Utilizing AI and Deep Learning for Early Identification of Retinopathy of Prematurity

Manjunatha M
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Abstract

Retinopathy of prematurity (ROP) is an abnormal blood vessel development in the retina of a prematurely-born infant or an infant with low birth weight. ROP is one of the leading causes for infant blindness globally. Early detection of ROP is critical to slow down and avert the progression to vision impairment caused by ROP. Yet there is limited awareness of ROP even among medical professionals. Consequently, dataset for ROP is limited if ever available, and is in general extremely imbalanced in terms of the ratio between negative images and positive ones. Retinopathy of Prematurity (ROP) is a serious condition affecting the retinal blood vessel development of prematurely-born or low-birth-weight infants, with a significant risk of progressing to blindness if not detected and treated early. Globally, ROP is one of the leading causes of infant blindness, particularly in regions with improving neonatal survival rates but limited access to specialized screening and treatment. Early diagnosis is essential to intervene at stages where therapeutic measures, such as laser photocoagulation or anti-VEGF therapy, can prevent vision loss. However, the lack of awareness about ROP among healthcare providers, particularly in low- and middle-income countries, exacerbates the problem

1. Problem Statement

Retinopathy of Prematurity (ROP) is a leading cause of preventable infant blindness worldwide, predominantly affecting premature and low-birth-weight infants. Despite the critical importance of early detection to prevent irreversible vision impairment, there is a significant lack of awareness about ROP, even among medical professionals. This knowledge gap, coupled with limited access to specialized diagnostic tools, results in delayed or missed diagnoses, particularly in resource-constrained settings.

Additionally, the development of automated diagnostic systems for ROP is hindered by the scarcity of high-quality retinal image datasets. Existing datasets are not only limited in size but are also heavily imbalanced, with a disproportionately small number of positive cases (ROP images) compared to negative ones. This imbalance undermines the training of reliable machine learning models, which are crucial for scaling early detection efforts. Addressing these challenges is imperative to improve ROP screening, diagnosis, and treatment outcomes, especially in regions with a high burden of the disease.

2. Market and Customer Needs Assessment

2.1 Market Analysis

The market for Retinopathy of Prematurity (ROP) is driven by the increasing survival rates of premature infants and the rising prevalence of the condition, particularly in low- and middle-income countries (LMICs). Approximately 15 million preterm births occur globally each year, with a significant portion at risk for ROP. Advancements in neonatal care, coupled with growing awareness through efforts by organizations like WHO, have fueled the demand for diagnostic and treatment solutions. Key growth factors include innovations in wide-field imaging systems, AI-based diagnostic tools, and portable devices that improve accessibility and efficiency. However, challenges such as high costs, limited access to diagnostic equipment, and a shortage of trained specialists hinder widespread adoption, especially in resource-poor settings.

Regional trends reveal that North America leads the market due to advanced healthcare infrastructure, followed by Europe with its established neonatal care systems. The Asia-Pacific region is experiencing the fastest growth, driven by high preterm birth rates and improving healthcare infrastructure, while Africa and Latin America remain emerging markets with significant unmet needs. Treatments such as laser photocoagulation, anti-VEGF therapies, and vitrectomy dominate the therapeutic landscape, while AI-powered platforms and telemedicine are expanding access in underserved regions. Despite these advancements, the market faces challenges related to affordability, data scarcity, and specialist availability. Projected to grow at a compound annual growth rate (CAGR) of 6–8%, the ROP market is expected to surpass USD 1 billion by 2030. Opportunities lie in the development of low-cost, portable diagnostic tools, scalable telemedicine platforms, and public-private partnerships to address the global burden of ROP and reduce infant blindness effectively.

2.2 Customer Segmentation

Customer segmentation for Retinopathy of Prematurity (ROP) products focuses on addressing the unique needs of various stakeholders in the ROP care ecosystem. Healthcare providers, including neonatologists, pediatric ophthalmologists, and NICU staff, require advanced diagnostic tools such as wide-field imaging systems, AI-powered screening platforms, and portable devices for resource-limited settings. Hospitals and clinics, particularly neonatal intensive care units (NICUs) and maternity centers, need scalable and affordable diagnostic and treatment solutions integrated into their workflows, along with ongoing maintenance support. Parents and caregivers of premature infants seek awareness about ROP risks, access to affordable and timely care, and telemedicine services to facilitate consultations and follow-ups.

Governments and NGOs play a critical role in implementing large-scale screening and treatment programs, necessitating cost-effective portable diagnostic tools, AI-driven mass screening systems, and partnerships for training and capacity building. Research institutions and technology developers require access to ROP datasets, research-grade tools, and market insights for developing innovative diagnostic and therapeutic solutions. Insurance providers are an emerging segment, focusing on integrating ROP care into neonatal insurance plans and partnering with healthcare providers to offer bundled care packages. Regionally, high-income countries demand cutting-edge technologies, while emerging markets like Asia-Pacific and

Africa need low-cost, portable devices and training initiatives to address high preterm birth rates and specialist shortages. This segmentation helps ROP product developers create targeted solutions, ensuring effective market penetration and support in combating infant blindness globally.

3. Target Specifications

3.1 Core Functionality and Design

Data Security and Privacy

- Ensure SSL encryption for secure data exchange.
- Adhere to healthcare data privacy standards (e.g., HIPAA, GDPR).

User Authentication and Access Control

- Provide secure user authentication processes for different stakeholders.
- Implement access control for personalized access to resources and data.

Mobile Responsiveness

- Ensure the website is fully responsive across all devices and screen sizes.
- Maintain usability and navigation ease on smartphones and tablets.

Accessibility

- Comply with WCAG 2.1 standards to make the site usable for individuals with disabilities.
- Include features like text-to-speech, high-contrast visuals, and keyboard navigability.

Content Management System (CMS)

- Enable easy content updates by administrators for resources, treatment protocols, and research findings.
- Support uploading and organizing time-sensitive content.

Search Functionality

- Include advanced search features to help users quickly locate ROP-related content.
- Provide filters and sorting options for effective content discovery.

Multilingual Support

- Offer resources and content in multiple languages for a global audience.

3.2 Performance Requirements for the ROP Website

Website Load Speed

- Ensure the website loads in under 3 seconds for optimal user experience.
- Optimize images and resources to minimize delays.

