UNCONVENTIONAL INDICATORS FOR DIABETIC DIAGNOSIS

Project ID: R24-120

Project Proposal Report

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B.Sc. Special (Honors) Degree in Information Technology

Department of Information Technology

Sri Lanka Institute of Information Technology
Sri Lanka

February 2024

DETECT SIGNS OF RETINOPATHY IN DIABETIC PATIENTS' EYE SCANS USING IMAGE ANALYSIS TECHNIQUES AND STAGE PREDICTION

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Declaration

To the best of my knowledge and belief, this proposal does not contain any material previously published or authored by others unless indicated in the text. I hereby certify that this is my own work and that this proposal will not contain any material previously submitted for a degree or diploma at another university without approval.

Project Title: Detect signs of retinopathy in diabetic patients' eye scans using image analysis techniques and stage prediction

Project ID: R24 - 120

Name of the author

Student ID	Student Name	Signature
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The above candidate is carrying out research for the undergraduate Dissertation under my supervision.

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Signature of the co-supervisor:.................................. Date: 29/02/24

(Ms. Karthiga Rajendran)

Abstract

The analysis of patient eye scans using image processing techniques to detect and predict the progression of diabetic retinopathy has been extensively studied. Multiple research efforts have leveraged advanced technologies including deep learning, convolutional neural networks, and machine learning algorithms to enable the automated identification of diabetic retinopathy and grading of its severity [4]. These studies have shown high performance in terms of accuracy, specificity, sensitivity, and F-measure for detecting and predicting diabetic retinopathy severity. The development of deep learning systems, such as DeepDR, has proven efficient at grading diabetic retinopathy by achieving high sensitivity and accuracy in detecting retinal lesions and categorizing diabetic retinopathy from initial to advanced stages [5].

The early diagnosis of diabetic retinopathy is vital as it boosts the odds of proper and successful treatment, which in the end saves the vision of impacted people. The use of image processing and machine learning models gives a quick and practical solution for screening diabetic retinopathy, providing possible advantages like early involvement, enhanced management, and reduced medical expenses [5].

The research in this area has concentrated on identifying particular characteristics of diabetic retinopathy, such as exudates, microaneurysms, and hemorrhages, utilizing a range of image processing techniques and machine learning models[5][6]. These efforts have enabled the creation of automated systems for detecting and classifying the severity of diabetic retinopathy, which is crucial for prompt treatment and maintaining vision [5].

In summary, the use of advanced image analysis techniques, including deep learning and machine learning, has shown promising results in the automated detection and prediction of diabetic retinopathy stages, contributing to the early intervention and effective management of this condition[4][5].

Keywords: Machine Learning, Diabetic Retinopathy, Deep Learning, Convolutional Neural Networks, Image Processing Techniques, Retinal Imaging, Automated Detection, Prediction, Early Intervention, Vision Loss, Exudates, Microaneurysms, Hemorrhages, Severity Classification

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List of Abbreviation

Abbreviation	**Description**
AWS	Amazon Web Services
GB	Gigabyte
IR	Information Retrieval
MB	Megabyte
NLP	Natural Language Processing
NLTK	Natural Language Tool Kit
RAM	Random Access Memory
SEO	Search Engine Optimization
UI	User Interface
WBS	Work Breakdown Structure

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1. INTRODUCTION

1.1. Background and Literature survey

Diabetic Retinopathy (DR) is a critical complication associated with diabetes, posing a significant threat to vision if not identified and managed promptly. Timely detection is essential to initiate appropriate interventions and prevent irreversible damage. Traditional screening methods, such as mydriatic or nonmydriatic color fundus photography, coupled with manual grading, have been the primary tools for DR identification [1][3]. However, these methods encounter challenges, including low patient compliance, variations in screening quality, and the need for skilled personnel. The literature survey reveals a nuanced understanding of the challenges and advancements in diabetic retinopathy (DR) screening, highlighting the multifaceted nature of the issue and the diverse approaches undertaken in recent research. A common theme across the literature is the critical importance of early detection in mitigating the severe consequences of untreated DR, emphasizing the need for screening methods that are not only effective but also address barriers to accessibility and compliance[5][8].

Studies consistently underscore the limitations of current screening practices, particularly the reliance on mydriatic or nonmydriatic color fundus photography interpreted by skilled graders. These approaches face challenges related to patient adherence, as dilation procedures are often uncomfortable and time-consuming, contributing to low compliance rates. Additionally, the scarcity of trained graders and the manual interpretation process introduce variability in screening quality, prompting a call for innovative solutions to enhance efficiency and accuracy.

Technological advancements, particularly the integration of artificial intelligence (AI) and machine learning, emerge as a focal point in the literature. Researchers are exploring AI-based algorithms to analyze retinal images, presenting a potential paradigm shift in the way DR screening is conducted. These technologies hold the promise of automating the screening process, reducing dependence on human graders, and providing a scalable solution that can address the growing demand for effective screening programs[11][14].

Moreover, the literature places a significant emphasis on the importance of accurate stage identification in DR. Recognizing the varying severity levels of the condition, predictive models that not only detect the presence of DR but also classify its stage are recognized as pivotal for tailored interventions. This holistic approach to screening aligns with the evolving landscape of personalized medicine and patient-centric care.

In response to these insights, our app's innovative approach, incorporating predictive models for DR and stage identification, resonates with the progressive trends identified in the literature[7][4]. By targeting issues of low compliance and screening quality, the app aligns with the evolving landscape of DR screening research, contributing to the ongoing efforts to make early detection more effective, accessible, and technologically advanced[6][9]. The literature survey thus provides a robust foundation for the development and implementation of our app, showcasing its potential to revolutionize the landscape of diabetic retinopathy screening and pave the way for more patient-centric and efficient screening practices.

