Capstone Project Concept Note and Implementation Plan

Project Title: Malaria Screener

Team Members – Group 16

1. Abel Mekonn
2. Delina Mulubrhan
3. Zelalem Abera
4. Zelalem Wubet

Project Overview

Malaria continues to pose a significant global health threat, especially in regions with limited access to skilled healthcare professionals. Traditional diagnostic methods, such as manual microscopy, are often time-consuming, labor-intensive, and susceptible to human error. To address these challenges, this project explores the development of an integrated, AI-powered mobile health solution aimed at enhancing the accuracy, efficiency, and accessibility of malaria diagnosis.

The proposed system combines a Flutter-based mobile application for field screening, a Next.js-powered dashboard for real-time monitoring and data visualization, a Django backend for robust data management, and an AI-driven chatbot to support patient interaction and guidance. This comprehensive approach is informed by a thorough review of existing research in AI-based diagnostics, mobile health (mHealth) technologies, and chatbot-assisted healthcare, highlighting current limitations and the need for a more unified, scalable solution.

Project Objectives

The primary aim of this project is to develop an integrated, AI-powered digital health platform to enhance malaria diagnosis and patient support in resource-limited settings. The specific objectives are:

1. **Automate Malaria Detection**
   Develop and integrate AI-based models within a Flutter mobile application to automatically detect malaria parasites in blood smear images, reducing reliance on manual microscopy and minimizing diagnostic errors.

2. **Enable Real-Time Data Access and Monitoring**
   Build a Next.js dashboard for healthcare providers to visualize diagnostic results, monitor patient trends, and manage case data in real time, improving decision-making and response times.

3. **Establish a Robust Backend Infrastructure**
   Implement a Django-based backend to securely store, manage, and retrieve patient records, ensuring data integrity, privacy, and scalability.

4. **Provide Instant Patient Support via Chatbot**
   Design a malaria-specific AI chatbot to assist users with symptom checks, treatment guidance, and general malaria-related queries, enhancing patient engagement and health literacy.

5. **Promote Accessibility and Scalability**
   Ensure the system is cross-platform and optimized for low-resource environments, making it accessible to underserved communities and scalable across regions with high malaria prevalence.

Contribution to Addressing the Problem

This project directly addresses the diagnostic and healthcare delivery challenges associated with malaria by:

- **Improving diagnostic accuracy and speed** through AI automation.
- **Reducing the burden on healthcare workers** by streamlining workflows.
- **Enhancing patient outcomes** through timely diagnosis and support.
- **Supporting global health initiatives**, particularly **SDG 3.3**, which aims to end malaria by 2030.

Background

Malaria remains one of the most pressing public health challenges globally, with the World Health Organization (WHO) reporting hundreds of millions of cases and hundreds of thousands of deaths annually—most of which occur in sub-Saharan Africa. Early and accurate diagnosis is critical for effective treatment and control of the disease. However, in many resource-limited settings, access to skilled microscopists and diagnostic infrastructure is severely constrained.

Current Diagnostic Methods and Limitations

The gold standard for malaria diagnosis is microscopic examination of stained blood smears. While effective when performed by trained professionals, this method is:

- **Time-consuming** and labor-intensive.
- **Highly dependent on human expertise**, leading to variability in results.
- **Inaccessible in rural or under-resourced areas**, where the disease burden is often highest.

Rapid Diagnostic Tests (RDTs) offer an alternative, but they can be expensive, have limited sensitivity for certain malaria species, and still require physical distribution and handling.

Existing Digital and AI-Based Initiatives

Several initiatives have explored the use of digital tools and artificial intelligence to improve malaria diagnosis:

- **AI-powered image recognition** systems have been developed to detect malaria parasites in blood smear images with promising accuracy.
- **Mobile health (mHealth) applications** have been used to collect and transmit health data in remote areas.
- **Chatbots and virtual assistants** have been introduced in healthcare for triage, education, and patient support.

However, these solutions often operate in isolation, lack integration, or are not optimized for low-resource environments.

