Automated Cataract Detection and Hospital Recommendation System

- Detecting Cataracts and Guiding to Care

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(task-0)

1. PROBLEM STATEMENT

According to the World Health Organization report, one of the world's leading causes of blindness is reported to be due to cataracts. Even though cataract majorly affects the elderly population however now they can be seen among minors too. Among the various types, the prominently three types of cataract affect masses in high numbers which are nuclear, cortical, and post-subcapsular cataract. Conventional methods of cataract diagnoses include slit lamp image tests by doctors which do not prove to be effective in classifying cataracts in the early stages and can also have inaccuracies in identifying the correct type of cataract. Therefore, there is a critical need for a reliable and automated system that can accurately detect cataracts based on clinical symptoms and recommend the nearest hospital for further evaluation and management, ultimately improving patient outcomes and reducing the burden of visual impairment caused by untreated cataracts.

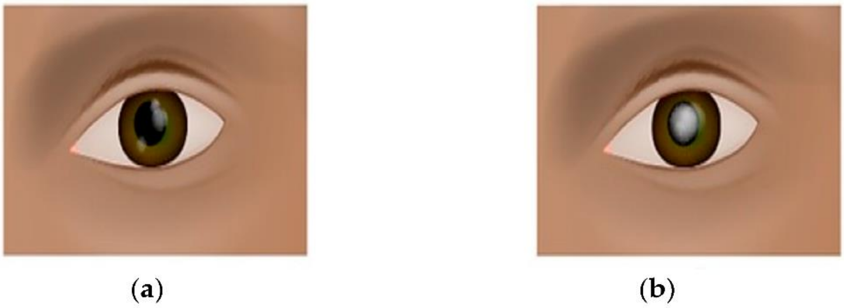


Figure 1. Illustration of eye conditions: (**a**) normal eyes and (**b**) cataracts.

As per the statistics given by the National Blindness and Visual Impairment Survey India 2015-19, cataracts are responsible for 66.2% of blindness cases, 80.7% severe visual impairments, and 70.2% moderate visual problems for an age group of above 50 years of year. Even though cataract develops very slowly it can cause long-term problems as it moves from covering a very small portion to spreading over the eye lens causing vision loss since light can no longer reach the retina due to the cloud that is formed on the lens.

1.1 SIGNS AND SYMPTOMS

1. Blurry Vision.
2. Difficulty to see things at night.
3. Eyes get sensitive to light.
4. Brighter light needed for reading
5. Halo or circular formation is seen around light sources.
6. The colors appear to be more yellowish.

1.2 CAUSES AND RISK FACTORS:

1. Ultraviolet radiation
2. Diabetes
3. Hypertension
4. Obesity
5. Smoking
6. Use of corticosteroid medications.
7. Medical history of eye injury or survey.
8. Alcohol consumption.
9. High rate of myopia
10. Previous Family history

1.3 Scope of the Project

The aim of this project is to detect the presence/absence of cataracts. The system would provide quick results to the user with great accuracy and efficiency. The user can upload the image on the website and obtain the results any time and based on the results the user can take appropriate actions and hospital recommendation system that addresses the needs of both patients and healthcare providers.

1.4 Objectives

- To build a system that will help to detect the presence of cataracts and also determine the type of cataract.
- To build a system that improves the efficiency of detection.
- To build a system that is accessible anywhere and at any time.
- To help save the time of the patient by producing immediate results.
- To recommend nearest hospital.

2. ASSESSMENT

2.1 MARKET NEED

1) **Prevalence of Cataracts:** Cataracts are a significant global health issue, affecting millions worldwide, particularly the elderly population.
2) **Limited Access to Eye Care Services:** Many regions lack sufficient ophthalmic healthcare infrastructure, leading to delays in cataract diagnosis and treatment**.**
3) **Rising Demand for Automation:** Healthcare systems are increasingly adopting automated solutions to improve efficiency and accuracy in diagnosis, aligning with the growing trend towards digital healthcare.
4) **Aging Population:** With the aging demographic in many countries, there is a growing need for early detection and management of age-related cataracts.
5) **Patient Convenience:** Patients seek convenient and accessible healthcare solutions, including streamlined processes for cataract detection and referral to specialized services.

