Pontifical Catholic University of Rio Grande do Sul (PUC-RS)

Algorithmic Trading: Enhancing Efficiency in Financial Markets Decision-Making

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Sumario

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[**1. RESUMO 2**](#_Toc83580266)

[**2. INTRODUÇÃO 3**](#_Toc83580267)

[**3. TRABALHOS RELACIONAIS 4**](#_Toc83580268)

[**4. METODOLOGIA 5**](#_Toc83580269)

[**5. RESULTADOS 6**](#_Toc83580270)

[**6. DISCUSSÃO 7**](#_Toc83580271)

[**7. CONCLUSÃO E TRABALHOS FUTUROS 8**](#_Toc83580272)

# ABSTRACT

Payment card fraud presents a significant challenge to businesses and financial institutions, resulting in substantial annual financial losses that have risen sharply over the years. The 2019 Nilson Report highlights a staggering increase in card fraud losses from $9.84 billion in 2011 to $27.85 billion in 2018, with projections exceeding $40 billion by 2027 [rep19].

Detecting fraudulent patterns in payment card transactions is increasingly difficult due to the sheer volume of data generated, characterized by numerous dimensions and constant updates. Traditional methods are insufficient, prompting a shift towards machine learning (ML) techniques that automate fraud detection processes [CLBC+19, DP15, PP19, SSB18]. This shift has significantly enhanced fraud detection efficiency, aiding payment processors in identifying illicit transactions and potentially saving billions annually. The adoption of ML solutions has also contributed to a decline in the percentage of losses attributed to fraud since 2016 [rep19].

Despite these advancements, reproducibility remains a critical issue in ML-based fraud detection research [LJ20, PL18, PP19, ZAM+16]. Access to confidential payment card transaction data and inadequate sharing of code hinder reproducibility efforts. This thesis addresses this challenge by focusing on benchmarking and enhancing the reproducibility of payment card fraud detection techniques.

The thesis emphasizes essential techniques such as handling class imbalance and utilizing ensemble models, pivotal in designing robust credit card fraud detection systems. It also explores less documented aspects such as performance metrics selection, validation strategies, and innovative preprocessing and learning techniques like feature embeddings and neural networks.

While the primary focus is on payment card fraud detection, the techniques and insights presented are applicable across broader fraud detection domains. The thesis adopts a Jupyter Notebook format for transparent and reproducible experimentation, facilitating easy replication and validation of results. The open-source nature of the thesis, available on a public GitHub repository, encourages collaboration and feedback from the research community.

**Keywords:** Payment card fraud; fraud detection; machine learning; class imbalance; feature engineering; validation strategies; data preprocessing; Logistic Regression; Decision Trees; Random Forest; Gradient Boosting Machines; SMOTE; AUPRC; PCA.

# INTRODUCTION

As financial markets continue to evolve at a rapid pace, the adoption of technology in trading practices has become increasingly prevalent. Among these technological advancements, algorithmic trading has distinguished itself as a significant development. Algorithmic trading, which involves the use of computer algorithms to execute trades based on predefined criteria, offers a method to streamline decision-making processes in financial markets. This thesis, titled "Algorithmic Trading: Efficiency in Financial Markets Decision-Making Processes," aims to comprehensively explore the efficacy and challenges of algorithmic trading systems.

The primary advantage of algorithmic trading lies in its ability to execute trades at speeds and volumes that are unattainable by human traders. By automating the trading process, these systems can analyze large datasets quickly, identify market trends, and make decisions free from the emotional biases that typically affect human judgment. This capability not only enhances the efficiency of trading operations but also contributes to more consistent and disciplined trading strategies.

However, the benefits of algorithmic trading are not without their challenges. One of the main concerns is the risk of overfitting models to past market data, which may not accurately predict future market conditions. Additionally, algorithmic trading systems depend heavily on the quality of the data and the algorithms themselves; any flaws in the design or execution of these algorithms can lead to significant financial losses. Moreover, the increasing complexity of these systems necessitates continuous oversight and sophisticated risk management strategies to prevent potential malfunctions or exploitations.

In this thesis, we will investigate various aspects of algorithmic trading across different market segments, including equities, derivatives, and foreign exchange. We will delve into specific trading strategies such as trend following, mean reversion, and statistical arbitrage to evaluate their effectiveness and adaptability under different market conditions.

Risk management will be a focal point of our analysis, highlighting how algorithmic traders can incorporate techniques like stop-loss orders, trailing stops, and risk assessment models to mitigate losses and protect gains. Furthermore, the importance of back-testing trading strategies will be emphasized, demonstrating how historical data can be used to refine algorithms and ensure their reliability before being deployed in live trading environments.

The objective of this thesis is to provide a balanced perspective on algorithmic trading, illustrating both its potential benefits and inherent risks. Through a detailed examination of its impact on decision-making in financial markets, we aim to offer insights that could improve the design and implementation of algorithmic trading systems.

Ultimately, this thesis seeks to contribute to the broader understanding of how technology can be effectively integrated into financial trading to enhance market efficiency, reduce errors, and maintain a high level of trading discipline. Through this investigation, we hope to provide valuable recommendations for traders, financial analysts, and policymakers engaged in the rapidly evolving landscape of financial technology.

# TRABALHOS RELACIONAIS

Apresentar um breve resumo sobre o estado da arte comentando e comparando trabalhos relacionados ao descrito.

# METODOLOGIA

Descrever a metodologia usada para resolver o problema sob análise, incluindo arquitetura desenvolvida, recursos e materiais utilizados. Descrever os tipos de experimentos feitos sempre visando um detalhamento que viabilize a reprodução desse estudo. Aplicar os métodos e técnicas vistos ao longo do curso.

# RESULTADOS

Apresentar os resultados de forma clara, adequada e coerente, procurando explorar os recursos e técnicas de comunicação e visualização vistos no curso.

# DISCUSSÃO

Discutir os resultados do estudo, questionando sua significância, relevância e limitações.

# CONCLUSÃO E TRABALHOS FUTUROS

Apresentar as considerações finais sobre o trabalho e melhorias que poderiam ser realizadas como passos futuros de desenvolvimento.