Why a Machine Learning Approach is Necessary

Machine learning (ML), particularly deep learning, offers a transformative opportunity to automate and enhance malaria diagnosis by:

- **Improving diagnostic accuracy** through pattern recognition in blood smear images.
- **Reducing diagnostic time and human error**, especially in high-volume or emergency settings.
- **Enabling scalable, low-cost deployment** via mobile devices, making it ideal for rural and underserved communities.
- **Supporting continuous learning and improvement**, as models can be updated with new data over time.

By integrating ML with mobile and web technologies, this project aims to deliver a comprehensive, accessible, and intelligent system that not only diagnoses malaria but also supports healthcare providers and patients through real-time data and conversational AI.

Methodology

This project employs a multi-component architecture that integrates machine learning, mobile development, web technologies, and conversational AI to deliver a comprehensive malaria screening and support system. The methodology is structured into four core components:

AI-Powered Malaria Detection

Objective: Automate the detection of malaria parasites in blood smear images.

- **Technique:** Convolutional Neural Networks (CNNs), which are highly effective for image classification and object detection tasks.
- **Model Candidates:**
    - **ResNet-50** or **EfficientNet** for feature extraction and classification.
    - **YOLOv5** or **Faster R-CNN** for object detection if bounding box localization of parasites is required.
- **Training Data:** Publicly available malaria datasets such as the NIH Malaria Dataset, containing labeled images of infected and uninfected cells.
- **Frameworks:**
    - **TensorFlow** or **PyTorch** for model development and training.
    - **OpenCV** for image preprocessing and augmentation.

Mobile Application (Flutter)

Objective: Provide a user-friendly interface for field workers to capture and upload blood smear images.

- **Functionality:**
    - Image capture and upload.
    - Display of diagnostic results.
    - Integration with chatbot for patient interaction.
- **Integration:** The app will send images to the backend for AI inference and receive results in real time.

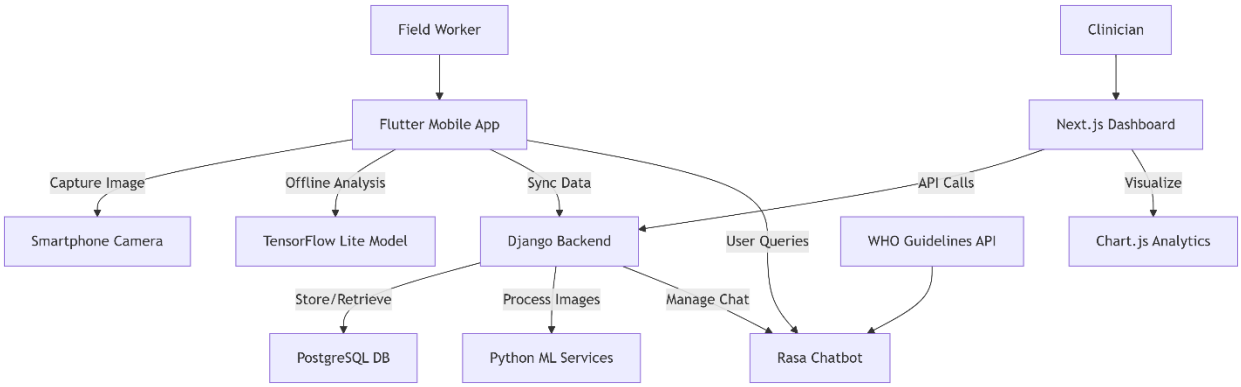
Backend and Dashboard

Objective: Manage data flow, storage, and visualization.

