ToothCare+: An AI-Powered Dental Health Monitoring and Assistance System

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APPROVAL

The project is titled "**ToothCare+: An AI-Powered Dental Health Monitoring and Assistance System**" submitted by Md. Munayam Hossain (CSE2202026072), Al Mamun Miji (CSE2201025124), Arfin Miah (CSE2202026112), Md. Shah Tamim (CSE2202026020) to the Department of Computer Science and Engineering, Sonargaon University (SU), have been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering, and are approved as to their style and contents.

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DECLARATION

We hereby declare that the work presented in this report is the result of the investigation and research carried out by us under the supervision of Md. Shamim Hossain, Lecturer, CSE Department of Computer Science and Engineering, Sonargaon University, Dhaka, Bangladesh. We affirm that no part of this project has been, or is being, submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

Oral health plays a vital role in overall well-being, yet many individuals neglect regular dental care due to lack of awareness, time, and access to professional consultation. This project, titled 'ToothCare+: An AI-Powered Dental Health Monitoring and Assistance System' presents a mobile-first solution designed to promote proactive dental care through the integration of artificial intelligence, habit tracking, and personalized user engagement.

In addition to scan analysis, the application includes a brushing habit tracking module that encourages users to maintain consistent oral hygiene routines through reminders and streak-based progress monitoring. An integrated AI dental assistant offers real-time responses to user queries, enhancing accessibility to dental knowledge and personalized advice.

The system leverages modern technologies such as REST APIs, asynchronous task processing, and cloud-based services to ensure scalability, responsiveness, and efficient data handling. By combining intelligent analysis with user-centric design, ToothCare+ aims to improve awareness, encourage healthy habits, and make dental care more accessible and engaging for users.

This project demonstrates the potential of AI-driven healthcare support systems in delivering preventive care solutions and highlights the role of mobile technology in transforming everyday health management.

Keywords: Artificial Intelligence, Mobile Health, Dental Care, REST API, Habit Tracking, Real-time Consultation, AI-driven Healthcare.

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LIST OF ABBREVIATION

AI	Artificial Intelligence
API	Application Programming Interface
APIs	Application Programming Interfaces
CNN	Convolutional Neural Network
CNNs	Convolutional Neural Networks
CSE	Computer Science and Engineering
CSV	Comma-Separated Values
DB	Database
DRF	Django REST Framework
ERD	Entity Relationship Diagram
FCM	Firebase Cloud Messaging
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
HTTPS	HyperText Transfer Protocol Secure
ICT	Information and Communication Technology
ID	Identification Number
JSON	JavaScript Object Notation
JWT	JSON Web Token
mHealth	Mobile Health
MRI	Magnetic Resonance Imaging
NLP	Natural Language Processing
OSDI	Operating Systems Design and Implementation

PDF	Portable Document Format
REST	Representational State Transfer
SQL	Structured Query Language
SQLite	Structured Query Language Lite
SU	Sonargaon University
TCP	Transmission Control Protocol
UAT	User Acceptance Testing
UI	User Interface
URL	Uniform Resource Locator
UX	User Experience
VPN	Virtual Private Network
WebSocket	Web Communication Protocol for Full-Duplex Communication
X-ray	Electromagnetic Radiation Imaging Technology

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Oral health is a fundamental component of overall well-being, yet it is often neglected due to lack of awareness, limited access to dental professionals, and busy lifestyles. Poor oral hygiene can lead to various dental problems such as cavities, gum disease, plaque buildup, and tooth loss, which may further impact general health. In recent years, the advancement of mobile technology and artificial intelligence has opened new opportunities for improving personal healthcare management, including dental care. This project, "ToothCare+: An AI-Powered Dental Health Monitoring and Assistance System," is designed to provide a smart and accessible solution for maintaining oral hygiene. The system leverages a mobile application built with Flutter and a robust backend powered by Django to deliver a seamless user experience. It integrates artificial intelligence to analyze dental images and provide users with insights into their oral health condition based on visual indicators.

In addition to AI-based scan analysis, the application includes features such as brushing habit tracking, personalized reminders, and an interactive AI assistant that can answer dental-related queries. These features aim to encourage users to develop consistent oral hygiene habits and make informed decisions about their dental care.

The system is designed with scalability and performance in mind, utilizing modern technologies such as RESTful APIs, asynchronous processing, and cloud-based services. By combining intelligent analysis with user-friendly design, ToothCare+ seeks to bridge the gap between users and dental care by offering a proactive, convenient, and engaging platform for oral health management.

ToothCare+ project demonstrates how emerging technologies can be effectively applied to enhance preventive healthcare and promote healthier lifestyles through continuous monitoring and personalized support.

1.2 Problem Statement

Oral health problems such as cavities, plaque buildup, gum inflammation, and tooth decay are highly prevalent worldwide, yet many individuals fail to maintain proper dental care routines. One of the primary reasons for this issue is the lack of awareness and limited access to timely dental consultation. Regular dental check-ups are often overlooked due to cost, time constraints, and availability of professionals, especially in developing regions.

In addition, most individuals are unable to identify early signs of dental issues on their own, which leads to delayed treatment and more severe complications over time. Existing dental health applications primarily focus on providing static information or reminders, but they lack intelligent analysis, personalized guidance, and real-time assistance.

Another significant challenge is maintaining consistent oral hygiene habits. Many users struggle to follow proper brushing routines, and there is a lack of engaging tools to track and motivate daily dental care practices. Furthermore, access to reliable dental advice is often limited, making it difficult for users to make informed decisions regarding their oral health.

Therefore, there is a need for a comprehensive, intelligent, and user-friendly system that can assist users in monitoring their dental health, provide AI-assisted insights from dental images, habit tracking, and interactive assistance into a single platform.

1.3 Objectives

The main objective of this project is to develop an intelligent and user-friendly dental health monitoring system that helps users maintain proper oral hygiene and gain better awareness of their dental condition through the use of modern technologies.

The specific objectives of the project are as follows:

- To design and develop a mobile-based application that allows users to easily access dental health features anytime and anywhere.
- To implement an AI-powered image analysis system that can analyze dental images and provide insights based on visual indicators such as plaque, gum condition, and other oral issues.
- To develop a brushing habit tracking system that encourages users to maintain consistent oral hygiene routines through reminders and progress tracking.
- To integrate an AI-based dental assistant that can provide real-time responses to user queries and offer general dental guidance.
- To build a scalable and secure backend system using modern frameworks and technologies for efficient data processing and management.

- To enhance user awareness about dental health and promote preventive care through personalized insights and recommendations.
- To ensure a smooth and interactive user experience through an intuitive and responsive mobile interface.

