**Thesis Project Portfolio**

**LiveNet: Robust, Minimally Invasive Multi-Robot Control for Safe and Live Navigation in Constrained Environments**

(Technical Report)

**Will the Autonomous Mobile Robots Revolution Endanger Us?**

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Srikar Gouru

Spring, 2025

Department of Computer Science

## Table of Contents

## Executive Summary

A major innovation occurring in warehouses recently is the introduction of robots. Specifically, the usage of autonomous mobile robots (AMRs) has taken off in an effort to improve company profits. Robots in densely populated real-world environments such as warehouses frequently encounter constrained and cluttered situations such as passing through narrow doorways, hallways, and corridor intersections. It is imperative that we study the variability of these autonomous vehicles and their reliability and impact on human safety. There are primarily two components at play with the use of robots in human-centered environments: worker safety and overall productivity. Oftentimes, these factors can clash, and greedy attempts to increase production could result in worker injuries. On the flip side, overprotective measures in the robots could result in a lack of productive behavior, rendering them nearly useless. Thus, finding a balance between safety and efficiency is key to developing an optimal system for humans and AMRs to interact in. The technical work in this portfolio proposes an efficient algorithm for more optimal AMR planning while also maintaining safety constraints. The socio-technical work investigates the integration of AMRs and the impact that AMRs have had on worker safety and productivity in the warehouse industry.

My technical project sought to build a machine learning algorithm to generate safe and optimal trajectories in constrained environments. Current decentralized state-of-the-art optimization- and neural network-based approaches (i) are predominantly designed for general open spaces, and (ii) are overly conservative, either guaranteeing safety, or optimality, but not both. While some solutions rely on centralized conflict resolution, their highly invasive trajectories make them impractical for real-world deployment. My capstone project, LiveNet, is a fully decentralized and robust neural network controller that enables human-like yielding and

passing, resulting in agile, non-conservative, deadlock-free, and safe, navigation in congested, conflict-prone spaces. LiveNet is minimally invasive and doesn't require inter-agent communication or cooperative behavior. LiveNet utilizes a unified Control Barrier Function (CBF) formulation for simultaneous safety and liveness, which is then integrated within a neural network for robustness. In simulation, LiveNet was able to succeed in scenarios where general optimization- and learning-based navigation methods fail to even reach the goal. LiveNet performs 10 times faster and generates paths that are more time-optimal than other algorithms.

My STS project investigates the safety and productivity impact of autonomous mobile robots (AMRs) on warehouse workers. In 2022, 3.8% of warehouse workers were estimated to have had serious injuries (Costa, 2024). As AMRs become increasingly prevalent in logistics and manufacturing sectors, it is imperative that we study their reliability and impact on human safety. This study employs Susan Leigh Star's *Ethnography of Infrastructure* as the primary STS framework to analyze how AMRs interface with existing workplace systems, standards, and human labor. By drawing on Star's concepts—such as visibility in breakdowns, adherence to standards, and the layering of new technologies onto established infrastructures—this paper examines both the benefits and potential risks of AMR integration. Empirical data including worker injury rates, productivity metrics, and mental health data pre- and post-AMR deployment, are used to evaluate the tangible effects of these technologies. This work contributes to the STS field by offering a critical perspective on how automation reshapes labor infrastructures and challenges existing safety protocols. The findings emphasize the need for human-centered integration of robotic systems that prioritize productivity and technological advancement while also improving worker well-being.

Working on both the technical and STS projects simultaneously helped understand the scope of the problem at hand. Through my STS research, I discovered various cases of AMR navigation algorithms failing when deployed in the real-world. My technical literature review was able to back that up as it revealed several problem points with existing algorithms, such as their inability to be robust to new environments or their lack of either safety or efficiency. Additionally, by tackling the technical project and investigating the socio-technical ramifications of this technology in parallel, my work on the project felt more impactful and helped fuel my motivation to continuously improve the algorithm. I think that having a socio-technical insight is crucial to understanding the heart of any engineering problem. It helps the engineer convert the mathematical problem formulation into a societal issue that they are tackling, helping them understand the real-world consequences of their project and the technology that they are developing.