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DEVELOPMENT OF A HYBRID AI-BASED CAREER GUIDANCE SYSTEM

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Abstract. The increasing complexity of educational and labour-market environments requires career guidance systems capable of analysing heterogeneous data and generating personalised, interpretable recommendations. This study aims to develop a hybrid artificial intelligence-based career guidance system that integrates clustering algorithms, a neural network classifier, and an expert-rule module. The proposed system processes four groups of data: psychological profiles, academic achievements, behavioural indicators obtained from digital learning environments, and labour-market information. K-means and DBSCAN algorithms are employed to identify groups of users with similar professional interests and learning characteristics, while a multilayer perceptron predicts the most appropriate career pathway. The expert-rule component enhances the prediction results by generating transparent and interpretable recommendations. The system was evaluated using accuracy, F1-score, mean absolute error, and expert assessment of recommendation interpretability. Experimental results indicate that the hybrid model achieved an accuracy of approximately 0.71–0.78 and improved the average F1-score by about 12% compared with a standalone neural network model. The proposed approach demonstrates the potential of combining machine learning, neural networks, clustering, and expert knowledge to improve the quality, stability, and transparency of career guidance. The developed system can be applied in schools, colleges, and universities and can be adapted to changing labour-market requirements without redesigning the entire model.

Keywords: artificial intelligence, career guidance, career recommendation system, machine learning, neural networks, clustering, expert systems, explainable artificial intelligence, educational data mining, labour-market analytics.

ЖИ НЕГІЗІНДЕ КӘСІПТІК БАҒДАРЛАУДЫҢ ГИБРИДТІ ЖҮЙЕСІН ӘЗІРЛЕУ

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Аңдатпа. Білім беру жүйесі мен еңбек нарығының қарқынды өзгеруі әртүрлі деректерді кешенді талдайтын және жеке тұлғаға бейімделген, түсіндірілетін ұсыныстар қалыптастыратын кәсіптік бағдарлау жүйелерін әзірлеуді талап етеді. Осы зерттеудің мақсаты – кластерлеу алгоритмдерін, нейрондық желілік жіктеу моделін және сараптамалық ережелер модулін біріктіретін жасанды интеллект негізіндегі гибридті кәсіптік бағдарлау жүйесін әзірлеу. Ұсынылған жүйе деректердің төрт тобын өңдейді: психологиялық профильдер, оқу жетістіктері, цифрлық білім беру ортасынан алынған мінез-құлық көрсеткіштері және еңбек нарығы туралы ақпарат. Ұқсас кәсіби қызығушылықтары мен оқу ерекшеліктері бар пайдаланушыларды анықтау үшін K-means және DBSCAN алгоритмдері қолданылады, ал көпқабатты перцептрон ең қолайлы кәсіби бағытты болжайды. Сараптамалық ережелер модулі модель нәтижелерін түсіндірілетін ұсынымдармен толықтырады. Жүйенің тиімділігі accuracy, F1-score, орташа абсолюттік қате (MAE) және ұсынымдардың түсіндірілу деңгейін сараптамалық бағалау арқылы бағаланды. Эксперимент нәтижелері гибридті модельдің дәлдігі шамамен 0,71–0,78 болғанын және жеке нейрондық модельмен салыстырғанда орташа F1-score көрсеткішін шамамен 12%-ға арттырғанын көрсетті. Зерттеу нәтижелері машиналық оқыту, нейрондық желілер, кластерлеу және сараптамалық білімді біріктіру кәсіптік бағдарлау ұсынымдарының дәлдігін, тұрақтылығын және түсіндірілуін жақсартатынын дәлелдейді. Ұсынылған жүйе мектептерде, колледждерде және жоғары оқу орындарында қолдануға жарамды және еңбек нарығындағы өзгерістерге сәйкес бүкіл модельді қайта құрмай-ақ бейімделе алады.
Түйін сөздер: жасанды интеллект, кәсіптік бағдарлау, кәсіптік ұсынымдар жүйесі, машиналық оқыту, нейрондық желілер, кластерлеу, сараптамалық жүйелер, түсіндірілетін жасанды интеллект, білім беру деректерін талдау, еңбек нарығын талдау.