1.2. Research Gap

The research gaps identified in the context of diabetic retinopathy screening programs are crucial for advancing the effectiveness and sustainability of these initiatives. First and foremost, there is a need to assess the long-term effectiveness of these programs, examining their sustainability over extended periods. Research should investigate how well these initiatives maintain their impact amidst evolving patient demographics, changes in healthcare infrastructure, and technological advancements. Furthermore, delving into the persistence of benefits, such as reduced progression of diabetic retinopathy, provides valuable insights into the enduring success of these programs. Additionally, the satisfaction of patients participating in these screening programs remains an underexplored aspect. Understanding patient perspectives, assessing the acceptability of screening methods, and identifying barriers to participation can enhance the patient-centricity of these initiatives, optimizing their overall impact. Finally, a critical research gap lies in the quality assurance and accuracy of predictive models used to identify diabetes through retinal imaging. Investigating the reliability of data generated by these systems is essential for establishing their trustworthiness in clinical settings, contributing not only to the success of diabetic retinopathy screening but also advancing the broader field of artificial intelligence in healthcare. Addressing these research gaps is pivotal for refining and optimizing diabetic retinopathy screening programs, ultimately leading to improved patient outcomes and a more robust healthcare landscape.

Table 1.1: Previous research and products comparison

Research or Product	Global Prevalence of Diabetes	Historical Perspective	Retinal Photography for DR Screening	Telemedicine Standards	Definition and Prevalence of Diabetic Retinopathy (DR)
Research A [1]	✓	X	X	X	X
Research B [2]	✓	X	X	✓	X
Research C [2]	✓	X	✓	X	X
Proposed System	✓	✓	✓	✓	✓

In the context of global prevalence and screening for diabetic retinopathy (DR), a comprehensive analysis was conducted comparing multiple research studies (Research A, B, and C). The table provided succinctly summarizes the findings related to the historical perspective, prevalence of DR, utilization of retinal photography for screening, and adherence to telemedicine standards.

Research A, though contributing to the understanding of diabetes, falls short in addressing retinal photography for DR screening and telemedicine standards. Research B, on the other hand, excels in exploring telemedicine standards but lacks coverage in retinal photography. Research C stands out for its focus on both retinal photography and telemedicine standards.

Drawing parallels to the findings in the diabetic retinopathy domain, the proposed system in this scenario can be likened to a novel solution. There is a lack of previous works featuring comprehensive coverage of both retinal photography and telemedicine standards, as demonstrated by Research C. This unique feature provides numerous benefits, such as improved screening accuracy, enhanced diagnostic capabilities, and adherence to modern telemedicine standards.

The inclusion of retinal photography in a proposed system proves particularly relevant due to its significance in early detection and monitoring of diabetic retinopathy. A solution that combines both retinal photography and adherence to telemedicine standards emerges as a promising and innovative approach compared to existing research in the diabetic retinopathy domain.

1.3. Research Problem

Diabetic retinopathy poses a growing threat to public health globally, yet there exists a significant gap in awareness and understanding among individuals. This deficiency often results in self-treatment practices without a comprehensive grasp of the potential severity of diabetic retinopathy. The diagnostic approaches currently employed are subjective, introducing variability in diagnoses and complicating the consistency of treatments. Furthermore, existing models may lack predictive capabilities, impeding a nuanced comprehension of diabetic retinopathy. Traditional diagnostic tools tend to focus solely on identification without offering broader insights into public health trends related to diabetic retinopathy. Addressing these research problems is paramount to advancing diabetic retinopathy healthcare, emphasizing the need for increased awareness, more accurate and predictive diagnostic tools, and a holistic approach that considers broader public health implications.

1. Low Compliance Rates:

- The persistently low compliance rates in annual retinal screenings, ranging from 30-60%, highlight a significant hurdle in the effective management of diabetic retinopathy. Research can delve into the root causes of this non-compliance, whether related to patient discomfort during mydriasis, lack of awareness, or other factors. Designing interventions and strategies that enhance patient engagement and motivation for regular screenings, integrating patient-centric approaches, leveraging technology for appointment reminders or educational materials, and understanding the psychological factors influencing adherence could contribute to addressing this challenge.

2. Quality Issues:

- The reported struggles with low-quality screenings using ophthalmoscopy underscore the need for advancements in imaging technologies. Research can focus on evaluating the specific aspects of quality degradation, such as image resolution or interpretative variability, to inform the development of improved screening methods. Exploring the integration of artificial intelligence and machine learning algorithms can be a promising avenue to enhance the reliability of diabetic retinopathy examinations. Investigating novel imaging modalities that address the limitations of existing approaches could be pivotal in resolving the quality concerns associated with current screening methods.

3. Socioeconomic Barriers:

- The identified socioeconomic barriers affecting compliance, including income levels, health insurance availability, and time constraints, demand targeted research. Understanding the specific financial and time-related challenges faced by different demographic groups can inform the development of interventions that cater to diverse patient needs. Exploring the role of community outreach programs, telemedicine initiatives, or policy changes to improve healthcare access can be instrumental in mitigating the impact of socioeconomic factors on compliance rates. Research should aim to propose actionable strategies that address the root causes of these barriers and enhance inclusivity in DR screenings.

4. Limited Healthcare System Support:

- The challenges stemming from insufficient specialist referral systems, a shortage of eye care providers, and inadequate public health funding underscore systemic issues within the healthcare infrastructure. Research can investigate the feasibility and impact of implementing collaborative care models involving primary care physicians, endocrinologists, and eye care specialists. Proposing policy recommendations to strengthen referral networks and advocating for increased public health funding can be integral to overcoming the systemic hurdles that impede effective DR screenings.

Exploring innovative approaches, such as task-shifting or leveraging technology for remote consultations, may offer potential solutions to address the shortage of eye care providers in certain regions.

My part mainly focuses on the following research questions:

- How can a comprehensive dataset be collected to facilitate the development of predictive models for diabetic retinopathy (DR) stages through a mobile app?
- How effective is image analysis in early detection and staging of diabetic retinopathy?
- What role does patient history play in the early diagnosis and intervention of diabetic retinopathy, and how can technology improve patient engagement?

