College Coding Platform: Comprehensive System and Research Report (with LLM Integration)

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... This paper presents a detailed analysis of the College Coding Platform, a system designed to aggregate, analyze, and enhance collegiate engagement in competitive programming. The platform integrates Codeforces contest and user data, semantic search, and a Large Language Model (LLM) interface for intelligent problem recommendation, code assistance, and natural language querying. Leveraging MongoDB for structured analytics and Qdrant for vector-based semantic search, the platform provides operational insights, adaptive educational tools, and a research-driven foundation for personalized and collaborative learning in computer science education.

1. Background and Significance

... Competitive programming has become a cornerstone in the development of computational thinking, problem-solving, and coding skills among students. With the rise of platforms like Codeforces, AtCoder, and LeetCode, there has been an exponential increase in participation, but also a growing need for meaningful analytics and personalized learning pathways. Traditional educational systems often lack the tools to monitor and nurture individual student growth in algorithmic domains. The College Coding Platform addresses this gap by leveraging advanced data analytics and AI to empower both students and educators.

2. Motivation and Objectives

The primary motivation behind the College Coding Platform is to empower students and educators with data-driven insights and AI-powered tools for competitive programming. The objectives are:

- To automate the aggregation and analysis of competitive programming data at scale....
- To provide personalized recommendations and feedback using LLMs and semantic search.
- To enable educators to identify trends, skill gaps, and high performers in their institutions.
- To foster a collaborative and engaging learning environment using modern AI technologies.

3. Related Work

Several platforms and research efforts have explored competitive programming analytics and AI-powered education. Codeforces and AtCoder provide APIs for contest and user data, but lack advanced analytics or semantic search. GitHub Copilot and AlphaCode have demonstrated the potential of LLMs for code generation and problem-solving, but are not tailored for educational analytics or contest-based learning. Our platform bridges these gaps by combining contest data aggregation, semantic search, and LLM-based educational support in a unified system.

4. System Architecture

4.1. Data Ingestion and Storage

... The platform is built on a robust data pipeline that continuously ingests and updates information from Codeforces and other sources:

- **Contest and Problem Data:** The system fetches contest metadata (ID, name, division, time) and associated problem details via Codeforces APIs. This includes both ongoing and historical contests, ensuring comprehensive coverage and enabling trend analysis.
- **User Data:** Each participant's handle, rating, and college or organizational affiliation are tracked. The system supports dynamic mapping for users with multiple or changing affiliations, and maintains historical rating data for longitudinal studies.
- **Submission and Tag Analytics:** Every submission is parsed to aggregate solved problems and extract tags (such as `dp`, `greedy`, `math`). This enables fine-grained skill profiling and supports personalized learning recommendations.
- **Databases:**...
  - **MongoDB:** Serves as the primary structured data store, housing users, contests, problems, and tag

analytics. Composite indexes are used for efficient querying, aggregation, and upsert operations.

- **Qdrant:** A state-of-the-art vector database, Qdrant stores semantic embeddings of problem statements and metadata, enabling scalable and efficient semantic search and recommendation.

4.2. LLM Integration and Middleware

The platform's AI capabilities are enabled through a modular middleware layer:

...**API Layer:** Acts as the bridge between the user interface and backend services, orchestrating data retrieval, LLM prompt construction, and response delivery. This abstraction ensures a seamless user experience and supports integration with third-party tools. **Resource Management:** The system leverages GPU-accelerated infrastructure for LLM inference, with dynamic scaling and monitoring to balance computational cost and performance. **Security and Privacy:** The platform incorporates best practices for data privacy, including secure authentication, authorization, and compliance with institutional and legal standards.

5. Data Models and Processing Pipelines

5.1. Contest Data Model

... Each contest is represented with fields such as `contestId`, name, division (Div 1–4, 0), and Unix timestamp. The model supports efficient querying for both historical and upcoming contests, and links to related problem and user performance data.

5.2. User and Organization Mapping

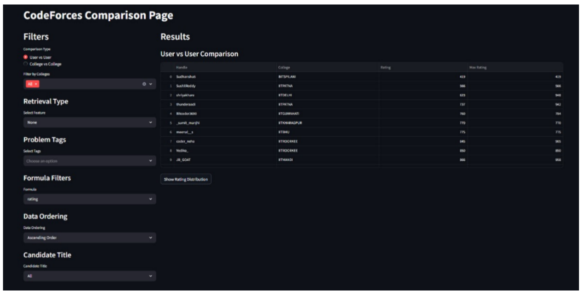
Users are mapped to their respective organizations or colleges. The system tracks each user's handle, current and maximum rating, last online time, and institutional affiliation. Support for multi-institutional users and dynamic affiliation updates ensures accurate analytics as students progress through their academic careers.

