Team 7: Autonomous Guidance Robot Proposal

Andre Nguyen*, Emma Brown†, Gabriel Kim‡, Jacob Wilkinson§, and Samuel Mandody¶
Department of Electrical and Computer Engineering, Tennessee Technological University
Cookeville, TN
Email: *annguyen42@tntech.edu, †egbrown42@tntech.edu, ‡gakim42@tntech.edu, §jawilkinso43@tntech.edu, ¶sgmandody42@tntech.edu

I. Introduction

Entering a building for the first time can be confusing. A new layout that one is unfamiliar with can feel like a labyrinth. An insufficient amount of information is typically provided to help one traverse a maze-like building. Furthermore, buildings usually do not have someone personally guide one to their desired location. With the new Ashraf Islam Engineering Building (AIEB) that is currently being built for Tennessee Technological University (TTU), the same issues will occur. However, there is a solution for these future problems: an autonomous robot (AuR) [2] to guide students, faculty, guests, etc. to their destination within the AIEB.

II. Formulating the Problem

It is a waste of resources, such as money and personnel, to have an employee dedicated to guiding visitors throughout the AIEB. Thus, having an AuR to perform these duties will be more effective. The objective of this capstone project is to design the navigation, power, and safety systems of this AuR. Due to the scope of the project, creating these three systems will require multiple specialized engineers.

A. Specifications and Constraints

A custom fit SLAM algorithm will be designed for the AuR which will allow it to identify and avoid collisions with objects/people in its immediate path, return to its starting point, and have an average positional error of 5 ft when guiding visitors to their destination. Having just one form of location validation will definitely skew the destination error. To ensure that the error is as low as possible, at least one more form of location validation will be made by polling signals from the rooms (e.g. Wi-Fi, radio waves, Bluetooth) to triangulate the AuR's location and or using physical landmarks with an appropriate sensor to distinguish destinations from one another. The home base will need to be able to charge the AuR without a need from external intervention and without creating an unnecessary obstacle while the AuR is away. Wireless charging is a dual purpose solution to this specification which will be implemented in the AuR design. To ensure that the AuR can operate for at least 3-4 hours, rigorous testing will be done to emulate the various loads on the power system which could occur during the navigation and return process with varying amounts of charge. Since safety is a major concern with the AuR, there will be a manual override switch that will cut power from and notify staff that the AuR encountered an issue and needs to be serviced. The AuR will be designed to work exclusively on a single floor to limit problems such as stairs and elevators and memory utilization by the SLAM algorithm.

Seeing as this is an autonomous robot, we will be following IEEE Standard 1872.2-2021 when describing the functionality of the AuR [2]. Another IEEE Standard that we will be following is 1873-2015 since regardless of the base SLAM algorithm is used for the final design, there will be a streamlined process that can be followed to ensure that the mapping for the AuR and any subsequent maps added afterwards will be tidy, uniform and easily maintainable [3].

B. Challenges

A challenge the team will encounter when developing the AuR is the available space, both internal and external. This can be solved by working with the Mechanical Team to provide more space for the AuR's components. Additionally, the budget could become a challenge for us. Budget issues can be addressed by finding cheaper alternatives for components and optimizing the AuR to utilize fewer resources. Prototyping can be a challenge during the development of the AuR, and this can be resolved by using 3d printing to cost-effective structural components. Moreover, using previous components can assist with prototyping. Lastly, unforeseen delays are a challenge that could be encountered. The delays can be due to part ordering and minor accidents. To accommodate for delays, the team can spend extra time working on the AuR.

C. The Measures of Success

The navigation system of the AuR will be evaluated by having the AuR navigate through the hallways of one of the preexisting buildings at TTU. This method of testing will simulate the hallways of the AIEB and provide accurate information. The safety system of the AuR will be evaluated by placing and moving objects around the AuR. This method will simulate people walking around the AIEB as the AuR performs its main objective. The power system of the AuR will be evaluated by charging the battery to its full capacity using the implemented power system and then connecting the battery to a load similar to the AuR to test the duration of the battery. This method will simulate the AuR's power system during its operations.

