QuestionCraft: Reinforce Knowledge, Enhance Understanding

King Monkut's University Of Technology Thonburi

Submitted by

64130500255 Khush Agarwal

Present

Assoc.Prof.Dr. Jonathan Hoyin Chan

Course CSC494 Natural Language Processing

Semester 1, Academic Year 2024

Table of Contents

Introduction:

This project aims to develop an AI-powered system that enhances student learning and engagement through automated question generation and evaluation. By utilizing advanced AI models, we intend to create a dynamic platform that generates diverse, contextually relevant question sets to support active recall and scaffolded learning. The system will aid comprehensive exam preparation by offering tailored question sets on various topics, thereby improving students' understanding of the content. By providing easy access to questions on relevant subjects, the system promotes deeper comprehension and reinforces learning. Drawing on research that shows the effectiveness of active recall over passive reading, our approach offers students a practical method for testing and reinforcing their knowledge on selected topics in relevant contexts.

Scope:

The project will develop an intelligent question generation and evaluation system capable of analyzing educational documents, generating diverse question-answer pairs, and providing a platform for students to practice and prepare for exams. The scope includes integrating advanced AI models for natural language processing, embedding techniques for content clustering, and developing a user-friendly interface to support interactive learning experiences.

Objectives:

1. **Automate Question Generation:** Create a system to automatically generate question-answer pairs from educational documents, utilizing advanced AI models for natural language understanding and generation.
2. **Integrate Advanced AI and Embedding Techniques:** Utilize tools such as Llama 3.1-ChatNVIDIA and nv-embedqa-e5-v5 to ensure high-quality question generation and relevance, supported by Faiss for efficient storage and retrieval of embeddings.
3. **Develop an Interactive Platform:** Build a user-friendly frontend using Gradio, allowing educators and students to upload documents, interact with generated questions, and customize question sets.

Problem Statement:

Students often face challenges with traditional study methods that emphasize passive learning, such as re-reading textbooks or reviewing notes. Research suggests that these approaches can be less effective in promoting long-term retention and deeper understanding of complex subjects compared to active learning techniques (Vallino, 2003; Mahmood et al., 2011). Additionally, the lack of dynamic and contextually relevant question sets tailored to individual learning needs may hinder effective exam preparation and the ability to identify knowledge gaps. Active recall methods, which involve answering questions or retrieving information from memory, have been shown to be more beneficial for retaining information and developing critical thinking skills (Diepreye & Odukoya, 2019; Kooloos & Bergman, 2020). Therefore, there is a pressing need for a solution that provides customized and varied question sets to enable students to actively engage with the material, enhance comprehension, and build confidence in their knowledge.

Solution Statement:

To address these challenges, we propose the development of an AI-powered system designed to transform how students learn and prepare for exams. This system will leverage advanced AI models to automate the generation and evaluation of questions, creating dynamic and contextually relevant question sets aligned with the student's curriculum. By focusing on active recall and scaffolded learning, the system will help students transition from passive study methods to more engaging forms of learning (Ang et al., 2021; Matthews, 1997). The AI-driven approach will facilitate the creation of diverse question formats—including multiple-choice, short answer, and critical thinking questions—tailored to individual learning needs. This comprehensive tool for exam preparation will promote a deeper understanding of the material and allow easy access to questions that reinforce specific areas of knowledge. Integrating research-backed methods, such as testing and recalling information, provides an effective way for students to track their progress and confidently master their chosen topics (Michel et al., 2009; Minhas et al., 2012).

Segmentation and Target Audience:

Students/Learners: The primary target audience includes students from various educational levels who are studying core subjects such as Science and English. These students will benefit from structured question sets directly aligned with their curriculum, enabling them to engage more deeply with the material and improve their understanding of key concepts. The AI-powered system will offer specialized question sets tailored to their specific fields of study, helping them prepare more effectively for exams and other assessments.

Features:

Automatic Topic and Subtopic Identification:

- The system can automatically analyze and extract topics and subtopics from uploaded documents. This feature helps students pick a particular topic, subtopic they want to learn about ensuring focus, relevant questions and answers.

Dynamic Question Generation:

- The system dynamically generates a diverse range of questions based on the topics and subtopics identified from the uploaded documents. This includes various formats such as multiple-choice, short answer, and essay questions. Each question is accompanied by detailed answers and explanations that help clarify why a specific answer is correct, thereby enhancing the learning experience through deeper comprehension and active recall. The dynamic nature of this feature allows for continuous adaptation to the user's evolving understanding and study needs.

