CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Thirty Gallon Robot, Part III: The Smiling Tour guide	
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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 "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 into pieces manageable by Capstone teams, it has been split into the following three significant milestones, which have been tackled by successive Capstone teams:

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. This will likely involve improving the basic sensor and other hardware capabilities as needed.
III. Proof of concept. Program the robot 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!), but these three milestones represent the key steps towards proving that a capable platform has been produced.


Figure 1: Currently implemented robot

The Project so far

Parts I and II have largely been completed by previous Capstone teams (Figure 1): Team 1 made a base robot that is mobile and programmable. Team 2 attempted to add the following elements, with some excellent success: :

- 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 for arbitrary new buildings, or build the capability for the robot to create its own map. The map data structure must indicate 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.
- This part was completed but not integration tested due to circumstances at the University (and the state, the country, and the world). There are research components, materials, and reports that can be used as research for this current project

Part III – Project Details

We are now ready to build on the previous parts to accomplish the ultimate goal: a robot that can give autonomous tours of the Engineering building…or any other building it is moved to. Although it will of course ultimately run on the robot, development of this part will be separated out into an independent software module. This will avoid practical hassles (don't need to access the robot all the time…good for COVID times!), plus packaging as an independent module would allow it to be used on any robot or even on a mobile device operating within a building that does not otherwise have access to mapping/localizing information but does have access to wireless routers. For purposes of this project, we will use the term "device" to label the working unit…which could be the robot, a laptop, or even a smartphone. The initial device would presumably be a laptop but it might also be placed on a hand-held device such as a mobile phone or tablet. The desired product is the software module for building a navigational map and using this to navigate (no hitting walls!) to various points in the building.

<u>Training Component</u>

- The robot is provided a to-scale floor map of a given building. The user takes the device to specified locations and indicates the location. Examples might be a numbered room door, a corner of the building, stairs, elevator, etc. The device notes the router IDs and signal strengths at that location and stores it

- Note that this will be a three-dimensional problem as the device must be able to tell its location in a multi-story building
- After a certain number of training locations are provided to the device, it is placed in a new location and queried. Upon device response, the user indicates if this is correct or not, and if the device was incorrect, the user provides it the correct location
- The device must also keep track of the number of training actions conducted for future analysis
- The device's learning process will be considered successful when it can report its location within one meter for at least 95% of a given set of attempts

Implementation Component

- Once the learning process has been developed, the device can be moved (most likely carried for purposes of this project) toward a given goal location (e.g., room number, east end or door of building, any location identifiable on the floor plan). The device will indicate whether it should be moved up or down floors and it will direct the user toward the desired location in the same format as a GPS device would outside the building
- The device's implementation process will be considered successful when it can direct someone to a given location to within one meter for at least 95% of a given set of attempts

Stretch Goals

- The device shows the user's position on a moving map as the device is moved around the building, possibly with other displayed information such as floor number, distance from nearest exterior door, stairs, etc.
- The software is downloaded to and implemented on a smaller mobile device such as a mobile phone or tablet
- The software is enhanced with a "tour" capability that takes a client to a given location and once there, describes the location in a few sentences or plays a video

Knowledge, skills, and expertise required for this project:

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

Equipment Requirements:

- Laptop with wifi capability, as well as standard free IDEs, frameworks and other development tools.
- We anticipate that no specialized equipment will be needed. If it does turn out to be, client will work with team to procure the needed items.

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 software product capable of navigating the NAU Engineering Building and at least one other building on the NAU campus