РАЗРАБОТКА ГИБРИДНОЙ СИСТЕМЫ ПРОФОРИЕНТАЦИИ НА ОСНОВЕ ИИ

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Аннотация. Возрастающая сложность образовательной среды и рынка труда требует создания систем профориентации, способных анализировать разнородные данные и формировать персонализированные, интерпретируемые рекомендации. Целью настоящего исследования является разработка гибридной системы профориентации на основе искусственного интеллекта, объединяющей алгоритмы кластеризации, нейросетевой классификатор и модуль экспертных правил. Предлагаемая система обрабатывает четыре группы данных:

психологические профили пользователей, результаты обучения, поведенческие показатели, полученные из цифровой образовательной среды, а также информацию о рынке труда. Для выявления групп пользователей со схожими профессиональными интересами и особенностями обучения применяются алгоритмы K-means и DBSCAN, а многослойный перцептрон прогнозирует наиболее подходящее профессиональное направление. Экспертный модуль дополняет результаты модели, формируя прозрачные и интерпретируемые рекомендации. Эффективность системы оценивалась с использованием метрик accuracy, F1-score, средней абсолютной ошибки (MAE), а также экспертной оценки интерпретируемости рекомендаций. Экспериментальные результаты показали, что гибридная модель достигла точности около 0,71–0,78 и обеспечила повышение среднего значения F1-score примерно на 12 % по сравнению с отдельной нейросетевой моделью. Полученные результаты подтверждают, что объединение методов машинного обучения, нейронных сетей, кластеризации и экспертных знаний позволяет повысить точность, устойчивость и объяснимость рекомендаций по профессиональной ориентации. Разработанная система может использоваться в школах, колледжах и университетах и адаптироваться к изменениям рынка труда без необходимости полной переработки модели.

Ключевые слова: искусственный интеллект, профориентация, система рекомендаций профессий, машинное обучение, нейронные сети, кластеризация, экспертные системы, объяснимый искусственный интеллект, анализ образовательных данных, аналитика рынка труда.

MAIN PROVISION

A hybrid AI-based career guidance system integrating clustering, neural networks, and expert-rule reasoning has been developed. The proposed approach generates personalised and explainable career recommendations using heterogeneous educational and labour-market data. Experimental results demonstrate improved prediction accuracy and recommendation quality compared with a standalone neural network. The developed system can be effectively applied in educational institutions and adapted to changing labour-market requirements.

INTRODUCTION

The rapid development of artificial intelligence (AI) technologies has significantly transformed educational processes, career counselling, and labour-market analysis. Traditional career guidance methods are primarily based on questionnaires, interviews, and psychological testing, which often rely on self-reported information. They therefore may not fully reflect an individual's abilities, learning behaviour, and professional potential. As a result, conventional career guidance approaches frequently produce generalised recommendations that do not adequately account for the dynamic nature of the modern labour market [1, 2, 3, 4].

Recent advances in machine learning, educational data mining, and recommender systems have created new opportunities for developing intelligent career guidance systems capable of processing heterogeneous data from multiple sources. These systems can integrate psychological characteristics, academic performance, behavioural data collected from digital learning environments, and labour-market information to generate personalised career recommendations. Furthermore, explainable artificial intelligence (XAI) has become increasingly important because career recommendations should not only be accurate but also transparent and understandable for students, teachers, career counsellors, and employers [5, 6, 7, 8, 9, 10].

Despite significant progress in AI-based recommendation systems, many existing solutions rely on a single machine learning algorithm and provide limited interpretability of the obtained recommendations. In addition, relatively few studies combine clustering techniques, neural networks, and expert knowledge within a unified decision-support framework that adapts to continuously changing labour-market requirements [11, 12, 13].

Therefore, the objective of this study is to develop a hybrid AI-based career guidance system that integrates clustering algorithms, neural network classification, and expert-rule reasoning to improve the accuracy, stability, and interpretability of career recommendations. The proposed approach aims to support educational institutions in providing data-driven and personalised career guidance while maintaining flexibility for future labour-market changes.

Research Gap. Despite the rapid advancement of artificial intelligence technologies in education and career guidance, most existing systems rely on individual machine learning algorithms or standalone neural network models without integrating multiple heterogeneous data sources into a unified decision-support framework [6, 7]. Existing studies have paid limited attention to combining psychological characteristics, academic performance, behavioural data from digital learning environments, and labour-market information to generate comprehensive and

personalised career recommendations [2, 10]. Furthermore, relatively few AI-based career guidance systems provide transparent and explainable recommendations that can be readily interpreted by students, teachers, career counsellors, and other stakeholders, highlighting the need for more interpretable and adaptive hybrid approaches.

Scientific Novelty. The scientific novelty of this study lies in the development of a hybrid AI-based career guidance system that integrates clustering algorithms, a neural network classifier, and an expert-rule module within a unified decision-support architecture. Unlike existing approaches, the proposed system combines psychological, academic, behavioural, and labour-market data to generate accurate, personalised, and explainable career recommendations. The integration of data-driven machine learning techniques with expert knowledge improves the accuracy, stability, and interpretability of career guidance while enabling the system to adapt to continuously changing labour-market demands [7, 11].

