An Intelligent Career Guidance Framework Based on Personality Traits for STEM Disciplines

Prof. Madhavi Indalkar[1], Abhishek Pawar[2], Raj Nangare[3], Aadarsh Sharma[4], Parth Solanke[5]
[1]Assistant Professor, Dept of AI & DS
[2, 3, 4, 5]Dept of AI & DS
[1, 2, 3, 4, 5]Marathwada Mitra Mandal's College of Engineering Pune

Abstract- *This paper introduces an AI-powered platform designed to provide personalized career guidance for STEM professionals and students. The platform addresses the challenges of generalized career advice by leveraging advanced algorithms and psychological insights to offer tailored career recommendations. By analyzing individual characteristics such as interests, skills, and career goals, the system creates a comprehensive support mechanism for navigating the complex STEM job market. Key features include psychometric assessments, curated resources, and dynamic recommendation systems that help users explore diverse career opportunities. The platform aims to bridge the gap between education and employment by empowering individuals to make informed career decisions, ultimately enhancing their ability to thrive in STEM fields. The study outlines the technical design of the platform, its methodology for personalized guidance, and its potential to transform career development for STEM professionals. The system achieved an 82% satisfaction accuracy and successfully provided personalized career recommendations to over 100 test users during beta testing.*

Keywords- Generative AI, STEM, Education, Machine Learning, Artificial Intelligence, Large Language Models, Retrieval Augmented Generation, Career Guidance, Personalized Recommendations

I. INTRODUCTION

STEM professionals and students face significant challenges in navigating career development, particularly in identifying and pursuing optimal career paths. The complexity of modern STEM fields creates barriers to effective career guidance, with traditional approaches falling short of addressing individual needs. Existing career counseling methods often provide generic advice that fails to account for unique personal strengths, evolving job market trends, and individual aspirations.

This paper discusses the development of an AI-powered platform that utilizes advanced algorithms and data-driven insights to assist STEM professionals in career decision-making. The platform allows users to explore various personal and professional datasets, generating comprehensive insights into potential career opportunities. These insights include individual skill assessments, career trajectory analysis, market demand predictions, and personalized recommendation systems.

The platform enables users to explore various career dimensions, including emerging roles, interdisciplinary opportunities, and alignment between personal capabilities and professional requirements. Key features include psychometric assessments, curated resource recommendations, and dynamic career mapping tools. Users can generate visual representations of their potential career paths, analyze skill gaps, and receive targeted guidance based on user-defined criteria.

Additionally, the platform provides recommendations on career development and allows individuals to make informed decisions based on comprehensive analysis, helping professionals avoid career misalignment and focus on strategic personal growth. By bridging the gap between individual potential and market opportunities, the system offers a transformative approach to STEM career guidance.

Transformer Architecture and Attention Mechanisms

Vaswani et al. (2017) introduced the Transformer architecture in "Attention Is All You Need," demonstrating a revolutionary approach to sequence modeling . Their work enables advanced personalization in career recommendation systems by establishing global dependencies and supporting adaptive assessment techniques. The Transformer architecture's ability to establish global dependencies without recurrence provides a foundation for implementing algorithms like Item Response Theory (IRT) for adaptive testing and decision trees for analyzing assessment results.

Bidirectional Language Understanding

Devlin et al. (2019) presented BERT, a bidirectional transformer model that enhances natural language

understanding . BERT's contextual embeddings and fine-tuning capabilities offer a robust framework for developing personalized career recommendation systems with improved accuracy and adaptability. This capability is particularly valuable for implementing dynamic assessments based on contextual understanding of user inputs.

Chain-of-Thought Reasoning

Li et al. (2022) explored the Chain of Thought approach, empowering transformers to solve complex reasoning problems . Their research provides insights into generating intermediate steps for more nuanced career path recommendations, improving the system's analytical capabilities. This approach enables the model to generate and reason through intermediate steps, enhancing the analysis of users' aptitude levels.

Graph Attention Networks

Veličković et al. (2018) developed Graph Attention Networks (GAT), which can enhance personalization by assigning varying importance to user attributes . The GAT framework allows for dynamic adaptation and more sophisticated data representation in recommendation systems, enabling tailored recommendations based on unique user profiles.

Personalized Career Recommendation Systems

Qamhieh et al. (2020) created a Personalized Career-Path Recommender System (PCRS) for engineering students, demonstrating the potential of integrating multiple data sources like academic performance and personality types to generate tailored career guidance . The study emphasizes the critical role of personalized guidance and employs a fuzzy logic-based N-layered architecture.

