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AI-Driven Course Recommendation System for Enhanced Career Alignment in Engineering Education

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Abstract

In today's fast-paced and ever-evolving job market, students often struggle with course selection, finding it difficult to align their academic paths with the skills required by industries. This gap between education and employment readiness poses a significant challenge, particularly for students aiming to enter the workforce in industry or national laboratories. To address this, we propose developing an AI-driven course recommendation tool focused on the Electrical and Computer Engineering (ECE) domain, designed to bridge this gap by empowering students with data-driven guidance that improves career alignment.

The tool leverages machine learning (ML) algorithms to analyze job postings from industry careers pages, extracting key trends and skills currently in demand. Using keywords associated with various ECE subfields—such as controls, power electronics, and power systems—, the system will provide students with a curated list of recommended courses corresponding to these market demands. Additionally, the tool will incorporate student input, allowing them to tailor recommendations based on their interests and career aspirations. This dual input system ensures that course recommendations are aligned with real-world opportunities and personalized to individual student goals.

This is a work in progress, henceforth, as the tool evolves, it could also include more specializations and certifications offered by the university, allowing students and professionals at different stages of their careers to receive tailored guidance. Furthermore, the tool can adapt to the unique strengths and specializations of individual institutions, ensuring that the recommendations are market-driven and reflective of the best academic resources available at the student's university. By integrating university-specific course catalogs, the tool enhances its relevance to students while maintaining adaptability to changing industry demands and local job markets.

By combining market analysis with personalized learning paths, the tool is designed to enhance students' employability by preparing them for the specific demands of their desired industries. The use of AI/ML not only allows for scalable, real-time data processing but also provides an adaptive framework that evolves alongside changing market needs. This innovation addresses a critical need in engineering education by helping students make more strategic, informed decisions about their academic preparation. Furthermore, by fostering closer alignment between education and employment, this tool supports universities' mission to produce career-ready graduates, ultimately contributing to a more responsive and adaptable educational system.

Introduction

In today's dynamic and competitive job market, students face significant challenges in aligning their academic paths with industry requirements. Despite the availability of advisors and career platforms like LinkedIn and Indeed, many students lack actionable guidance tailored to their individual goals and the rapidly changing demands of the workforce. The absence of tools that directly connect academic offerings to career opportunities leaves students without clear strategies for achieving their professional aspirations.

Existing career planning resources provide valuable insights but have limitations. Online platforms like LinkedIn and Indeed offer vast repositories of job postings but lack the capability to personalize advice or correlate industry demands with academic courses. University course catalogs and academic advisors, while helpful, often do not have access to real-time labor market data or the means to predict emerging trends. This disconnect leaves a gap that requires innovative, data-driven solutions.

To address these issues, we propose an AI-driven course recommendation tool for the Electrical and Computer Engineering (ECE) domain. By combining machine learning algorithms, real-time job market data, and personalized user input, the tool bridges the gap between education and employment. It ensures that students receive tailored recommendations aligned with their career aspirations and current industry trends.

At this stage, the tool serves as a prototype, demonstrating a proof-of-concept for how real-time job market analysis can be integrated with university course offerings. While the current version includes a limited dataset from two companies and a single university, the framework is designed to be expanded. Future iterations will incorporate a broader range of industry partners, universities, and user feedback to enhance its accuracy and impact. Additionally, planned user testing with students will provide valuable insights into its effectiveness in career planning.

Previous studies, such as [1] and [2], demonstrate the potential of machine learning and data mining for career guidance. However, these approaches often lack integration with university-specific course data. Collaborative filtering techniques [3] and skill mapping frameworks [4] provide foundational methodologies, but the proposed tool extends these capabilities by incorporating dual-input personalization and adaptability to university strengths.

Background

The process of job searching has evolved significantly with the advent of online platforms like LinkedIn, Indeed, and other social media channels. These contemporary methods have become the go-to tools for professionals seeking employment, offering vast repositories of job postings, skill requirements, and networking opportunities. LinkedIn, for instance, allows users to build professional profiles, connect with industry experts, and apply directly to job postings. Similarly, platforms like Indeed aggregate job listings from various sources, providing users with centralized access to a wide array of opportunities. Social media platforms such as Twitter and Facebook also play a role in job discovery, with companies posting openings and employees sharing opportunities within their networks.