Question Customization:

- The system offers significant flexibility by allowing users to generate additional questions as needed and customize question formats to align with their specific objectives. Users can adjust question difficulty, types, and focus areas to better meet their unique study or teaching requirements. This customization feature facilitates the creation of diverse question sets, which helps in maintaining engagement and addressing individual learning preferences.

Intuitive User Interface:

- The platform features a highly intuitive and user-friendly interface designed to simplify the process of document uploading and question management. Users can easily navigate through various functionalities, view questions and answers, and choose to expand or collapse detailed explanations for a streamlined experience. This design minimizes the learning curve and maximizes usability, making the system accessible to users with varying levels of technical proficiency.

Advanced Assessment Creation (Optional):

- For users seeking a more comprehensive evaluation tool, the system offers an optional advanced assessment creation module. This feature allows users to design assessments that include a mix of multiple-choice questions, short answer questions, and essay prompts, all based on the content of the uploaded document. The assessments come complete with answers, evaluation criteria, and explanations. Additionally, the AI

provides automated grading and detailed feedback on these assessments, helping users to better understand their strengths and areas for improvement. This functionality is particularly useful for educators and students looking for thorough, personalized assessments.

Technology and Methodology:

Backend:

APIs with Lang Chain and LangServe: Develop backend APIs for handling requests such as document upload, question generation, and evaluation.

Content Analysis and Retrieval:

Document Loaders: Use document loader to facilitate uploading of documents and converting them to relevant format and creating chunks.

Embedding and Vector Search: Utilize tools like Faiss as vector stores and embeddings to store and retrieve embeddings for content categorization clustering.

Question Generation:

Model Selection: Use Llama 3.1-ChatNVIDIA from Nvidia foundation models for generating question-answer pairs with the help of the vector store to generate relevant information with references.

Relevant prompt: Write detailed prompts in order to generate high quality question-answer pairs.

Embedding Model: Utilize nv-embedqa-e5-v5 to create high-quality question embeddings that are semantically meaningful and contextually relevant.

(Optional) Generate assessments and use Ai models to evaluate the assessment using the generated question, answer, evaluation criteria and explanation, especially important for short answer/essay questions as they have no fixed answers.

Frontend and Backend Development:

Front End Development with Gradio: Create an interactive and user-friendly interface where students can upload documents, interact with the generated questions and see answers with explanations. In addition, generate more questions, change topics.

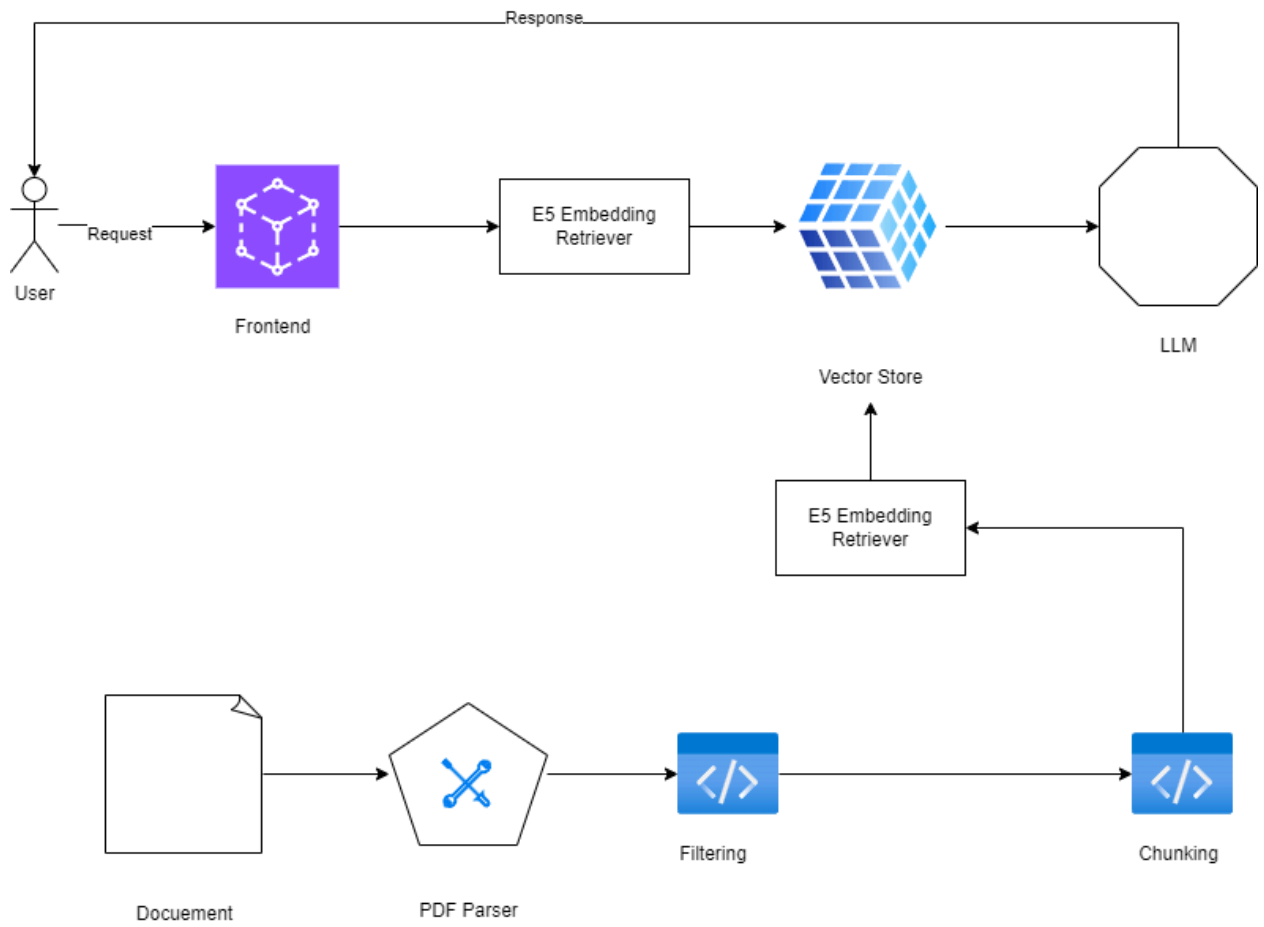(Optional) Allow students to create and take assessments with automatic evaluation and feedback.