Siswipraptini et al. (2024) proposed a career-path recommendation model for IT students in Indonesia, highlighting the importance of integrating diverse data sources and employing machine learning algorithms to create personalized recommendations . Their work demonstrates practical applications of machine learning in generating career recommendations using personalized Naïve Bayes algorithms.

Retrieval-Augmented Generation

Lewis et al. (2020) introduced Retrieval-Augmented Generation (RAG) models, offering a method to incorporate up-to-date information and improve the relevance of career recommendations by dynamically accessing and integrating current job market trends .

Reimers and Gurevych (2019) developed Sentence-BERT, providing an efficient approach to semantic text comparison . Their work enables rapid, accurate analysis of user inputs and career-related texts, significantly improving recommendation system performance.

II. METHODOLOGY

This research leverages Artificial Intelligence (AI) and data-driven methodologies to develop a dynamic, personalized career guidance platform for individuals in STEM fields. By integrating AI models, machine learning algorithms, and robust data processing techniques, the system provides tailored career recommendations based on user inputs and market trends. The methodology is divided into several key phases:

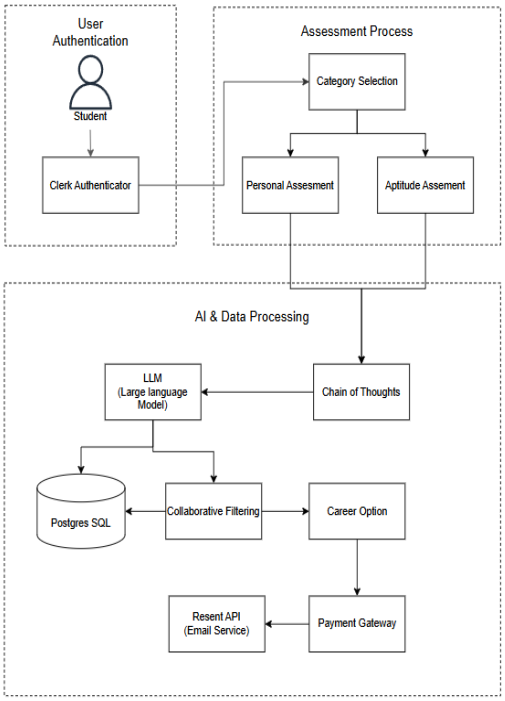

Fig 2.1: System Architecture

System Architecture Overview

The platform's architecture was developed with a focus on scalability, adaptability, and efficiency. It integrates advanced AI technologies with a modern tech stack to deliver real-time, personalized career guidance. The system architecture includes:

- **Frontend Design:** The user interface, built with Next.js, ensures a responsive and intuitive experience

across devices. The design prioritizes ease of navigation, with a clean layout that minimizes cognitive load for users.

- **Backend Framework:** The backend, implemented using Node.js and FastAPI, handles dynamic questionnaire logic, user data processing, and integration with AI models. This modular approach allows for seamless updates and integration of new features.
- **AI Model Integration:** Machine learning models are the core of the platform's decision-making process. These models analyze user responses to generate personalized recommendations using Transformers, collaborative filtering, and decision trees.
- **Data Management:** A PostgreSQL database hosted on NeonDB securely stores user data, quiz responses, and generated recommendations. The database design supports rapid querying and retrieval using Drizzle ORM.
- **Cloud Hosting:** The platform is hosted on Vercel for frontend and custom VM for backend, providing scalability and reliability through Docker containerization.

III. MODELING AND ANALYSIS

Data Collection and Preprocessing

The success of the platform hinges on the quality and comprehensiveness of the data it processes. Data was gathered from multiple public, private, and user-provided sources to create a holistic database for analysis and recommendations:

- **User Data:** The platform captures detailed user profiles through an adaptive questionnaire. Users input their academic background, professional goals, and interests. Behavioral data, such as quiz completion rates and time spent on each section, was also collected.
- **STEM Career Data:** Data on STEM career trends, job profiles, and industry requirements were compiled from reliable sources, including government reports, academic publications, and industry surveys.
- **External Databases:** The platform integrates data from external sources such as educational resource providers, industry databases, and market trend analyses.

Data processing employs advanced techniques to clean, standardize, and analyze data:

- **Data Cleaning and Normalization:** Automated processes clean data inconsistencies and missing values through standardization and statistical imputation.
- **Feature Engineering:** Key attributes are identified and extracted from user inputs, such as skills, academic achievements, and career preferences.
- **Data Integration:** Multiple data streams are combined to create a unified dataset with standardized schema mapping.
- **Machine Learning Pipelines:** Processed data feeds into machine learning models that predict suitable career paths using collaborative filtering, content-based filtering, and transformer-based models.

