Cyber Security and Network Management E-ISSN: 3124-0054

Research Article

Machine Learning Model Development for Adaptive Recruitment Recommendation System Based on Portfolio Analysis and Professional Network

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Abstract: The rapid advancement of digital transformation and artificial intelligence has significantly reshaped recruitment processes within organizations. Conventional recruitment systems predominantly rely on curriculum vitae screening and keyword-based matching, which often fail to capture contextual competencies and relational professional evidence. This study proposes the development of an adaptive machine learning–based recruitment recommendation system that integrates professional portfolio analytics and professional network structures within a unified graphbased framework. The proposed approach adopts a Research and Development (R&D) methodology under a data-driven system development paradigm. Candidate data from an existing recruitment system are integrated with external professional data sources, including GitHub and LinkedIn. A heterogeneous graph representation is constructed to model relationships among candidates, skills, projects, and organizations. Graph Neural Networks (GNN) are employed to learn contextual relational embeddings, while a Gradient Boosting Machine (GBM) is utilized for candidate job suitability classification. The proposed framework is designed to enhance objectivity, contextual awareness, and adaptability in recruitment decision-making. By leveraging multi-source digital professional evidence and incorporating an adaptive learning mechanism, the system aims to reduce skills mismatch and improve alignment between candidate competencies and evolving industry requirements. Future work will focus on empirical validation using real-world recruitment datasets and the integration of fairness-aware and explainable AI mechanisms to ensure transparency and ethical compliance.

Received: March,17,2026;
Revised: April,16,2026;
Accepted: May,29,2026;
Published: May,31,2026;
Curr. Ver.: May,31,2026;

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Keywords: Adaptive Machine Learning; Graph Neural Network; Human Resource Analytics; Professional Portfolio Analytics; Recruitment Recommendation System.

1. Introduction

Digital transformation and the rapid advancement of artificial intelligence (AI) have significantly reshaped organizational functions, including human resource management (HRM) and recruitment processes. The integration of AI into organizational systems has enabled data-driven decision-making and predictive analytics across multiple domains [1]. Within HRM, electronic human resource management (e-HRM) has evolved into a strategic enabler of digital transformation, redefining traditional talent acquisition and workforce planning mechanisms [2], [3]. In this context, recruitment is no longer perceived as a routine administrative activity but as a strategic function that directly influences workforce quality, organizational innovation, and long-term competitiveness [8], [20]. In dynamic digital industries where required competencies evolve rapidly, organizations demand recruitment systems capable of evaluating candidates objectively and comprehensively. The emergence of

people analytics and AI-driven HR systems has strengthened the role of empirical evidence in recruitment decision-making [19]. However, despite these advancements, many recruitment practices remain dependent on curriculum vitae screening and keyword-based matching within conventional Applicant Tracking Systems. Such systems primarily rely on textual similarity and structured filtering mechanisms, which often fail to capture contextual competencies, collaborative dynamics, and evolving professional capabilities. Recent studies have highlighted critical concerns regarding algorithmic opacity, bias, and fairness in automated hiring systems [4], [5], [16], [17]. While AI-enabled recruiting tools offer efficiency and scalability benefits [6], their reliance on limited or biased training data may perpetuate discrimination and reduce transparency in decision-making processes. These limitations indicate the need for more robust, explainable, and context-aware recruitment architectures.

To enhance recruitment systems, researchers have applied machine learning techniques, including predictive analytics, recommender systems, and intelligent job-matching algorithms [6], [7]. Graph-based collaborative filtering and neural recommender architectures have demonstrated strong capabilities in modeling interaction patterns between entities [12], [14]. Nevertheless, most existing recruitment models still focus predominantly on structured tabular data or textual representations and often neglect the relational structures embedded within professional ecosystems. Recent advances in graph-based learning, particularly Graph Neural Networks (GNNs), provide promising opportunities for modeling complex interconnections among candidates, projects, skills, and organizations. GNNs enable representation learning over non-Euclidean data structures, capturing structural dependencies and relational proximity that conventional machine learning approaches cannot effectively represent [9], [10]. Furthermore, graph-based recommender systems and heterogeneous network representation learning have shown superior performance in integrating multi-source relational data [11], [13].