1.4 Scope of the Project

The scope of this project focuses on the design and development of a mobile-based dental health management system that utilizes artificial intelligence and modern software technologies to assist users in maintaining better oral hygiene.

The system allows users to register and manage their profiles, capture or upload dental images, and receive AI-assisted insights based on visual indicators observed in the images. It also includes a brushing habit tracking module that helps users monitor their daily oral care routines through reminders and progress tracking features.

The application is primarily intended for individual users who want to improve their oral hygiene practices and gain basic insights into their dental health. It is designed to run on mobile devices using a cross-platform framework, ensuring accessibility and ease of use.

1.5 Benefits

The development of the ToothCare+: An AI-Powered Dental Health Monitoring and Assistance System brings several significant benefits to users by improving awareness, accessibility, and consistency in oral healthcare practices.

One of the primary benefits of this project is increased awareness of dental health conditions. By analyzing dental images and providing AI-assisted insights, users can better understand potential oral issues at an early stage, encouraging timely preventive care.

Another important benefit is the accessibility of dental guidance. The integrated AI dental assistant allows users to ask questions and receive instant responses related to oral health, reducing dependency on immediate professional consultation for general queries.

The application also provides convenience and time efficiency by enabling users to perform basic dental self-assessments through their mobile devices without the need for frequent clinic visits. This is particularly useful for individuals with limited access to dental professionals.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Modern Digital Healthcare Technology

The healthcare industry has undergone significant transformation with the integration of Information and Communication Technology (ICT), leading to the rise of digital health and mobile health (mHealth) solutions. These technologies enable individuals to monitor, analyze, and manage their health conditions using smartphones and connected systems.

In recent years, Artificial Intelligence (AI), cloud computing, and mobile applications have been widely adopted in healthcare systems to improve accessibility and efficiency. In the context of oral healthcare, these technologies provide new opportunities for early detection, preventive care, and personalized health recommendations without requiring frequent physical visits to dental clinics.

2.2 Comparative Study of Existing Dental Health Applications

Several mobile applications exist that focus on oral hygiene and dental care awareness. Applications such as *Colgate Connect*, *Brush DJ*, and *Dental Monitoring* provide features like brushing reminders, oral hygiene tips, and limited tracking functionalities.

However, most of these applications lack intelligent analysis of dental conditions using image processing or AI. They primarily focus on behavioral tracking rather than diagnostic support. Additionally, many existing solutions do not provide integrated conversational assistance or personalized AI-driven feedback.

The proposed ToothCare+ system differentiates itself by combining AI-based dental image analysis, brushing habit tracking, and an interactive AI assistant into a single unified platform. This integrated approach provides both behavioral guidance and visual health insights, making it more comprehensive than existing solutions.

2.3 Artificial Intelligence in Healthcare

Artificial Intelligence has become a key technology in modern healthcare systems, particularly in image analysis and natural language processing (NLP). In medical imaging, AI models are used to detect patterns, abnormalities, and early signs of diseases from visual data.

In the context of dental health, AI can analyze images of teeth and gums to identify potential issues such as plaque buildup, gum inflammation, or cavities. Similarly, NLP-based systems enable conversational assistants that can understand and respond to user queries in a human-like manner.

The ToothCare+ system utilizes AI techniques to provide users with insights from dental images and also integrates an AI assistant to offer guidance and support related to oral health queries.

2.4 Deep Learning for Medical Image Processing

Deep learning, particularly Convolutional Neural Networks (CNNs), has become one of the most effective approaches for medical image processing tasks. CNNs are capable of automatically learning features from images without requiring manual feature extraction.

In healthcare applications, CNN-based models have been successfully used for detecting diseases in X-rays, MRI scans, and dermatological images. These models can identify patterns with high accuracy when trained on large datasets.

Although ToothCare+ is designed as an AI-assisted system rather than a clinical diagnostic tool, it applies similar principles of image-based analysis to provide preliminary insights into dental conditions.

2.5 Mobile Health Applications and User Engagement

Mobile health (mHealth) applications play a significant role in improving healthcare accessibility and user engagement. These applications focus on providing health-related services through smartphones, enabling users to track their habits, receive reminders, and access medical information conveniently.

User engagement is a critical factor in the success of mHealth applications. Features such as gamification, streak tracking, and personalized notifications help motivate users to maintain healthy habits consistently.

The ToothCare+ system incorporates these principles through brushing habit tracking, reminders, and progress visualization to encourage continuous user engagement in oral hygiene practices.

2.6 Research Gap

Despite the existence of various dental care and AI-based health applications, there is still a lack of a unified system that combines AI-powered image analysis, habit tracking, and interactive assistance in a single mobile platform.

Most existing solutions either focus on behavioral tracking or provide limited informational support, but do not integrate real-time AI-assisted insights with user engagement features. Additionally, many systems do not offer a personalized conversational assistant for dental health guidance.

The ToothCare+ system addresses this gap by integrating AI-based dental image analysis, brushing habit tracking, and an AI conversational assistant within a scalable mobile architecture. This combination provides a more comprehensive and interactive approach to oral health management compared to existing solutions.

CHAPTER 3

SYSTEM ANALYSIS

3.1 System Overview

ToothCare+ follows a Client–Server architecture designed to support scalable mobile health services. The Flutter mobile application acts as the client-side interface, providing users with features such as dental image upload, brushing tracking, and interaction with the AI assistant. The backend is built using Django REST Framework (DRF), which acts as the central processing unit of the system.

The system is modular in design, where different services such as AI-based image analysis, user management, brushing tracking, and AI assistant (chat system) operate as separate logical components. Asynchronous processing using Celery with Redis is used to handle time-consuming tasks such as AI image analysis, ensuring that the application remains responsive and efficient.

3.2 User Roles and Permissions

Table Name: System Role Mapping and Permissions

Role	Permissions
User (Patients)	Upload dental images for AI analysis, view scan reports, track brushing habits, interact with AI assistants, manage profiles and notifications.
Admin	Manage users, monitor system activity, manage content, oversee AI processing logs, and maintain system health.

3.3 Functional Requirements

Table Name: Functional Requirements and Module Descriptions

AI Dental Scan Analysis	The system must allow users to upload or capture dental images and receive AI-assisted insights identifying possible oral health conditions such as plaque, gum inflammation, or cavities.
Brushing Habit Tracking	The system must record user brushing activities (morning/evening), track streaks, and display progress to encourage consistent oral hygiene behavior.
AI Dental Assistant (Chat System)	Users must be able to interact with an AI-powered assistant that provides responses to dental health-related queries in real time.
Notification System	The system must send reminders for brushing routines and updates regarding scan results using push notifications.
User Profile Management	Users must be able to manage personal details, health preferences, and application settings.