2.2 CUSTOMER NEED

1) **Early Detection:** Patients desire early detection of cataracts to prevent vision loss and maintain quality of life.
2) **Accessibility:** Customers seek easy access to reliable diagnostic services, particularly in underserved areas or regions with limited healthcare facilities.
3) **Quality Care:** Patients value accurate diagnosis and timely referral to reputable eye care centers for comprehensive evaluation and treatment.
4) **Convenience:** Busy individuals or those with mobility issues prefer convenient solutions for cataract screening and hospital recommendation.
5) **Affordability**: Cost-effective options for cataract detection and access to affordable treatment are essential for many customers, including those without adequate insurance coverage.

2.3 BUSINESS NEED

1) **Market Opportunity:** There is a substantial market opportunity for a reliable automated cataract detection and hospital recommendation system, given the widespread prevalence of cataracts and the growing demand for digital healthcare solutions.
2) **Competitive Advantage:** Developing an innovative and accurate system can provide a competitive edge in the healthcare market, attracting customers and driving revenue growth.
3) **Enhanced Patient Care:** By offering a seamless pathway from cataract detection to specialized care, the system can improve patient outcomes and satisfaction, leading to positive referrals and brand loyalty.

4) **Cost Savings:** Automating the cataract detection process can result in cost savings for healthcare providers by reducing manual labor and improving resource allocation.
5) **Regulatory Compliance**: Ensuring compliance with relevant healthcare regulations and standards is crucial for gaining market approval and building trust among customers and stakeholders.

3. TARGET SPECIFICATION

1. **Age Group:** Primarily targeting individuals aged 50 and above, as they are at higher risk for age-related cataracts.
2. **Demographic:** Aimed at both genders, with a focus on regions with a high prevalence of cataracts and limited access to eye care services, including rural areas and developing countries.
3. **Technological Proficiency:** Designed to be user-friendly for individuals with varying levels of technological proficiency, ensuring accessibility for older adults and those less familiar with digital tools.
4. **Accessibility Needs:** Consideration given to individuals with disabilities or impairments that may affect their ability to use traditional diagnostic methods, such as visual or mobility impairments.
5. **Socioeconomic Status:** Tailored to cater to diverse socioeconomic backgrounds, offering cost-effective solutions for individuals with limited financial resources and options for those with higher disposable incomes seeking premium services.
6. **Healthcare Access:** Targeting individuals with limited access to eye care services due to geographical constraints, lack of transportation, or financial barriers, aiming to bridge the gap in healthcare access through digital solutions.
7. **Language and Cultural Sensitivity:** Multilingual support and culturally sensitive design to accommodate diverse linguistic and cultural preferences, ensuring inclusivity and effective communication with customers from various backgrounds.
8. **Medical History and Risk Factors:** Integration of risk assessment tools to identify individuals with predisposing factors for cataracts, such as diabetes, steroid use, or family history of ocular diseases, enabling targeted screening and intervention.
9. **Health Literacy:** Incorporation of educational resources and clear, jargon-free information to empower individuals with the knowledge to understand the importance of cataract detection and seek timely medical care.
10. **Privacy and Confidentiality:** Implementation of robust data protection measures to safeguard patient privacy and confidentiality, complying with relevant healthcare regulations and earning trust among customers regarding data security.

