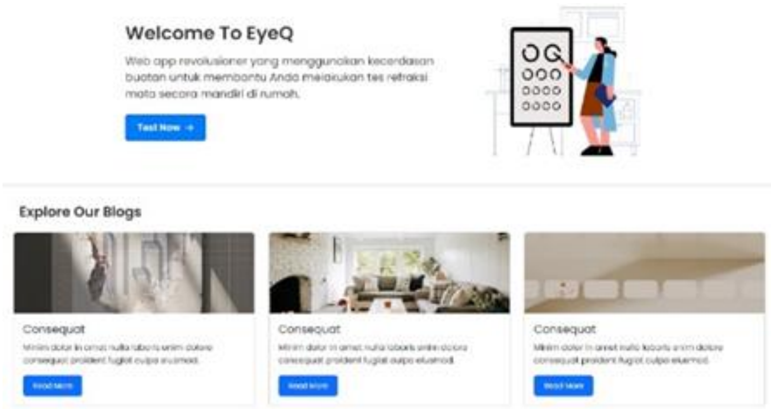


Figure 2. Home page

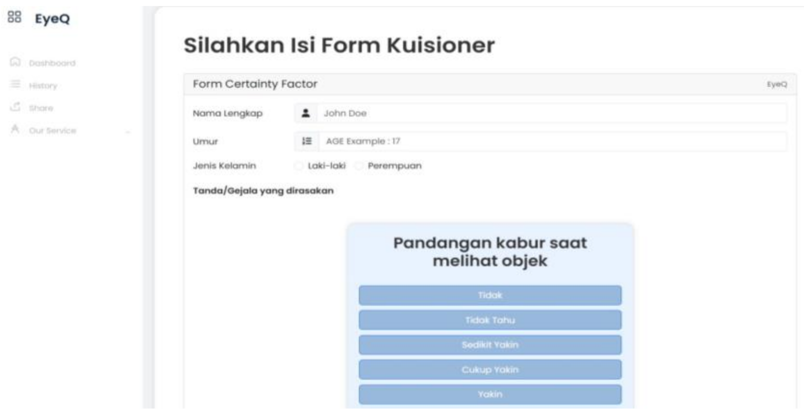


Figure 3. Consultation page

(a)

(b)

Figure 4. Consultation results (a) expert system diagnosis results and (b) educational overview

This paper will explain the manual calculation of eye refraction detection using the CF method. It will be illustrated with case examples. In this system, to determine the type of eye refraction disease, there is a calculation in determining the CF. The following are symptoms of myopic eye refractive disease:

- Blurred vision when looking at objects
- Headache
- Frequent rubbing of the eyes
- Excessive blinking frequency
- Eye fatigue

The following example illustrates the calculation of the CF.

Eye refraction (Myopia)
Symptom 1 [h1,e]: Blurred vision when looking at objects (MB [h1,e]=0.7, MD [h1,e]=0.4)
Therefore, CF[h1,e]=0.7*0.4=0.28

Symptom 2 [h2,e]: headache (MB[h2,e]=0.5, MD[h2,e]=0.4).
Therefore, CF[h1^h2,e] can be calculated as follows:
CF[h2,e]=0.5*0.4=0.20
CF[h1,e]+CF[h2,e]*(1-CF[h1,e])
=0.28+0.20*(1-0.28)
=0.424

Symptom 3 [h3,e]: frequent eye rubbing (MB[h3,e]=0.8, MD[h3,e]=0.4)
CF[h3,e]=0.8*0.4=0.32
CF[h1,h2^h3,e] can be calculated as follows:
CF[h1,h2,e]+CF[h3,e]*(1- CF[h1,h2,e])
=0.424+0.32*(1-0.424)
=0.60