Testing and Evaluation:

Ground Truth Evaluation: Implement simple ground truth evaluations to measure the quality and accuracy of generated questions and answers.

Experiment with factors like embedding sizes, context limits, new prompts, different models to get better performance.

Architecture Diagram

Response

User

Request

Frontend

E5 Embedding Retriever

Vector Store

LLM

E5 Embedding Retriever

Docuement

PDF Parser

Filtering

Chunking

References

- Vallino, J. (2003). Design patterns: Evolving from passive to active learning. *Frontiers in Education Conference*. PDF Link.
- Mahmood, M. A., Tariq, M., & Javed, S. (2011). Strategies for active learning: An alternative to passive learning. *Academic Research International*. PDF Link.
- Diepreye, F. F., & Odukoya, J. A. (2019). The impact of passive and active teaching methods on students' learning. *Journal of Physics: Conference Series*. PDF Link.
- Kooloos, J. G. M., & Bergman, E. M. (2020). The effect of passive and active education methods applied in repetition activities on the retention of anatomical knowledge. *Anatomical Sciences Education*. PDF Link.
- Ang, K. C. S., Afzal, F., & Crawford, L. H. (2021). Transitioning from passive to active learning: Preparing future project leaders. *Project Leadership and Society*. Link.
- Matthews, J. C. (1997). Intermeshing passive and active learning strategies in teaching biochemistry. *American Journal of Pharmaceutical Education*. PDF Link.
- Michel, N., Cater III, J. J., & Varela, O. (2009). Active versus passive teaching styles: An empirical study of student learning outcomes. *Human Resource Development Quarterly*. PDF Link.
- Minhas, P. S., Ghosh, A., & Swanzy, L. (2012). The effects of passive and active learning on student preference and performance. *Anatomical Sciences Education*. Link.
- Johnson, J., Douze, M., & Jégou, H. (2017). Billion-scale similarity search with GPUs. *arXiv preprint arXiv:1702.08734*. Link to Paper
- Abid, A., Farooqi, M., & Zou, J. (2019). Gradio: Hassle-Free Sharing and Testing of Machine Learning Models in the Wild. *arXiv preprint arXiv:1906.02569*. Link to Paper
- Lewis, P., Oguz, B., Rinott, R., Riedel, S., & Schwenk, H. (2020). Retrieval-Augmented Generation for Knowledge-Intensive NLP Tasks. *Advances in Neural Information Processing Systems (NeurIPS)*. Link to Paper.
- NVIDIA. (2023). Build Enterprise Retrieval-Augmented Generation Apps with NVIDIA Retrieval QA Embedding Model. *NVIDIA Developer Blog*. Link to Post.
- Acknowledge the use of GPT 4 in order to help write the document and correct the english.