4. EXTERNAL SEARCH

4.1 Information Source

1. **National Eye Institute (NEI):** NEI provides comprehensive information on various eye conditions, including cataracts, their causes, symptoms, and treatment options. Website: [NEI - Cataracts](https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/cataracts)
2. **World Health Organization (WHO):** WHO offers global statistics, reports, and guidelines on eye health and vision care, including initiatives aimed at addressing cataract-related challenges. Website: [WHO - Vision](https://www.who.int/health-topics/vision)
3. **American Academy of Ophthalmology (AAO):** AAO provides resources for both healthcare professionals and patients, covering a wide range of eye diseases, including cataracts. Website: [AAO - Cataracts](https://www.aao.org/eye-health/diseases/what-are-cataracts)
4. **PubMed:** A database of medical research articles, PubMed can be a valuable resource for accessing scientific literature on cataract diagnosis, management, and technological advancements. Website: [PubMed](https://pubmed.ncbi.nlm.nih.gov/)
5. **ClinicalTrials.gov:** ClinicalTrials.gov is a registry and database of publicly and privately supported clinical studies, which may include ongoing trials related to cataract diagnosis, treatment, and technology evaluation. Website: ClinicalTrials.gov

4.2 Literature Survey

1. Hans Morales-Lopez, Israel Cruz-Vega & Jose Rangel-Magdeleno., "Cataract Detection and Classification Systems Using Computational Intelligence" , year 2020.
2. Chi-Ju Lai, Ping-Feng Pai, Marvin Marvin, Hsiao-Han Hung, Si-Han Wang, Din-Nan Chen, "The Use of Convolutional Neural Networks and Digital Camera Images in Cataract Detection", published in 11 March 2022.
3. Md. Sajjad Mahmud Khan, Mahiuddin Ahmed, Raseduz Zaman Rasel, Mohammad Monirujjaman Khan, "Cataract Detection Using Convolutional Neural Network with VGG-19 Model", published in 10 May 2021.
4. Recent Approaches for Automatic Cataract Detection Analysis Using Image Processing" Journal of Network Communications and Emerging Technologies (JNCET), October (2017)
5. Tawfik, H.R., Birry, R.A., & Saad, A.A. (2018). Early Recognition and Grading of Cataract Using a Combined Log Gabor/Discrete Wavelet Transform with ANN and SVM.

5. BENCH MARKING ALTERERNATE PRODUCTS

Benchmarking against existing products or services in the market is crucial to understand the strengths and weaknesses of your automated cataract detection and hospital recommendation system.

1. **Traditional Manual Diagnosis:**
    - Criteria: Accuracy, Speed, Expertise Required, Accessibility.
    - Comparison: Evaluate how your automated system improves upon the accuracy and speed of traditional manual diagnosis by ophthalmologists. Highlight the system's accessibility, especially in underserved areas lacking access to specialized eye care.
2. **Other Automated Cataract Detection Systems:**
    - Criteria: Accuracy, Speed, User Interface, Integration.
    - Comparison: Compare your system's accuracy and speed with other automated cataract detection systems available in the market. Highlight any unique features or advantages, such as a user-friendly interface or seamless integration with existing healthcare systems.
3. **Telemedicine Platforms:**
    - Criteria: Remote Access, Consultation, Integration.
    - Comparison: Assess how your system integrates with telemedicine platforms for remote access and consultation. Highlight the efficiency of your system in providing accurate cataract detection and hospital recommendations remotely, compared to other telemedicine solutions.
4. **Hospital Referral Services:**
    - Criteria: Recommendations, Hospital Network, Feedback.
    - Comparison: Evaluate how your system's hospital recommendation module compares to existing hospital referral services. Highlight the accuracy and relevance of your recommendations, as well as the breadth and quality of your hospital network.
5. **AI-Based Medical Imaging Systems:**
    - Criteria: Algorithm Accuracy, Validation, Adaptability.
    - Comparison: Benchmark your system's AI algorithm against other AI-based medical imaging systems. Highlight any specific adaptations or optimizations for cataract detection and emphasize the clinical validation and accuracy of your system.

6. BUSINESS MODEL

6.1 Proposed System

Project is divided into two phases. First phase aims to detect the presence of cataract, if cataract is present then the second phase classifies the type of cataract on the severity level: normal, mild and severe. The following steps are involved in designing and training the model.

