Prospectus

Rigorously Investigating Autonomous Decisions

(Technical Topic)

The Financial Revolution: Insights into the Economic Behavior of Young Adults

(STS Topic)

By

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May 3 2022

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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:

When John McCarthy coined the term Artificial Intelligence in 1955 at a conference at Dartmouth, he planted a powerful seed to gestate in the minds of the greatest scientists and technological mavens (Haenlein & Kaplan, 2019). Since the adoption of machine learning, the market economy has valued individuals' data tremendously. For example, the company Credit Karma was acquired by Intuit in 2020 for $7.1 billion. Credit Karma, like other credit score companies, sells its user data to banks (Trelewicz, 2017, p. 10). How can a company be valued at and sold for $7.1 billion when its primary form of revenue is selling data to banks? The answer: the demand for individual data is high and has become a stable avenue for profit-making. Focusing on the lucrative opportunities of data mining, companies have failed to recognize the pernicious consequences to their users, such as failing to value their time and money equally to their own.

To better understand the potential impairments to society—namely the exploitation of consumers' psychology through machine-learned optimized features—I will conduct research through two related avenues: a technical report and an STS paper. My technical topic will address the ethical and technical issues with assessing accountability when autonomous agents make decisions with adverse consequences. I plan to accomplish this by formally generating counterfactuals to process the available data and reverse engineer autonomous agents' "intentions." In an overlapping yet tangential fashion, the pervasiveness of autonomous agents in the field of behavioral and market economics relates to my STS research topic. For my STS topic, I will analyze society's democratization of finance, thus increasing the ease with which young adults incur debt and participate in risky behavior. The democratization of finance, I will argue, is directly related to society's overemphasis on data and machine learning. I plan to

accomplish this by reading and analyzing various peer-reviewed sources pertaining to FinTech and behavioral economics , performing time series analyses on economic and financial indicators over time, and by interviewing young adults. I plan to determine the root causes of the relative rise in debt over time to more accurately outline a direction in which society can better develop to increase everyone's overall utility. The theoretical framework and lens through which I will analyze these detrimental actors is social construction of society (SCOT). Indeed, the prevalence of risky financial behavior in young adults is based on society's typical behavior. As technology and computing power have evolved, so, too, has society. Our progression was not engendered without unintended side effects, however.

Technical Topic

On May 6th, 2010, the US-based stock market suddenly saw massive and irrational price swings, leading to trillions of dollars of cumulative losses, all within the course of minutes. The collapse was not the result of fundamental economic uncertainty. Rather, a complex sequence of human and automated decision-making turned one slightly anomalous order into a breakdown in the proper functioning of the markets (CFTC & SEC, 2010). This "flash crash" provoked both regulatory and criminal investigations, which struggled to assign responsibility for this near calamity. Traditional trading activities had triggered and reinforced cycles in the intricate, emergent dynamics of the automated markets (Poirier, 2012, p. 455). As autonomous agents are deployed with greater independence and less complete information into more complicated environments, accountability will become only more necessary.

I will approach the problem of formally assigning accountability by working with doctoral candidate Samuel Judson and his advisor, Dr. Ruzica Piskac of Yale University, along

with a UVa advisor to oversee the writing of my technical report. My goal is to present a refinement loop that supports rigorous, principled inference of computational analogues of decision artifacts like knowledge, beliefs, and intentions of autonomous black box agents. Explaining the decision processes of deep neural networks has become a major focus of research into their accountable and trustworthy use of machine learning (Amina & Berrada, 2018). Notwithstanding that black-box models generally express highly-complex and non-interpretable transformations across the full input space, locally the model can often be represented by simpler hypotheses (Ribeiro et al., 2016). The question of whether formal methods—particularly programming-by-example—can substitute for statistical learning methods in generating local representations of black-box models for the purpose of explanations and accountability is central to my technical report.

Assessment of human culpability requires inferring the reasoning underlying harmful decisions. Experts do so by interpreting the knowledge, beliefs, desires, and intentions of the decision maker. Formal accountability processes, such as trials and accident review boards, rely upon an investigation of the observed events that led to the injury, with counterfactual analysis playing a critical role. Just as there is a meticulous process of ensuring accountability in human matters, it is equally important to promote the answerability of autonomous agents. In my technical report, I will show how formal methods can be employed for human-in-the-loop analysis of decisions drawn from program verification, symbolic execution, and program synthesis by investigating a crash involving a reinforcement-learned agent given faulty sensor data within a simulated traffic environment. This approach will support agents that rely upon both logical (algorithmic) and statistical (machine learning) reasoning. The connection between a self-driving car and market making artificial intelligent algorithms is very similar. Regardless of

the field in which an autonomous agent operates, a proper system would be able to provide guidance in assigning accountability in the event of any unintended adverse outcomes (Poirier, 2012).

STS Topic

From the 1970s to the 2000s, both unsecured and student loan debts have increasingly contributed to young adult indebtedness. The amount of debt relative to the total economic resources of young adults, that is, the debt burden, has increased appreciably over time (Houle, 2014). Those identified in lower social classes, moreover, are disproportionately affected, as they are more likely to have incurred uncollateralized debt. With meticulous advertisements tailored to each individual through machine learning and an ever increasing arsenal of consumer goods from which to choose, it can be easy for young adults to spend money on items that yield utility in the present, disregarding the opportunity cost of saving the capital for the future.