Scalability and Traffic Management

- Design scalable infrastructure to handle high traffic volumes without performance degradation.
- Use cloud hosting and load balancing to support traffic surges during events or campaigns.

High Availability and Uptime

- Maintain 99.9% uptime for reliable access.
- Implement backup systems to minimize downtime.

Content Delivery and Media Support

- Integrate a CDN for fast delivery of high-quality images, videos, and documents.
- Provide seamless streaming for webinars or telemedicine sessions.

High-Quality Media Support

- Ensure retina-level image resolution for detailed ROP educational and diagnostic visuals.
- Include support for video tutorials and large medical document downloads.

Performance Monitoring and Analytics

- Use tools like Google Analytics for tracking site speed, engagement, and real-time issue identification.
- Monitor metrics such as bounce rates and user behavior to optimize performance.

Low Maintenance Design

- Minimize maintenance needs through reliable hosting and regular updates.
- Ensure the system runs efficiently with minimal downtime.

4. External Search

Designing an effective website for Retinopathy of Prematurity (ROP) requires a user-centric approach that caters to healthcare professionals, parents, and researchers. Key considerations include:

Comprehensive Information: Provide detailed, up-to-date content on ROP, including causes, symptoms, treatment options, and guidelines. Ensure the information is accurate and accessible to both medical professionals and the general public.

User-Friendly Navigation: Implement intuitive menus and clear categorization to facilitate easy access to various sections, such as educational resources, research articles, and support services.

Visual Aids: Incorporate high-quality images and diagrams to enhance understanding, especially for complex medical information. Ensure these visuals are optimized for quick loading times.

Accessibility: Design the website to be accessible to individuals with disabilities by adhering to WCAG 2.1 standards, including features like text-to-speech, high-contrast visuals, and keyboard navigability.

Mobile Responsiveness: Ensure the website is fully responsive and functions seamlessly across various devices and screen sizes, as users may access it via smartphones or tablets.

Multilingual Support: Offer content in multiple languages to cater to a diverse audience, enhancing the website's global reach and usability.

Interactive Elements: Include features such as forums, Q&A sections, or live chat support to engage users and provide real-time assistance.

Regular Updates: Maintain the website with the latest research findings, treatment guidelines, and news related to ROP to ensure users have access to current information.

4.1 Benchmarking

Benchmarking for Retinopathy of Prematurity (ROP) focuses on evaluating existing diagnostic and treatment tools, such as wide-field imaging systems, AI-assisted screening platforms, and telemedicine solutions. It involves comparing their accuracy, usability, affordability, and scalability to identify gaps and set performance standards. Current leaders emphasize high-resolution imaging, AI-driven analysis, and portable, cost-effective designs. Effective benchmarking guides innovation, ensuring new solutions meet global healthcare needs, especially in resource-limited settings.

4.2 Analysis of Existing Platforms

1. Wide-Field Retinal Imaging Systems

Platforms like RetCam are widely used for capturing high-resolution retinal images.
Strengths: High accuracy in imaging, detailed visualization, and established clinical reliability.
Limitations: High cost, bulky equipment, and steep learning curve for operators, making them less suitable for resource-limited settings.

AI-Assisted Screening Solutions

AI platforms such as i-ROP DL use deep learning to analyze retinal images and predict disease severity.
Strengths: High diagnostic accuracy, rapid analysis, and potential to alleviate the burden on specialists.
Limitations: Dependence on large, high-quality datasets, regulatory approval challenges, and limited integration in clinical workflows.

Telemedicine Platforms

Solutions like ROPtool and remote screening initiatives enable specialists to review images from distant locations.
Strengths: Facilitates access to expert opinions in remote or underserved areas, reduces travel burden for families.

Limitations: Requires robust internet connectivity and trained local staff for image capture, which can be barriers in low-resource regions.

Portable Retinal Imaging Devices
Emerging devices like handheld fundus cameras offer compact and affordable alternatives for ROP screening.
Strengths: Portability, ease of use, and cost-effectiveness.
Limitations: Often limited by lower image quality compared to larger systems and less integration with AI-based diagnostics.

2. Exploration of Recommendation Algorithms

Rule-Based Algorithms: Use predefined clinical thresholds like birth weight and gestational age for early risk identification.

Machine Learning Algorithms: Analyze clinical data to predict ROP severity and progression.

Deep Learning Algorithms: Employ neural networks to analyze retinal images for automated and precise diagnosis.

Hybrid Recommendation Systems: Combine clinical and image data for more accurate risk prediction.

Collaborative Filtering: Compare new cases with historical data to assess ROP risk.

Temporal Algorithms: Track time-based data to identify disease progression patterns.

Reinforcement Learning Models: Optimize screening schedules by learning from patient-specific responses.

3. Safety and Security Features

- **Data Privacy Compliance**: Ensure adherence to global regulations like GDPR and HIPAA to protect sensitive health data and user privacy.
- **Secure Data Transmission**: Use HTTPS and SSL/TLS encryption for all external data exchanges, ensuring data integrity and protection from interception.
- **Authentication and Access Control**: Implement multi-factor authentication (MFA) and role-based access control (RBAC) to restrict data access to authorized individuals.
- **End-to-End Encryption**: Employ end-to-end encryption for the transmission and storage of sensitive ROP data, ensuring that only authorized parties can access it.
- **Incident Response Plans**: Have a well-defined incident response strategy to quickly address any security breaches or data vulnerabilities, minimizing risks to user and patient data.

5. Applicable Regulations

5.1 Data Privacy and Security

- **ISO/IEC 27001**: This international standard sets guidelines for establishing, implementing, and maintaining an information security management system (ISMS), ensuring comprehensive data security measures are in place.

- **HIPAA (U.S.)**: If the website is handling healthcare data, it must comply with HIPAA, which sets strict rules for securing health data, including the use of encryption and secure data storage.

- **GDPR (EU)**: For users in the EU, the website must comply with the GDPR, ensuring that users' health data is collected, stored, and processed lawfully, transparently, and securely.