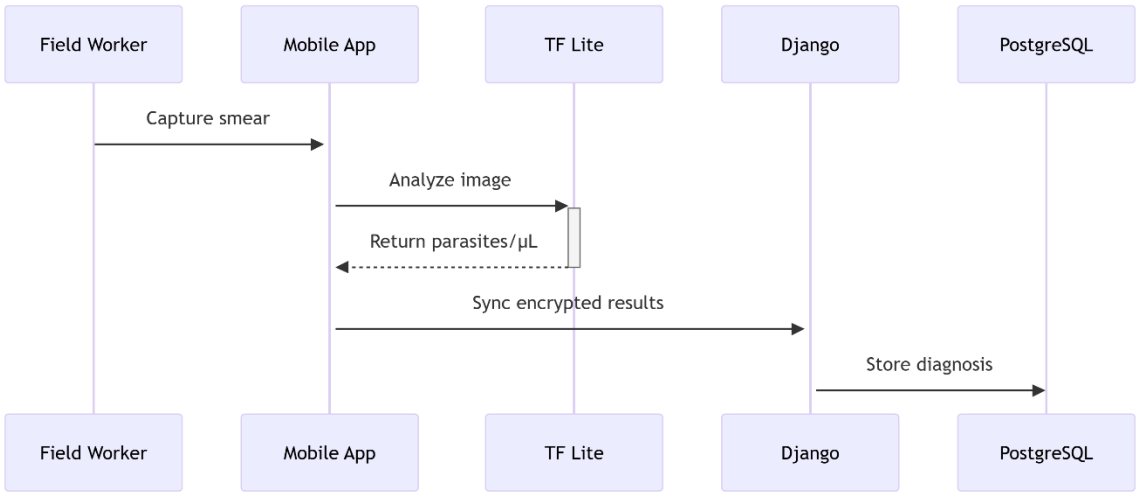
- **Backend (Django):**
    - RESTful API development using Django REST Framework.
    - Secure storage of patient records and diagnostic results.
    - Authentication and role-based access control.
- **Dashboard (Next.js):**
    - Real-time visualization of diagnostic data.
    - Case tracking and reporting tools for healthcare providers.

Architecture Design Diagram

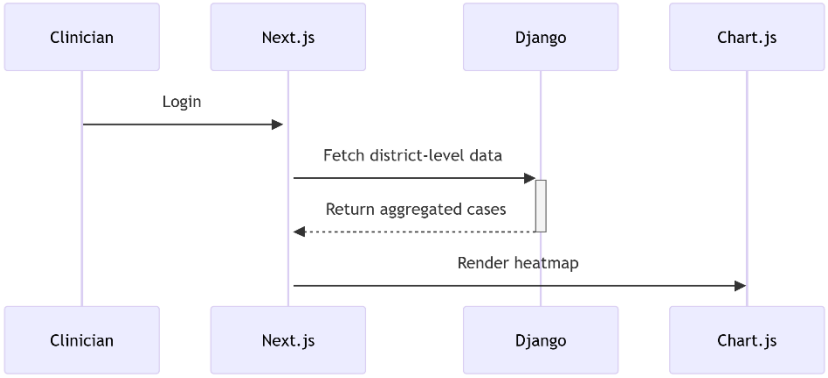
System Architecture: AI-Powered Malaria Diagnosis



Field Workflow



Clinician Workflow



Data Sources

This project will utilize three primary types of data to support its core functionalities. For malaria diagnosis, image data will be sourced from the publicly available NIH Malaria Dataset, which contains thousands of labeled blood smear images in JPEG or PNG format. These images will undergo preprocessing steps such as normalization, augmentation (e.g., rotation, flipping), and segmentation to enhance model robustness and accuracy. For the chatbot component, textual data will be compiled from authoritative sources including WHO malaria treatment guidelines and peer-reviewed medical literature. This data will be structured into frequently asked question (FAQ) pairs and symptom-treatment mappings, then processed through natural language processing (NLP) pipelines involving text cleaning, tokenization, and intent classification. Additionally, patient-related data—such as demographics, diagnostic results, and medical history—will be securely stored in a PostgreSQL database designed for healthcare applications, ensuring data integrity, privacy, and compliance with medical data standards.

