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At the Heart of South Leinster

An exploration of Simultaneous Localisation and Mapping using Lidar

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Functional Specification

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1. Introduction

In this document, I will be outlining the fundamental aspects of my envisaged system. I will break it down into its core aspects and give a brief explanation of how they work. Following this, a series of use cases and diagrams will help explain and describe the system's functionalities.

In basic terms, I am creating an unmanned vehicle (UV) that will be able to navigate around a room while avoiding any obstacles in its path. The key technology that will achieve this functionality is a Lidar scanner. A lidar scanner will provide a 2D map of its surroundings in the form of a point cloud and will be converted into a live 2D map. A central hub (in this case a raspberry pi) will take in the raw data from the lidar scanner and convert it into the map. Also, the software the drives the UV will be housed here. The data from the lidar scanner will be used to inform the UV of any obstacles in its path and course correct them. All this functionality will be available to the user to view from a laptop. Additionally, the user will be able to take control of the system and drive the robot via an integrated camera. An 'autopilot' on-off switch will be necessary for the user to switch back to unmanned mode.

2. Application

In this section, I will break down what I feel are the core components of this system and explain how it works. I will do so under a series of headings each about that core aspect of the system. The first of these headings is Mapping.

2.1 Mapping

This is a fundamental aspect of my system. Mapping will be achieved as previously stated by reading in data from the Lidar scanner and converting it to a usable 2D point cloud. This will be achieved using Hector slam, a Linux-based ROS package. The slam algorithm will provide the map which will be shown to the user. I feel this is one of the most important aspects of the system as the data being created here powers the obstacle avoidance and autonomous navigation portions of the system.

2.2 Obstacle Avoidance

This will be achieved as previously stated by reading in a 2D point cloud. A series of conditional statements will search for various scenarios. For instance, if something is detected directly ahead of the UV's relative position by a certain distance the UV will pivot. This will repeat until there is nothing ahead of the UV. This is powered by the wall follower algorithm which is discussed in the next heading. Additionally, I will take advantage of the onboard camera on the Picar and display a live camera feed to the user while it is navigating around.

2.3 Navigation and Obstacle Avoidance.

Navigation will be handled by a python script. I have taken inspiration from the wall follower algorithm for solving mazes in my solution to this. This algorithm states that in solving a maze an optimal solution provided the maze is 'simple' is to always follow the right wall. I find this to be a good solution as it allows the drone to pass through doors consistently. If the UV was to randomly wander the chances of it passing through a door would be unlikely. The robot will essentially have a set distance from the wall and attempt to keep that distance from the wall on its right. In this case, if it moves away from the wall or an obstacle in its path turn left. When it reaches a corner, it turns left. I have created a truth table below that will help Illuminate how this system will operate.

Wall forward	**Wall right**	**Situation**	**Action**
No	No	UV is driving away from the wall	Pivot left until returned to the wall
Yes	No	UV is driving away from the wall and there's an obstacle	Hard left to return parallel with the wall
Yes	Yes	UV has reached a corner	Hard left
No	Yes	UV is following a wall	Keep forward

2.4 Storage

A storage system will be necessary to keep map data for later use. This will allow the user to view complete maps. The map data is saved in a GeoTIFF file format. This will be done with a simple SQL server. A simple post and get request will be used to store and retrieve the data.

2.5 User Control

The UV will possess two modes, an autonomous and user control mode. I've discussed the autonomous mode above but as for the user control mode, it will be activated with a button in the application. They will then be able to control the robot with either the W, A, S, D, or arrow keys. The autonomous mode will be re-enabled in the same manner via a button in the software.