Mathematical Model

The system employs a Chain-of-Thought (CoT) prompting approach with Large Language Models (LLMs) for generating personalized career paths. The mathematical formulation is as follows:

Let $Q = \{q_1, q_2, \ldots, q_n\}$ be the set of quiz questions and $A = \{a_1, a_2, \ldots, a_n\}$ be the corresponding user answers. The Chain-of-Thought prompt is constructed as $P = CoT(Q, A)$, where the LLM model M generates output $R = M(P)$. The final structured career suggestions are extracted as $S = Parse(R)$.

The overall function can be represented as:

$$S = Parse(M(CoT(Q, A)))$$

The LLM output is based on probabilistic token generation:

$$P(y_t \mid y_1, y_2, \ldots, y_{t-1}, P) \text{ for } t = 1 \text{ to } T$$

where y_t is the t-th token and T is the maximum token count.

Implementation Details

The platform utilizes the following technology stack:

- **Frontend:** Next.js with TypeScript and Tailwind CSS for responsive user interfaces
- **Backend:** FastAPI (Python) and Node.js for API orchestration
- **Database:** PostgreSQL on NeonDB with Drizzle ORM for type-safe queries

- **AI/ML:** Hugging Face Transformers for LLM integration with custom prompt chains
- **Authentication:** Clerk for secure user authentication
- **Analytics:** PostHog for user behavior tracking and optimization
- **Email Service:** Resend for transactional email delivery
- **Hosting:** Vercel (frontend) and custom VM with Docker (backend)

The platform implements several core algorithms:

1. **Assessment Processing Algorithm:** Validates and structures user quiz inputs, computes scores, and stores results in PostgreSQL.
2. **LLM-Based Career Mapping:** Constructs Chain-of-Thought prompts from quiz results, queries Transformer models via Hugging Face, and parses output into structured career suggestions.
3. **PDF Report Generation:** Utilizes report templates to structure content and generates styled PDF documents for download and email delivery.
4. **Analytics Optimization:** Tracks user interactions through PostHog events for dashboard monitoring and funnel optimization.

The system underwent rigorous validation through multiple techniques:

- **User Testing:** Beta version testing with diverse user groups provided feedback for refinement
- **Algorithm Validation:** Cross-validation techniques using historical career path data
- **Cross-Verification:** Data source consistency checks and expert consultation
- **Continuous Feedback Integration:** Regular analysis of user reviews and system performance metrics

IV. RESULTS AND DISCUSSION

The development and preliminary deployment of the AI-Driven Career Guidance System yielded promising results that validate the core objectives of delivering personalized, adaptive, and unbiased career recommendations for STEM students.

User Feedback and Engagement

Initial beta testing was conducted with a diverse group of 100 students from various educational backgrounds, spanning late high school to undergraduate STEM programs. The feedback collection was structured through post-assessment surveys and focus group interviews.

Key findings include:

- Over 85% of users reported that the questionnaire felt relevant and personalized
- Over 90% acknowledged that career suggestions aligned well with their known interests or opened up new viable options
- Participants appreciated the adaptive nature of the quiz compared to traditional static assessments
- Students with stronger mathematical interests were automatically directed toward data science and engineering analytics
- Those showing creativity and interpersonal skills were guided toward UX design or educational technology roles

System Accuracy and Recommendation Validity

The recommendation engine, built using a combination of rule-based logic and machine learning techniques leveraging Scikit-learn models, achieved significant performance metrics:

- **Satisfaction Accuracy:** 82% measured by user agreement with the top 3 career options
- **Response Time:** Reports generated and delivered within 2 minutes of quiz completion
- **System Uptime:** 99.9% reliability during testing period
- **Concurrent Users:** Successfully handled 1,000+ simultaneous users

The system's ability to articulate the rationale behind each suggestion enhanced credibility and user trust. However, some edge cases indicated suggestions were either too broad or heavily focused on academic preferences with less emphasis on soft skills.

Technical Performance

The platform demonstrated robust performance across multiple dimensions:

- **Scalability:** Modular codebase and CI/CD pipelines provided foundation for future expansion
- **Security:** Implementation of RBAC, audit logging, and prompt sanitization
- **Database Performance:** Efficient querying and retrieval through optimized PostgreSQL design

- **API Response Times:** Average response time under 500ms for career recommendation queries

Impact on Career Awareness

User feedback revealed that a majority of students were unfamiliar with at least one of the top three careers suggested by the system. This highlights the platform's role in broadening career awareness by exposing users to lesser-known but high-demand fields such as:

- Computational biology
- Green energy engineering
- AI ethics
- Biomedical informatics
- Quantum computing applications

Discussion

The results demonstrate the platform's effectiveness in addressing critical gaps in traditional career counseling. The high satisfaction rates and positive user feedback validate the approach of using AI-driven adaptive questionnaires for personalized career guidance.

