Prospectus

User-Focused Tour Guide Robot
(Technical Topic)

Actor-Network Theory and the Design of a Robotics Course to Engage Diverse Students
(STS Topic)

By

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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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Introduction

Robotics, a multidisciplinary field involving mechanical engineering, electrical engineering, and computer science, has emerged as a dominant method to introduce students of all ages to science, technology, engineering, and mathematics (STEM) fields, with particular success in encouraging and maintaining underrepresented groups interest (Garcia, Jimenez, Santos, & Armada, 2007; Mataric, n.d.). Social research into the causes of the gender-gap in STEM has shown that many women have low self-efficacy values when initially exploring engineering and robotics, but, hands-on learning, vicarious experiences, and inspirational role models such as teachers or peers increase their self-efficacy and ultimately encourage them to pursue STEM careers (Gomoll, Hmelo-Silver, Šabanović, & Francisco, 2016; Hamner, n.d.; Milto, Rogers, & Portsmore, 2002; Nugent, Barker, Grandgenett, & Adamchuk, 2010; Weinberg, Pettibone, Thomas, Stephen, & Stein, n.d.; Zeldin, Britner, & Pajares, 2008). The American Society of Engineering Education (ASEE) research has shown that women make up a larger share of graduate STEM degrees than undergraduates, signaling that once women are confident in their abilities in engineering, they feel motivated to pursue additional STEM education (Yoder, 2015). If more women are encouraged in their STEM abilities before deciding their major in college, the gender disparity in STEM may begin to disappear, and more young women may pursue a bachelors in STEM. Therefore, how can we better use robotics in late high school and early university education to interest women in pursuing STEM degrees?

To encourage a greater diversity of the University of Virginia's undergraduates to pursue Mechanical Engineering my team is proposing to design and build a robot that can act as an engaging and welcoming Department tour guide. To achieve this overarching technical goal, I will propose a mobile, aesthetically appealing, user-interface focused robot tour guide. As the motivation for the project is to construct a tour-guide robot, social factors will play a large role in the design decisions of the robot. By studying Robotic Autonomy, a seven-week introductory summer camp course on robotic technology that was successful in developing male and female students' interest in STEM, the social factors important to the design decisions of the robot can be better understood (Nourbakhsh et al., 2005).

Designing a tour-guide robot for the Mechanical and Aerospace Engineering Department at UVA is not just a mechatronic, technical problem of interfacing circuits, hardware, and code. It is a socio-technical problem that necessitates a well-designed technical robot paired with a well-planned user-interface and aesthetic appearance that can engage all students and not just those already interested and confident in Mechanical Engineering. Below, I outline how the technical project will deliver a functioning robot to the Department. Afterward, I use Actor-Network Theory (ANT) to analyze how a robotics summer camp curriculum was effectively designed to form a stable network of human and non-human actors that successfully encouraged both young men and women in their abilities to succeed in STEM. By applying the lessons learned from this case study, it will be possible to design a tour-guide robot capable of motivating male and female students at UVA in STEM.

Technical Problem

The University of Virginia's Department of Mechanical and Aerospace Engineering currently has one student-designed humanoid robot that is capable of performing three automated routines of motions to showcase the range of motion of its arms and the tilt of its head. The robot is built of hollowed out aluminum plates and consists only of an upper-body above the waist. As shown in Figure 1 below, the robot was designed to be brawny and intimidating (G. Garner, personal communication, September, 2019).

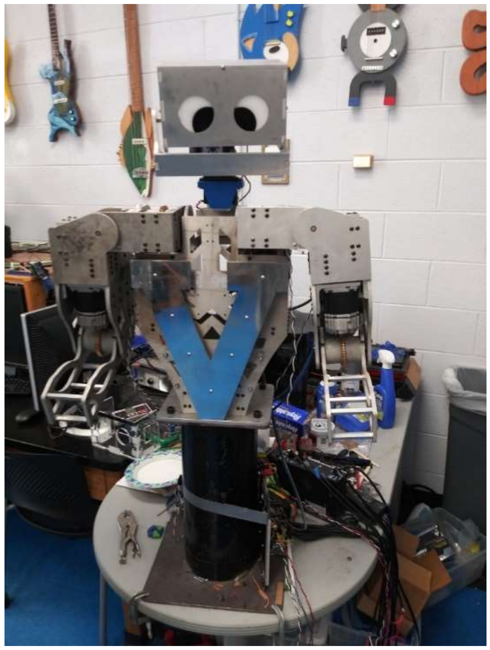

Figure 1: The only current humanoid student-built robot in Mechanical Engineering
This brawny robot is bolted to a steel base, which is clamped to a table in the Department, and many of the wires are long and loose, making the robot largely immobile and inaccessible to users.