D. Broader Implications, Ethics, and Responsibility as Engineers

Although the AuR will provide great benefit to visitors of the AIEB, there are several resulting impacts that must be considered. Firstly, the AuR will increase congestion in the hallways while directing individuals due to its slow pace. The AuR will partially mitigate this increased congestion by returning to its home base between guiding visitors.

Secondly, maintenance of the AuR will potentially increase the workload for employees overseeing the AIEB. These maintenance issues will be partially alleviated by the planned modularity of the AuR. Employees will be able to easily swap out and upgrade malfunctioning and outdated components.

Another potential concern is damage to users and their property. In the event of sensor malfunction, the AuR could potentially run over a user's foot or belongings. In order to reduce the risk of these damages, the AuR will be equipped with an additional copy of all safety-related sensors for redundancy.

The final point of concern is the potential environmental impacts of the AuR. There are two main facets of this issue: power inefficiency due to wireless charging and e-waste of replaced components. The first facet, power inefficiency, will be partially mitigated by providing an alternative plug-in method of battery charging. According to data gathered by Girish Bekaroo and Amar Seeam, the average power consumption for wireless charging of phones is roughly 70% greater than that of plug-in charging [1]. It is not an unreasonable assumption that the efficiency difference between charging methods for the AuR will be similar.

The second facet, e-waste of replaced components, will be partially mitigated by designing the AuR to be as future-proof as possible within the given budget. According to Directive 2002/96/EC of the European Parliament, E-waste is defined as “Waste electrical and electronic equipment, including all components, subassemblies and consumables which are part of the product at the time of discarding“ [1].

III. The Resources

A. Personnel

The following list shows the team members’ skills that can be used for this project.

1) Andre Nguyen
   - Power System Analysis
   - Soldering
   - Leadership Skills
2) Emma Brown
   - Knowledge of SMD/SMT Components
   - Sensors
   - Soldering
3) Gabriel Kim
   - Arduino
   - IoT Devices
   - MQTT Protocol
4) Jacob Wilkinson
   - Embedded Devices
   - Soldering
   - General Software
5) Samuel Mandody
   - Embedded Systems
   - RTOS
   - C Language

Additional skills that the team may need to successfully complete the project are KiCAD, 3D Printing, PCB Design, and machine learning.

B. Budget

Raspberry pi 3b+: $45
ESP32S3: $20
Bluetooth Beacons: $100
Bluetooth 5.1 Module: $20
Wireless Charging: $225
Battery: $125
Collision Sensors: $25
LIDAR: $100
Overhead Due to Shortage: $130
TOTAL: $790

C. Timeline

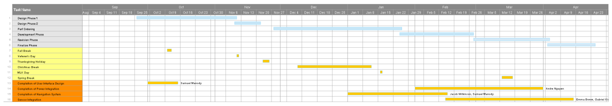

Fig. 1. Gantt Chart

IV. References

[1] G. Bekaroo and A. Seeam, ”Improving wireless charging energy efficiency of mobile phones: Analysis of key practices,” 2016 IEEE International Conference on Emerging Technologies and Innovative Business Practices for the Transformation of Societies (EmergiTech), 2016, pp. 357-360, doi: 10.1109/EmergiTech.2016.7737366.

[2] ”IEEE Standard for Autonomous Robotics (AuR) Ontology,” in IEEE Std 1872.2-2021 , vol., no., pp.1-49, 12 May 2022, doi: 10.1109/IEEESTD.2022.9774339.

[3] ”IEEE Standard for Robot Map Data Representation for Navigation,” in 1873-2015 IEEE Standard for Robot Map Data Representation for Navigation , vol., no., pp.1-54, 26 Oct. 2015, doi: 10.1109/IEEESTD.2015.7300355.