5.2 Medical Device and Software Regulations

- **Software as a Medical Device:** Relevance: If the website includes diagnostic tools or AI-based systems for detecting ROP, it may qualify as Software as a Medical Device (SaMD). For such products, compliance with medical device regulations is mandatory. In the U.S., the FDA requires regulatory approval, such as 510(k) clearance or De Novo classification. In the EU, the website would need to comply with the Medical Device Regulation (MDR).

5.3 Artificial Intelligence and Algorithm Regulations

Artificial Intelligence (AI) Act (EU)

- **Relevance**: The website uses AI for diagnosing ROP through retinal images or other medical data, it may fall under the scope of the proposed **AI Act** in the EU, which regulates high-risk AI applications. The AI system must be transparent, explainable, and safe to use, with built-in safeguards to prevent bias and errors in ROP diagnosis.

Software and Algorithm Transparency (FDA, EU)

- **Relevance**: The website uses machine learning models or algorithms to detect ROP, it may need to demonstrate algorithmic transparency, ensuring that the decision-making process is explainable and justifiable. This is particularly important when using AI models for health-related diagnoses.

6. monetization strategies for Retinopathy of Prematurity website

Sponsored Content

- **Medical Device Companies**: Partner with companies that produce neonatal medical equipment (e.g., incubators, oxygen monitoring devices) to sponsor articles, research, or sections of the website.
- **Pharmaceutical Companies**: Collaborate with firms developing treatments or therapies for ROP-related conditions

Premium Content

- **Membership Plans**: Offer exclusive resources, research papers, or expert interviews for a subscription fee.
- **Reports**: Sell detailed market or medical trend reports about ROP to professionals and institutions.

Advertising

- **Display Ads**: Use Google AdSense or similar platforms to display targeted ads on your site.
- **Direct Ad Sales**: Sell ad space to relevant companies (e.g., neonatal equipment manufacturers, hospitals).

Partnerships

- **Hospitals and Clinics**: Build partnerships with hospitals to feature their services or research, generating referral income.
- **Nonprofits**: Collaborate with nonprofits for joint campaigns, sharing a portion of raised funds.

Mobile App Integration

- **ROP Screening Apps**: Develop an app for ROP screening and management, with in-app purchases or subscription models.
- **Parent Support App**: Create a parent-centric app offering tips, reminders, and tracking tools, with optional premium features.

Online Courses and Webinars

- **Professional Training**: Offer paid webinars or courses for healthcare professionals on ROP screening, management, and prevention.
- **Parental Guidance**: Create affordable online courses or workshops for parents about ROP care and long-term management.

7. Final Product Prototype

Retinopathy of Prematurity (ROP) Detection Platform is an advanced application designed to support early diagnosis and management of ROP using AI and deep learning technologies. The platform empowers healthcare providers by offering accurate analysis of retinal images, personalized risk assessments, and essential educational resources.

Key Features

1. **AI-Powered Image Analysis**:

- ➢ Secure image upload for real-time analysis.
- ➢ AI-powered detection of ROP stages with confidence scores.
- ➢ Generates detailed reports with recommendations for further action.

2. **Personalized Dashboard**:

- ➢ Visualization of patient data trends.
- ➢ Risk analysis and progress tracking for individual infants.
- ➢ Integration with electronic medical records (EMR) for seamless data sharing.

3. **Educational Resources**:

- ➢ ROP awareness guides tailored for parents and healthcare providers.
- ➢ Training modules on ROP screening and AI interpretation.
- ➢ Access to the latest ROP-related research and case studies.

4. **Teleconsultation and Specialist Access**:

- ➢ Direct connection with ROP specialists for second opinions.
- ➢ Video consultations integrated with AI reports for collaborative decision-making.

5. **Compliance and Security**:

- ➢ HIPAA and GDPR compliance for patient data privacy.
- ➢ Encrypted storage of retinal images and reports.

User Flow

1. **Onboarding**:

- ➢ New users (clinics or healthcare professionals) sign up and create an account.
- ➢ Complete a profile with details like clinic/hospital information, user roles, and permissions.

2. **Image Analysis**:

- ➢ Upload retinal images via secure portals.
- ➢ AI processes the images to detect signs of ROP and provides a detailed analysis report.
- ➢ Users can download or share the results for further consultation.

3. **Recommendations and Follow-Up**:

- ➢ The system suggests follow-up actions based on ROP severity levels.
- ➢ Integration with telemedicine tools allows immediate consultation with specialists.

4. **Learning and Improvement**:

- Users can access training resources to improve their understanding of ROP and AI diagnostics.
- Real-time updates ensure the AI model continuously improves based on feedback.

Safety and Security

Data Privacy:

- Adheres to international standards for data protection.
- All user information is encrypted and securely stored.

Emergency Alerts:

- Notification system for high-risk cases requiring urgent attention.

Travel-Friendly Access:

- Offline capabilities for remote areas with intermittent internet access.

8. Product Details

1. How Does It Work?

- **Image Upload**:
  Healthcare providers securely upload retinal images of premature infants using the platform.

- **AI and Deep Learning Analysis**:

  AI algorithms analyze the retinal images in real-time to identify early signs of ROP. The model assigns confidence scores for detected ROP stages (e.g., Stage 1-2, Stage 3+, or no ROP).

- **Result Generation**:
  A detailed report is generated, including: Findings from the analysis. Recommendations for further action (e.g., monitoring, immediate referral).

- **Follow-Up Support**:
  Integration with teleconsultation allows users to connect with specialists for second opinions.

2. Data Sources

- **Medical Data**
  - Retinal images from neonatal care units worldwide (DICOM format preferred).
  - Historical datasets of ROP cases for training and validation.

- **Open Datasets:**
  - Publicly available medical image datasets, such as those used in academic ROP studies.

3. Algorithms, Frameworks, and Software Needed

- **Algorithms**:
  - Convolutional Neural Networks (CNNs): For image analysis and feature extraction.
  - Ensemble Learning: To combine outputs of multiple models for higher accuracy.
  - Decision Support Algorithms: For personalized recommendations based on ROP stage.

- **Frameworks**:
  - TensorFlow or PyTorch: For building and training deep learning models.
  - Scikit-learn: For statistical analysis and supplementary machine learning tasks.
  - OpenCV: For image preprocessing and augmentation.