While these tools offer significant advantages, they also come with notable limitations. From a user's perspective, these platforms often provide an overwhelming amount of information without sufficient personalization. Job seekers are left to sift through countless listings, many of which may not align with their qualifications or interests. Moreover, these platforms lack the capability to connect industry demands directly to academic preparation, leaving users without actionable guidance on how to tailor their education to meet job market needs. This gap highlights the need for tools that go beyond simple job aggregation to provide meaningful, personalized recommendations.

The proposed AI-driven course recommendation tool addresses this gap by bridging the disconnect between contemporary job search methods and academic preparation. The tool leverages machine learning algorithms to analyze job postings directly from company career pages, extracting key trends and skills that are currently in demand. By correlating these insights with university course catalogs, the tool offers personalized course recommendations tailored to industry needs and student aspirations. This approach not only guides students in selecting relevant courses but also empowers them to align their academic paths with specific career opportunities.

The computational and programming tools underpinning this research include Python-based frameworks for data scraping, processing, and analysis. Libraries such as BeautifulSoup and Selenium are used to scrape job postings and extract relevant data, while machine learning models could leverage libraries like Scikit-learn and TensorFlow for trend analysis and prediction. Natural language processing (NLP) techniques are employed to identify and map keywords from job descriptions to academic courses in future iterations. Additionally, the tool incorporates university-specific course data, making the recommendations contextually relevant to the user's institution.

It is important to note that this research is not intended to replace human interaction or the role of academic advisors. Instead, it aims to advance the mentoring process by providing advisors and students with a strong foundation for discussion. By offering data-driven insights, the tool enhances the quality of academic advising sessions, ensuring that students make more informed decisions about their education and career trajectories.

One of the most significant advantages of this tool is its potential to save time. Instead of manually searching through numerous websites, students can rely on the tool to aggregate and analyze relevant job and course data, presenting them with tailored recommendations in a fraction of the time. This efficiency allows students to focus on building their skills and preparing for their careers, rather than navigating the complexities of job market research on their own.

In summary, the proposed AI-driven course recommendation tool bridges the gaps in contemporary job search methods by integrating real-time job market analysis with academic course recommendations. By leveraging advanced computational tools and maintaining the human element of mentorship, it provides a comprehensive solution that saves time, enhances career alignment, and supports more strategic academic planning.

Methodology

The design and implementation of the course recommendation tool involve the following sequential steps:

1. **User Input:** Users access the tool via a graphical user interface (GUI) and input their preferences, including academic interests (e.g., Control Systems, Robotics) and job market preferences (e.g., Automotive, Energy). Optional inputs, such as specific universities or companies, allow for further customization.
2. **Keyword Mapping:** A predefined keyword library maps user inputs to relevant keywords. These keywords form the foundation for subsequent analyses.
3. **Job Market Analysis:** Job postings are scraped from platforms like company career pages using BeautifulSoup and Selenium. Text similarity techniques analyze these postings to identify in-demand skills and trends.
4. **University Course Integration:** The tool maps extracted keywords to university course descriptions. Cosine similarity [5] is used to rank courses based on their alignment with job market trends.
5. **Recommendation Generation:** The system generates a ranked list of courses based on similarity scores. Recommendations are displayed with detailed information, including matched keywords and job links.
6. **User Interaction:** Users interact with the GUI to explore recommendations, view job links, and refine their inputs. The interface includes list boxes and dropdown menus for selection, with buttons for submitting inputs and accessing job details.

Methods/ System Design and Implementation

The proposed AI-driven course recommendation tool integrates data collection, analysis, and user interaction to provide personalized and actionable course recommendations. The system follows a sequential workflow, combining advanced computational methods with a user-friendly interface to achieve its objectives efficiently. Below, we describe the core components of the system's design and implementation in detail.

The system begins with a launch phase, where users access the tool through a graphical user interface (GUI). This interface allows users to input their preferences and refine their options. Users first interact with the input selection module, where they can choose their academic interests (e.g., Control Systems, Machine Learning) and job market preferences (e.g., Automotive, Robotics). Additional options, such as specifying a school or targeting specific companies, allow for further customization and tailoring of recommendations. The general workflow of the tool is illustrated in Figure 1, which provides an overview of the system's logical flow from input to personalized recommendations.

