DESIGN OF A CYBER-PHYSICAL SCHEDULING AND ROUTING SYSTEM FOR PORTS USING QUANTUM COMPUTING

DECONSTRUCTING TECHNO-DETERMINIST VIEWS OF AUTOMATION TECHNOLOGIES

A Thesis Prospectus
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By
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TECHNICAL TEAM MEMBERS
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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.

Signed: Sidney Jennings Date: December 2, 2021

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As of mid-October 2021, wrote Swanson et al. of *The New York Times,* 25 freight ships are in line outside of the Port of Los Angeles waiting an average of 11 days before service. In response, it will join the Port of Long Beach in operating 24 hours per day every day (Swanson et al., 2021). The 12.3 million workers within the US logistics industry are experiencing a spike in demand including a shortage of 68,000 truck drivers (Franklin, 2021). The new demand contradicts predictions for labor trends such as Han et al.'s (2019) classification of logistics jobs which placed truck drivers in the worst category for declining jobs with high risk of automation. The logistics labor shortage has damaged the greater United States economy by contributing to the 5.4 percent increase in the Consumer Price Index from September 2020 to September 2021 (Swanson et al., 2021). The stress placed on port logistics and significant economic impact begs for research into methods for decreasing port congestion and deadlock in addition to critically examining predictions for decreased labor requirements from automation.

This prospectus outlines a technical project that addresses issues within America's supply chain in addition to a tightly coupled STS research paper. The technical project will serve as one piece within a much larger project of establishing a cloud-based quantum computing system for assignment and routing problems at ports. The system will draw data from various physical sources within the port and run optimization algorithms that yield instructions for autonomous machines as well as humans. However, human responses to and interactions with automated processes do not often occur as planned, and existing approaches to human resource management fail to incorporate humans and machines into a singular system (Stein & Scholz, 2021). Thus, this prospectus argues that current literature about automation fails to distinguish between two forms: human supplanting automation, and human incorporating automation. The STS research paper will argue for the distinction between the two forms of automation and analyze the

differences in how each behaves within a sociotechnical system of the US logistics industry, private and public companies, workers, consumers, and engineers.

DESIGN OF A CYBER-PHYSICAL SCHEDULING AND ROUTING SYSTEM FOR PORTS USING QUANTUM COMPUTING

Within the field of Computer Science, the runtime of an algorithm can be classified as P (polynomial time) or NP (nondeterministic polynomial time). For NP problems, finding an answer usually takes a very long time (eg. exponential), but verifying an answer takes polynomial time (Fortnow, 2009). For example, a password is difficult to guess but easy to verify.

Many of the operations within ports follow imperfect solutions because the problems fall into the NP category. The shortest path between many points, obviously an important problem for logistics, is NP-hard (Fortnow, 2009). Dan Hendrickson, VP of Asset Management for The Port of Virginia, described the difficulty of storing and retrieving shipping containers as "solving a Rubik's cube while it's changing colors" (personal communication, October 21, 2021). Fortunately, the rapidly developing technology of quantum computing has been proven to solve certain NP-hard problems such as the shortest path problem (Pelofske et al., 2020).

This project makes use of and continues research into prior applications of quantum computing for problems within port environments and logistics in general. Many such applications employ quantum annealing, an optimization method that uses the principal of quantum tunneling to outperform the traditional computing equivalent (Heim et al., 2015). Li & Li (2021) have demonstrated the application of quantum annealing for assigning berth space to incoming vessels and scheduling quay cranes to offload shipping crates to optimize vessel waiting time.

In discussing the goal and scope of this project, a distinction must be made between the overarching project, and the University of Virginia SEAS capstone project. The overarching project plans to develop a cyber-physical cloud-based quantum computing system and implement it at The Port of Virginia. This ambitious project coordinates with faculty all over the United States and seeks a multimillion-dollar budget. Mashrur Chowdry, professor of Civil Engineering at Clemson University, will lead the project with support from faculty at the University of Virginia, and Virginia State University among others. The three-year project timeline is shown in Figure 1.

