The City College of New York, CUNY
Groove School of Engineering
Department of Electrical Engineering
160 Convent Ave, New York, NY 10031

EE 59866 - Senior Design I
Engineering Design Report

Omnidirectional Ground Penetrating Radar Robot

Submitted in partial fulfillment of
the requirements for the award of the degree of

Bachelor of Engineering
in
Electrical Engineering

Submitted by:
Sanjib Lamichhane, Daniel Bloom, Miguel James, Zu Q. Gao, Xiaoke Liu

Under the guidance of
Professor Jizhong Xiao, and Professor Edward Baurin

Date Submitted: 10/25/2020

Contents

Abstract iii

Acknowledgement v

1 Feasibility Study 1
- 1.1 Introduction . . . 1
- 1.2 Need For Our Product . . . 2
  - 1.2.1 Scholarly Journals and Similar Products . . . 2
- 1.3 Problems To Be Solved . . . 2
- 1.4 Requirements . . . 2
  - 1.4.1 External Requirements . . . 3
  - 1.4.2 Internal Requirements . . . 3
  - 1.4.3 Assembly . . . 5
- 1.5 Restrictions . . . 5
- 1.6 Stakeholders . . . 5
- 1.7 Project Charter . . . 5

2 Scope 7

3 Organization 9

References 11

Appendix A 13
- .1 Wheels . . . 13

Omnidirectional Ground Penetrating Radar Robot

Sanjib Lamichhane[1], Miguel James[1], Zu Qiang Gao[1], Daniel Bloom[1], Xiaoke Liu[1], Prof. Jhizong Xiao[1], and Prof. Edward Baurin[1]

[1] *The City College of New York, The City University of New York(CUNY), Groove School of Engineering, Department of Electrical Engineering, New York, NY, 10031*

November 15, 2021

Abstract

Nulla ac nisl. Nullam urna nulla, ullamcorper in, interdum sit amet, gravida ut, risus. Aenean ac enim. In luctus. Phasellus eu quam vitae turpis viverra pellentesque. Duis feugiat felis ut enim. Phasellus pharetra, sem id porttitor sodales, magna nunc aliquet nibh, nec blandit nisl mauris at pede. Suspendisse risus risus, lobortis eget, semper at, imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam enim. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

Acknowledgement

Nulla ac nisl. Nullam urna nulla, ullamcorper in, interdum sit amet, gravida ut, risus. Aenean ac enim. In luctus. Phasellus eu quam vitae turpis viverra pellentesque. Duis feugiat felis ut enim. Phasellus pharetra, sem id porttitor sodales, magna nunc aliquet nibh, nec blandit nisl mauris at pede. Suspendisse risus risus, lobortis eget, semper at, imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam enim. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

Chapter 1

Feasibility Study

1.1 Introduction

A traditional ground-penetrating radar(GPR) is labor-intensive for surveying the sub-surface to investigate underground utilities such as concrete, metals, cables, asphalt, or masonry . Therefore, as a group, we intend to design an Omni-directional robot with GPR, which will autonomously detect objects around it, avoid obstacles and use radar pulses to image a subsurface. Our objective is to run the robot automatically in a given area, with the GPR extracting and loading the result of the scan of the surface layers for the image processing.

The design of our project contains a four-wheel configuration with the ground-penetrating radar mounted in the middle, and it will be controlled by a Robot-operating system(ROS) package, which will be written in python. ROS will contain a path-finding algorithm, which will have the robot correctly running through the area as a grid without repeating any path. The robot will send its GPR scanning to a web interface so the result can be presented. Our group will be using specially designed Omni-wheels[1]that can go in any direction. Since the robot has a specific wheel, the motor will have to match the wheels and handle the total weight running at an approximate speed of 1.5m/s, following with motor drivers whose operating voltage range is 12 V to 24 Volts. A printed circuit board will be designed to manage input/output terminals of the system. Therefore, the group's most significant focus at the beginning is to find the perfect fit motors, drivers, and the type

[1]See Appendix A

of board that is compatible with all hardware components.