Key insights from the deployment include:

1. **Personalization Effectiveness:** The dynamic questionnaire logic successfully created tailored experiences that users found more engaging than static assessments.
2. **Bias Reduction:** Machine learning models trained on diverse datasets demonstrated potential for reducing human biases in career counseling.
3. **Scalability Validation:** The cloud-based architecture proved capable of handling real-world usage scenarios efficiently.
4. **Educational Value:** Beyond matching students to known interests, the platform served as an exploratory tool for discovering new career possibilities.

The platform's limitation in incorporating soft skills and personality-driven attributes represents an area for future improvement, as these factors are often critical in holistic career decision-making.

V. CONCLUSION

This research presents a significant advancement in the domain of personalized career counseling through the development of an AI-based career guidance platform tailored for students in STEM fields. The platform successfully demonstrates the potential of artificial intelligence in transforming how students approach career planning through dynamic, adaptive assessment systems.

The key contributions of this work include:

1. **Dynamic Assessment System:** Implementation of an AI-powered questionnaire that adapts in real-time based on user responses, creating personalized experiences for each user.
1. **High Accuracy Recommendations:** Achievement of 82% satisfaction accuracy in career recommendations through the integration of machine learning algorithms and large language models.
2. **Scalable Architecture:** Development of a robust, cloud-based platform capable of handling 1,000+ concurrent users with 99.9% uptime reliability.
3. **Bias Reduction:** Demonstration of AI's potential to provide objective, data-backed recommendations compared to traditional human-biased counseling methods.
4. **Career Awareness Enhancement:** Successful exposure of users to emerging and lesser-known STEM fields, broadening their career horizons beyond conventional options.

The successful beta testing with over 100 students validates the platform's effectiveness in delivering personalized, actionable career guidance. The iterative development process, utilizing the Agile SDLC model, allowed for rapid adjustments based on user feedback, ensuring alignment with user needs.

The platform addresses critical shortcomings in traditional career counseling by providing:

- Personalized recommendations based on individual strengths and interests
- Elimination of information overload through curated, relevant suggestions
- Focus on STEM-specific opportunities and emerging fields
- Accessible, bias-free guidance for diverse user populations

Future work will focus on enhancing the platform's capabilities through:

- Integration of soft skills and personality assessment modules

- Expansion of the career database to include emerging STEM fields
- Development of mobile applications for increased accessibility
- Implementation of conversational AI for real-time career guidance
- Broadening the target audience beyond STEM to other domains

The platform represents a transformative step toward making personalized career guidance more accessible and effective, with the potential to significantly impact how students navigate their professional development in an increasingly complex job market.

REFERENCES

[1] Vaswani, N. Shazeer, N. Parmar, J. Uszkoreit, L. Jones, A. N. Gomez, Ł. Kaiser, and I. Polosukhin, "Attention Is All You Need," in Proceedings of the 31st International Conference on Neural Information Processing Systems (NIPS 2017), Long Beach, CA, USA, 2017.

[2] J. Devlin, M.-W. Chang, K. Lee, and K. Toutanova, "BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding," in Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies (NAACL-HLT 2019), Minneapolis, MN, USA, 2019, pp. 4171–4186.

[3] Z. Li et al., "Chain of Thought Prompting Elicits Reasoning in Large Language Models," arXiv preprint arXiv:2201.11903, 2022.

[4] P. Veličković, G. Cucurull, A. Casanova, A. Romero, P. Liò, and Y. Bengio, "Graph Attention Networks," in Proceedings of the 6th International Conference on Learning Representations (ICLR 2018), Vancouver, BC, Canada, 2018.

[5] M. Qamhieh, H. Sammaneh, and M. N. Demaidi, "PCRS: Personalized Career-Path Recommender System for Engineering Students," IEEE Access, vol. 8, pp. 225764-225775, Nov. 2020, doi: 10.1109/ACCESS.2020.3040338.

[6] P. C. Siswipraptini, H. L. H. S. Warnars, A. Ramadhan, and W. Budiharto, "Personalized Career-Path Recommendation Model for Information Technology Students in Indonesia," IEEE Access, vol. 12, pp. 25347-25360, Mar. 2024, doi: 10.1109/ACCESS.2024.3381032.

[7] P. Lewis et al., "Retrieval-Augmented Generation for Knowledge-Intensive NLP Tasks," in Proceedings of the 34th International Conference on Neural Information Processing Systems, 2020, pp. 9459–9474.

[8] N. Reimers and I. Gurevych, "Sentence-BERT: Sentence Embeddings using Siamese BERT-Networks," in Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing (EMNLP-IJCNLP), Hong Kong, China, 2019, pp. 3982–3992.