- **Software and Tools**:
  - **Frontend**: React.js, Angular, or Vue.js for the user interface.
  - **Backend**: Python (Django or Flask) or Node.js for managing AI services and database operations.
  - **Cloud Services**: AWS, Azure, or Google Cloud for secure data storage and GPU-accelerated computations.
  - **Databases**: PostgreSQL, MongoDB, or Firebase for storing user and patient data.
  - **APIs**: RESTful APIs for EMR and teleconsultation integration.

4. Team Required to Develop

- **Core Team**:
  - **AI/ML Engineers**: Develop and fine-tune deep learning models.
  - **Software Developers**: Build the platform’s backend and frontend.
  - **UI/UX Designers**: Create a user-friendly interface optimized for healthcare providers.

- **Data Scientists**: Analyze and process medical datasets to improve model accuracy.
- **Medical Experts**: Collaborate to validate model performance and annotate datasets.

➢ **Supporting Team**:

- **Cybersecurity Experts**: Ensure data privacy and security compliance.
- **Project Manager**: Oversee development timelines and team coordination.
- **Quality Assurance Engineers**: Test and validate platform functionality.
- **Customer Support Team**: Assist users with technical and operational issues.

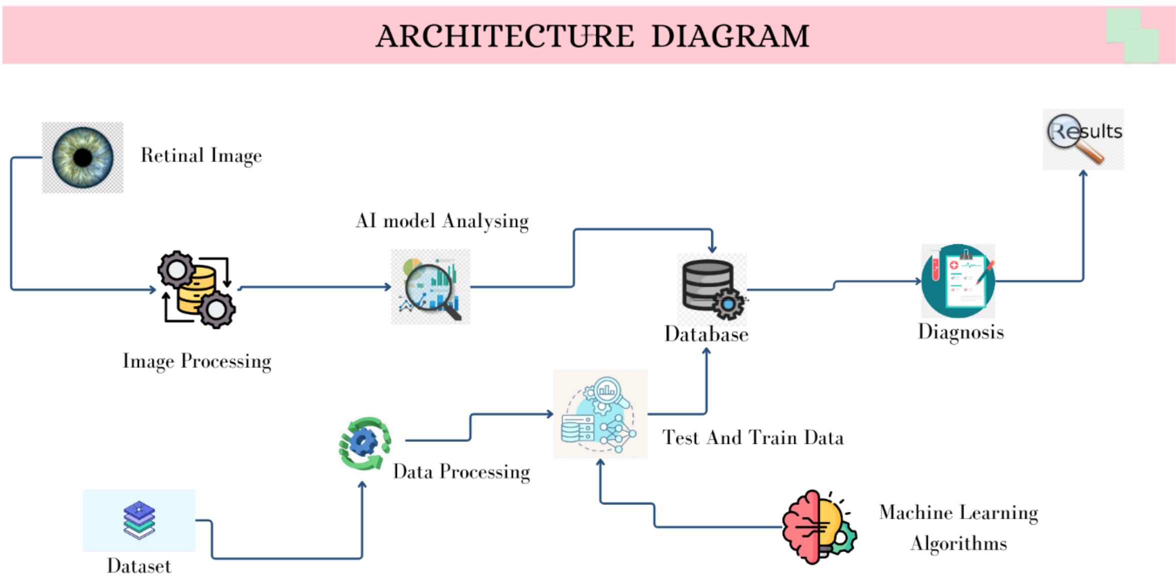
➢ **What Does it Cost?**

- The costs include salaries for the multidisciplinary team, cloud server infrastructure, database management, and collaboration with hospitals. Ongoing expenses cover updates to AI algorithms, platform maintenance, and regulatory compliance, ensuring the system's accuracy and scalability.

9. UML (Unified Modeling Language) diagrams

To illustrate the **Early Detection of Retinopathy of Prematurity (ROP)** system using UML (Unified Modeling Language) diagrams, we can focus on key aspects such as system architecture, use case, workflows, and Activity.

Architecture Diagram:



This architecture diagram illustrates the process flow for an **Early Detection of Retinopathy of Prematurity (ROP)** system, focusing on how data is processed, analyzed, and used to generate diagnostic results. Here's a step-by-step explanation of each component:

1. Retinal Image

- The system starts with the **capture of retinal images** of premature infants using specialized imaging devices.
- These images are the primary input for the system and are uploaded to the platform.

2. Image Processing

- The uploaded retinal images go through **image preprocessing** to enhance quality and remove noise.
- Tasks include:
  - Normalizing image brightness and contrast.
  - Cropping or resizing to meet the requirements of the AI model.
  - Highlighting key features for analysis.

3. AI Model Analyzing

- The preprocessed images are sent to an **AI model**, which uses deep learning algorithms to:
  - Detect early signs of ROP.
  - Classify the ROP stage (e.g., mild, moderate, severe).
  - Generate confidence scores for each diagnosis.
- The model relies on large datasets for training and fine-tuning.

4. Database

- The analyzed data, including raw images, processing metadata, and diagnostic results, is stored in a **database** for:
  - Secure record-keeping.
  - Future reference or follow-up analysis.
  - Integration with electronic medical records (EMR).

5. Diagnosis

- Based on the AI analysis, a detailed **diagnostic report** is generated, which includes:
  - The detected stage of ROP.
  - Recommendations for treatment or follow-up.
  - Visual markers (if applicable) for the findings.

6. Results

- The results are displayed to the user (e.g., healthcare providers or ROP specialists) through the platform's user interface.
- Providers can:
  - Review the diagnosis.
  - Download reports.
  - Take immediate action for treatment or consultation.

Data Processing (Training Phase)

- **Datasets**:
  Large volumes of retinal image data (both healthy and ROP-affected) are collected for training the AI model.
- **Data Processing**:
  The dataset is cleaned, labeled, and preprocessed to ensure the AI model learns effectively.
- **Test and Train Data**:
  The dataset is split into training and testing sets to:
  - Train the model to recognize ROP patterns.
  - Validate the model's accuracy and reliability.