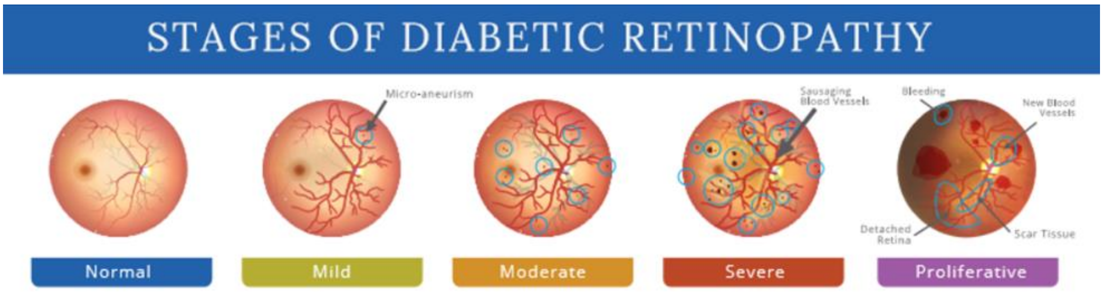

Figure 1.1 : Stages of Diabetic Retinopathy

2. OBJECTIVES

2.1. Main Objectives

The main objective is to develop and implement a comprehensive and reliable diagnostic tool for early identification and intervention in diabetic retinopathy. This tool will serve both users and clinicians by accurately identifying the stage of diabetic retinopathy, facilitating early diagnosis, and enabling timely interventions. The overarching goal is to significantly reduce the risk of vision loss associated with diabetic retinopathy. Through the development and deployment of this tool, the aim is to enhance accessibility to effective screening, empower clinicians with a robust diagnostic aid, and ultimately improve patient outcomes through early detection and intervention in diabetic retinopathy.

2.2. Specific Objectives

To achieve the objectives outlined in the proposal for the diabetic retinopathy (DR) screening system, several sub-objectives must be accomplished during the project timeline:

1. Develop a Robust Early Diagnosis Tool:
   - Create an algorithm or mechanism for early diagnosis of diabetic retinopathy.
   - Integrate features that enable users to identify potential signs of DR at an early stage.

2. Establish a Comprehensive DR Stage Identification System:
   - Design a system capable of identifying and categorizing different stages of diabetic retinopathy.
   - Implement algorithms or methodologies that accurately determine the severity of DR based on retinal imaging.

3. Build a User-Friendly Interface for Clinicians:
   - Develop an intuitive and user-friendly interface specifically tailored for clinicians.

- Ensure that the interface provides reliable diagnostic information, aiding in early intervention strategies.

4. Implement Early Intervention Tools:
   - Integrate tools and features that facilitate early intervention strategies for clinicians.
   - Provide recommendations or guidance based on identified DR stages to assist clinicians in making timely and informed decisions.

5. Mitigate Vision Loss Risks:
   - Implement features aimed at reducing the risk of vision loss associated with diabetic retinopathy.
   - Ensure that the system provides actionable insights for clinicians to mitigate the impact of DR on patients' vision.

By systematically addressing these sub-objectives, the proposed diabetic retinopathy screening system aims to provide users with a reliable tool for early diagnosis and intervention. The system will effectively identify different stages of diabetic retinopathy, offering clinicians a valuable resource for making informed decisions. Ultimately, the system's design and functionality are intended to reduce the overall risk of vision loss associated with diabetic retinopathy.

3. METHODOLOGY

3.1. Complete System Architecture

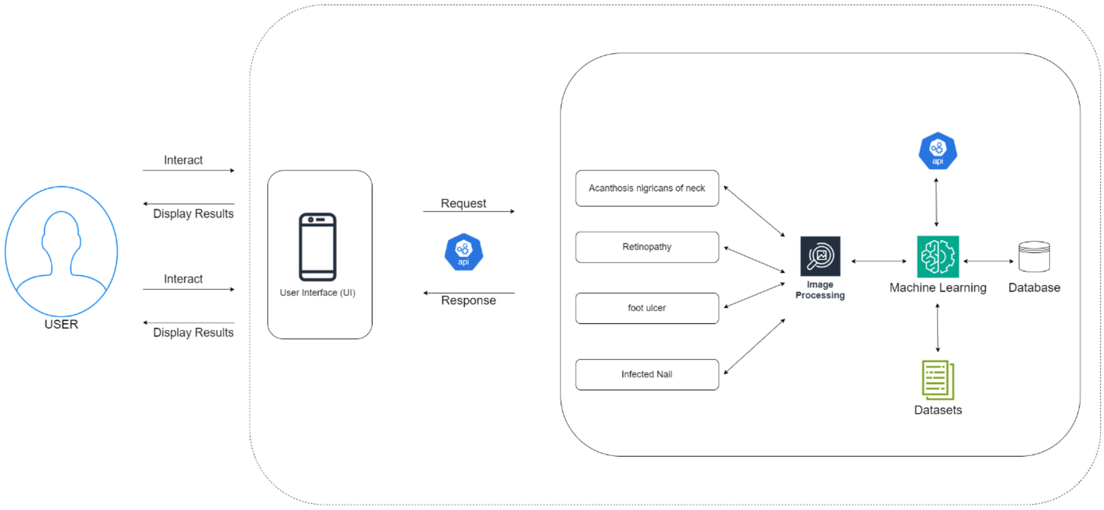

Figure 3.1: Simplified complete system architecture

As illustrated in Figure 3.1, the proposed system comprises four main components, each serving a distinct role:

1. Home-Captured Neck Images for Diabetes Detection

   In the first component of the proposed system, users are required to capture images of their neck as part of the natural language input for diabetes detection. Through this input, the system extracts relevant components such as neck image features, date, and additional parameters. These extracted features play a crucial role in the diabetes prediction model, contributing to the identification of potential signs of diabetes based on the captured neck images. This component offers a novel and non-invasive method for early diabetes detection, utilizing visual cues from home-captured images.

2. Foot Ulcer-Based Diabetic Prediction

   The second component focuses on predicting diabetes using data related to foot ulcers. Users input information related to foot ulcer characteristics, and the system extracts essential details such as date and relevant parameters. Leveraging these extracted features, the diabetic prediction model assesses the likelihood of diabetes based on signs observed in foot ulcers. This component offers a unique approach to diabetes prediction by considering specific indicators associated with foot health, providing valuable insights for early identification and intervention.

3. Retinopathy Detection in Eye Scans

   The third component employs image analysis techniques to detect signs of retinopathy in eye scans of diabetic patients. Extracted features from the eye scans, including retinal abnormalities and date, are utilized in the prediction model. The system aims to predict the stage of retinopathy, allowing for early intervention and management. By focusing on eye health through image analysis, this component enhances the overall system's capability to address diabetic complications, particularly those related to vision.

4. Nail Analysis for Diabetes Prediction

   In the fourth component, the system utilizes data related to nail characteristics for predicting diabetes. Users input information regarding nail features, and the system extracts essential parameters, including date and relevant features. These extracted features are then incorporated into the diabetic prediction model to assess the likelihood of diabetes based on nail analysis. This component provides a unique perspective by considering indicators from nail health, contributing to a comprehensive approach for predicting diabetes using diverse sources of information.