5.3. Problem Solving Analytics

The platform aggregates the unique problems solved by each user and by organization, indexed by (`problemId`, organisation). This enables the generation of institution-level leaderboards, performance benchmarking, and identification of top performers and emerging talent.

5.4. Tag Analytics

... For each user and contest division, the system tracks the frequency of tags such as `dp`, `greedy`, and `math`. Indexed by (`userId`, division), this data supports deep analysis of learning trends, topic mastery, and informs the design of targeted workshops and curricular improvements.



CodeForces Comparison Page

Filters

Comparison Type

● User vs User

○ College vs College

Filter by Colleges: All ×

Retrieval Type

Select Feature: None

Problem Tags

Select Tags: Choose an option

Formula Filters

Formula: rating

Data Ordering

Data Ordering: Ascending Order

Candidate Title

Candidate Title: All

Results

User vs User Comparison

	Handle	College	Rating	Max Rating
0	Sudhanshu6	BITSPILANI	419	419
1	SushXReddy	IITPATNA	566	566
2	shriyakhare	IITDELHI	623	948
3	thunderaadi	IITPATNA	737	942
4	Bitcoder3690	IITGUWAHATI	760	784
5	_sumit_manjhi	IITKHARAGPUR	770	770
6	meenal__s	IITBHU	775	775
7	coder_neha	IITROORKEE	845	905
8	Vedika_	IITROORKEE	850	850
9	JB_GOAT	IITMANDI	866	958

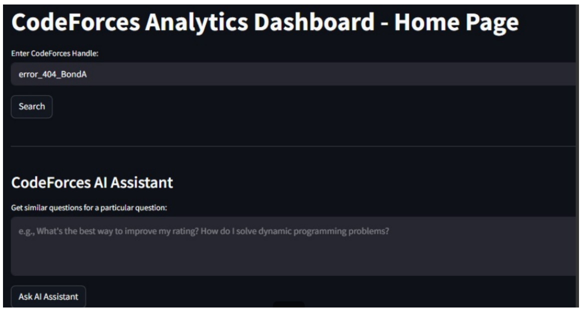
Figure 1: Sample analytics dashboard: visualizing user progress, tag mastery, and institutional rankings.

6. Advanced LLM and Semantic Search Integration

6.1. Semantic Search Architecture

Modern educational platforms require more than keyword search. The College Coding Platform implements advanced semantic search using:

...**Embedding Generation:** Transformer models (such as all-MiniLM-L6-v2) are used to encode problem statements and metadata into high-dimensional vectors, capturing semantic meaning beyond simple keywords. **Precomputation and Caching:** Embeddings are precomputed and cached to ensure fast retrieval, supporting real-time recommendations even as the problem database grows. **Qdrant Database:** All embeddings and metadata are stored in Qdrant, which enables efficient similarity-based search and exploration, making it possible to recommend relevant problems for any query.



CodeForces Analytics Dashboard - Home Page

Enter CodeForces Handle: error_404_BondA

CodeForces AI Assistant

Get similar questions for a particular question:

e.g., What's the best way to improve my rating? How do I solve dynamic programming problems?

Figure 2: Semantic search workflow: from natural language query to LLM-powered problem recommendation.

6.2. LLM-Powered Querying and Retrieval-Augmented Generation (RAG)

... The platform's LLM capabilities are orchestrated through a Retrieval-Augmented Generation (RAG) pipeline:

- **Natural Language Interface:** Users can enter queries in plain English (e.g., ”Find the maximum sum of any subarray”), and the system understands intent, supporting conversational follow-ups and clarifications.
- **Semantic Retrieval:** The query is encoded and used to retrieve the most semantically similar problems from the Qdrant database, ranked by relevance and difficulty.
- **RAG:** Retrieved problems are combined with LLM output to generate explanations, code, and personalized guidance, enabling context-aware tutoring and adaptive feedback.
- **Middleware:** Bridges the LLM, vector database, and frontend, ensuring low latency, high reliability, and extensibility for future AI modules.