Machine Learning Algorithms

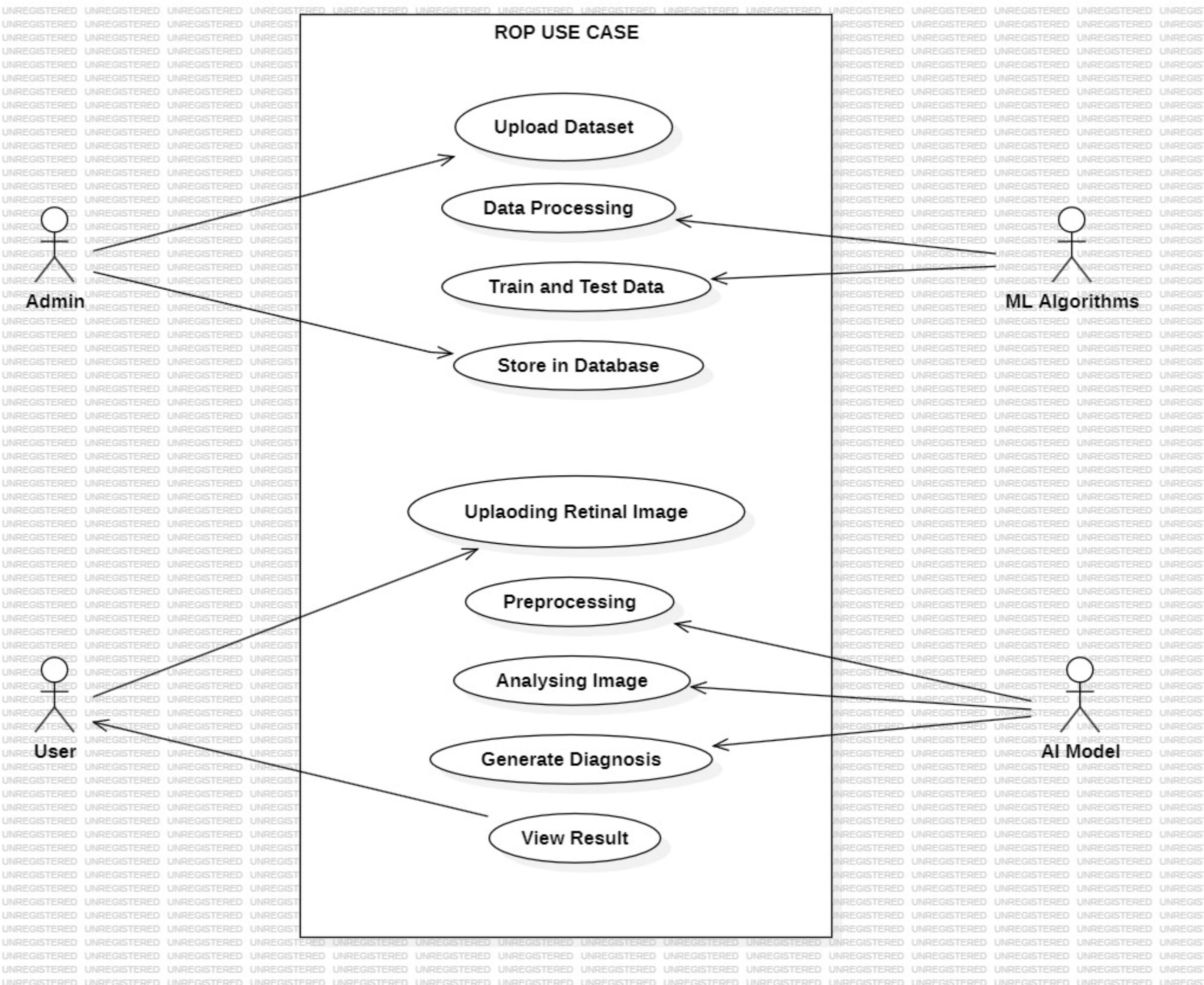
- The system uses **machine learning (ML) and deep learning (DL)** algorithms, such as:
  - Convolutional Neural Networks (CNNs) for image recognition.
  - Ensemble learning techniques for improved accuracy.
  - Gradient-based optimizers to fine-tune model predictions.

Use Case Diagram:

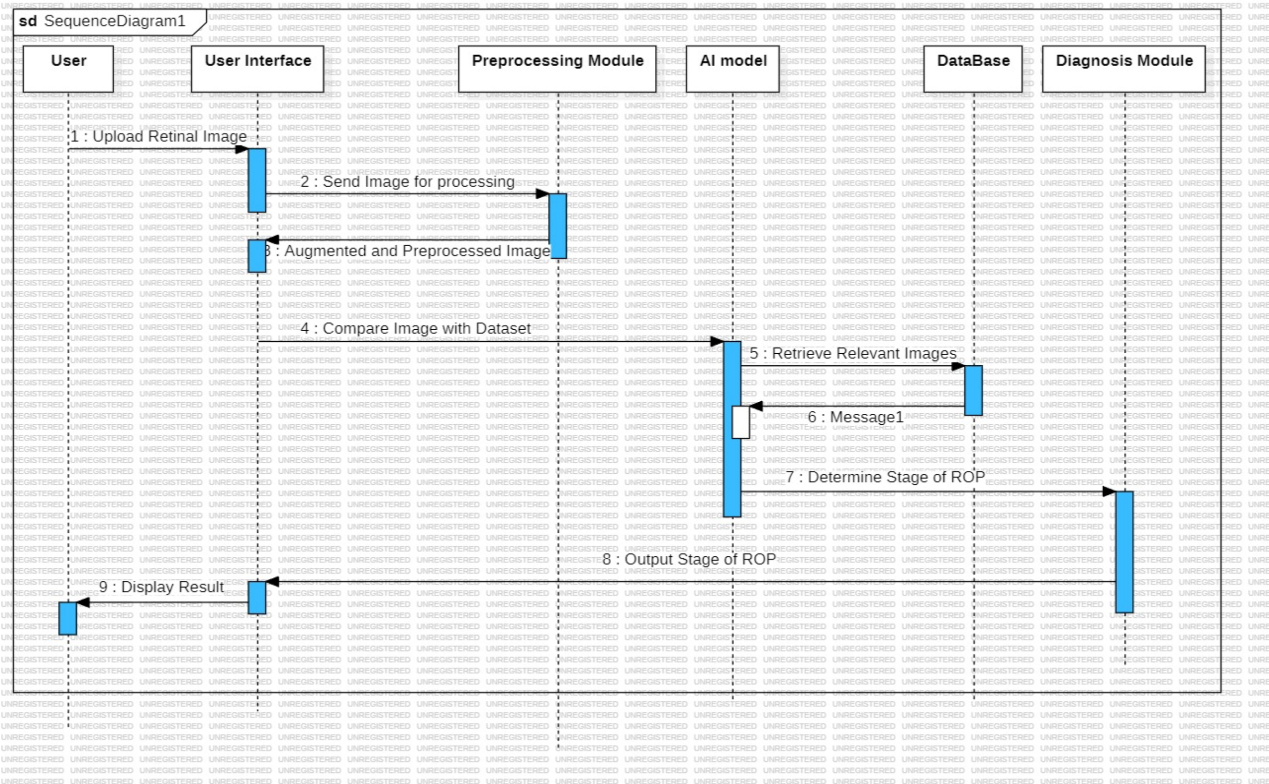
This use case diagram illustrates the interaction between users (Admin and User) and the system for the early detection of Retinopathy of Prematurity (ROP).

