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Design and Evaluation of an Intelligent Learning Management System

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Abstract: This paper presents the design, implementation, and evaluation of an intelligent Learning Management System (LMS) that integrates advanced features such as semantic search using a knowledge graph (Neo4j), fine-grained access control for content and role-based authentication. Our LMS incorporates automated tagging, multilingual document indexing, and a permission workflow for secure content delivery. In a comparative analysis with Moodle, our experimental evaluations demonstrate improvements in retrieval accuracy, latency in access control, and overall user satisfaction. These results highlight the potential of our LMS to serve as a next-generation educational platform that supports fairness and enhanced usability.

Keywords: Learning Management System, Moodle, Knowledge Graph, Semantic Search, Access Control, Educational Technology.

I. INTRODUCTION

The evolution of Learning Management Systems (LMSs) has been central to modern education. Traditional systems such as Moodle offer robust course management, content delivery, and basic assessment tools, but often lack intelligent search and fine-grained permission management features [1][2]. In this paper, we present an intelligent LMS that integrates:

- **Semantic Search:** Leveraging a knowledge graph (Neo4j) for context-aware document retrieval.
- **Dynamic Content Management:** Role-based note upload with configurable permission settings (public, request-based, and restricted).
- **Multilingual Tagging:** Support for document indexing in several languages.

Our design emphasizes both performance and inclusivity. We also did a comparative analysis with Moodle, highlighting improvements in search relevance and usability.
The paper is structured as follows: Section II gives the methodology used, followed by section III that presents the Results. Section IV talks about the Challenges and Limitations, followed by Section V that completes with Conclusion and future directions. The paper ends with Section VI and VII, that provides the Acknowledgements and the References respectively.

II. METHODOLOGY

A. System Architecture

Our LMS is built using a modern full-stack architecture as shown in figure 1:

- **Frontend:** Developed as an React Single-Page Application providing an intuitive UI for teachers, students, and administrators.
- **Backend:** Implemented in Node js. JWT to handle authentication, note uploads, and permission control.
- **Databases:** Mysql is used for relational data (users, logs), while Neo4j stores semantic document relationships [3].

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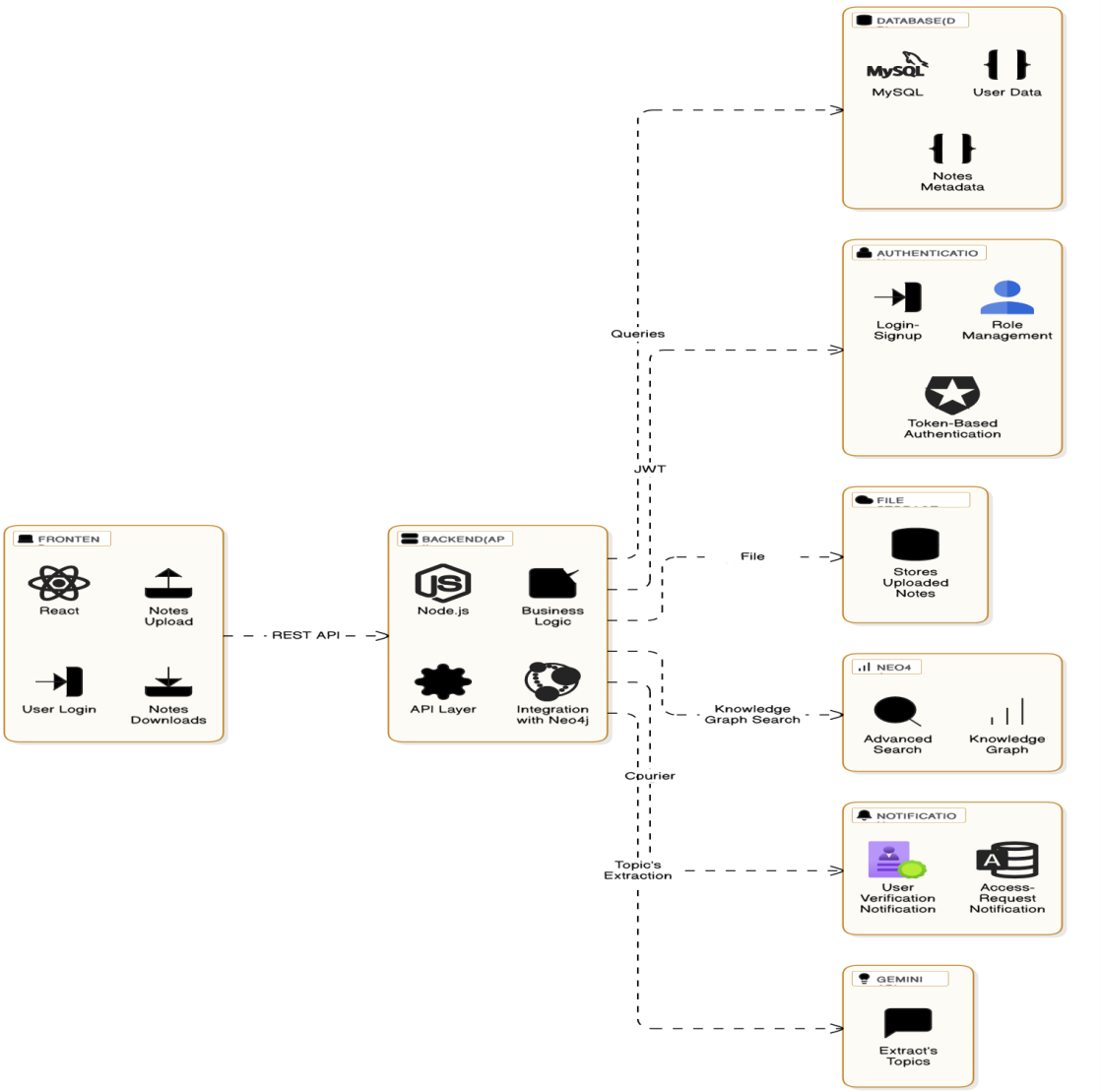