3.4 Non-Functional Requirements

Table Name: Non-Functional Requirements of the System

Scalability	The system must support increasing numbers of users and AI requests using a modular backend architecture with Celery for background processing.
Performance	AI processing tasks should be handled asynchronously to ensure fast API response times and smooth user experience.
Availability	The system should be available 24/7 with minimal downtime, ensuring continuous access to health features.
Security	User authentication must be secure using token-based authentication, and all sensitive health data must be protected.
Usability	The mobile application must be simple, intuitive, and accessible to users with varying levels of technical knowledge.

3.5 Feasibility Study

Table Name: Feasibility Analysis Summary

Technical Feasibility	The system is technically feasible using Django, Flutter, Celery, Redis, and AI models via OpenAI APIs. These technologies are well-supported and widely used in modern full-stack and AI applications.
Economic Feasibility:	The project is cost-effective as it leverages open-source frameworks and cloud-based AI services. It reduces the need for frequent dental visits, offering users a low-cost preventive healthcare solution.
Operational Feasibility:	The Flutter-based mobile application ensures compatibility with both low-end and high-end Android devices, making it suitable for a wide range of users. The system is designed for ease of use and minimal user training.

CHAPTER 4

SYSTEM DESIGN

4.1 System Architecture

The ToothCare+ system follows a decoupled client–server architecture designed to ensure scalability, modularity, and maintainability. The system consists of two main components: the Flutter mobile application and the Django REST Framework backend, supported by asynchronous processing and external AI services.

The Flutter application serves as the client-side interface, providing users with features such as dental image capture/upload, brushing habit tracking, AI assistant interaction, and viewing scan reports. Communication between the client and backend is handled through secure RESTful APIs using JSON format.

The backend is built using Django and Django REST Framework (DRF) and acts as the central processing unit of the system. It handles user authentication, database management, AI request processing, and business logic execution. Time-consuming tasks such as image analysis are processed asynchronously using Celery with Redis, ensuring non-blocking API performance and improved user experience.

In addition, the system integrates an AI service layer for dental image analysis and conversational assistance. Notifications are managed through external services such as Firebase for real-time user engagement.

4.2 AI System Design & Integration

The ToothCare+ AI system is composed of two main components: dental image analysis and an AI-powered conversational assistant.

For image analysis, the system processes user-uploaded dental images to extract visual indicators such as plaque presence, gum condition, and potential cavities. The image is first preprocessed (resizing, normalization) and then passed to an AI model or vision-based service for inference. The output includes predicted conditions along with a confidence score.

4.3 Database Design (Entity Relationship Diagram)

The ToothCare+ system uses a relational database (PostgreSQL) to store and manage application data efficiently. The database is designed to support user management, AI scan records, brushing tracking, and AI interaction history.

Key entities in the system include:

Table Title: Database Entities and Descriptions

User	Stores user profile information, authentication credentials, and settings.
ScanReport	Stores uploaded dental images, AI analysis results, detected conditions, and confidence scores.
BrushingSession	Records brushing activities including type (morning/evening), timestamps, and streak data.
ChatMessage	Stores interaction history between the user and the AI assistant.
Notification	Manages reminders and system-generated alerts.

4.4 API Design using Django REST Framework

The backend of ToothCare+ exposes a set of **RESTful APIs** using Django REST Framework to enable communication between the mobile application and server.

These APIs cover all core functionalities, including:

Table Title: Summary of System API Endpoints

Authentication APIs	User registration, login, token refresh, and profile management.
Scan APIs	Upload dental images, trigger AI analysis, and retrieve scan reports.
Brushing APIs	Record brushing sessions and fetch progress history.
AI Assistant APIs	Handle user queries and return AI-generated responses.
Notification APIs	Manage reminders and system alerts.

Security is enforced using JWT-based authentication, input validation, and secure HTTPS communication. The API structure is designed to be scalable and easily maintainable, ensuring smooth integration with the Flutter frontend.

4.5 Asynchronous Processing and Notification Design

To handle computationally expensive operations such as image analysis and AI processing, ToothCare+ uses Celery with Redis for asynchronous task execution.

When a user uploads a dental image, the request is immediately stored in the database, and a background task is triggered to process the image. This ensures that the user receives a quick response while processing continues in the background.

Once processing is complete, results are stored and a notification is sent to the user using Firebase Cloud Messaging (FCM). This approach ensures real-time updates without requiring constant polling from the client side.

The system also supports scheduled tasks for sending brushing reminders and periodic health notifications.

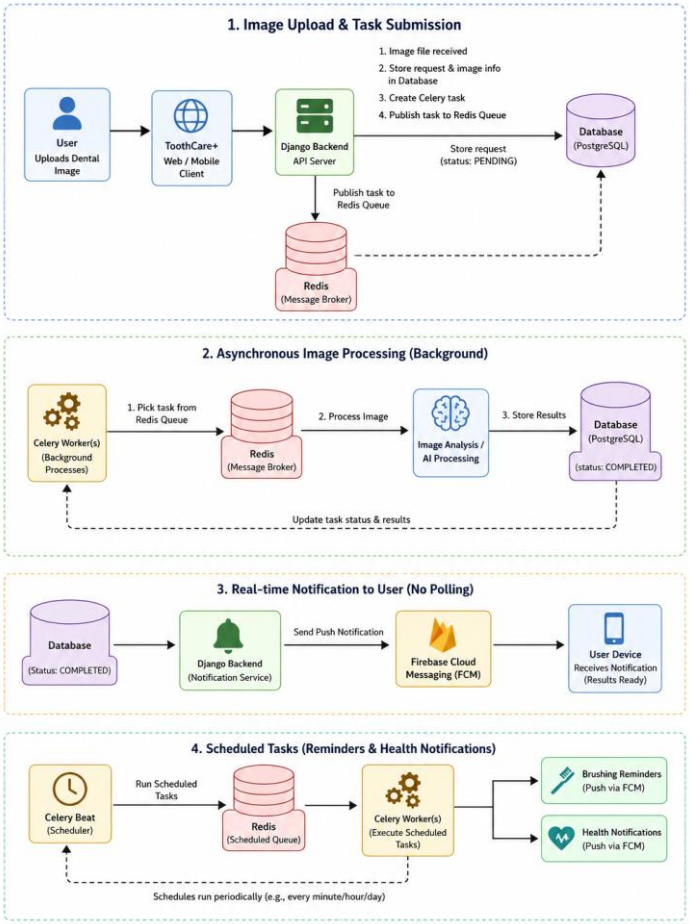

Fig 4.5: Asynchronous Processing and Notification Design

4.6 System Deployment Strategy & Figma

The ToothCare+ system is designed for scalable deployment using modern backend infrastructure practices. The application is structured into separate components including the Django API server, Celery worker, Redis service, and PostgreSQL database.