Despite these technological advancements, there remains a lack of an integrated recruitment framework that simultaneously combines digital portfolio analytics, professional network structures, and adaptive classification mechanisms within a unified architecture. Boosting-based algorithms, such as gradient boosting machines and XGBoost, have consistently demonstrated high predictive performance in classification tasks and offer potential for enhancing recruitment decision optimization [15].

Based on these research gaps, this study proposes the development of an adaptive machine learning–based recruitment recommendation framework integrating professional portfolio data and professional network information using graph-based representation learning and boosting-based classification. The novelty of this research lies in three primary contributions: (1) integrating multi-source professional evidence into a unified analytical model, (2) utilizing Graph Neural Networks for contextual relational representation, and (3) incorporating adaptive learning mechanisms capable of responding dynamically to evolving industry competency demands. This study aims to provide a conceptual and methodological foundation for next-generation intelligent recruitment systems that are objective, contextual, and responsive to digital transformation.

2. Method

Research Methodology

This research methodology is designed to achieve the objective of developing an adaptive machine learning model for a recruitment recommendation system based on professional portfolio analysis and professional network analysis. The approach adopted in this study is Research and Development (R&D) within a data-driven system development framework, integrating quantitative methods, machine learning techniques, and information system design principles. The R&D approach is selected because this study aims not only to develop a theoretical model but also to design and implement a practical recruitment recommendation system that can be integrated into an existing recruitment platform. The data-driven framework ensures that the entire model development process is grounded inempirical analysis of historical recruitment data and enriched with external professional data sources.

The overall research methodology is illustrated in Figure 2, which presents the research flow from the planning phase to system implementation and dissemination of results.

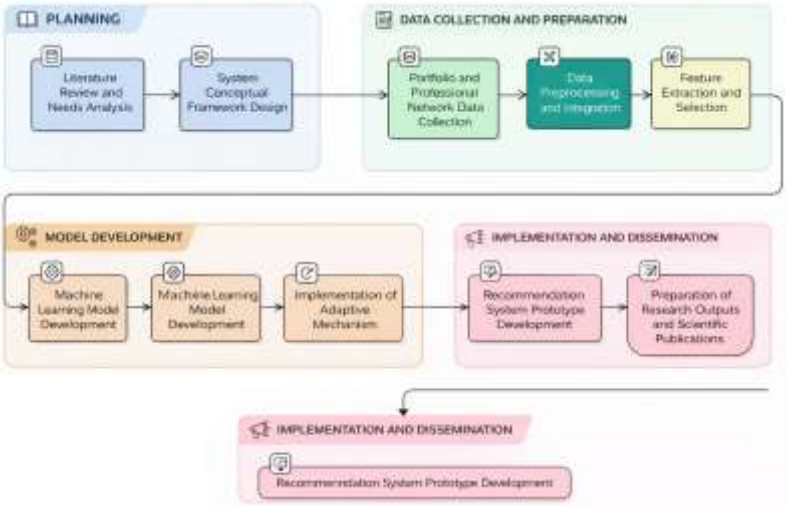


Figure 1. Research Flow Diagram.

Based on the research flow diagram shown in Figure 2, the study is conducted through several systematically structured phases using a data-driven machine learning methodology for adaptive recruitment recommendation systems. The stages are designed to support the development of a model that integrates professional portfolio analytics and professional network structures in a unified framework.