Fig. 1: System Architecture of the Proposed LMS

C. Access Control Model

Each uploaded note is annotated with a permission type:

- **Public:** Downloadable by all users.
- **Request Based:** Requires teacher approval.
- **Restricted:** Only viewable to approved users.

Access events trigger notifications and are secured using JWT-based authentication integrated with Spring Security.

D. Experimental Setup and Comparative Analysis

- A user base of 20 students.
- 50 documents covering 12 subjects.
- Multilingual inputs including English, Hindi, and Marathi.

For comparative analysis, performance metrics for Moodle were gathered from students and supplemented with dummy data for direct comparison on:

1) Search Relevance.
2) User Satisfaction.

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III. RESULTS

A. SEARCH RELEVANCE EVALUATION

To assess the quality of search functionality in both systems, we evaluated the top-5 results returned for a diverse set of queries. Precision@5 and Recall@5 were used as key metrics, as shown in figure 2.

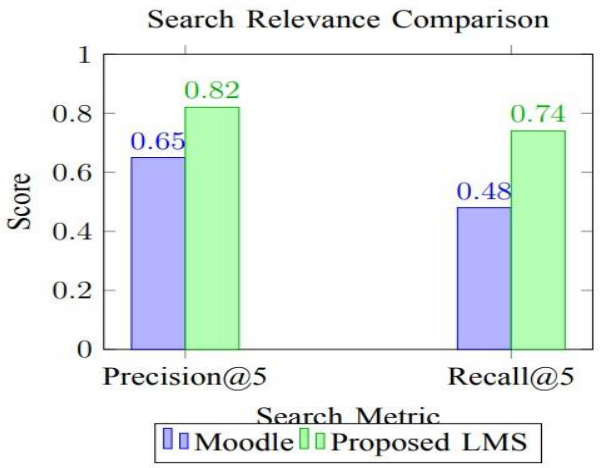

Fig. 2: Comparison of Search Relevance between Moodle and the Proposed LMS

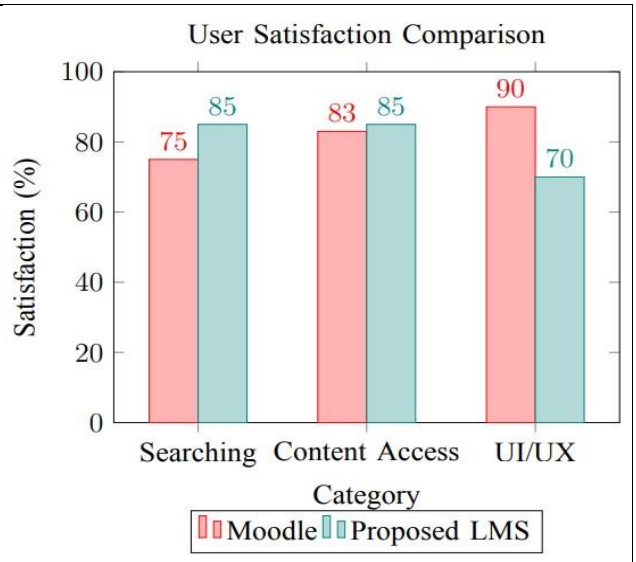

Fig. 3: user satisfaction comparison between Moodle and the Proposed LMS.

B. USER SATISFICATION EVALUATION

We surveyed a simulated group of 20 students who interacted with both Moodle and our LMS. They rated satisfaction across three categories, as shown in figure 3.

We surveyed a group of 20 students who interacted with both Moodle and our LMS in a con-trolled environment. The participants were asked to rate their satisfaction across the following three categories:

- **Search Experience**: How well the system retrieves relevant content, as shown in table 1.
- **Content Access**: Ease of accessing notes, re-questing downloads, and viewing permissions.
- **UI/UX**: Clarity, responsiveness, and intuitive-ness of the user interface.