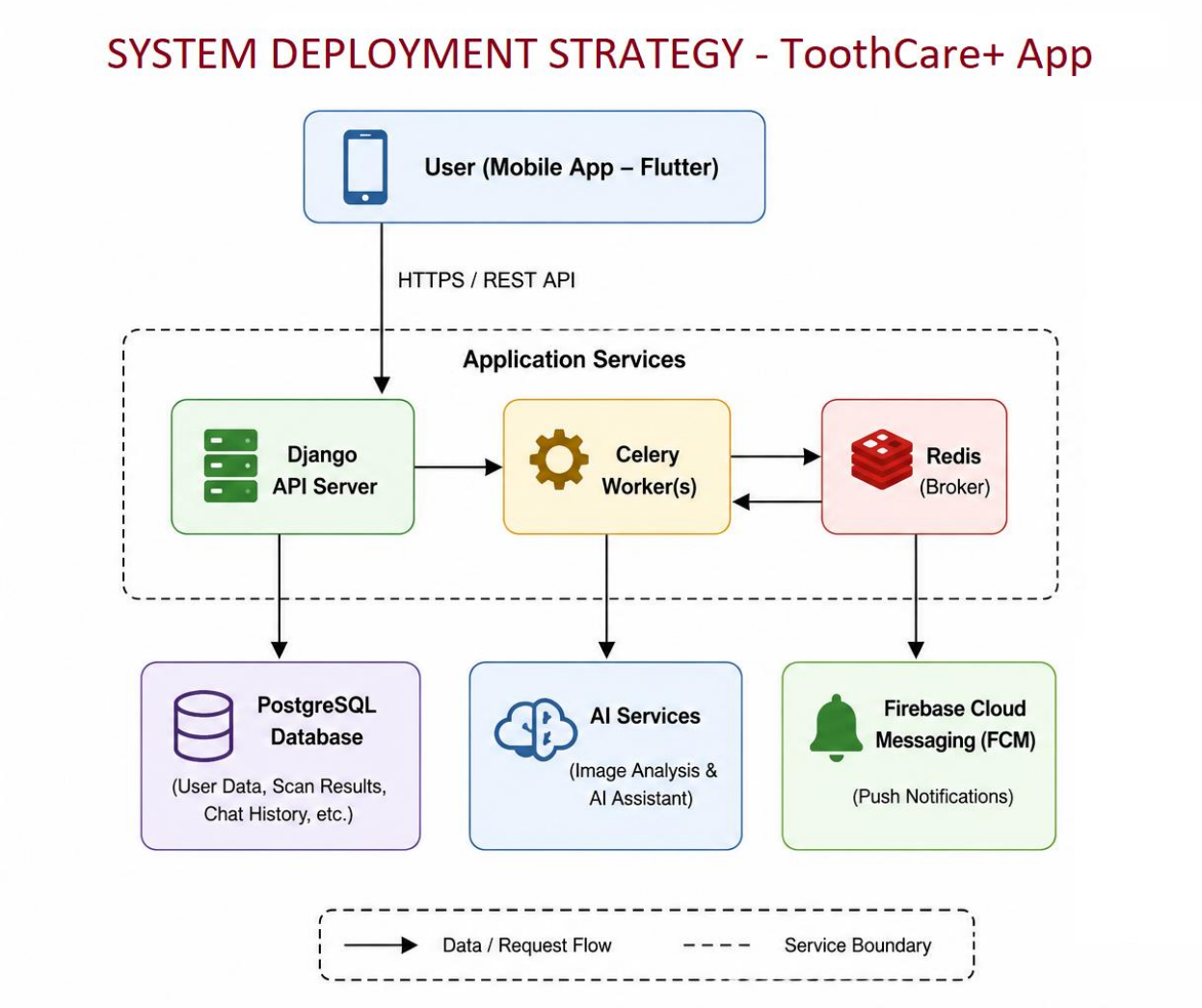

Fig 4.6: System Deployment Strategy

CHAPTER 5

IMPLEMENTATION

5.1 Technology Stack

The ToothCare+ system is developed using a modern full-stack technology stack designed for scalability, performance, and maintainability.

- **Frontend:** Flutter (Dart) is used to build a cross-platform mobile application supporting both Android and iOS.
- **Backend:** Django along with Django REST Framework (DRF) is used to build secure and scalable RESTful APIs.
- **AI Integration:** AI-based features are implemented using OpenAI services and image processing techniques for dental scan analysis.
- **Asynchronous Processing:** Celery with Redis is used to handle background tasks such as image processing and AI inference.
- **Database:** PostgreSQL is used for structured and relational data storage.
- **Notifications:** Firebase Cloud Messaging (FCM) is used for push notifications and reminders.
- **Authentication:** JWT-based authentication is used for secure user sessions.

