RESEARCH PAPER

Fuzzy Analysis in Ophthalmology

M. Geethalakshmi[1*], R. Maheswari[2], Dr. K. Saranya[3], Jennifer I[4], D. Mythili[5], Dr. Bhawna Singla[6], P. Boomi[7], Dr. T. Vengatesh[8], Dr. B. Anbuselvan[9], Dr. L. Jerlin Rubini[10]

[1*] Associate Professor, Department of Mathematics, KCG College of Technology, Karapakkam, Chennai, Tamil Nadu, India (Corresponding Author). Email: geetharamon@gmail.com

[2] Assistant Professor, Department of Electronics and Communication Engineering, KCG College of Technology, Karapakkam, Chennai, Tamil Nadu, India. Email: maheswari.kaja@gmail.com

[3] Assistant Professor, Department of Mathematics, R P Sarathy Institute of Technology, Salem. Email: saranya.k@rpsit.ac.in

[4] Assistant Professor, Department of BCA, New Horizon College, Marathahalli, Main Rd, near Marathahalli, Kaverappa Layout, Kadubeesanahalli, Bellandur, Bengaluru, Karnataka - 560103. Email: jenniferisrael93@gmail.com

[5] Assistant Professor, Department of Mathematics, Erode Sengunthar Engineering College, Perundurai - 638057. Email: mythimkp@gmail.com

[6] Assistant Professor, Department of Sciences (Mathematics), Manav Rachna University, Faridabad, Haryana, India. Email: bhawnasingla@mru.edu.in

[7] Assistant Professor, Department of Mathematics, V.S.B. Engineering College (Autonomous), Karur, Tamilnadu, India. Email: rpboomi@gmail.com

[8] Assistant Professor, Department of Computer Science, Government Arts and Science College, Veerapandi, Theni, Tamilnadu, India. Email: venkibiotinix@gmail.com

[9] Assistant Professor, Department of Computer Science, Government Arts and Science College, Veerapandi, Theni, Tamilnadu, India. Email: selvananbume@gmail.com

[10] Assistant Professor, Department of Computer Science, Government Arts and Science College, Veerapandi, Theni, Tamilnadu, India. Email: jel.jerlin@gmail.com

Received: 20th Feb, 2026; **Revised:** 4th Mar, 2026; **Accepted:** 25th Mar, 2026; **Available Online:** 10th Apr, 2026

ABSTRACT

This paper deals with the technique of image processing analysis through surveillance systems in order to categorize the images of cataracts. The purpose of this work is to implement a new fuzzification technique called Fuzzy Estimation Rule (FER) for observing and analyzing the side effects of steroids usage for a COVID-infected patient through Artificial Intelligence (AI). Nowadays, there is a bloom in plenty of image processing ideas, the challenging task is to fix the observations of the image which in turn leads to the formation of cataract layers in both the eyes. FER is used to analyze the patients whose eyes are observed with a layered pattern which in turn converted to cataract formation. This work helps to analyze the identification of the post-COVID symptoms after a long time, even when the patient is unaware of the issue. Even though several contributions on this issue have been made, the surveillance system has yet to achieve adequate efficiency. This study helps to attain the accuracy of the image with clarity by getting the input values as data and converting it in the form of plots. This process will undergo different hidden layers of Fuzzy Neural Network (FNN) and finally the graph is generated using the MATLAB tool through AI. Step-by-step comparison is done by repeating the process of plotting once in a while for improving the quality of the image. The execution of FER along with the combined effect of AI and FNN helps to get a clear image. The proposed study will be a better alternative for pattern classification.

Key words: Fuzzy Estimation, Covid, Cataract, MATLAB, FNN, AI.

How to cite this article: Geethalakshmi M, Maheswari R, Saranya K, Jennifer I, Mythili D, Singla B, Boomi P, Vengatesh T, Anbuselvan B, Rubini LJ. Fuzzy Analysis in Ophthalmology. Int J Drug Deliv Technol. 2026;16(26s): 40-48. DOI: 10.25258/ijddt.16.26s.3

Source of support: Nil.

Conflict of interest: None

1. Introduction

Fuzzy analysis in ophthalmology involves applying fuzzy logic to medical imaging and clinical data to enhance the diagnosis, screening, and evaluation of problems related to human eye such as macular edema, glaucoma and diabetic retinopathy. By addressing uncertainty and ambiguity commonly found in medical data such as blurred image boundaries or imprecise measurements fuzzy logic enables more flexible, accurate, and nuanced classifications compared to conventional binary approaches. Post-covid symptoms are observed in getting cataract formation in human eyes. Eyes playing a significant role in our day-to-day life. In severe cases, post-covid complications may result in vision problems and, in extreme case, the loss of the eye will also occur. Nowadays CCTVs play a major role by enabling real-time monitoring of various locations. With the rise of online examinations and assessments during the pandemic, surveillance systems have also been adapted for online proctoring. However, most existing systems lack advanced image processing capabilities. Even when image processing is incorporated, challenges such as dynamic backgrounds, poor image quality, insufficient differentiation algorithms, and approximation errors can limit effectiveness. Moreover, the security of processed data remains a significant concern due to the shortcomings of current algorithms.

