Exploring Spiking Neural Networks for Real-Time Control in Myoelectric Prosthetic Devices

From Drivers to Monitors: The Impact of Autonomy and Platooning on Truckers and the Trucking Industry

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Science

By
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November 8, 2024

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

In 2022, trucks were responsible for moving 72.5% of freight by value in the United States (United States. Department of Transportation. Bureau of Transportation Statistics, 2023). However, the industry has struggled against persistent labor shortages (Costello, 2017). The rapid development of artificial intelligence (AI) and machine learning (ML) has given rise to implementation in industries otherwise outside of the technology industry. One of the most influential applications is the development of autonomous vehicles. While early research has centered around passenger cars, there is a developing interest in integration with commercial trucks. The most promising development is truck platooning, which allows trucks to connect wirelessly and transmit acceleration and braking patterns between vehicles reducing following distances, decreasing air resistance, and improving fuel efficiency. Varying levels of automation exist within these systems, some allowing following trucks to function without a human operator. As this technology progresses, it is crucial to understand its impact on the trucking industry and the millions of truck drivers who will interact with these systems daily.

The technical portion of this report will focus on the potential application of Spiking Neural Networks (SNN) in myoelectric prosthesis. Myoelectric prosthetics are prosthetic limbs that use surface electrodes to detect muscle activity and interpret intended movements for the prosthetic using the electromyographic (EMG) signals (*Myoelectric Control - an Overview | ScienceDirect Topics*, 2021). These prosthetics provide an alternative to body-powered systems, which can cause discomfort, and may be better for more consistent lightweight work (Carey et al., 2015). The current challenge within myoelectric prosthetics is getting consistent real-time interpretations of the EMG data. This paper proposes the application of SNNs, because of their lower energy needs and intuitive application because of the temporal-spiking nature of the EMG signals (Yan et al., 2024).

These problems face similar challenges, in that dependability and user acceptance are vital for the technology's success. The largest barrier facing myoelectric prosthetics is their energy efficiency and difficulty of use. As these technologies advance, it is vital to understand the impacts they will have on users' daily lives.

Exploring Spiking Neural Networks for Real-Time Control in Myoelectric Prosthetic Devices

Approximately 41,000 people in the US are upper limb amputees (*Amputation of Upper Limb - an Overview | ScienceDirect Topics*, 2020). It is estimated that the rejection rate of upper limb prosthetics is 44% (Salminger et al., 2022). The most common complaint about the prosthetic was comfort, which depends on system weight, materials, and heat. Another common complaint is the lack of function. The function of a hand is difficult to replicate, which only further exacerbates the difficulty of creating a functional prosthetic. Many available myoelectric prostheses offer limited movement. Terminal devices, which are located at the end of a prosthetic, mimicking the user's hand, are generally able to open and close, unable to replicate the abilities of a hand (National Academies of Sciences et al., 2017).

This paper will analyze the dependability of SNNs in the decoding and intent prediction of EMG signals in myoelectric prosthetics. Myoelectric prosthetics utilize a set of sensors that read electrical signals from user muscle activity. These EMG signals can then be processed, reducing the noise within the signal, and reducing the input information to limit the amount of computing power needed to predict the user's intent (Li et al., 2022). The prediction of the intent of movement within the prosthetic is widely researched. The field has traditionally used classical ML techniques like support vector machines, however with the advancement of deep learning, more advanced prediction methods are being implemented. These methods have been shown to reduce prediction time and increase the accuracy of intent (Yu et al., 2023).

The application of SNNs in myoelectric prosthetics, using EMG data collected from non-amputee patients performing several gestures, has shown promise (Sun et al., 2023). This study showed that SNNs can improve accuracy in some cases and reduce the power consumption of classification. SNNs have also been shown to learn the training space in fewer examples compared to other deep learning techniques (Ma et al., 2018). The ability to learn on a limited sample space is critical for adapting the system to the user, increasing accuracy for specific users. To analyze the feasibility of this technology's implementation, it is necessary to understand the dependability of this technology. Unreliable and inconsistent predictions can be frustrating and worsen the already prevalent difficulty of use and rejection problems.

