Bachelor Thesis Exposé

**Research and observation of reference market problems with artificial intelligence trading agents in a high-fidelity equity market simulator**

Can anomalies be detected and explained when autonomous trading agents are injected into a simulated equity market simulation environment to research and observe reference market problems from a stock exchange and market maker perspective?

Paul Helstab (358303)

in cooperation with Boerse Stuttgart Group

Content

[**Bachelor Thesis Exposé** 3](#_Toc118026949)

[Abstract 3](#_Toc118026950)

[Background and Problem formulation 3](#_Toc118026951)

[Synopsis and Significance 4](#_Toc118026952)

[Objective 5](#_Toc118026953)

[Structure 5](#_Toc118026954)

[Accurals 5](#_Toc118026955)

[Content of each part 5](#_Toc118026956)

[(1) Explanation of terms and background 5](#_Toc118026957)

[(2) Preparing market experiments to solve reference market problems 5](#_Toc118026958)

[(3) Examination of agent-based reference market experiments 6](#_Toc118026959)

[(4) Conclusion and Outlook 6](#_Toc118026960)

[Main References 7](#_Toc118026961)

**Bachelor Thesis Exposé**

# Abstract

This bachelor thesis is divided into 4 main parts and explores the practice of observing reference market problems from a stock exchange perspective through “Discrete Event Multi-Agent Simulation” (DEMAS). The aim of this work was to fundamentally explain DEMAS and how complex reference market problems could be resolved through experiments. Introducing first, important terminology and background of DEMAS and a new "Agent-Based Interactive Discrete Event Simulator" (ABIDES).

Thereafter, I want to examine complex reference market problems in the area of exchange market and market maker fee effects with the ABIDES framework. To address these reference market problems, we transfer and develop them as experiments in a customized environment and observe the experiments through advanced data analysis features.

We conclude this thesis by introducing solution approaches to the previously observed experiments and providing stock exchanges or market makers an advanced version of ABIDES as a “strategic business navigation system” to challenge related reference market problems.

# Background and Problem formulation

A team of artificial intelligence researchers from the Georgia Tech University and the J.P. Morgan AI Research center published in April 2022 the first open-source solution of an agent-based interactive discrete event simulator called ABIDES, including an OpenAI gym environment for training reinforcement learning agents within market simulations.

This toolset provides numerous possibilities for the public to research on financial market problems including complex reference market problems that cannot be definitively solved using historical data.

Complex financial market problems could be for example, financial market experiments on latency (co-location) problems, lawmaker intransparency problems (regulations, MiFID II and PFOF), market impact simulations (e. g. How large orders affect financial markets?) and define interpretable “non-black box” AI experiments by evaluating the behavior of reinforcement learning agents based on decision, intent, behavior, and outcome/reward. One subsection of complex financial market problems that can only be experimentionally observed and assessed, are reference market problems with influencing factors on exchange market and market maker fees. The importance for looking at market fees is that stock exchanges and market makers would like to find out how their turnaround variies in different market phases, how their fee structure influences traders and what anomalies can arise from different market fees.

The following subquestions are to be answered within this bachelor thesis:

* What are discrete multi-agent event simulations (DEMAS) and what is an agent-based interactive discrete event simulator (ABIDES)?
* How do stock exchanges work, how do they generate turnover and what are the opportunities and possible use cases for research and observation in the area of DEMAS in ABIDES?
* What are complex reference market scenarios that cannot be solved with conventional evaluation methods and how can these be assessed through DEMAS?
* How can we define and transfer reference market problems to discrete multi-agent event simulations?
* How can ABIDES be used as a corporate strategy navigation system for market makers and stock exchanges to help them make better decisions?

# Synopsis and Significance

Previous work with ABIDES observed capital market problems like investment banks and hedge funds might have. For example, the whitepaper "Towards Realistic Market Simulations: a Generative Adversarial Networks Approach" explored the creation of synthetic markets through which trading strategies can be observed under realistic conditions.

This study takes previous work as an example and expands the subject area, by implementing and applying reference market problems and new data analysis methods to help exchanges and market makers gain a deeper understanding of their market fees.