Once the inputs are provided, the system proceeds to the keyword extraction phase. Here, a predefined keyword library maps the selected preferences to relevant keywords. These keywords serve as the foundation for analyzing job market trends and mapping academic courses to

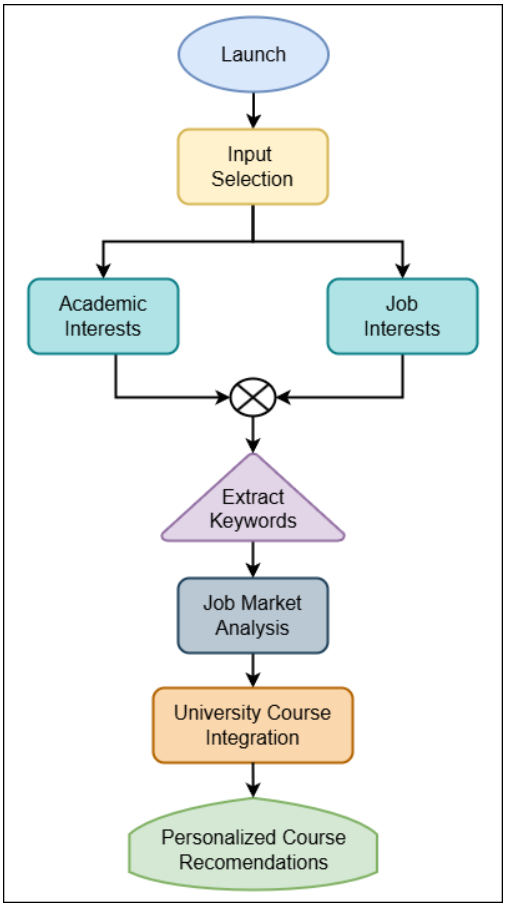

Figure 1: Workflow of the proposed tool, showing the sequential process from input selection to course recommendations.

industry requirements. This phase ensures a direct link between user input and the system's data-driven recommendations.

The extracted keywords are then used in the job market analysis module. Python-based tools such as BeautifulSoup and Selenium scrape job postings directly from company career pages, extracting relevant information for analysis. The extracted data is analyzed using natural language processing (NLP) techniques to identify trends and in-demand skills. This analysis enables the system to determine the most relevant industry requirements and their alignment with the extracted keywords.

Following job market analysis, the system transitions to the university course integration phase. Here, the extracted keywords are mapped to institution-specific course catalogs. By analyzing course descriptions and syllabi, the system identifies courses that align closely with the skills and trends identified in the job market. This integration ensures that recommendations are not only market-driven but also contextually relevant to the academic offerings of the user's institution.

The university course integration process involves extracting course descriptions directly from the university's catalog. These descriptions are analyzed to determine their alignment with industry

demands using a similarity score, which quantifies the relevance of a course based on its textual overlap with job market trends. Currently, course prerequisites are not considered in the recommendation process; the focus remains on course content as described in the catalog. Cosine similarity, a widely used text-matching technique, is employed to compare job-related keywords with course descriptions. This method ensures that recommended courses closely match the skills sought by employers. Additionally, each time a student runs the tool, real-time job market data and course descriptions are fetched, ensuring that course recommendations remain dynamic and reflect the latest industry trends. This continuous updating mechanism enables the tool to adapt to shifting workforce demands and provide students with up-to-date academic guidance.

Finally, the tool generates personalized recommendations, presenting users with a ranked list of courses that best align with their interests and job market trends. These recommendations include detailed information, such as matched keywords and relevant job links, to provide actionable insights for the user. The recommendations are displayed through the GUI, as shown in Figure 2, where users can explore job descriptions, refine their inputs, or take further action, such as applying to jobs or consulting with academic advisors.

