WIF3002 Software Process and Quality

System Design Document

Version 0.4

6/5/2024

Approvals

Approved Date	Approved Version	Approver role	Approver

1.0 Background

1.1 Introduction

In the realm of educational assessment, the accurate and efficient evaluation of multiple-choice question (MCQ) answer sheets remains a critical task. Traditional manual grading methods are time-consuming and prone to human error. To address these challenges, the development of an Optical Character Recognition (OCR) system presents a compelling solution. This project endeavors to leverage the capabilities of Tesseract OCR technology to automate the evaluation process of handwritten MCQ answer sheets.

Currently, the manual grading process for handwritten MCQ answer sheets is time-consuming, labour-intensive, and susceptible to human error. Educational institutions often rely on traditional methods for evaluating student responses, resulting in inefficiencies and inconsistencies in assessment procedures.

This project aims to revolutionize the assessment landscape by introducing an automated grading system powered by OCR technology. This system will interpret handwritten answers on MCQ answer sheets, match them with corresponding question numbers, and generate a comprehensive summary of students' marks for the MCQ test. By automating the grading process, This system enhances efficiency, accuracy, and consistency in educational assessment.

1.2 Purpose of the SDD

The System Design Document (SDD) serves as a blueprint or roadmap for the development team, stakeholders, and project managers involved in creating the automated grading system for handwritten MCQ answer sheets using OCR technology. Its primary purpose is to provide a comprehensive overview of the system's architecture, components, functionalities, and interactions, ensuring clarity and alignment among all parties involved in the project. The specific purposes of SDD are as below:

- **Communication**

  The SDD facilitates clear communication between team members, stakeholders, and project managers by documenting the system's design decisions, requirements, and specifications in a structured format. It ensures that everyone involved has a common understanding of the system's architecture and functionality.

- **Guidance for Development**

The SDD guides the development team in implementing the system by outlining the technical details, including the choice of technologies, algorithms, and frameworks. It provides guidance on how different system components will be designed, implemented, and integrated to achieve the desired functionality.

- **Alignment with Requirements**

  The SDD ensures that the system design aligns with the project requirements and objectives. It helps verify that the proposed solution adequately addresses the needs of end-users and stakeholders, promoting customer satisfaction and project success.

- **Reference for Implementation**

  Developers can refer to the SDD during the implementation phase to understand the design rationale, component interactions, and dependencies. It serves as a reference guide for writing code, building modules, and integrating system components effectively.

2.0 System Objective

2.1 Business Goal

- **Efficiency Improvement**

  The system aims to improve the efficiency of the grading process for handwritten MCQ answer sheets by automating the evaluation process, reducing manual effort, and streamlining assessment procedures.

- **Accuracy Enhancement**

  The system aims to enhance the accuracy of grading by leveraging OCR technology to interpret handwritten answers accurately and match them with the corresponding question numbers reliably.

- **Cost Reduction**

  By automating the grading process, the system seeks to reduce costs associated with manual grading, including labor costs, time expenditure, and resource utilization.

- **Scalability Enhancement**

  The system aims to support scalability by efficiently handling an increasing volume of MCQ answer sheets as school enrollments grow or during peak testing periods without compromising performance or accuracy.

2.2 System Assumptions

- **Technological Readiness**

  Schools and educational institutions have the necessary infrastructure (scanners, computers with adequate specifications) to support the use of the OCR system.

- **User Competence**

  Educators and administrative staff possess basic digital literacy skills required to interact with the desktop and web-based applications of the OCR system.

- **System Compatibility**

  The OCR system is designed to be compatible with multiple operating systems (Windows, macOS, Linux) and perform efficiently across these platforms.

- **Consistent Answer Formatting**

  The system assumes that students will consistently format their answers next to the corresponding question numbers in a predetermined manner and write the answer in Capital Letters (e.g., letters A-E for multiple-choice questions).

- **Readable Handwriting**

  The system assumes that students' handwriting will be legible and recognizable by the OCR technology used for text recognition.

- **Stable Internet Connection**

  For web-based functionality, the system assumes a stable internet connection for users to access the application, submit answer sheets, and retrieve grading results.

- **Standardized Answer Sheets**

  The system assumes that answer sheets will adhere to a standardized format and layout, facilitating accurate interpretation and grading.

2.3 System Risks

- **OCR Accuracy Risk**

  There is a risk that OCR technology may not accurately interpret all types of handwriting styles, leading to errors or inconsistencies in grading results.

- **Performance Risk**
  There is a risk that the system may not perform efficiently under high loads or concurrent processing of large volumes of answer sheets, impacting responsiveness and user experience.

- **Compatibility Risk**
  There is a risk of compatibility issues arising from the integration of multiple technologies and platforms, including operating systems, web browsers, and third-party services.

2.4 User Manual

RajaMark User Manual v0.1

3.0 Requirements

3.1 Functional Requirements

Authentication Module

FR001- Register

FR001.1

When the user clicks the “Don’t have an account? Register here” button on the Login page, the system should redirect the user to the Register page.

FR001.2

Once the user has been directed to the Register page, the system shall provide the user with the ability to fill in the required information, which are Username, Email Address, Password, and Confirm Password. If the Password and Confirm Password does not match, the system shall prompt an Error Message “Password does not match”.

FR001.3

When the user clicks the ”Register” button, the system should create a new record in the account database after validating the account. If the Username entered has existed in the database, the system shall prompt an Error Message “Username Has Existed. Please try again”. If the Email Address entered has existed in the database, the system shall prompt an Error Message “Email Has Existed. Please try again”.

FR001.4

When the new record is created, the system shall redirect the user to the Login page after displaying “REGISTRATION SUCCESS” message.

FR002- Login

FR002.1

When the user is redirected to the Login page, the system should provide the user with the ability to fill in the required information, which are Username/Email and Password.

FR002.2

When the user clicks the “Login” button, the system should change status to login after validating login. If the Username and Password does not match in the database, the system shall prompt an Error Message “Username/Email is incorrect. Please try again”

FR002.3
When the system status is changed to login, the system shall redirect the user to the Home

page

FR003 - Logout

FR003.1

When the user has clicked the “LogOut” button on the Home page, the system shall terminate the current session.

FR003.2

Once the session is terminated, the system shall be able to redirect users to the Login page.

FR004 - Forget Password

FR004.1

When the user clicks the “Forget Password?” link on the Login page, the system shall be able to redirect the user to the Forget Password page.

FR004.2

Once the user has redirected to the Forget Password page, the system shall provide the user with the ability to enter their registered email address.

FR004.3

When the user clicks the “Reset Password” button, the system shall be able to send an email with a password reset link after validating the email address exists. If the email address is not found in the database, the system shall prompt an Error Message “Email is not found. Please try again”

FR004.4

Upon clicking the reset link, the system shall provide the user with the ability to create a new password, and upon success, redirect the user to the Login page with a “Password Reset Successfully” message.

Exam Module

FR005 - Manage Exam

FR005.1

After the user has logged in, the system shall provide the user with the ability to create a new exam record by clicking the “Create button”.

FR005.2

When the user clicks on the “Create” button, the system should redirect to another page to allow the user to enter the exam details including exam title, description, course code, session, grade.

FR005.3

The system shall set the default grade according to the image below and allow users to edit the grading system.

Grade	Marks
A	80-100
A-	75-79
B+	70-74
B	65-69
B-	60-64
C+	55-59
C	50-54
D	40-49
F	0-39

FR005.4

After the user has added an exam record, the system shall provide the user with the ability to click “Edit” and “Delete” to amend the existing exam record.

FR006 - View Exam

FR006.1

After the user has added an exam record, the system shall provide the user with the ability to view available exam records listed on the Home page.

FR006.2

After the user has clicked into a particular exam record, the system shall be able to redirect the user to the Exam Details page and display exam details, including exam title, description and list of student details (if available) for the user to view.

FR007 - Upload Sample Answer

FR007.1

After the user has entered the Exam Details page, the system shall provide the user with the ability to upload sample answers, either key in manually or upload the sample answers in text file format for each

FR007.2

When the user clicks the “Upload Answer” button, the system shall prompt a pop-up to allow the user to key in the answer. If any of the question number is empty, the system shall prompt an Error Message “Please fill up Question XX”

FR007.3

After the user clicks the “Complete” button, the system shall save the answer into the database for further action.

FR008 - Upload Student Data

FR008.1

When a user has created an exam record, the system shall provide the user with the ability to upload student data, including their name, student ID and answer sheet (all at one time or one by one) on the Exam Details.

FR008.2

After the user has clicked into a particular exam record, the system shall redirect the user to the Exam Details page and allow the user to click the “Add Student Record” button and a pop-up should appear to allow the user to key in the name, Student ID and answer sheet.

FR008.3

When the user clicks the “Upload” button to upload the answer sheet, the system shall allow the user to choose “Take Photo” or “Choose from Gallery”. If the user uploads anything other than image format, the system shall prompt the Error Message “Only image is allowed”.

FR008.4

The system shall preprocess the image and extract the answer, student ID and student name from the answer sheet. If the system detects no answer written for a certain question, the system shall remain the answer blank for that question. If the system detects there are multiple answers for a question, the system shall remark a message “Multiple Answer detected”.

FR008.5

The system shall cross check if the student ID matches the selected student record. If the student ID does not match, the system shall prompt a Confirmation Message “Warning! Student ID does not match. Please confirm to proceed.”

FR008.6

The system shall allow users to edit the student Name and student ID extracted from the answer sheet.

FR008.7

After the user has added the data and clicked the “Add” button, the system shall prompt a success message “Record has been saved”.

FR009 - View Student Score

FR009.1

Once a user has uploaded students’ answers, the system shall provide the user with the ability to view a list of students’ scores for an exam on the Exam Details page.

FR009.2

When the user clicks the eye icon, the system shall redirect to the Student Answer Page and display the extracted answer in the form of text and the original image of the question paper.

FR009.3

If the user wants to edit the student data, the user clicks the pencil icon at the student record, the system shall prompt the pop-up with the existing data of the student including the name, student ID and the answer sheet uploaded.

FR009.4

If the user wants to delete the student data, the user clicks the trash icon at the student record in Exam Details Page, the system shall prompt a confirmation message. After the user clicks “Confirm”, the system shall remove the student from the class list

FR010 - Generate Student Report

FR010.1

Once a user has uploaded students’ answers, the system shall provide the user with the ability to view the overall report of an exam, including the mean and median scores of students for an exam.

FR010.2

When the user clicks the “View Result” button at the exam record page, the system shall redirect the user to the Results page. The system shall display the details of the exam including the mean and median scores of the result and the individual score of each student.

Text Extract Module

FR011 - Preprocess Image

FR011.1

When the user clicks the “Upload” button to upload students’ answers, the system shall allow the user to choose “Take Photo” or “Choose from Gallery”. The system shall automatically preprocess any question paper uploaded in image format, adjusting resolution and format to optimize for text extraction.

FR011.2

After the user has uploaded the question paper, the system shall enhance image quality to ensure high accuracy in text recognition and store the image into the temporary database. If the image preprocess failed, the system shall prompt an Error Message “Image Preprocessing failed. Please try again”

FR012 - Extract Answer

FR012.1

Upon uploading an image, the system shall perform OCR to extract answers in the form of text from the image. If the system cannot detect any answer written, the system shall prompt an Error Message “Extracting failed”

FR012.2

Once the system finishes extracting answers from text to image, the system shall display the extracted answers to the user for confirmation or editing.

FR012.3

When the user clicks “Confirm”, the system shall store the answer and the image of the question paper into the student record based on the Student ID.

Grade Assessment Module

FR013 - Compare Answer to Question

FR013.1

Once the system extracted the students’ answers, the system shall compare extracted students’ answers to the sample answers for correctness.

FR014 - Calculate Exam Score

FR014.1

Once the system finishes comparing answers to questions, the system shall calculate the scores based on the match percentage from the comparison of extracted answers to the sample answers.

FR014.2

Once the system finishes calculating scores, the system shall update the students' score record upon calculation and display the updated score on the Exam Details page.

User Manual

FR015 - View User Manual

FR015.1

Once the user clicks the User Manual link, the system should provide users with the ability to view user manual

3.2 Non Functional Requirements

NFR001 - Performance Efficiency

NFR001.1

The system shall process answer sheets efficiently, with a response time of less than 15 seconds per sheet.

NFR001.2

The system shall be capable of handling a high volume of answer sheets concurrently, supporting simultaneous grading processes.

NFR002 - Usability

NFR002.1

The user interface (UI) shall be intuitive, user-friendly, and accessible across different devices and screen sizes.

NFR002.2

The system shall provide clear instructions and guidance for users on how to submit answer sheets, view grades, and navigate the system.

NFR002.3

The system should have a usable interface that allows educators and administrative staff to upload answer sheets, manage the evaluation process, and view results.

NFR003 - Reliability

NFR003.1
The system should have a high level of reliable summarised results consistently without failure to minimise errors in grading.

NFR003.2
The system shall maintain high availability, with a target uptime of at least 99%.

NFR003.3
The system shall implement backup and recovery mechanisms to ensure data integrity and continuity of operations in the event of system failures.

NFR004 - Security

NFR004.1

The system should comply with relevant data protection and privacy regulations, ensuring that student information is handled securely and ethically.

NFR004.2

The system shall encrypt data transmission and storage to prevent unauthorized access, interception, or tampering of data.

NFR005 - Maintainability

NFR005.1

The system should have a codebase that is well-structured and documented to facilitate future updates and maintenance tasks, allowing for easy integration of updates or improvements in the future

NFR005.2

The system shall support version control using tools like Git and GitHub to manage code changes, track revisions, and collaborate effectively among developers.

NFR006 - Compatibility

NFR006.1

The system should be compatible with various operating systems, including Windows, macOS, and Linux.

NFR006.2

The system shall integrate seamlessly with third-party services and APIs (e.g., Firebase, Tesseract OCR) without compatibility issues or conflicts.

3.3 System Constraint

3.3.1 Performance Optimization

Utilizing multiple frameworks and libraries can impact the performance of the system. Optimizing performance across different components, especially for tasks like real-time image preprocessing and OCR recognition, may require careful tuning and optimization to meet performance requirements, particularly in resource-constrained environments such as mobile devices.

3.3.2 Resource Utilization

Firebase, being a cloud-based platform, relies on network connectivity and server-side resources. Managing and optimizing resource utilization, including bandwidth usage, database queries, and storage space, is crucial to prevent performance bottlenecks, minimize costs, and ensure scalability.

3.3.4 Vendor Lock-in

Depending heavily on Firebase for database and storage introduces the risk of vendor lock-in. Considerations should be made regarding data portability, interoperability with other platforms, and potential migration strategies in the future to mitigate the risk of being tied to a specific vendor ecosystem.

3.3.4 Integration Complexity

Integrating multiple technologies like Flutter for UI and logic, Firebase for database and storage, OpenCV for image preprocessing, and Tesseract OCR for handwritten text recognition can introduce complexity. Ensuring seamless integration and interoperability

among these technologies while maintaining system performance and reliability might pose challenges.

4.0 System Architecture

4.1 Architecturally Significant Design Decisions

The OCR system will be developed with a **serverless architecture**. Serverless architectures refer to applications that significantly depend on third-party services (known as Backend as a Service or “BaaS”).The system specifies several key requirements that influence the way the system is designed. These key requirements can be grouped into the following categories described in the subsequent sections :

a) Scalability

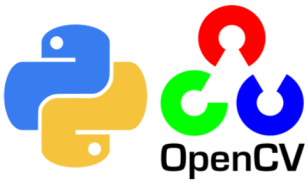
In this context, Firebase will serve as BasS in the project. As the user increases or decreases, Firebase responds by rapidly scaling the number of virtual server instances needed to run your function.

b) Modularity

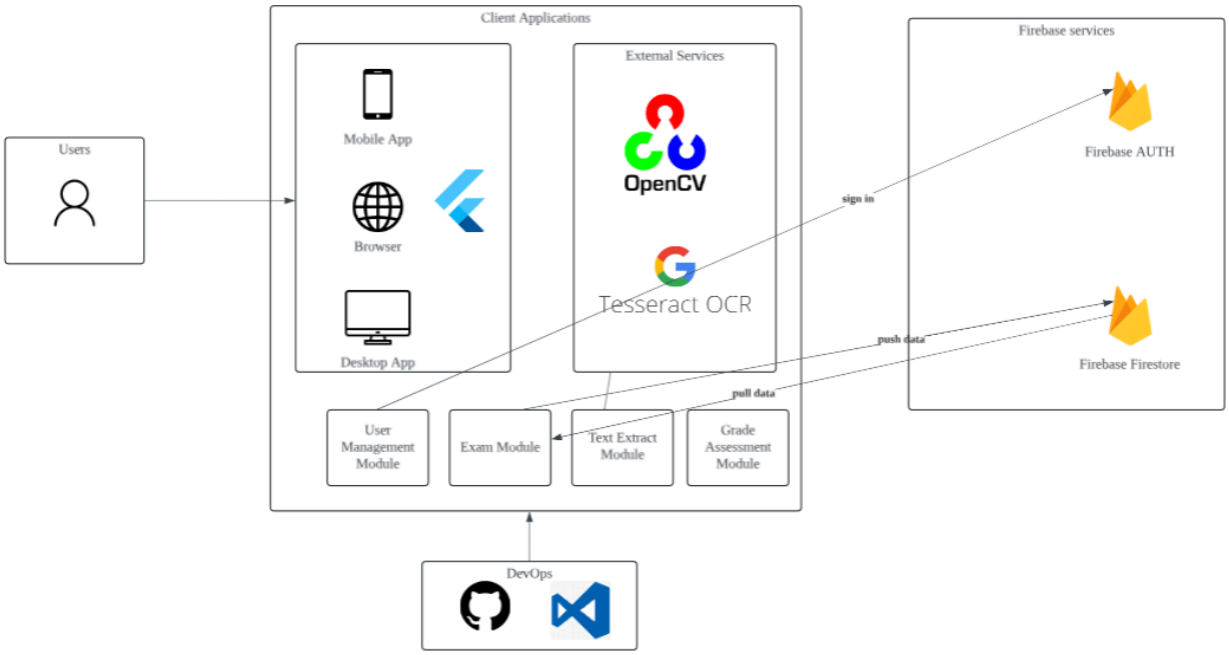
Flutter's architecture enables developers to create reusable UI components, business logic, and data layers that can be shared across different platforms such as desktop, mobile and browser. This allows developers to reuse the same codebase and shorten the development time.

4.2 Architecturally Significant Open Source Products/Frameworks

Tools	Version	Description
Firebase		Comprehensive mobile and web development platform provided by Google, offering authentication, real-time database, storage, hosting, and cloud functions.
Flutter		Open-source UI toolkit developed by Google for building natively compiled applications for mobile, web, and desktop platforms.
OpenCV		Provides bindings for the OpenCV library in Flutter, enabling integration of image preprocessing functionalities into Flutter applications.

		
Tesseract OCR		Open-source OCR engine maintained by Google, capable of recognizing text within images and extracting textual information.

4.3 Architecture View



4.4 Data Model Specifications

In this report, we outline the data models linked to specific functions of our Firestore-based application. Each function, such as user registration or exam management, is connected to a particular set of data structures within Firestore. This setup helps organize and manage data

effectively. For developers and team members, this clear structure simplifies understanding the application's workings, making it easier to maintain and enhance.

4.4.1 User (Lecturer)

Id	Name	Description	Type	Additional Type Information	Default	Unique	Example
DM4411	user_id	Unique identifier	String	128 bits	uuid	True	550e8400-e29b-41d4-a716-446655440000
DM4412	user_name	Name of user	String	Up to 100 characters	Extract from email	True	alex
DM4413	user_email	Email of user	String	Up to 320 characters	-	True	alex@gmail.com
DM4414	user_password	Password of user	String	Up to 100 characters	-	False	123456

4.4.2 Exam

Id	Name	Description	Type	Additional Type Information	Default	Unique	Example
DM4421	exam_id	Unique Identifier	String	128 bits	uuid	True	550e8400-e29b-41d4-a716-446655440000
DM4422	exam_title	Title of exam	String	Up to 100 characters	-	False	SPQ Exam
DM4423	exam_desc	User friendly description of exam	String	Up to 5000 characters	-	False	This is a SPQ mid term test

DM4424	course_code	Course code of the subject	String	Up to 50 characters	-	False	WIA1005
DM4425	session	Session of the current semester	String	Up to 50 characters	-	False	23/24
DM4426	sample_answer	Text answer for the exam	Array	-	Empty array	False	[‘A’,’B’,’C’’,’D’,’E’]
DM4427	mean_score	Mean score of all students	Double	Up to 100	0	False	80.5
DM4428	median_score	Median score of all students	Double	Up to 100	0	False	81.0
DM4429	user_id	Id of user	String	128 bits	uuid	False	550e8400-e29b-41d4-a716-446655440000

4.4.3 Exam Grade

Id	Name	Description	Type	Additional Type Information	Default	Unique	Example
DM4431	exam_id	Unique Identifier	String	128 bits	uuid	True	550e8400-e29b-41d4-a716-446655440000
DM4432	grade_label	Label of grade	String	-	-	False	“A”
DM4433	grade_upper_score	Upper score of the grade	Integer	-	100	False	100
DM4434	grade_lower_score	Lower score of this grade	Integer	-	0	False	80

4.4.4 Student Result

Id	Name	Description	Type	Additional	Default	Unique	Example

				Type Information			
DM4441	student_id	Unique identifier	String	128 bits	uuid	True	550e8400-e29b-41d4-a716-446655440000
DM4442	student_name	Name of the student in the answer sheet	String	Up to 100 characters	-	False	Ali Abu
DM4443	exam_id	Unique Identifier	String	128 bits	uuid	True	550e8400-e29b-41d4-a716-446655440000
DM4444	answer_text	Answer of each questions	Array	Up to 5000 characters	-	False	[‘A’, ‘B’, ‘A’, ‘C’, ‘D’]
DM4445	score	Score of student	Integer	Up to 100	0	False	80
DM4446	date	Date of the uploaded image	Date	Firestore's Timestamp	Current Date	False	Dec, 2019
DM4447	img_id	Image link of the uploaded student answer	String	-	Null	False	“https//firebasestorage/12818978”

4.5 Database Design

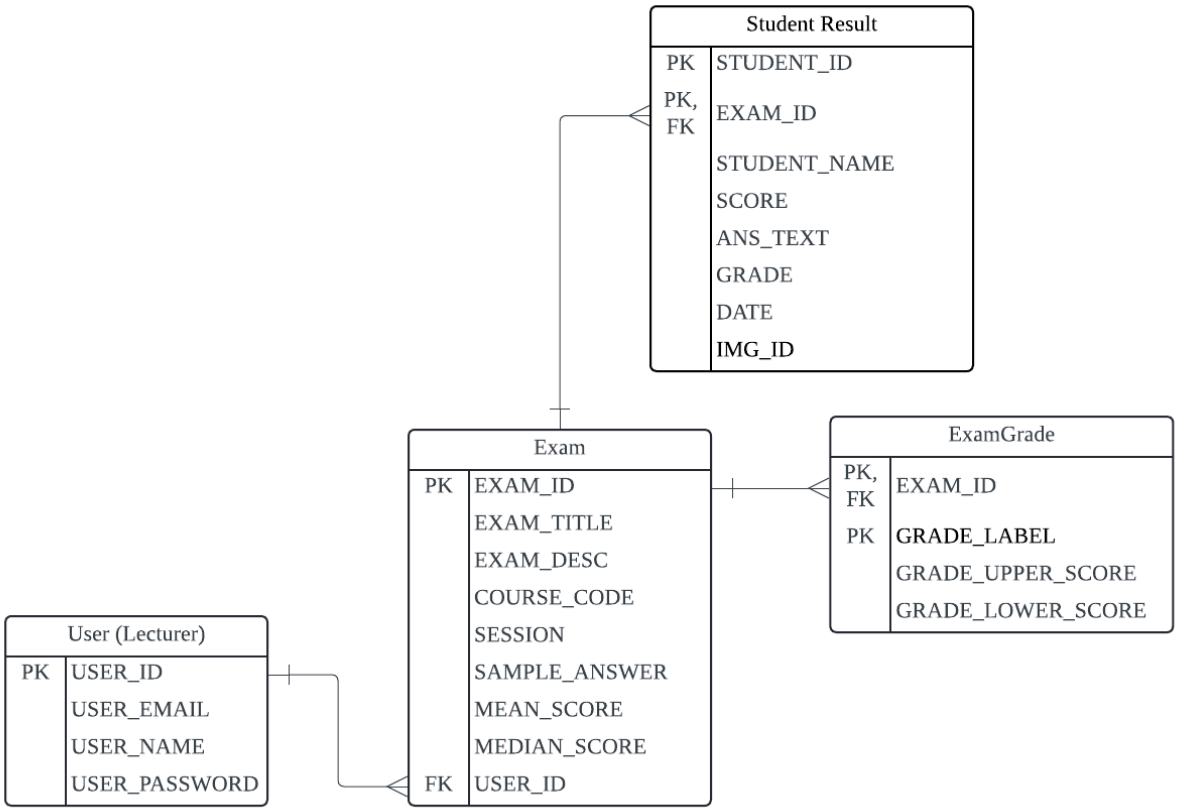
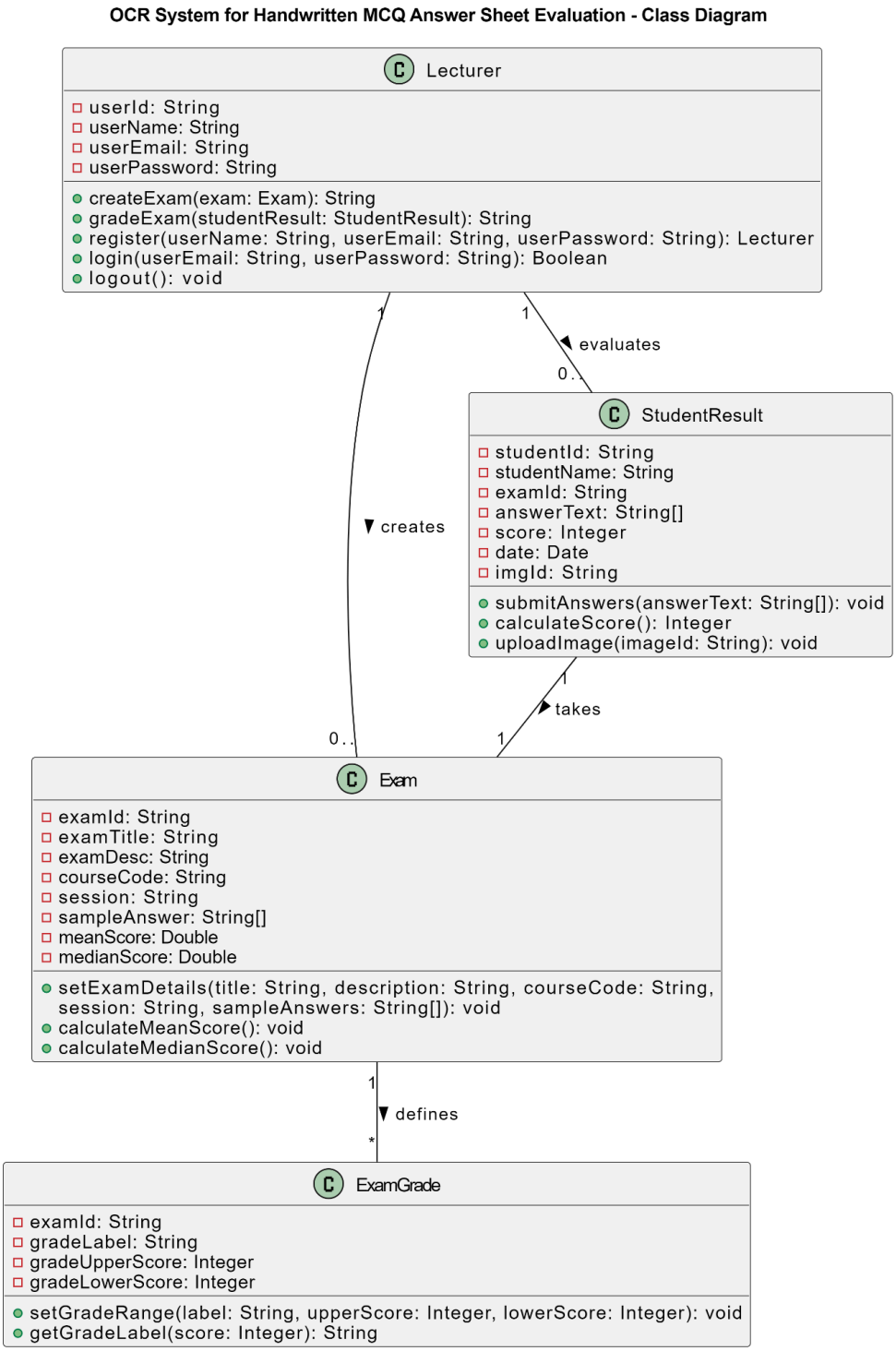


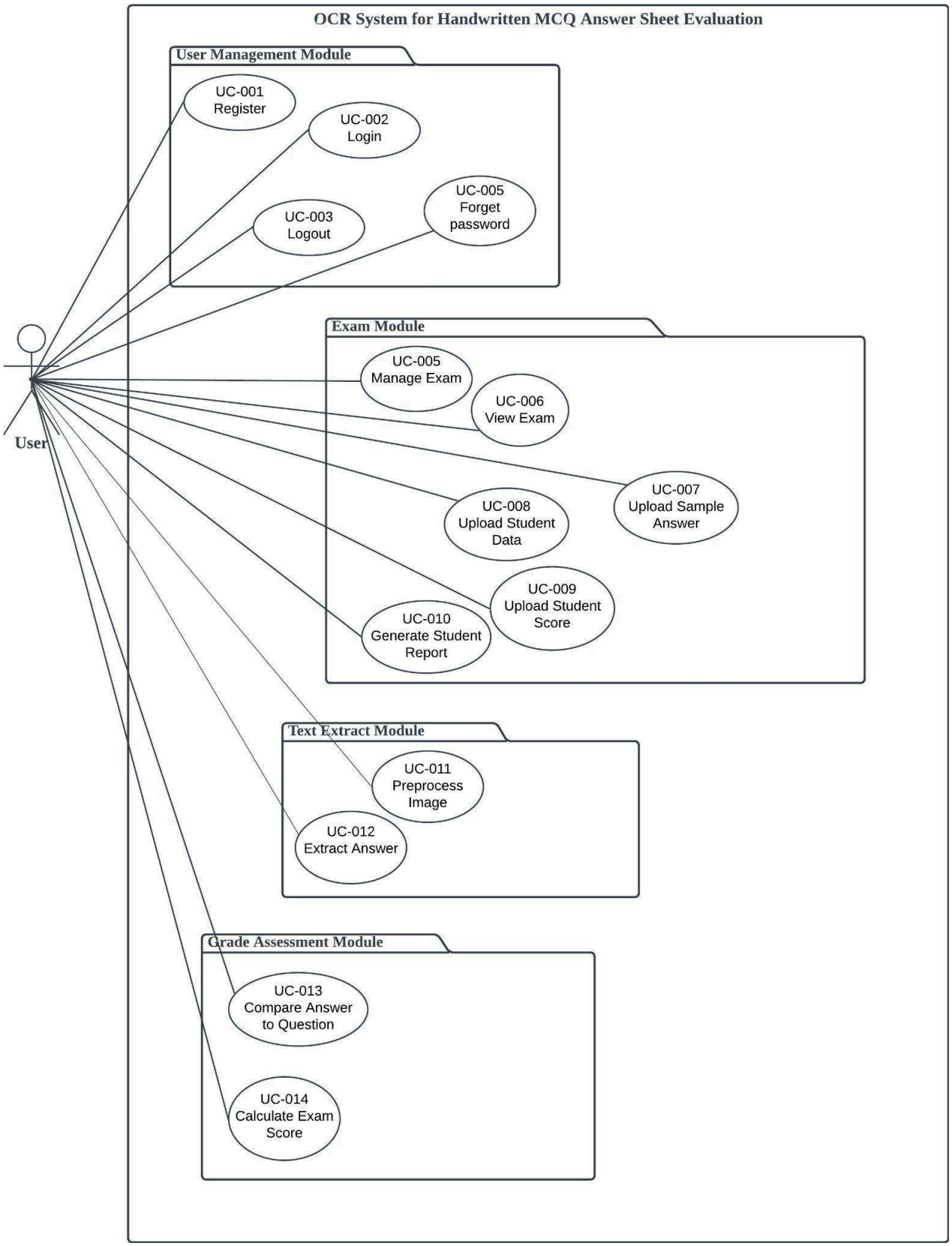
Diagram 4.5 : Entity Relationship Diagram For RajaKing

5.0 UML Modelling

5.1 Class Diagram

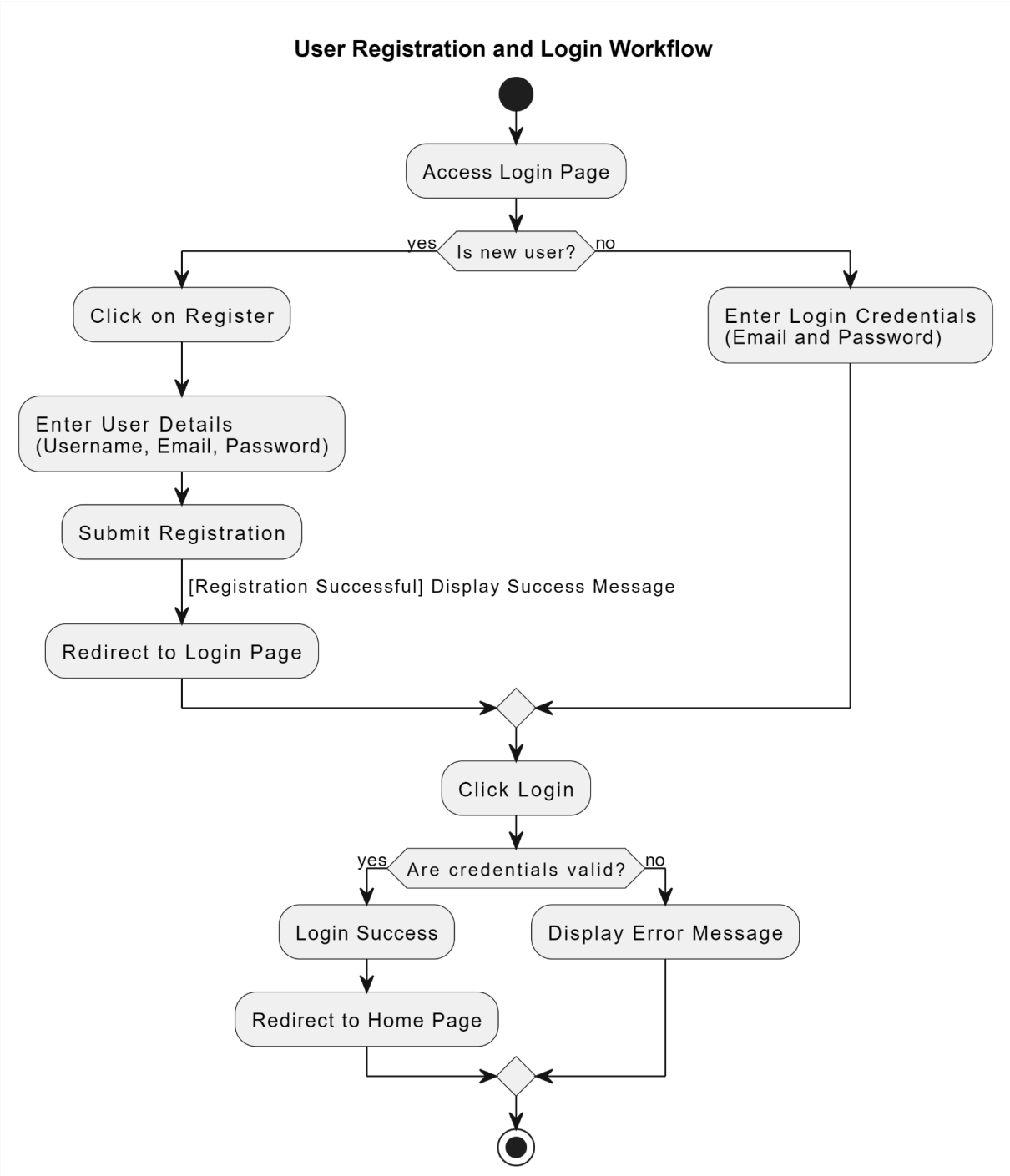


5.2 Use Case Diagram

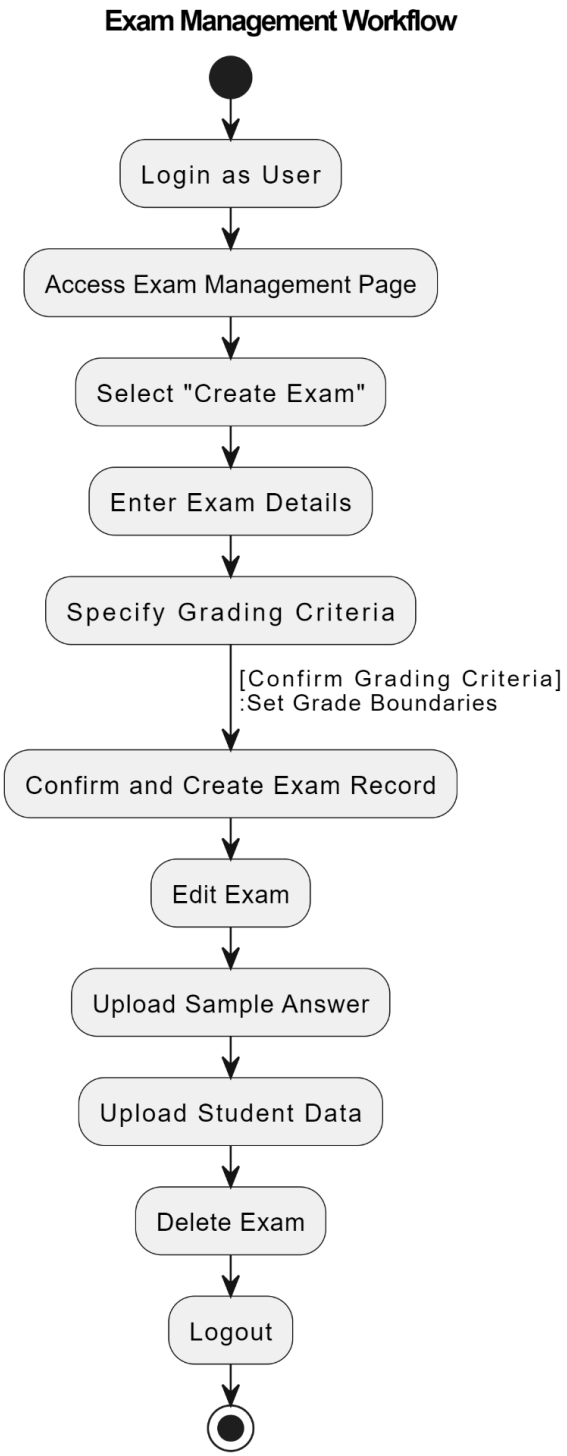


5.3 Activity Diagram

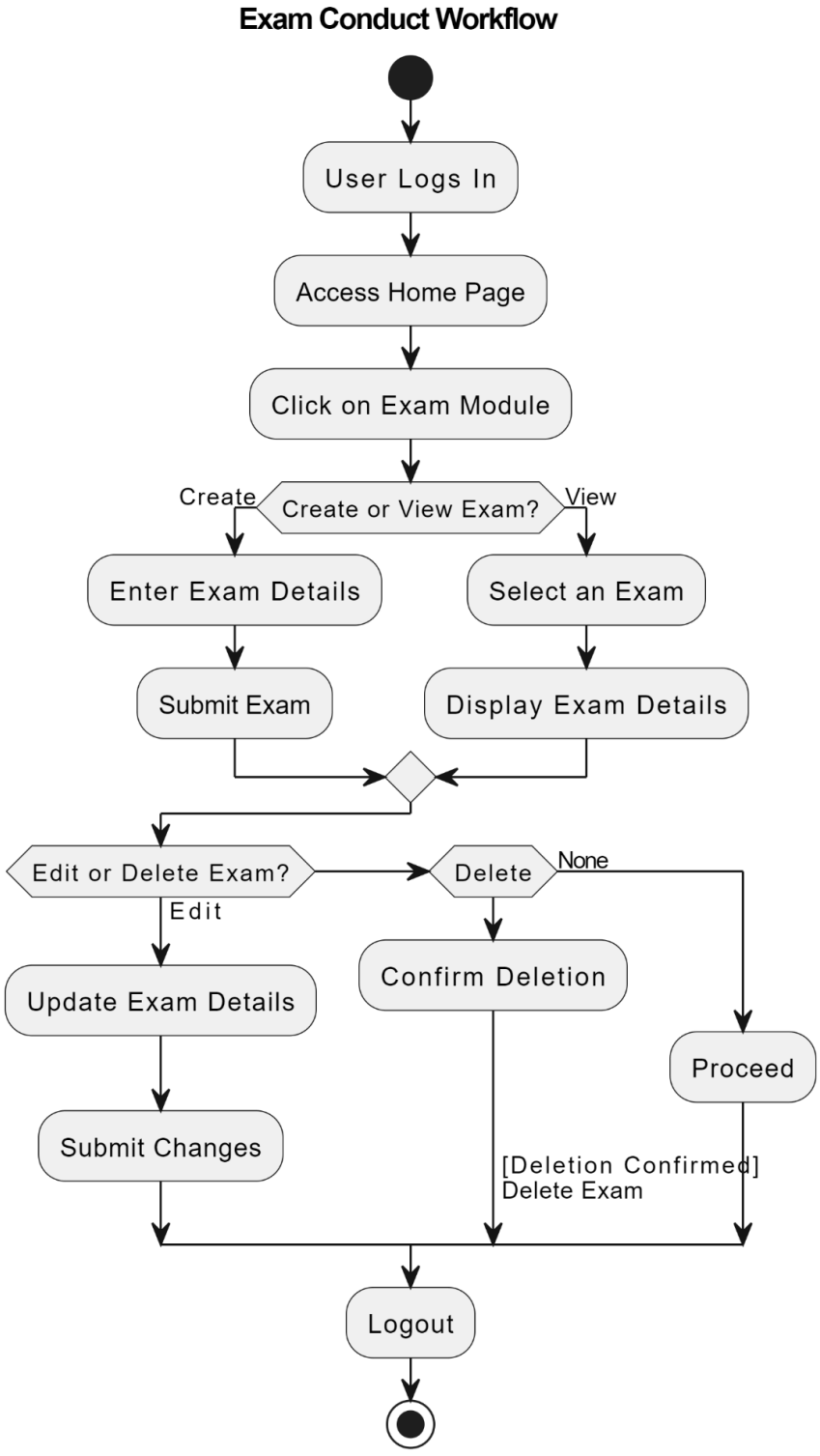
5.3.1 User Registration and Login



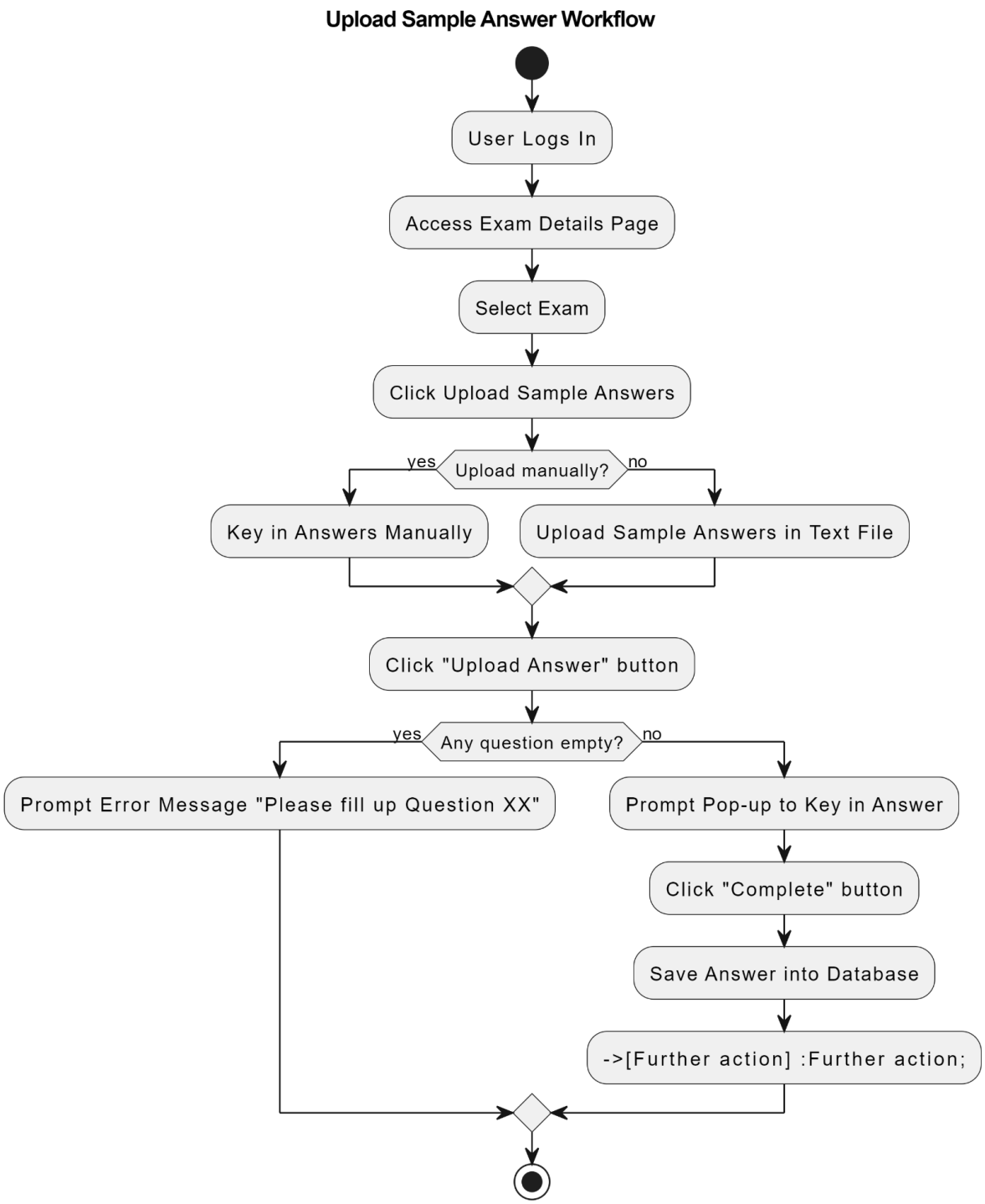
5.3.2 Exam Management



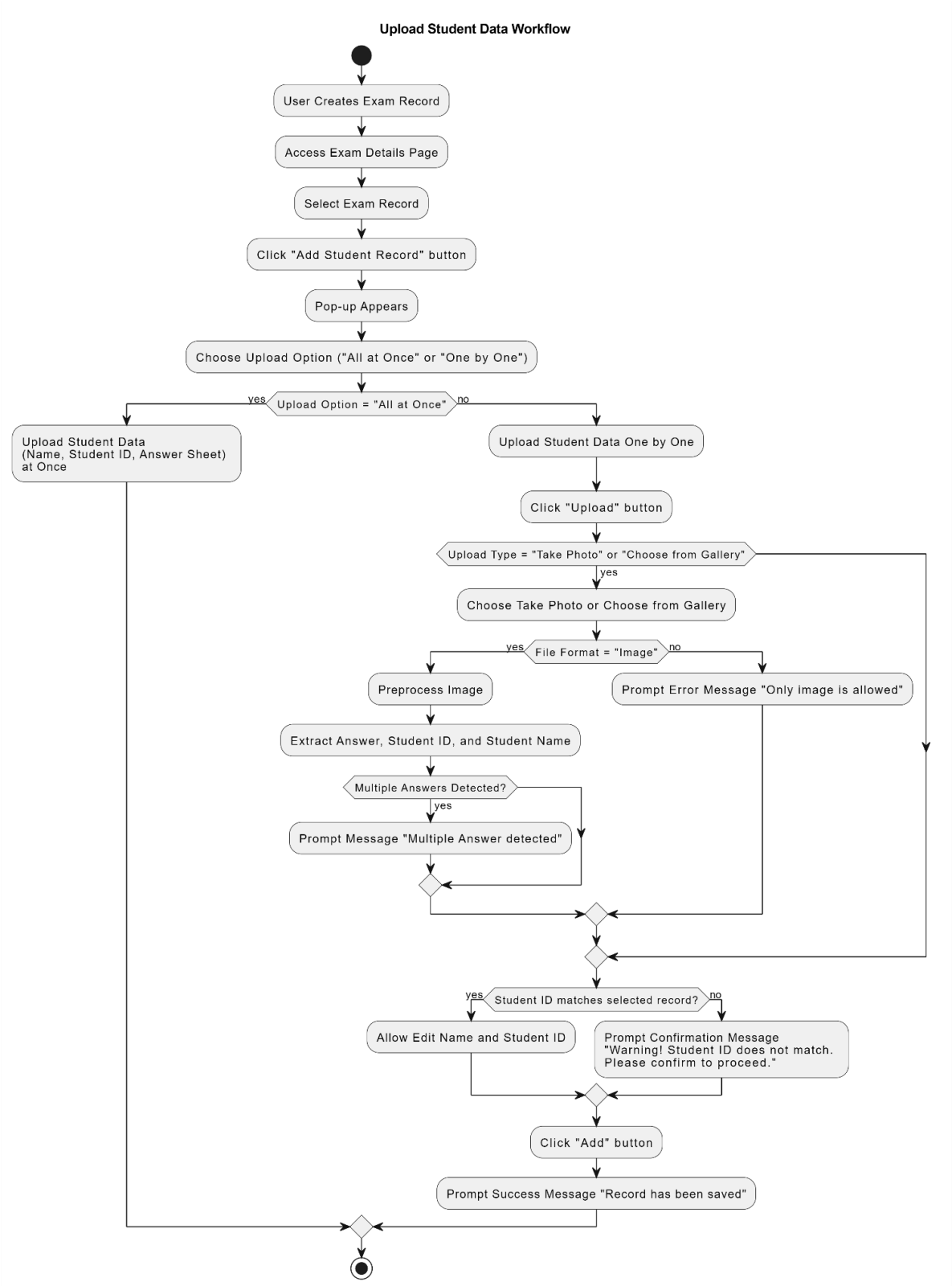
5.3.3 Exam Conduct



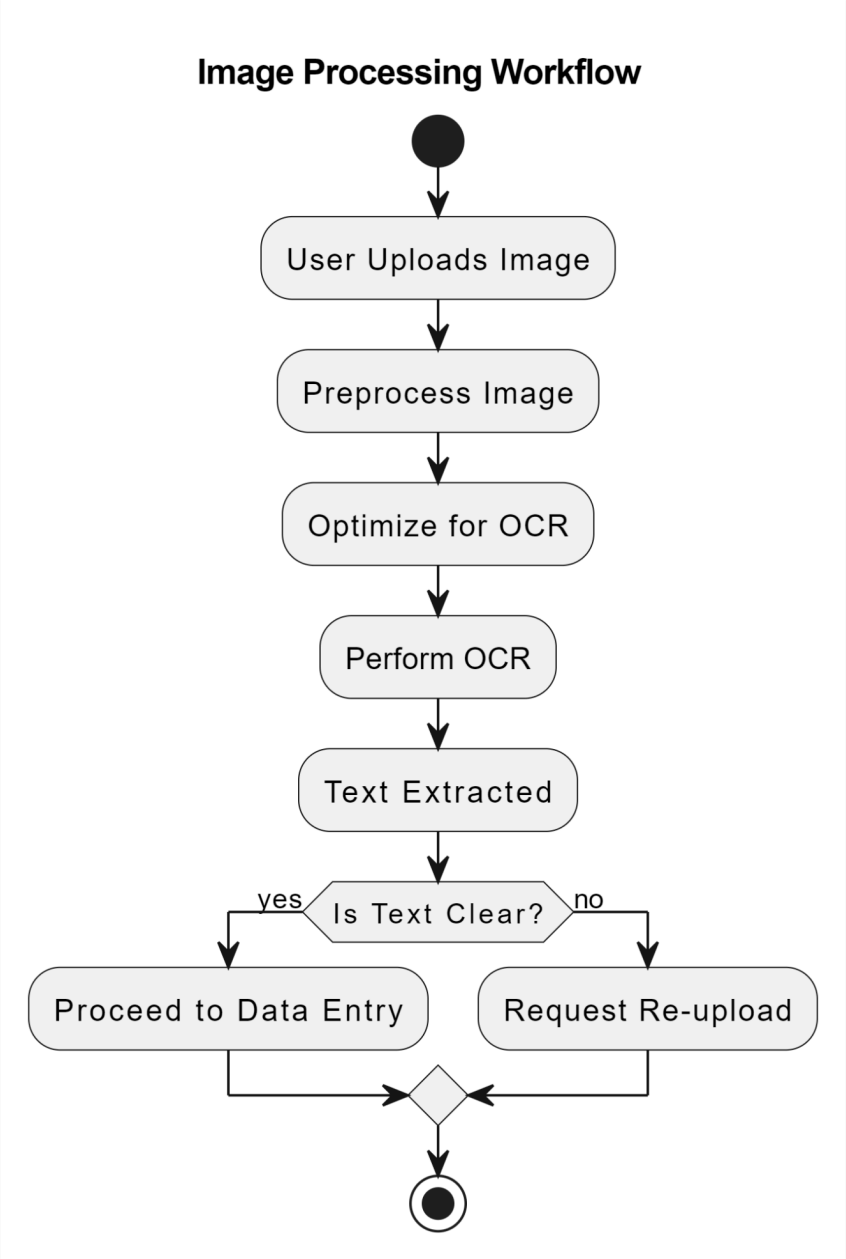
5.3.4 Upload Sample Answer



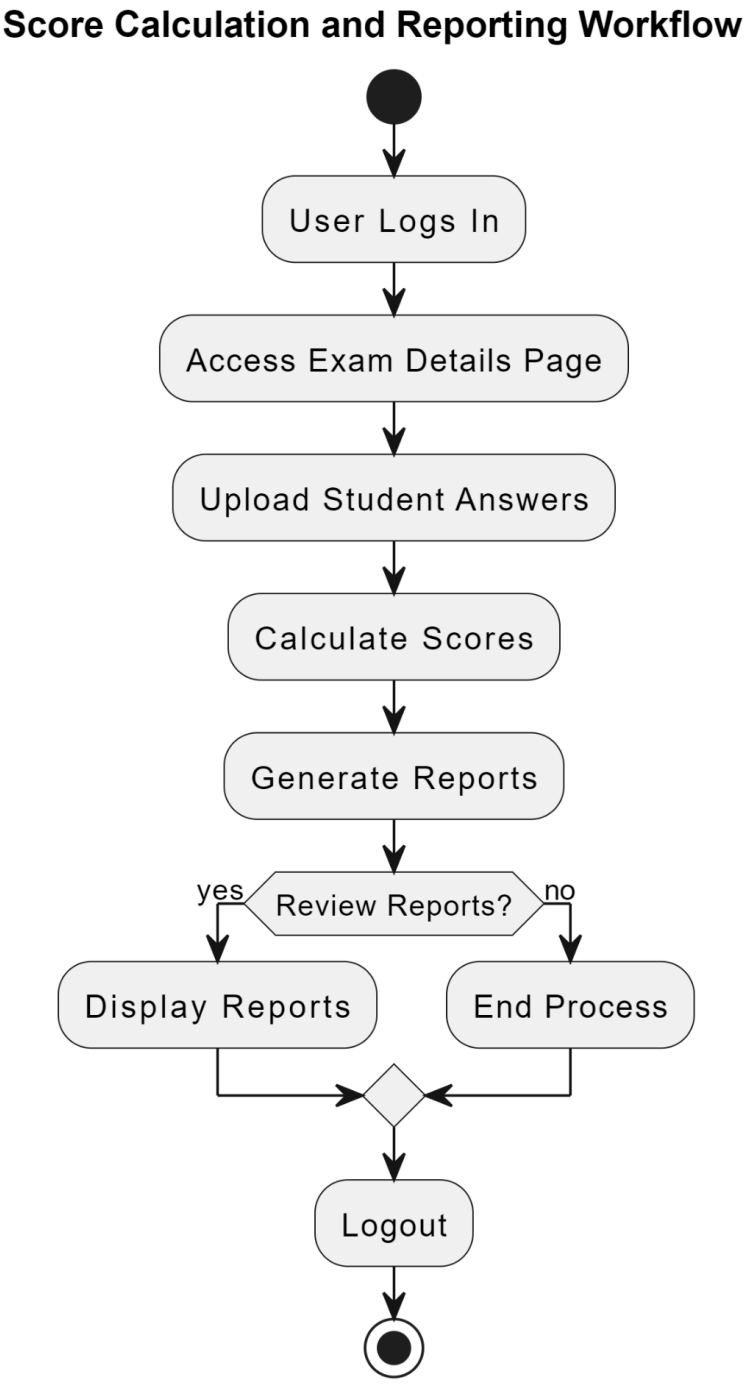
5.3.5 Upload Student Answer



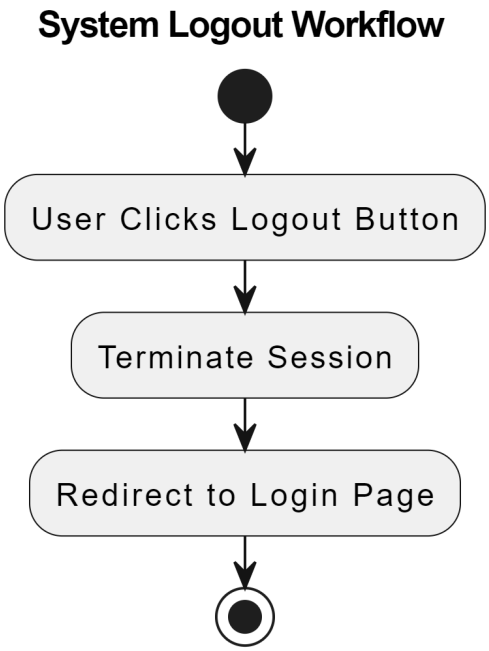
5.3.6 Image Processing



5.3.7 Score Calculation and Reporting

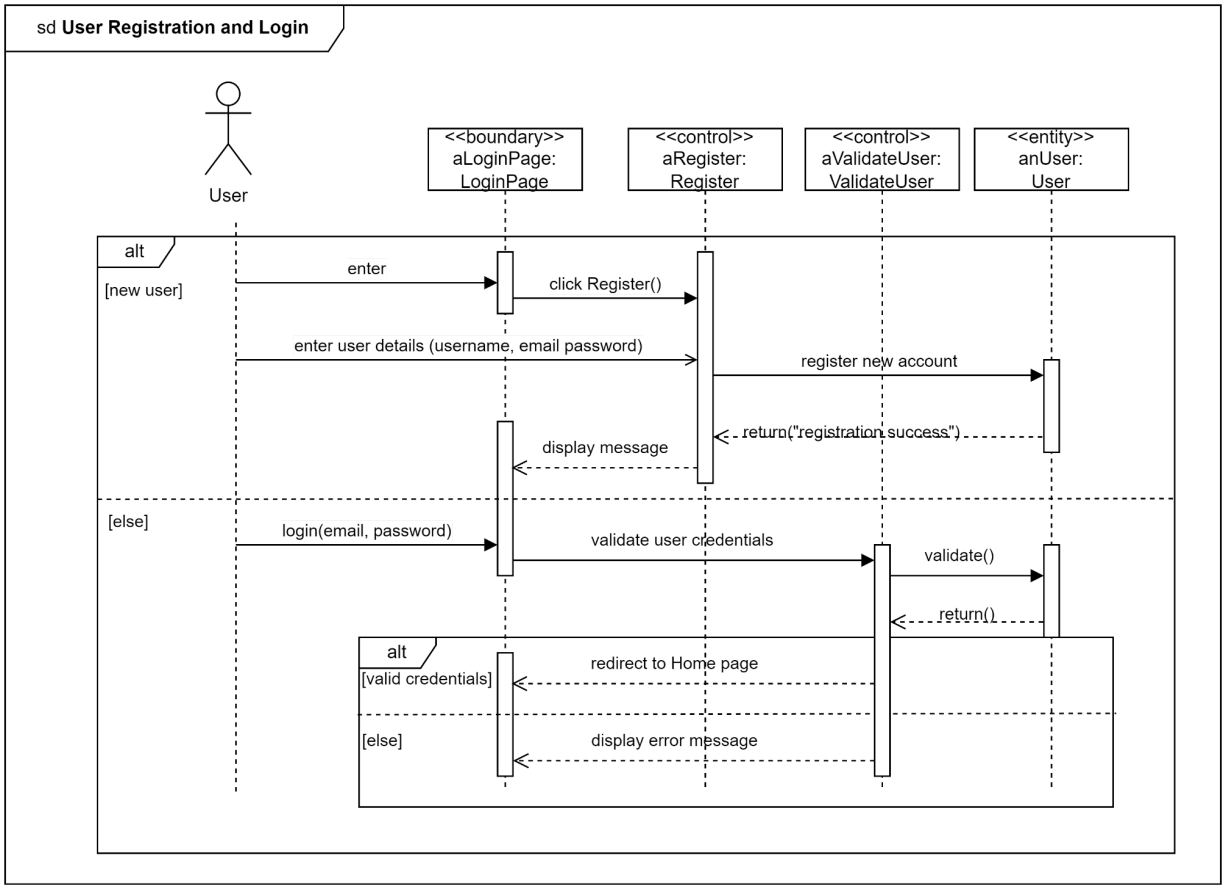


5.3.8 System Logout

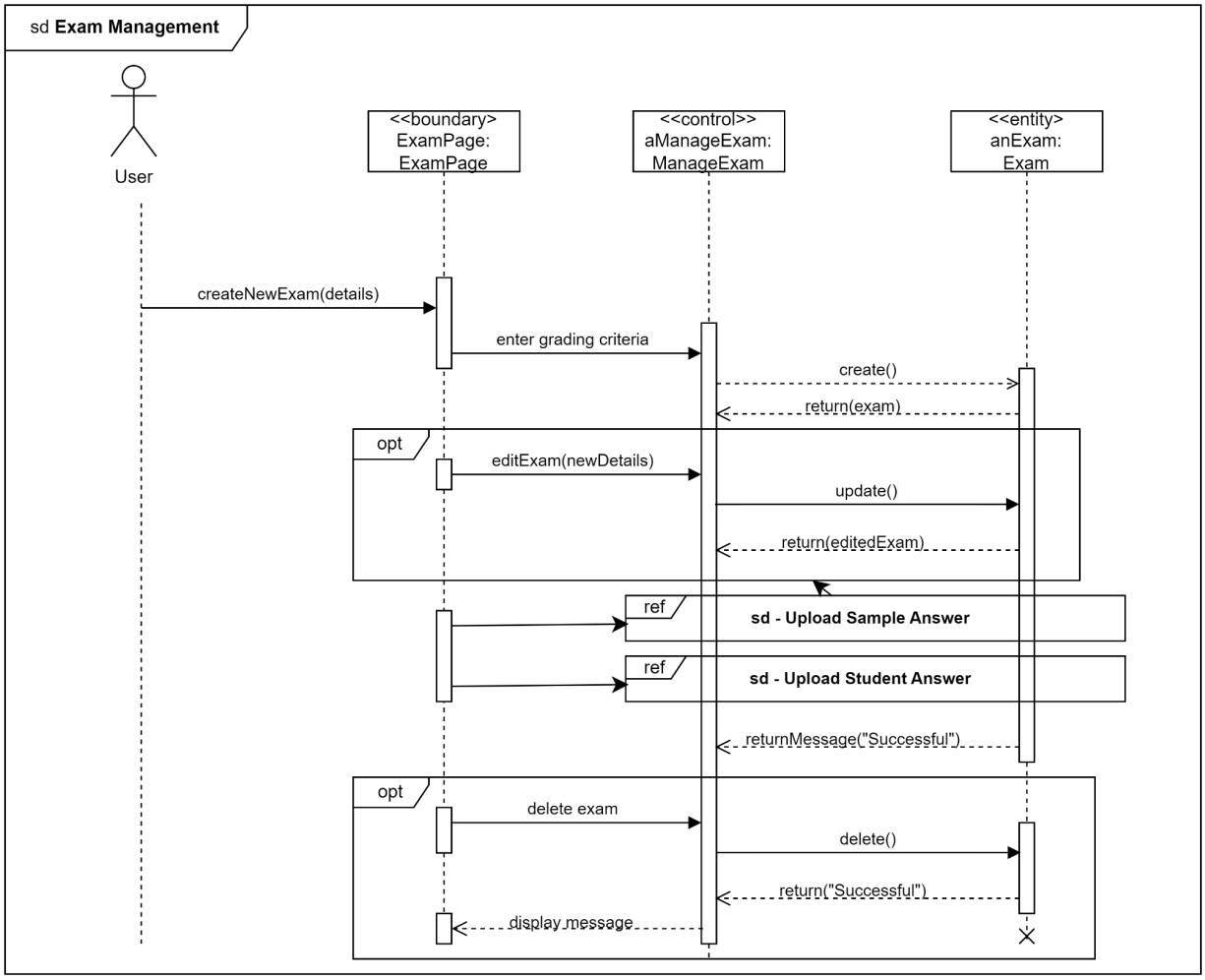


5.4 Sequence Diagram

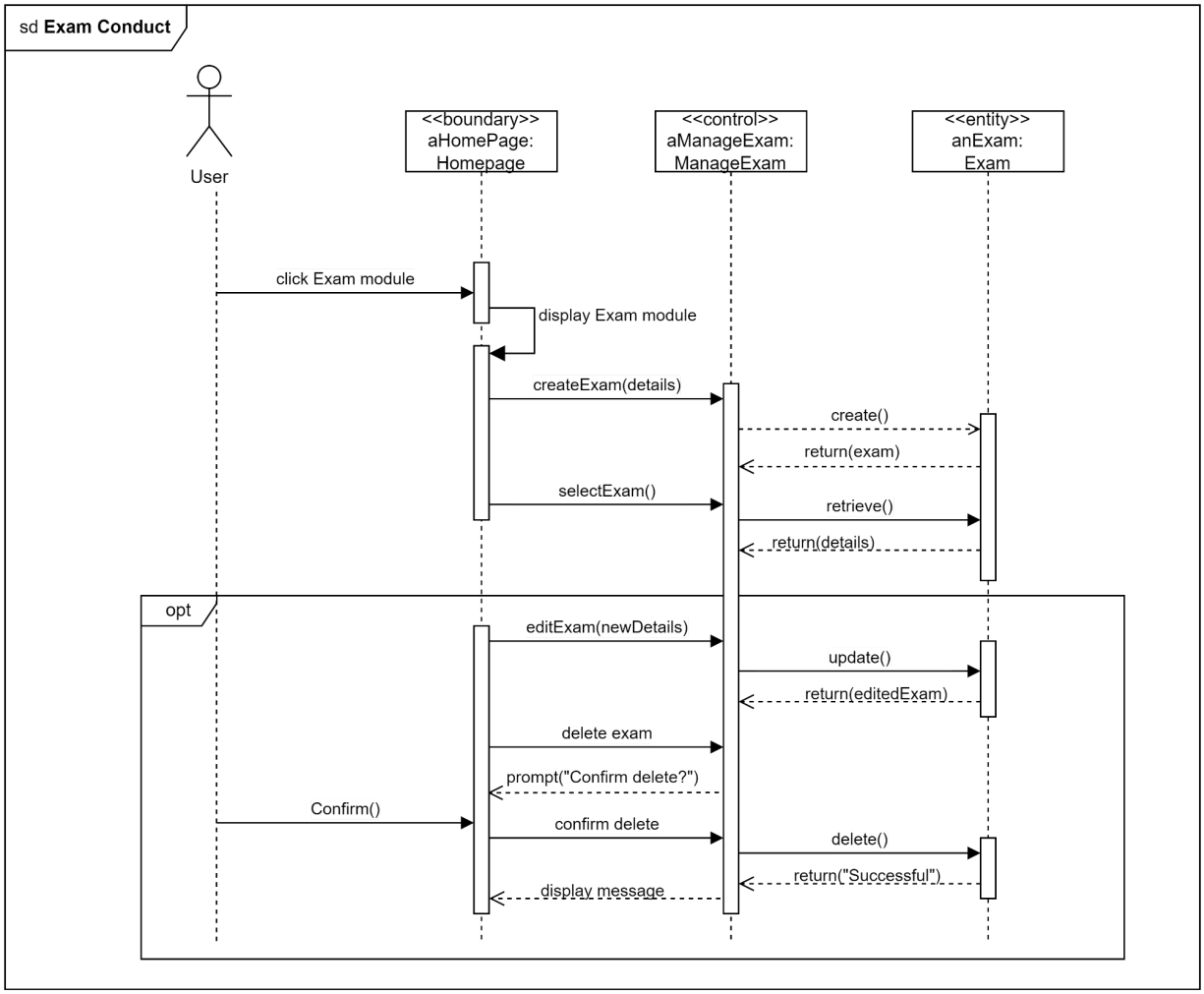
5.4.1 User Registration and Login



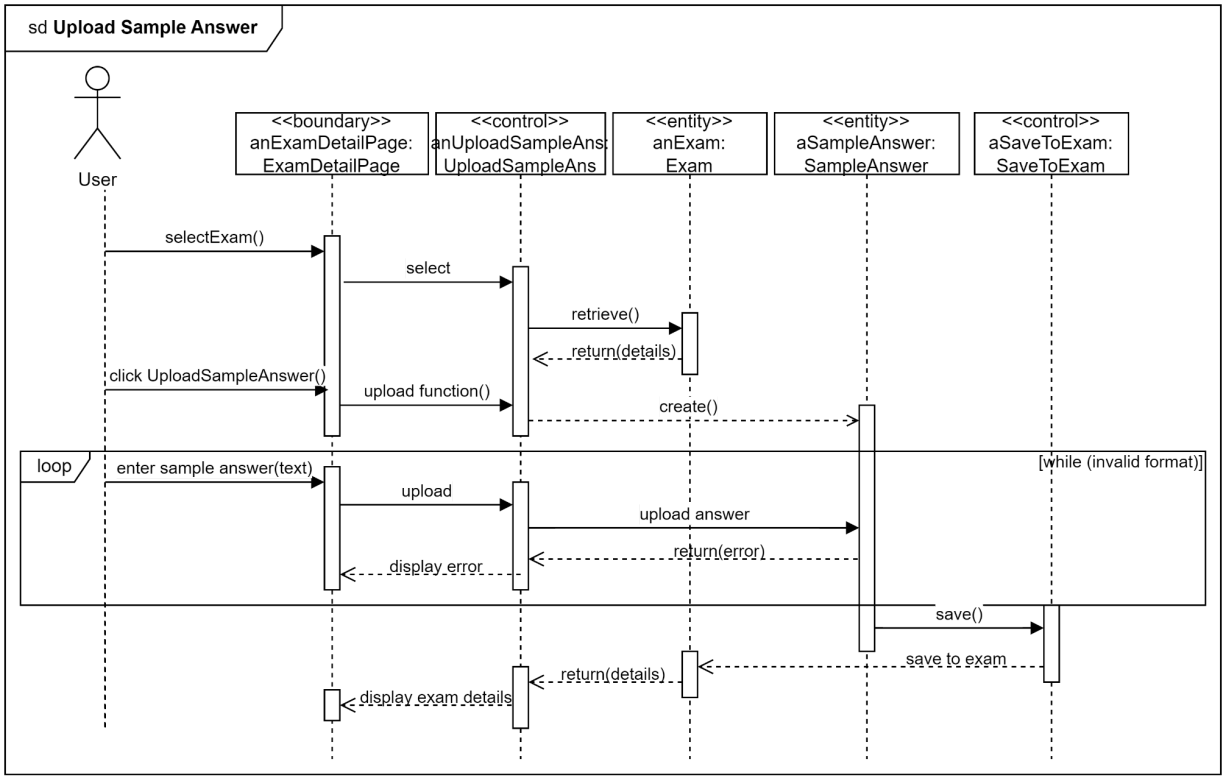
5.4.2 Exam Management



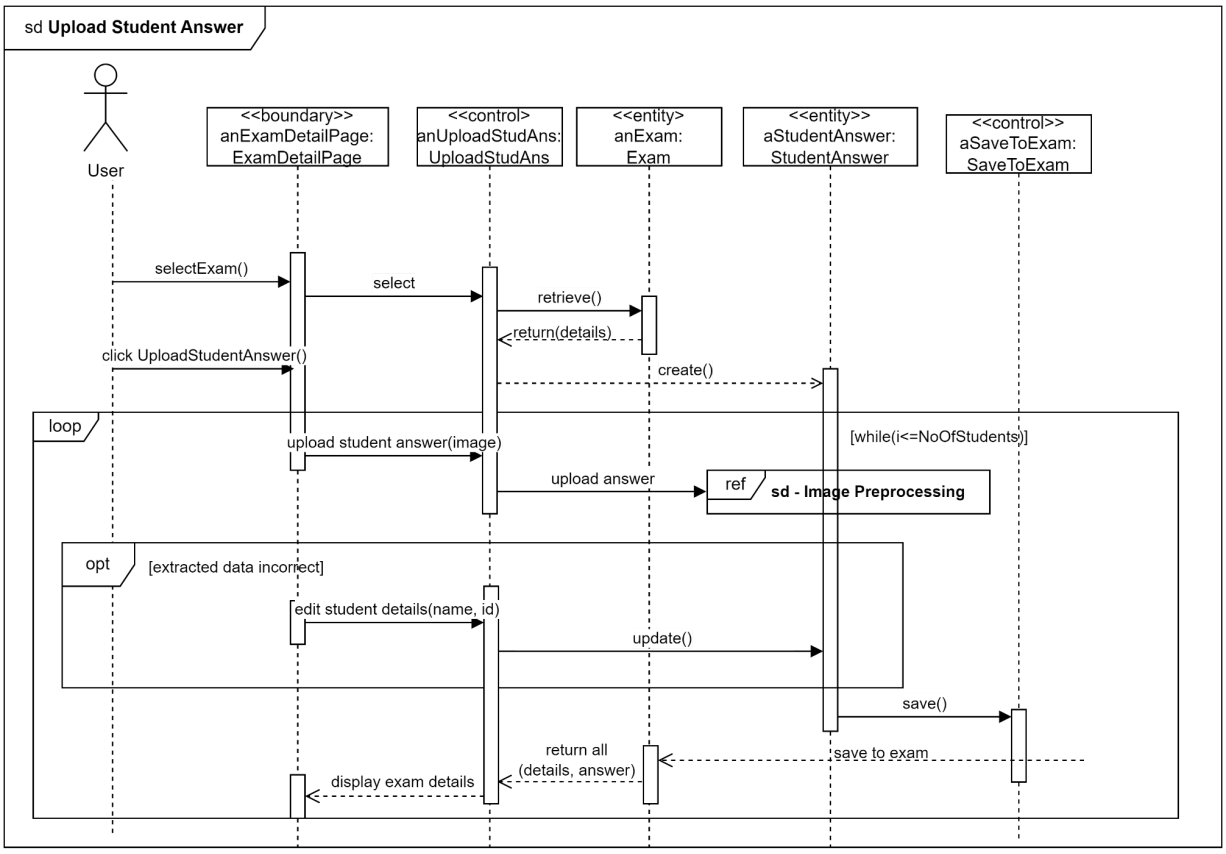
5.4.3 Exam Conduct



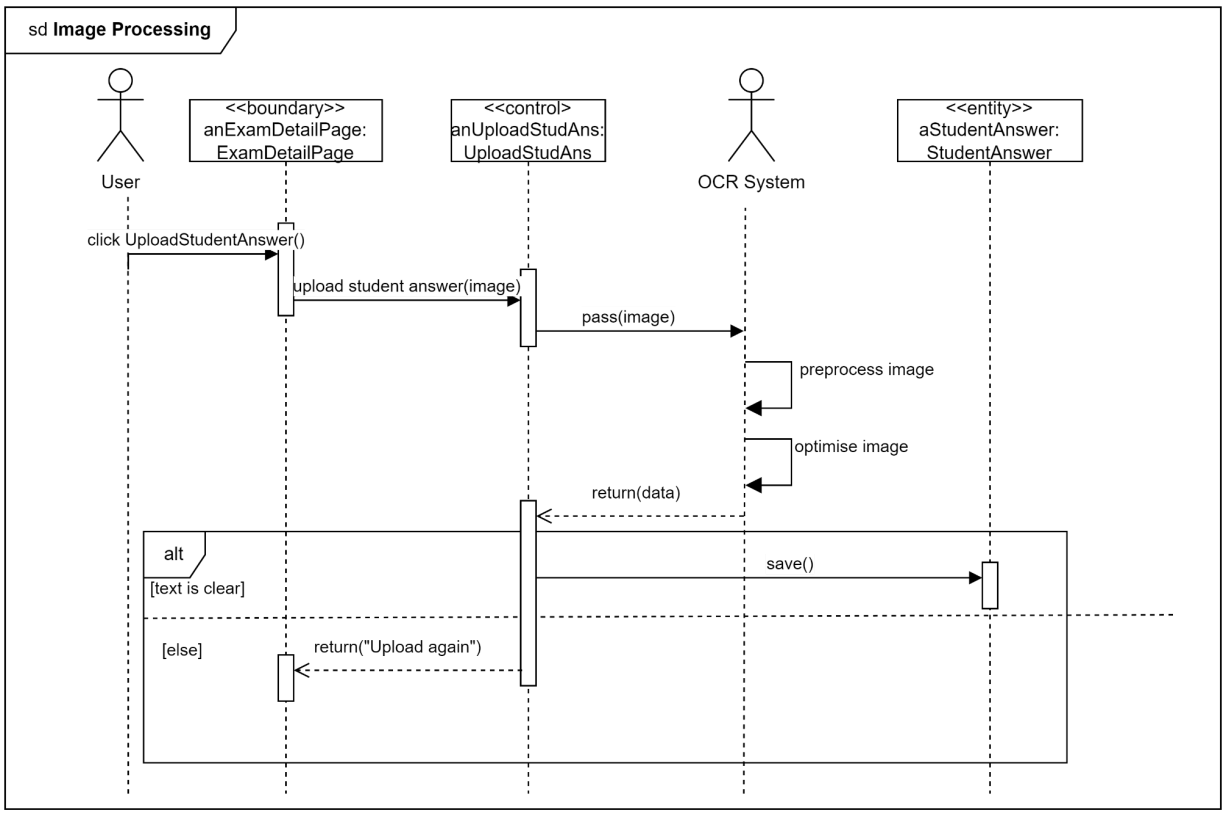
5.4.4 Upload Sample Answer



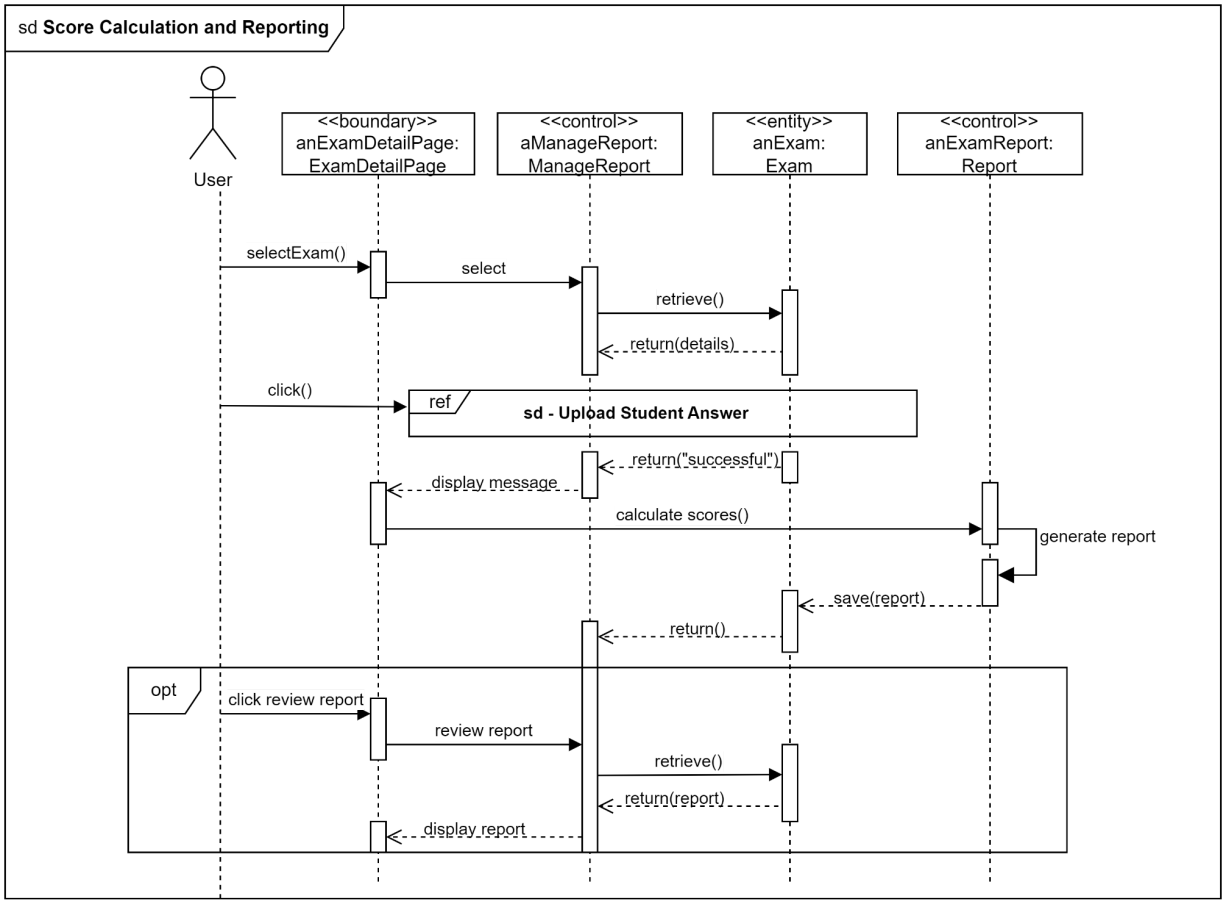
5.4.5 Upload Student Answer



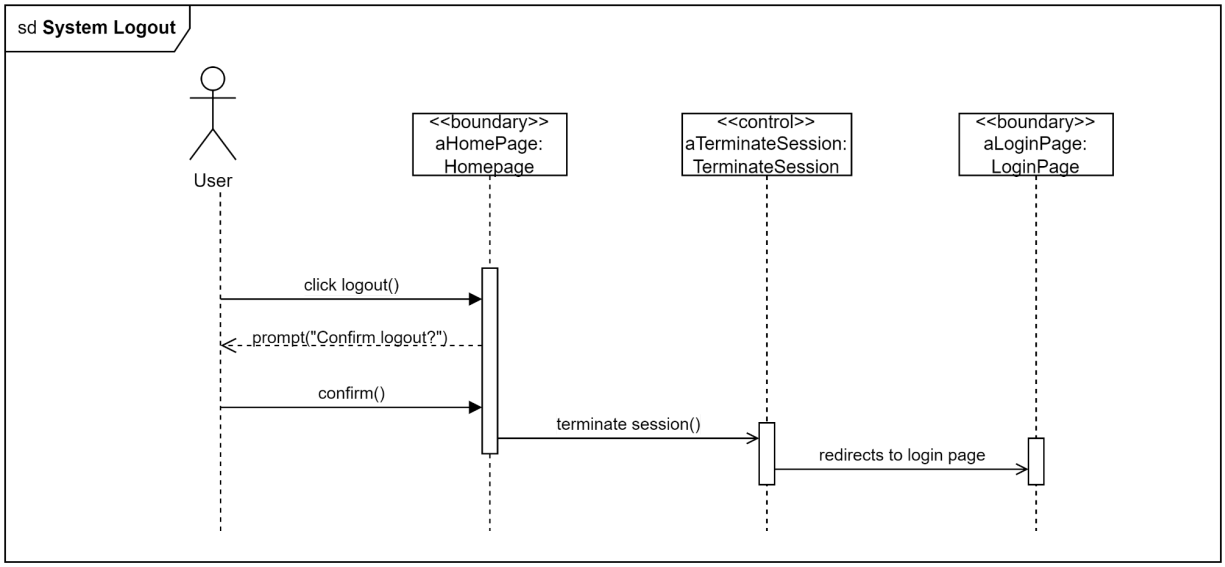
5.4.6 Image Processing



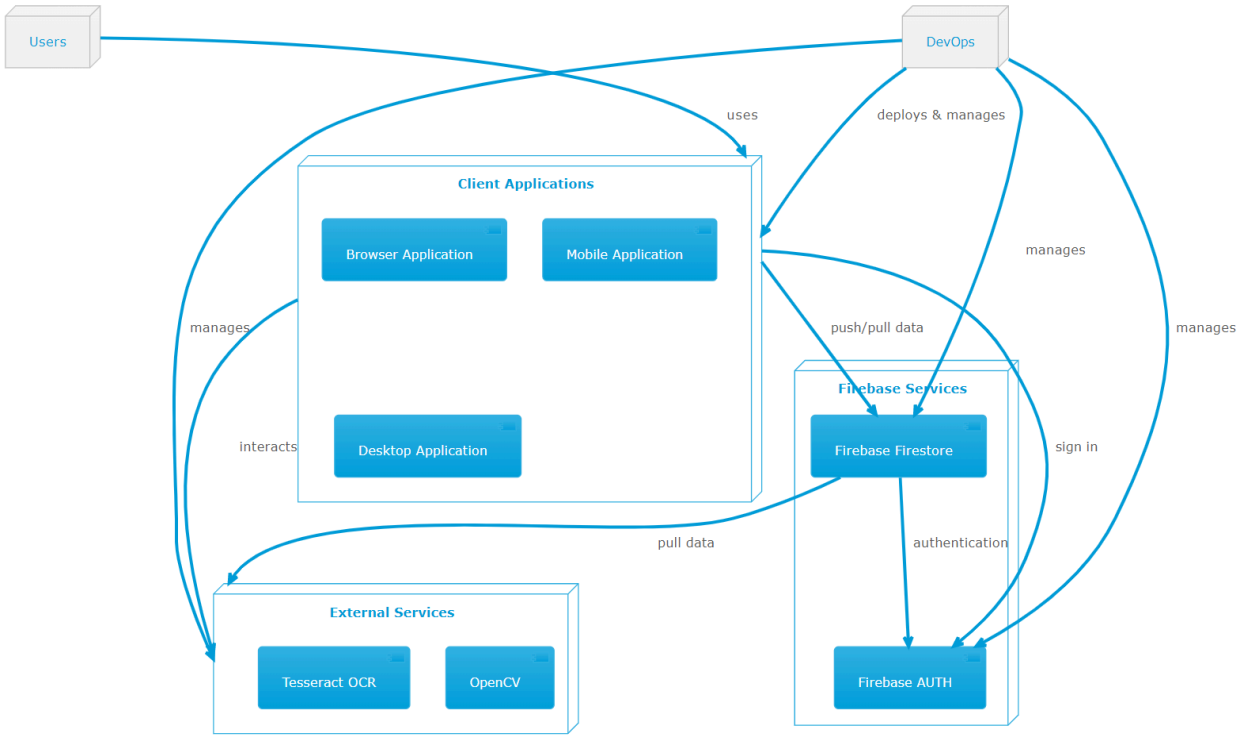
5.4.7 Score Calculation and Reporting



5.4.8 System Logout



5.5 Deployment Diagram



6.0 Main Issues

Upon developing the automated grading system for handwritten MCQ answer sheets using OCR technology, the team might encounter several issues as below:

- **Handwriting Variability**

  Handwriting can vary greatly among individuals, making it challenging for OCR technology to accurately interpret all types of handwriting styles. This variability may lead to inaccuracies in the recognition process, affecting the accuracy of the grading results.

- **Ambiguity in Answer Representation**

  Handwritten answers may not always be neatly aligned next to their corresponding question numbers, leading to ambiguity in answer representations. OCR algorithms may struggle to correctly match answers with the appropriate questions, especially if there are deviations from expected formatting.

- **Noise and Distortions in Scanned Images**

  Scanned images of answer sheets may contain noise, distortions, or imperfections that can interfere with OCR accuracy. Factors such as smudges, stains, creases, or poor scanning quality may degrade the performance of the OCR system, requiring robust image preprocessing techniques to enhance readability.

- **Mobile Responsiveness for Web Application**

  Designing a web-based application that is mobile responsive presents its own set of challenges. Optimizing the user interface and layout to accommodate various screen sizes, resolutions, and device orientations while maintaining usability and functionality is essential for a positive user experience.

- **Algorithm Complexity**

  Developing algorithms for question-answer matching and score calculation that can handle the variability and complexity of handwritten responses effectively requires careful consideration and testing. Balancing accuracy and efficiency while accounting for different handwriting styles, answer formats, and error scenarios is crucial for the success of the grading system.

7.0 System Design Document Version History

Version	Date	Links	Change Log
v0.1	5/4/2024	https://docs.google.com/document/d/1yx0NtTVOFVB24fXKMb4q6o6LbFyc1e5snVZVqFD8SJs/edit?usp=drive_link	1. Introduced functional requirements and non-functional requirements for the OCR system 2. Outlined basic system architecture and design principles using Firebase and Flutter 3. Detailed the authentication and exam modules for the system
v0.2	17/4/2024	https://docs.google.com/document/d/1hlpnRCznYBpCcIcnmlfbGslCZYWS1zxlP-Rv356aeHg/edit?usp=sharing	1. Updated SDD to refine the user authentication flow, particularly the registration and login procedures 2. Enhanced the exam management functionalities, including process of uploading the students' data and sample answer 3. Improved error handling across various modules to include more specific error messages or conditions 4. Revised non-functional requirements to emphasize system scalability and reliability 5. Added background, system objectives and main issues for the system 6. Expanded the architecture section to discuss modularity and the use of open-source products like OpenCV and Tesseract OCR

			7. Introduced initial UML models and sequence diagrams to better visualize system operations
v0.3	22/4/2024	https://docs.google.com/document/d/1Qr1WGjPWfmT-Jb3KPCz9UYHWJZQqnmYR/edit?usp=sharing&ouid=103601021233860471869&rtpof=true&sd=true	1. Update NFR 2. Added ERD database design under the system architecture session to further visualize the database design of the system 3. Added deployment diagram for the UML modelling to to ensure comprehensive understanding and implementation guidance 4. Updated sequence diagrams to specify boundary, control and entity class for each object 5. Added reference section 6. Added document change log section
v0.4	6/5/2024	https://docs.google.com/document/d/1A-eyBIIe1mVbb398r_yoAZoL5qJyCGDT/edit?usp=sharing&ouid=113871154722430685267&rtpof=true&sd=true	1. Updated sequence diagram based on QA review 2. Added ID for data model section, FRs, NFRs and constraints 3. Added user manual 4. Updated FRs for uploading students' answers and sample answers 5. Updated activity diagram for uploading students' answers and sample answers

8.0 References

Balachandran, V. (2024, March 25). How to create a software design Document. Document360. https://document360.com/blog/software-design-document/

Education, I. C. (2022, January 5). What is optical character recognition (OCR)? - IBM blog. IBM Blog. https://www.ibm.com/blog/optical-character-recognition/

Firebase Realtime Database | Store and sync data in real time. (n.d.). Firebase. https://firebase.google.com/products/realtime-database#:~:text=The%20Firebase%20Realtime%20Database%20is,app%20data%20at%20global%20scale.

Doan, D. (2024, March 26). Tesseract OCR: What is it and why would you choose it? Klippa. https://www.klippa.com/en/blog/information/tesseract-ocr/

Tripathi, P. (2023, December 27). Major limitations Of OCR technology and how IDP systems overcome them. https://www.docsumo.com/blog/ocr-limitations

Appendix

🗀 Meeting Minutes