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RULE-BASED MACHINE LEARNING IN A HIERARCHICAL FRAMEWORK FOR CORPORATE BANKRUPTCY PREDICTION

Abstract: *this article explores the application of rule-based machine learning, specifically decision trees, for predicting corporate bankruptcy within a hierarchical framework. Using a dataset from the Taiwan Economic Journal (1999–2009), the study evaluates the economic performance indicators that critically influence financial distress. The decision tree model achieved an error rate of 1.6%, outperforming neural networks (2.67%) and Kohonen maps (2.98%). The most significant factors identified include Persistent EPS (22.4%), Working Capital to Equity ratio (20.1%), and Pretax Income to Capital (15.5%). The results provide a transparent, scalable tool for investors and creditors to mitigate financial risks.*

Keywords: *machine learning, hierarchical framework, economic performance, bankruptcy prediction, financial health, decision tree.*

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МАШИННОЕ ОБУЧЕНИЕ НА ОСНОВЕ ПРАВИЛ В ИЕРАРХИЧЕСКОЙ МОДЕЛИ ДЛЯ ПРОГНОЗИРОВАНИЯ КОРПОРАТИВНОГО БАНКРОТСТВА

Аннотация: *в статье исследуется применение машинного обучения на основе правил, в частности деревьев решений, для прогнозирования корпоративного банкротства в рамках иерархической модели. На основе набора данных из Taiwan Economic Journal (1999–2009 гг.) в исследовании оцениваются показатели экономической эффективности, критически влияющие на финансовую несостоятельность. Модель дерева решений достигла уровня ошибки 1,6%, превзойдя нейронные сети (2,67%) и карты Кохонена (2,98%). Наиболее значимыми выявленными факторами стали: устойчивая прибыль на акцию (Persistent EPS) (22,4%), коэффициент отношения оборотного капитала к собственному капиталу (Working Capital to Equity ratio) (20,1%) и отношение прибыли до налогообложения к капиталу (Pretax Income to Capital) (15,5%). Полученные результаты*

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предоставляют прозрачный и масштабируемый инструмент для инвесторов и кредиторов с целью минимизации финансовых рисков.

Ключевые слова: *машинное обучение, иерархическая модель, экономическая эффективность, прогнозирование банкротства, финансовое состояние, дерево решений.*

Introduction: forecasting corporate bankruptcy plays a pivotal role in modern economic stability, protecting investors, creditors, and employees from severe financial disruptions. Early risk detection enables companies to optimize resource management and adapt to market challenges. While complex neural networks offer high predictive capabilities, their «black-box» nature limits stakeholder trust. Rule-based machine learning, particularly decision trees, provides an interpretable, hierarchical framework that automatically identifies key financial factors, facilitating informed and transparent decision-making in risk management.

Materials and Methods: the empirical base of the study comprises financial records from the Taiwan Economic Journal spanning 1999 to 2009. The dataset includes diverse economic indicators reflecting liquidity, profitability, and capital structure. Data preprocessing involved imputing missing values and applying correlation analysis with a 0.1 threshold to eliminate multicollinearity and insignificant variables. The primary modeling tool is the decision tree algorithm, which partitions the data space into hierarchical nodes based on attribute thresholds. This method is highly effective for economic datasets as it handles non-linear dependencies, requires minimal data normalization, and inherently performs feature selection, outputting a transparent hierarchy of decision rules.

Results: the comparative analysis of ML techniques revealed the superiority of the decision tree in both accuracy and interpretability for this specific financial domain.

- Neural Network: Yielded an error rate of 2.67%.

- Kohonen Maps: Resulted in a 2.98% error, struggling with the high dimensionality of financial ratios.

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- Decision Tree: Achieved the lowest error rate of 1.6%. The hierarchical structure of the tree isolated the most critical predictors of bankruptcy:

1. Persistent EPS in the Last Four Seasons (Net Income): Significance of 22.4%, highlighting the paramount importance of sustained profitability.

2. Working Capital / Equity: Significance of 20.1%, reflecting short-term financial resilience and liquidity.

3. Pretax Income / Paid-in Capital: Significance of 15.5%, indicating the efficiency of capital utilization.

4. Cash / Total Assets (8.5%) and Net Income to Stockholder's Equity (6.2%) further reinforced the dominance of liquidity and return-on-equity metrics in distress prediction.