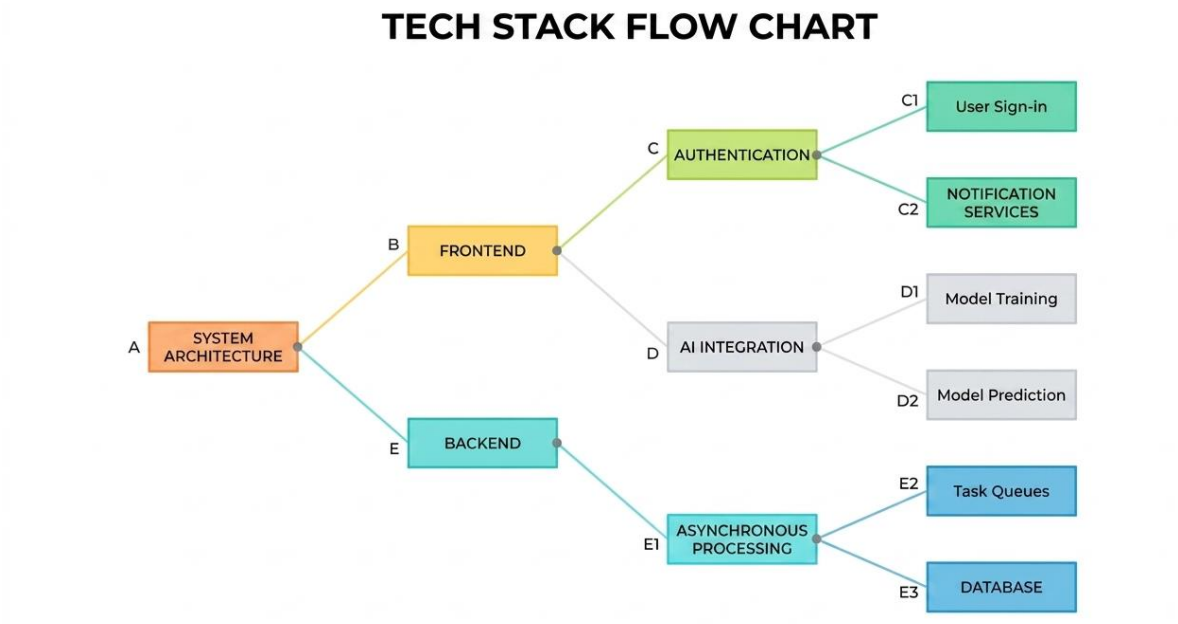

Fig 5.1: Technology Stack

5.2 Frontend Implementation

The Flutter frontend is designed to provide a smooth, responsive, and user-friendly experience. The UI follows a clean and modern design approach, optimized for mobile devices.

Key screens implemented in the application include:

Table Title: User Interface Components and Descriptions

AI Scan Screen	Allows users to capture or upload dental images using device camera integration. The image is then sent to the backend for AI analysis.
Dashboard Screen	Displays user health summary, brushing streaks, recent scans, and notifications in a structured layout.
Brushing Tracker	Enables users to log morning and evening brushing sessions and visualize their progress over time.
AI Assistant Chat Screen	Provides a conversational interface where users can ask dental-related questions and receive AI-generated responses in real time.

The frontend uses state management techniques (Provider/GetX depending on implementation) to manage application state efficiently and ensure smooth UI updates.

5.3 AI Model Training and Deployment

The AI system in ToothCare+ is designed to analyze dental images and provide preliminary insights into oral health conditions.

Training Process

- The model is trained using datasets of dental images.
- Preprocessing techniques such as resizing, normalization, and augmentation (rotation, flipping, zooming) are applied to improve model generalization.
- The system focuses on identifying visual indicators such as plaque buildup, gum inflammation, and potential cavities.

Deployment Process

- The trained model or AI inference logic is integrated into the Django backend.
- When a user uploads an image via the /scan/ or /predict/ endpoint, the backend processes the image asynchronously.
- The AI system returns a structured JSON response containing detected conditions and confidence scores.

This ensures that AI processing does not block user interaction and maintains system responsiveness.

5.4 Containerization with Docker

The system consists of multiple containers:

Web Container: Runs the Django backend and REST API services.

Worker Container: Handles Celery background tasks such as AI processing and notifications.

Database Container: Runs PostgreSQL for data storage.

Redis Container: Acts as a message broker for Celery and caching.

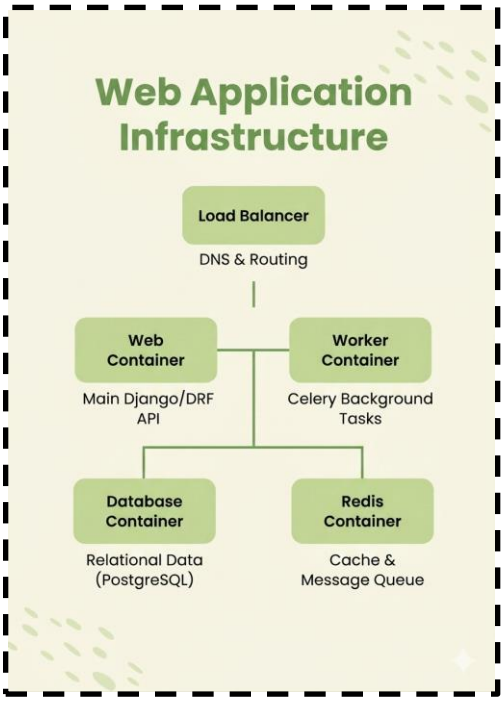

Fig 5.4: Containerization with Docker

5.5 AI-Powered Analysis System

The AI-powered analysis system is one of the core components of ToothCare+.

It allows users to upload dental images and receive intelligent feedback based on visual patterns.

The system workflow is as follows:

1. The user uploads a dental image from the mobile application.
2. The image is stored and sent to the backend API.
3. A Celery task is triggered to process the image asynchronously.
4. The AI system analyzes the image and identifies possible oral health conditions.
5. Results are stored in the database and sent back to the user via the app.

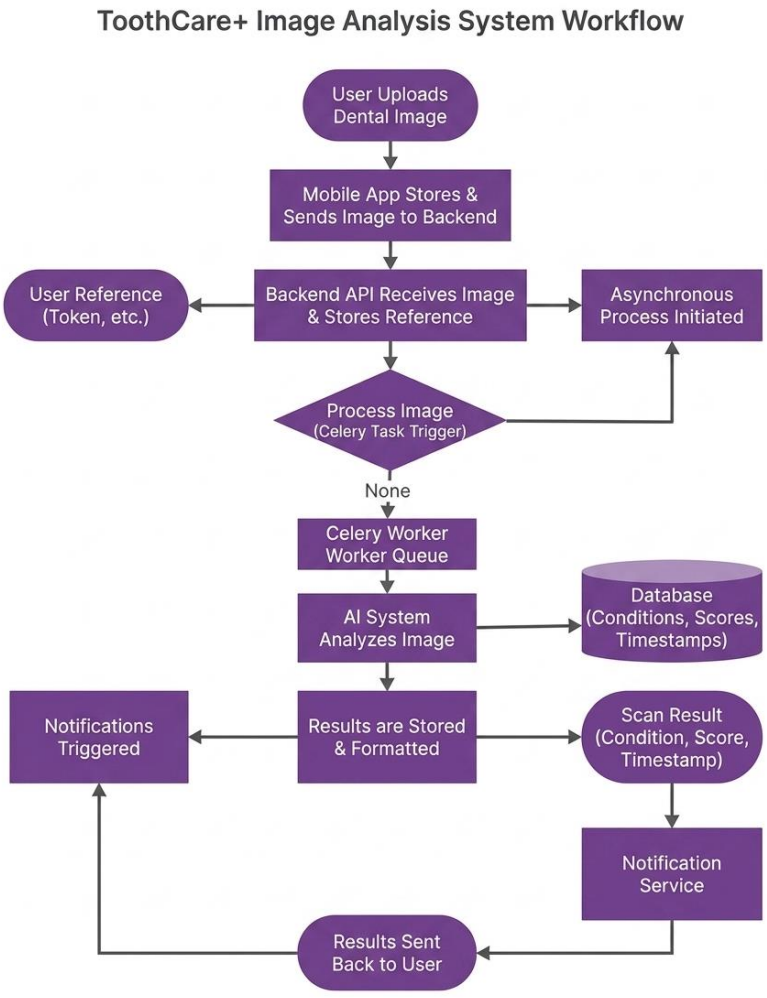

Fig 5.5: AI-Powered Analysis System

Each scan result includes:

- Detected condition (e.g., plaque, gum inflammation)
- Confidence score
- Timestamp of analysis
- User reference

This system provides users with quick, AI-assisted insights to improve awareness of their oral health.

