Explorer51 - Indoor Mapping, Discovery, and Navigation for an Autonomous Mobile Robot

(Technical Paper)

Investigation of Social Pressures on the Evolution of Machine Learning and Autonomous Robot Systems

(STS Paper)

A Thesis Prospectus Submitted to the

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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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General Research Problem

How do autonomous vehicle systems affect the perceptions and interests of different groups, and vice versa?

Autonomous robots and vehicles have been used in a wide range of applications for decades, both tangentially and separately from humans depending on the application. One relatively recent use case of these machines is in search and rescue missions, in which targets- usually victims of a disaster scenario- must be identified and evacuated to safety. To do this, autonomous vehicles must be capable of area mapping, target identification, and quick mobility. Because the "success [of an autonomous robot] is highly dependent on the time needed for first responder awareness that a human life is in imminent danger," it is imperative that the robot performs these actions consistently well (Lygouras, 2019, p. 1).

As our understanding of the field of robotic autonomy grows every year, engineers develop more efficient ways to program and design machines for specific purposes. A popular trend nowadays is to implement machine learning algorithms to combat some of the complex problems faced in certain scenarios. However, as the complexity of robot systems and machine learning applications surges, so does the disconnect between developers of the technology and the general public. Many of those not involved in the development of autonomous robots see the technology as a sort of "black box" which is beyond their understanding- that, coupled with the perceived loosening of human control over robots over time, stir up a general mistrust of machines to perform critical tasks. Current robot system designers and engineers must take into account the prevailing "measure of negative [public] attitude toward robots" to address the concerns of the general populace (Liang & Lee, 2017, p. 2). For the purposes of this prospectus, any reference of the general public refers to those who have been or are expected to be impacted by autonomous robots, but have very little to no contribution to the development of the robots. This includes previous victims and families of victims who have interacted with an autonomous robot, and those who may not have interacted with them but are concerned, at some level, with the application of robots as a means of saving people.

As we design a 3D-printed autonomous robot to perform tasks such as indoor mapping, waypoint control, and target identification, my Capstone team at the University of Virginia aims to acknowledge the strengths and challenges of the technology which affect our system. I intend to extend my team's work by researching the state of autonomous robot technology in society, in order to determine how such striking differences in perception of emerging technology came to exist.

Technical Research Problem: Indoor Mapping and Navigation for a 3D-Printed Autonomous Robot

How can an autonomous robot's abilities to navigate and map an indoor space be improved to better meet realistic system criteria?

My Capstone group's technical work revolves around the development and testing of a 3D-printed autonomous robot, whose core functions are to identify targets in an indoor area, reach target points and "return to base" when instructed to do so, as well as any other functionalities we plan to include over the course of the project. We are collaborating with a team from MITRE Corporation, which is supplying our group with valuable hardware and human resources- namely, a robot they helped to develop, program, and iterate on for similar

Capstone projects from past years. The functionalities to include are under our discretion, as are the goals of the system, and any hardware and software system design changes. We anticipate MITRE Corporation's input will be very helpful in achieving our goals.

A major focus of our work should be to design a system which overcomes several obstacles seen in robot applications today: physical and environmental hindrances, time constraints, and hardware recovery/ repair problems. For example, we hope to program the robot to perform functions which are likely to be applicable in scenarios in which humans are not able to operate on their own, due to constraints such as time or small spaces. A robot system like ours would also have the benefit of being easily constructed and repaired in the field, without the need for stocking a large inventory of parts. In addition, by giving operational personnel access to the design, the systems can be modified in the field to meet unforeseen mission requirements, essentially enlisting the operators as "hackers" to improve the design.

