HematoVision: Advanced Blood Cell Classification - Comprehensive Project Document

1. Executive Summary

This document provides a comprehensive overview of the HematoVision project, an AIpowered system designed for the accurate and efficient classification of blood cells. Leveraging advanced deep learning techniques, particularly transfer learning with pretrained Convolutional Neural Networks (CNNs), HematoVision aims to address the critical need for automated blood cell analysis in medical diagnostics. This report synthesizes information from various project documents, including problem statements, ideation, solution requirements, technical architecture, customer journey maps, and project planning details, to present a holistic view of the project from conception to proposed implementation.

2. Project Overview

HematoVision is a web-based application developed to assist pathologists and healthcare professionals in the analysis of blood cell images. The project's core objective is to provide a reliable, scalable, and user-friendly tool that reduces the manual workload, minimizes human error, and accelerates diagnostic processes associated with traditional blood cell classification. It also serves as an educational resource for medical training.

2.1 Project Details

Field	Value
Date	31 June 2025
Team ID	LTVIP2025TMID41359
Project Name	Hematovision: Advanced Blood Cell Classfication
Maximum Marks	4 Marks

3. Problem Definition

3.1 Core Problem

The accurate identification and classification of blood cells are critical for diagnosing various hematological disorders. However, manual microscopic analysis of blood smears is time-consuming, labor-intensive, and prone to human error due to variability in expertise and fatigue. Existing automated systems often lack the precision and robustness needed to handle diverse blood cell types and abnormalities under varying imaging conditions.

3.2 Problem Validation

Evidence for this problem is abundant, with numerous research efforts focused on automating blood cell classification and the availability of large public datasets specifically for this task. The manual process leads to inaccurate or delayed diagnoses, impacting patient outcomes and increasing healthcare costs. Therefore, an advanced, automated system is critically needed.

4. Ideation and Brainstorming

4.1 Brainstorming Key Ideas

Initial brainstorming for HematoVision focused on:

- Developing a deep learning model for image classification.
- Utilizing transfer learning to leverage pre-trained models for efficiency and accuracy.
- Building a web-based interface for easy access.
- Focusing on common blood cell types (Eosinophil, Lymphocyte, Monocyte, Neutrophil).
- Considering integration with existing clinical workflows.

4.2 Empathy Mapping

An empathy map was utilized to understand the user's (hematologist/pathologist) behaviors and attitudes. This tool helped in considering the user's perspective, goals, and challenges, ensuring the solution is user-centric.

5. Solution Requirements

5.1 Functional Requirements

Functional requirements define the specific actions the HematoVision system must perform:

- **User Management:** User registration (email, social media), login, and password recovery.
- **Image Upload and Management:** Allow users to upload blood cell images (JPEG, PNG), validate them, securely store them temporarily, and delete them after processing.
- **Blood Cell Classification:** Preprocess images, classify blood cells into predefined categories (Eosinophil, Lymphocyte, Monocyte, Neutrophil), provide confidence scores, and integrate a pre-trained machine learning model.
- **Result Presentation:** Display classification results, including predicted cell type and confidence, with potential visual feedback and future historical result viewing.

5.2 Non-Functional Requirements

Non-functional requirements specify the quality attributes of the system:

- **Performance:** Response time (5-10 seconds), scalability for concurrent users, and high throughput.
- **Security:** Data privacy, secure authentication and authorization, and data encryption (HTTPS).
- **Usability:** Intuitive and user-friendly interface, accessibility, and informative error messages.

- **Reliability:** High uptime (99.9%), data integrity, and fault tolerance.
- **Maintainability:** Modular architecture, high code quality, and testability.
- **Portability:** Platform independence and use of widely supported open-source technologies.

6. Technical Architecture and Tech Stack

6.1 High-Level Architecture

HematoVision follows a client-server architecture. A web-based frontend interacts with a Python-based backend that hosts the machine learning model. The core components include:

- **Client-Side (Web Browser):** User interface (HTML, CSS, JavaScript) for image upload and result display.
- **Web Application Backend (Flask):** Handles user requests, manages image uploads, and orchestrates interactions with the ML model.
- **Machine Learning Model (TensorFlow/Keras):** The trained deep learning model responsible for blood cell classification.
- **Storage:** Local filesystem for temporary storage of uploaded images.