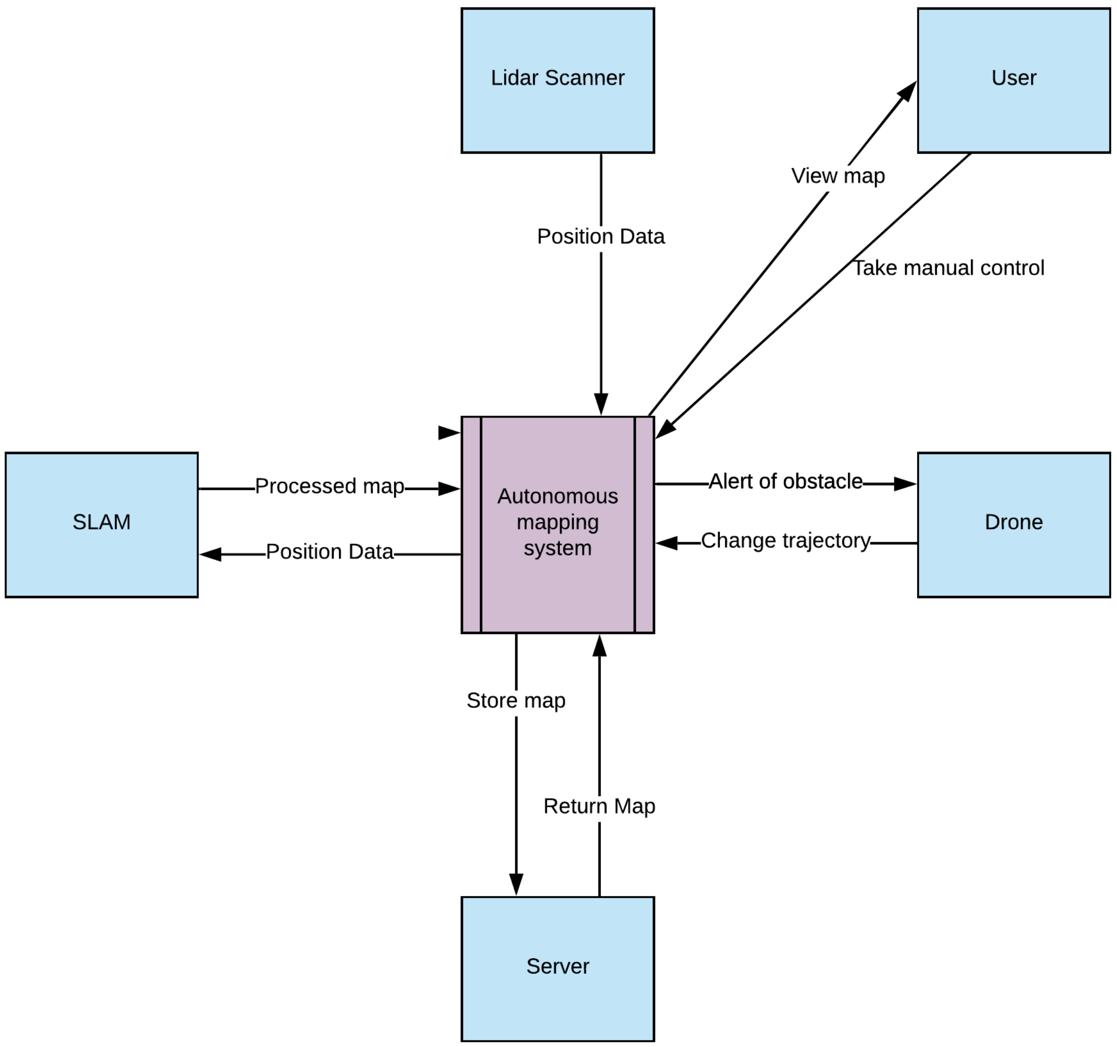
3. Target Audience

The target audience for this system will be robotic enthusiasts and developers. As this system is proof of concept it is currently not very marketable. This will change as further concepts are added to this system in the future but as of its current form, I cannot see it being profitable. Where it will shine is with people who understand the hardware or software. I have not seen a system like this that uses LiDAR as its sole form of navigation. I aim to prove LiDAR as a more useful technology as I feel it is underutilized in the industry. It has gained recent attention with its incorporation into the newest iteration of apple devices. A project such as this may further cement the technology's usefulness.