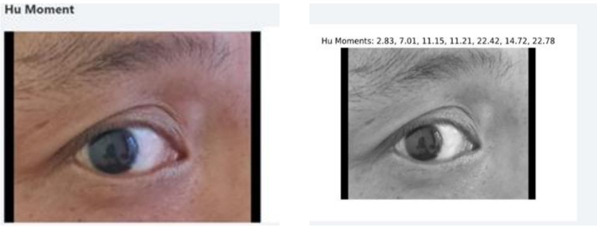
Symptom 4 [h4,e]: the frequency of blinking is excessive (MB[h4,e]=0.7, MD[h4,e]=0.3).
CF[h3,e]=0.7*0.3=0.21.
To find CF[h1, h2, h3^h4,e], one may use the following formula:
CF[h1,h2,h3^h4,e] can be calculated as follows:
CF[h1,h2^h3,e]+CF[h4,e]*(1-CF[h1,h2^h3,e])
=0.60+0.21*(1-0.60)
=0.68

Symptom 5 [h5,e]: eye fatigue (MB[h5,e]=0.8, MD[h5,e]=0.4)
Therefore, CF[h3,e]=0.8*0.4=0.32
The value of CF[h1,h2,h3,h4^h5,e] can be calculated as follows:
CF[h1,h2,h3,h4^h5,e]=CF[h1,h2,h3^h4,e]+CF[h4,e]*(1- CF[h1,h2,h3^h4,e])
=0.68+0,32*(1–0,68)
=0.78

As illustrated in the aforementioned example, the confidence factor associated with myopic refraction when selecting these three symptoms yields a confidence factor of 0.78, which represents a level of confidence of 78%. The subsequent user interface for detecting refractive error is based on the analysis of patient eye photographs. This employs image processing feature extraction with Hu-moments plus statistical approaches, including mean, variance, uniformity and entropy.

In Figure 5 illustrate the application of Hu-moments for image processing in the identification of refractive errors. Figure 5(a), displayed on the left, depicts a colour photograph of an eye that has been employed as the initial data set for image processing, with the objective of extracting the Hu moments. These comprise a set of seven invariant numerical values that describe the shape of the eye and are indispensable for analysis. Figure 5(b), displayed on the right, depicts a greyscale version of the same eye image, wherein the image has been simplified to focus on structural features. The Hu moments listed above the greyscale image (2.83, 7.01, 11.15, 11.21, 22.42, 14.72, 22.78) are employed for the purpose of characterising the structure of the eye and detecting specific refractive errors.

The test was conducted using a total of 80 images, with dimensions of 50×50 pixels. The data division ratio was 9:1, with 90% allocated for training data and 10% for test data. The results of the tests conducted in this study are displayed in Figure 6 and Table 5. The calculations presented in Table 5 indicate that the entropy value is 6.2846, which corresponds to a match.



(a) (b)

Figure 5. Hu-moments visualization (a) color photograph and (b) grayscale image with Hu-moments analysis

```
Image shape: (50, 50)

Pixel Value Matrix:
 [[130 121 127 ... 171 157 162]
 [137 122 131 ... 162 168 173]
 [131 132 142 ... 147 160 164]
 ...
 [141 136 137 ... 130 137 138]
 [140 134 133 ... 132 135 140]
 [136 136 138 ... 135 135 138]]
```

Figure 6. The 50×50 retinal matrix

Table 5. Statistical approach results

Calculations	Results
Mean	121.0928
Standard deviation	513.4322
Smoothness	0.9999
Uniformity	0.0174
Entropy	6.2846

5. CONCLUSION

The results of this study demonstrated that the methodology employed exhibited 100% accuracy in the identification of refractive errors. The photographic analysis of the eyes achieved a value of 6.2846, thereby demonstrating the high degree of precision in the discernment of refractive characteristics. These findings support the hypothesis that artificial intelligence can effectively assist in determining the type of refractive error and provide relevant information to the general public. This application is particularly advantageous for individuals with limited familiarity with the various refractive conditions, as it facilitates the identification of their specific condition in a more straightforward and efficient manner. This study concentrated on the potential of artificial intelligence in the detection of refractive eye disorders, with a particular emphasis on the CF and image processing techniques. The importance of this research lies in its potential to provide accessible and efficient diagnostic methods, particularly in regions where specialised eye care is limited or costly. These findings lend support to the hypothesis that artificial intelligence can effectively assist in determining the type of refractive error and provide relevant information to the general public. Further research could explore the integration of this artificial intelligence system with mobile health applications to increase its accessibility and utility. Additionally, further studies could aim to improve the accuracy and functionality of the artificial intelligence system by incorporating larger and more diverse datasets.