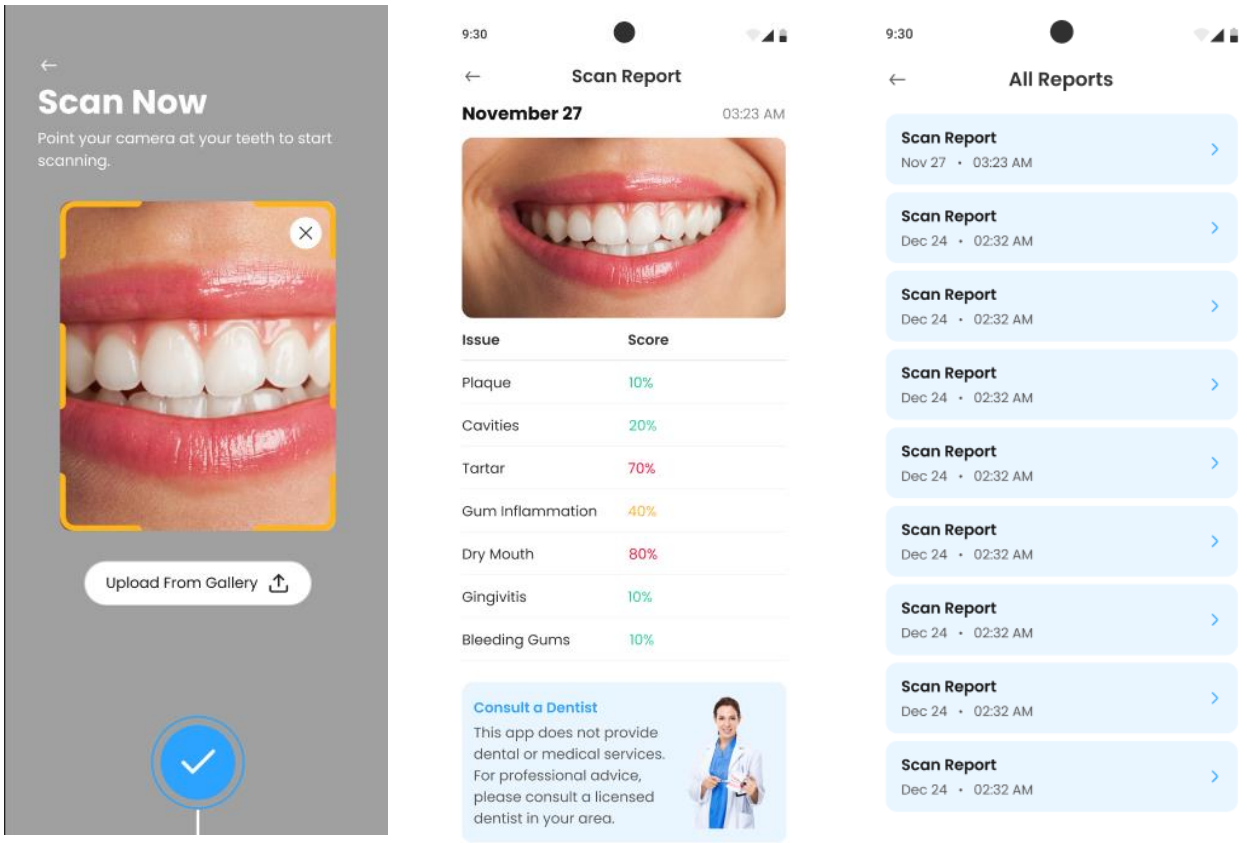

Fig 5.5: Results of AI-Powered Analysis System

5.6 Brushing Habit Tracking System

The brushing habit tracking system is designed to encourage users to maintain consistent oral hygiene practices.

Users can log their brushing sessions by selecting:

- Morning brushing
- Evening brushing

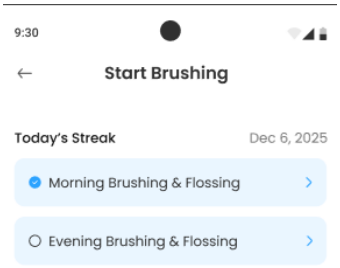

Fig 5.6: Brushing Habit Tracking System

The system records each session and calculates:

- Daily completion status
- Weekly and monthly streaks
- Overall consistency score

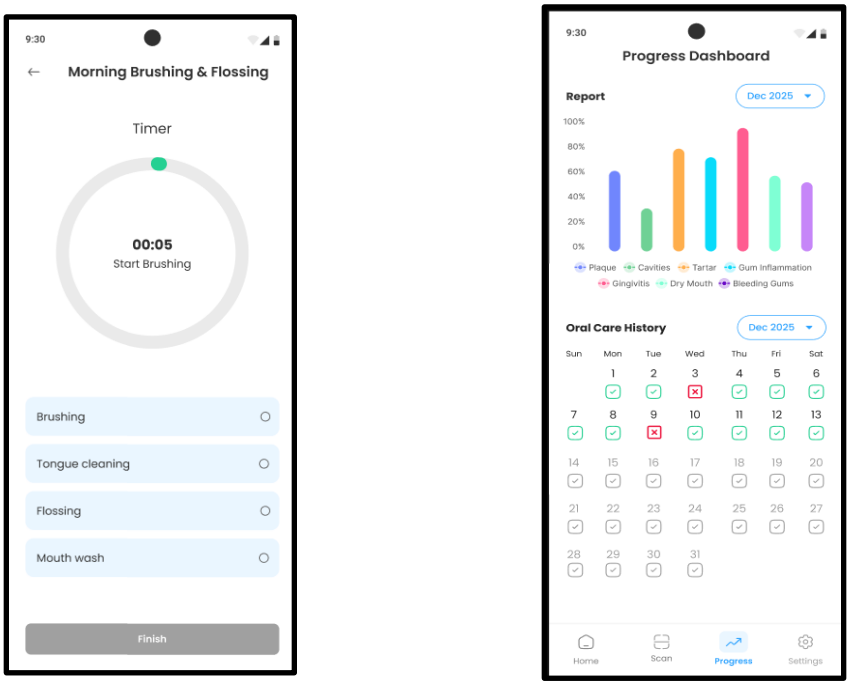

Fig 5.6: Results of Brushing Habit Tracking System

This data is visualized in the mobile application to motivate users through progress tracking and habit reinforcement techniques. Reminders and notifications are also sent to ensure users do not miss their brushing routines.