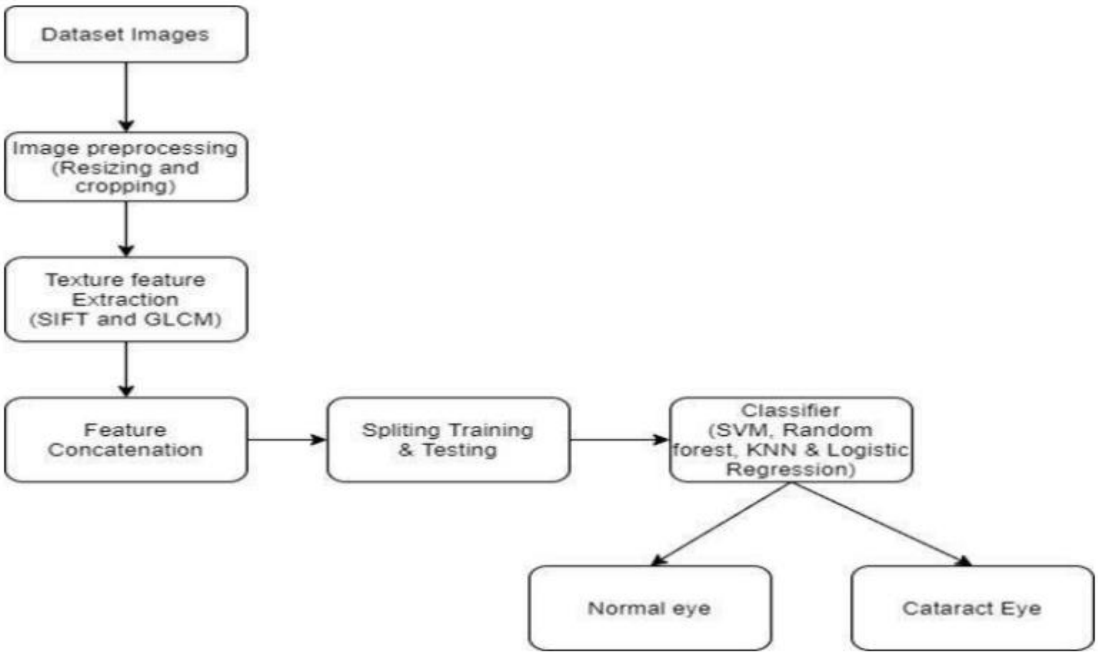


Fig 5. Data Flow binary classification

1. Image pre-processing involves adjusting the dimensions and selecting relevant regions of interest through resizing and cropping raw dataset images to enhance the effectiveness of subsequent feature extraction.

2. Texture feature extraction involves utilizing SIFT for detecting invariant keypoints and GLCM for analyzing pixel intensity relationships to distinguish between normal and cataract eyes, crucial for classification.

3. Feature Concatenation: The extracted features (from SIFT and GLCM) are concatenated into a single feature vector. This combined feature representation enhances the discriminative power for classification.

4. Classifier (SVM, Random Forest, KNN & Logistic Regression): The classifier predicts whether an eye image belongs to the normal or cataract category.

6.2 Deep learning convolutional algorithm

Data Augmentation: Neutral networks require more training data because they extract the features on their own. The performance of CNN highly depends on the data which is fed into the neural network. However in instances where the amount of data available is less, the popular technique of data augmentation is used where in each sample in the data set is changed in response to some categories and new images are generated. These new images can be fed into the neural network as a single batch. The variations that can be made to the image include flip, scale, prop, translation, zoom, Gaussian Noise, etc. In our implementation we have used horizontal flip and zoom of the factor 0.2.

The process of multiclass classification is performed using transfer learning and the following pre-trained models have been used to perform multiclass classification on the pre-processed images.