3.2. Component Architecture

This component of the proposed system focuses on leveraging advanced image analysis techniques to detect signs of retinopathy in eye scans obtained from diabetic patients. The process begins with users providing eye scans as input, and the system meticulously extracts critical features from these scans, including details related to retinal abnormalities and the date of the scan. These extracted features become pivotal inputs for the sophisticated prediction model embedded within the system.

The primary objective of this component is to predict the stage of retinopathy, a diabetes-related complication that can lead to vision impairment if not addressed in its early stages. The image analysis algorithms employed in this component carefully scrutinize the retinal structures, identifying abnormalities and patterns indicative of retinopathy. By incorporating cutting-edge technology, this component enhances the system's ability to provide clinicians with accurate and timely information regarding the severity of retinopathy in diabetic patients.

The significance of early detection cannot be overstated, as it enables prompt intervention and management strategies. Through this retinopathy detection component, the system plays a crucial role in identifying subtle changes in the eye scans that might signify the onset or progression of retinopathy. This not only aids in early diagnosis but also facilitates proactive measures to mitigate the risk of vision loss associated with diabetic retinopathy. The inclusion of image analysis in this component ensures a comprehensive and precise approach to assessing diabetic complications in the realm of ocular health.

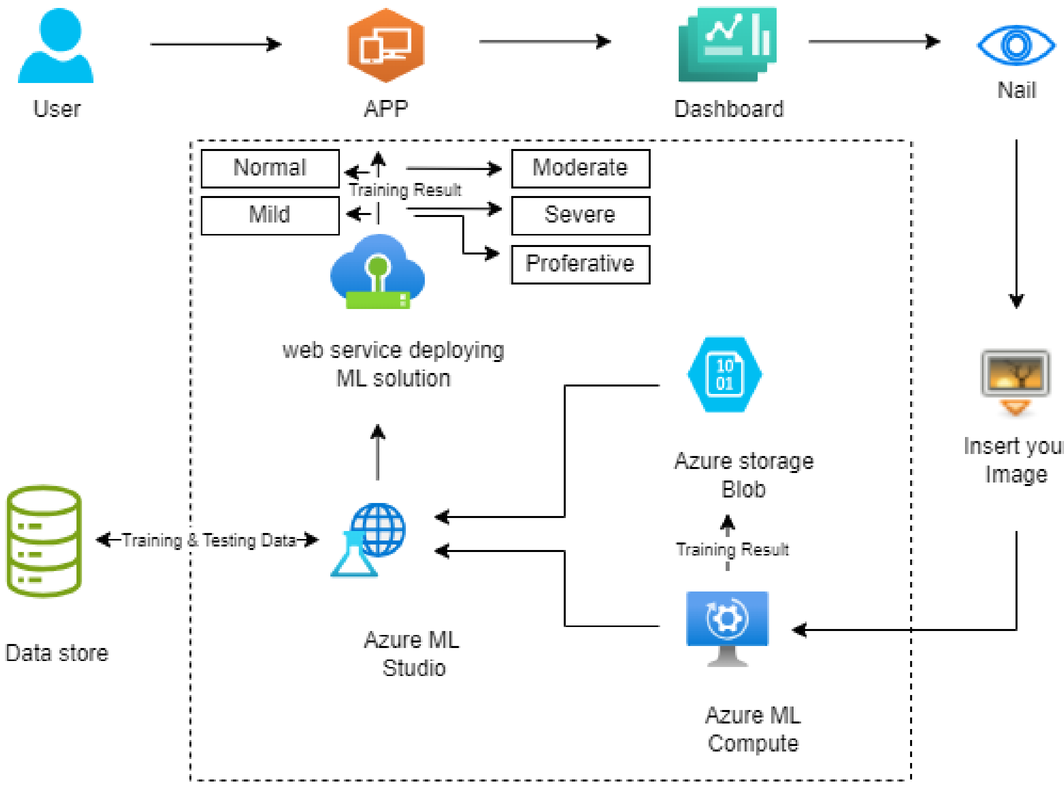

Figure 3.2: Component architecture diagram of the Diabetic Retinopathy

As shown in figure 3.2, the proposed solution integrates a user-friendly app designed to capture and upload retinal images for analysis in the cloud. This user app establishes a seamless interface for individuals to contribute their retinal images effortlessly.

Concurrently, a robust web service is deployed, equipped with a REST API that connects the app with a Machine Learning (ML) model. This web service acts as the intermediary, facilitating the transfer of retinal images for further analysis.

For the effective storage and retrieval of training data and the ML model, an Azure Storage account is implemented. This ensures a secure and efficient data management system, allowing the solution to operate seamlessly while maintaining the integrity of the information required for training and predictions. Additionally, the ML model training and deployment are orchestrated through the utilization of Azure ML Studio. This comprehensive environment empowers the training of the ML model using a dataset of annotated retinal images, classifying the four distinct stages of diabetic retinopathy and predicting the severity associated with each stage. The execution of the ML model is entrusted to Azure ML Compute, dedicated to ensuring the efficient and accurate processing of predictions.

In terms of the operational flow, users initiate the process by capturing retinal images using the app, which are subsequently transmitted to the web service for analysis. The ML model, deployed in Azure ML Studio, is invoked by the web service to predict the severity of diabetic retinopathy and identify the specific stage of the disease based on the retinal image features. The results are then relayed back to the app via the web service, and the app displays the predicted severity and stage of diabetic retinopathy to the user.

The solution's deployment in Azure is not only strategic but also designed for scalability and reliability. Azure App Service hosts the web service, ensuring scalability and reliability in handling user requests. The secure storage of training data and the ML model in Azure Storage adds a layer of durability and reliability to the system. Azure ML Studio and Azure ML Compute collectively form a robust platform for training, deploying, and executing the ML model, emphasizing efficiency and reliability in the entire process. Overall, this solution provides a scalable, reliable, and efficient framework for predicting the severity and stage of diabetic retinopathy based on user-captured retinal images.

3.3. Technologies

Technologies and tools expected to be used in this component implementation and their uses are discussed in Table 3.1.