Planning Phase

The planning phase begins with a comprehensive literature review to identify the current state of the art in machine learning–based recruitment systems, particularly those involving digital portfolio integration and professional network analysis. This phase aims to identify research gaps, methodological limitations, and emerging trends in intelligent recruitment systems. In parallel, a needs analysis is conducted on the existing recruitment system to determine its limitations, such as reliance on curriculum vitae screening and keyword-based matching mechanisms. The outcomes of this phase are used to design the conceptual framework of the adaptive recruitment recommendation system, which incorporates multi-source data integration, graph-based modeling, and adaptive classification mechanisms. This conceptual framework forms the basis for determining the system architecture and research parameters.

Data Collection and Preparation

This phase involves collecting data from the operational internal recruitment system and integrating it with relevant external professional data sources. Internal data are obtained from the organization's recruitment database, which stores candidate information including educational background, work experience, technical assessment scores, interview results, and final hiring decisions. These historical hiring outcomes serve as ground-truth labels within a supervised learning framework.

To enrich candidate representation, external data are integrated from GitHub and LinkedIn. GitHub data are used to quantify technical contributions through indicators such as the number of repositories, commit frequency, pull request participation, and dominant programming languages. LinkedIn data are used to represent professional network characteristics and career experience, including number of connections, employment history, duration of experience, and professional reputation indicators.

All collected data undergo preprocessing procedures, including data cleaning, duplicate removal, normalization of numerical features, and anonymization of sensitive attributes to ensure privacy protection. Multi-source data integration and feature extraction are subsequently performed to generate relevant technical, social, and behavioral representations aligned with recruitment objectives.

Model Development

The model development phase focuses on constructing a hybrid machine learning model based on Graph Neural Networks (GNN) and Gradient Boosting Machine (GBM) as the core of the adaptive recruitment recommendation system.

The integrated dataset is first represented as a heterogeneous graph to capture relational structures among professional entities. The graph is formally defined as:

$G=(V,E)$ ……(i)

where V denotes the set of entities such as candidates, repositories, skills, and organizations, and EEE represents the relationships among these entities. This graph representation enables the system to model collaboration patterns and competency proximity that cannot be effectively captured using conventional tabular data structures.

The Graph Neural Network is employed to learn relational representations of candidates through neighborhood aggregation mechanisms. The node representation update at layer l is expressed as:

$$H^{(l+1)} = \sigma\left(\hat{A}H^{(l)}W^{(l)}\right) \quad \text{……..(ii)}$$

where A denotes the normalized adjacency matrix, $H^{(l)}$ represents node embeddings at layer l, $W^{(l)}$, denotes learnable weight parameters, and σ is the activation function. The final candidate embeddings generated by the GNN are combined with non-relational features from the internal recruitment system and used as input to a Gradient Boosting Machine classifier. The boosting model iteratively constructs decision functions to minimize classification error and predict candidate-job suitability. An adaptive learning mechanism is incorporated to allow periodic model updates based on newly acquired candidate data and evolving industry competency requirements. This adaptive capability ensures that the system remains responsive to dynamic labor market conditions. Model development concludes with evaluation and validation using performance metrics including accuracy, precision, recall, and F1-score to assess effectiveness, robustness, and predictive reliability.

Implementation and Dissemination

The final phase involves implementing the validated model in the form of a web-based recruitment recommendation prototype integrated with the organization's internal recruitment system. The prototype provides an interface that enables recruiters to view ranked candidate recommendations based on suitability scores generated by the model. The research outcomes are subsequently disseminated through scientific publications and research reports in accordance with the predetermined research output targets. This phase ensures that the developed model contributes both academically and practically to data-driven recruitment systems.

3. Result and Discusion

This section presents the expected outcomes based on the methodological design described in Chapter II. Since the study is currently in the development and planning phase, the discussion focuses on projected results and anticipated contributions of the proposed adaptive recruitment recommendation framework. Based on the integration of Graph Neural Network (GNN) and Gradient Boosting Machine (GBM), the proposed model is expected to improve candidate-job suitability prediction compared to conventional recruitment approaches that rely primarily on curriculum vitae screening and keyword-based matching. By integrating professional portfolio data from GitHub and professional network data from LinkedIn into a heterogeneous graph structure, the system is projected to generate a more comprehensive and context-aware representation of candidates.