1. **Mobile Net:** This convolution neural network architecture was proposed by Andrew G. Howard. This streamlined architecture was specially designed for mobile and embedded devices with the capability of giving results in a lesser amount of time using less computation power. The architecture follows the principle of depth wise separable convolutions. The main idea was to separate the filter's depth and spatial dimensions which is then followed by point-wise 26 convolution. The overall architecture of MobileNet consists of 28 layers. It can easily be distinguished from a standard CNN since each 3x3 depth separable layer is followed by batch normalization and ReLU activation function layer. This is again repeated for the point-wise separable layer. This model takes an input of size 224x224x3[27].

2. **VGG-16:** This convolution neural network was initially proposed for the purpose of classification and detection. This model gives an accuracy of 92.7% on the famous imageNet dataset. The motivation behind developing this model was to improve the existing accuracy of the Alexnet model by changing the large kernels into multiple 3x3 kernel-sized filters which are placed in series with each other. The model accepts an input of size 224x224 in RGB format. All the convolution layers have a filter size of 3x3 and all the max pooling layers have pool size of 2x2[28]. In the output layer the model uses softmax activation function. As the name suggests it consists of 16 layers in total and the other variants can have 19 layers with corresponding weights.

3. **SqueezeNet:** This convolution neural network model was specially designed by considering the fact that the same level of accuracy can be obtained by reducing the size and number of parameters that the model uses during the training phase. The Squeezenet model gives alexnet level of accuracy however it uses 15 times less parameters and also the size of the model is less than 0.5 MB. Use of such a compressed and squeezed model helps to run the model on various distributed servers and also in the environment where there is a limitation of the memory available. It replaces the conventional 3x3 filters with 1x1 point wise filters which required

processing power 9 times lesser than the former, these reduced filters are termed as fire modules. It consists of 18 layers and uses an input size of 227x227 in the input layer.

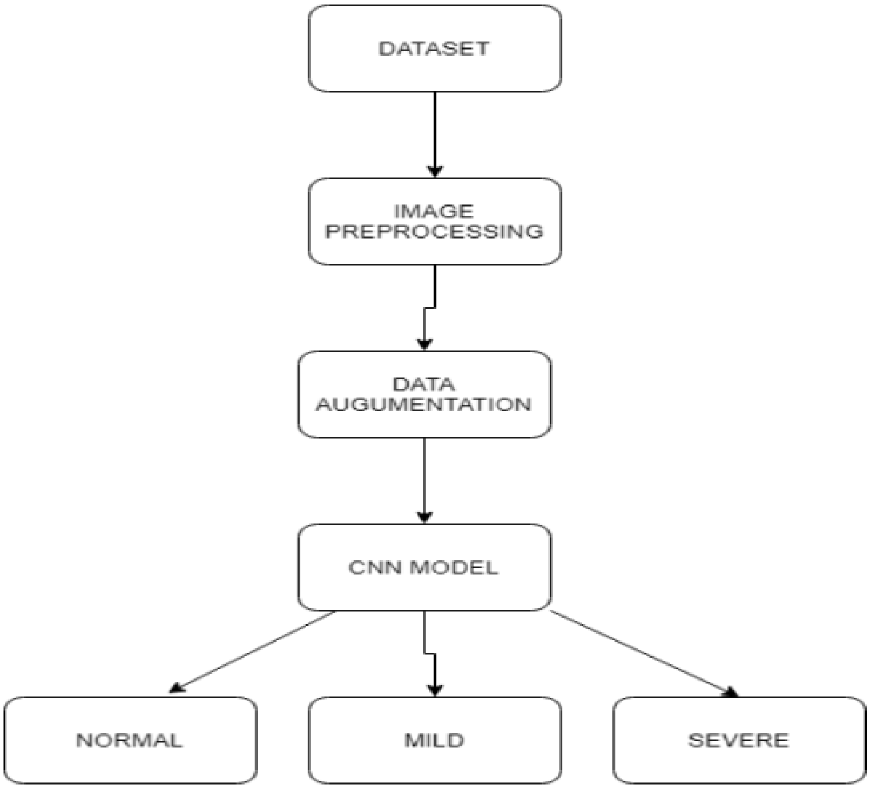


Fig. Data Flow multiclass classification

6.2 System Requirements

Dataset: Labelled Eye Images converted into format suitable for Model Training.

