Embodied AI for Financial Literacy Social Robots

(Technical Paper)

Low Latency Network Systems in High-Frequency Trading

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

My technical project is titled: "Systems Engineering and Embodied AI for Financial Literacy Social Robots." My team's ultimate goal is to program financial literacy lesson plans for K-12 students into robots which we will test across schools in Charlottesville. This programming will be done through Google Dialogflow and the effectiveness of the lesson plans will be measured by factors including lesson duration, conversation completeness, and intent-match detection confidence. Intent-match detection confidence is a metric used to indicate the confidence of our AI in matching user dialog to our preselected options. My research question is: "How can we improve the robustness of our lesson plans to improve financial literacy amongst K-12 Charlottesville students?" This is a relevant question because research shows that "75% of American teens lack confidence in their knowledge of personal finance" (Hanson, 2022). Although most of the work for this project will be technical, we also plan to investigate some of the sociotechnical issues with financial literacy. For example, many students who will struggle with financial literacy may not have access to the internet or a telephone at home. Therefore, we must also improve accessibility to achieve our goal.

My STS project is titled: "Low Latency Network Systems in High-Frequency Trading." My main goal is to investigate how retail investors are affected by high-frequency trading firms' low-latency network systems. Firms invest millions of dollars annually into optimizing their servers, software, and network systems to reduce their latency with exchanges by nanoseconds. In the world of high-frequency trading, every nanosecond counts and the competitive edge gained in First In First Out (FIFO) markets can be worth a fortune. Firms also pay brokerages such as T.D. Ameritrade and Robinhood for their users' order flow to deliver execution on stocks and bonds as well as other financial derivates such as options. My research question is: "What

are the consequences of high-frequency trading firms' low-latency network systems on retail investors?" The SEC recently took issue with Payment for Order Flow (PFOF) since an "inherent conflict of interest" exists for brokerages who may route retail investors to the firms with the highest PFOF instead of ensuring the best price for their customers (Spilka, 2021). While both my technical and STS projects are related to the financial industry, they share no other similarities.

Throughout this prospectus, I plan to further explain the relevance of my technical and STS projects. Additionally, I plan to define some relevant social groups while investigating the STS frameworks which will be useful in my analysis.

Technical Project

Financial literacy is crucial for saving money, avoiding debt, establishing strong credit, and many other skills that help build wealth throughout an individual's life. 75% of American teens from all demographics and backgrounds do not have the basic financial and economic knowledge to sustain themselves financially (Hanson, 2022). Our proposed solution to tackle financial illiteracy is to ensure students are taught the foundational expertise at a young age so that they make wise financial choices by the time they reach adulthood. We plan to develop a virtual voice assistant that will improve financial literacy by offering lessons that will cover all topics within the National Standards in K-12 Personal Finance Education educational curricula. Data will be collected and analyzed in order to assess the effectiveness, robustness, and engagement of the voice assistant. We plan to test the bot using baseline goals for effectiveness and robustness which can further be improved through more intent training and testing on potential users. Furthermore, we plan to investigate other ways in which we can increase accessibility to financial literacy for those without telephones or internet access. We plan to do

this by using NAO V6 robots and testing them in schools across Charlottesville with the ultimate goal of the robots being used as full-time teaching assistants.

STS Project

The technology that I plan to investigate includes the hardware, software, and smart routing technology that high-frequency trading firms use to reduce their latency with the exchange and execute their orders. Firms hire some of the brightest minds in tech to write the most efficient processing software. Additionally, I am interested in the actual physical hardware and routing logic that firms use for their servers. My research question is: "What are the consequences of high-frequency trading firms' low-latency network systems on retail investors?" When we compare the average Robinhood user placing trades through the app with these market-making firms, we observe a large disparity in the quality of order execution. Even institutional investors are able to ensure quality execution by trading in sizeable quantities and negotiating with firms through their brokers. The average investor is getting poor execution on their trades and through my research, I would like to quantify this disparity.