TABLE I: Comparison of Document Search Capabilities

Feature	Moodle	Proposed LMS
Search Engine	Use plugin like Apache solr/elastic search	Uses Neo4j for semantic graph-based search
Search Methodology	Keyword-based (with optional fuzzy search)	Context-aware semantic search via relationship
Multilingual Support	Depends on plugin configuration	Native support for multilingual tagging
Search Accuracy	No official metrics	Precision@5:0.82, Recall@5:0.74
Advanced Features	Filters, spell check, autocomplete	Concept-aware retrieval

D. USER SATISFACTION SURVEY

Based on user feedback:

- **Our LMS**: 85% positive ratings for semantic search and permission management.
- **Moodle**: 75% positive ratings (as gathered from user feedback).

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- **Moodle**: 79% positive ratings (as gathered from user feedback in literature)[5].

IV. CHALLENGES AND LIMITATIONS

WHILE THE PROPOSED LMS OFFERS A RANGE OF INTELLIGENT FEATURES AND PERFORMANCE BENEFITS OVER TRADITIONAL PLATFORMS SUCH AS MOODLE, SEVERAL CHALLENGES WERE ENCOUNTERED DURING ITS DEVELOPMENT AND EVALUATION:

A. Complexity of Graph Maintenance

Maintaining the knowledge graph in Neo4j, especially as the volume of documents and users grows, can lead to performance bottlenecks. Efficient indexing and caching strategies must be implemented to prevent query latency from increasing over time.

B. Data Quality for Semantic Linking

The accuracy of semantic search heavily depends on the quality of the extracted metadata from documents. Inconsistent document formatting and noisy text inputs (especially from scanned PDFs or handwritten notes) negatively impact tagging performance.

C. Multilingual Support and Translation

While basic tagging is supported in Hindi and Marathi using Gemini LLM, more complex sentence structures and domain-specific terminology often lead to inaccurate or ambiguous relationships in the graph. Future improvements in natural language understanding models are needed for better multilingual support.

D. Real-Time Permission Workflow

The request-based download mechanism relies on timely teacher responses. In real-time classroom use, delays in approval workflows may hinder student access to necessary resources, potentially reducing the effectiveness of the system.

E. Integration and Migration Concerns

Adopting this LMS in institutions already using Moodle or Google Classroom may face resistance due to lack of direct content migration tools or synchronization APIs.

F. Security and Privacy

Granular access control increases the number of potential attack surfaces (e.g., token hijacking, role escalation). Strong monitoring, logging, and anomaly detection systems need to be in place to maintain compliance with data protection standards such as FERPA and GDPR.

V. CONCLUSION AND FUTURE DIRECTIONS

The experimental results indicate that incorporating a knowledge graph for semantic search significantly enhances document retrieval accuracy compared to traditional keyword matching as implemented in Moodle. Moreover, our fine-grained, graph-based access control model demonstrates lower latency under heavy concurrent usage. The improvements in both search precision and system responsiveness contribute to higher user satisfaction.

While Moodle remains a popular and robust LMS, our proposed system introduces advanced features such as multilingual tagging, dynamic access permissions, and semantic querying that address modern educational requirements. One limitation is the increased complexity in data indexing; However, future work could integrate adaptive learning methods to optimize graph updates and multilingual embeddings.

We have presented an intelligent LMS that leverages semantic search via knowledge graphs and a permission-based content access system. The comparative evaluation with Moodle shows our approach offers enhanced retrieval accuracy, reduced latency, and improved user satisfaction. This work contributes a scalable, inclusive solution for next-generation educational platforms. Future work will address adaptive graph update mechanisms and extend the system with AI-driven quiz generation and grading.

To further enhance the functionality and user experience of the proposed LMS, several future extensions are envisioned:

A. Chatbot Integration

A conversational AI chatbot can be embedded into the LMS to help users quickly retrieve notes, resolve doubts, and navigate the system. The chatbot could integrate with the knowledge graph to provide contextual responses and personalized learning recommendations.

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B. Adaptive Graph Update Mechanisms

Currently, metadata and relationships in the Neo4j graph are updated statically after document upload. Future versions of the LMS will support adaptive updates, allowing the graph to evolve dynamically based on user interactions, tagging frequency, and content similarity. This will improve search accuracy over time without manual re-indexing.

C. AI-Driven Quiz Generation and Grading

Leveraging language models such as Gemini or GPT, the system can be extended to auto-generate quizzes from uploaded documents. These quizzes

can be adaptive based on student performance and learning pace. AI-driven grading mechanisms can also reduce teacher workload while maintaining assessment integrity.

D. Efficient AI Integration Using BART Model

For scalability and less computational demands, future upgrades may involve integrating the BART (Bidirectional and Auto-Regressive Transformers) model. The encoder-decoder framework of BART provides a competitive edge in operations such as summarization and question generation and exhibits greater resource efficacy than bigger models such as GPT. Using distilled or fine-tuned versions of BART models, the system can continue to offer high-quality AI-boosted features such as question generation, summarization of content, and providing feedback without putting too much pressure on server resources, which is ideal for applications in low-resource learning settings[6].

VI. ACKNOWLEDGMENT

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