As one can imagine, there are countless possible sources of failure in each design choice, functionality, and method of execution when working with intricate, multicomponent machines. My team's work is no exception, and has such discovered several inconsistencies between what we planned for the robot to do, and what we observed in action. For example, when approaching a hard surface, we believed the robot had been programmed to stop a set distance away from the surface, and not continue forward even when instructed to do so. The robot did this, but we also observed that the robot would not allow for backward movement either- it must turn left or right at first to escape, which is not optimal. On the hardware side, the current iteration of our robot uses a Light Detecting and Ranging (LIDAR) sensor and a Simultaneous Localization and Mapping (SLAM) algorithm for mapping, but we often encountered inconsistencies in the data procured. It is our responsibility to iterate and optimize our system based on defined requirements and goals, to ensure these discrepancies do not occur in the future.

My team's intended deliverable is a robot with enhanced sensing and communication designs, which better performs under our and MITRE's determined criteria for success. Our team aims to test the current system's capabilities, to assess the performance of the current and future prototypes as they develop. In order to do this, we need to explore relevant open-source frameworks (Robot Operating System, ArduPilot), to improve the system's ability to create maps of unknown spaces and provide robust control with low latency. My team will iteratively modify the robot and system to better meet our objectives for the project, as well as collect quantitative and visual data on robot performance as we progress.

STS Research Problem: Investigation of Social Pressures on the Evolution of Machine Learning and Autonomous Robot Systems

How did conflicting societal perspectives on robot technology contribute to the differences among stakeholders regarding faith in autonomous robots and interests in their uses?

I. Introduction

Engineers and developers have championed machine-learning algorithms for processing information in situations in which human brainpower would simply not be powerful enough. This is definitely the case in the realm of autonomous robotics, which are usually used out of a need to perform tasks which humans are unwilling or unable to do themselves. These machine learning and deep learning algorithms have been popularized lately for that exact purpose, but due to the unexplored nature of the "new" technology, there is ample room for error in the execution of crucial tasks. Failure during a search and rescue mission could result in injury or death, and would also damage the reputations of the engineers involved. I would like to investigate how differing perceptions of these effects on lives and reputations have changed the ways autonomous robots have been developed and used. The results of this study may help to better understand why different groups, with inequitable levels of contribution to a sociotechnical system, react differently to how advanced technology is used.

II. Background and Theoretical Framework

A profound fear "which may serve to affect how people will respond to and interact with robots" is rapidly increasing, likely due to the fact that the general population's understanding of advanced technology has stagnated (Liang & Lee, 2017, p. 1). This fear is not consistent across the relevant groups in the sociotechnical system, which may have to do with the disconnect between the public and higher technology. In an effort to establish a foundation for further research on my topic regarding faith in robot technology, I would like to uncover how the differing perspectives of engineers and the public shaped the autonomous robot's role in civilization.

I will consult several sources of relevant literature to gain an understanding of the existing research on my topic. The primary focus of my literature review will be to examine the extensive documentation of experiments involving autonomous robots, as well as the prevailing sentiments of responsibility and fear surrounding the deployment of autonomous robots. For documentation of relevant experiments, I can draw from several studies concerning robots used in real scenarios, such as in Wurman, D'Andrea, and Mountz's report on using hundreds of autonomous vehicles in a warehouse setting. Their findings on the foundation of a "multiagent system"- one in which "autonomous agents carry out actions and communicate with each other through messages"- should be helpful in determining some of the strengths and weaknesses of systems implementing multiple unmanned robots at once, as well as some of the engineers' design decisions made to effectively reach the goals of their particular system (2008, p. 10).

According to some reports, engineers must be cautious when implementing certain system design decisions, in order to align with the worries of the general public. One pertinent worry is in the robot's ability to navigate and operate in an unfamiliar space. A more relatable comparison would be that humans can generally follow all the rules of the road while driving in ordinary conditions, but very few can adapt all aspects of driving in unfamiliar situations. For example, in a snowstorm, one's vision is impaired and it would be difficult to see and make fast decisions; similarly, in a different country, the rules of the road may be different, and it may be difficult to adapt quickly. The same is true for autonomous robots in disaster scenarios, in which "it is not possible to simultaneously meet the constraints placed on the problem," such as finding injured people in a snowstorm, or avoiding collisions in an unfamiliar building (Gerdes et al., 2015, p. 94). Advancements in area mapping (using LIDAR sensors and SLAM algorithms, for example) aim to minimize errors in this particular problem, but still are not at the level to work in all cases. Over the course of my technical project, my team intends to identify areas in which area mapping can be improved and similar errors can be minimized.