The graph-based modeling approach enables the system to capture relational structures among professional entities, including candidates, projects, skills, and organizations. Unlike traditional tabular models that treat candidates as isolated feature vectors, the graph representation incorporates collaboration patterns, contribution intensity, and competency proximity. Through neighborhood aggregation mechanisms in GNN, candidate embeddings are expected to reflect both structural and contextual professional information. The subsequent use of GBM as a classification mechanism is projected to enhance predictive optimization by leveraging both relational embeddings and non-relational features derived from the internal recruitment system. The iterative boosting process is expected to reduce classification errors progressively, leading to improved performance across evaluation metrics such as accuracy, precision, recall, and F1-score. The planned ablation study is expected to further validate the contribution of each system component. Conceptually, removing the graph structure is anticipated to result in a noticeable decrease in predictive performance due to the loss of relational information. Similarly, excluding GitHub or LinkedIn features is

expected to reduce model effectiveness, as the system would lose critical signals related to technical contribution and professional network context. These projected findings are expected to support the argument that multi-source professional evidence and relational modeling are essential components of an adaptive recruitment recommendation system.

From a theoretical perspective, this study is expected to contribute to the advancement of graph-based representation learning in the domain of human resource analytics. The integration of graph neural networks with boosting-based classification introduces a novel methodological approach for intelligent recruitment systems. This framework extends traditional talent evaluation models by incorporating digital professional evidence and network-aware analytics. From a practical standpoint, the proposed system is anticipated to enhance recruitment decision-making by providing a more objective and data-driven evaluation mechanism. The integration of real technical contributions and professional network information is expected to reduce the risk of skills mismatch and improve alignment between industry competency requirements and candidate profiles. Furthermore, the adaptive learning mechanism is designed to allow periodic model updates, ensuring responsiveness to evolving labor market demands.

However, several anticipated challenges must be acknowledged. The effectiveness of the system may depend on the availability and completeness of external professional data. Variations in digital activity levels among candidates could also influence feature representation. Additionally, privacy and ethical considerations related to the use of professional digital data must be carefully managed to ensure fairness and transparency in recruitment decision-making. Overall, the proposed framework is expected to provide a more contextual, evidence-based, and adaptive recruitment recommendation system compared to conventional approaches. Empirical validation through real-world dataset implementation will be necessary to confirm the projected performance improvements and practical applicability of the model.

4. Conclusion

This study proposes the development of an adaptive machine learning based recruitment recommendation system that integrates professional portfolio analytics and professional network structures within a unified graph-based framework. The research adopts a data-driven system development approach using a hybrid model that combines Graph Neural Networks (GNN) for relational representation learning and Gradient Boosting Machine (GBM) for predictive classification. The proposed framework is designed to address limitations of conventional recruitment systems that rely primarily on curriculum vitae screening and keyword-based matching. By incorporating digital professional evidence from sources such as GitHub and LinkedIn, the system aims to provide a more contextual, objective, and evidence-based evaluation of candidates. The graph-based representation enables the modeling of complex relationships among candidates, skills, projects, and organizations, while the boosting mechanism enhances predictive optimization.

Although empirical validation will be conducted in the subsequent research phase, the conceptual and methodological design presented in this study establishes a structured foundation for next-generation intelligent recruitment systems. The integration of multisource professional data and adaptive learning mechanisms is expected to improve prediction accuracy, reduce skills mismatch, and support more data-driven recruitment decision-making Future work will focus on implementing the proposed framework using real-world recruitment datasets, conducting comprehensive experimental evaluation, and incorporating fairness-aware and explainable AI mechanisms to ensure transparency and ethical compliance in automated recruitment processes.

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