Software Requirements

Python 3.x (preferably, 3.5 or higher) installed and set-up

Required libraries: python-opencv, sklearn, numpy, pandas

Hardware Requirements

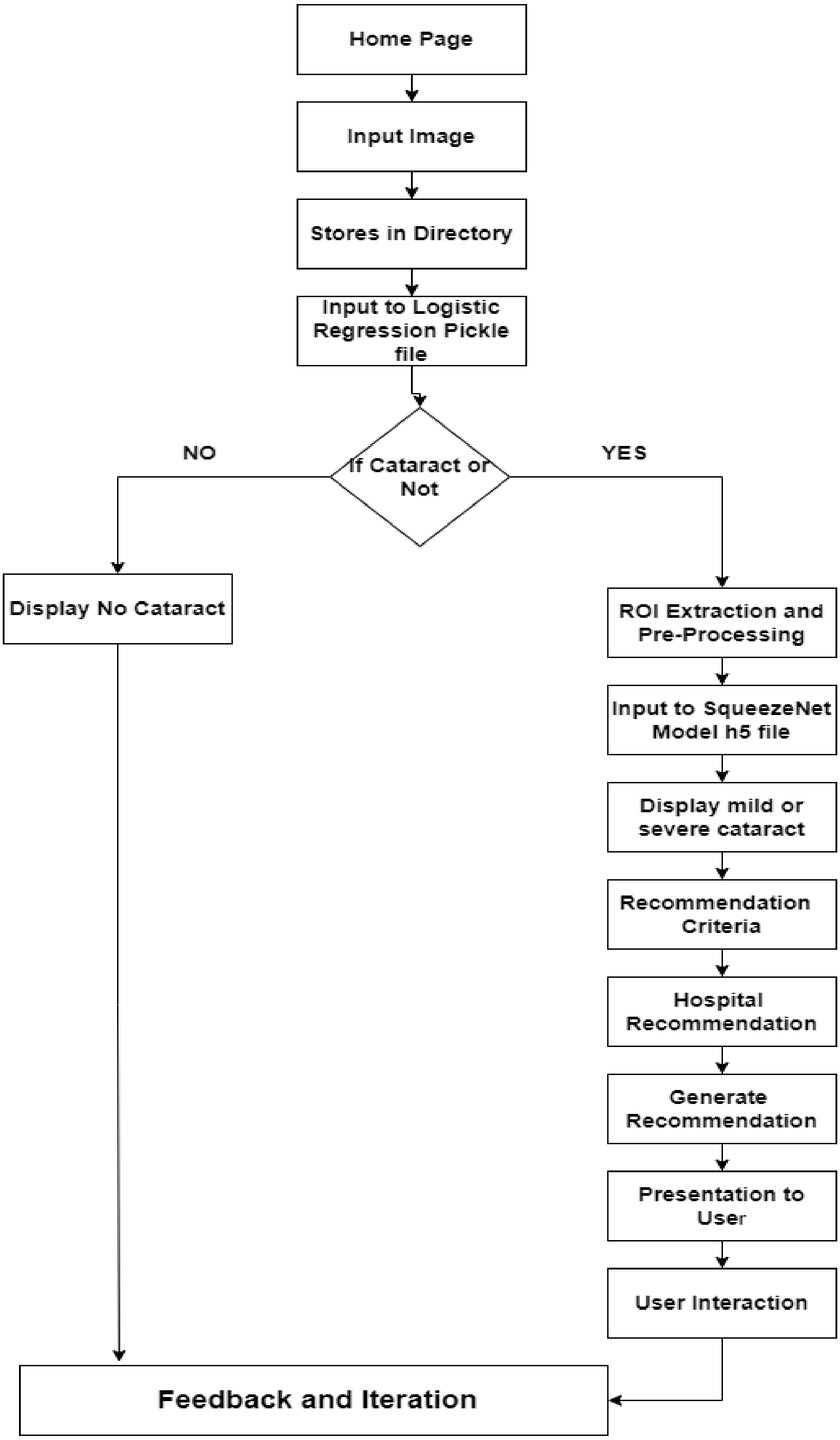
CPU with a minimum 4GB of RAM

GPU

7. FINAL PRODUCT PROTOTYPE

7.1 Schematic Diagram

To make our results available to the end user, we have developed a web based graphical user interface using a popular python based framework which is FLASK.