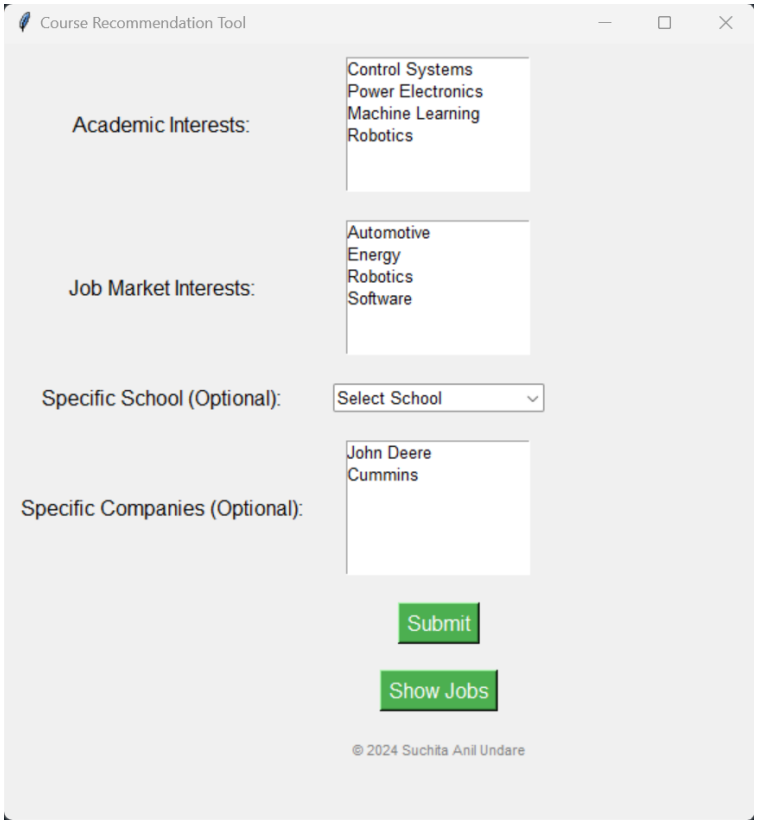

Figure 2: Graphical User Interface of the course recommendation tool, illustrating input selection and actions.

The user interface is designed to be intuitive and functional, ensuring ease of use. The input section allows users to select preferences using list boxes and dropdown menus. Two primary buttons—Submit and Show Jobs—drive the process forward. The Submit button initiates data analysis, while the Show Jobs button provides access to job-specific details, enhancing

transparency and usability. The interface ensures that users can navigate the tool with minimal effort and quickly access personalized recommendations.

The computational implementation relies on Python frameworks for data processing and analysis. Libraries like BeautifulSoup and Selenium enable efficient web scraping, while Tkinter serves as the backbone for the GUI, enabling seamless user interaction.

This research emphasizes that the tool is not intended to replace human advisors but to complement their expertise. By providing data-driven recommendations, the tool equips advisors and students with a strong foundation for mentoring discussions, thus advancing the academic advising process. Additionally, the tool is a significant time-saver, aggregating and analyzing data from multiple sources to deliver actionable insights quickly. Instead of navigating multiple websites and resources manually, users receive curated recommendations that align their education with market demands in a matter of seconds.

In summary, the system is designed to integrate real-time job market data with academic offerings, providing tailored recommendations through an efficient and user-friendly platform. By leveraging advanced computational tools, the system bridges the gap between education and employment, enhancing career alignment and supporting strategic academic planning.

Prototype Results

The prototype of the course recommendation tool was tested using specific user preferences. The selected inputs included academic interests in control systems, job market interests in automotive, the university chosen as University of Colorado Colorado Springs (UCCS), and the target company specified as John Deere. The system successfully generated two outputs: a summary of results and a detailed list of job links, accessible through the ”Show Jobs” button.

The results summary, shown in Figure 3, provides an overview of the tool’s ability to analyze job market demands and align them with university courses. For job postings from John Deere, the tool identified relevant keyword matches, including four matches for control systems, five matches for controls, zero matches for nonlinear control and feedback control, two matches for automotive, ten matches for vehicle, one match for autonomous, and six matches for electric vehicle. These results illustrate the tool’s capacity to identify skills and trends that align with the selected academic and job market interests.

Additionally, the university course recommendations were generated based on the analysis of the UCCS course catalog. The tool calculated similarity scores to quantify the alignment between job market trends and university courses. For example, ECE 5580 - Multivariable Control Systems achieved the highest similarity score of 0.23, followed by ECE 4560 - Digital Control Laboratory with a score of 0.23, and ECE 5570 - Optimization Methods in Systems and Control with a score of 0.22. These similarity scores indicate the degree to which each course matches the job market demands. Detailed recommendations with similarity scores are presented in Figure 3.

When the ”Show Jobs” button was clicked, the tool displayed a detailed pop-up, shown in Figure 4, listing job postings that matched the user’s preferences. For example, the system identified roles such as part-time student positions in electrification and electrical engineering, a summer internship in battery engineering, and senior engineering positions in vehicle electronics

