Department of Software Engineering

FAST – National University of Computer & Emerging Sciences
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1. Introduction

Oncology treatment planning is crucial for modern cancer care, yet traditional Clinical Decision Support Systems (CDSS) often fall short due to their rigid, rule-based nature. DoctorPath AI addresses these limitations by combining structured and unstructured data from MIMIC-III V1.4 records with the reasoning power of large language models (LLMs) and graph-enhanced retrieval mechanisms. This system generates personalized, guideline-aligned treatment recommendations, enhancing the efficiency and effectiveness of oncology decision support.

2. Vision Document

This section outlines the problem statement, business opportunities, research problem, objectives, and scope of the DoctorPath AI project, providing a high-level overview of its goals and impact.

2.1. Problem Statement:

Table 1 Problem Statement for DoctorPath AI

Category	Description
Problem	• Existing clinical decision support tools for oncology are rigid and fail to integrate multimodal data such as EHRs, imaging, and pathology reports. • General-purpose LLMs lack domain-specific biomedical training, limiting their usefulness in oncology. • Manual data integration is slow, error-prone, and unscalable. • Absence of patient-specific modeling reduces personalization in treatment planning. • Lack of dynamic updates to reflect latest clinical guidelines.
Affects	• Oncologists experience cognitive overload due to fragmented information and manual synthesis of data. • Treatment delays occur due to inefficient workflows. • Variability in clinical decision-making leads to inconsistent care quality. • Healthcare institutions struggle to maintain standardized oncology protocols.
Impact	• Higher rates of misdiagnosis and treatment delays reduce survival outcomes. • Increased operational costs due to inefficiency and specialist dependency. • Reduced trust in clinical decision-making systems. • Missed opportunities for research-driven, data-backed treatment improvements.
Solution	DoctorPath AI offers an advanced clinical decision support platform that: • Ingests and processes both structured and unstructured oncology data using automated pipelines. • Builds dynamic, patient-specific knowledge graphs linking disease, treatment, and biomarker relationships. • Leverages biomedical LLMs fine-tuned for oncology, ensuring domain relevance. • Uses Retrieval-Augmented Generation (RAG) to align treatment recommendations with the latest guidelines. • Provides interactive dashboards and downloadable treatment plans for clinicians. • Collects expert feedback for continuous learning and model refinement. • Improves treatment accuracy and enhances standardization in oncology care.

2.2. Opportunities and Research Challenges

This section covers the business opportunities and research challenges of the DoctorPath AI project, emphasizing market value and technical hurdles.

2.2.1 Business Opportunities

DoctorPath AI addresses a critical global health challenge and presents substantial business opportunities across multiple healthcare sectors:

- **Hospital & Cancer Center Value**: Enhances treatment standardization, reduces diagnostic errors, and improves patient outcomes while lowering malpractice risks and increasing operational efficiency.
- **Academic & Research Use**: Supports clinical research, treatment outcome analysis, and integration into oncology training programs.
- **Global Reach**: Scalable design enables deployment in underserved regions through telemedicine and remote oncology support.
- **Cost & Workflow Efficiency**: Automates treatment planning to reduce oncologist workload, minimize unnecessary procedures, and cut healthcare costs.

2.2.2 Research Problem Statement

Traditional Clinical Decision Support Systems (CDSS) are limited by rule-based reasoning and lack the capacity to generalize from real-world treatment histories. There is an unmet need for an AI-driven framework capable of integrating structured EHR data, imaging biomarkers, and unstructured clinical narratives to learn from prior patient outcomes and inform future treatment planning. DoctorPath AI addresses this by creating a continuously learning, interpretable CDSS trained on real-world oncology data to personalize and optimize treatment recommendations for lung and liver cancers.

Research Problem:

How can an AI-based CDSS leverage multimodal patient data including structured EHR (MIMIC-III V1.4), imaging (TCIA, LiTS), and text reports to generate personalized, explainable, and evidence-aligned treatment recommendations for lung and liver cancer patients?

2.3 Objectives

Following are the objectives of DoctorPath AI:

- Develop data ingestion pipelines to extract and normalize oncology data from MIMIC-III V1.4 datasets (structured EHRs and unstructured clinical narratives).
- Construct patient-specific knowledge graphs integrating patient attributes, disease characteristics, treatments, and NCCN/WHO/ESMO guidelines.
- Fine-tune biomedical LLMs on oncology guidelines, clinical trials, and medical literature for cancer-specific treatment recommendation generation.
- Implement RAG mechanisms to retrieve relevant clinical guidelines ensuring evidence-based, up-to-date recommendations.
- Generate personalized treatment recommendations considering cancer type, stage,

biomarkers, comorbidities, and treatment history.

- Establish feedback loops incorporating expert oncologist evaluations for continuous model refinement.
- Validate recommendations for clinical feasibility, contraindications, and real-world workflow integration.
- Evaluate system performance using automated metrics (BLEU, ROUGE, HealthBench) and structured expert assessments.
- Reduce oncologist workload by automating multimodal data synthesis and guideline integration.
- Minimize diagnostic errors and treatment delays through rapid, accurate recommendation generation.
- Standardize oncology treatment pathways while maintaining patient-specific personalization.

2.4 Scope

The scope of DoctorPath AI includes developing an AI-powered clinical decision support system for oncology treatment planning. The system will extract and consolidate cancer patient data from MIMIC-III V1.4 datasets using ICD-9/ICD-10 codes, construct knowledge graphs modeling patient-disease-treatment relationships, fine-tune biomedical LLMs with RAG mechanisms for guideline-aligned recommendations, develop a web-based dashboard for patient profile review and AI recommendation generation, implement validation using automated metrics and expert feedback, enable treatment plan export in multiple formats, and provide real-time performance monitoring for system evaluation.

2.5 Constraints

The following constraints apply to DoctorPath AI:

- System requires institutional SSO authentication. Deployment limited to healthcare institutions with existing identity management infrastructure. Independent practices without SSO infrastructure are out of scope for initial release.
- The system provides clinical decision support recommendations only and cannot replace oncologist judgment or authorize treatments independently, requiring oncologists to review and validate all AI-generated recommendations before clinical implementation.

2.6 Stakeholder and User Description

This section provides an overview of the key stakeholders and users involved in the DoctorPath AI project, including their roles and responsibilities.

2.6.1 Market Demographics

DoctorPath AI target users are medical researchers, oncologists, statisticians, and academic organizations conducting clinical studies. The system is especially valuable for users dealing with MIMIC-III V1.4 or similar healthcare databases, which need disease-based extraction and analysis of data.

2.6.2 User Environment

DoctorPath AI operates in hospital oncology departments and cancer treatment centers where oncologists access the system through desktop or laptop computers connected to institutional networks. Users interact via modern web browsers during clinical workflows in outpatient clinics, tumor board meetings, or research offices. The system integrates with hospital infrastructure through SSO authentication and HL7 HTML interfaces for EHR connectivity. Users work with MIMIC-III V1.4 datasets requiring stable internet connectivity for guideline retrieval and LLM inference. The environment assumes basic familiarity with oncology terminology and web-based clinical tools, with minimal technical training required.

2.6.3 Stakeholder Profiles

This section outlines the roles, responsibilities, and contributions of key stakeholders in the DoctorPath AI project.

2.6.3.1 Supervisor Team

Table 2 Supervisor Team

Attribute	Details
Representatives	Mr. Ali Raza (Supervisor)
Description	They have the task of managing the academic and technology development of the project.
Type	Technical sponsors with AI research and medical data processing expertise.
Responsibility	1. Give guidance to the development team 2. Complete the system within the specified time period 3. Ensure that system results satisfy study goals 4. Follow up and give feedback 5. Be able to conform with project documentation and ethical guidelines.
Success Criteria	The completion of core deliverables, including the cancer persona dataset and supporting documentation.
Involvement	1. Requirement reviewer 2. Technical guidance 3. Academic supervision
Comments/Issues	None

2.6.3.2 Research and Development Team

Table 3 Research and Development Team

Attribute	Details
Representatives	Muhammad Hamza, Muhammad Abdul Hanan, Imama Kainat
Description	They are involved in the research and development of the project.
Type	Technical stakeholders (developers, requirement engineers, data engineers)
Responsibility	1. Fully engaged in research and development

	2. Specify technical requirements 3. Implement data pipelines and cancer persona extraction 4. Deliver all committed features on time.
Success Criteria	Successful integration of patient demographics, diagnoses, labs, prescriptions, and notes into a unified cancer dataset.
Involvement	Research, development, and documentation of the system.
Comments/Issues	None

2.6.3.3 End Users

Table 4 End Users

Attribute	Details
Representatives	End Users (Oncologists, Patients Medical Researchers, Data Scientists)
Description	They are the project's end users who will use it for their specific purposes.
Type	External stakeholders
Responsibility	Utilize the cancer persona dataset for oncology research and predictive modeling.
Involvement	Minimal (primarily dataset usage, not development).
Comments/Issues	None

2.6.3.4 Stakeholder Summary

Table 5 Stakeholder Summary

Name	Description	Responsibility
Development Team	Students developing DoctorPath AI.	Build, test, and deliver the system.
Supervisor Team	Faculty advisors	Provide guidance, validate outcomes, ensure academic quality.
End User	They are the project's end users and will use it for their own reasons.	Use the application for making treatment plans.

3.System Requirements Specification

This section defines the functional and non-functional requirements for the DoctorPath AI system, detailing its features, performance, security, and user interface specifications.

3.1 System Features

DoctorPath AI offers a range of critical features, including:

- **User Authentication & History**: Ensures secure login and maintains session history for doctors.
- **Doctor-AI Conversational Interface**: Allows doctors to interact with the chatbot, share patient information, and get AI responses.