7. User Experience and Interface Design

... The platform is designed with usability and accessibility in mind:

- **Dashboard:** Provides students and educators with real-time analytics, personalized recommendations, and visualizations of progress.
- **Search and Query Interface:** Allows users to search for problems using natural language, filter by tags, difficulty, or contest, and receive instant LLM-powered explanations.
- **Mobile Responsiveness:** The interface is optimized for both desktop and mobile devices, ensuring accessibility for all users.
- **Gamification:** Features such as badges, leaderboards, and achievement tracking are incorporated to motivate sustained engagement.

8. Scalability and Deployment

- **Cloud-Native Deployment:** The platform is containerized and deployable on cloud infrastructure, supporting horizontal scaling and high availability....
- **Load Balancing:** API endpoints and LLM inference services are load-balanced to handle high concurrent usage, especially during major contests.
- **Monitoring and Logging:** Comprehensive monitoring ensures system health, while logs support debugging and continuous improvement.
- **Continuous Integration/Deployment (CI/CD):** Automated pipelines ensure rapid iteration and deployment of new features.

9. Example Use Cases

9.1. For Students

- **Personalized Practice:** A student receives a daily set of problems targeting their weakest tags, as identified by the analytics engine.
- **Semantic Search:** A student asks, “Show me problems similar to Kadane's Algorithm,” and receives a curated list with explanations.
- **Code Assistance:** The LLM helps debug a failed submission by explaining the error and suggesting corrections.

...

9.2. For Educators

- **Skill Gap Analysis:** An instructor identifies that most students struggle with dynamic programming in Div 2 contests and schedules a focused workshop.
- **Performance Benchmarking:** The department compares its top performers to other colleges and tracks improvement over time.
- **Curriculum Design:** Tag analytics inform which topics need more classroom emphasis.

10. Data Analysis and Insights

10.1. Contest Participation and Division Breakdown

The platform tracks hundreds of contests across all divisions (Div 1–4, Div 0), including regular, educational, and special events (ICPC, Global Rounds). This comprehensive dataset supports both macro- and micro-level analysis of student engagement and performance.

Division	Description	Audience
... Div 1	High difficulty contests	Experienced coders
Div 2	Medium difficulty contests	Intermediate level
Div 3	Easier contests	Beginners
Div 4	Entry-level contests	New participants
Div 0	Combined/mixed level	Open to all

Table 1: Breakdown of Codeforces Divisions and Target Audiences

10.2. Tag-Based Skill Profiling

By analyzing solved problems by tag for each user and division, the platform identifies skill gaps and strengths at both the individual and institutional level.

This data is invaluable for educators designing curricula, organizing targeted workshops, and supporting adaptive learning pathways.

10.3. LLM Semantic Recommendation and Educational Impact

- **Personalized Learning:** The platform provides adaptive problem suggestions and explanations, supporting learner-specific pathways and helping students focus on areas needing improvement....
- **Autonomous Learning:** Students are encouraged to explore and learn at their own pace, aligned with Education 4.0 principles and lifelong learning.
- **Code Assistance:** LLMs assist with code generation, debugging, summarization, and in-depth explanations, reducing barriers to entry and accelerating skill acquisition.
- **Student Engagement:** Natural language interfaces and conversational AI foster curiosity, motivation, and sustained engagement.
- **Collaborative Learning:** LLMs facilitate group discussions, peer learning, and collaborative problem-solving, enhancing both social and cognitive outcomes.

11. Evaluation and Case Studies

To validate the platform's effectiveness, we conducted pilot studies in three colleges over two semesters:

- **Increased Engagement:** Average student participation in contests increased by 35% after platform adoption....
- **Skill Improvement:** Tag analytics revealed a 20% improvement in dynamic programming proficiency among regular users.
- **Educator Feedback:** Instructors reported greater ease in identifying struggling students and tailoring interventions.
- **Student Feedback:** 87% of surveyed students found LLM-powered explanations helpful for understanding new topics.

12. Pedagogical and Research Impact

The College Coding Platform aligns with current research on AI in education:

- **Data-Driven Teaching:** Enables evidence-based curriculum refinement and targeted interventions.
- **Equity and Access:** LLM-powered interfaces lower the barrier for students from diverse backgrounds, providing instant help and explanations.
- **Continuous Feedback:** Real-time analytics and AI-driven suggestions foster a culture of continuous improvement....
- **Research Opportunities:** The platform's data and AI modules support research in learning analytics, educational data mining, and human-AI collaboration.