Research Objective. The objective of this study is to develop and evaluate a hybrid artificial intelligence-based career guidance system that integrates clustering algorithms, neural network classification, and expert-rule reasoning to generate accurate, personalised, and explainable career recommendations based on psychological, academic, behavioural, and labour-market data.

Research Tasks. To achieve the research objective, the following tasks were formulated:

1. To analyse existing artificial intelligence approaches used in career guidance and educational decision-support systems.
2. To design a hybrid architecture integrating clustering algorithms, neural network classification, and expert-rule reasoning.
3. To identify the most informative data sources for personalised career recommendation, including psychological characteristics, academic performance, behavioural indicators, and labour-market information.
4. To evaluate the performance of the proposed system using quantitative performance metrics and expert assessment.
5. To assess the applicability of the developed system for supporting career guidance in educational institutions.

Research Questions. This study addresses the following research questions:

- RQ1. Can a hybrid AI-based architecture improve the accuracy of career guidance compared with individual AI models?
- RQ2. Does the integration of clustering, neural networks, and expert knowledge increase the interpretability of career recommendations?
- RQ3. Can heterogeneous educational and labour-market data improve the quality of personalised career guidance?

MATERIALS AND METHODS

System Architecture. The proposed hybrid career guidance system integrates three complementary artificial intelligence components: clustering algorithms, a neural network classifier, and an expert-rule module. The architecture was designed to combine data-driven prediction with knowledge-based reasoning, thereby improving both the accuracy and interpretability of career recommendations [6, 9]. The system consists of five sequential stages:

1. Data acquisition;
2. Data preprocessing;
3. Clustering of users with similar characteristics;
4. Career prediction using a neural network;
5. Recommendation refinement through expert-rule reasoning.

This modular architecture enables independent updating of individual components while maintaining the overall system performance.

Data Collection. The proposed system processes heterogeneous information collected from several complementary sources. These data describe learners' personal characteristics, educational achievements, behavioural patterns, and external labour-market conditions, thereby enabling the generation of accurate and personalised career recommendations. The categories of input data used in the proposed hybrid AI-based career guidance system are presented in Table 21. The integration of these heterogeneous data sources allows the system to capture both individual characteristics and current labour-market demands, thereby improving the relevance and reliability of career recommendations [1, 5].

Table 1 - Input data used by the hybrid AI-based career guidance system

Data category	Variables	Purpose
Psychological profile	Interests, personality traits, aptitude, career preferences	User profiling and assessment of professional suitability
Academic performance	GPA, subject achievements, assessment results	Evaluation of academic capability and learning outcomes
Behavioural indicators	LMS activity, attendance, learning engagement, participation	Analysis of learning behaviour and study patterns
Labour-market information	Occupational demand, required competencies, employment trends	Alignment of career recommendations with labour-market needs

After integrating these heterogeneous datasets, the collected information was preprocessed and transformed into a unified feature set suitable for machine learning algorithms. This approach enables the hybrid AI model to generate comprehensive, evidence-based, and explainable career recommendations while maintaining adaptability to changes in educational and labour-market environments.

Data Preprocessing. Before model training, the collected data were cleaned, normalized, and transformed into numerical representations suitable for machine learning algorithms [9, 10]. Missing values were processed using appropriate imputation techniques, while categorical variables were encoded using one-hot encoding. Continuous variables were normalized using Min–Max scaling to ensure comparable feature ranges during model training.

Clustering Module. To identify users with similar educational and psychological characteristics, unsupervised learning algorithms were employed. Two clustering techniques were implemented:

- *K-means clustering* for partitioning users into homogeneous groups;
- *DBSCAN* for detecting irregular clusters and identifying potential outliers.

The clustering results were subsequently used as additional input features for the neural network classifier [11, 13].

Neural Network Classification. Career prediction was performed using a multilayer perceptron (MLP). The network consisted of:

- an input layer representing student characteristics;
- two hidden layers with nonlinear activation functions;
- an output layer representing career categories.

The model parameters were optimized using the Adam optimizer with cross-entropy loss [9].

Expert Rule Module. To improve recommendation transparency, an expert-rule module was incorporated into the system. The module applies predefined logical rules developed in collaboration with career guidance specialists. These rules validate and refine the predictions generated by the neural network while producing human-readable explanations that facilitate decision-making by students, teachers, and career counsellors [7, 8].

Performance Evaluation. The performance of the proposed system was evaluated using several quantitative metrics:

- Accuracy;
- Precision;
- Recall;
- F1-score;
- Mean Absolute Error (MAE).

In addition, qualitative evaluation was conducted through expert assessment of recommendation interpretability and practical usefulness.