Conclusion: the implementation of rule-based ML in a hierarchical framework provides a robust, transparent mechanism for early bankruptcy detection. The decision tree's 1.6% error rate and explicit attribute significance empower stakeholders to focus on critical financial health indicators, such as sustained EPS and working capital ratios. This approach not only minimizes investment risks but also contributes to the broader stability of the financial market by enabling proactive corporate restructuring. Future work will explore ensemble tree methods to capture complex macroeconomic interactions.

References

1. Adaptivnyi energomenedzhment na baze modelei onlain-obucheniya kak faktor sotsial'no-ekonomicheskoi effektivnosti predpriyatii [Adaptive energy management based on online learning models as a factor of socio-economic efficiency of enterprises] / O. O. Oleynikova, D. A. Tkachenko, G. V. Korableva, A. S. Prudkii // Strategii ustoichivogo razvitiya: sotsial'nye, ekonomicheskie i yuridicheskie aspekty : Materialy II Vserossiiskoi nauchno-prakticheskoi konferentsii, Cheboksary, 26 avgusta 2026 goda [Sustainable development strategies: social, economic and legal aspects : Proceedings of the II All-Russian Scientific and Practical Conference, Cheboksary, August 26, 2026]. – Cheboksary : Sreda, 2026. – P. 221–224. – EDN JGZIZE.

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2. Integratsiya geoinformatsionnykh sistem i algoritmov iskusstvennogo intellekta dlya monitoringa geotekhnicheskoi ustoichivosti ob»ektov gornoi infrastruktury [Integration of geographic information systems and artificial intelligence algorithms for monitoring geotechnical stability of mining infrastructure objects] / L. A. Kazakovtsev, A. S. Prudkii, I. A. Vakhrusheva, M. S. Nikanorov // Izvestiya Tul'skogo gosudarstvennogo universiteta. Nauki o Zemle [News of the Tula State University. Earth Sciences]. – 2026. – No. 1. – P. 354–359. – EDN EGFSPA.

3. Korableva G. V. Analiz i sovershenstvovanie vozmozhnostei podderzhki protsessov upravleniya kachestvom avtomatizirovannymi ERP-sistemami [Analysis and improvement of capabilities for supporting quality management processes by automated ERP systems] / G. V. Korableva, A. N. Ushakov // Ekonomika i predprinimatel'stvo [Economics and Entrepreneurship]. – 2024. – No. 5 (166). – P. 1088–1094. – DOI 10.34925/EIP.2024.166.5.224. – EDN BABPJJ.

4. Korableva G. V. Sovershenstvovanie protsessov planirovaniya na predpriyatiyakh za schet vnedreniya avtomatizirovannykh sistem podderzhki prinyatiya reshenii [Improvement of planning processes at enterprises through the implementation of automated decision support systems] / G. V. Korableva // Resursosberezhenie. Effektivnost'. Razvitie : Sbornik materialov IX Vserossiiskoi nauchno-prakticheskoi konferentsii, Donetsk, 01 noyabrya 2024 goda [Resource saving. Efficiency. Development : Proceedings of the IX All-Russian Scientific and Practical Conference, Donetsk, November 01, 2024]. – Donetsk : Donetsk National Technical University, 2024. – P. 63–65. – EDN WIOIYS.

5. Pravovye aspekty upravleniya promyshlennymi potokami dannykh v raspredelennykh IIoT-arkhitekturakh [Legal aspects of industrial data flow management in distributed IIoT architectures] / O. O. Oleynikova, E. S. Almazova, B. V. Potapov, G. V. Korableva // Strategii ustoichivogo razvitiya: sotsial'nye, ekonomicheskie i yuridicheskie aspekty : Materialy II Vserossiiskoi nauchno-prakticheskoi konferentsii, Cheboksary, 26 avgusta 2026 goda [Sustainable development strategies: social, economic and legal aspects : Proceedings of the II All-Russian Scientific and Practical

Content is licensed under the Creative Commons Attribution 4.0 license (CC-BY 4.0)

Conference, Cheboksary, August 26, 2026]. – Cheboksary : Sreda, 2026. – P. 390–393. – EDN OOJPWN.

6. Korableva G. Adaptive method of generation of optimal production orders / G. Korableva, E. Kucherova // E3S Web of Conferences : 2018 International Science Conference on Business Technologies for Sustainable Urban Development, SPbWOSCE 2018, St. Petersburg, December 10–12, 2018. – Vol. 110. – St. Petersburg : EDP Sciences, 2019. – P. 02127. – DOI 10.1051/e3sconf/201911002127. – EDN CFFBTL.

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