ACKNOWLEDGEMENTS

The author would like to thank the Directorate of Research, Technology and Community Service Ministry of Education, Culture, Research and Technology of the Republic of Indonesia has funded this research.

REFERENCES

[1] M. Ang, D. Gatinel, D. Z. Reinstein, E. Mertens, J. L. Alió del Barrio, and J. L. Alió, "Refractive surgery beyond 2020," *Eye*, vol. 35, no. 2, pp. 362–382, Feb. 2021, doi: 10.1038/s41433-020-1096-5.

[2] I. McCormick, I. Mactaggart, A. Bastawrous, M. J. Burton, and J. Ramke, "Effective refractive error coverage: an eye health indicator to measure progress towards universal health coverage," *Ophthalmic and Physiological Optics*, vol. 40, no. 1, pp. 1–5, Jan. 2020, doi: 10.1111/opo.12662.

[3] S. Longwill, M. Moore, D. I. Flitcroft, and J. Loughman, "Using electronic medical record data to establish and monitor the distribution of refractive errors," *Journal of Optometry*, vol. 15, pp. S32–S42, 2022, doi: 10.1016/j.optom.2022.09.001.
[4] E. N. Harb and C. F. Wildsoet, "Origins of refractive errors: environmental and genetic factors," *Annual Review of Vision Science*, vol. 5, no. 1, pp. 47–72, Sep. 2019, doi: 10.1146/annurev-vision-091718-015027.
[5] L. Wang and D. D. Koch, "Intraocular lens power calculations in eyes with previous corneal refractive surgery: review and expert opinion," *Ophthalmology*, vol. 128, no. 11, pp. e121–e131, Nov. 2021, doi: 10.1016/j.ophtha.2020.06.054.
[6] T. V. Tkatchenko, R. L. Shah, T. Nagasaki, and A. V. Tkatchenko, "Analysis of genetic networks regulating refractive eye development in collaborative cross progenitor strain mice reveals new genes and pathways underlying human myopia," *BMC Medical Genomics*, vol. 12, no. 1, p. 113, Dec. 2019, doi: 10.1186/s12920-019-0560-1.
[7] M. Labkovich *et al.*, "Portable hardware and software technologies for addressing ophthalmic health disparities: a systematic review," *Digital Health*, vol. 8, p. 205520762210900, Jan. 2022, doi: 10.1177/20552076221090042.
[8] A. A. Jabber, A. H. Hadi, S. M. Wadi, and G. A. Shaded, "Cataract detection and classification using deep learning techniques," *International Journal of Computing and Digital Systems*, vol. 16, no. 1, pp. 1–10, 2024, [Online]. Available: https://journals.uob.edu.bh/bitstream/handle/123456789/5748/1571037888.pdf?sequence=1&isAllowed=y
[9] I. Kuric *et al.*, "Approach to automated visual inspection of objects based on artificial intelligence," *Applied Sciences*, vol. 12, no. 2, p. 864, Jan. 2022, doi: 10.3390/app12020864.
[10] G. Dimauro, M. E. Griseta, M. G. Camporeale, F. Clemente, A. Guarini, and R. Maglietta, "An intelligent non-invasive system for automated diagnosis of anemia exploiting a novel dataset," *Artificial Intelligence in Medicine*, vol. 136, p. 102477, Feb. 2023, doi: 10.1016/j.artmed.2022.102477.
[11] J. Camara, A. Neto, I. M. Pires, M. V. Villasana, E. Zdravevski, and A. Cunha, "A comprehensive review of methods and equipment for aiding automatic glaucoma tracking," *Diagnostics*, vol. 12, no. 4, p. 935, Apr. 2022, doi: 10.3390/diagnostics12040935.
[12] J. H. L. Goh *et al.*, "Artificial intelligence for cataract detection and management," *Asia-Pacific Journal of Ophthalmology*, vol. 9, no. 2, pp. 88–95, Mar. 2020, doi: 10.1097/01.APO.0000656988.16221.04.
[13] A. R. Wahab Sait, "Artificial intelligence-driven eye disease classification model," *Applied Sciences*, vol. 13, no. 20, p. 11437, Oct. 2023, doi: 10.3390/app132011437.
[14] S. Hardi, F. P. Surbakti, and Elviwani, "Expert system for detection glaucoma disease using certainty factor method," *Journal of Physics: Conference Series*, vol. 1641, no. 1, p. 012100, Nov. 2020, doi: 10.1088/1742-6596/1641/1/012100.
[15] R. Sayres, N. Hammel, and Y. Liu, "Artificial intelligence, machine learning and deep learning for eye care specialists," *Annals of Eye Science*, vol. 5, pp. 18–18, Jun. 2020, doi: 10.21037/aes.2020.02.05.
[16] D. Lin *et al.*, "Application of comprehensive artificial intelligence retinal expert (CARE) system: a national real-world evidence study," *The Lancet Digital Health*, vol. 3, no. 8, pp. e486–e495, Aug. 2021, doi: 10.1016/S2589-7500(21)00086-8.