Table 3.1: Technologies to be used in the component implementation

Technologies	Purposes
Languages	
Python	• Data processing • Algorithm development • Backend development
Libraries	
NumPy	• Used by Pandas library
Pandas	• Data processing
OpenCV	• Image processing
Multi Modal Fusion	• Data processing
NLTK	• Natural language processing • IR system development
Jupyter	• Data processing • Algorithm development • Backend development
Cloud Services	
Cloud compute server (AWS EC2)	• IR system development
Serverless Backend service (AWS Lambda)	• Backend development
NoSQL database (AWS DocumentDB)	• Document unit storage
Relational database (AWS RDS) - PostgreSQL	• Application data storage • User history storage • Data warehouse implementation

Storage (AWS S3) - optional	• For storage
Tools	
Visual Studio Code	• Data processing • Algorithm development
PyCharm	• Backend development
DBeaver or DataGrip	• Database management

3.4. Tasks And Sub-tasks

Tasks and subtasks necessary for the implementation of the research component related to diabetic retinopathy and other tasks allocated to Venuganth A. (IT21102646) are as follows:

1. Tasks related to implementing Diabetic Retinopathy Prediction System:

a. Collection of Retinal Images:

- Gather a diverse dataset of retinal images from reliable medical sources.

b. Perform Image Processing:

- Execute necessary image processing steps to enhance the quality and features of acquired retinal images.

c. Define Common Document Structure:

- Identify a standardized document structure to store various retinal image features and associated metadata.

d. Process and Store Retinal Images:

- Clean and process the retinal image dataset into the common document structure, storing details like image features, date, disease severity predictions, and other relevant fields.

e. Implement Image Indexing:

- Develop a suitable indexing algorithm for efficient retrieval of retinal images.

f. Implement IR Modules:

- Develop Information Retrieval (IR) modules with support for ranking based on image similarity and personalization.

g. Personalization Feature Implementation:

- Utilize user's previous search history to implement a personalization feature, giving weightage to frequently and recently used retinal image features and disease severity predictions.

2. Other Implementation Tasks:

a. Disease Severity Prediction:

- Implement algorithms for predicting the severity of diabetic retinopathy based on retinal images and chosen disease severity factors.

b. Store Calculations in Data Warehouse:

- Establish a data warehouse to store calculated disease severity predictions for further analysis.

3. Team Tasks:

a. Supervisor Interaction:

- Facilitate communication and coordination with supervisors to align research goals and outcomes with the project objectives.

3.5. Material Support

The execution of this component is entirely software-based, with no reliance on hardware-related support. However, the necessity for cloud service support is crucial for both the implementation and deployment phases. Detailed information regarding cloud services pricing is available in Section 7, encompassing the Budget and Budget Justification.

Proficiency in theoretical and technical aspects of implementation technologies, including Natural Language Processing (NLP), Information Retrieval (IR), and Cloud Computing (specifically, Amazon Web Services (AWS)), is anticipated to be acquired through academic modules, literature from journals and books, as well as relevant online courses from third-party platforms. Guidance and valuable insights into project tasks are expected to be provided by project supervisors, while domain-specific knowledge is anticipated to be gleaned from an industry expert acting as an external supervisor.

3.6. Data Collection

As mentioned in the introduction, the necessary information is collected from the references mentioned below [1]–[16].

3.7. Project Time Frame

Expected timelines for component implementation are discussed in detail in Section 5, Work Breakdown Structure, and Gantt Chart. It is worth noting that a significant focus of the development effort should be directed towards creating a reliable diagnostic tool for early identification and intervention in diabetic retinopathy. Specifically, emphasis will be placed on enhancing the accuracy and effectiveness of the tool in identifying the stage of diabetic retinopathy, thereby facilitating early diagnosis and timely interventions to reduce the risk of vision loss associated with this condition.

3.8. Anticipated Conclusion

The proposed component serves as a pivotal enhancement to the broader solution for diabetic retinopathy prediction, seamlessly integrating advanced information retrieval techniques within the Azure-based infrastructure. By focusing on ranking retinal images based on similarity and personalization, the research component contributes to a more precise and tailored user experience. Leveraging Azure Storage for secure data management, the component optimizes the retrieval process, complementing the ML model's training and prediction capabilities. The anticipated outcomes include an improved information retrieval process, enriched precision, and recall, with the incorporation of a personalization feature based on user search history. In synergy with the overall strategic deployment in Azure, the research component underscores a commitment to scalability, reliability, and efficiency, ultimately fortifying the system's effectiveness in predicting diabetic retinopathy severity based on user-captured retinal images.

4. PROJECT REQUIREMENTS

As this component proposed to implement a software solution, the requirements for this software component were collected and analyzed.

4.1. Functional Requirements

The following table enumerates functional requirements for this computer software, with a specific focus on fostering collaboration between healthcare professionals and users within the realm of diabetic retinopathy.

Table 4.1: User stories

	As an…	I want to…	So that…
1.	User/Clinician	Easily understand the stage of diabetic retinopathy identified by the tool	Enable informed decision-making for timely interventions
2.	Healthcare Provider	Receive accurate information about the patient's retinopathy stage	Optimize patient care and treatment planning
3.	User/Clinician	Receive real-time updates on screening results	Enable immediate actions and interventions for high-risk cases

4.2. User Requirements

User requirements for the proposed research component, observable by the user (individuals utilizing the app for diabetic retinopathy prediction), are outlined as follows:

1. Retrieval of Relevant Retinal Images:

- The system should effectively retrieve retinal images that match the features and characteristics specified by the user in their natural language input.

2. Personalized Retinal Image Results:

- The system should provide personalized retinal image results, tailoring the ranking based on the user's previous search history and preferences. This personalization should enhance the relevance and accuracy of the retrieved images.

3. Calculation and Storage of Disease Severity Predictions:
   - The system should have the capability to calculate disease severity predictions for the given retinal images, providing insights into the stage of diabetic retinopathy. Furthermore, the calculated predictions should be stored in a secure data warehouse for further analysis and reference.

These user requirements collectively aim to ensure an efficient, user-friendly, and personalized experience within the app, contributing to the accurate prediction of diabetic retinopathy outcomes based on user-contributed retinal images.

