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?

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**Bachelor Thesis Exposé**

# Abstract

This bachelor thesis analyzes 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 financial market problems could be resolved through experiments instead of evaluating and proving with historical data. Thereafter, I want to examine complex reference market problems with an “Agent-based interactive discrete Simulator” (ABIDES). In the last part of this thesis, solution approaches to the previously defined reference market problems are introduced and evaluated. In addition, I want to provide a further developed and advanced version of ABIDES as a “strategic business navigation system” for stock exchanges who are challenged by reference market problems.

# Problem formulation

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

1. What is a market maker and what are multilateral/bilateral exchange systems?
2. What are possibilities for stock exchanges generating return?
3. What are discrete multi agent event simulations (DEMAS) and what is an agent-based interactive discrete event simulator (ABIDES)?
4. What are opportunities and possible use cases with DEMAS in ABIDES?
5. What are complex capital market scenarios that can’t be solved with conventional evaluation methods and how can these be assessed through DEMAS?
6. How can ABIDES be used as a corporate strategy navigation system for market makers and stock exchanges to help them make decisions?
7. How can reinforcement learning trading agents be trained to tackle the defined reference market problem and minimize risk or maximize portfolio value by training a policy in the defined market environment?

# Target setting

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, including an OpenAI gym environment for training reinforcement learning agents within market simulations. This toolset provides numerous possibilities for public research on financial market problems including complex reference market problems that cannot be solved with certainty with historical data. E. g. capital market experiments with latency (co-location) problems, lawmaker intransparency problems (Regulatory, MiFID II and PFOF), market impact simulations (e. g. How large orders affect financial markets?) and define explainable "non-blackbox" artificial intelligence experiments through an evaluation of reinforcement learning agent’s actions based on the decision, intent, behaviour and result.

The aim of this thesis is to fundamentally explain the topic of Agent-based interactive discrete event simulations, extend ABIDES with new data analysis features, develop a strategic navigation tool for stock exchanges and market makers and evaluate capital 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 capital market experiments 20

(4) Conclusion and outlook 5

# Accurals

This thesis focuses on research and observation of capital market scenarios with (reinforcement learning) trading agents with a special 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 be beyond the scope of this work.

# Content of each part

## (1) Explanation of terms and background

To fully understand the concept 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.

This chapter deals with the following questions:

* How do stock exchanges work and how do they generate turnover?
* What are “unsolvable” capital market problems?
* What are discrete event simulations (DEMAS)?
* What is the Agent-based interactive discrete simulator (ABIDES)?
* How can we define and transfer reference marktet problems to discrete multi agent event simulations?
* What is a Market decision process?
* What is a reinforcement learning trading agent, what is meant by training and evaluating a policy?

I will conclude this chapter with providing opportunities of agent-based interactive event simulation and explaining the ABIDES toolset that could be used for solving reference market problems that can only be proven by experimental evidence.

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

*First of all, I will explain how data scientists, financial market researchers, developers and artificial intelligence experts could use ABIDES for solving and evaluating reference market problems.*

*After that I want to define what I want to achieve within my bachelor thesis, how I plan to implement this problem through an experiment and what are the requirements to achieve the expected outcome. I also want to define for what purpose this tool with the solution could be used*.

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

In this chapter I will decode the reference market problems in order to transfer it as experiment, implement and evaluate them*.*

Moreover, I will explain how a customized reference market experiment can be configurated, simulating this reference market problem and evaluate it afterwards.

Another subchapter in this chapter could focus on placing an extended reinforcement learning agent into our customized reference market experiment to find out how a reinforcement learning Markov decision process learning agent would handle our reference market problem and to iteratively train a policy in our environment.

## (4) Conclusion and Outlook

In this chapter I will state the outcome of my bachelor thesis, how this conclusion could be interpreted, how we extended the ABIDES tool and what future discrete multi agent event simulation experiments could be to solve different reference market problems or new financial market problems.

The bachelor thesis concludes with the assessment of one or a combination of several proposed reference market problems for future observations and how stock exchange could use the new extended version of ABIDES for strategic decisions.

**Abbreviations**

The following abbreviations are 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 |
| PnL | Profits and losses |
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