6.2 Detailed Tech Stack

Category	Technology/Tool	Purpose
Programming Languages	Python	Backend logic, machine learning
Web Frameworks	Flask	Lightweight web application backend
ML Frameworks	TensorFlow/Keras	Deep learning model development, training, deployment
Frontend	HTML5, CSS3, JavaScript	Structuring, styling, and interactivity of web pages
Data Storage	Local Filesystem	Temporary storage for uploaded images
Database (Future)	SQLite/PostgreSQL	User management, historical results, preferences
Version Control	Git	Collaborative development, tracking changes
Dev Environment	Jupyter Notebook, IDEs	ML model experimentation, code development
Package Management	pip	Managing Python dependencies (`requirements.txt`)
Deployment	Cloud Platforms (AWS, GCP, Azure), Gunicorn/uWSGI, Nginx/Apache	Scalable and reliable production environment, serving application and static files

6.3 Machine Learning Model Details

- **Architecture:** Fine-tuned MobileNetV2 Convolutional Neural Network.

- **Dataset:** 12,500 augmented blood cell images from Kaggle.
- **Training:** 5 epochs, Adam optimizer, categorical cross-entropy loss.
- **Accuracy:** Approximately 85.3% validation accuracy.
- **Model Persistence:** Saved as `blood_cell.h5` for deployment.

7. Customer Journey Map

The customer journey for HematoVision involves several stages, primarily for pathologists and healthcare professionals:

1. **Sample Acquisition:** Pathologist receives a blood sample (manual, time-consuming).
2. **Image Capture:** Pathologist captures digital images of blood cells using microscopy equipment.
3. **Image Upload:** User uploads images to the HematoVision web application (`home.html`).
4. **Image Processing and Classification:** The backend (`app.py`) processes the image using the ML model (`model.ipynb`).
5. **Result Display:** Classification results are presented to the user on `result.html` .

8. Project Planning and User Stories

8.1 Product Backlog and Sprints

The project planning adheres to agile methodologies, with a product backlog organized into functional epics and user stories with estimated story points and priorities. The development is structured into sprints.

8.2 Key User Stories (Customer - Mobile User)

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	R
Customer (Mobile user)	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	I can access my account / dashboard	High	S 1

Customer (Mobile user)	Registration	USN-2	As a user, I will receive confirmation email once I have registered for the application	I can receive confirmation email & click confirm	High	S 1
Customer (Mobile user)	Registration	USN-3	As a user, I can register for the application through Facebook	I can register & access the dashboard with Facebook Login	Low	S 2
Customer (Mobile user)	Registration	USN-4	As a user, I can register for the application through Gmail		Medium	S 1
Customer (Mobile user)	Login	USN-5	As a user, I can log into the application by entering email & password		High	S 1

9. Problem-Solution Fit Analysis

9.1 Alignment

HematoVision directly addresses the core problem of inefficient and inaccurate manual blood cell classification by providing an automated, AI-driven alternative. It targets pain points like time consumption, human error, and the need for specialized expertise. The solution is highly desirable for pathologists as it saves time, reduces errors, improves workflow, and enhances diagnostic confidence.

9.2 Value Proposition Clarity

The value proposition is clear and compelling: "Accurate and efficient blood cell classification using AI, leveraging transfer learning for enhanced precision and reduced analysis time." Users can easily understand the benefits of faster, more accurate, and consistent blood cell analysis.

9.3 Feasibility & Viability

- **Technical Feasibility:** The solution is technically feasible, leveraging established deep learning techniques (transfer learning with MobileNetV2) and a widely used web framework (Flask). The provided `model.ipynb` and `app.py` demonstrate the viability.
- **Economic Viability:** The solution has strong potential for economic viability by reducing labor costs, improving throughput, and potentially leading to earlier and more accurate diagnoses.
- **Risks and Assumptions:** Potential risks include data bias, generalization issues, regulatory approval processes, integration challenges with existing systems, and user adoption hesitancy.

9.4 Next Steps

Further validation is needed through prospective clinical validation, User Acceptance Testing (UAT), performance benchmarking, and robustness testing. Key metrics to track include diagnostic accuracy, turnaround time, user satisfaction, cost savings, and error rate reduction. Action items involve expanding the dataset, model refinement, feature enhancement, regulatory pathway planning, pilot programs, and scalability assessment.

10. Conclusion

HematoVision represents a significant advancement in automated blood cell analysis. By integrating cutting-edge machine learning with a user-friendly web interface, the project offers a robust, efficient, and scalable solution to a critical medical need. The comprehensive planning and detailed architectural design ensure a solid foundation for development, promising a valuable tool for healthcare professionals and a significant contribution to the field of medical diagnostics.