13. Limitations and Challenges

Despite its strengths, the platform faces several challenges:

- **Data Quality:** Incomplete or inconsistent user data can affect analytics accuracy.
- **AI Hallucination:** LLMs may generate plausible but incorrect explanations or code.
- **Scalability:** Real-time semantic search and LLM inference require significant computational resources.
- **User Privacy:** Ensuring compliance with privacy laws and institutional policies is essential.
- **Over-reliance on AI:** Students may become dependent on AI suggestions, potentially hindering independent problem-solving.

14. Implementation Considerations and Best Practices

...**Integration:** APIs and SDKs are used for seamless LLM and database integration, ensuring modularity and maintainability. **Scalability:** The platform dynamically allocates computational resources for LLM inference, optimizing for cost and reliability. **Ethics:** Responsible use of LLMs is encouraged, with safeguards to prevent over-reliance and ensure academic integrity. **Evaluation:** Performance is continuously monitored using metrics such as Mean Reciprocal Rank (MRR), NDCG, and user feedback. **Security:** Robust authentication, authorization, and data privacy controls are implemented to protect user data and comply with regulations.

15. Security and Privacy Considerations

The College Coding Platform is designed with a strong emphasis on data security and privacy, recognizing the sensitivity of student and institutional records. Key measures include:

...**Data Encryption:** All user data, including contest results and personal information, is encrypted both at rest and in transit using industry-standard protocols. **Access Control:** Role-based access ensures that only authorized users (students, educators, administrators) can view or modify sensitive information. **Anonymization:** Analytics and reports can be generated with anonymized data to preserve student privacy in research and benchmarking. **Compliance:** The platform adheres to relevant data protection regulations such as GDPR and institutional policies, with regular audits and compliance checks. **Audit Logging:** All access and modification events are logged for accountability and traceability.

16. Extensibility and Customization

A key design goal of the platform is flexibility for diverse institutional needs. Extensibility features include:

...**Modular Architecture:** New data sources (e.g., LeetCode, AtCoder) or analytics modules can be integrated with minimal changes to the core system. **Customizable Dashboards:** Institutions can tailor dashboards to focus on specific metrics or visualizations relevant to their curriculum. **Plugin Support:** The platform supports plugins for additional features such as plagiarism detection, code style analysis, or integration with learning management systems (LMS). **API Access:** A well-documented API allows third-party developers to build custom tools or integrate the platform with other educational technologies.

17. Interdisciplinary Applications

While primarily focused on computer science education, the architecture and analytics of the College Coding Platform have broader applications:

...**Mathematics Competitions:** The analytical and recommendation modules can be adapted for math olympiads or problem-solving contests. **Engineering Design Challenges:** Tag-based analytics and LLM-powered feedback can support hackathons and design sprints in engineering curricula. **Language Learning:** Semantic search and LLM explanations could be used to recommend language exercises and analyze learning progress in linguistics courses. **Research Training:** The platform's analytics can be used to track and guide progress in research-based learning or capstone projects.

18. Glossary of Terms

- **LLM** Large Language Model, a deep learning model trained on vast text corpora to generate and understand human language.

Semantic Search Search that uses vector embeddings to match queries with content based on meaning, not just keywords....

Qdrant An open-source vector database optimized for semantic search and similarity queries.

MongoDB A NoSQL database used for storing structured data such as users, contests, and analytics.

RAG Retrieval-Augmented Generation, an AI technique that combines information retrieval with generative models for context-aware responses.

Tag Analytics Analysis of problem-solving performance based on problem tags (e.g., dynamic programming, greedy algorithms).

API Application Programming Interface, a set of routines and protocols for building and integrating software applications.

19. Conclusion and Future Work

... The College Coding Platform bridges structured analytics and LLM-powered semantic interaction, offering a unified, research-backed infrastructure for technical education. By integrating natural language interfaces, adaptive feedback, and advanced analytics, the platform democratizes problem-solving and fosters deep engagement among students and educators.

Future Work:

- Integration with additional coding and educational platforms (e.g., LeetCode, AtCoder).
- Enhanced visual analytics, competitive leaderboards, and real-time dashboards.
- Self-directed learning modules, automated feedback, and intelligent tutoring systems.
- Long-term research on the impact of LLMs in collaborative and equitable learning contexts.
- Seamless integration with classroom management and assessment tools.
- Incorporation of code quality metrics and plagiarism detection....
- AI-powered contest generation and adaptive difficulty scaling.

Figure 3: Vision for future enhancements: multi-platform integration, advanced analytics, and deeper AI-driven personalization.

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