CS476 – Senior Capstone Design in Computer Science
Project Description

Project Title:	Thirty Gallon Robot, Navigation Component
Sponsor Information: NAU Northern Arizona University School of Informatics, Computing, and Cyber Systems	Michael Leverington, SICCS michael.leverington@nau.edu 928-523-5448

Project Overview:

Autonomous and semi-autonomous mobile platforms have been slowly making their way from the lab into the consumer market in recent years. Whether it's small programmable toys like the Lego MindStorms kits or consumer items like the Roomba, developing mobile platforms with the "brains" – which are often referred to generically as "autonomous mobile robots" – that are able to do various clever things is becoming an important new area of computer science.

Of course, learning to program and develop solutions for mobile robots requires that you have access to an actual robot to test your solutions on; there is limited fun/utility in developing a navigational technique for a robot that only runs in a virtual simulator! Until quite recently, classroom use of real robots was prohibitively expensive, with only the most well-funded research labs able to afford the robots themselves. In recent years, however, technology manufacturers have continued the ever-increasing trend of packing more and more computing power into ever smaller and cheaper packages; other components like accurate motors, batteries and sophisticated sensors have become cheaper and available on the consumer market as well. As a result, it has now become feasible to construct simple, relatively cheap robots with a surprising amount of sophistication.

The project sponsor has been following this trend with interest, with particular focus on developing a flexible, cost-effective robotics platform to use within college level programs for educational purposes. This means first developing a low-cost, easy-to-assemble robot that has an open-ended set of capabilities, attachments, and other devices with the goal of having something that can be programmed to do a maximum number of things, i.e., would offer a large number of interesting robot programming challenges. Once you have the robot, the challenge becomes developing some proof of concept "programs" for it, that demonstrate some of the cool things the robot could do around an educational setting.

The high-level goals of this project are therefore as follows:

1) Develop a simple, cheap, easy-to-build and yet very capable robotic platform that can be programmed in a large variety of ways, and could therefore serve as the implementation target for a robotics course. As a proof-of-concept test piece to demonstrate that a truly functional solution has been developed, the robots should be capable of leading tours of the engineering building for visitors. Based on an overall itinerary of places to visit (at each of which the robot would, presumably, show some information or play an explanatory video) and some sort of internal representation of the building layout, the robot would plan a route and then take off and lead the tour…of course avoiding people and other obstacles along the way. Note that, as this is a multi-story building, the robot must be able to navigate not just hallways but the elevator, as well as doors (perhaps invoking human

assistance if closed); it will not be required to manage stairs. This task and all of its implications represents the core specific functional goal of the project.

2) As a broader goal, the aim is to refine the mobile robotics platform to the point where it can be disseminated to any school wanting to train students in robotics on a tight budget. This will require refining both hardware and software to be as clean and easy to source/build/deploy as possible; any high school tech club should be able to join in. We envision a website that contains complete parts lists, sources, and assembly instructions, as well as a growing archive of programs developed by various community members.

To help break this ambitious project down, it can be split into the following three significant milestones:

I. The Basics. Build the basic mobile robot platform; provide the basics in sensors, actuators and mobility and support basic programmability.

II. Add basic mobile navigation: building map, self-localization, planning/navigating, object avoidance.

III. Proof of concept. Program the robot to give tours of the NAU Engineering Building

Part I has been completed as follows:

- Robot (Figure 1) is mobile and programmable. However, as he has been through Covid and other growing pains, he needs a bit of an overhaul. That will occur soon . . .

- When he comes back, he will have an updated frame, more mounts for experiments, and a really powerful onboard computer

Figure 1: Currently implemented robot (to be updated soon)

Part II has been challenging for the big robot, so a new little one has offered to temporarily pinch hit for the big guy. See Figure 2.

If this looks a little like a Roomba vacuum cleaner, it is because it is made by the same folks. However, while this unit does not conduct any cleaning operations, he is fully outfitted with a significant number of sensors. Check out this little guy's capabilities here.

Figure 2: Pinch Hitter Robot

- The problem that has not yet been solved is how to get the robot to navigate around the hallways of the Engineering building in such a way that he could provide tours to new or incoming Engineering students.

- Part III will integrate Parts I and II into a robot that can provide tours of all or part of the Engineering building. This is proposed for the 2023-2024 academic year

- The challenges for this year's project are as follows:

a) The minimum viable product (MVP) is that the robot must start at the beginning of the second floor hallway near the foyer and stairs, move to the end of the hallway at the back door, turn around, and navigate back to the starting point. This includes managing various doorways and hallway multiple-door entry areas

b) If the MVP can be accomplished, the robot must again start at the beginning of the second floor hallway near the foyer and stairs, and move around the 'U' shaped hallway, returning to the starting point

c) If the robot can navigate the second hallway area, then the robot must move to a given location in one or the other hallway, and then return to the starting point

- The robot's navigation process will be considered successful when it can arrive at its location within one meter for at least 95% of a given set of attempts

Knowledge, skills, and expertise required for this project:

- Research and analytical skills necessary to evaluate the current state of the robot and use this information to progress to the next current goals
- Extended design skills to develop and/or refine, and then implement an overlying navigational strategy
- Ability to research the integrated navigational components, and then integrate these into the robot system
- Learning and understanding device and/or robot programming, including implementing programs within the ROS programming environment

Equipment Requirements:

- Some computing/programming device, most likely a laptop
- Robot (iRobot, Create 3), with currently integrated sensors and utilities

Note that equipment not free or immediately available will be purchased and/or facilitated by the sponsor

Software and other Deliverables:

- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide an effective manual describing the development and use of the navigation system and strategies, and strong basis for future development and/or extension of the product.
- Code base posted on Github or other version control system, as well as stored on a local USB drive provided to the sponsor
- Software product capable of navigating the NAU Engineering Building as specified above