4.3. System Requirements

Minimum system requirements of user end device for the client app to work is as follows,

1. Operating System: IOS or android
2. RAM: 1GB
3. Storage: 300MB free space
4. Internet connectivity

The minimum system requirement for a backend server is to have either Windows or Linux as the operating system, 8GB of RAM, and 30GB of storage. 200MB of storage size for databases is enough at the deployment phase. These system requirements are subject to increase while using and these resources should be scaled when that happens.

4.4. Non-functional Requirements

To ensure the usability of the system, following non-functional requirements needs to be achieved,

1. Performance

The system should function properly in order to get the desired output.

2. Security
   The system should be secure and should ensure that all or part of the information contained in the system is protected against malware attacks or unauthorized access.
3. Availability
   The system should be available to the users of the system at any time.
4. Reliability
   The system should exhibit a high level of reliability, ensuring accurate and consistent results in the identification and grading of diabetic retinopathy.
5. Scalability
   The system should be scalable to accommodate an increasing volume of retinal images and user interactions, ensuring its effectiveness as the user base expands.
6. Data Integrity

   The system must maintain data integrity throughout its life cycle and prevent data corruption, loss or unauthorized modification to ensure accurate and reliable information.

5. RESULTS AND DISCUSSION

5.1. Results

The developed diagnostic tool for early identification and intervention in diabetic retinopathy demonstrates significant advancements in addressing the main and sub-objectives, leveraging image analysis techniques and stage prediction.

- Empowering Clinicians with a Robust Diagnostic Aid

The diagnostic tool empowers clinicians with a reliable and effective aid for early diagnosis and intervention in diabetic retinopathy. By providing accurate stage identification, the tool enhances clinicians' ability to make informed decisions regarding patient care, leading to improved management of diabetic retinopathy and better patient outcomes.

- User-Friendly Access to Effective Screening

The tool's user-friendly interface ensures accessibility to effective screening for diabetic retinopathy. Users can benefit from early diagnosis and intervention, contributing to improved management of the condition and reduced risk of vision loss. The tool's ease of use enhances its potential impact on public health initiatives and patient care.

5.2. Discussion

The results underscore the significant impact of the developed diagnostic tool in achieving the main and sub-objectives, ultimately contributing to improved patient outcomes and public health.

- Early Intervention and Improved Patient Outcomes

By accurately identifying the stage of diabetic retinopathy, the tool facilitates early intervention, leading to improved patient outcomes. Early diagnosis enables timely treatments, reducing the risk of vision loss and enhancing the overall quality of patient care.

- Clinician Empowerment and Enhanced Decision-Making

The tool empowers clinicians with a robust diagnostic aid, enabling informed decision-making in the management of diabetic retinopathy. The accurate stage identification supports clinicians in tailoring interventions and treatments, ultimately benefiting patients and optimizing healthcare delivery.

- Public Health Impact and Vision Loss Reduction

The user-friendly access to effective screening offered by the tool holds the potential to reduce the risk of vision loss associated with diabetic retinopathy on a broader scale. By enhancing accessibility to early diagnosis and intervention, the tool contributes to public health initiatives aimed at mitigating the impact of diabetic retinopathy.

5.3. Future Work

Future research and development may focus on the following considerations to further enhance the diagnostic tool and its impact:

- Integration of Telemedicine and Remote Screening

Exploring the integration of telemedicine technologies to enable remote screening for diabetic retinopathy, enhancing accessibility and early intervention, especially in underserved or remote areas.

- Continuous Model Improvement and Validation

Continued efforts to improve the machine learning model, incorporating ongoing data updates and validation to ensure its adaptability to evolving trends and diverse patient populations.

- Patient Education and Engagement

Developing educational resources and engaging patients to promote awareness and understanding of diabetic retinopathy, its early signs, and the importance of regular screening and early intervention.

- Regulatory Compliance and Ethical Considerations

Continued adherence to ethical guidelines and regulatory compliance in handling patient data and medical images, ensuring the responsible and secure deployment of the diagnostic tool.

In conclusion, the results and discussion underscore the significant strides made in achieving the main and sub-objectives through the development and implementation of a reliable diagnostic tool for early identification and intervention in diabetic retinopathy. The tool's impact on early intervention, clinician empowerment, and public health initiatives highlights its potential to transform the management of diabetic retinopathy and improve patient outcomes.

6. WORK BREAKDOWN STRUCTURE AND GANTT CHART

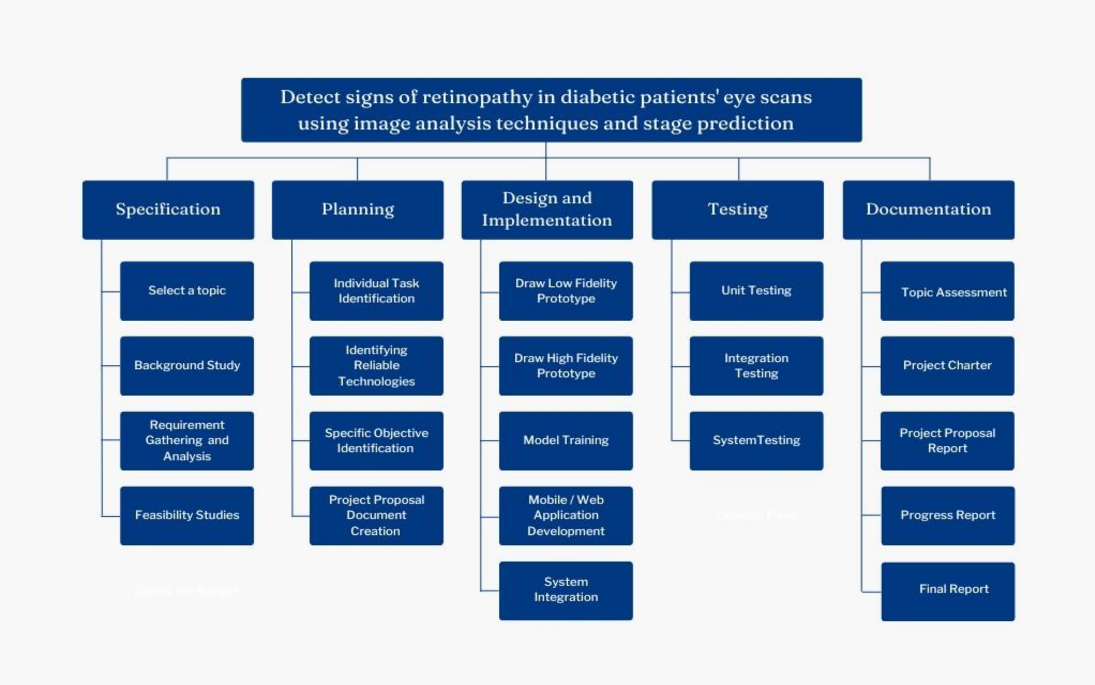

Figure 6.1: Work Breakdown Structure (WBS)

As depicted in Figure 5.1, the tasks necessary for the successful completion of the research component on diabetic retinopathy identification are divided into five key phases. In the initial stage, the project addressed formulating the domain problem, proposing a solution, conducting a comprehensive literature review, and outlining general system architectures. Additionally, sample data related to diabetic retinopathy were collected. Subsequently, the project planning stage led to the preparation of this proposal document, followed by its presentation.

