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 solved through experiments instead of evaluating and proofing with historical data. 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 to challenge 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 the 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 we assess them through DEMAS?
6. How ABIDES can be used as a corporate strategy navigation system for market makers and stock exchanges to help them make decisions.
7. How Reinforcement learning trading agents can 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 provided in April 2022 the first Open Source publish of a stable agent-based interactive discrete event simulator including an OpenAI gym environment for training reinforcement learning agents within market simulations. This toolset is providing nearly unlimited possibilities for the public researching on capital market problems including complex capital market problems that can’t be solved with certainty by proofing them 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 assessment of a reinforcement learning agents actions evaluating the decision, intent, behaivour and result.

The aim of this thesis is to explain the topic of Agent-based interactive discrete event simulations fundamentally, extend ABIDES with new analysis features and 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 examination, I want to develop, observe and evaluate trading agent experiments from a stock exchange and market maker perspective. This is because an examination of more and more complex financial market problems would be beyond the scope of this thesis.

# Content of each part

## (1) Explanation of terms and background

*To fully understand the concepts of:*

* *How stock exchanges work and how they generate turnover*
* *How we define reference marktet problems*
* *What are discrete event simulations (DEMAS)*
* *What is the Agent-based interactive discrete simulator (ABIDES)*
* *What is a Markov decision process?*
* *What is a reinforcement learning trading agent, what is meant by training a policy?*

#### (1.1) Opportunities of agent-based interactive event simulations

*In this chapter I will explain the opportunities financial institutes and invidividuals with interests in capital markets theory will get with the toolset around ABIDES. And how this toolset could be used for solving for example financial market problems that can only be proven by experimental evidence, not by mathematical proof.*

## (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*.

*Opportunities of agent-based interactive event simulations*

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

*In this chapter I will decode, implement and evaluate some reference market problems. I will explain how we can create our customized reference market experiment, simulating this reference market problem and evaluate it afterwards.*

*Another subchapter in this chapter could be placing an extended reinforcement learning agent into our customized reference market experiment to see how a reinforcement learning Markov decision process learning agent would handle this problem by iterative learning in an environment.*

#### (3.1) Reinforcement learning agents in reference market experiments

*In this chapter I will explain how we can train a reinforcement learning trading agent in our customized reference market experiment, running this reference market experiment and evaluate the problem again.*

## (4) Conclusion and Outlook

*In this chapter I will explain what the outcome of my bachelor thesis was, how this conclusion could be seen and what the future of discrete event simulation experiments*

*((The bachelor thesis concludes with one or a combination of several proposed reference market problems for future observations and how stock exchange could use discrete event simulations 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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