1.2 Need For Our Product

According to Google Trend, the term 'Ground Penetrating Radar" has been searched 2223 times in the last 12-months online. Among the related queries, 'ground penetrating radar services near me' and 'ground-penetrating radar rental' are the most common terms people searched on the internet. From this information alone, we can be assertive that there's a need for our proposed product - an omnidirectional ground-penetrating radar robot(GPR).Therefore, we make a hypothesis that ground-penetrating radar robot is mostly demanded for infrastructure development; and, since there's a significant number of online queries about rental GPR, we assume that the current market supplies an non-affordable product to purchase.

1.2.1 Scholarly Journals and Similar Products

Hence, the manual scanning of subsurface is costly and filled with high risks. But with "automation could both lower the cost and shorten the time needed to perform the necessary steps."

1.3 Problems To Be Solved

In order to automate the process, we will need to implement the following technologies into our Omni-GPR robot: a path-finding algorithm running that interfaces between the sensor and micro controller. In the initial stages,a robotic chasis will be built, upon which we will buid Omni-directional robot.

1.4 Requirements

The need of the potential customers are external requirements and the expectations of stakeholders and team members are considered as the internal requirements.

1.4.1 External Requirements

The primary external requirement of our design is to have an automated ground scanning facility available on an ground-penetrating radar robot. Our priority is to develop a minimum viable prototype that performs the following:

- Operating Condition: Indoor, following lab safety protocols.
- Temperature: Room Temperature
- Surfaces: Smooth, non-inclined floors
- Network: Wireless LAN
- Size: 17" x 17" x 6"
- Weight: 30lbs including wheels, motors, and drivers.

1.4.2 Internal Requirements

The internal requirements of the company are divided into Marketing and Manufacturing as follows:

Marketing

Market

There are many possible options for these demands. Military applications include detection of unexplored ordnance and detecting tunnels. Archaeology applications include detecting and mapping subsurface archaeological artifacts. Construction Companies can use them to investigate underground substances (Andrews, Ralston, & Tuley,).

Competition: WaveSense

Wavesense develops ground penetrating radar for vechicles and robots. The ground penetrating radar technology is used for the localization for autonomous vechicles in any condition. Since, a ground-penetrating radar is

unaffected by snow, heavy rain, fog or poor lane markings, GPR can significantly reduce navigation failure rates and assist self-driving functionality (*WaveSense develops ground-penetrating radar for vehicles, robots*,).
As our product performs all these functions in essence, we consider Wavesense as our competitor.

Time to market

The minimum viable prototype will be developed by May 2022. The product will be ready to manufacturing phase afterwards.

Niche

Our product will be specialized for underground scanning, and the niche market is the construction and manufacturing industry.

Necessary advertising resources.

Upon completion of the first phase (prototype development), we would publish our papers about the product, which will serve as our technical advertisement.Professor Xiao will help us in the publication. Additionally, information about the product will be published in the social medias for the general public.

Manufacturing

Purchasing

The wheels will be provided by Professor Xiao. The Department of Electrical Engineering at City College will provide us funding to purchase motors, drivers, and boards.

Fabrication

Fabrication technologies such as 3D printing can be used for robot frames and general structures that keep it together. The 3D printing facility in the Robotics Club Lab at City College will be used for this purpose.

1.4.3 Assembly

The hardware tools at Robotics lab will be used for the assembly of the products.

1.5 Restrictions

Our device will be suitable for personal use, research and development, and industrial use. The estimated size of of the product is 17"x17"x6" which will weigh about 30 lbs including drive and wheels. Additionally, the product will be restricted for indoor, lab use only.