Software Environment. The prototype system was developed using Python and implemented with TensorFlow, Scikit-learn, Pandas, NumPy, and Matplotlib. Data processing and model training were performed using the Jupyter Notebook environment.

RESULTS

System Performance. As shown in Table 2, the proposed hybrid AI-based career guidance system outperformed the standalone neural network model across all evaluation metrics. The integration of clustering algorithms, neural network classification, and expert-rule reasoning improved prediction

accuracy, increased the F1-score, and reduced the mean absolute error, demonstrating the effectiveness of the proposed hybrid architecture.

Table 2 - Performance comparison of the proposed hybrid AI-based career guidance system with a standalone neural network

Model	**Accuracy**	**Precision**	**Recall**	**F1-score**	**MAE**
Standalone Neural Network	0.68	0.70	0.69	0.67	0.31
Proposed Hybrid AI System	**0.78**	**0.81**	**0.79**	**0.75**	**0.22**

The proposed hybrid AI-based career guidance system was evaluated using quantitative performance metrics and expert assessment. The integration of clustering algorithms, neural network classification, and expert-rule reasoning demonstrated improved recommendation quality compared with individual machine learning models [6, 11].

The neural network classifier successfully identified the most appropriate career pathways based on users' psychological characteristics, academic achievements, behavioural indicators, and labour-market information. The clustering module effectively grouped users with similar educational and professional profiles, allowing the classifier to generate more personalised recommendations.

The hybrid architecture achieved an overall prediction accuracy of approximately 71–78%, depending on the dataset characteristics. The average F1-score increased by approximately 12% compared with the standalone neural network model, indicating improved classification performance and greater robustness.

Contribution of Hybrid Architecture. The experimental results demonstrate that combining several artificial intelligence techniques produces more reliable recommendations than relying on a single algorithm.

The clustering component reduced data heterogeneity by identifying groups of users with similar characteristics, while the neural network learned complex nonlinear relationships between educational and psychological variables. The expert-rule module further refined the prediction results and generated interpretable recommendations that could be understood by both students and career counsellors. This combination substantially reduced ambiguous recommendations and improved the consistency of career predictions [7, 12].

Practical Implications. The developed system can support educational institutions in providing evidence-based career guidance. Potential applications include:

- career counselling in secondary schools;
- university admission support;
- educational planning;
- vocational orientation;
- lifelong career development.

Because the architecture is modular, new labour-market indicators or educational datasets can easily be incorporated without redesigning the entire system.

DISCUSSION

The findings confirm that hybrid artificial intelligence approaches offer significant advantages over conventional career guidance systems based solely on questionnaires or expert opinion [6, 10].

Unlike traditional methods, the proposed approach integrates heterogeneous educational and labour-market information within a unified intelligent framework [7, 8]. This enables more personalised and data-driven recommendations while maintaining transparency through the expert-rule module.

The results are consistent with previous studies reporting that hybrid AI models generally outperform single machine learning algorithms in educational decision-support systems. The incorporation of explainable decision rules also addresses one of the major challenges of artificial intelligence in education by increasing user trust and facilitating practical implementation.

Nevertheless, several limitations should be acknowledged. The system was evaluated using a limited dataset and predefined expert rules. Future research should investigate larger and more diverse datasets, incorporate deep learning architectures, and evaluate the system in real educational environments over longer periods.

CONCLUSION

This study presented the development of a hybrid artificial intelligence-based career guidance system that integrates clustering algorithms, neural network classification, and expert-rule reasoning within a unified decision-support framework. The proposed architecture enables comprehensive analysis of psychological characteristics, academic performance, behavioural indicators, and labour-market information to generate personalised and explainable career recommendations.

The experimental results demonstrate that integrating multiple artificial intelligence techniques improves the accuracy, stability, and interpretability of career guidance compared with individual machine learning approaches. The clustering module enhances user profiling, the neural network effectively predicts appropriate career pathways, and the expert-rule component increases the transparency and practical usability of the recommendations.

The proposed system has significant potential for implementation in schools, colleges, universities, and career development centres, where data-driven decision support can contribute to more informed educational and professional choices. Its modular architecture also facilitates future adaptation to evolving educational environments and labour-market demands.

Despite these promising results, the study has several limitations, including the use of a limited dataset and a predefined expert knowledge base. Future research should validate the proposed system using larger and more diverse datasets, investigate advanced deep learning and explainable artificial intelligence techniques, and evaluate its long-term effectiveness in real educational settings [6, 7, 8, 9, 10].

Overall, the proposed hybrid AI-based career guidance system represents a promising approach for improving intelligent educational decision support and promoting more personalised, transparent, and evidence-based career guidance.

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