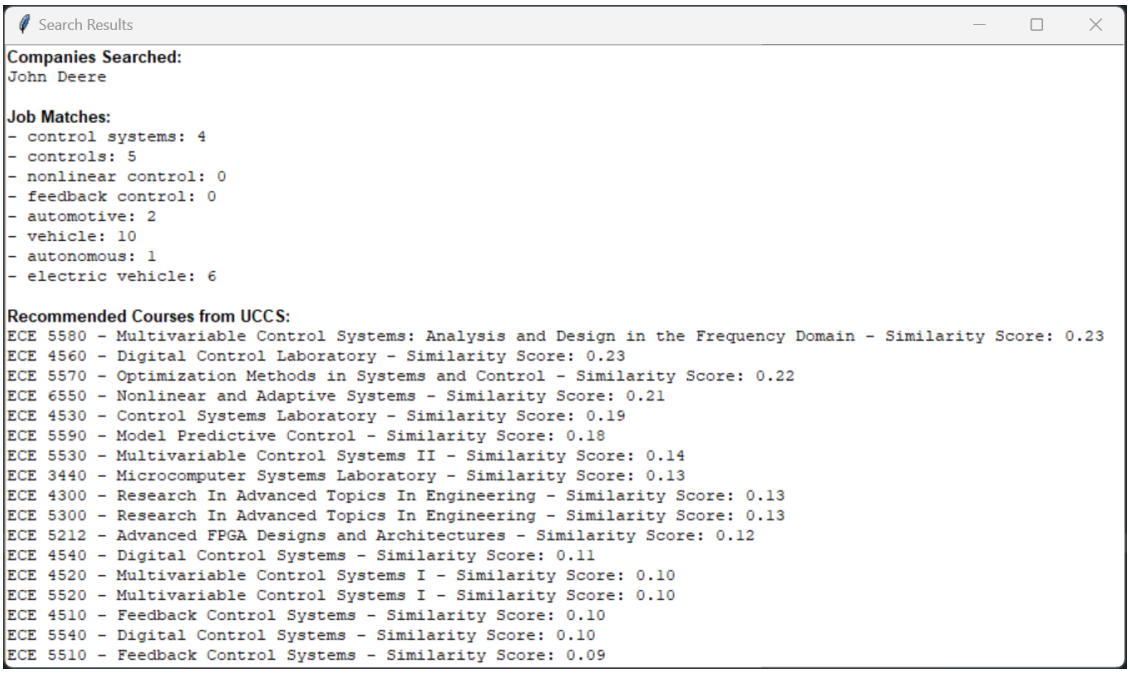

Figure 3: Results summary showing job keyword matches and recommended courses from UCCS based on user inputs.

design. Each job entry included matched keywords such as control systems, vehicle, autonomous, and electric vehicle, demonstrating the alignment between industry needs and the user's input. The pop-up also provided clickable links, enabling users to navigate directly to job postings for further exploration.

These results validate the tool's capability to integrate job market trends with academic offerings effectively. By automating the processes of keyword extraction, job analysis, and course alignment, the tool significantly reduces the time and effort required to navigate the complex landscape of job markets and academic catalogs. This approach provides students with a streamlined, data-driven framework to make informed decisions about their academic and career trajectories.

Discussion

The AI-driven course recommendation tool demonstrated significant potential in aligning academic preparation with job market demands. The prototype results show that the tool effectively bridges the gap between students' academic interests and industry needs by providing personalized recommendations based on real-world data. The integration of job market analysis with university-specific course catalogs enables students to tailor their educational paths toward career readiness, ensuring both relevance and practicality.

One of the strengths of this tool lies in its ability to automate a traditionally manual process. By analyzing job postings and university courses, the system offers data-driven insights that save significant time for students and advisors. Furthermore, the interactive feature allowing users to

