Thesis Project Portfolio

Evolutionary-based Coordination of Multi-Robot Systems with Dynamic Constraints

(Technical Report)

Ethical Look at Coordination of Multi-Robot Systems in Industrial Environments

(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

Vihar Shah

Spring, 2024

Department of Systems and Information Engineering

Table of Contents

Executive Summary

Human-robot interaction is rapidly growing as a building block of technological and societal advancement prompting many technical innovations and ethical considerations for a harmonious integration of humans and robots. The technical research, *Evolutionary-based Coordination of Multi-Robot Systems with Dynamic Constraints*, explores solving the multiple Traveling Salesman Problem (mTSP) using an algorithm that simulates the evolutionary process of population genetics to quickly provide optimal paths to robots that need to complete several tasks around a warehouse or hospital where some tasks may be dangerous for a human. The sociotechnical research dives into the social and ethical concerns related to introducing autonomous robots into the workplace. As human-robot work becomes more prevalent and efficient, the mental and physical security of all humans involved can vary without technical standards. Together, the research helps provide an outlook on advancing autonomous robot technology to be readily applicable to realistic situations.

The technical research adds to existing knowledge on the mTSP and evolutionary algorithms specifically for precise and efficient inspection of real-world industrial and complex systems. Our proposed architecture to solve this problem consists of formulating an algorithm to assign a set of tasks to each robot so that the total operation time is shared and minimized. The steps involved consist of developing a digital twin of our environment to use as a map, optimizing the distance traveled by assigning tasks using our genetic algorithm, and using a go-to-goal algorithm to travel to its destination with artificial potential fields that aid in emergency obstacle avoidance and changing direction.

The results of this research included realistic simulations of varying human input constraints in experimental simulations. Our results fit our heuristic of minimizing the time that

each robot traveled by sharing the task load among the available robots. Furthermore, a prioritized task would modify the paths of robots to incentivize earlier completion including any close task on the way. This produces a robust prioritization solution in addition to solutions that allow task completion task to be specified and precedence, where one task must be completed before another in a specific order, constraints.

The sociotechnical research considered the emotional implications of introducing autonomous robots to industrial environments including mistrust, fear, job security, over-reliance, responsibility, safety, and satisfaction. To investigate these potential effects, the research examined surveys, studies, and data to determine what major concerns lie in introducing robots to the industry and what methods have worked to quickly and/or effectively integrate robots into a human environment where already implemented.

The results of the sociotechnical research indicated that regular contact with robots and time for familiarization were more comfortable and held more trust in the robots. Existing industries have implemented training sessions between workers and robots before production which bolstered positive robot sentiment, higher productivity, less fear, fewer dangerous tasks for humans, and consistent usage of robots. Moreover, robots that physically acknowledge nearby humans with any motion or cue are better socially integrated into the workplace and have fewer effects on the mental health of workers.

The conclusions drawn from the technical and sociotechnical research have shown great potential for positive advancements in society allowing workers to perform safer tasks and have higher productivity while corporations are satisfied with the output from the human-robot collaboration. As humans can further ethically integrate with performing tasks alongside autonomous robots, technical advancements become more valuable to society.