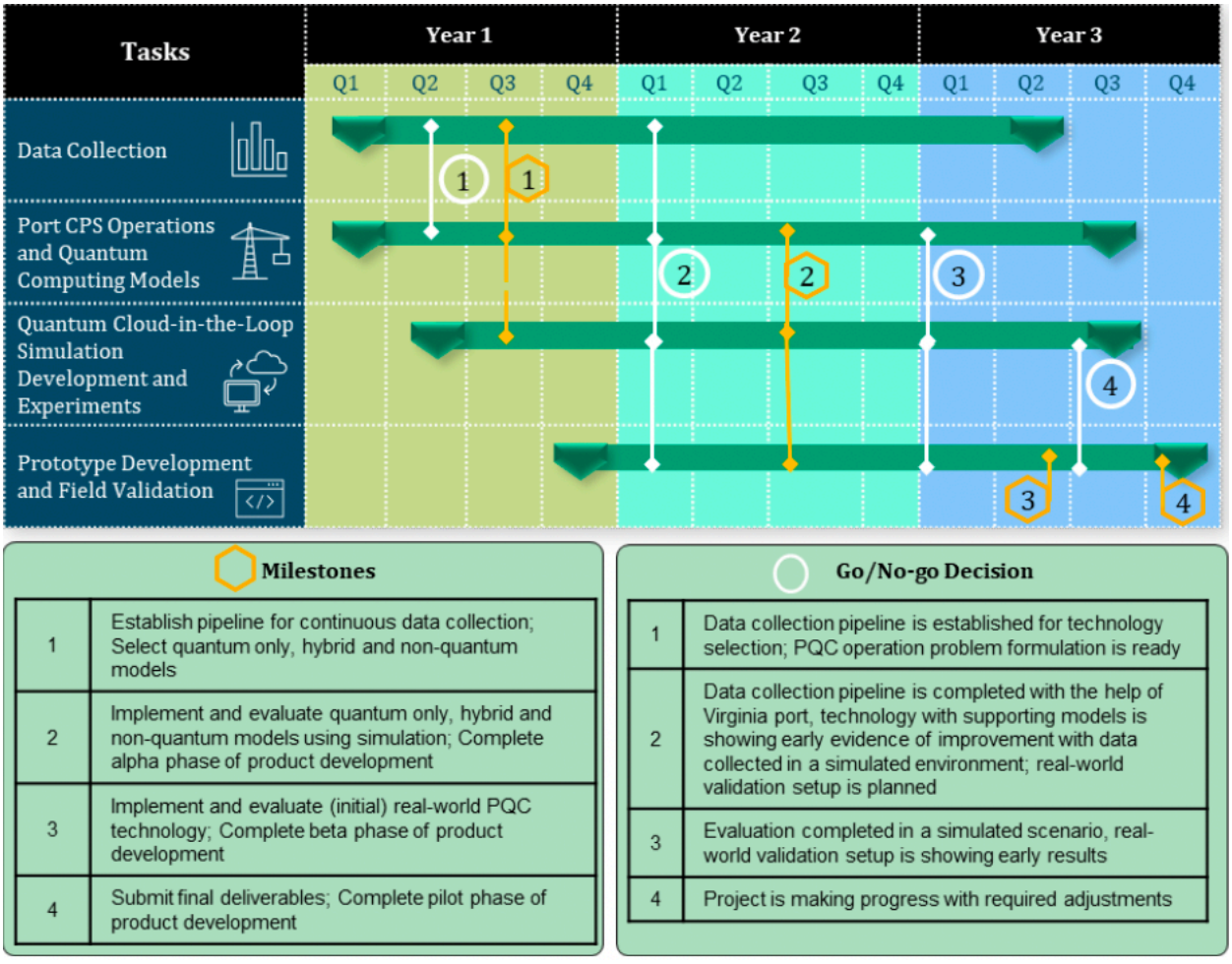

Figure 1: This figure details a 3 year project timeline with specific points for milestones and decisions to continue the project or not (Chowdhury, 2021, p.11).

The SEAS capstone project will have a very limited scope in comparison to the greater objective. Within a one-year timeframe, the capstone team will research existing literature that might apply to the project, gather data to develop quantum computing models, and work with The Port of Virginia to outline requirements under the guidance of Prof. James Lambert and graduate students, Timothy Eddy and Elijah Crawford, from the University of Virginia department of Engineering Systems and Environment. The undergraduate team will include Max St. John, James Roberts, Tiago Magalhaes, and Sidney Jennings, fourth-year students studying Systems Engineering, and Ibrahim Hamdy, a fourth-year student studying Computer Science. Main deliverables will include a technical paper, presentation, and poster for the Systems and Information Engineering Design Symposium at the University of Virginia in addition to a separate technical report and presentation for The Port of Virginia.