While credit is a powerful tool to facilitate extra opportunities for many individuals, it increases financial risk for young adults (Houle, 2014). Therefore, debt must be handled properly to avoid adverse consequences in the future. The wealth inequality gap has been expanding. The overall rise in wealth over the period from 1989 to 1998 was predominantly realized by the top 20% wealthiest households. In particular, the top 1% wealthiest realized 53% of the wealth gain over that period (Obenberger, 1994). The research method of Obenberger's paper utilized data collected via a questionnaire from a random sample of individual investors with substantial positions in Fortune 500 companies to analyze the investing decisions and behavior of those individuals. The way in which the sample was constructed increases the validity of the findings, and the researcher ensured that as little statistical assumptions were violated as possible.

Social constructivism theory asserts that because humans, who comprise society, forge technology, technology itself must be a social construct (Bijker, et. al, 2012). Bijker, et. al (2012) contend that "a problem is defined as such only when there is a social group for which it constitutes a problem" (p. 414). The wealth inequality in the US and around the world is one such problem created by the social groups it both benefits and harms. Taking advantage of the methods by which individuals have grown their wealth over time, particularly through keen investments, could help minimize the incurring of debt for the younger generations. Individual investors' behavior can be explained by fundamental wealth-maximization theory (Obenberger, 1994). Investors, however, do not achieve these ends by just one set of means. Decision-making procedures vary from one individual to another. Neumann and Morgenstern made four key assumptions about the behavior of agents in defining wealth-maximization theory: investors are rational, selective among complex choices, risk-averse (all else being equal), and wealth-maximizing (Obenberger, 1994). With so many choices, investors, particularly young adults, can become overwhelmed.

On June 12, 2020, twenty year-old Alexander Kearns committed suicide. His parents found a note on his computer: Kearns had incurred a negative balance of $730,165 trading options on the app Robinhood (Klebnikov, 2021). With the advancement of financial technology over the past three decades—online banking in the 1990s, mobile wallets in the 2000s, banking chatbots and zero-commission trading apps like Robinhood in the 2010s—financial access has become greatly democratized, increasing the ease with which retail investors can exchange money and access the financial markets. The COVID-19 pandemic facilitated the interest of new, young investors who were "armed with government stimulus checks" (Tan, 2021, p. 2). The influx of government capital into the market economy increased the disposable income with

which young adults could invest. Corporations like Apple and Google have focused on augmenting—increasing simplicity with pretty, clean interfaces—the iOS and Android operating systems. As a result, apps like Robinhood can easily exploit user psychology, enticing them to invest, trade, and incur risk with the prospect of zero-commission trades. The graphical design interface (GUI) of Robinhood is a major catalyst in the recruitment and continued use of users. Robinhood allows new investors to trade options immediately, disguising the vast risks involved by keeping the process minimal. Gamification of investing has also reinforced the desire to achieve one's financial goals (Tan, 2021). Although FinTech—the evolution of finance effectuated by new technologies—has been a powerful accelerator in the widespread use of trading and exchange of virtual money, there is a predatory relationship between platforms like Robinhood and its users.

Many young adults in particular also fall victim to the high percent return lure of speculation in equities, options, cryptocurrencies, and NFTs. NFTs or non-fungible tokens are digital assets that contain unique cryptographic signatures, making them non-cloneable. The markets on which NFTs trade are unregulated, which means that there are no financial intermediaries as there are in other financial markets, vastly increasing uncertainty in transactions. Each trade is performed in an auction setting on websites such as OpenSea and Rarible, where Gas fees could cost as much as hundreds of dollars for each sale (Kong & Line, 2021). Young, inexperienced traders gamble with high-risk, high-reward securities that, eventually, lead most speculators to lose money, incur vast margin debt, and—in the worst case—become overwhelmingly depressed, as in the case of Kearns. My theoretical framework employs social constructivism: society itself—namely leaders in governments and corporations—facilitated the evolution of FinTech. This societal trend advanced hand-in-hand

with the increased susceptibility of the young adult population to act rashly, an exploitation of their higher risk tolerance. The progression of society's reliance on AI and Big Data is evident, and it affects the lives of all young adults every day. The typical spending behavior of young adults as demonstrated by behavioral economics reveals the grave dangers of having access to too many choices from which to choose, many of which are geared by business owners to entice risky spending and gambling.

Conclusion:

My anticipated technical deliverable is to design a formal method to conscientiously infer the decision-making process of machine-learned models. Many successful techniques only work to explain the model's inferences over a small part of the input space. I am interested in the many more possible small perturbations in underlying counterfactual examples that can be generated for the model. For my STS research paper, I plan to address society's exploitation of users through meticulously engineered applications. The tendency for companies like Robinhood and OpenSea to take advantage of young adults is a powerful feedback loop that must be stopped by careful analysis of the underlying incentives behind those companies at large and the economic behavior of the users. Approaching both topics requires careful analysis of the foundations on which these pertinent problems lie, yet the potential to benefit young adults and society at large will justify the means.

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