1.6 Stakeholders

Team Members: Sanjib Lamichhane, Miguel James, Daniel Bloom, Zu Qiang Gao, Xioke Liu
Mentors: Prof. Xiao, Prof. Edward Baurin
Department Chair: Prof. Roger Dorsinville

1.7 Project Charter

Date: 10/18/2021
Project Name: Omnidirectional Ground Penetrating Radar(GPR) Robot
Project Manager: Sanjib Lamichhane
Project Tracking Number: N/A

Project Justification(problem or opportunity addressed):
Our project will eliminate the need for manual scanning by providing an autonomous, omnidirectional robotic platform.

Overview of Deliverable(high-level, broad-brush only):
Omnidirectional Robot Prototype of size 17"x17"x6", and weight of 30 lbs, Product expenses within $500, Robotic Platform Running on Python Environment, Operation Voltage within 12 - 24 Volts, Speed : 1.5 m/s, Object

detection

Specific Project Objectives & Success Criteria(schedule, cost, quality):
To develop an autonomous, omnidirectional robotic platform for a GPR antenna, a four-wheeled omnidirectional chassis including a PCB for control systems and power distribution, as well as the software-driven control and path navigation functionality will be built by the end of May 20th, 2022 within the allocated funds of $500.

Primary Stakeholders & Toles (including a broad statement of roles and responsibilities of all customers, sponsors, contributors, reviewers, managers, sign-off authorities, project manager, etc.):
Professor Xiao, the head of the robotics research lab, and Professor Baurin, the faculty advisor for the department of Electrical Engineering at City College are mentoring us in product development and project management respectively. The evaluation of results will be reviewed by the mentors. The design engineers are Sanjib Lamichhane, Daniel Bloom, Qiang Gao, Miguel James, Zu Xiaoke Liu, who are working on the research and development of the robotic platform. Sanjib Lamichhane is also the project manager.

Key Assumptions(including a broad statement of sponsor/stakeholder inputs and resources to be provided, as well as a delineation of "what's outside" project scope):
The GPR antenna as well as the mechanical components such as the omnidirectional wheels will provided by Prof. Xiao's robotics lab at City College. Our product is expected to be autonomous. It is important to note that the GPR post-processing software is outside the scope of this project.

Signatures: The following people agree that the above information is accurate:
Project Team Members:
Sanjib Lamichhane, Miguel James, Daniel Bloom, Zu Qiang Gao, Xiaoke Liu
Project Sponsor and/or authorizing manager(s): Prof. Jizhong Xiao, Prof. Edward Baurin

Chapter 2

Scope

Chapter 3

Organization

References

Alford, N., Jordan, M., Konakchiev, G., Kueny, T., Mizgorski, J., Salotti, F. J., ... Tobiassen, T. (2021, Sep). *underground infrastructure sensing using unmanned aerial vehicle (uav).*

Andrews, A., Ralston, J., & Tuley, M. (1999). *Research of ground-penetrating radar for detection of mines and unexploded ordnance: Current status and research strategy* (Tech. Rep.). INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA.

Code of federal regulations (No. Title 47). (n.d.). online. Retrieved from https://www.ecfr.gov/current/title-47

Nfpa 70, national electrical code 2020. (n.d.). Book. Retrieved from https://www.nfpa.org/NEC/About-the-NEC/Explore-the-2020-NEC

Standard guide for using the surface ground penetrating radar method for subsurface investigation. (n.d.). Retrieved from https://www.astm.org/Standards/D6432.htm

Wavesense develops ground-penetrating radar for vehicles, robots. (n.d.). Retrieved from https://www.therobotreport.com/wavesense-develps-ground-penetrating-radar-vehicles-robots/

Zhang, H., Li, L., & Wu, K. (2007). 24ghz software-defined radar system for automotive applications. In *2007 european conference on wireless technologies* (pp. 138–141).

Appendix A

.1 Wheels

Authors: Sanjib Lamichhane, Miguel James, Zu Qiang Gao, Daniel Bloom, Xiaoke Liu

Cite as: