Bilkent University - Computer Science

CS491 - Senior Design Project I

Project Specification Document

T2401

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1. Introduction

Medical school students encounter an overwhelming amount of information throughout their education. The academic study conducted by Dattathreya shows that medical school students have difficulty memorizing all of this information [1]. The reasons for these difficulties vary, but research indicates that most students rely heavily on lecture slides and avoid textbooks [2]. As a result, they are 'learning passively', they re-read the same material over and over again, which is an inefficient learning method that leads to memorization problems [3].

ReMediCard.io aims to solve these challenges and make studying easier for medical school students. In this report, the structure and specifications of the project are discussed.

1.1. Description

Recognizing the challenges inherent in medical education, we will develop ReMediCard.io—an AI-powered flashcard application designed to streamline the study process for medical students. By leveraging computer vision, machine learning, and natural language processing, our platform automatically generates flashcards from lecture notes, videos, and images, thereby reducing the manual effort required. This automation allows students to focus more on learning and less on preparation.

Furthermore, ReMediCard.io incorporates adaptive learning algorithms that tailor study sessions to individual progress and performance. This personalized approach not only enhances learning efficiency but also aligns with the diverse needs of medical students. Our commitment to innovation in medical education is underscored by the integration of these advanced technologies, aiming to provide a comprehensive solution that addresses both the academic and practical challenges faced by medical students.

1.2. High Level System Architecture & Components of Proposed Solution

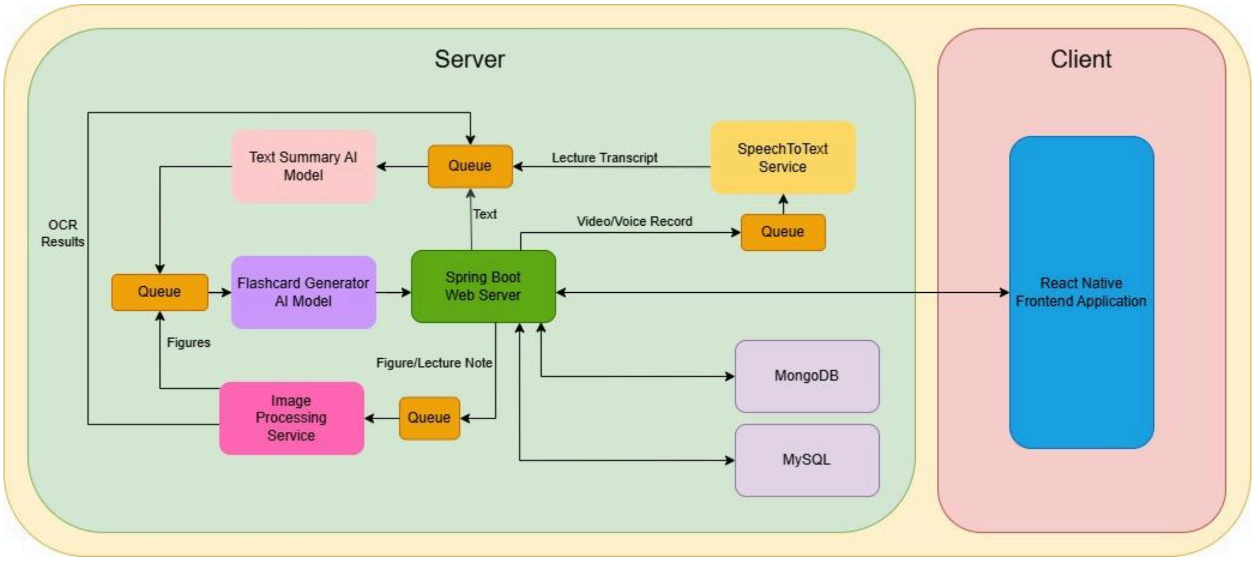

Figure 1: High Level System Design

Micro-service architecture will be preferred to manage diverse services in our application. A Spring Boot Web Server will interact with the front-end React-Native client and will manage requests between the other microservices. AI-powered Flashcard Generator Service will be used to generate flashcards and answer relevant questions. Video and voice records will be processed by the Speech To Text Service to extract the transcripts and feed them into the Text Summary Service. Similarly, images for the figures and the lecture notes will be first processed by the Image Processing Service and then will be fed to the Flashcard Generator Service.

There will be two different databases. MongoDB will be used to store text-indexed documents like notes and transcripts, which might be returned to the users as search results or feedback. MySQL will be used as the relational database for all the structured user data that must be stored persistently. Further, several queueing systems will be used for asynchronous processing of the inputs, avoiding blocking calls and waiting times for other services.

1.3. Constraints

We have defined some limitations within which the application must operate. Ensuring that our resources, technical capabilities, and ethical concerns align with the project goals and external requirements.

1.3.1. Implementation Constraints

Technological Requirements:

- The integration of machine learning models and computer vision tools requires robust frameworks such as TensorFlow, PyTorch, and OpenCV, along with substantial backend development for data processing.
- The app must handle various data types, including images, audio, and text, and ensure smooth interaction among different modules.

Computational Resources:

- High computational power is necessary for processing images, running ML algorithms, and transcribing audio to text. This may require the use of adequate cloud-based services.

Data Privacy:

- To safeguard user data and securely manage sensitive information, such as lecture videos and personal notes, it is essential to implement robust encryption and comply with established data protection protocols.

Platform Compatibility:

- The application needs to work across multiple mobile platforms (e.g., iOS, Android), leading to a need for cross-platform development tools.

1.3.2. Economic Constraints

Development Costs:

- Leveraging proprietary libraries or APIs for advanced functionality, such as speech-to-text conversion or specialized ML tools, could lead to licensing fees.
- There could be fees involved for the use of medical books, presentations, sample questions, and any other resources.

Server and Infrastructure Costs:

- Running AI models and storing multimedia data (images, audio, and video) may involve significant server costs, especially for real-time processing and storage.

Maintenance and Updates:

- Continuous updates, bug fixes, and model retraining to keep up with the latest advances in AI and maintain accuracy will require ongoing funding.

1.3.3. Ethical Constraints

Bias and Fairness:

- Machine learning models might introduce biases if not properly trained on a diverse dataset.
- The content and generated questions should be checked to ensure fairness and inclusivity.

User Consent:

- Users should be fully informed about data collection and use.
- Consent for processing audio and image data is crucial, and transparency regarding data storage and privacy should be maintained.

Intellectual Property:

- Care must be taken to avoid infringing on proprietary medical content and copyrighted materials when generating content.
- Data uploaded by the users should be checked by administrative personnel to prevent any abuse.

Accuracy and Reliability:

- Providing students with accurate information is crucial; incorrect or misleading content could have serious implications for their education and future medical practice.
- Professional help from the medical field is required to check the content used in the application.

Mental Health Considerations:

- A balanced approach should be maintained to prevent stress and cognitive overload in students by not overwhelming them with difficult questions or excessive repetitions.

1.4. Professional and Ethical Issues

As ReMediCard.io is planned to be an everyday application for medicine students, it contains professional and ethical issues. Such issues can be grouped in the below subheadings:

1.4.1. Data Privacy and Security

- The application will utilize private data such as lecture notes, voice recordings, and video recordings. Ensuring the safety and confidentiality of the user data is a must. In our project, we will encrypt all kinds of data during storage and transmission.
- We will use data protection regulations such as the General Data Protection Regulation (GDPR) [4] to ensure user data privacy.

1.4.2. Potential Problems of AI Usage

- The use of large language models (LLMs) such as ChatGPT or T5 may introduce bias in generated content. We will take steps to minimize the harmful biases in flashcards, questions, and feedback.
- The system will include disclaimers about the limitations of generated content to prevent reliance on potentially incomplete or incorrect information.

1.4.3. Accessibility

- The application aims to reach a large number of users. Hence, the system will support both Turkish and English to ensure people from different backgrounds can utilize the application.

1.4.4. Accuracy and Trustworthiness

- As the accuracy of information in flashcards and quizzes is crucial, the application will incorporate quality assurance measures, such as validating content against trusted medical sources.

1.5. Standards

The standards for ReMediCard.io include standards for software development, data handling, and user interaction:

1.5.1. Software Engineering Standards

- **IEEE 830-1998**: Used for documenting requirements specifications [5].
- **IEEE 1016-2009**: Will be used for system design description [6].
- **UML 2.5.1**: Will be used for system modeling, including use-case diagrams, activity diagrams, and sequence diagrams [7].

1.5.2. Data Security and Privacy Standards

- **ISO/IEC 27001**: Will be used for information security management to protect sensitive data and prevent unauthorized access [8].
- **GDPR Compliance**: Will be used to ensure the system is designed to meet European data protection standards for handling user data [4].

1.5.3. AI/ML Development Standards

- **IEEE 7001-2021**: Will be used for ethical considerations in AI design and development [9].

1.5.4. Coding Standards

- **Google Style Guide (Java)**: Will be used for Java development [10].
- **RESTful API Design Standards**: Will be used for integration and communication between system components.

1.5.5. Testing Standards

- **ISO/IEC/IEEE 29119**: Will be used for software testing to ensure reliability for testing of application features [11].

2. Design Requirements

2.1. Functional Requirements

- The user can register/login by using their email.
- The user can register/login by using their Google accounts.
- The user can reset their password using their email.
- The user can delete their account.
- The user can create custom flashcard decks.
- The user can create/edit custom flashcards and add them to the decks.
- The user can attach media(link, voice record, image, or video) to each side of a flashcard.
- The user can upload a video lecture record and generate a deck of cards automatically.
- The user can upload a voice record and generate a deck of cards automatically.
- The user can upload their lecture notes and generate a deck of cards automatically.
- The user can upload a figure with labels and generate the corresponding deck automatically.
- The user can upload test questions with their answers to the systems and can generate corresponding flashcards and similar questions.
- The user can automatically generate a test by selecting a set of flashcards or decks.
- The user can be shown flashcards based on the spaced repetition algorithm. For example, if they have struggled last time remembering the backside of the flashcard, they can expect to encounter it more often when reviewing the corresponding deck or vice versa.
- The user can get feedback for the solutions of the practice test questions in the application.
- The user can get indirect hints while solving test questions or before flipping the flashcards.

- The user can search flashcards, questions or media(if available) based on keywords.
- The user can monitor their study statistics.
- The user can share their flashcard decks with other users
- The user can see and use other user’s flashcard decks if the publishing user consents to share.
- The user can set study goals and receive notifications about these goals.

2.2. Non-Functional Requirements

2.2.1. Usability

User Friendly UI:

- A clean, simple, and visually appealing design will be applied
- The application will have easily understandable content where users can manage learning materials and create flashcards.
- The application will be designed in a way that users can easily learn and use different features of the application.

Easy Registration and Login:

- Users will be able to log in to the system more practically by registering, logging in via email, and integrating with their Google accounts

Responsive Design:

- The system should be designed to adapt to different screen sizes and devices.

Feedback:

- Users will be able to learn whether their actions were successful or not with visual or text-based feedback when using the application.
- Explanatory warnings will be presented to the user when incorrect or incomplete actions are taken.

2.2.2. Reliability

Uninterrupted Service:

- The system will be accessible to users at all times.
- In case of possible interruptions, the application will be put back into service as soon as possible.

Data Consistency and Management:

- User data and system logs should always be stored accurately and up to date.
- Systematic backups will be made to prevent data loss.
- In case of data loss, the system will be able to be quickly restored from the latest backup.

Version Control and Updates:

- Updates will be performed without harming existing user data and the ongoing system.
- A rollback procedure will be prepared, and in case of possible version update errors, this procedure can be followed to revert to the last working version.

Monitoring and Testing:

- The system will undergo extensive testing before deployment.
- New updates will undergo necessary tests before being released to the user.
- Once the system is deployed, it will be continuously monitored to identify performance and reliability issues.

2.2.3. Performance

User Interaction:

- The system should respond instantly to user actions, providing smooth interaction.
- The system should handle simultaneous active users without a reduction in performance.

Hosting:

- The project will be hosted in an environment strong enough to meet the required user demands.
- The hosting environment will be scalable to adapt to different levels of traffic and provide uninterrupted service during peak usage times.

Optimization:

- The application will be optimized to utilize system resources (CPU, memory, network) efficiently, ensuring no waste of resources.
- The system will be designed to meet user demands without compromising performance.

2.2.4. Supportability

Documentation:

- The reports and documentation we prepare will contain the necessary information about how the system is built and works.
- The structure and working procedure of new updates will be added to the documentation.

User Support:

- Detailed user manuals and FAQs will be provided for ease of use.
- Users will be able to report problems they encounter, and they can seek assistance through support channels such as email.

Compatibility:

- The mobile application will be compatible with commonly used mobile operating systems.
- The website will be compatible with commonly used browsers.
- The system will be tested regularly to ensure compatibility with newer versions of browsers and operating systems.