The relevant social groups are retail investors, institutional investors, and market makers. Retail investors are "non-professional investors who buy and sell securities, mutual funds, or ETFs [typically] through a brokerage" (Hayes, 2021). Retail investors are everyday working people who usually invest some fraction of their earnings into stocks and ETFs via a brokerage such as Vanguard or T.D. Ameritrade. Institutional investors are organizations such as banks, pension funds, or insurance companies that trade securities in large enough quantities to qualify for preferential treatment. Examples of institutional investors include companies such as Morgan Stanley, J.P. Morgan, and Credit Suisse which will typically have a broker directly in contact with market makers at all times. Market makers are high-frequency trading firms that use

"powerful computer programs to transact a large number of orders in fractions of a second" (Chen, 2021). These firms provide liquidity to the market by always being willing to buy and sell securities even through periods of high volatility. Some notable high-frequency trading firms include Jane Street Capital, Citadel Securities, and Hudson River Trading.

Other relevant parties which we are leaving out include the SEC, the Commodity Futures Trading Commission (CFTC), the Federal Reserve, and the exchanges on which these securities are traded. The SEC and CFTC regulate the entire industry by establishing and enforcing the rules which all market-makers must abide by. The Federal Reserve controls the Federal Funds Rate which describes the interest rates at which banks can lend to each other. This rate is highly relevant for all institutional investors. Finally, the Chicago Mercantile Exchange (CME) and New York Stock Exchange (NYSE) account for the fees which all market participants pay and the exchanges are also responsible for connecting market makers with institutional and retail investors.

The STS frameworks that I plan to use are technological momentum and diffusion of innovations. Technological momentum is particularly significant in this industry since so many people are invested in the stock market either through personal investments or their 401(k) plan. The introduction of new technology on behalf of retail investors, institutional investors, and market makers have irreversible impacts on all counterparties. For example, Robinhood introduced the ability for retail investors to purchase partial shares of companies, and that had far-reaching effects on all market participants. It should be noted that these effects could be either direct or indirect, but essentially this feature made it easier for companies to raise capital.

Another framework that I plan to investigate is the diffusion of innovations. When one firm comes up with an innovation that allows for better execution by even a few nanoseconds, all

other firms immediately lose priority in FIFO markets. Therefore, all these market-making firms are in a metaphorical arms race in which they must always pay for the latest and greatest technology. The diffusion of innovations theory can be useful in this instance to explain how and why these technologies spread as well as the rate at which these new ideas spread.

Key Texts

The first text that I am using is a list of fascinating financial literacy statistics from 2022. Savannah Hanson highlights the role that financial literacy plays in a productive life while also showcasing some statistics about the failure of the American education system. Many Americans have no one they can ask for trusted financial guidance. Many people find themselves in hopeless credit card debt very early in their lives. I plan to cite statistics from Hason's article to support the significance of my financial literacy project.

The next text I plan to analyze is Dmytro Spilka's exploration of the SEC's bid to ban Payment for Order Flow. PFOF is a significant part of what allows these high-frequency trading firms to exist. Additionally, the SEC chairman claimed that there was an inherent conflict of interest associated with PFOF. However, recently, the SEC has dropped this bid after realizing that PFOF allows for liquidity in portions of the market which would otherwise become illiquid. Illiquid markets would result in low price transparency for those securities and higher prices on average for all customers. The entire history of the SEC's role in managing these laws is of interest to me.

Retail investors are my primary group of interest and Adam Hayes' article describing them is particularly relevant. Without defining my group of interest, it would be difficult to answer my research question. Furthermore, all of us can sympathize with retail investors since a

large majority of people are retail investors. Anyone who has invested through Vanguard, T.D. Ameritrade, or another brokerage would be considered a retail investor. Therefore, it is also important to the most number of people that retail investors get quality execution on their trades.

Finally, I will use James Chen's article on understanding High-Frequency trading to explain the background information in my paper to the best of my ability. In Chen's article, he explains what high-frequency trading firms do, the technologies that they use, the reasons that firms have been criticized, and basic definitions for liquidity and other common market terminology. Chen's article will be critical for providing my reader with essential background information.

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