- **AI Processing & RAG Engine**: Med-Gamma fine-tuned model + MIMIC-III V1.4 data to extract insights, generate notes, and recommend treatment paths.
- **Dynamic Graph Visualization**: Displays decision trees where each node represents a possible treatment or diagnosis.
- **Treatment Plan Recommender**: Shows full treatment plan upon clicking an "ideal" node.
- **Export & Download Module**: Enables downloading treatment plans as structured PDFs.
- **Knowledge Base Integration**: Connects to medical datasets (MIMIC-III V1.4 , X-rays, PubMed) for RAG-based reasoning.

3.2 Functional Requirements

The system must fulfill specific functional requirements, including:

Table 6 Functional Requirements for DoctorPath AI

Req. ID	Requirement Name	Description
FR-1	**User Authentication & Session Management**	• The system shall allow doctors to register, log in, and log out securely. • The system shall support password recovery and two-factor authentication (optional). • Each user shall have an isolated workspace where all patient cases are private.
FR-2	**Patient Case Creation**	• The system shall allow the doctor to create a new patient case and enter details. • Upon submission, the system shall extract key information (diagnosis, test results, history).
FR-3	**AI-Powered Information Extraction**	The system shall automatically extract relevant medical entities such as: • Patient demographics • Diagnosis and stage • Comorbidities and medical history • Lab results and biomarkers • Imaging or pathology findings (if provided) The system shall summarize these findings for doctor verification before proceeding.

FR-4	**Evidence Retrieval (RAG Engine)**	• Once a patient case is accessible to the doctor, upon the doctor's command, the system shall retrieve relevant evidence from medical databases. • Retrieved evidence shall include: o Guidelines (NCCN, ESMO, WHO) o Research studies or clinical trials o MIMIC-III V1.4 -derived treatment patterns (de-identified data) • The system shall prioritize evidence-based recommendations.
FR-5	**Treatment Recommendation Generation**	Based on the patient profile and retrieved evidence, the AI shall: • Generate multiple candidate treatment options (2-6 recommended paths). • Provide for each: o Treatment name o Type (Chemotherapy, Immunotherapy, Surgery, etc.) o Rationale o Contraindications o Required tests before initiation o Expected outcomes o Confidence score The system shall clearly mark one path as "Ideal/Recommended" based on evidence strength and patient suitability.
FR-6	**Decision Graph Visualization**	The system shall display a dynamic, interactive decision graph with: • Nodes representing treatments, diagnoses, biomarkers, and evidence links. • Edges showing relationships (e.g., "Applicable for", "Requires biomarker X", "Contraindicated with"). • The ideal node shall be visually distinguished (e.g., highlighted in green or gold). • The graph shall support clicking a node to view the complete treatment plan.
FR-7	**Detailed Treatment Plan View**	When a doctor clicks on a treatment node, the system shall open a detailed plan view, including: • Medication names, dosages (if available) • Administration schedule • Pre-treatment requirements • Monitoring steps and possible side effects • References to supporting studies or guidelines.

FR-8	**Treatment Plan Download**	• The doctor shall be able to download any treatment plan (AI or edited) in PDF format. • The downloaded file shall include: Patient summary Chosen treatment path Supporting rationale and evidence Date/time and doctor name Disclaimer that it is an AI-assisted recommendation.
FR-9	**History & Case Management**	The system shall maintain a case history dashboard: • Showing all cases created by the user • Search and filter options (by diagnosis, date, or stage) The doctor can reopen past cases and view the previous graph and plans.

3.3 Non-Functional Requirements

Table 7 Non-Functional Requirements for DoctorPath AI

Req. ID	Requirement Name	Description
NFR-1	**User-Friendly Interface**	• The system shall comply with WCAG 2.1 Level AA accessibility standards and achieve a task completion rate of ≥85% in usability testing (n ≥ 15 oncologists). • The web interface shall follow a clean, minimal design (dashboard-style) with clear medical terminology and meaningful labels for buttons, icons, and forms. • Accessibility standards (contrast, text size, colorblind-friendly palette) will be maintained for better readability in hospital environments.
NFR-2	**Data Security**	• The system shall implement encryption protocols (e.g., AES-256) for all sensitive data both at rest and in transit. • Role-based access control (RBAC) shall restrict access to patient data, ensuring only authorized doctors can access patient cases. • The system shall adhere to HIPAA regulations, implementing auditing to track and ensure compliance with privacy standards.

NFR-3	**Performance**	• The system will be optimized to ensure fast model inference and efficient data processing. • Resource utilization (CPU, GPU, and memory) will be monitored to maintain smooth execution. • The model's accuracy and response time will be evaluated to achieve high overall system performance.
NFR-4	**Privacy**	• The system shall support **role-based access control (RBAC)** to restrict access to patient data based on user roles. • **Multi-factor authentication (MFA)** shall be implemented for all user logins to ensure secure access. • User privacy shall be protected by restricting data visibility and maintaining **secure access controls**.
NFR-5	**Compatibility**	• The system shall be compatible with **Windows 10/11**, **macOS**, and **Android** operating systems. • The system shall support **major web browsers**, including **Chrome**, **Firefox**, and **Safari**, ensuring consistent performance across these platforms. • The application shall perform smoothly on **different operating systems and hardware configurations**. .
NFR-6	**Reliability**	• The system shall handle missing, inconsistent, or corrupt data with fallback mechanisms for recovery, ensuring continuous operation without crashes. • Error logging and monitoring mechanisms shall be implemented to ensure stable performance under various load conditions.
NFR-7	**Maintainability**	• The system shall follow coding standards as per **PEP8 for Python]**. • The system shall have **90% unit test coverage** for all **modular components**, ensuring quick debugging and enhancement. • System documentation shall be updated with each release to ensure easy updates and maintenance.

4: Literature Review

This section reviews recent research on AI-driven clinical decision-making in oncology, highlighting key advancements and their relevance to the DoctorPath AI system.

4.1 Research Item #1 – Development and Validation of an Autonomous AI Agent for Clinical Decision-Making in Oncology

Source: Ferber et al. (2025), *Nature Cancer*

4.1.1 Summary

Ferber et al. developed an autonomous AI agent that combines GPT-4 with medical-specific tools (ViT, MedSAM, OncoKB, PubMed) to interpret multimodal oncology cases including CT/MRI images, histopathology, genomics, and clinical narratives. Validated on gastrointestinal cancers, the system achieved high accuracy in diagnostic reasoning and guideline citation, proving that LLMs enhanced by domain tools outperform generic language models.

4.1.2 Critical Analysis

Strengths

- Demonstrates tool-augmented LLM reasoning with >85 % diagnostic accuracy.
- Integrates imaging, genomic, and textual data MIMIC-III V1.4 king real clinical reasoning.
- Validated by oncologists, providing practical credibility.

Weaknesses

- Only 20 validation cases limit statistical generality.
- High computational cost.
- Focused on gastrointestinal oncology, not lung or liver.

4.1.3 Relation to DoctorPath AI

Ferber's framework forms DoctorPath AI's **architectural base**. DoctorPath extends it from diagnosis to treatment planning by:

- Integrating MIMIC-III V1.4 -IV EHR data for temporal reasoning.
- Adding lung and liver cancer-specific modules.
- Employing knowledge graphs and RAG mechanisms for dynamic evidence retrieval. This alignment provides a validated blueprint for DoctorPath's multimodal decision engine.

4.2 Research Item #2 – Leveraging Medical Knowledge Graphs into Large Language Models (DR.KNOWS)

Source: Gao et al. (2025), *JMIR AI*

4.2.1 Summary

DR.KNOWS integrates the UMLS ontology into LLMs through Retrieval-Augmented Generation (RAG). It extracts medical entities from EHR text, retrieves relevant UMLS subgraphs, and augments LLM prompts for semantically grounded predictions. Validation on MIMIC-III V1.4 -III shows marked accuracy gains and reduced hallucinations.

4.2.2 Critical Analysis

Strengths: ontology-grounded reasoning, transparency, and MIMIC-III V1.4 validation.
Weaknesses: diagnosis-centric, static graph structure, and no multimodal inputs.

4.2.3 Relation to DoctorPath AI

DoctorPath AI adopts DR.KNOWS's graph-augmented architecture as its **semantic reasoning core**, linking patient entities to guideline evidence. DoctorPath adds dynamic updates (from NCCN and PubMed), treatment-specific relationships, and multimodal nodes (genes, imaging, labs). This ensures evidence-based, explainable treatment recommendations.

4.3 Research Item #3 – Multimodal Deep Learning Approaches for Precision Oncology

Source: Yang et al. (2025), *Briefings in Bioinformatics*

4.3.1 Summary

A survey of 651 studies on multimodal deep learning (MDL) in oncology classified fusion strategies into early, intermediate, and late fusion. Results show consistent performance gains when combining EHR, genomic, and imaging data. Vision Transformers and Graph Neural Networks emerged as dominant architectures.

4.3.2 Critical Analysis

Strengths: Comprehensive taxonomy; proves multimodal fusion superiority; applicable to lung and liver cancers.
Weaknesses: Review paper (no new methods) and limited focus on treatment generation.

4.3.3 Relation to DoctorPath AI

DoctorPath implements **late fusion** for robustness and **attention mechanisms** for dynamic modality weighting. This architecture supports the integration of clinical notes, EHR, and imaging data into DoctorPath's treatment scoring and recommendation modules.

4.4 Research Item #4 – AI-Based Biomarkers for Treatment Decisions

Source: Ligero et al. (2025), *Trends in Cancer*

4.4.1 Summary

Ligero et al. argue that AI-derived biomarkers from routine data (imaging, EHR, pathology) can replace costly molecular tests in predicting therapy response. They showcase applications in lung and liver cancer for immunotherapy and systemic therapy selection.

4.4.2 Critical Analysis

Strengths: Direct treatment-decision focus; cost-effective approach; validates LLMs for EHR mining.
Weaknesses: Perspective paper with limited quantitative validation and bias mitigation discussion.

4.4.3 Relation to DoctorPath AI

DoctorPath uses these findings to derive AI biomarkers from MIMIC-III V1.4 data predicting therapy eligibility and tolerance. The system computes dynamic biomarkers and shows their impact via explainable visualizations within its decision graph.

4.5 Research Item #5 – Reasoning-Enhanced Healthcare Predictions with Knowledge Graph Community Retrieval (KARE)

Source: KARE Research Team (2024), *ICLR 2025*

4.5.1 Summary

KARE improves RAG by retrieving entire knowledge graph communities rather than single entities. Tested on MIMIC-III V1.4 -III/IV, it yielded 10–15 % accuracy gains for prediction tasks through context-rich retrieval of medical concept clusters.

4.5.2 Critical Analysis

Strengths: MIMIC-III V1.4 -validated; significant performance improvement; interpretability via community visualization.
Weaknesses: Focused on prediction (not prescription) and requires domain adaptation for oncology.

4.5.3 Relation to DoctorPath AI

DoctorPath adopts KARE's **community-level retrieval** to fetch treatment pathway clusters (e.g., chemotherapy or targeted-therapy communities). The approach enhances DoctorPath's RAG engine, boosting contextual accuracy and guideline alignment for treatment generation.

Table 8 Comparative Summary of Key Research

Paper	Year	Venue	Core Focus	Key Techniques	Dataset	Main Contribution	Link to DoctorPath AI
Ferber et al.	2025	*Nature Cancer*	Autonomous AI agent for oncology decision-making	GPT-4 + ViT + MedSAM	20 GI cancer cases	Demonstrated tool-augmented multimodal reasoning and high diagnostic accuracy	Foundation for DoctorPath's autonomous reasoning engine
Gao et al. (DR.KNOWS)	2025	*JMIR AI*	Knowledge graph + LLM integration	RAG with UMLS ontology	MIMIC-III V1.4 - III	Reduced hallucinations through ontology-grounded reasoning	Semantic reasoning core for DoctorPath's knowledge graph module
Yang et al.	2025	*Briefings in Bioinformatics*	Multimodal fusion in precision oncology	Late fusion + ViT + GNN	651 studies (review)	Showed multimodal fusion consistently outperforms unimodal models	Fusion architecture blueprint for DoctorPath's data integration
Ligero et al.	2025	*Trends in Cancer (Cell Press)*	AI biomarkers for therapy and treatment decisions	LLM + radiomics + EHR analysis	Clinical datasets	Introduced cost-effective AI biomarkers for therapy stratificati	Supports DoctorPath's biomarker and treatment scoring modules

						on	
Jiang et al. (KARE Team)	2024	*ICLR 2025 / arXiv Preprint 2410.04585*	Community-based RAG retrieval for healthcare	Hierarchical graph communities + multi-source KG	MIMIC-III V1.4 -III / MIMIC-III V1.4 -IV	Achieved ≈ 12 % accuracy gain via context-rich retrieval	Enhances DoctorPath's RAG engine and evidence retrieval pipeline

4.6 Comparative Insights

Collectively, these studies validate DoctorPath AI's hybrid architecture. Ferber and Yang prove multimodal fusion efficacy; Gao and KARE provide knowledge graph reasoning methods; Ligero bridges AI outputs with clinical utility. DoctorPath unites all five threads into a single oncology platform for personalized treatment recommendation.

4.7 Research Gap Analysis

Table 9 Research Gap Analysis: Existing Work vs. DoctorPath AI

Gap Category	**Limitation in Existing Work**	**DoctorPath AI Advancement**
Treatment Planning Depth	Most systems stop at diagnosis or prognosis.	End-to-end therapy selection and contraindication checking.
Oncology Specialization	Generic AI frameworks.	Dedicated lung and liver cancer pipelines.
Dynamic Knowledge Updates	Static graphs and tools.	Automated guideline and literature refresh.
Fusion + Graph Integration	Addressed separately in literature.	Unified fusion + KG architecture.
MIMIC-III V1.4 Oncology Focus	General ICU patients only.	Oncology-specific MIMIC-III V1.4 -IV cohort.

Explainability	Limited interpretability in deep fusion.	Interactive decision graph visualization.
Validation Scale	Small sample or retrospective.	Multi-phase expert evaluation and temporal splits.

4.8 Conclusion

The review demonstrates that recent AI advances collectively support DoctorPath AI's design philosophy. Ferber et al. proved autonomous multimodal agents; Gao and KARE introduced knowledge graph-based reasoning; Yang validated fusion architectures; and Ligero highlighted AI biomarkers for treatment decisions. DoctorPath AI synthesizes these concepts into a deployable oncology platform capable of learning from MIMIC-III V1.4 trajectories to recommend safe, personalized, and evidence-aligned therapies. Its multi-layer validation strategy, combining automated accuracy tests, guideline concordance, and expert review positions DoctorPath AI as a cutting-edge clinical decision support system for lung and liver cancer care.

Use Case Diagram

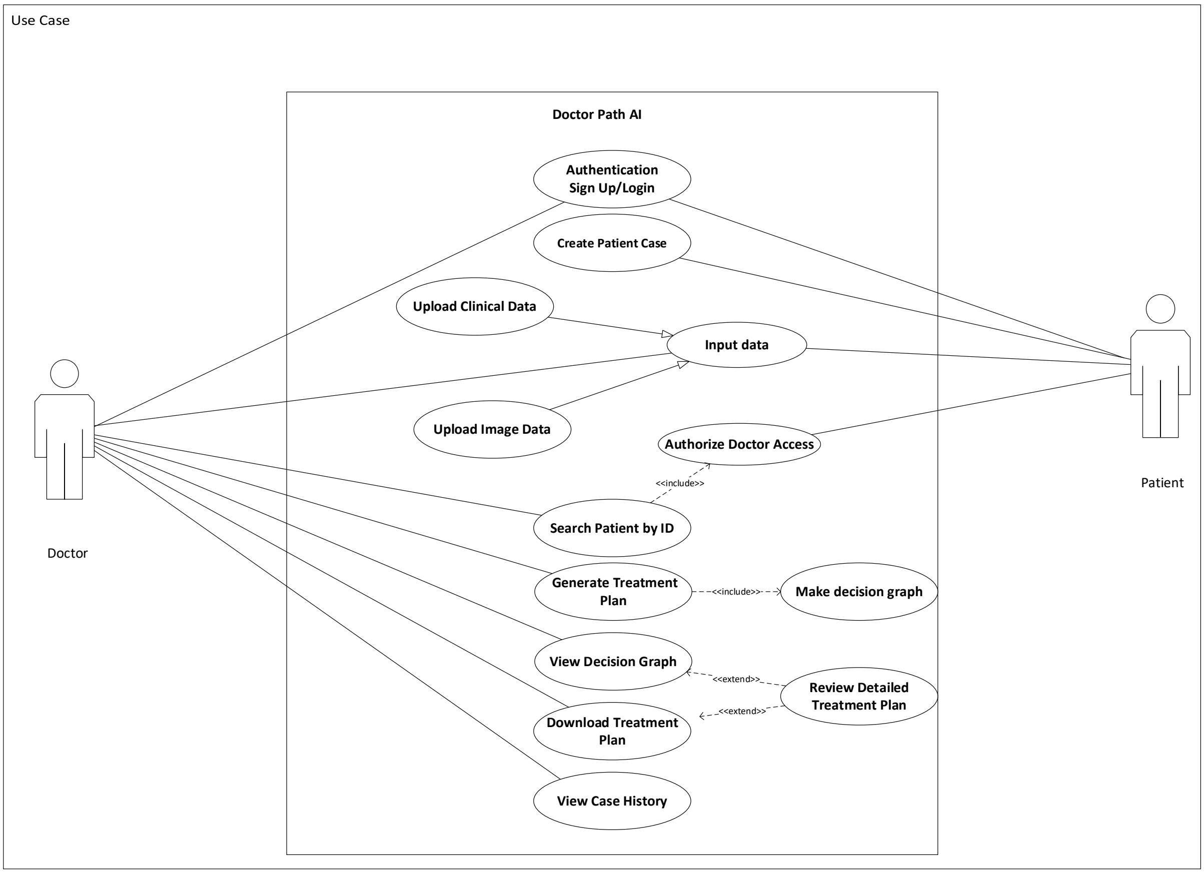

Figure 1 Use Case Diagram of DoctorPath AI

Expanded Use Cases for DoctorPath AI

Here are the detailed expanded use cases for the most critical functionalities:

UC-001: Authentication (Sign Up / Login)

Table 10 Authentication (Sign Up / Login)

Attribute	**Details**
Use Case ID	UC-001
Use Case Name	Authentication (Sign Up / Login)
Actors	Doctor, Patient
Description	Allows users to create accounts and authenticate securely with role-based access.
Preconditions	• User has internet access • System operational • Valid email/phone available
Postconditions	• User logged into respective portal • Session token generated • Redirected to respective (Doctor,Patient)dashboard
Normal Flow (Highlights)	1. User selects **Sign Up** or **Login** 2. System validates input 3. System creates or verifies account 4. User is redirected to **Doctor/Patient dashboard**
Alternative Flows	A1: Invalid credentials A2: Email already exists A3: Weak password
Exceptions	E1: Account locked after 5 failed attempts E2: Email verification timeout
Assumptions	Users have valid email and understand Doctor/Patient roles

UC-002: Create Patient Case

Table 11 Create Patient Case

Attribute	**Details**
Use Case ID	UC-002

Use Case Name	Create Patient Case
Actor	Patient
Description	Allows a patient to create a case by entering demographic, symptom, and health data.
Preconditions	• Patient logged in • Authentication complete • Has medical information available
Postconditions	• Case created and saved • Unique Patient ID generated • Case status = Draft/Active
Normal Flow (Highlights)	1. Patient fills form with personal and medical details 2. System validates input 3. System generates Patient ID 4. Case is saved
Alternative Flows	A1: Save as Draft A2: Missing mandatory fields
Exceptions	E1: Database error E2: Duplicate case detected
Assumptions	Patient understands terminology and has accurate info

UC-003: Generate Treatment Recommendations

Table 12: Generate Treatment Recommendations

Attribute	**Details**
Use Case ID	UC-003
Use Case Name	Generate Treatment Recommendations
Actor	Doctor
Description	Doctor requests AI-generated oncology treatment recommendations using RAG + LLM + Knowledge Graph.
Preconditions	• Doctor logged in • Patient case authorized and complete • Guideline and graph data available
Postconditions	• Recommendations generated and stored • Linked to patient case

	• Decision graph ready
Normal Flow (Highlights)	1. Doctor opens case 2. Confirms generation 3. System retrieves data and constructs graph 4. AI engine outputs ranked recommendations
Alternative Flows	A1: Missing data A2: No guidelines found A3: Contraindications detected
Exceptions	E1: Processing timeout E2: Cancer-specific model failure E3: Graph DB error
Assumptions	Up-to-date guidelines, working AI services, valid patient data

UC-004: View Decision Graph

Table 13 View Decision Graph

Attribute	Details
Use Case ID	UC-004
Use Case Name	View Decision Graph
Actor	Doctor
Description	Allows the doctor to view the AI-generated decision graph for the patient's treatment plan.
Preconditions	• Doctor logged in • Treatment plan generated • Case data complete
Postconditions	• Decision graph displayed • Relevant treatment options and evidence shown
Normal Flow (Highlights)	1. Doctor opens case 2. Doctor selects "View Decision Graph" 3. System displays the graph
Alternative Flows	A1: Decision graph is not available due to missing data
Exceptions	E1: System fails to retrieve graph E2: Graph rendering error
Assumptions	Doctor has validated AI output and stable internet connection

UC-005: Search Patient by ID

Table 14 Search Patient by ID

Attribute	**Details**
Use Case ID	UC-005
Use Case Name	Search Patient by ID
Actor	Doctor
Description	Enables a doctor to find and access a patient’s case using a unique Patient ID.
Preconditions	• Doctor logged in • Patient shared valid ID

	• Doctor authorized by patient
Postconditions	• Doctor gains case access • Access logged in audit trail
Normal Flow (Highlights)	1. Doctor enters Patient ID 2. System validates and retrieves the case 3. Authorization is verified 4. Case is displayed
Alternative Flows	A1: Invalid ID format A2: ID not found A3: Advanced search used
Exceptions	E1: Access denied E2: Access revoked E3: Access expired
Assumptions	Patient shared correct ID and granted access

UC-006: Authorize Doctor Access

Table 15 Authorize Doctor Access

Attribute	Details
Use Case ID	UC-006
Use Case Name	Authorize Doctor Access
Actor	Patient
Description	Allows the patient to grant or revoke access to their medical data for the doctor.
Preconditions	• Patient logged in • Patient case exists
Postconditions	• Doctor access granted or revoked • Access logged
Normal Flow (Highlights)	1. Patient selects "Authorize Access" 2. System requests confirmation 3. Patient confirms or revokes access
Alternative Flows	A1: Patient chooses to revoke access A2: Patient declines to grant access
Exceptions	E1: Access denied due to incorrect credentials E2: Access revocation fails
Assumptions	Patient has stable internet connection and understands the implications of granting access

UC-007: Download Treatment Plan

Table 16 Download Treatment Plan

Attribute	**Details**
Use Case ID	UC-007
Use Case Name	Download Treatment Plan
Actor	Doctor
Description	Allows doctor to download AI-generated treatment plan (PDF, HTML, DOCX).
Preconditions	• Doctor logged in • Treatment plan generated • Case data complete
Postconditions	• Plan downloaded • Log created • Copy stored in patient record
Normal Flow (Highlights)	1. Doctor selects plan 2. Chooses format 3. System generates file 4. Plan is downloaded
Alternative Flows	A1: HTML or DOCX format selected A2: Include decision graph
Exceptions	E1: PDF generation fails E2: File too large E3: Download interrupted
Assumptions	Doctor has validated AI output and stable internet connection

Summary Table: All Expanded Use Cases

Table 17 All Expanded Use Cases

UC ID	Use Case Name	Primary Actor	Complexity	Priority
UC-001	Authentication (Sign Up/Login)	Doctor, Patient	Medium	High
UC-002	Create Patient Case	Patient	Medium	High
UC-003	Generate Treatment Recommendations	Doctor	High	Critical
UC-004	View Decision Graph	Doctor	Medium	Medium
UC-005	Search Patient by ID	Doctor	Low	High
UC-006	Authorize Doctor Access	Patient	Low	High
UC-007	Download Treatment Plan	Doctor	Medium	High
UC-008	Review Detailed Treatment Plan	Doctor	Medium	Medium
UC-009	Upload Clinical Data	Patient	Low	High
UC-010	Upload Image Data	Patient	Low	Medium
UC-011	View Case History	Doctor	Low	Medium

Activity Diagram

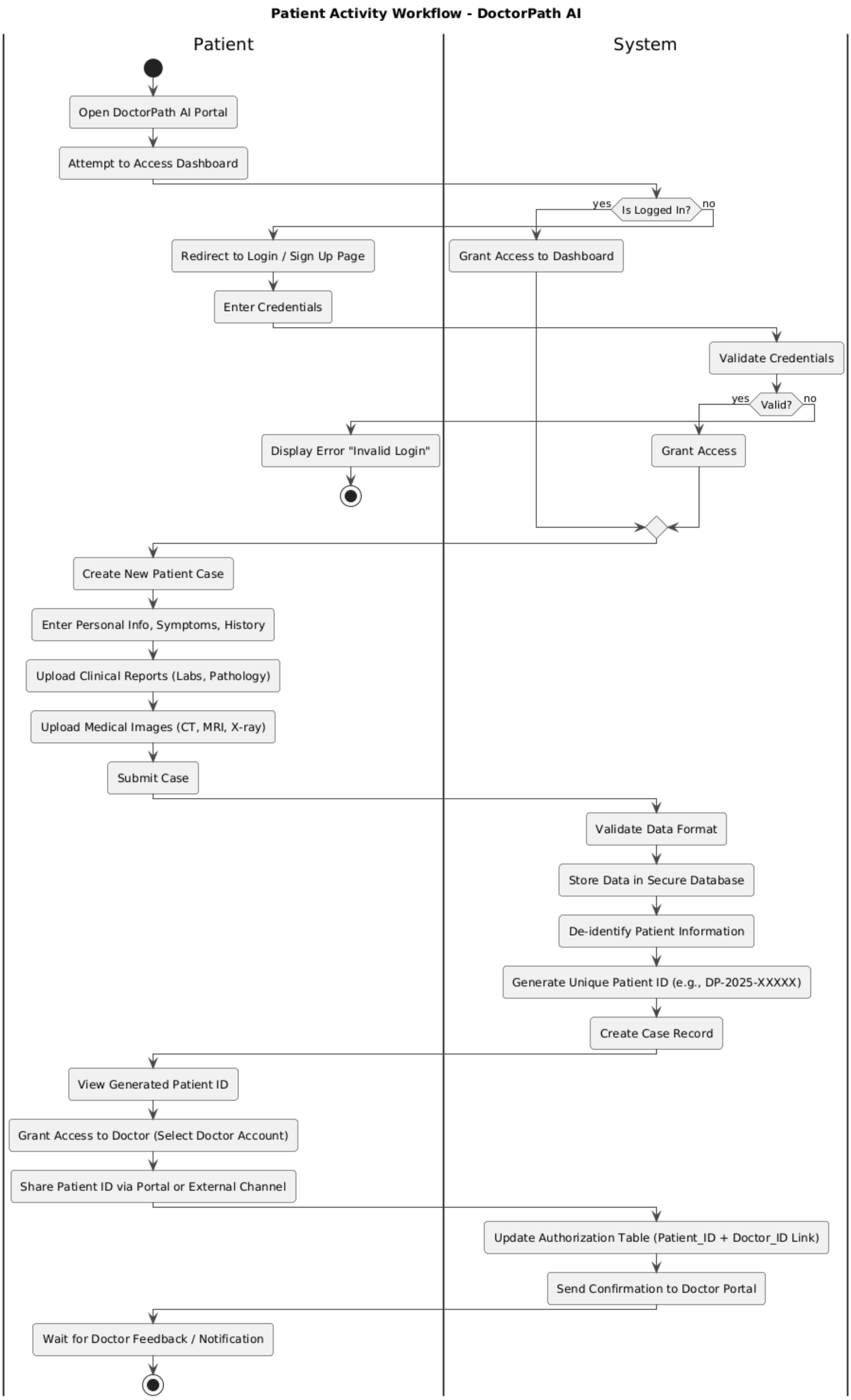

Figure 2 Patient Activity Diagram

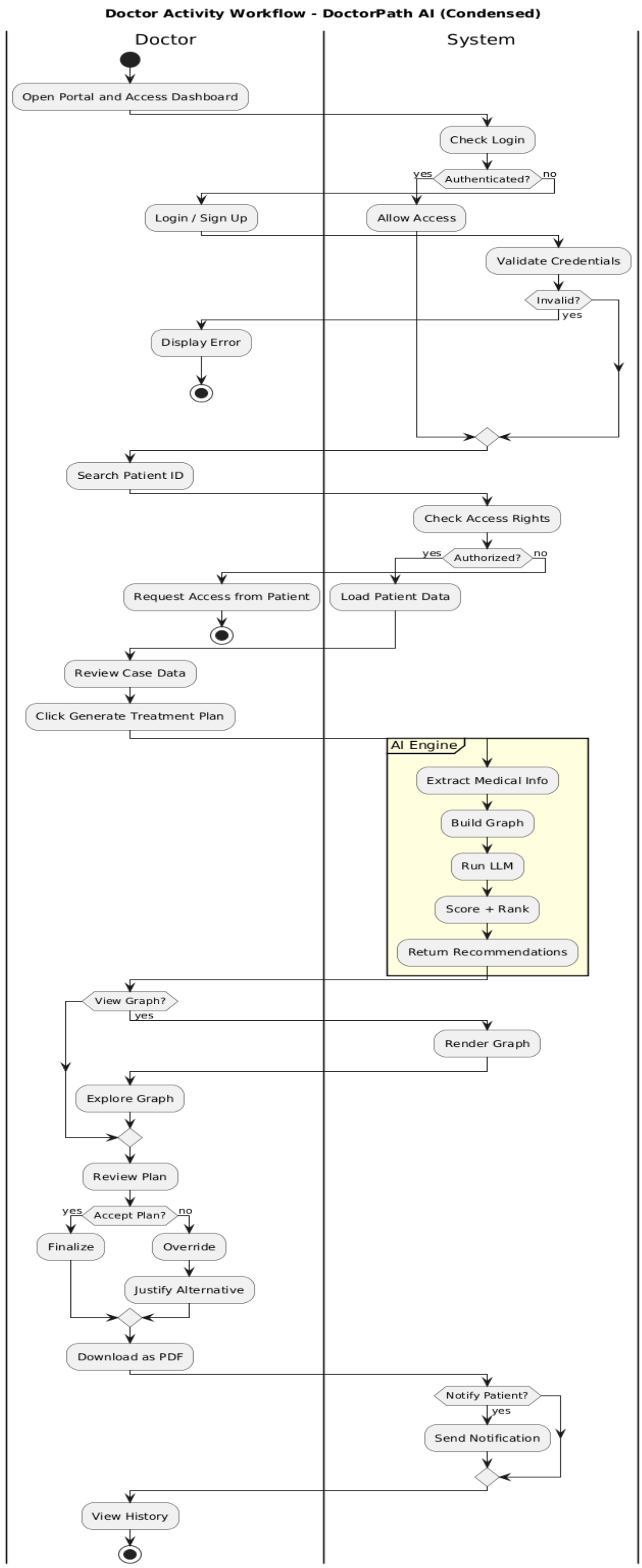

Figure 3 Doctor Activity Diagram

System Sequence Diagram (SSD)

SSD 1: User Authentication / Login

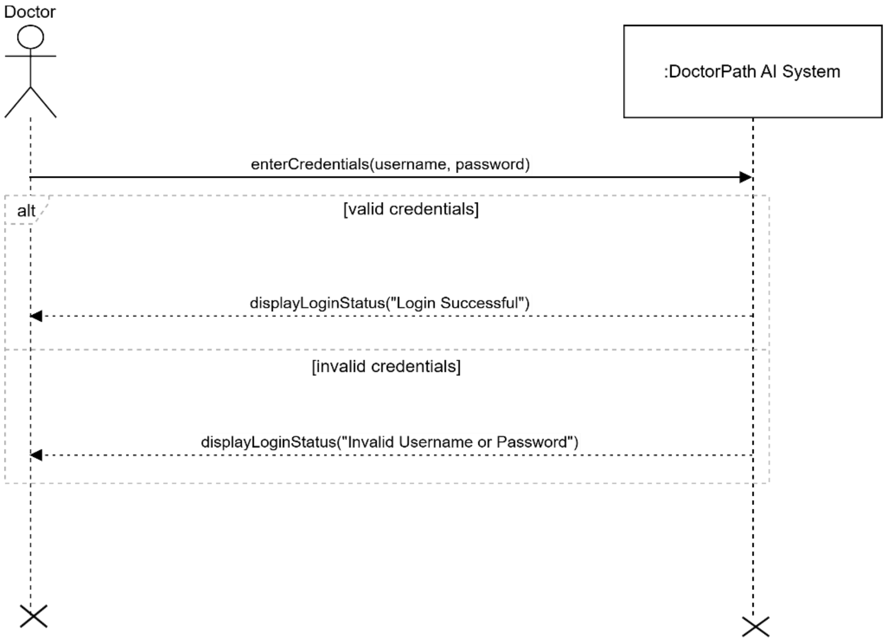

Figure 4 System Sequence Diagram (SSD) for User Authentication/ Login

SSD 2: Create New Patient Case

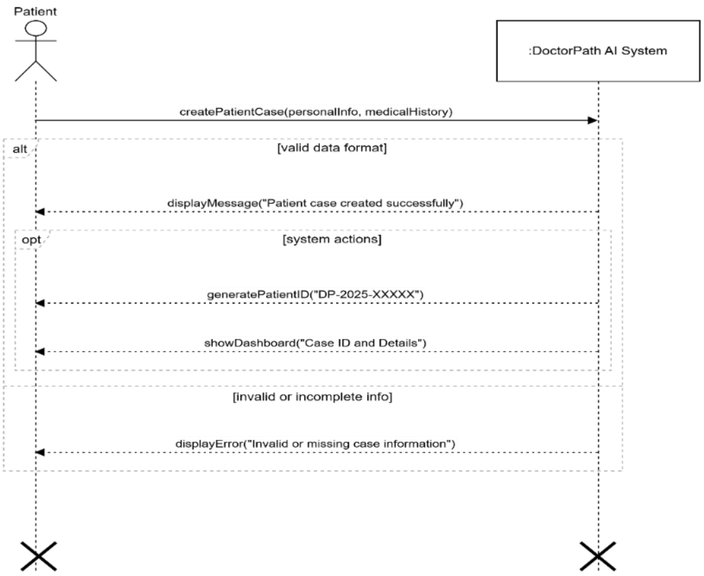

Figure 5 System Sequence Diagram (SSD) for Create New Patient Case

SSD3. Upload Clinical and Imaging Data

Scenario: Patient finalizes and submits the case for doctor review.

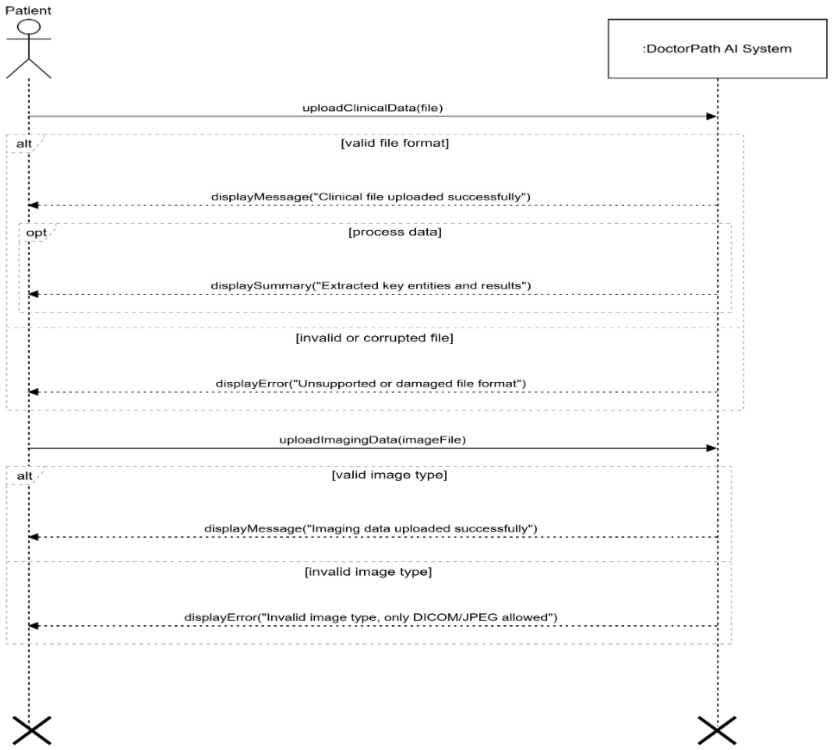

Figure 6 System Sequence Diagram (SSD) for Upload Clinical and Imaging Data

SSD 4: Authorize Doctor Access

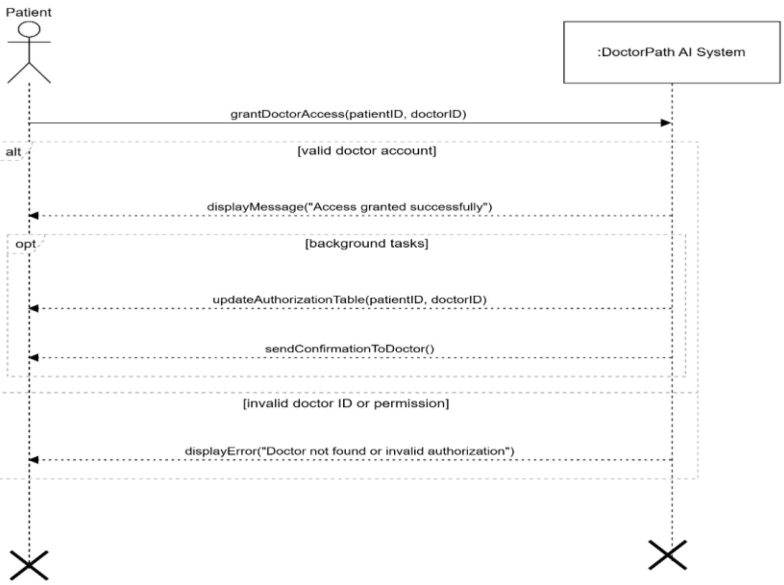

Figure 7 System Sequence Diagram (SSD) for Authorize Doctor Access

SSD 5: Doctor Searches Patient Case

Scenario: Doctor searches patient case using shared patient ID.