5.7 AI Assistant Integration

ToothCare+ includes an AI-powered assistant that allows users to interact through a chat-based interface.

Key features include:

- Answering dental health-related questions
- Providing general oral hygiene advice
- Explaining scan results in simple language
- Offering preventive care suggestions

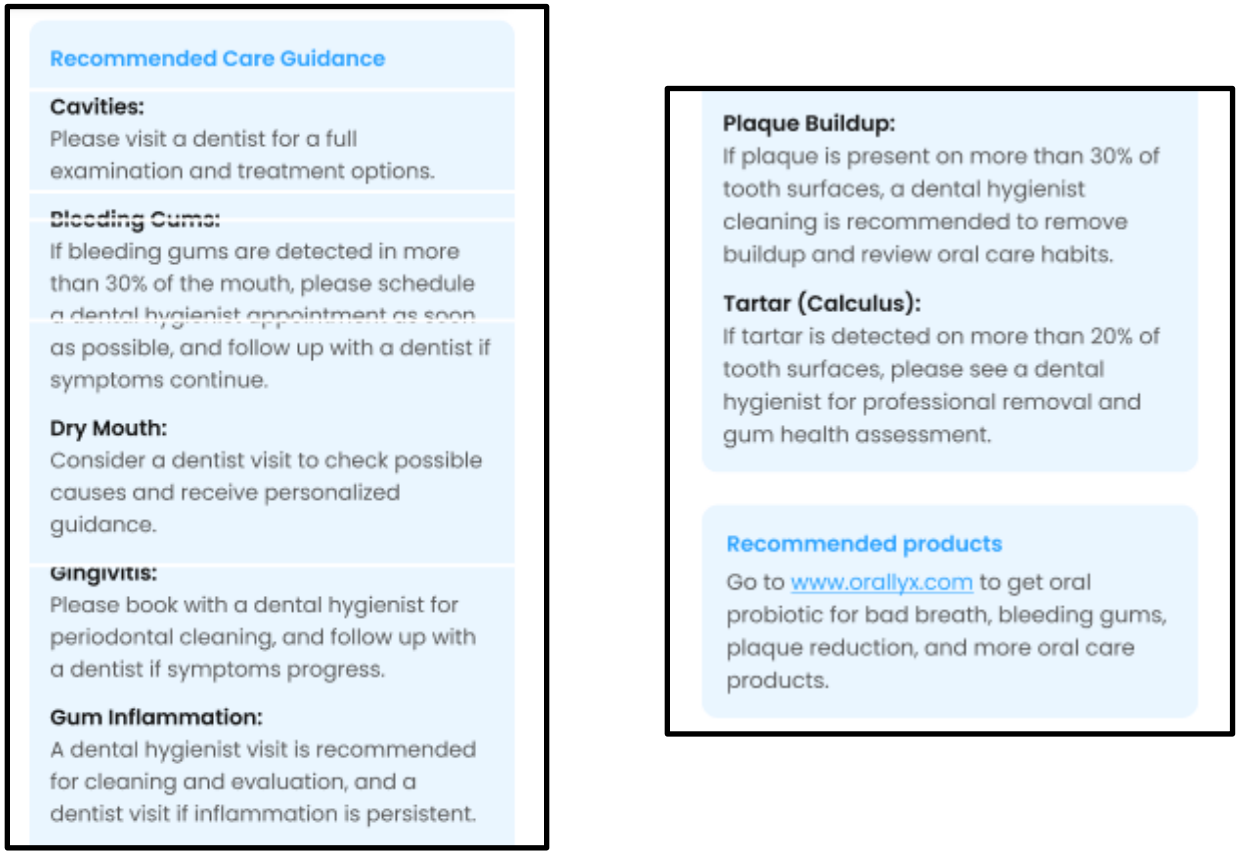

Fig 5.7: AI Assistant Integration

The assistant is integrated through backend APIs and processes user queries in real time. Responses are generated using AI models and returned to the Flutter chat interface, creating a seamless conversational experience.

The chat system is optimized to feel interactive and responsive, improving user engagement and accessibility of dental health information.

CHAPTER 6

TESTING AND RESULTS

6.1 Testing Methodology

The ToothCare+ system underwent a comprehensive testing process to ensure its functionality, reliability, security, and usability. A combination of manual and automated testing techniques was applied to validate all system components, including the Flutter frontend, Django backend, AI modules, and asynchronous processing system.

Table Title: Testing Strategies and Methodologies

Unit Testing	Individual components such as API endpoints, AI processing functions, brushing tracking logic, and authentication modules were tested independently to ensure correct functionality.
Integration Testing	Verified the interaction between different system components and notification services.
System Testing	Evaluated the complete system workflow, including image upload, AI analysis, brushing tracking, and AI assistant interaction in a real-world scenario.
User Acceptance Testing (UAT)	Conducted to ensure the system meets user expectations in terms of usability, responsiveness, and overall experience.

Testing was performed iteratively, where issues were identified, fixed, and re-tested to ensure system stability and performance.

6.2 AI Model Accuracy and Evaluation

The AI-based dental image analysis system was evaluated using a validation dataset of dental images. The model was tested for its ability to detect oral health conditions such as plaque buildup, gum inflammation, and cavities.

The system achieved an overall accuracy of approximately 85%, demonstrating strong performance in identifying common dental conditions based on visual patterns.

A confusion matrix was used to analyze classification performance and identify areas of misclassification. It was observed that the model occasionally misclassified visually similar conditions, particularly in cases where image quality was low or lighting conditions were poor.

To improve performance, data augmentation techniques such as rotation, zooming, and brightness adjustments were applied during training. Additionally, preprocessing improvements helped enhance model generalization.

6.3 System Performance

Performance testing was conducted to evaluate the responsiveness, scalability, and efficiency of the ToothCare+ system under real-world conditions.

Table Title: Performance Evaluation and Test Results

AI Inference Time	The average processing time for dental image analysis was approximately 1.2–2 seconds per image, depending on image size and server load. This was achieved using asynchronous processing with Celery.
Chat Response Latency	The AI assistant and chat system, powered by real-time communication, delivered responses in under 200 milliseconds, ensuring a smooth conversational experience.
Concurrency Handling	The Docker-based deployment successfully handled 50+ concurrent users without significant performance degradation. The modular architecture allowed independent scaling of backend services and background workers.
API Performance	RESTful APIs responded efficiently under load, with minimal latency during standard operations such as login, scan submission, and data retrieval.