- Admin: Manages system operations by uploading datasets, preprocessing data, and training/testing machine learning algorithms, which are stored in the database.

- User: Uploads retinal images for analysis, which undergo preprocessing and AI-based analysis to detect signs of ROP.
- AI Model: Processes images using trained machine learning algorithms to generate diagnostic results.Users can view results through the system interface, enabling timely diagnosis and intervention.



sequence diagram



This sequence diagram represents the workflow of a system analyzing retinal images to determine the stage of Retinopathy of Prematurity (ROP):

1. **Image Upload and Processing:** The user uploads a retinal image through the User Interface, which is then sent to the Preprocessing Module for augmentation and preprocessing.

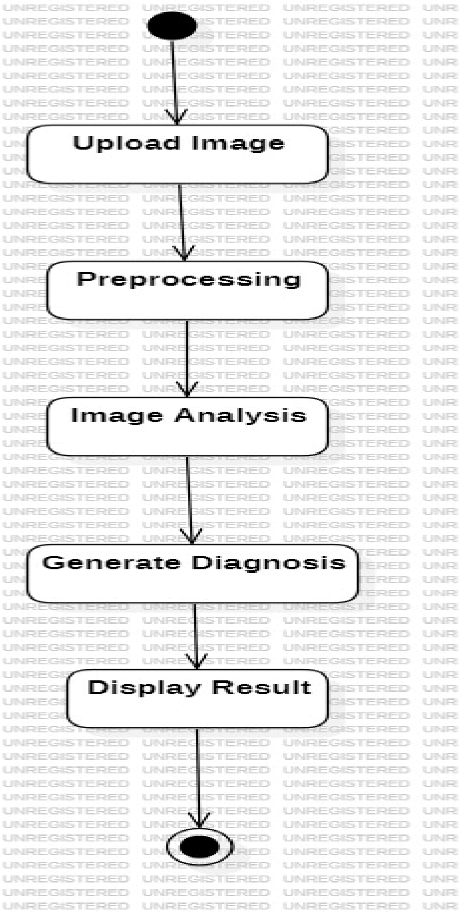
2. **Image Comparison:** The preprocessed image is compared with a dataset by the AI model to retrieve relevant images.

3. **Data Retrieval**: The AI model retrieves images and information from the database to determine the ROP stage.

4. Diagnosis and Result Determination: The Diagnosis Module determines the ROP stage based on the retrieved data.

5. **Result Display**: The diagnosed stage of ROP is displayed to the user through the User Interface.

Activity Diagram



This activity diagram represents the workflow for analyzing an image and generating a diagnosis:

1. **Start Process:** The workflow begins with the user uploading an image.
2. **Preprocessing:** The uploaded image undergoes preprocessing to prepare it for analysis.
3. **Image Analysis:** The preprocessed image is analyzed to extract meaningful information.
4. **Diagnosis Generation:** Based on the analysis, a diagnosis is generated.
5. **Result Display:** The system displays the diagnosis to the user, concluding the workflow.

10. Code Implementation

These are the libraries and modules for data processing, visualization, deep learning (PyTorch, TensorFlow), and evaluation, focusing on tools like EfficientNetB0 for model development.

```
•[2]: import numpy as np
      import pandas as pd
      import matplotlib.pyplot as plt
      import os
      import pandas as pd
      from pandas import Series, DataFrame
      import torch
      from torch.utils.data import Dataset
      import torch.nn as nn
      import torchvision
      import torchvision.models as models
      import torchvision.transforms as transforms
      import torch.nn.functional as
      from PIL import Image
      import seaborn as sns
      from sklearn.metrics import confusion_matrix, accuracy_score, classification_report
      import warnings
      from tensorflow.keras.applications import EfficientNetB0
```

```
[3]: for dirname, _, filenames in os.walk(r"C:\Users\manju\Downloads\ML projects\ROP\Retinaimg"):
        for filename in filenames:
         x=Image.open(os.path.join(dirname, filename))
         print('File Name',os.path.join(dirname, filename))
         print('Picture Size', x.size)
```

```
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient1.jpg
Picture Size (1600, 1200)
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient10.jpg
Picture Size (1600, 1200)
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient10_2.jpg
Picture Size (1600, 1200)
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient10_2_eye2.jpg
Picture Size (1600, 1200)
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient11.jpg
Picture Size (1600, 1200)
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient12.jpg
Picture Size (1600, 1200)
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient13.jpg
Picture Size (1600, 1200)
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient14.jpg
Picture Size (1600, 1200)
File Name C:\Users\manju\Downloads\ML projects\ROP\Retinaimg\NoROP_Patient15.jpg
Picture Size (1600, 1200)
```

```
[4]: #Assign the used device to GPU if available
     device = ("cuda" if torch.cuda.is_available() else "cpu")

     #Creation of the Dataframe
     train_df = pd.DataFrame(columns=["img_name","label"])

     #Assign each images from the input folder to a label corresponding to ROP or No ROP
     train_df["img_name"] = os.listdir(r"C:\Users\manju\Downloads\ML projects\ROP\Retinaimg")
     for idx, i in enumerate(os.listdir("C:/Users/manju/Downloads/ML projects/ROP/Retinaimg")):
         '''Here we give a label for ROP/No ROP to every images depending on the name they have (the stage they correspond to) '''
         if "NoROP" in i:
             train_df["label"][idx] = 0
         if "Stage1" in i:
             train_df["label"][idx] = 1
         if "Stage2" in i:
             train_df["label"][idx] = 1
         if "Stage3" in i:
             train_df["label"][idx] = 1

     #View the dataframe created
     print(train_df)

     #Create a csv file out of our dataframe
     train_df.to_csv (r'train_csv.csv', index = False, header=True)
```

```
                     img_name label
0          NoROP_Patient1.jpg     0
1         NoROP_Patient10.jpg     0
2       NoROP_Patient10_2.jpg     0
3  NoROP_Patient10_2_eye2.jpg     0
4         NoROP_Patient11.jpg     0
..                        ...   ...
86        Stage3_Patient5.jpg     1
87        Stage3_Patient6.jpg     1
88        Stage3_Patient7.jpg     1
89        Stage3_Patient8.jpg     1
90        Stage3_Patient9.jpg     1

[91 rows x 2 columns]
```