Literature Review

Recent advancements in artificial intelligence and mobile health technologies have shown significant promise in improving malaria diagnosis and management. Studies such as Rajaraman et al. (2018) demonstrated the effectiveness of convolutional neural networks (CNNs) in classifying parasitized and uninfected red blood cells with high accuracy using the NIH Malaria Dataset. Other research has explored the integration of AI into mobile platforms, highlighting the potential for real-time, field-deployable diagnostic tools in low-resource settings. Additionally, the use of chatbots in healthcare—such as those developed using Rasa or Dialogflow—has been shown to enhance patient engagement and provide scalable health education. Despite these advances, most existing solutions operate in silos, lacking integration across diagnostic, data management, and patient support systems. This project builds upon these foundations by combining AI-powered image analysis, a cross-platform mobile interface, a centralized backend, and a malaria-specific chatbot into a unified, accessible solution tailored for underserved communities.

Implementation Plan

Technology Stack

1. Programming Languages

- **Python** – For machine learning model development, backend logic, and data processing.
- **Dart** – For building the cross-platform mobile application using Flutter.
- **JavaScript / TypeScript** – For frontend development with Next.js and chatbot integration.

2. Frameworks and Libraries

Machine Learning & Image Processing

- **TensorFlow** or **PyTorch** – For training and deploying AI models.
- **OpenCV** – For image preprocessing (e.g., normalization, segmentation).
- **scikit-learn** – For auxiliary ML tasks like evaluation and preprocessing.

Mobile Development

- **Flutter** – For building a cross-platform mobile app (Android & iOS).

Web Development

- **Next.js** – For building the healthcare provider dashboard (React-based).
- **Django** – For backend development and API management.
- **Django REST Framework** – For building RESTful APIs.

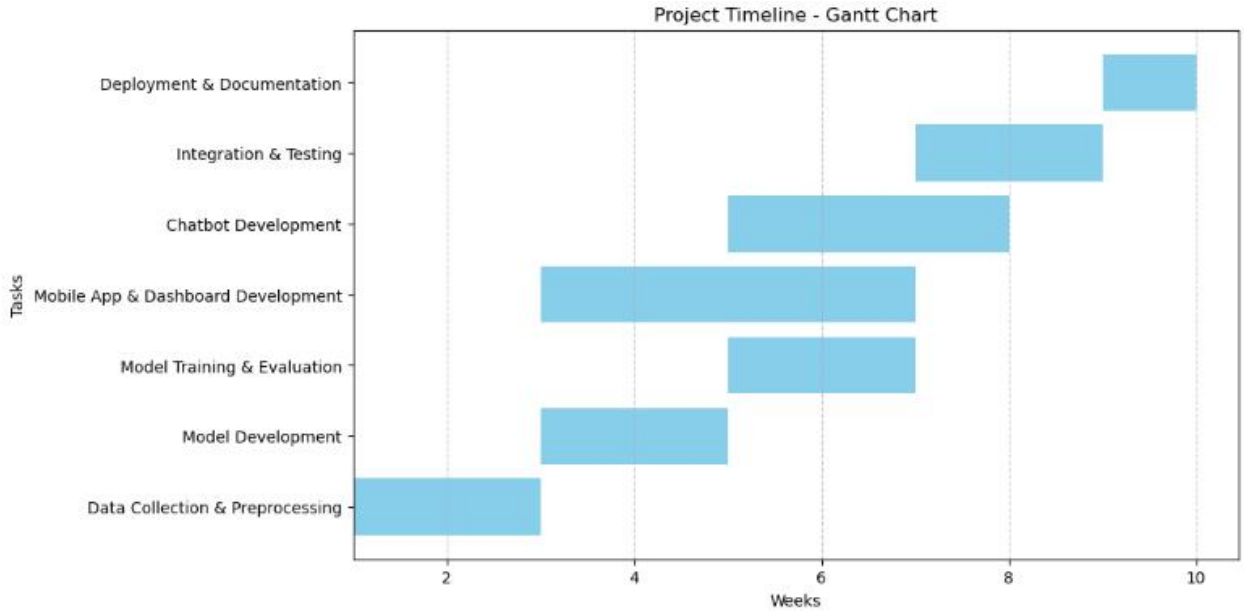
3. Database and Storage

- **PostgreSQL** – For secure storage of patient records and diagnostic data.