Working Method

At the home page once the user clicks on proceed the screen for inputting an image from them would be shown. This image is stored in our directory hence can be used to expand our dataset later. For convenience of the user the same image is flashed on the screen as well. This image is then given as an input to the pickle file that contains the Logistic Regression classifier trained on SIFT + GLCM features. This classifier then outputs the result as zero or one. The function in our flask web page then interprets the result as “cataract not detected” or “cataract detected” respectively. If cataract has been detected then the system will move ahead to check the intensity of cataract. Before feeding the image to our deep learning model the region of interest is extracted and further sent for prediction. This is done by our transfer learning SqueezeNet model which is converted into .h5 format as the binary data file. The system then finally interprets and displays the result as mild or severe. After detecting cataract, the recommendation system applies predefined criteria to suggest suitable hospitals or clinics for evaluation and treatment. It selects facilities based on factors like proximity, specialized services, and quality. The system then presents these recommendations to users through its interface, allowing interaction and feedback. This iterative process ensures users access relevant healthcare services, enhancing their decision-making and overall experience.

Abstract

The Automated Cataract Detection and Hospital Recommendation System (ACDHRS) represents a ground breaking solution aimed at revolutionizing the diagnosis and management of cataracts. Leveraging cutting-edge artificial intelligence (AI) algorithms and advanced medical imaging technology, ACDHRS offers a seamless and efficient process for early cataract detection and referral to specialized healthcare facilities. The system employs deep learning techniques to analyze digital retinal images or slit-lamp photographs, accurately identifying the presence and severity of cataracts with high sensitivity and specificity. Furthermore, ACDHRS integrates geographic information system (GIS) data to recommend the nearest hospitals or ophthalmic clinics equipped for cataract evaluation and surgery. By streamlining the diagnostic pathway and facilitating timely intervention, ACDHRS aims to enhance patient outcomes, reduce healthcare disparities, and alleviate the global burden of cataract-related vision loss. Through the integration of automated cataract detection and hospital recommendation, this system represents a significant advancement in the field of ophthalmic care. By leveraging technology to enhance efficiency and accessibility, it has the potential to make a meaningful impact on the prevention and management of cataracts, ultimately improving the quality of life for individuals affected by this prevalent eye condition.

8. Conclusion

In conclusion, the Automated Cataract Detection and Hospital Recommendation System presents a comprehensive solution to address the challenges associated with cataract diagnosis and treatment. By harnessing the power of advanced image processing, machine learning, and personalized recommendation algorithms, this system offers a promising approach to enhance ophthalmic care delivery.

Through early detection of cataracts and tailored hospital recommendations, the system aims to expedite access to timely interventions, thereby reducing the risk of vision impairment and blindness. By automating the screening process and optimizing patient referrals, it streamlines workflow efficiencies for healthcare providers while ensuring optimal outcomes for patients.

As technology continues to evolve, there is vast potential for further refinement and integration of this system into existing healthcare infrastructure. Future research efforts may focus on expanding the scope of the system to encompass other ophthalmic conditions, as well as integrating with electronic health records and telemedicine platforms for seamless care coordination.

Overall, the Automated Cataract Detection and Hospital Recommendation System represents a significant advancement in ophthalmic care, offering a scalable and sustainable solution to address the growing burden of cataracts worldwide. Through collaborative efforts between clinicians, technologists, and policymakers, this innovative approach has the potential to revolutionize the delivery of eye care and improve the quality of life for millions of individuals affected by cataracts.