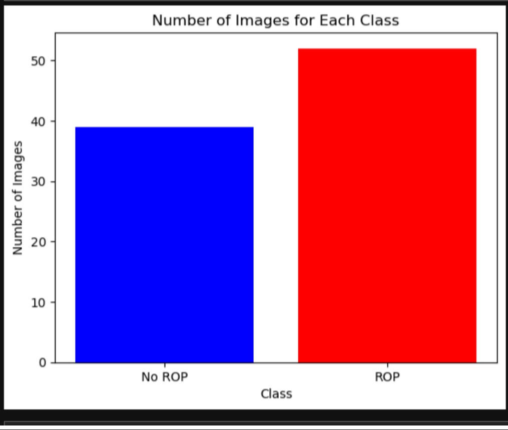
```
[5]: #Create a list to make classes label explicite
     classes=['No ROP','ROP']
     for label_number in range(2):
         print('Label',label_number,'corresponds to',classes[label_number])
```

```
Label 0 corresponds to No ROP
Label 1 corresponds to ROP
```

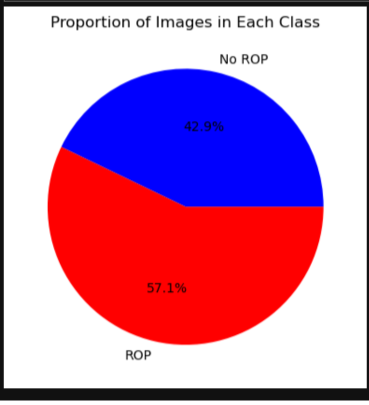
```
•[13]: #Create a list of labels from our data frame
       ListOfLabels=train_df["label"].to_list()

       #Here we are gonna count how many images for each stages we have
       #No ROP
       NoROP_Size=ListOfLabels.count(0)
       print('Number of NoROP images', NoROP_Size)

       #ROP
       ROP_Size=ListOfLabels.count(1)
       print('Number of ROP images', ROP_Size)
       print('the size of our dataset is',len(train_df["label"]))
```

```
Number of NoROP images 39
Number of ROP images 52
the size of our dataset is 91
```

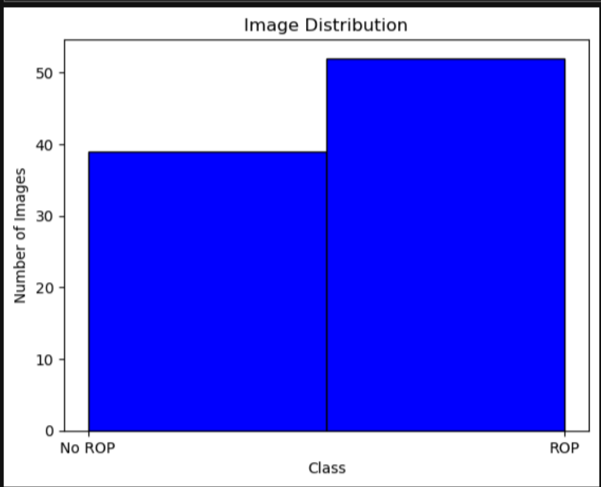
[31]:
```python
import matplotlib.pyplot as plt
label_counts = {'No ROP': NoROP_Size, 'ROP': ROP_Size}
plt.bar(label_counts.keys(), label_counts.values(), color=['blue', 'red'])
plt.title('Number of Images for Each Class')
plt.xlabel('Class')
plt.ylabel('Number of Images')
plt.show()
```



[32]:
```python
# Create a pie chart
plt.pie(label_counts.values(), labels=label_counts.keys(), autopct='%1.1f%%', colors=['blue', 'red'])
plt.title('Proportion of Images in Each Class')
plt.show()
```