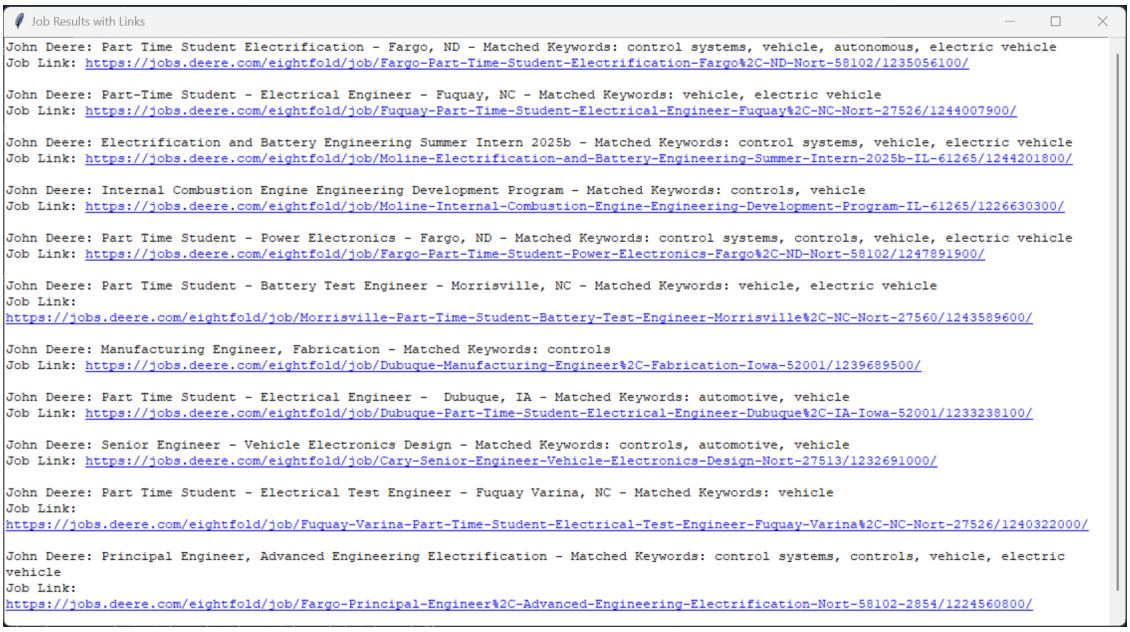

Figure 4: Detailed job links pop-up for John Deere, displaying matched keywords and links to job postings.

access job links directly enhances its usability and provides actionable outputs for students seeking internships or employment opportunities.

However, the tool is not without limitations. Currently, it is restricted to a single university's course catalog and two specific companies. While effective within this scope, its scalability could be improved by incorporating additional universities, companies, and broader datasets. Another limitation is the reliance on predefined keywords, which may not capture emerging trends in dynamic industries. Incorporating advanced natural language processing techniques could further enhance the precision of keyword extraction and job-course mapping.

The integration of similarity scores into the course recommendation tool highlights its potential to bridge the gap between academic preparation and industry demands. The ranking of courses based on relevance provides students with actionable insights, allowing them to make informed decisions about their educational paths. While effective within its current scope, the tool could be enhanced by incorporating model-based machine learning techniques to improve the accuracy and adaptability of recommendations.

Further advancements could involve training models on historical student data and industry feedback to predict emerging trends. These enhancements would enable the tool to adapt to the evolving job market dynamically, ensuring that recommendations remain relevant over time. Additionally, the tool could be enhanced to accept user-provided statements or sentences as input to identify academic and job market interests, moving beyond the limitations of pre-specified options. This flexibility would provide a more personalized and intuitive user experience, further aligning the tool with individual goals and preferences.

Additionally, while the tool provides valuable recommendations, it does not replace the role of

academic advisors or mentors. Instead, it aims to complement their guidance by equipping them with detailed data-driven insights. This ensures that human interactions remain a core component of academic and career planning, allowing for deeper discussions tailored to individual student goals.

The broader applicability of the methodology also warrants discussion. Although designed for engineering education, the framework could be adapted to other disciplines, enabling students in diverse fields to align their educational decisions with industry demands. This adaptability underscores the potential of tools like this to transform the way educational and career planning is approached across academia.

Conclusion

The AI-driven course recommendation tool represents a significant advancement in bridging the gap between education and employment. By integrating job market analysis with university-specific course offerings, the tool empowers students to make more strategic and informed decisions about their academic and career trajectories. The prototype evaluation demonstrated its ability to extract meaningful insights from job postings and align them with academic courses, offering actionable guidance tailored to the user's preferences.

One of the key outcomes of this research is the demonstration of how automation and machine learning can streamline academic and career planning. By reducing the time and effort required for students to navigate job postings and course catalogs, the tool addresses a critical need in modern education. Moreover, its dual-input approach, incorporating both job market trends and student preferences, ensures that the recommendations are not only data-driven but also personalized.

Future iterations of the tool could address current limitations, such as expanding the scope to include additional universities and companies. User feedback and more advanced computational models could further refine the system, enhancing both its accuracy and usability.

By leveraging similarity scores and a user-friendly interface, the system provides personalized recommendations that save time and enhance career readiness. Future iterations could integrate advanced machine learning models to refine the system further and expand its applicability across disciplines and institutions.

In conclusion, this research provides a scalable and adaptable framework that has the potential to benefit students, advisors, and educational institutions. By fostering closer alignment between academic preparation and industry requirements, the tool supports the broader mission of producing career-ready graduates. With further development, it could become an indispensable resource for enhancing career readiness and supporting informed educational planning across a wide range of disciplines.

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