To raise the stakes even more, studies show that the effects of robot failure in high-risk scenarios are even more profound than a comparable human error. This is due to the fact that the public generally attributes more blame of failure to autonomous robots than nonautonomous ones, even if they are performing the same task with similar human control. Such a phenomenon may exist because “autonomous robots may appear to have more freedom of choice […] due to their independence of action and mimicking of a decision-making process,” and the public associates this freedom with unpredictability of action, or in other words, a rogue robot (Furlough et al., 2019, p. 6). It is clear from this sentiment that engineers and common people have conflicting views on responsibility for robot blunders. As such, the question of which party should take the blame for failure has been debated heavily in the realm of ethics in autonomy: some engineers believe that if robots are to bear the responsibility for their actions, then “we may need to be prepared to cede more control to them.” (Gerdes et al., 2015, p. 101). Many of those afraid of unmanned robots vehemently disagree.

For my STS research, I hope to reveal how each group- namely, engineers and the public- shaped the ways autonomous vehicles have been used and developed in the past, by identifying what each stakeholder group considers to be the strengths, challenges, opportunities, and threats of robots to their interests. The role each group plays in the maintenance and development of systems involving autonomous robots are vastly different. For instance, the general public often has very little input into the technical and ethical implementation of robots, and is only able to react to the outcomes of the usage of robots. An engineer is primarily concerned with optimization of system performance, and minimizing unexpected error in operation. I thus anticipate that an engineer and a person unconcerned with the development of a robot believe there are very different benefits and downfalls in using the technology freely. I also expect that comparing and contrasting certain groups' expectations of the technology's impact on society will elucidate the reasons some may have for fearing autonomous robots, ultimately affecting how they have been used in various scenarios. As of now, I have not determined which engineers- whether academic, government, or corporate- to focus on. Further research into the group will help me decide whether focusing on one type of engineer will be necessary, or if the overarching goals of each are similar enough to group the three together. I anticipate comparing the goals of each type of engineer in similar projects may give me enough insight before making the decision.

III. Data Collection and Analysis

In order to map different groups to their corresponding beliefs of the potential benefits and detriments of autonomous robots, this project will investigate sources in which members of each group present their sentiments on autonomous robot use. Sources of this nature include policies enacted which expand or limit the development of the technology, likely after some important breakthrough or major failure, as well as individual statements and opinions recorded after experiencing the robots in action. Sources at both the wide scale and individual scale should provide me enough information to roughly categorize the views of members in each stakeholder group. To do this, I will extract the major themes which span across group members' statements, and compare and contrast those themes across groups to understand what is most important to each group. Prevalent similarities among groups can serve as middle grounds for the relevant stakeholders of the sociotechnical system, and striking thematic differences may illuminate the motivations and pressures to change the system.

By the end of my STS project, I aim to better understand how the ways autonomous robots have been used for critical tasks have changed, due to pressures from those in charge of their development, and from those who actually feel the effects of their actions. Delving into the dominant views of each group's constituents will help to convey the reasons one person may feel differently about the same technology as another, and how those reasons pressured robots to be used in more conservative or liberal ways in society.

Conclusion

Each individual has his or her own interests, ideas, and desires when it comes to the application of a technology which may affects him or her in some way. This is why I believe taking a deeper look into the profiles of relevant groups may help me illustrate how the public and robotics engineers interact with each other and the technology in an interconnected way. I do not wish to form conclusions, but rather to learn from this complex, sociotechnical system and understand how each person plays a role in its operation. My work should provide insight for future studies involving how people interact with advanced machinery given different and everchanging predispositions.

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