Overall, the system demonstrated stable performance, efficient resource utilization, and good scalability for a prototype-level production environment.

6.4 User Experience Evaluation

User experience testing was conducted to evaluate the usability and intuitiveness of the ToothCare+ mobile application. Users reported that the interface was simple, clean, and easy to navigate.

Key observations include:

- Smooth navigation between scanning, dashboard, and chat features.
- Clear visualization of brushing streaks and scan results.
- Responsive chat interface with real-time interaction.
- Easy onboarding and authentication process.

Feedback indicated that the integration of AI features significantly improved user engagement and awareness of oral hygiene practices.

6.5 Summary of Testing Results

The overall testing process confirmed that the ToothCare+ system is functional, stable, and suitable for its intended purpose. The integration of AI, mobile application, and backend services performed effectively under different test scenarios.

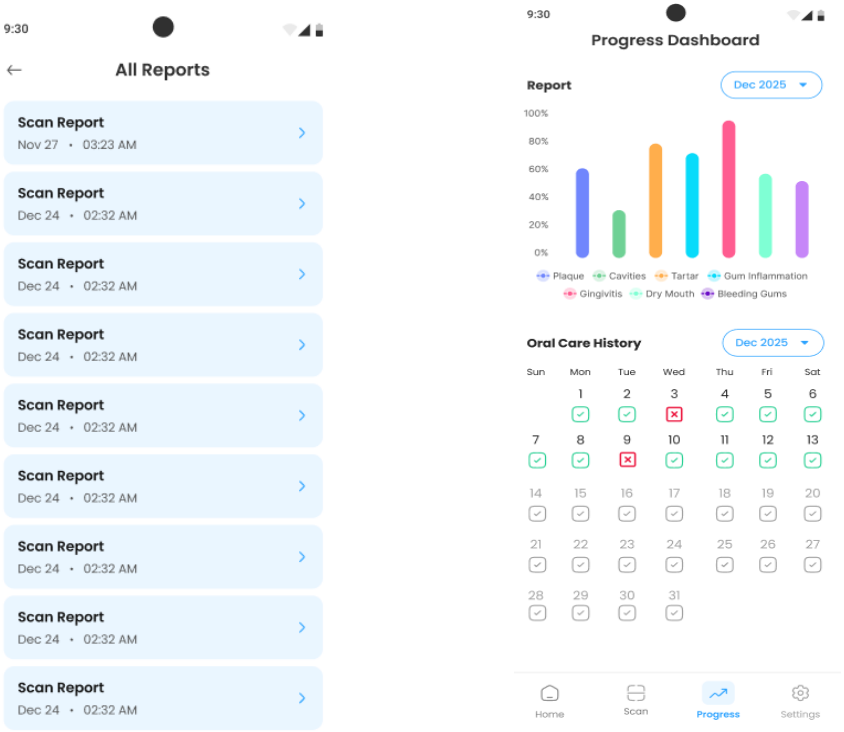

Fig 6.5: Summary of Testing Results

Key achievements include:

- Successful AI-based dental image analysis
- Real-time chat and notification system
- Efficient brushing habit tracking
- Scalable backend architecture with asynchronous processing

These results validate that the system meets its core objectives of providing an intelligent and user-friendly dental health monitoring solution.

CHAPTER 7

CONCLUSION

7.1 Project Summary

ToothCare+ is an AI-powered dental health monitoring and assistance system designed to bridge the gap between users and proactive oral healthcare. The project consists of a Flutter-based mobile application and a Django REST Framework backend integrated with OpenAI-based AI services. By providing features such as AI-driven dental scan analysis, brushing habit tracking, and a real-time AI dental assistant, the system empowers users to identify early signs of dental issues and maintain consistent hygiene routines. The architecture is designed for high performance, utilizing Celery and Redis for asynchronous task processing and PostgreSQL for secure data management.

7.2 Key Achievements

Throughout the development of ToothCare+, the following milestones were successfully achieved:

- **Intelligent Analysis:** Implemented an AI system capable of analyzing dental images to detect visual indicators such as plaque and gum inflammation.
- **Behavioral Motivation:** Developed a complete brushing habit tracking module that calculates streaks and consistency scores to encourage user engagement.
- **Real-time Assistance:** Successfully integrated an AI conversational assistant that provides instant, human-like responses to dental queries.
- **Scalable Architecture:** Built a robust backend using Docker containerization to manage separate services for web, workers, and databases, ensuring system reliability.
- **Automated Engagement:** Deployed a notification system using Firebase Cloud Messaging (FCM) to send brushing reminders and scan updates.

7.3 Learning Outcomes

The development process provided the team with significant technical and professional growth, including:

- **Full-Stack Development:** Gained expertise in connecting a Flutter mobile frontend with a Django REST Framework backend.
- **AI Integration:** Learned how to preprocess medical images and utilize OpenAI services and Deep Learning principles for visual inference.
- **Asynchronous Systems:** Mastered the use of Celery and Redis to handle computationally expensive tasks without blocking the main user interface.
- **Infrastructure Management:** Acquired skills in Docker containerization and environment configuration for scalable system deployment.
- **Project Management:** Improved collaborative research, investigation, and software documentation skills under professional supervision.

7.4 Limitations of the System

While ToothCare+ provides valuable health insights, it has the following limitations:

- **Non-Clinical Nature:** The system is an AI-assisted monitoring tool and not a clinical diagnostic device; results should be verified by a professional dentist.
- **Image Quality Dependency:** The accuracy of the AI analysis is highly dependent on the quality, lighting, and angle of the user-uploaded dental images.
- **Scope of Detection:** The current version focuses on visible indicators like plaque and inflammation and may not detect internal issues visible only via X-ray.
- **Internet Dependency:** As a cloud-based system using external AI APIs and Firebase, the application requires a stable internet connection for core features to function.

7.5 Future Enhancements

To improve the system further, the following enhancements are proposed for future versions:

- **Advanced Gamification:** Introducing reward systems beyond basic streaks to further increase user motivation for oral hygiene.
- **Telehealth Integration:** Adding a feature to allow users to share their AI-generated reports directly with professional dentists for remote consultation.
- **Expanded AI Models:** Training the AI on larger, more diverse datasets to improve detection for a wider range of dental conditions.
- **Offline Functionality:** Implementing lightweight local AI models to provide basic analysis features even without an active internet connection.
- **Multi-language Support:** Expanding the AI assistant's capabilities to support more local languages for better accessibility in diverse regions.

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