DECONSTRUCTING TECHNO-DETERMINIST VIEWS OF AUTOMATION TECHNOLOGIES

Andrew Yang's rise to popularity during the 2020 Democratic Party presidential primary election for his universal basic income policy reflects the growing fear among Americans that automation will supplant human labor. Yang's "Freedom Dividend" would give each American citizen a monthly thousand dollar check to counter automations impending doom remarking, "All you need is self-driving cars to destabilize society" (Roose, 2018). Jesse Ramirez, assistant professor of America studies at the University of St. Gallen, Switzerland, examines such rhetoric in *Against Automation Mythologies: Business Science Fiction and the Ruse of Robot*. The author noticed that popular culture tends to portray automation as either the downfall of civilization, or the beginning of a utopic "rapture for nerds" (Ramirez, 2020, p. 3). Ramirez considers both views unreasonably founded in technological determinism without any consideration for the

social construction of technologies. One such method, the Actor-Network Theory, proposes that technologies are not only created or discovered by scientists and engineers, but they are embedded in a sociotechnical system of many actors who develop and adapt them (Fioravanti & Velho, 2010). By examining automation through the Actor-Network Theory there emerges two related but distinct technological artifacts, human supplanting automation, and human integrating automation.

As the logistics industry becomes more automated, the relationship between humans and machines requires a thorough reexamination. Stein & Scholz (2020) mirror Ramirez's thoughts towards absolutes, "The prevalent discourse structure on the future relationship between humans and robots resembles an either/or discussion" (p. 392). The authors allude to a research gap in synergies between humans and robots and methods of incorporating machines into a network of humans rather than each existing isolated with no communication from machine to machine or machine to human (Stein & Scholz, 2020). Raisch & Krokowski (2021) offer similar but more nuanced opinions regarding human integrated automation, which they refer to as "augmentation." After reading and synthesizing several business focused books on AI they conclude automation and augmentation complement each other and one should situationally favor one over the other (Raisch & Krokowski (2021).

AUTOMATION AT AMAZON

Perhaps more than any other company, Amazon has fully bought into human integrated automation. Ramirez cites a corporate blog post that describes robots as "dance partners" (2020, p. 58). Will Evans, investigative journalist for *Reveal News*, suggested that Amazon's robots make poor partners in his Pulitzer finalist series criticizing Amazon's safety practices (2019). Evans painted a dire picture in which ruthless quotas, apathetic safety managers, and thoughtless

automation combine in an injury rate twice the industry standard. Jeff Wilkes, former Amazon CEO of Worldwide Business claimed, "the robots change the work, so people don't have to walk as far … They make the job safer" (Evans, 2020). The investigative data, shown in Figure 2, demonstrates the extent to which Amazon's automation does not make work safer.

