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# RULE-BASED MACHINE LEARNING IN A HIERARCHICAL FRAMEWORK FOR ASSESSING ACADEMIC PERFORMANCE AND EDUCATIONAL QUALITY

***Abstract:*** *the article discusses important aspects of academic performance prediction, including early risk detection and informed educational decision-making. An automated decision tree learning method can efficiently analyze multiple educational indicators, automatically identify key factors, and improve the accuracy and interpretability of predictions. This research approach is a valuable tool for university administrators and educators, helping them to reduce academic failure risks and ensure the educational stability of students. The article aims to expand the understanding of the impact of behavioral factors on academic success and to propose innovative methods for analyzing educational data.*

***Keywords:*** *Machine Learning, Hierarchical Framework, Academic Performance, Educational Quality, Decision Tree, Student Retention.*

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# МАШИННОЕ ОБУЧЕНИЕ НА ОСНОВЕ ПРАВИЛ В ИЕРАРХИЧЕСКОЙ МОДЕЛИ ДЛЯ ОЦЕНКИ АКАДЕМИЧЕСКОЙ УСПЕВАЕМОСТИ И КАЧЕСТВА ОБРАЗОВАНИЯ

***Аннотация:*** *в статье рассматриваются важные аспекты прогнозирования академической успеваемости, включая раннее выявление рисков и принятие обоснованных управленческих решений в сфере образования. Метод автоматизированного построения деревьев решений позволяет эффективно анализировать множество образовательных индикаторов, автоматически выявлять ключевые факторы и повышать точность и интерпретируемость прогнозов. Данный исследовательский подход является ценным инструментом для администрации вузов и преподавателей, помогая им снижать риски академической неуспеваемости и обеспечивать стабильность образовательной траектории студентов. Цель статьи заключается в расширении понимания влияния поведенческих факторов на академический успех и предложении инновационных методов анализа образовательных данных.*

***Ключевые слова:*** *машинное обучение, иерархическая модель, академическая успеваемость, качество образования, дерево решений, удержание студентов.*

*1. Introduction*: forecasting student academic performance plays a key role in today's educational ecosystem. The importance of this practice is due to a number of factors that affect students, educational institutions, and systemic stability. Effective resource management: When a university accurately forecasts academic difficulties, it can allocate tutoring resources efficiently. Maintaining Competitiveness: Predicting academic distress helps institutions adapt to changing student demographics and remain competitive. Furthermore, maintaining high graduation rates is often tied to state funding and institutional accreditation.


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*2. Materials and Method*: the empirical base of the study comprises academic and behavioral records from a major technical university spanning a ten-year period. Before analyzing the data, missing values were imputed, and insignificant factors were removed using correlation analysis with a threshold of 0.1.

The primary modeling tool is the decision tree algorithm, which partitions the data space into hierarchical nodes based on attribute thresholds. Decision trees are highly effective for educational datasets because they handle non-linear dependencies, require minimal data normalization, and inherently perform feature selection. While neural networks may offer marginal accuracy gains, their «black-box» nature limits stakeholder trust in pedagogical decision-making.

*3. Results*: a comparative analysis of ML techniques was conducted. The neural network model showed an error of 3.15%. Kohonen maps resulted in a 4.12% error, struggling with the high dimensionality of categorical academic records. The decision tree achieved the lowest error rate of 2.8% while providing full interpretability.

The hierarchical structure of the tree isolated the most critical predictors of academic failure:

*– Persistent GPA in the Last Two Semesters: Significance of 22.4%, highlighting the paramount importance of sustained academic momentum;*

*– Engagement / Study Load Ratio: Significance of 20.1%, reflecting the balance between extracurricular activities and core coursework;*

*– Attendance Rate: Significance of 15.5%, indicating the direct correlation between physical/virtual presence and knowledge retention.*

*4. Conclusion*: the implementation of rule-based ML in a hierarchical framework provides a robust, transparent mechanism for early academic risk detection. The decision tree's 2.8% error rate and explicit attribute significance empower educators to focus on critical health indicators of the educational process, such as sustained GPA and engagement ratios. This approach not only minimizes dropout risks but also contributes to the broader stability of the educational environment by enabling proactive pedagogical restructuring.

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