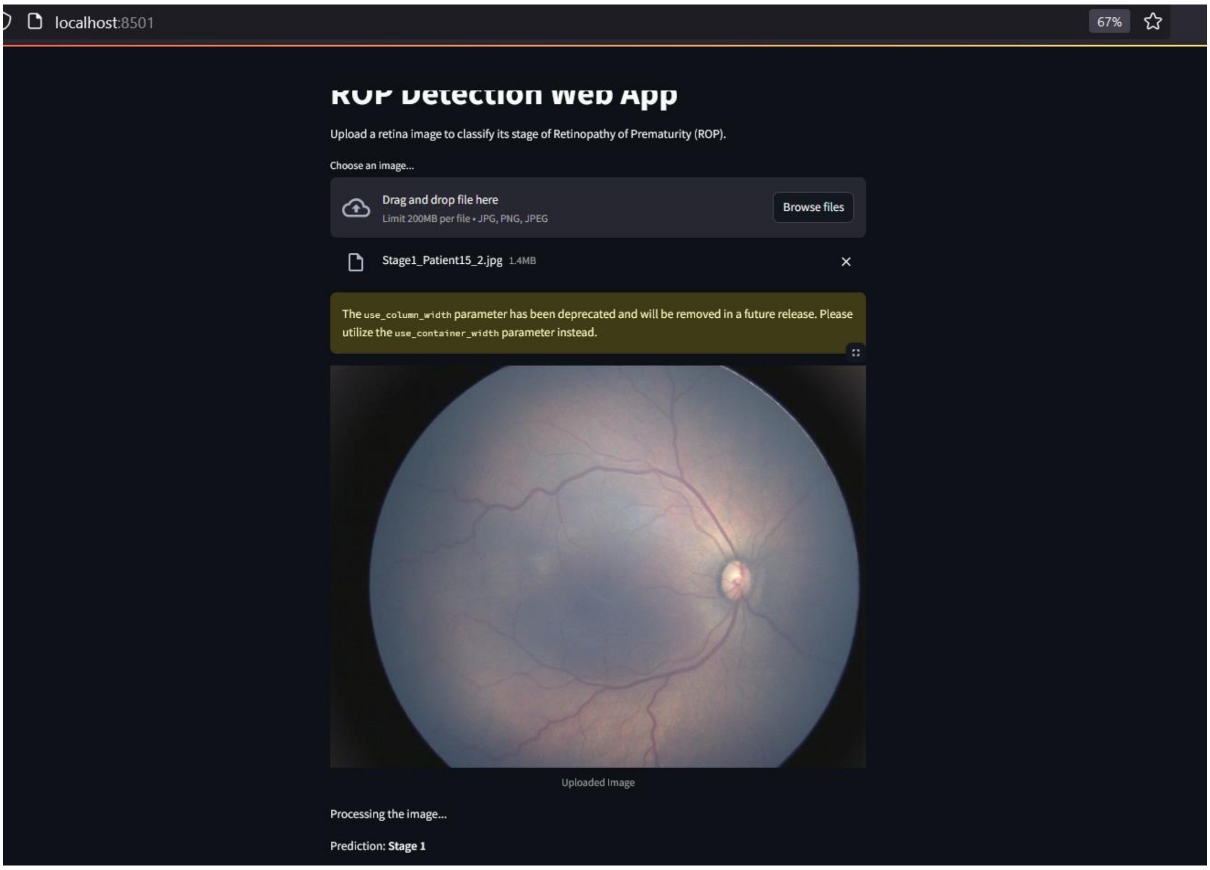


[36]:
```python
# Create a histogram with one color per class
plt.hist(ListOfLabels, bins=2, edgecolor='black', color='blue')  # Single color for the whole dataset
plt.xticks([0, 1], ['No ROP', 'ROP'])
plt.title('Image Distribution')
plt.xlabel('Class')
plt.ylabel('Number of Images')
plt.show()
```



```
[12]: import os
import pandas as pd
from sklearn.model_selection import train_test_split

# Define the path to your images
image_folder = r"C:\Users\manju\Downloads\ML projects\ROP\Retinaimg"

# Get the list of all image filenames
all_images = os.listdir(image_folder)

# Create a DataFrame with image filenames and labels
image_labels = []
for img in all_images:
    label = 0 if "NoROP" in img else 1  # Modify based on your naming convention
    image_labels.append((img, label))

df = pd.DataFrame(image_labels, columns=["img_name", "label"])

# Split into train and test sets (80% train, 20% test)
train_df, test_df = train_test_split(df, test_size=0.2, random_state=42)

# Save the DataFrames to CSV
train_df.to_csv('train_csv.csv', index=False)
test_df.to_csv('test_csv.csv', index=False)

print("CSV files for train and test sets created.")

CSV files for train and test sets created.
```

OUTPUT:



BUSINESS MODEL

Monetization Strategy

The platform employs a diversified revenue approach to ensure scalability and accessibility for hospitals, clinics, and individual practitioners:

1. **Freemium Model:**
    - Free access to basic ROP screening and risk assessment to encourage adoption among healthcare providers.
2. **Premium Services:**
    - Advanced AI analytics for precise staging of ROP.
    - IoT integration with neonatal imaging devices.
    - Real-time expert consultations for difficult cases.
    - Customizable alerts and follow-up tracking for at-risk infants.
    - Comprehensive historical patient data storage and retrieval.

Subscription Plans

1. **Individual Plans:**
    - Affordable pricing for small clinics and independent pediatric ophthalmologists.
    - Focus on early detection and patient management.
2. **Hospital & Clinic Plans:**
    - Bulk subscriptions for hospitals, NICUs, and eye-care networks.
    - Centralized dashboards for patient tracking and reporting.
3. **Enterprise Plans:**
    - Tailored solutions for large healthcare networks and telemedicine providers.
    - API and EHR (Electronic Health Record) integration for seamless workflow.

Advertising & Sponsorship

- Revenue through targeted ads from medical equipment manufacturers, pharmaceutical companies, and neonatal care brands.
- Sponsored educational content, including webinars and research updates on ROP management.

Financial Equation

$y=m\cdot x(t)-C$

Where:

- $m=100$ (reduced price per screening in ₹)
- $C=20{,}000$ (fixed monthly operational cost)
- $x(t)$ = Tests conducted per year (unchanged from previous values)

Revised Yearly Calculations

For 2025:

Tests Conducted:

$x(2025)=26,540$

Profit Calculation:

$y=100\times26,540-20,000$
$y=26,54,000-20,000=₹26,34,000$

For 2029:

Tests Conducted:

$x(2029)=299,350$

Profit Calculation:
$y=100\times299,350-20,000$
$y=2,99,35,000-20,000=₹2,99,15,000$

Observations After Reducing mmm (Price per Screening):

- Revenue and profit **drop significantly** due to the price cut.
- Even though market penetration is increasing, lower pricing affects total earnings.
- The model might need **higher penetration rates** to compensate for lost revenue.

11. Conclusion

The application of artificial intelligence (AI) and deep learning (DL) for early detection of retinopathy of prematurity (ROP) is transforming neonatal healthcare. These technologies enable accurate, efficient, and scalable screening, ensuring timely intervention to prevent vision loss in premature infants. By automating retinal image analysis, AI reduces reliance on specialists and extends access to underserved regions. This approach enhances early diagnosis, enabling effective treatments like laser therapy or anti-VEGF injections.
The system is cost-effective and adaptable, integrating seamlessly with telemedicine platforms to improve healthcare delivery. Despite challenges like data standardization and regulatory requirements, continuous advancements in AI research and collaboration between experts are addressing these hurdles. AI-driven ROP detection promises a future of improved neonatal outcomes, reducing the global burden of preventable blindness and ensuring equitable access to care for at-risk infants.