Pattern recognition and image processing which is playing a key role for the development of intelligent systems for medical diagnosis. Early research by King-Sun Fu and Azriel Rosenfeld in 1976 established the theoretical foundation of pattern recognition and digital image processing techniques used in automated decision systems. Their work demonstrated that machine-based classification of images can effectively identify patterns from complex visual data sets, which later became essential for medical image analysis. The use of artificial intelligence for visual recognition tasks was further explored in 1992 by K. Sutherland and colleagues through automatic face recognition systems. Their research highlighted how neural networks and computational models could identify and classify facial patterns using surveillance imagery. These early developments laid the groundwork for applying image recognition techniques in medical imaging and diagnostic surveillance systems.

Advancements in intelligent segmentation techniques were introduced by Bahadir Karasulu and Serkan Balli in 2010, where fuzzy logic, neural networks, and genetic algorithms were integrated for image segmentation. Their work demonstrated that fuzzy logic methods are capable of handling uncertainty and ambiguity present in medical images, particularly when boundaries between regions are unclear. Medical expert systems based on fuzzy logic have also been explored for clinical decision-making. In 2013, Smita Sushil Sikchi proposed a system using fuzzy for analyzing the cardiac diseases. Here the work shows that fuzzy inference systems can efficiently analyze uncertain medical data and assist clinicians in diagnosis by modeling human reasoning through fuzzy rules. In the area of fuzzy optimization methods, A. Praveen Prakash and M. Geethalakshmi introduced the Pascal's Triangle Graded Mean method in 2015, which provides an efficient approach for analyzing fuzzy numbers in optimization problems. This technique utilizes coefficients derived from Pascal's triangle to compute graded mean values for trapezoidal fuzzy numbers, thereby simplifying complex fuzzy computations.

Automated cataract detection using image processing has also gained attention in recent years. In 2016, S.Pathak and B.Kumar introduced an algorithm for cataract detection with robust automation using thresholding a diagnostic parameter. Their system was designed for telemedicine applications and demonstrated the potential of automated screening systems in detecting cataracts at an early stage. Further research in fuzzy systems applied to computational models was conducted by M. Geethalakshmi and G. Kavitha in 2019, who developed a synchronization model using fuzzy transition probability relation matrices in MATLAB. Their work demonstrated the applicability of fuzzy mathematical models in analyzing complex data structures. With the growth of biomedical sensor networks, intelligent routing and monitoring techniques were introduced by M. Geethalakshmi and collaborators in 2021 through the Trident Form routing method in wearable biomedical wireless sensor networks. This research demonstrated improved efficiency in medical monitoring systems through optimized data transmission techniques.

Recent advancements in ophthalmology research have focused on automated cataract screening systems. In 2022, Wan Mimi Diyana Wan Zaki and colleagues proposed a connected mobile cataract screening system capable of detecting cataract symptoms through mobile imaging devices. Their approach highlighted the importance of portable and accessible diagnostic tools for large-scale ophthalmic screening. Deep learning techniques have also been used extensively in surveillance and recognition systems. In 2022, Hameed Moqbel and Murali Parameswaran introduced an occluded facial recognition system using deep learning architectures. Their system demonstrated improved accuracy in identifying patterns from partially obstructed images, for specification in medical image scenarios in which images may contain noise or distortions. More recent developments between 2023 and 2025 have further expanded the application of artificial intelligence in ophthalmology. Studies have explained the importance of deep learning architectures like Convolutional Neural Network (CNN), Hybrid Neural Models (HNM), and Transfer Learning Frameworks (TLF) for detecting cataracts from retinal images. These models significantly increase the accuracy of classification and reducing the need for physical diagnosis.

For example, research conducted in 2024 proposed hybrid deep learning models that integrate multiple neural network layers to improve cataract diagnosis from ocular images. Similarly, CSDNet-based deep learning frameworks have been developed to classify cataract stages more accurately by learning detailed visual features from medical imaging datasets. Transfer learning techniques using deep neural networks such as ResNet-50 have also been widely adopted for cataract detection systems. These models utilize pre-trained deep neural networks to analyze retinal and fundus images and achieve high classification accuracy while reducing computational complexity. In addition, recent ophthalmology research has highlighted complications associated with steroid treatments during the COVID-19 pandemic. Studies published in 2025 have reported that prolonged steroid usage may lead to ocular complications such as posterior subcapsular cataracts. This observations emphasize the significance of fast detection along with the monitoring of cataract formation among post-COVID patients.

Recent research has increasingly concentrated on the importance of artificial intelligence in automated cataract detection. CNN-based diagnostic systems have been developed to classify cataract images with improved accuracy compared to traditional algorithms. Transfer learning techniques using deep neural networks such as ResNet-50 have also been applied for cataract classification from fundus images. Several machine-learning frameworks has introduced in early cataract identification using ocular image datasets. More recent studies further demonstrate that deep learning models can detect multiple ophthalmic diseases including cataracts using retinal images, thereby improving diagnostic efficiency and reducing manual screening efforts.

In 2024, researchers proposed a deep-learning model based on CNN and Random Forest Algorithms (RFA) to automatically detect cataracts from eye images. The study demonstrated that CNN-based models significantly improve diagnostic accuracy compared with traditional machine learning techniques. A 2024 study proposed a transfer learning approach using the ResNet-50 architecture for automatic cataract detection from fundus images. The model improves classification accuracy and reduces manual diagnostic effort by learning complex image features from pre-trained networks. In 2024, researchers developed a machine learning-based cataract detection system that processes ocular images through preprocessing, feature extraction, and classification stages. The system enables early diagnosis and improves screening efficiency using artificial intelligence techniques. Another 2024 study developed deep-learning framework depends on ResNet-50 for cataract detection from retinal fundus images. The model achieved accuracy above 95%, demonstrating the effectiveness of deep neural networks for automated ophthalmic diagnosis. A 2025 study proposed a deep learning framework capable of detecting multiple eye diseases including cataracts using retinal imaging datasets. The system assists ophthalmologists by providing early automated diagnosis of various ocular disorders.

Overall, the literature demonstrates that integrating fuzzy logic, artificial intelligence, neural networks, and image processing techniques can significantly enhance automated medical diagnosis systems. However, existing approaches still face challenges in achieving high accuracy, clarity in image classification, and efficient processing of uncertain medical data. Therefore, the present study introduces a Fuzzy Estimation Rule (FER) integrated with neural network architecture to improve cataract detection accuracy through enhanced fuzzy analysis and pattern recognition techniques. The inefficiency of current monitoring systems has led to the need for a supportive system to enhance performance and ensure that the monitoring is reliable and justified. Image processing refers to the systematic method of capturing images, analyzing the data contained within them, and generating meaningful outputs. The process flow for this method is shown in Figure 1.

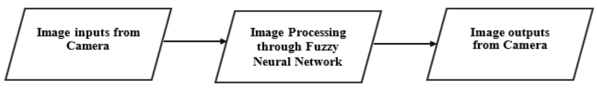

Figure 1. Image Processing

2. Preliminaries

2.1 Neural Network

A network that relies on a single surveillance layer is more susceptible to hacking or system breaches. To address this limitation, a Neural Network (NN) based approach provides enhanced security through its multilayered architecture. The inclusion of multiple hidden layers with strong interconnectivity improves processing efficiency while minimizing the likelihood of unauthorized access. Neural networks therefore serve as a fundamental component of the proposed algorithm.

The architecture comprises one input layer and one output layer, connected through several hidden layers, as depicted in Figure 2. This work aims to embed and encrypt all image processing operations within the hidden layers, preventing external access to the processing algorithms. By combining artificial intelligence and machine learning techniques with neural networks, the system is capable of continuous self-learning, leading to improved accuracy and performance over time.

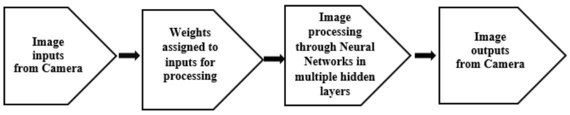

Figure 2. Neural Network and Surveillance

Neural Networks (NNs) are computational models that abstract the functioning of the biological nervous system and replicate certain capabilities in human-brain. It is composed of numerous highly inter linked processing elements, referred to as neurons, which operate together to process information efficiently. Neural networks demonstrate several notable features, including pattern association, robustness, mapping ability, fault tolerance, and rapid data processing. As mathematically formulated models inspired by biological neural mechanisms, NNs play a significant role in intelligent computing systems. The diagrammatic representation for a NN is presented in Figure 3.

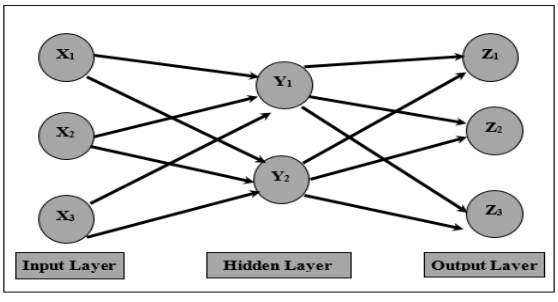

Figure 3. Representation of NN

2.2 Pattern Recognition

Pattern Recognition (PR) involves the acquisition of data from a physical process and the classification of that data into distinct patterns. This technique enables the systematic assignment of data samples to corresponding pattern classes. The concept was first proposed by Oliver Selfridge in 1955, highlighting the ability to identify and extract significant features from large amounts of irrelevant data. The structural interpretation of pattern recognition system is shown in Figure 4.

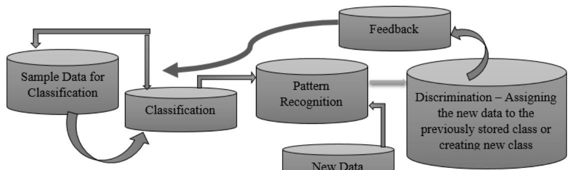

Figure 4. Representation for Pattern Recognition

2.3 Self organizing maps (Kohonen Maps)

Self organizing maps (SOM's) are the inspiration for the NN models attracted from the biological pattern with the functioning of neural systems. They employ competitive layers made up of counter propagation units that learn through a self-organizing mechanism. SOMs operate under an unsupervised learning paradigm and are trained using competitive learning algorithms. These networks are commonly used for clustering and mapping applications, particularly for reducing the dimensionality of multidimensional data into lower-dimensional representations, thereby simplifying complex problems and facilitating easier analysis. The SOM architecture comprises two layers: an input layer and an output layer. The schematic representation of the SOM is shown in Figure 5.

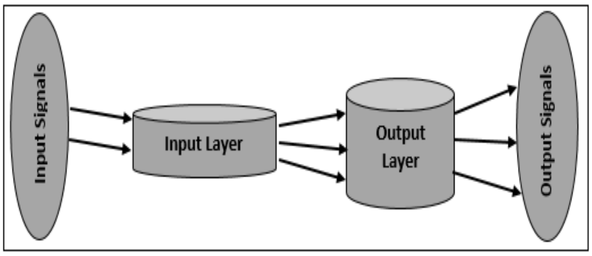

Figure 5. Self-Organizing Maps (Kohonen Maps)

3. Cataract Formation, Symptoms and its types

Cataract formation is caused due to various reasons such as Aging, Diabetes, Alcohol intake, Excessive sunlight exposure, Hereditary, Hypertension and overweight. These are usual cause for cataract formation. But apart from this, an alarming cause is due to steroid induced cataracts which is most uncommon.

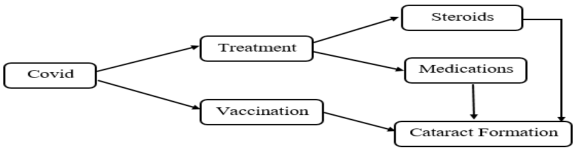

Figure 6. Post Covid Cataract

3.1 Symptoms of Cataract

The following are the symptoms of cataract (i) Blurry or Foggy Vision (ii) Poor night vision (iii) Glare from lights (iv) Fadded Colours (v) Double vision in one eye(vi) Frequent changes in vision prescription (vii)Visualizing halos around lights.

3.2 Steroid-induced Cataracts

Medical articles note that steroid-induced cataracts typically show up as cloudy lens opacities, most often forming in the central posterior region. In these cases, images of the eye often show a cloudy or opaque pupil with a reduced red reflex, signaling changes within the lens cells. The lens may display a frosted or grainy appearance due to abnormal accumulation of lens fibers, a detail that can be confirmed during a slit-lamp exam or observed in laboratory imaging.

Steroid-induced cataracts, typically presenting as posterior sub capsular cataracts, are primarily treated with surgical removal, as lens opacities are generally irreversible. The definitive treatment is standard phacoemulsification (cataract-surgery) for replacing the cloudy lens by an artificial intra-ocular lens. While stopping the steroid may halt progression, it usually does not reverse existing cataracts.

3.3 Types of Cataract

Cataracts are classified into various types based on the affecting areas. It will categorized depnding on their causes and the specific area of the lens involved. (i) Congenital Cataracts are cataract that originates from birth or early childhood. (ii) Acquired Cataracts occurs due to age factor and other influencing causes. (iii) Traumatic (injury causes) and Non-Traumatic Cataracts (systemic causes, ocular causes, drugs/steroid induced causes) are the other causes from Acquired Cataracts (iv) Cortical Cataracts are cataracts that occur along the peri-pheral regions and edges of lens. (v) Posterior subcapsular Cataracts are cataracts that forms at the posterior surface of the lens and affects the back of the lens.

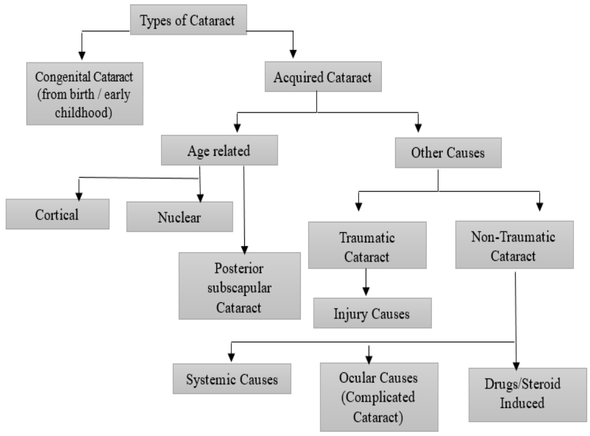

Figure 7. Types of Cataracts

3.4 Cataract Stages

The stages of cataract can be classified in to four stages as follows: (i) Early stage (ii) Immature stage (iii) Mature stage and (iv) Hyper mature stage. The pictorial representation is given in the following figure 8:

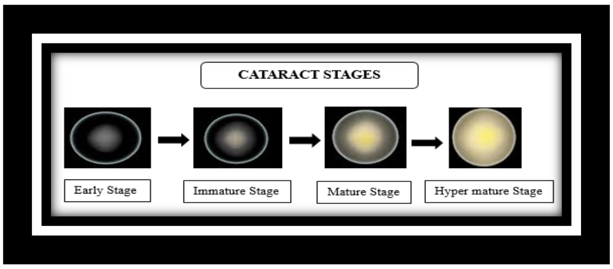

Figure 8. Different Stages of Cataracts

4. Proposed Method

The proposed method are analyzed in various stages are as follows:

4.1 Mathematical Model as Pascal's Triangle Graded Mean Approach

Generalized fuzzy numbers offers very simple and effective method called Graded mean integration representation for the determination of optimal solution using fuzzy variable in many of the transportation problems.

This method utilizes Pascal's Triangle with fuzzy variables as its coefficients corresponding to the numbers in the triangle. By summing these coefficients and divide by Pascal's triangle numbers total, the approach yields the idea of Pascal's Triangle Graded Mean method.

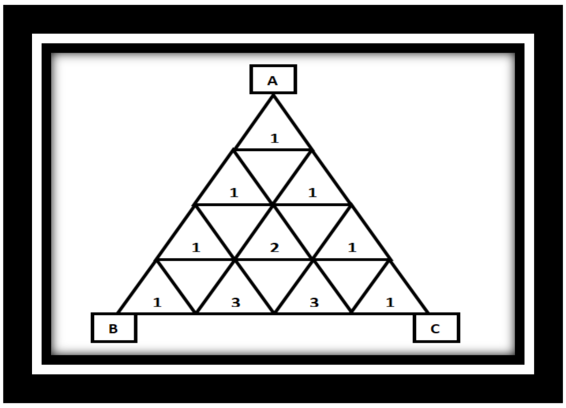

Figure 9. Pascal's Triangle

Let $\tilde{A} = (u_1, u_2, u_3, u_4)$ be a trapezoidal fuzzy number, then the Pascal's triangular approach is analyzed using the fuzzy numbers as the coefficients from Figure 9 and it is represented as

P $(\tilde{A})$ = $(u_1 + 3u_2 + 3u_3 + u_4)$ / 8; Coefficients of u_1, u_2, u_3, u_4 are 1, 3, 3, 1. An extension can be done till n-dimensional fuzzy order.

4.2 Fuzzy Estimation Rule (FER)

This proposed study employs the Fuzzy Estimation Rule (FER). This works by fuzzifying incoming values by processing five values at a time to accelerate computation and produces more accurate results. Integrating FER within the hidden layers of the neural network not only enhances processing efficiency but also strengthens system security.

Experimental analysis was performed on cataract image across five different criteria in five different angles, considering various performance metrics. The recorded results were then fuzzified using the fuzzy estimation rule approach as follows:

$$FER = \left(\frac{1}{5}\right) * \left({t_1}^{1/5} + {t_2}^{1/5} + {t_3}^{1/5} + {t_4}^{1/5} + {t_5}^{1/5}\right)$$

where t_1, t_2, t_3, t_4, t_5 are the observed absolute values.

4.3 Application of FER in Cataract Detection

The application is used to capture cataract image patterns in five different angles which is acting as input layer, the cataract detection and feature extraction using FER and cataract image classification is acting as the hidden-layer and identify the image as output layer determines the confirmation of the affected eye. In the form of neural network, it is pictorially represented as given in the following figure 10:

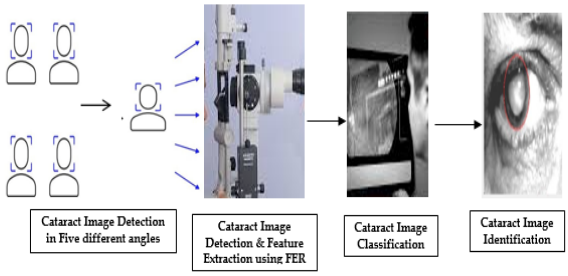

Figure 10. Cataract Image Detection

4.4 Proposed Algorithms

Algorithms:

Step 1: Start

Step 2: Inputting cataract image for image detection

Step 3: Cataract image conversion into fuzzy value

Step 4: Cataract image Classification

Step 5: Output as cataract image identification

Step 6: stop

5. Experimental Study

This study involving with various input values observed from cataract images and recorded from the cameras at various levels in five different angles with high magnification taken in the fuzzy interval varies from 0 and 1 for the implementation of FER. The cataract structures are captured using 5 various cameras in five different angles and the recorded pixels are turned into fuzzy value through FER. The values are recorded in five criteria's as follows:

The Criteria 1 observations are recorded and the approximation is done through FER as follows:

Table 1. Criteria I - Cataract image in five Angles

Criteria I	Angle I	Angle II	Angle III	Angle IV	Angle V	FER
CAMERA 1	0.6	0.3	0.7	0.7	0.5	0.88435
CAMERA 2	0.7	0.1	0.5	0.4	0.8	0.84431
CAMERA 3	0.8	0.5	0.4	0.2	0.7	0.86308
CAMERA 4	0.3	0.9	0.8	0.5	0.9	0.91424
CAMERA 5	0.7	0.2	0.5	0.4	0.8	0.86308

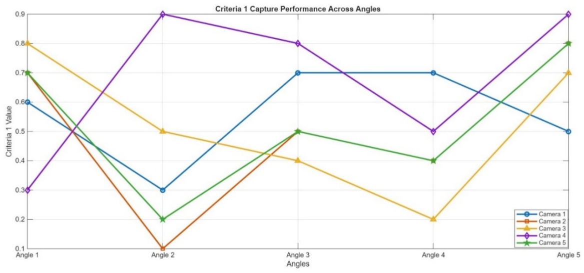

Figure 11. Graphical representation of Criteria 1 cataract capturing

The Criteria 2 observations are recorded and the approximation is done through FER as follows:

Table 2. Criteria II - Cataract image in five Angles

Criteria II	Ang le I	Ang le II	Ang le III	Ang le IV	Ang le V	FER
CAMER A1	0.3	0.6	0.7	0.8	0.9	0.911 11
CAMER A 2	0.1	0.4	0.5	0.7	0.3	0.810 24
CAMER A 3	0.5	0.2	0.6	0.7	0.5	0.859 98
CAMER A 4	0.6	0.4	0.7	0.4	0.3	0.857 03
CAMER A 5	0.9	0.3	0.8	0.2	0.6	0.869 83

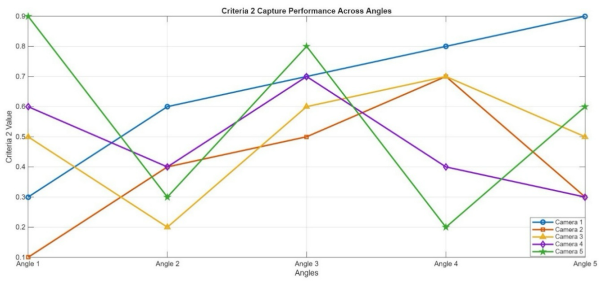

Figure 12. Graphical representation of Criteria 2 cataract capturing

The Criteria 3 observations are recorded and the approximation is done through FER as follows:

Table 3. Criteria III - Cataract image in five Angles

Criteria III	Ang le I	Ang le II	Ang le III	Ang le IV	Ang le V	FER
CAME RA 1	0.6	0.7	0.6	0.9	0.3	0.900 41
CAME RA 2	0.4	0.6	0.8	0.4	0.2	0.849 82
CAME RA 3	0.2	0.8	0.9	0.3	0.8	0.880 53
CAME RA 4	0.7	0.5	0.8	0.9	0.1	0.873 63
CAME RA 5	0.6	0.8	0.5	0.3	0.8	0.894 43

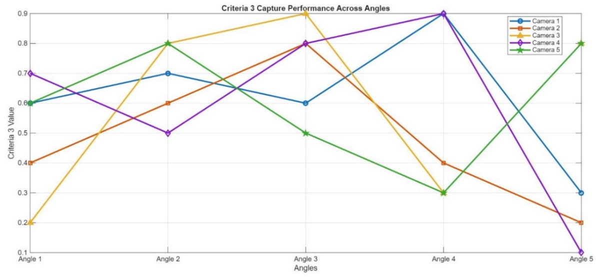

Figure 13. Graphical representation of Criteria 3 cataract capturing

The Criteria 4 observations are recorded and the approximation is done through FER as follows:

Table 4. Criteria IV - Cataract image in five Angles

Criteria IV	Ang le I	Ang le II	Ang le III	Ang le IV	Ang le V	FER
CAME RA 1	0.4	0.2	0.3	0.6	0.9	0.845 07
CAME RA 2	0.8	0.7	0.8	0.8	0.2	0.905 00
CAME RA 3	0.2	0.6	0.9	0.6	0.2	0.846 89
CAME RA 4	0.5	0.9	0.3	0.8	0.4	0.884 92
CAME RA 5	0.6	0.3	0.5	0.2	0.1	0.783 03

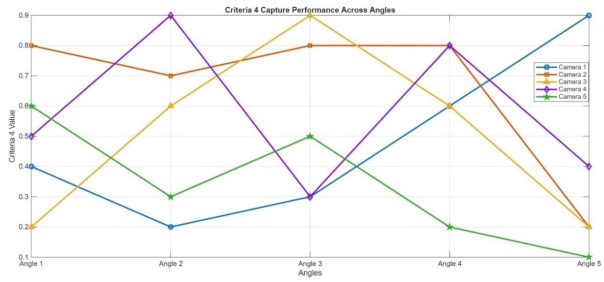

Figure 14. Graphical representation of Criteria 4 cataract capturing

The Criteria 5 observations are recorded and the approximation is done through FER as follows:

Table 5. Criteria V - Cataract image in five Angles

Criteria	Ang le I	Ang le II	Ang le	Ang le	Ang le V	FER

V			III	IV		
CAMERA 1	0.7	0.8	0.5	0.8	0.3	0.90008
CAMERA 2	0.9	0.2	0.6	0.5	0.2	0.84043
CAMERA 3	0.5	0.4	0.2	0.4	0.8	0.84336
CAMERA 4	0.4	0.3	0.5	0.3	0.6	0.83560
CAMERA 5	0.6	0.9	0.8	0.6	0.3	0.90545

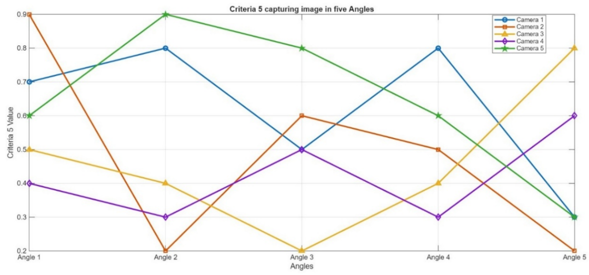

Figure 15. Graphical representation of Criteria 5 cataract capturing

The FER analysis for the observed set of data's through five different angles are given in the following table 6:

Table 6. FER Analysis

FER ANALYSIS					
Criteria's/ Cameras	**Criteria I**	**Criteria II**	**Criteria III**	**Criteria IV**	**Criteria V**
CAMERA 1	0.88435	0.91111	0.90041	0.84507	0.90008
CAMERA 2	0.84431	0.81024	0.84982	0.90500	0.84043
CAMERA 3	0.86308	0.85998	0.88053	0.84689	0.84336
CAMERA 4	0.91424	0.85703	0.87363	0.88492	0.83560
CAMERA 5	0.86308	0.86983	0.89443	0.78303	0.90545

The graphical representation of FER analysis through MATLAB tool is given in the following figure 16:

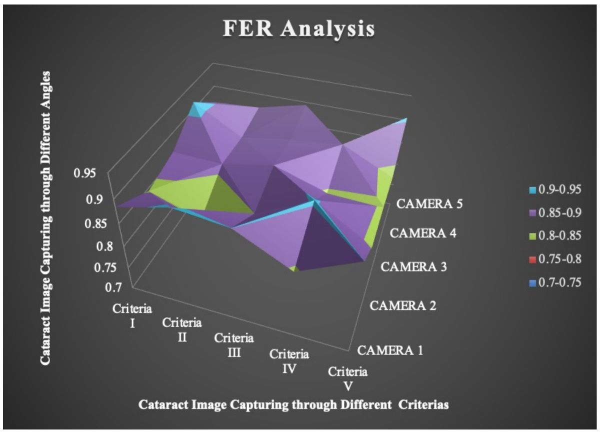

Figure 16. Graphical representation of FER Analysis

6. Proposed Solution and its Advantages

In the past few years, the cataract detection and grading methods are developed, but still advancement and improvement needed in simulating the results. In this proposed study, the cataract image will be captured in different angles and this image is further processed to neural network where the input layer acting as the image capturing and converting into fuzzy value (between 0 and 1) and the hidden layers for image detection and classification through FER analysis and finally, after undergoing FER analysis the cataract image are identified in the output layer. Throughout the entire process, the MATLAB tool is used for approximation and simulation and the accuracy is determined through FER analysis. Then the resultant values are observed and the images are identified. The advantage of the proposed method is to get a cataract image with clarity by improving the detection process with the help of the introduced fuzzy technique through advanced manner.