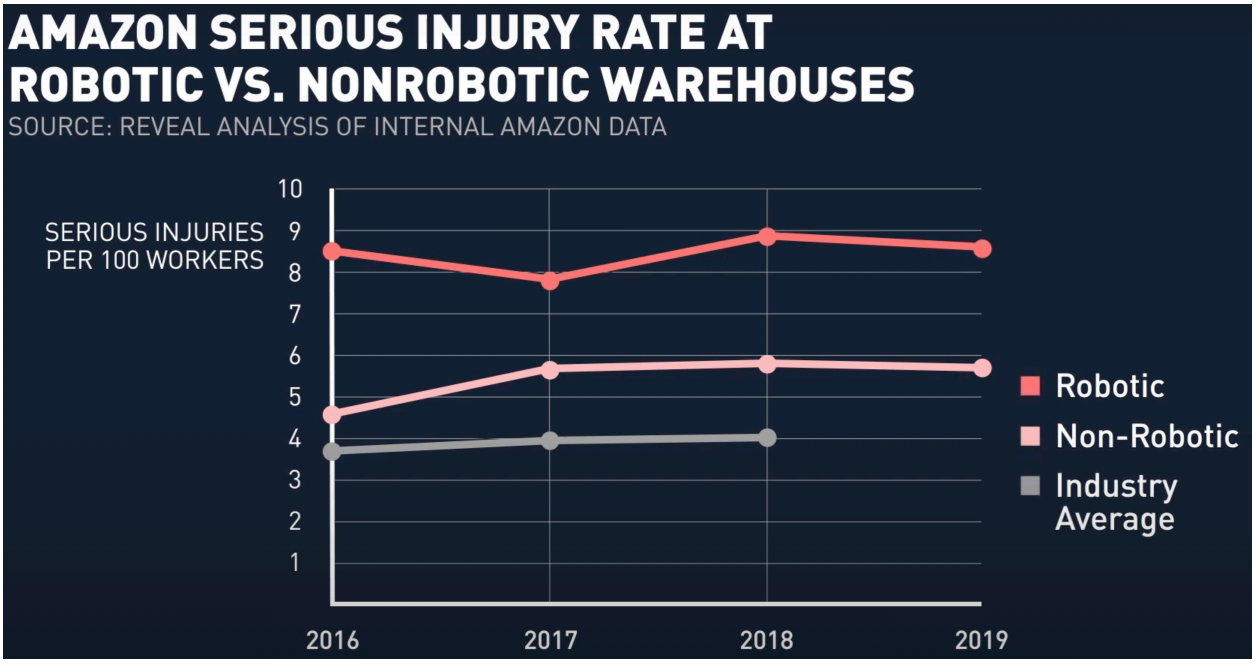

Figure 2: Contrary to public statements, injury rates at automated Amazon warehouses were much higher than non-automated and the industry average from 2016 to 2019 (Evans, 2019).

Amazon's approach to automation is best understood not as automation of work but rather automation of workers. Frey & Delfanti's (2021) examination of Amazon's patents indicates the company intends to continue doing so. Patents for technologies such as augmented reality glasses and new bio sensors suggest that Amazon's objective is to minimize thoughts and increase control (Frey & Delfanti, 2021). Ramirez offers similar sentiment, "The most plausible outcome of automation in the warehouse industry is not the disappearance of warehouse jobs but their further material and moral degradation" (2020, pp. 58-59).

THERE IS NO NEUTRAL: THOUGHTFUL ENGINEERING

To engineer automation technologies that positively impact society, one must avoid technological determinist points of view. For example, the framing of automation as an inevitable development that outpaces society prevents analysis of existing automation technologies at Amazon and how they differ from popular perceptions. To gain a more wholistic view, Fioravanti & Velho's (2010) Actor-Network Theory (ANT) provides insight into why there is a disconnect between what most people would expect automation to be at Amazon, and what it is. ANT is a method of social construction that maps relationships between both human and non-human actors to uncover how different actors affect each other (Fioravanti & Velho, 2010). The beginnings of an ANT diagram for automation technology are shown in Figure 3. The relationship between each of the actors is not static, so the condition of each actor is affected by them and gives feedback. Therefore, automation is not an obvious conclusion; it is the variable output of policy, corporate leadership, labor rates, engineering decisions, emergent technologies, and countless other factors. Considering Raisch & Krokowski's (2021) conclusion that neither automating nor augmenting alone is ideal, and a balance is optimal, the ANT model fits well.

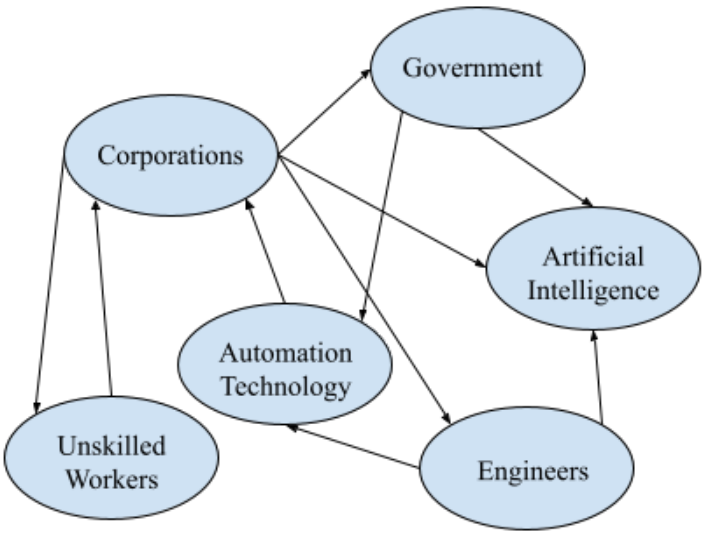

Figure 3: An example map of an actor network for automation technology (Jennings, 2021).

This research project will take the form of a scholarly article that examines the differences between automation technologies that supplant humans and/or incorporates them. It will explore more of the relationships between the technologies and other actors, especially popular media. It will use STS frameworks to examine whether there are two modes of one technology or two separate technologies. This topic applies to the technical project, because quantum computing elicits very optimistic projections and experiences the same "sci-fi effect" as robotic automation. Research claims bold numbers and promises reducing inefficiencies to a fraction (Neukart et al., 2017), but more work must be done into incorporating humans within automated environments before the full potential is tapped.

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