LLM powered autonomous agents driven simulation of stock markets

Assessing the effectiveness and limitations of LLM-based trading strategies in a simulated stock market environment

Graduate

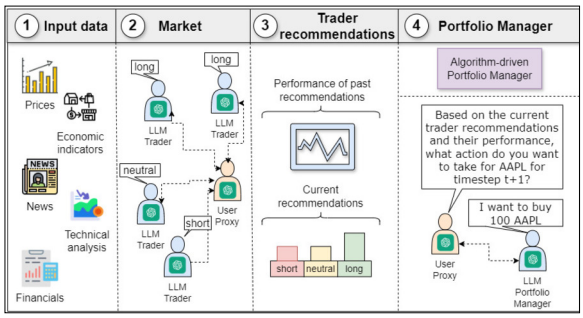
Micha Luginbühl

Introduction: Since the 1970s, the integration of computer science into trading has significantly evolved, from basic rule-based systems to the advanced application of machine learning and AI in algorithmic trading. Noteworthy among recent advancements are Large Language Models (LLMs), which have opened new possibilities for trading through their capability to analyze diverse data sources impacting the stock market. This thesis explores a novel approach using LLM-based autonomous agents for stock market simulations. These agents are autonomous, AI-powered programs driven by LLMs, designed to perform complex tasks by emulating human cognitive functions such as memory, planning, and decision-making. They can analyze vast amounts of data, interpret contextual information, and interact dynamically within their environments to achieve predefined goals. In this thesis, LLM agents emulate the roles of human traders and portfolio managers, processing various types of financial data to generate trading signals and execute trades in a simulated stock market environment. The aim is to evaluate whether these agents can develop effective and profitable investment strategies.

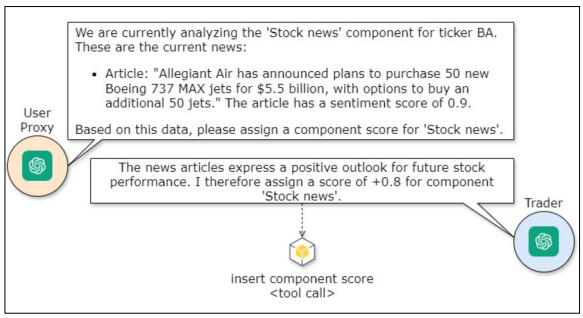
Approach: This work introduces a novel simulation framework for the stock market where human traders are represented by autonomous LLM agents that analyze input data. The input data is categorized into seven components: Stock News, Prices and Volumes, Technical Analysis, Financials, General News, Economic Indicators, and Miscellaneous. The data for these components was preprocessed and is ultimately presented to the LLM traders in form of a natural language prompt. After analyzing the input data, the LLM traders generate recommendations indicating the type of position they want to hold for the next timestep (long, short, or no position). To do this, the LLM traders must use tools that were provided to them. These tools are esentially Python functions which the LLM agent use to interact with the simulation environment. Using a backtesting approach, traders receive feedback on their recommendations, enabling them to improve over time.
Additionally, two types of portfolio managers were part of the simulation framework: one driven by LLMs and one based on a simple trading algorithm. Portfolio managers make decisions to buy, hold, or sell stocks. These decisions are based on the trader recommendations provided for the current timestep, as well as the past performance of every LLM trader. Each portfolio manager operates with an initially empty portfolio and a specified amount of starting capital, aiming to maximize profit.

Result: During the model selection phase, experiments were conducted with various proprietary and open-source LLMs. Ultimately, OpenAI's most cost-efficient model, GPT-3.5 Turbo, was chosen as the backbone for the LLM agents. Although LLM agents are still in their infancy and face significant limitations - such as high inference times, elevated costs, limited context length, rate limits, hallucinations, and model-specific issues - this study demonstrates the feasibility of simulating the stock market using autonomous LLM agents. Reasoning traces revealed that LLM agents occasionally misjudged input data or made incorrect assumptions, likely due to the limitations of the model used. Despite these challenges, both types of portfolio managers achieved positive performance in the simulation, although it was below the benchmark.

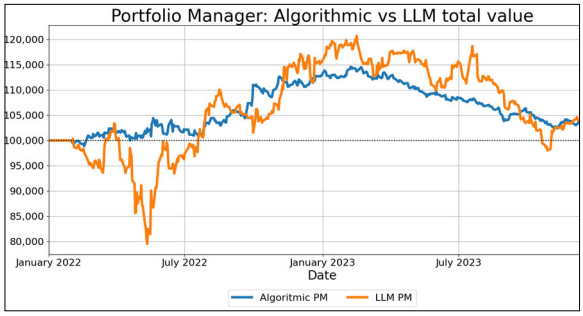
High level overview of the simulation architecture.
Own presentment



Sample conversation between LLM agents when analyzing recommendation components.
Own presentment



Comparison of the total portfolio value between the two types of portfolio managers.
Own presentment



Advisor
Dr. Shao Jü Woo

Co-Examiner
Ursula Engler Larson, LGT Financial Services AG, Vaduz, Liechtenstein

Subject Area
Data Science, Computer Science, Business Engineering

Project Partner
LGT Financial Services AG, Vaduz, Liechtenstein