7. Conclusion

In this paper, a new technique fuzzy estimation rule with five inputs is introduced for cataract detection using pattern recognition technique along with the help of deep learning neural networks. Application of FER in cataract detection is analyzed using neural networks. The development of algorithm for identifying the pattern in order to get more clarity in the image without any ambiguity. The observed fuzzy values are approximated and the simulation curve is obtained using MATLAB tool. The significance of this work is to get clear cataract image and also helps to improve the detection process in a better way through a new technique in an advanced manner.

References

[1] K. S. Fu and A. Rosenfeld, "Pattern recognition and image processing," *IEEE Transactions on Computers*, vol. C-25, no. 12, pp. 1336–1346, 1976.

[2] K. Sutherland, D. Renshaw, and P. B. Denyer, "Automatic face recognition," in *Proc. 1st Int. Conf. Intelligent Systems Engineering*, IEEE, 1992, pp. 29–34.

[3] B. Karasulu and S. Balli, "Image segmentation using fuzzy logic, neural networks and genetic algorithms: Survey and trends," *Machine Graphics and Vision*, vol. 19, no. 4, pp. 367–409, 2010.

[4] S. S. Sikchi et al., "Medical fuzzy expert system for diagnosis of cardiac diseases," *International Journal of Computer Applications*, vol. 66, no. 13, pp. 35–44, 2013.

[5] A. P. Prakash and M. Geethalakshmi, "Fuzzy optimum solution through Pascal's triangle graded mean," *International Journal of Applied Engineering Research*, vol. 10, no. 10, pp. 25843–25850, 2015.

[6] S. Pathak and B. Kumar, "A robust automated cataract detection algorithm using diagnostic opinion-based parameter thresholding for telemedicine application," *Electronics Journal*, vol. 5, no. 57, pp. 1–11, 2016.

[7] M. Geethalakshmi and G. Kavitha, "Synchronization of a square fuzzy transition probability relation matrix using MATLAB," *International Journal of Innovative Technology and Exploring Engineering*, vol. 8, no. 6, pp. 1573–1577, 2019.

[8] M. Geethalakshmi et al., "Optimal routing path using trident form in wearable biomedical wireless sensor networks," *Turkish Online Journal of Qualitative Inquiry*, vol. 12, no. 7, pp. 5134–5143, 2021.

[9] W. M. D. W. Zaki et al., "Towards a connected mobile cataract screening system: A future approach," *Journal of Imaging*, vol. 8, no. 41, pp. 1–19, 2022.

[10] H. Moqbel and M. Parameswaran, "Occluded facial recognition for surveillance using deep learning," in *Proc. 8th Int. Conf. Virtual Reality*, IEEE, 2022.

[11] M. Geethalakshmi, V. Sriram, and V. D. Rao, "Application of fuzzy approximation method in pattern recognition using deep learning neural networks and artificial intelligence for surveillance," in *Mathematical Models Using Artificial Intelligence for Surveillance Systems*. Wiley, 2024, pp. 149–167.

[12] Z. Algouti et al., "Bilateral central retinal vein occlusion revealing malignant hypertension and terminal renal failure: A case report," *Asian Journal of Research and Reports in Ophthalmology*, vol. 8, no. 1, pp. 48–53, 2025.

[13] Z. Zhang et al., "The hidden ophthalmic dangers of steroids in COVID-19 treatment: A case report," *Translational Pediatrics*, vol. 14, no. 3, pp. 516–521, 2025.

[14] Z. Akgun et al., "Ocular involvement in Stevens–Johnson syndrome and toxic epidermal necrolysis: Current management and trends," *Indian Journal of Ophthalmology*, vol. 73, no. 12, pp. 1711–1722, 2025.

[15] S. Gandhi et al., "Sustainable solutions for eye drop plastic waste: Challenges, innovations and environmental impact," *Journal of Ophthalmology*, 2025.

[16] S. K. Upadhyay and M. K. Srivastava, "Deep learning-based detection of cataract diseases using convolutional neural network," *Educational Administration: Theory and Practice*, vol. 30, no. 5, pp. 7792–7796, 2024.

[17] S. S. Mahmood, S. Chaabouni, and A. Fakhfakh, "Improving automated detection of cataract disease through transfer learning using ResNet-50," *Engineering, Technology & Applied Science Research*, vol. 14, no. 5, pp. 17541–17547, 2024.

[18] V. Rawat, H. Mishra, R. Rajak, and R. Thakur, "Automated cataract detection system: A machine learning approach for early diagnosis and intervention," ShodhKosh: Journal of Visual and Performing Arts, vol. 5, no. 2, pp. 1420–1429, 2024.

[19] I. Khan et al., "Enhancing ocular health precision: Cataract detection using fundus images and ResNet-50," *ICCK Transactions on Intelligent Systematics*, vol. 1, no. 3, pp. 145–160, 2024.

[20] A. Tashkandi, "Eye care: Predicting eye diseases using deep learning based on retinal images," *Computation*, vol. 13, no. 4, p. 91, 2025.