While the current robot is remarkable in its ability to freeze in positions without power supplied due to its worm gear system, it is immobile and must be mounted to a steel cylinder and then clamped to a table (as shown in Figure 1) in order to function safely due to its sheer size and weight (G. Garner, personal communication, September, 2019). In addition, the user interface is rather unsatisfactory, with the three push buttons that control the routines hanging off the robot along with a mass of wires. The user also has little direct control over the robot and is only capable of commanding the robot to perform the three preprogrammed movements. Due to the lack of a user-friendly interface and mobility, the current robot often goes unused and just sits in the corner of one of the Mechanical Engineering laboratories. By creating a mobile more user-oriented robot, the Mechanical Engineering Department could broaden the breadth of its robotics expertise while engaging a larger variety of people with the end product.

As a result, three other Mechanical Engineering students and I are proposing to design and build a more user-oriented humanoid robot that will be fully mobile. The primary goal of the project is to build a robot that is to be able to maneuver throughout the second floor of the Mechanical and Aerospace Engineering (MEC) building at the University of Virginia (UVA) while being directly controlled by a human user through a controller in order to act as a pseudo "tour guide." The overall design of the robot is intended to be more feminine, and constructed of lighter weight, more accessible materials such as 3D printed plastic that can be easily switched out if necessary. A key feature of the human-interface of the robot is the "puppet mode" during which the arms of the robot can be moved manually by a user and then the robot repeat these motions back (G. Garner, personal communication, October, 2019). A secondary technical goal of the project is to develop prerecorded routes through the building with audio capabilities that highlight things along the way in the building.

To test the capabilities of our robot, team members will first drive the robot throughout the second floor of the building. We will then move the arms through various positions within their range of motion and test whether the robot can repeat these movements back autonomously afterward. Then, the team will have individuals not a part of the project, such as other mechanical engineering students or students interested in mechanical engineering, repeat these two tasks to display the user-friendliness of the machine.

STS Problem

One group has taken a different approach to encouraging high-school-aged students in STEM; led by the Robotics Institute at Carnegie Mellon with collaboration from Gogoco, LLC., Acroname Inc., and the Learning Research and Development Center at the University of Pittsburg, the coalition has designed a robot and course curriculum from the ground-up to create an effective and affordable robotics program for secondary-level education and individual exploration (Nourbakhsh et al., 2005). Their program, titled the Robotic Autonomy, is a seven-week hands-on summer camp meant to introduce students to robotics and many of the STEM topics involved. Based on program feedback, the data indicated that the program was successful in its pedological goal of educating the students on autonomous robotic technology. But more importantly, the program was also successful in fostering meaningful student engagement with robotics (Nourbakhsh et al., 2005). In particular, the program was found to have increased girls' confidence in their abilities in STEM more than their male peers.

While the course designers emphasize the use of their custom-built robot, the Trikebot, rather than a commercially available product such as the popular LEGO Mindstorm, as the key factor for the program's success, this viewpoint overlooks other critical factors (Mataric, n.d.; Nourbakhsh et al., 2005; Skelton, Pang, Yin, Williams, & Zheng, 2010). Critical to the program's success was the curriculum's focus on robot programming rather than physical robot design and its emphasis on self-motivated exploration instead of short-terms contests that have been found to interest male more than female students ("Home," n.d.; "Robotics Can Get Girls Into STEM, but Some Still Need Convincing | Science | Smithsonian," n.d.; Milto et al., 2002, 2002). By considering all of the contributing factors, we can better understand why the Robotic Autonomy course was successful in teaching STEM concepts as well as interesting male and female high-school students in STEM.

Drawing on actor-network theory (ANT), I will examine how the course builders successfully created an educational, engaging, and affordable robotics program that was able to build genuine interest, skills, and confidence with science and technology among male and female participants. ANT, as developed by Callon, views technology, such as this robotics course, as a heterogeneous network of human and non-human actors, woven together for a common purpose by a network builder, in this case, the course designers (Callon, n.d.). Using ANT, I will analyze why this particular program was more effective than alternative robotics education programs due to its custom-built robot, curriculum focused on exploratory learning and robot functionalities, and the use of inspirational role models.

Conclusion

In this paper, my team and I propose a technical project to design and build a human-interface focused robot to serve as a tour guide for the Mechanical and Aerospace Engineering Department at the University of Virginia is proposed. Such a robot will be capable of motivating a greater diversity of students, such as women, to pursue Mechanical Engineering. I also set out a complementary STS project to analyze how the curriculum designers of the Robotic Autonomy summer camp built a course that was successful in engaging and empowering both male and female students to pursue STEM education further.

As a society, if we wish to shrink the gender-disparity in STEM fields and continue to produce innovative new technologies, we must find new ways to encourage underrepresented groups with untapped potential, such as females, to explore STEM. Robotics, with its multidisciplinary foundation and hands-on applications, stands as an excellent tool to continue to be used for STEM education and exploration. With a user-interface focused Department tour-guide robot, historically underrepresented groups in STEM can feel welcomed and encouraged to pursue its programs. Furthermore, by understanding all of the factors that contributed to why the Robotic Autonomy was successful in stimulating young men and women's interest in STEM, robotics education programs can better motivate diverse students to pursue futures in STEM.

Word Count: 1718

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