# Objective

The aim of this thesis is to fundamentally explain agent-based interactive discrete event simulations, developing new data analysis features for the ABIDES framework, extending ABIDES as a strategic navigation tool for exchanges & market makers and evaluating market fee reference market problems through discrete multi-agent event simulation experiments.

# Structure

To see where the focus lies within this bachelor thesis, here is a proposal of page counts for each part:

(1) Explanation of terms and background 10

(2) Preparing market experiments to solve reference market problems 3

(3) Examination of agent-based reference market experiments 20

(4) Conclusion and Outlook 5

# Accurals

This thesis focuses on research and observation of reference market scenarios with (reinforcement learning) trading agents, with a particular focus on market fees. For investigating on these scenarios, I will develop, observe and evaluate trading agent experiments from a stock exchange and market maker perspective as covering further perspectives would go beyond the scope of this work.

# Content of each part

## (1) Explanation of terms and background

To fully understand the concepts of this thesis, I start by explaining discrete multi-agent event simulations (DEMAS) within the agent-based interactive discrete event simulator (ABIDES), its practice and provide definitions and references from the ABIDES whitepapers, its authors and other experts in this scientific field. I'll explain how data scientists, financial market experts, researchers, developers, and artificial intelligence experts could use ABIDES for research and observation, especially on reference market problems. I will conclude this chapter by showing the possibilities of agent-based interactive event simulation experiments and explain the role of the ABIDES toolset, which can be used to solve reference market problems that can only be observed by experimental evidence.

## (2) Preparing market experiments to solve reference market problems

In this section, I will define what I want to achieve within my bachelor thesis, how I intend to observe on these problems experimentally, and what the prerequisites are to achieve the desired results. I also want to define the purpose for which new advanced versions of ABIDES can be used for.

## (3) Examination of agent-based reference market experiments

In this chapter I will decode the reference market problems in order to transfer it as experiments.

This will be possible when we develop and configure our own custom reference market experiments and evaluating them using new developed, data analysis methods.

Another subsection could focus on placing an extended reinforcement learning agent into our customized reference market experiment to understand how a Markov decision process agent for reinforcement learning handles our reference market problem in our environment by iterative training a policy.

## (4) Conclusion and Outlook

In this chapter, I will state the results of my bachelor thesis, how to interpret this conclusion, how we extended the ABIDES tool and what future multi-agent simulation experiments for solving different reference market problems or new financial market problems might be.

The bachelor thesis concludes with the assessment of one or a combination of several proposed reference market problems for future observations and how exchanges or market makers can use the new enhanced ABIDES to help making better strategic decisions.

**Abbreviations**

The following abbreviations are maybe used in this exposé:

|  |  |
| --- | --- |
| ABIDES | Agent-based interactive discrete simulator |
| DEMAS | Discrete multi-agent event simulation |
| RL | Reinforcement learning |
| DRL | Deep reinforcement learning |
| DNN | Deep neural network |
| MM | Market making |
| OTC | Over-the-counter, off-exchange or pink sheet |
| PnL | Profits and losses |
| E. g. | Example given |
| Multilateral exchange system | Bringing buy and sell orders together from a variety of trading participants. Stock exchanges like XETRA, NASDAQ, NYSE |
| Bilateral exchange system | OTC markets |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# Main References

D. Byrd, M. Hybinette, and T. H. Balch, Abides: Towards high-fidelity market simulation for ai research, 2019. doi: 10.48550/ARXIV.1904.12066. [Online]. Available: <https://arxiv.org/abs/1904.12066>.

D. Byrd, Explaining agent-based financial market simulation, 2019. doi: 10.48550/ ARXIV.1909.11650. [Online]. Available: https://arxiv.org/abs/1909.11650.

A. Coletta, M. Prata, M. Conti, et al., Towards realistic market simulations: A generative adversarial networks approach, 2021. doi: 10.48550/ARXIV.2110.13287. [Online]. Available: https://arxiv.org/abs/2110.13287

S. Amrouni, A. Moulin, J. Vann, S. Vyetrenko, T. Balch, and M. Veloso, “ABIDESgym,” in Proceedings of the Second ACM International Conference on AI in Finance, ACM, Nov. 2021. doi: 10.1145/3490354.3494433. [Online]. Available: https: //doi.org/10.1145%2F3490354.3494433.