2.2.5. Extensibility

Architecture:

- The system will be built in a way that allows for the easy addition of new features or components without breaking the existing ones.
- New functions can be integrated into the core system with minimal changes, providing flexibility for future updates.
- The data will be scalable as the user needs and traffic increases.
- Additional data can be added without requiring significant changes to the database.

Third-party Integrations:

- The system will support easy integration with third-party tools and services, such as cloud storage platforms and Google accounts.

2.2.6. Scalability

The system will allocate computation resources elastically to satisfy the dynamic workload stimulated by the user activity to avoid potential latencies and unpredicted downtime. It will adjust to user demand, and the use of computation resources will be cost-effective.

2.2.7. Security & Privacy

The system will comply with modern secure authentication/authorization design practices such as role-based authorization and Oauth2 to provide a secure, personalized experience for the end users. User data transactions will be done atomically to avoid partial updates and data losses. Sensitive user data will be encrypted in transit to secure user privacy.

2.2.8. Maintainability

The system design will consist of modular structures (services) to allow updates to be added with ease, and each modular service will be independently modifiable. The project will be maintained with Git to keep track of changes in the source code.

2.2.9. Availability

The system will have a fault-tolerant infrastructure with load balancers and disaster recovery scenarios providing high uptime. With the redundancy of the compute resources and a scalable architecture, the system will fit into the variable user demand.

2.2.10. Localization

The system will support multi-regional use through multiple languages (Turkish and English) and date formats. This will allow the students with different languages of study to use the application without any problems.

3. Feasibility Discussions

3.1. Market & Competitive Analysis

Global flashcard application market value is approximately USD 130 million, and it has been predicted to reach USD 230 million by 2030 [12][13], presenting robust growth driven by distinct trends and user preferences.

Currently, there are several applications that serve medical students in the market, but yet none of them really address the challenges of flashcard creation using advanced automation and personalization technologies. Existing applications like Anki and Quizlet provide tools for manual flashcard creation and limited customization, but they require significant time investment from students, which can be particularly challenging for medical students who have a lot of workload.

Anki and Quizlet are popular applications offering spaced repetition features. However, Anki in specific lacks the ability to automate flashcard generation from legacy lecture materials like handwritten notes [14]. Although Quizlet has a document scanning feature and lets users select specific words from the document they provide, it still depends on the user control to create flashcards manually [15]. ReMediCard.io bridges this gap by using computer vision to extract and format relevant information.

3.2. Academic Analysis

The research about flashcard usage highlights that spacing learning events apart using flashcards—instead of cramming—significantly improves long-term retention. This technique strengthens the spacing effect, a robust phenomenon where spreading out study sessions enhances memory compared to studying items repeatedly in close succession. Studies found that using larger stacks of flashcards in spaced intervals outperformed smaller, massed stacks, and was beneficial for 90% of participants tested. Despite these findings, many learners mistakenly believe that mass study is more effective due to the immediate ease of recall it offers during practice [16]. ReMediCard.io will change this belief by making the flashcard creation easier.

Medical students generally struggle with the vast volume of information and the need for memorization without an efficient technique. A study published in BMC Medical Education states that many students employ self-regulated learning techniques, including the use of flashcards, to manage their academic workload effectively. However, the manual creation of flashcards can be time-consuming and wasteful in terms of study time [2].

Advancements in computer vision and machine learning enable the extraction of data from the so-called legacy materials like lecture notes, figures, and videos. Tools such as OpenCV for image processing and TensorFlow/Pytorch for natural language processes facilitate these features.

4. Glossary

AI (Artificial Intelligence): AI is the field of computer science that investigates how machines provide intelligent responses to encountered situations.

Computer Vision: Computer vision is a field of AI that uses machine learning and neural networks to teach computers and systems to derive meaningful information out of visual inputs.

Flashcard: Flashcards are cards with both sides containing information related to each other. Usually, one side is for questions, and the other side is for answers. These cards are used for studying.

LLM: Large Language Models are advanced AI systems trained on huge datasets to understand and generate human-like text.

Machine Learning: Machine learning is a branch of AI that focuses on using data and algorithms to enable AI to imitate the way humans learn.

Natural Language Processing (NLP): NLP is the field of computer science that focuses on making machines understand and use the languages used by humans.

Spaced repetition algorithm: Evidence-based learning technique where newly introduced or harder problems are shown more frequently. On the other hand, older and well-understood problems are shown to the user less frequently.

Speech-to-Text: A technology that converts spoken language into written text using automatic speech recognition systems.

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