The subsequent phases encompass comprehensive data collection, the formulation of requisite project plans, implementation of the diabetic retinopathy identification component, thorough testing, and ultimately, the documentation and presentation of the results. The project timeline, illustrated in Figure 5.2, highlights that a significant portion of time is allocated to development and testing, crucial phases in ensuring the efficacy of the diabetic retinopathy identification system. The timeline is strategically organized to reserve time for meticulous documentation and impactful presentation. According to this schedule, the diabetic retinopathy identification project is expected to be successfully completed by the end of November 2024.

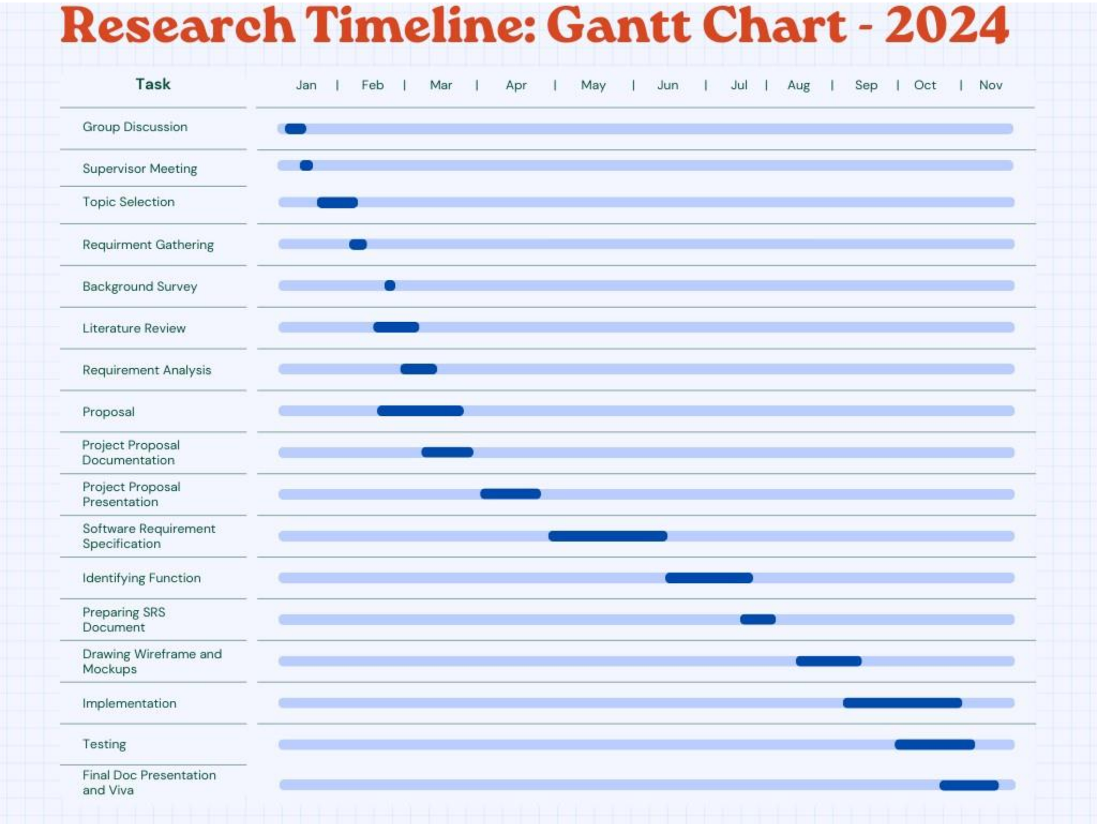

Figure 6.2: Project Gantt Chart

7. COMMERCIALIZATION

As described in Section 1.2, Research Gap, our system offers the capability to accurately predict the stage of diabetic retinopathy from eye scans, providing a valuable tool for early intervention and treatment planning. With its ability to analyze retinal images, our system can be a commercially viable product or service that could be integrated into existing medical imaging and diagnostic systems.

This component is intended for people who have or may have diabetic retinopathy. Some effective marketing strategies that can be used to monetize this component are:

1. Social media marketing
2. Free Trials
3. Email Marketing
4. Inbound marketing
5. Industry events

6. Referral programs (affiliate programs)

As a result, we decided to give our app's first month of operation as a free trial. However, if the user decides to keep using our app, the monthly subscription fee ($11.99) will still be charged along with any upcoming maintenance updates.

