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Hybrid Machine Learning Approach to Employee Effectiveness Evaluation

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Abstract. This thesis presents an electronic employee effectiveness evaluation system based on a hybrid K-Nearest Neighbours (KNN) and Random Forest (RF) classifier with confidence-based routing. Compared with a single-algorithm baseline, the hybrid model raised classification accuracy from 76.2% to 92.8% and halved processing time from 12.4 s to 6.1 s.

Keywords: employee evaluation, KPI, KNN, Random Forest, hybrid classification, AHP, HR analytics.

Relevance. Employee evaluation results drive decisions on pay, promotion, training and staffing, so their objectivity matters directly to an organisation's performance. Modern enterprises increasingly need evaluation tools that are automated, objective and scalable. Practice has moved from paper-based annual reviews, which are supervisor-led and highly subjective, to methods such as Management by Objectives, KPIs and 360-degree feedback, and then to electronic systems (ePA, HRIS, e-HRM) with digital forms and dashboards.

Even electronic systems still have important limitations. Their criteria are fixed in advance and do not adapt to the structure of a particular organisation; changing them often requires changing the database structure. Most of them do not use machine learning, so decisions remain rule-based. Where algorithms are used, they face a trade-off: fast methods such as KNN are less reliable for borderline employees, while accurate ensemble methods such as Random Forest are computationally heavier. Relational data models designed for multi-dimensional performance data are also lacking.

Aim and tasks. The aim of the research is to develop an electronic employee performance evaluation system based on modernised AI-inference methods. To reach it, the following tasks were set: to analyse existing evaluation methods and systems and their limitations; to design an optimised relational database for AI-based inference; to develop a hybrid classification algorithm combining KNN and Random Forest; and to determine the technical and economic benefits of the system in a real organisational environment.

Methods. Each employee is described by five performance dimensions: task performance, work quality, professional conduct, collaboration and communication,

and development and initiative. Each dimension score is scaled to the range [0, 1] by min–max normalisation, which gives a feature vector such as x = [0.82, 0.74, 0.91, 0.65, 0.58].

The criteria are formed in two stages. First, the Analytic Hierarchy Process (AHP) is used: HR experts compare criteria in pairs, and the weights are calculated from the comparison matrix. Second, Pearson correlation screening removes criteria that duplicate each other. HR specialists can add or change criteria at any time without changing the database structure.

The classification is carried out in three steps. In the first step, KNN computes the weighted Euclidean distance from the employee to all employees in the training set, finds the k nearest neighbours, and assigns the class chosen by most of them. The share of neighbours that voted for this class is the confidence score. In the second step, the confidence is compared with the threshold θ. In the third step, borderline cases are passed to Random Forest:

$$\hat{c}(x) = \begin{cases} c_{KNN}(x), & \text{if } conf(x) > \theta \\ c_{RF}(x), & \text{if } conf(x) \le \theta \end{cases}$$

The threshold θ = 0.72 was chosen by 5-fold cross-validation among values from 0.5 to 0.9, as the value that keeps accuracy at its highest level while sending most evaluations through the fast KNN path. The data are stored in a ten-entity relational database in Third Normal Form, where criteria are kept as records rather than as table columns. In addition, the system includes a KPI suggestion engine and a conversational AI advisor that prepares staffing and KPI recommendations from a short description of the organisation.

Results. The hybrid model outperformed the single-algorithm baseline on all metrics (Table 1).

Table 1. Evaluation metrics before and after applying the hybrid algorithm

Metric	Single algorithm	Hybrid algorithm	Change
Accuracy	76.2%	92.8%	+16.6 pp
Precision	75.1%	91.3%	+16.2 pp
Recall	74.3%	90.5%	+16.2 pp
F1-score	74.7%	90.9%	+16.2 pp
Processing time	12.4 s	6.1 s	−50.8%

The threshold analysis explains this result. At θ = 0.72, 78% of employees are classified by KNN alone and only 22% are sent to Random Forest, while accuracy is 92.8%. Lowering the threshold to 0.5 sends 70% of cases to Random Forest but increases accuracy by only 0.1 percentage points (to 92.9%). Raising it to 0.9 makes the system faster, but accuracy falls to 87.4%, because borderline employees are then decided by KNN alone. Thus, the errors of KNN are concentrated in the cases where it is least confident, and Random Forest is needed only for those cases.

The deployed system produces an individual report for each employee, including an overall score (for example, 59.4% – “Medium Performance”), a radar chart of the five dimensions, and a written recommendation. For a private school

with more than 150 students, 20 teachers and 4 departments, the AI advisor prepared a staffing plan of 30 positions with estimated salaries for each role.

Conclusion. The study shows that confidence-based routing between KNN and Random Forest gives almost the accuracy of an ensemble model at about half the processing time. The combination of AHP-based criteria formation, a normalised database schema and AI decision support allows the system to adapt to organisations of different types and sizes without structural changes, while HR specialists keep the final decision. The software has been registered with the Ministry of Justice of the Republic of Uzbekistan (certificate No. DGU 53438, 2025). Further research will test the system in organisations of other sectors and assess its economic effect.

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