CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Thirty Gallon Robot, Part Deux	
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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 "mobile robots" – that are able to do various clever things is becoming an important new area of computer science.

Figure 1: Currently implemented robot

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 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 door (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:

- **Phase 1: The Basics.** Build the basic mobile robot platform; provide the basics in sensors, actuators and mobility and support basic programmability.
- **Phase 2: Add basic mobile navigation.** building map, self-localization, planning/navigating, object avoidance. This will likely involve improving the basic sensor and other hardware capabilities as needed.
- **Phase 3: Prove ability on various real tasks.** As a first proof of concept, robot should be programmed to give tours of the NAU Engineering Building. Of course, there will be many other robotics projects that could be supported by this platform (that's the whole idea!)

Phase I has already been completed by a previous Capstone team (Figure 1): the robot is mobile and programmable. There are a few more updates to power management for the robot, but the robot **is ready for implementation of Phase 2; that is the aim of this capstone project.** For Phase II, the following specific functionalities must be accomplished:

Level 0, Minimum viable product:

- Must be able to be configured with a basic building map; the team will need to develop an appropriate format, plus an end-user tool for easily creating such building maps. The map data structure indicates the basic building layout, i.e., what rooms exist and distances/routes between them.
- Graphical interface (preferably web-based) to allow an operator to see where the robot is and monitor its progress. Allows for the robot to report alerts and other anomalous conditions.
- Navigation: The robot must accept a room number or other reference (e.g. "second floor lobby", "men's restroom") and be able to plan a route and proceed to that location. Reports progress along the way as well as arrival via the monitoring interface.

Level 1: Something that we could actually use moving forward

- The robot can be turned on at any location in the building, and must be able to "look around" and identify/report its location.
- Basic tours: the robot can be given a "tour" consisting of a set of rooms/places to visit, and information (e.g. a video clip, screen full of text) to "present" at each stop.

Level 2: Stretch goals and other creativity:

- The team is invited to be creative in defining other cool functionality, and will be given credit for achieving any such creative add-ons…but only after Phase 0 and Phase 1 features are functional.

Knowledge, skills, and expertise required for this project:

- Extended design skills to develop and implement an overlying navigational strategy
- Learning and understanding robot programming, including implementing programs within the ROS environment

- Some ability to work with small-scale processors. This robot has an Arduino processor to manage the motors and a Raspberry Pi for navigation
- Ability to work with an integrated team. A separate EE project will be working on improving certain electro-mechanical aspects of the robot. It will be important for the two teams to communicate and coordinate effectively throughout the year.

Equipment Requirements:

- There should be no special development equipment, machines, or software required other than a development platform and software/tools freely available online.
- The mobile robot and all related hardware and equipment will be provided by the client for testing purposes.
- Note that equipment not free or immediately available will be purchased and/or facilitated by the sponsor

Deliverables:

- The Phase II navigational and other software modules described above, installed and demonstrated on the prototype mobile robot.
- A complete and clear user manual detailing how to configure and use each of the software modules or features implemented.
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub, BitBucket, or some other version control repository; and as a physical archive on a USB drive.

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 a 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
- Assembled and functioning thirty-gallon robot capable of navigating the NAU Engineering Building