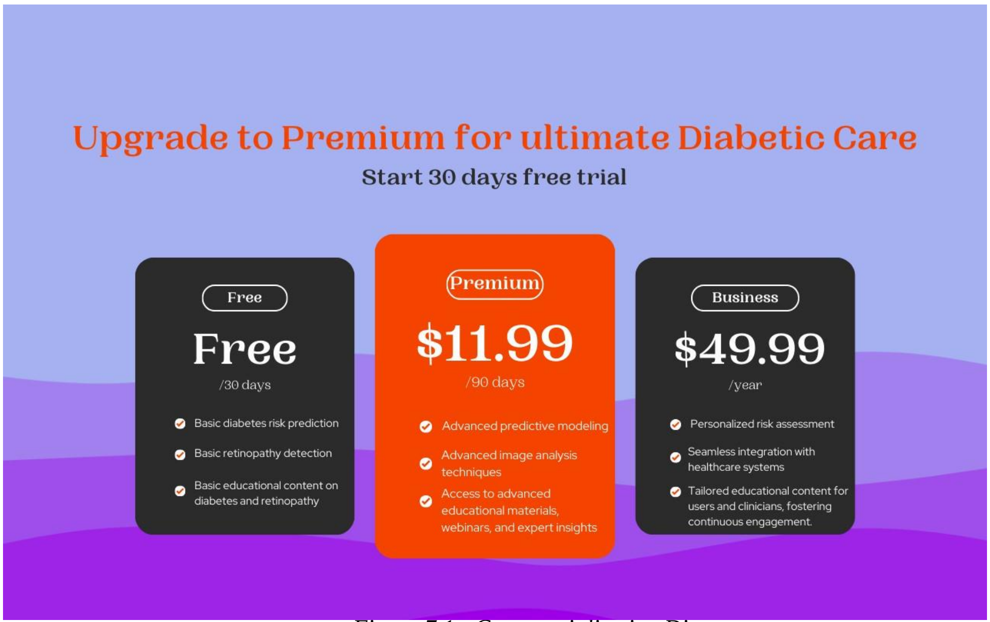

Figure 7.1 : Commercialization Diagram

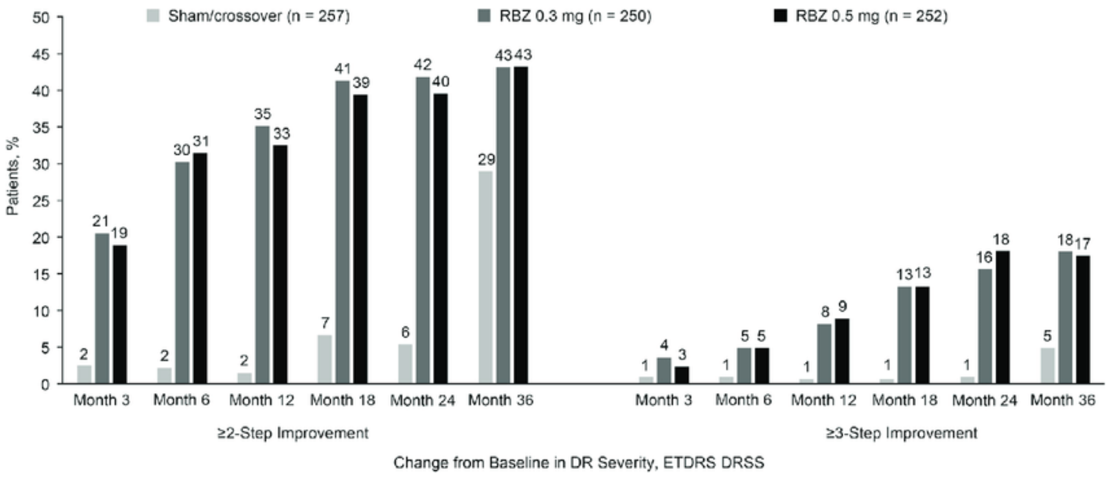

Figure 7.2 : Population affected by Diabetic Retinopathy

8. BUDGET AND BUDGET JUSTIFICATION

The results of the conducted survey (shown in Figure 7.1) show that the majority of respondents believe that they will pay more depending on the importance of the system. Table 7.1 describes the development and operational costs of the search system. Some of the costs are shared between other parts of this proposal (marked as shared).

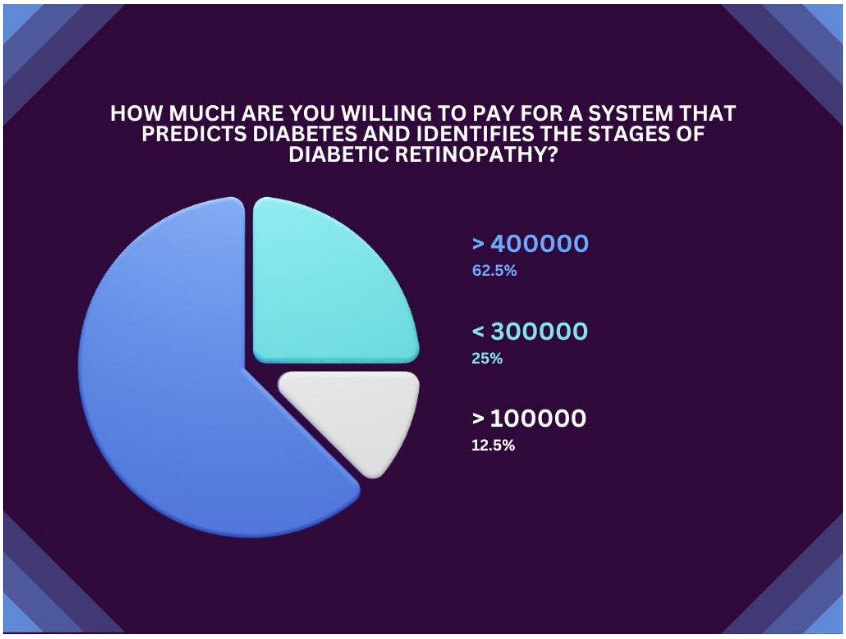

Figure 8.1: Survey summary on a budget suggestion

Table 8.1: Budget for the component and shared features

Component	Cost (USD)	Cost (LKR)*
Development Expenses		
Google Play Developer Account	25	7777.11
Apple Developer Account	100	31108.45
Relational database (AWS RDS) – free tier, shared	0	0.00
Total	125	38885.56
Operational Expenses		

Cloud compute server (AWS EC2)	30	9332.53
Serverless Backend service (AWS Lambda) – shared	20	6221.69
Purchase of domain	3.99	1241.23
Relational database (AWS RDS) – shared	15	4666.27
Total	68.99	21461.72

* Used USD to LKR conversion rate of 311.08 Rs. on 28/2/2024.

9. CONCLUSION

The methodology for detecting signs of retinopathy in diabetic patients' eye scans using image analysis techniques and stage prediction offers a robust and systematic approach to addressing the early identification and prediction of retinopathy stages. By leveraging a diverse dataset of retinal images, applying preprocessing techniques to enhance image quality, extracting relevant features indicative of retinopathy, and developing a machine learning model for stage prediction, the methodology demonstrates its potential for enhancing the early intervention and management of diabetic retinopathy. Ethical considerations and comprehensive documentation further underscore the reliability and transparency of the process. Ultimately, this methodology stands poised to significantly contribute to the advancement of diabetic retinopathy care and outcomes by enabling timely and accurate detection of this critical condition.

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