[17] R. Kurniawan, M. Z. A. Nazri, S. N. H. S. Abdullah, Z. A. Othman, and S. Abdullah, "Bayesian network and dempster-shafer theory for early diagnosis of eye diseases," *Compusoft*, vol. 9, no. 4, pp. 3642–3651, 2020.
[18] I. A. Wisky and T. A. Putra, "Optimization deep learning with rough set approach model classification Otitis," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 32, no. 3, p. 1795, Dec. 2023, doi: 10.11591/ijeecs.v32.i3.pp1795-1804.
[19] M. Hamiz, H. Haron, M. Bakri, and N. L. Mohd Lazim, "Ontology model for intake suggestion and preparation for malay confinement dietary recipes," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 17, no. 1, p. 481, Jan. 2020, doi: 10.11591/ijeecs.v17.i1.pp481-488.
[20] A. Khozaimi, "Mobile expert system for dengue fever based on certainty factor method," *Journal of Physics: Conference Series*, vol. 1569, no. 2, p. 022070, Jul. 2020, doi: 10.1088/1742-6596/1569/2/022070.
[21] G. G. A. Delilah, "Expert system of initial anamnesis process of menstrual disorders using certainty factor method," *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 9, no. 3, pp. 2906–2912, Jun. 2020, doi: 10.30534/ijatcse/2020/64932020.
[22] Z. Li *et al.*, "Artificial intelligence in ophthalmology: the path to the real-world clinic," *Cell Reports Medicine*, vol. 4, no. 7, p. 101095, Jul. 2023, doi: 10.1016/j.xcrm.2023.101095.
[23] J. Son, J. Y. Shin, E. J. Chun, K.-H. Jung, K. H. Park, and S. J. Park, "Predicting high coronary artery calcium score from retinal fundus images with deep learning algorithms," *Translational Vision Science & Technology*, vol. 9, no. 2, p. 28, May 2020, doi: 10.1167/tvst.9.2.28.
[24] D. M. Moshfeghi and M. T. Trese, "Reducing blindness resulting from retinopathy of prematurity using deep learning," *Ophthalmology*, vol. 128, no. 7, pp. 1077–1078, Jul. 2021, doi: 10.1016/j.ophtha.2021.04.028.
[25] R. Nuzzi, G. Boscia, P. Marolo, and F. Ricardi, "The impact of artificial intelligence and deep learning in eye diseases: a review," *Frontiers in Medicine*, vol. 8, Aug. 2021, doi: 10.3389/fmed.2021.710329.
[26] F. Li *et al.*, "A deep-learning system predicts glaucoma incidence and progression using retinal photographs," *Journal of Clinical Investigation*, vol. 132, no. 11, Jun. 2022, doi: 10.1172/JCI157968.
[27] G. Moraes *et al.*, "Quantitative analysis of OCT for neovascular age-related macular degeneration using deep learning," *Ophthalmology*, vol. 128, no. 5, pp. 693–705, May 2021, doi: 10.1016/j.ophtha.2020.09.025.
[28] A. Arrigo, E. Aragona, and F. Bandello, "Artificial intelligence for the diagnosis and screening of retinal diseases," *US Ophthalmic Review*, vol. 17, no. 2, p. 1, 2023, doi: 10.17925/USOR.2023.17.2.1.
[29] J. Zhang and H. Zou, "Insights into artificial intelligence in myopia management: from a data perspective," *Graefe's Archive for Clinical and Experimental Ophthalmology*, vol. 262, no. 1, pp. 3–17, Jan. 2024, doi: 10.1007/s00417-023-06101-5.
[30] A. Balasopoulou *et al.*, "Symposium recent advances and challenges in the management of retinoblastoma globe - saving treatments," *BMC Ophthalmology*, vol. 17, no. 1, p. 1, 2017.
[31] A. Herliana, T. Arifin, S. Susanti, and A. B. Hikmah, "Feature selection of diabetic retinopathy disease using particle swarm optimization and neural network," in *2018 6th International Conference on Cyber and IT Service Management (CITSM)*, IEEE, Aug. 2018, pp. 1–4. doi: 10.1109/CITSM.2018.8674295.
[32] S. Ghaffari, P. Soleimani, K. F. Li, and D. W. Capson, "Analysis and comparison of FPGA-based histogram of oriented gradients implementations," *IEEE Access*, vol. 8, pp. 79920–79934, 2020, doi: 10.1109/ACCESS.2020.2989267.
[33] Z. Wu *et al.*, "Application of image retrieval based on convolutional neural networks and Hu invariant moment algorithm in computer telecommunications," *Computer Communications*, vol. 150, Jan. 2020, doi: 10.1016/j.comcom.2019.11.053.
[34] A. M. Ashir, S. Ibrahim, M. Abdulghani, A. A. Ibrahim, and M. S. Anwar, "Diabetic retinopathy detection using local extrema quantized haralick features with long short-term memory network," *International Journal of Biomedical Imaging*, vol. 2021, pp. 1–12, Apr. 2021, doi: 10.1155/2021/6618666.