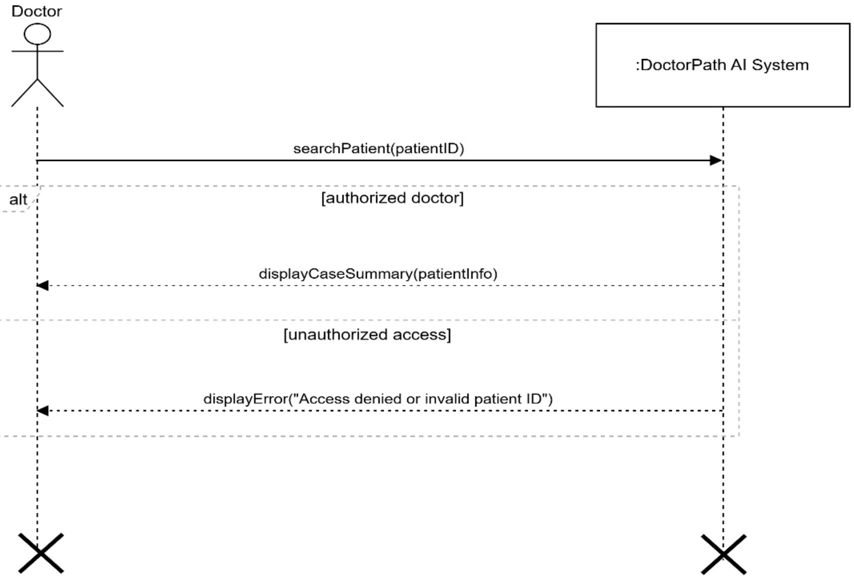

Figure 8 System Sequence Diagram (SSD) for Doctor Searches Patient Case

SSD 6: Generate Treatment Plan

Scenario: Doctor requests AI-assisted treatment plan.

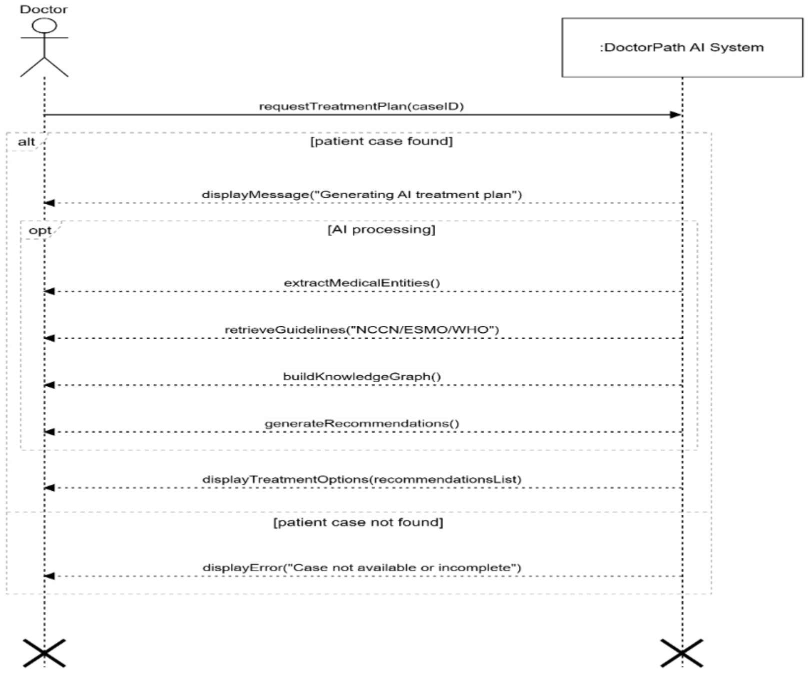

Figure 9 System Sequence Diagram (SSD) for Generate Treatment Plan

SSD 7: View Decision Graph

Scenario: Doctor visualizes AI decision graph.

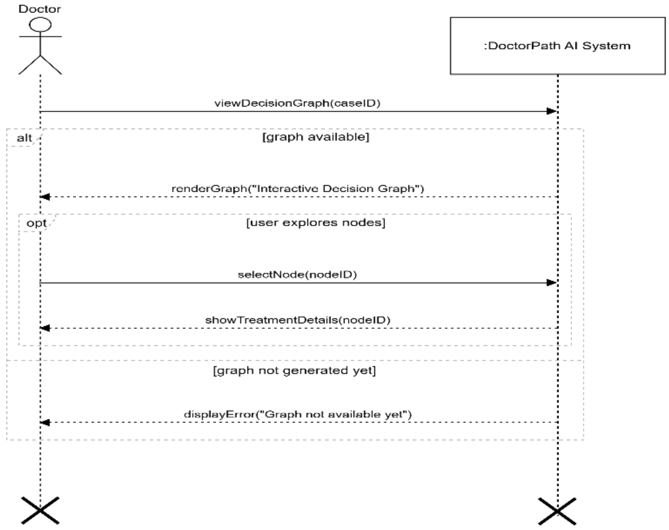

Figure 10 System Sequence Diagram (SSD) for View Decision Graph

SSD 8: Download Treatment Plan

Scenario: Doctor downloads AI-generated or reviewed plan.

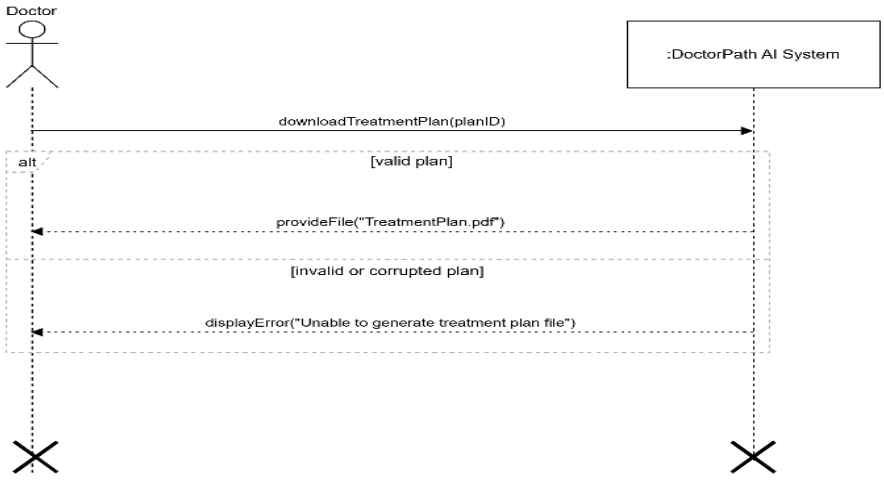

Figure 11 System Sequence Diagram (SSD) for Download Treatment Plan

SSD 9: Notify Patient

Scenario: Doctor finalizes plan and system notifies patient.

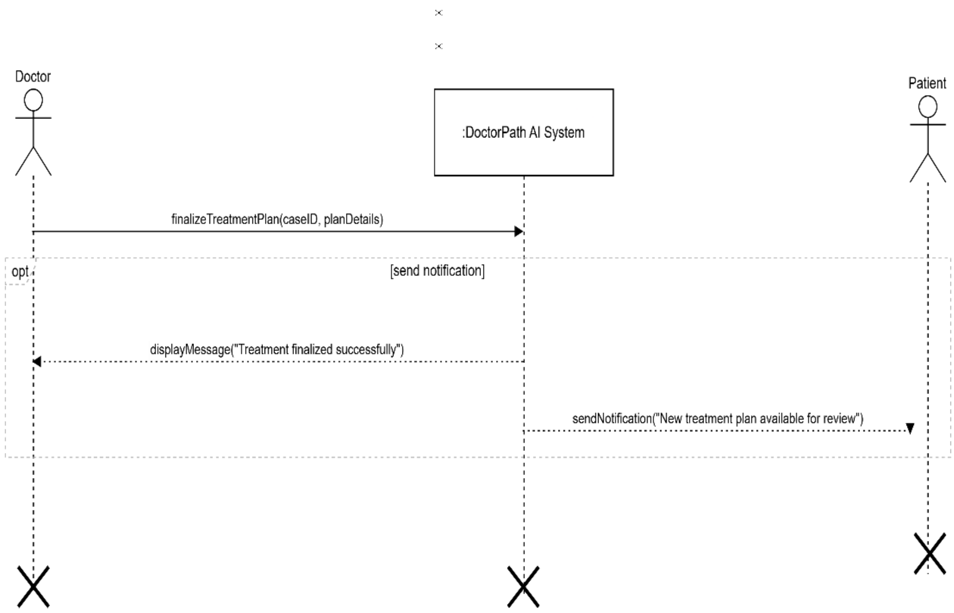

Figure 12 System Sequence Diagram (SSD) for Notify Patient

Structural Design: Layer Diagram

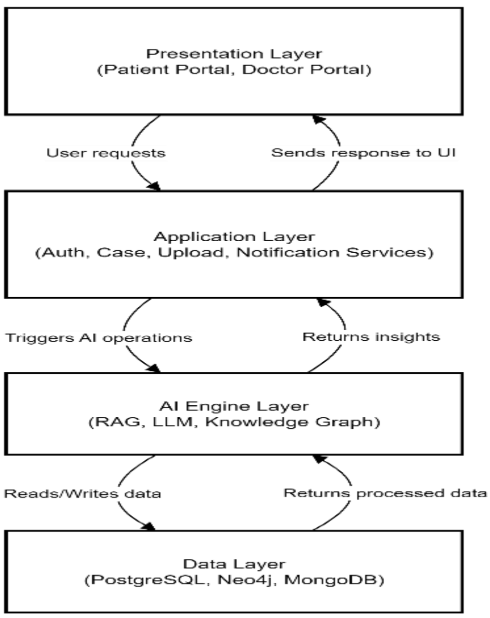

Figure 13 Layer Diagram

Component Diagram:

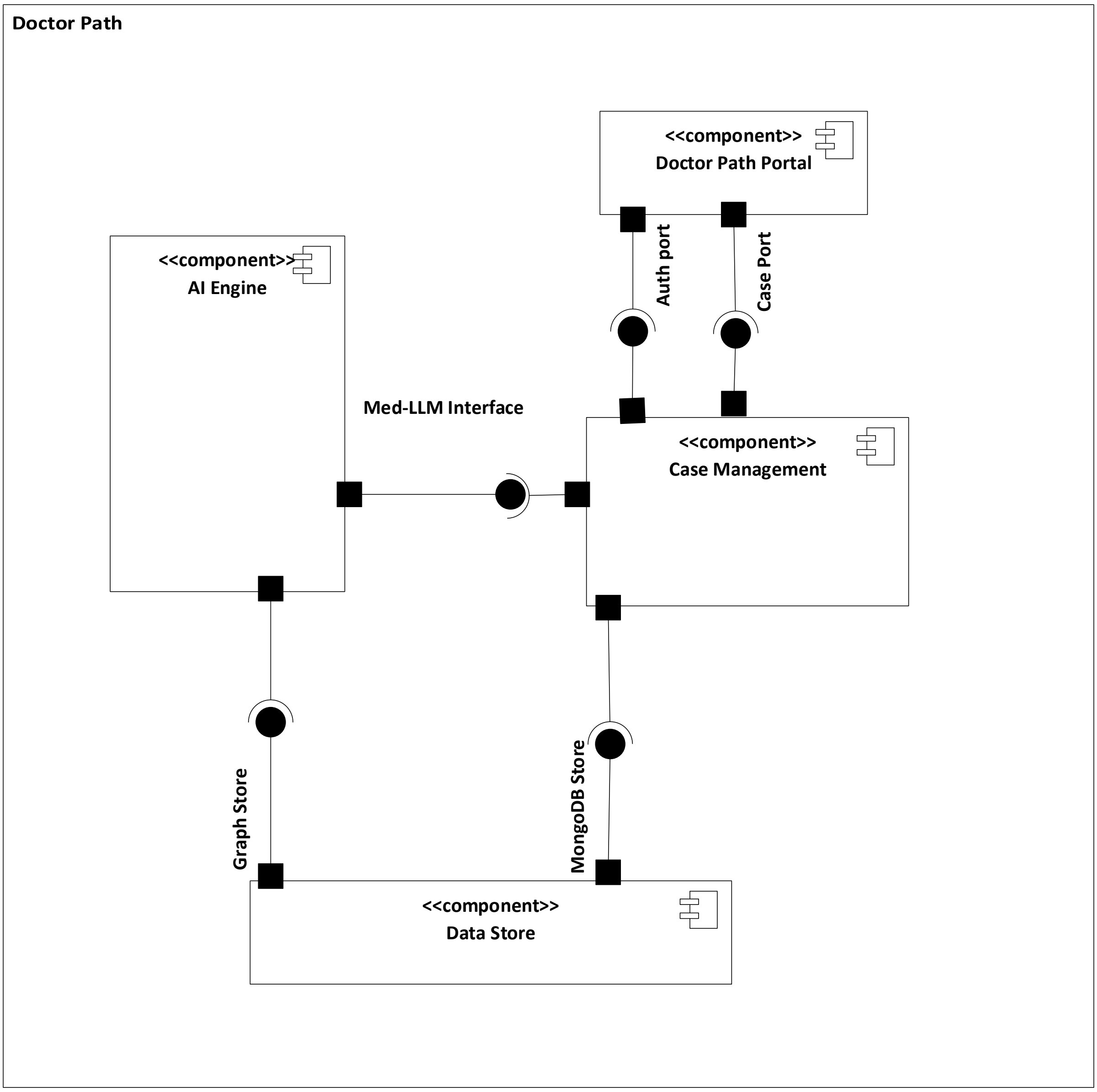

Figure 14 Component Diagram

Flow Diagram

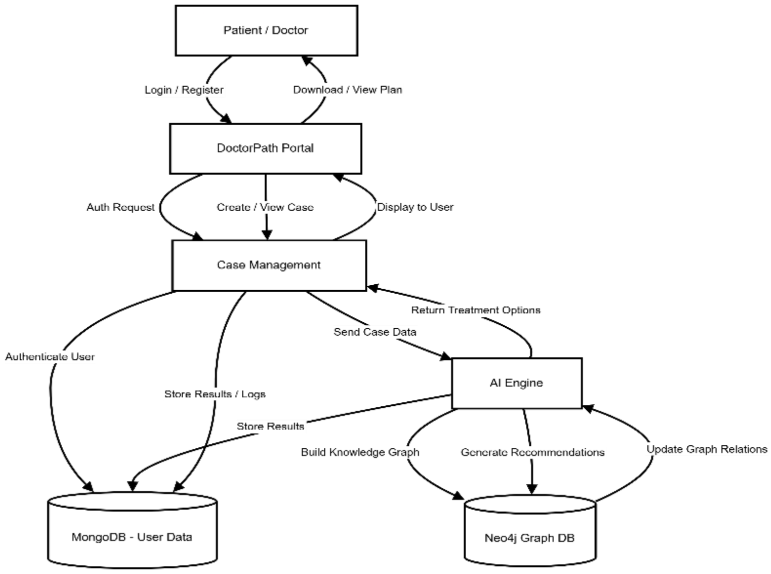

Figure 15 Flow Diagram

Data Flow Diagram

This section explains how data moves through the system, showing interactions between processes, data stores, and external entities.