To better understand the reliability of SNNs within myoelectric prosthetics. This study will utilize fault injection, where the noise in the signal transmitted through the EMG sensors will be amplified randomly. The additional noise introduced simulates real-world applications, where surface sensors can be unreliable and user muscle activity will vary based on the user. This will aid in the characterization of the reliability of future prosthetics. The consistency of the predictions made by the SNN will impact user experience, and understanding the shortcomings of current systems will inform areas for future development. Addressing the pain points recorded by amputees, acceptance rates of prosthetics will improve by reducing discomfort, training times, and system weight. Increasing reliability and ease of use is necessary for increasing acceptance rates and SNNs have been promising thus far.

From Drivers to Monitors: The Impact of Autonomy and Platooning on Truckers and the Trucking Industry

The trucking industry plays a critical role in the United States economy, moving over 72% of the nation's freight by value and filling a crucial role in the job market for citizens without higher education (United States. Department of Transportation. Bureau of Transportation Statistics, 2023). However, technological advances in AI are shifting the industry to more automation. The promise of improved traffic and fuel efficiency with the continued development of autonomous vehicles raises complex social and economic questions regarding labor displacement, worker adoption, and industry transformation.

This research will address the question: *What are the socioeconomic impacts of introducing autonomous vehicles into the trucking industry?* This question is significant given the massive economic footprint the trucking industry possesses; in 2022, the U.S. trucking industry had a market size of $217.3 billion (Kolmar, 2023). Although autonomous trucks have several potential benefits, it is necessary to understand the perspectives and concerns of those in the industry to avoid further alienating the already limited workforce as integration continues. This study will examine the thoughts and ideas of current drivers by analyzing past interviews and identifying current obstacles. I will also gather quantitative data summarizing the state of the industry to gain a better understanding of both the social and economic challenges facing the integration of autonomous trucks.

Truck drivers' views on automation reveal a complex relationship between technological advancements and independence. Many drivers are hesitant to accept innovative technologies, specifically expressing concerns about safety and job security. For example, the introduction of antilock braking systems and emergency braking assist systems are widely agreed to improve safety however some drivers feel that it impedes upon their agency by intervening too soon, making them feel out of control (Bhoopalam et al., 2023). Driver trust in these systems is crucial for effective operation, and understanding and mitigating driver concerns will be necessary as development continues.

Another significant issue is the increased monitoring of drivers through tracking technology. Customers and freight company managers have access to the driver's location, speed, routes, etc. This constant monitoring has eroded the independence that was once present in the industry (*Trucking Drive*, 2024). Drivers would not have contact with others except at set stops. This use of technology has also led to decreased interpersonal contact. One driver stated, "*Now we no longer communicate [with people at drop-off location]. It is just click and press, we are no longer in contact"* (Bhoopalam et al., 2023).

Truck platooning, a cooperative driving system that transmits acceleration and braking data between connected vehicles, has received mixed reactions from drivers. Truck platooning is the most prevalent and developed autonomous trucking technology available. It allows trucks to drive in a tight formation, reducing air resistance and improving fuel economy. One study examined the thoughts and opinions of drivers before and after participating in a truck platoon. Drivers were hesitant and questioned the utility of the technology in the initial surveys. However, the study found that after participating in a truck platoon overall perception of the technology improved (Castritius et al., 2020).

As this technology continues to advance and integrate more into industry, the continued evaluation of the social and economic impacts is essential. This research will continue to analyze the perceptions of truckers, as well as the stability of the industry as development continues.

Additionally, current, and future policies supporting truck platooning will be monitored. In several states, laws have passed allowing trucks in platoons to close the following distance, below previous legal limits (Goble, 2023). In others, autonomous trucking has been stymied due to the requirement driver presence requirements and no policies reducing following distance. Further monitoring and research into how these policies affect the industry will be necessary for understanding the impacts and future development of autonomous trucks.

Conclusion

In conclusion, this STS research aims to provide a comprehensive understanding of the sociotechnical impacts of autonomous vehicle integration in the trucking industry, focusing on driver perspectives, industry stability, and policy implications. The findings in this research have the potential to provide insights into solutions to the challenges presented in the trucking industry as autonomous integration continues, as well as illustrate the importance of the trucking industry and the broader societal implications of this technology.

The technical portion of this proposal will aid the understanding and application of myoelectric prosthetics, improving amputee quality of life and system acceptance rates. The characterization of the dependability of SNNs could also provide insights into the application of SNNs in other areas. The lower power consumption and ability to train on a reduced sample space show promise for applications in areas where there is limited data available. This study will help illuminate the generalizability of trained SNNs.

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