BIOGRAPHIES OF AUTHORS

Rizal Rachman studied undergraduate at Padjadjaran University in 2000-2005 majoring in Mathematics, Computer Science study program, Masters in Management at Bina Sarana Informatika University in 2013-2015 and Masters in Information Systems at STMIK LIKMI Bandung in 2019-2021. He has authored or coauthored more than 79 publications: 2 proceedings and 36 journals, with 10 H-index and more than 986 citations Research interests include data mining, artificial intelligence, and information system. He can be contacted at email rizalrachman@ars.ac.id.

Sari Susanti is a member of the Faculty of Engineering, majoring information system, at Adhirajasa Reswara Sanjaya (ARS) University. She graduated from the computer science master's program at Nusa Mandiri University Jakarta in 2019. She has authored or co-authored more than 64 publications, including 2 proceedings and 62 journals, with an H-index of 11 and more than 405 citations. Her research interests include information system, web programming, data mining. She can be contacted at email: sari.susanti@ars.ac.id.

Hendi Suhendi is a member of the Faculty of Engineering, majoring in Informatics Engineering, at Adhirajasa Reswara Sanjaya (ARS) University. He graduated from the Information Systems at STMIK LIKMI Bandung in 2012. He has authored or co-authored more than 55 publications, including 1 proceeding and 54 journals, with an H-index of 8 and more than 189 citations. His research interests include information system, web programming, data mining. He can be contacted at email: hendi2708@ars.ac.id.

Adi Karawinata Satyanegara is a bachelor student in the Faculty of Engineering, majoring in Informatics Engineering, at Adhirajasa Reswara Sanjaya (ARS) University. He has participated in research artificial intelligence detection of refractive eye diseases using certainty factor and image processing. He can be contacted via email: adi.karawinata.s@gmail.com.