Context Diagram

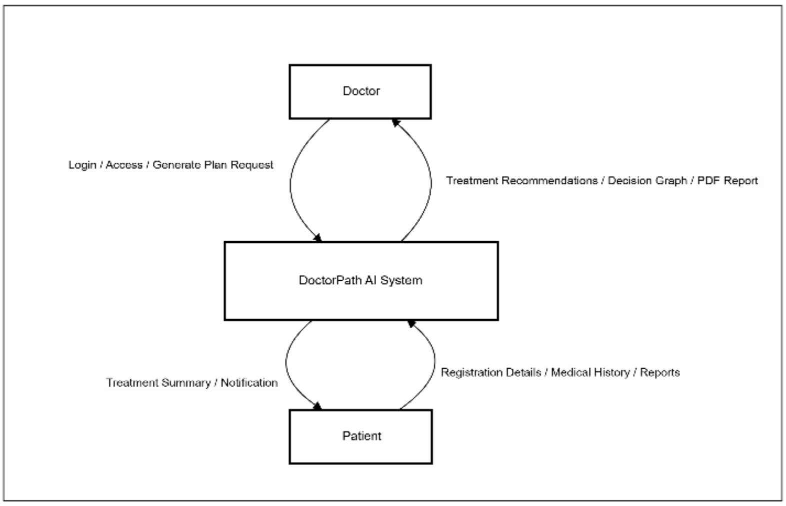

Figure 16 Context Diagram

DFD Level 0 Diagram

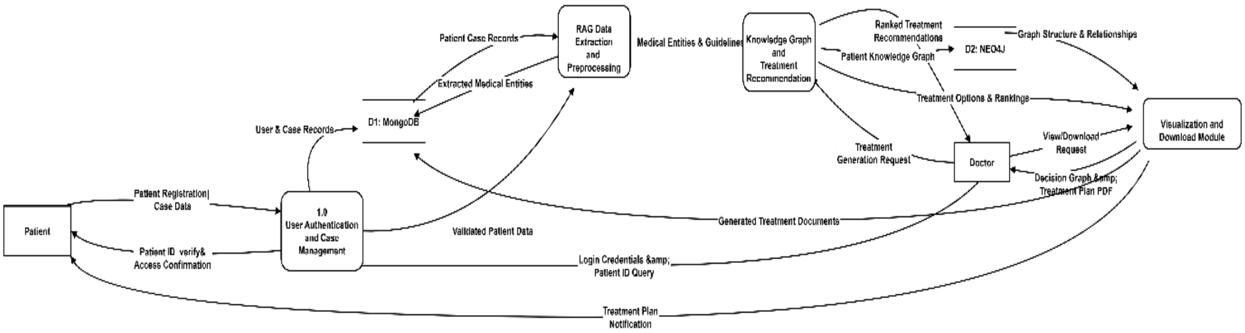

Figure 17 DFD Level 0 Diagram

DFD Level 1 - User Authentication & Case Management

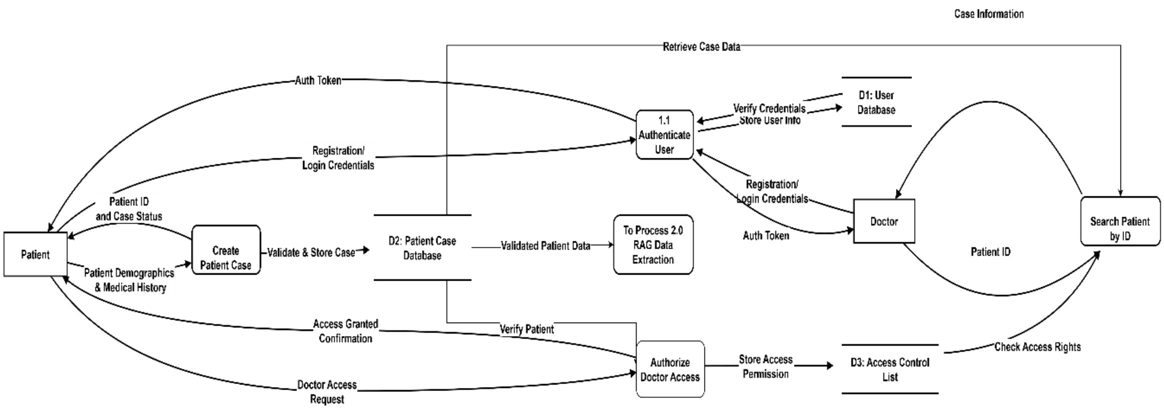

Figure 18 DFD Level 1.1 - User Authentication & Case Management

DFD Level 1 - RAG Data Extraction & Preprocessing

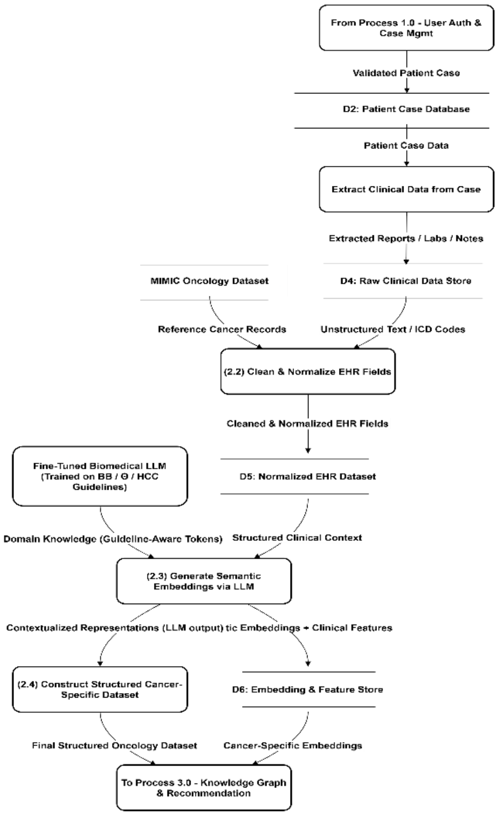

Figure 19 DFD Level 1.2 - RAG Data Extraction & Preprocessing

DFD Level - Knowledge Graph & Treatment Recommendation

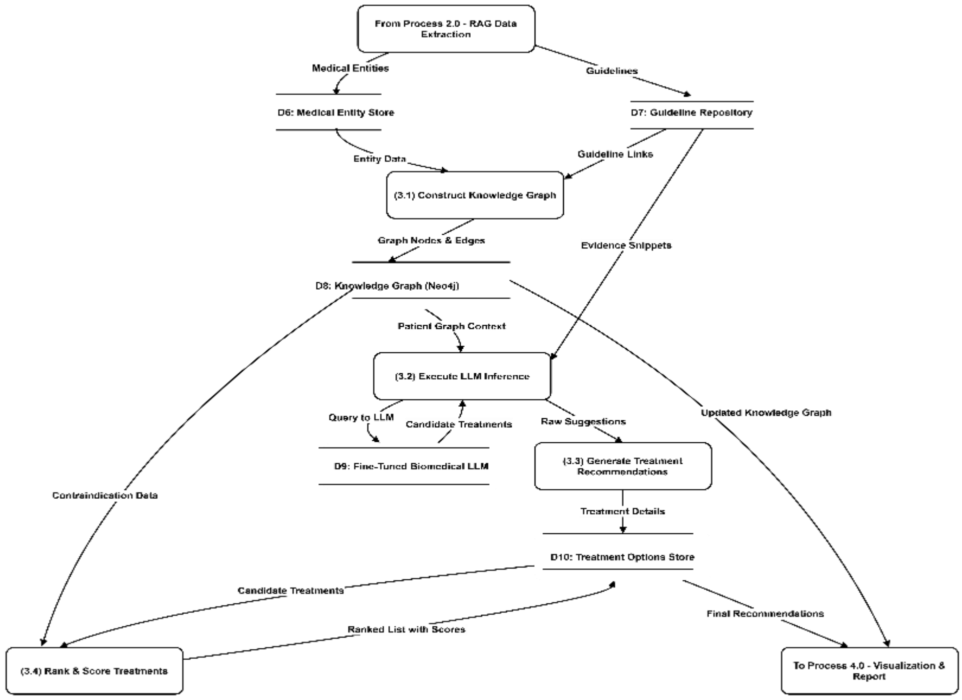

Figure 20 DFD Level 1.3 - Knowledge Graph & Treatment Recommendation

DFD Level 1- Visualization & Download Module

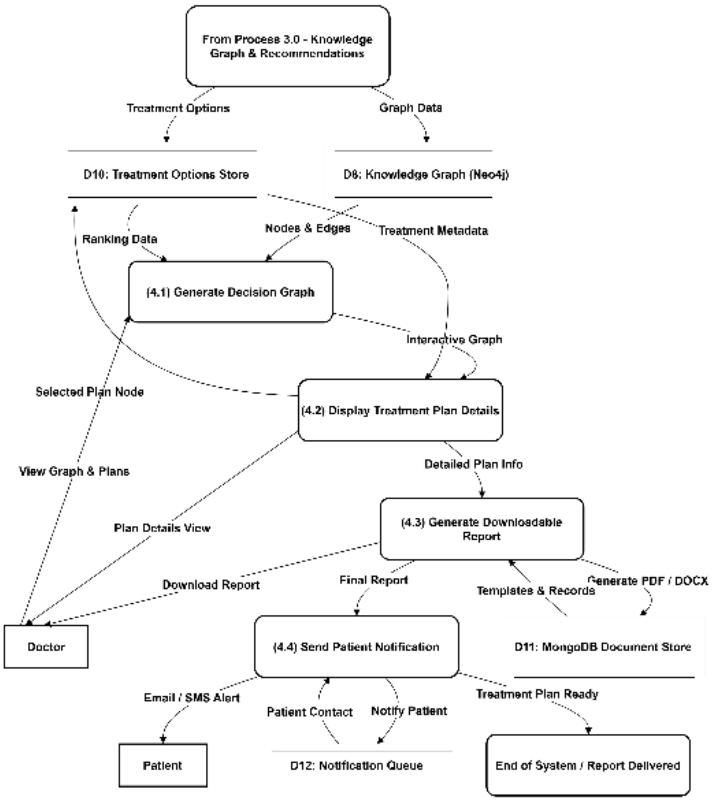

Figure 21 DFD Level 1.4 - Visualization & Download Module

Deployment Diagram

Doctor Path AI

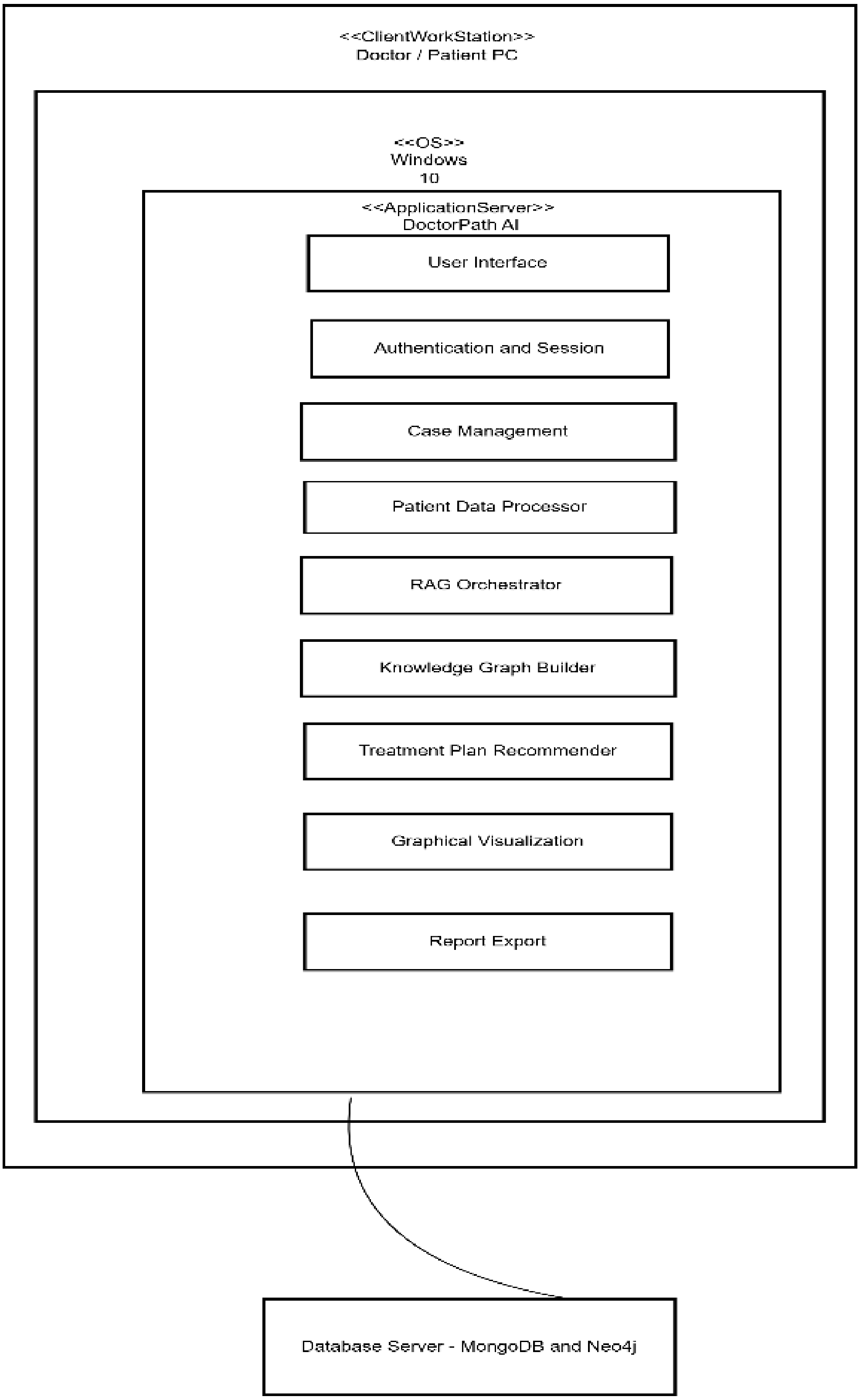

Figure 22 Deployment Diagram

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