4. Hardware

- **Smartphone with Camera** – For capturing blood smear images via the mobile app.

1. **Timeline**



Here's a comprehensive response covering **Milestones**, **Challenges and Mitigations**, and **Ethical Considerations** for your malaria diagnosis and support system project:

3. Milestones

Milestone	**Description**	**Target Week**
Data Acquisition Completed	Collection and preprocessing of image and text datasets	Week 2
AI Model Prototype Ready	Initial CNN model trained on malaria blood smear images	Week 4
Mobile App MVP Developed	Flutter app with image upload and result display	Week 6
Chatbot Functional	Malaria-specific chatbot integrated and responding to queries	Week 7

System Integration Complete	All components (AI, app, dashboard, chatbot) integrated	Week 8
Deployment and Documentation Finalized	System deployed and user documentation completed	Week 9

4. Challenges and Mitigations

Data Quality

- **Challenge:** Inconsistent image quality or mislabeled data can affect model performance.
- **Mitigation:** Apply rigorous preprocessing (normalization, augmentation) and use validated datasets like the NIH Malaria Dataset. Implement manual review of a sample of training data.

Model Performance

- **Challenge:** The model may underperform in real-world conditions due to domain shift.
- **Mitigation:** Use transfer learning with robust architectures (e.g., ResNet, EfficientNet) and validate on diverse datasets. Continuously retrain with new data from field use.

Technical Constraints

- **Challenge:** Limited computational resources in target deployment environments.
- **Mitigation:** Optimize models for mobile inference using TensorFlow Lite or ONNX. Use cloud-based inference for heavier tasks when necessary.

Integration Complexity

- **Challenge:** Ensuring seamless communication between mobile app, backend, dashboard, and chatbot.
- **Mitigation:** Use RESTful APIs with clear documentation and modular architecture to simplify integration and debugging.

5. Ethical Considerations

- **Data Privacy:** Patient data, including medical history and diagnostic results, must be securely stored and transmitted. The system will implement encryption, secure authentication, and comply with healthcare data standards (e.g., HIPAA or GDPR where applicable).

- **Bias and Fairness:** AI models trained on limited or non-representative datasets may exhibit bias. To mitigate this, the training data will include diverse samples, and model performance will be evaluated across different demographic groups.
- **Impact on Communities:** While automation can improve access, it must not replace human oversight. The system is designed to assist, not replace, healthcare professionals. Clear disclaimers and referral mechanisms will be included to ensure users seek professional care when needed.
- **Transparency:** Users will be informed about how their data is used and how AI decisions are made. The chatbot will be transparent about its limitations and avoid giving definitive medical advice.

References

1. Chittagong Medical College Hospital. (2020). *De-identified patient records*. IRB#129
2. Google Health. (2022). *AI for Malaria Diagnosis*. https://ai.google/social-good/health/
3. NIH Malaria Dataset. *National Institutes of Health*. https://lhncbc.nlm.nih.gov/publication/pub9932
4. Palanica et al. (2019). *AI Chatbots in Healthcare: A Systematic Review*. JMIR.
5. Rosado et al. (2017). *Mobile-Based Analysis of Malaria-Infected Blood Smears*. Sensors.
6. TensorFlow Team. (2023). *On-Device ML with TF Lite*. https://www.tensorflow.org/lite
7. WHO. (2021). *Digital Health Interventions*. https://www.who.int/health-topics/digital-health
8. WHO. (2021). *Malaria Treatment Guidelines*, 3rd Edition.
9. Yang et al. (2019). *Deep Learning for Smartphone-Based Malaria Parasite Detection*. IEEE JBHI.
10. Yu et al. (2020). *Malaria Screener: A Smartphone Application for Automated Malaria Screening*. BMC Infectious Diseases.