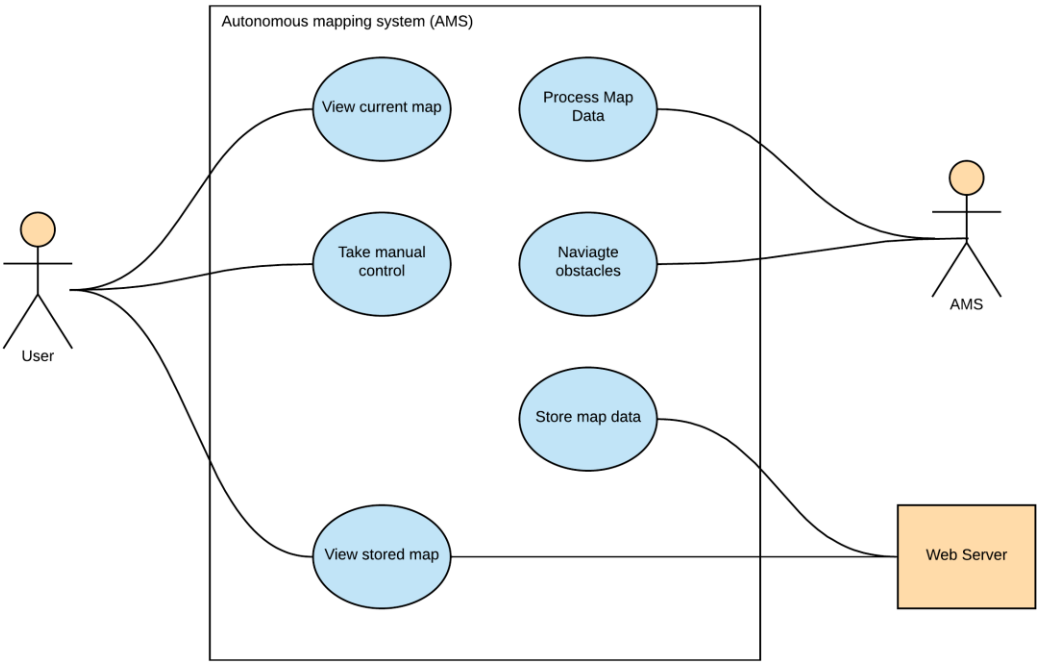
4. Diagrams

In this section, a series of diagrams will help to further illuminate aspects of this system. A context diagram explains the wider system and its subsystems followed by an array of use cases to explain each of these subsystem's functionality.

4.1 Context Diagram



4.2 Use Case Diagram



4.3 Use Cases

4.3.1 Process Map Data

Use case name: Process Map Data

Actors: AMS

Detailed Use Case:

1. The system receives lidar scan data.
2. The system sends the data to SLAM.
3. The SLAM point cloud is turned into a map.
4. A map is displayed.

Alternatives:

n/a

4.3.2 Navigate Obstacles.

Use case name: Navigate obstacles.

Actors: AMS

Detailed Use Case:

1. The system continues to move the UV forward.
2. The system detects an obstacle directly ahead.

Alternatives:

3a1. Obstacle directly ahead with wall adjacent.

3a2. The system turns hard left 90 degrees.

3b1.Obstacle directly ahead with no wall adjacent.

3b2.Turn left until returned to the wall.

4.3.3 Store Map Data

Use case name: Store map data.

Actors: Webserver

Detailed Use Case:

1. The point cloud is processed into a map.
2. The completed map is sent to the SQL server.

Alternatives:

4.3.4 View Stored Map

Use case name: View Stored Map

Actors: User, Webserver

Detailed Use Case:

1. User requests to view map.
2. The map is returned from the webserver.
3. The map is displayed to the user.

Alternatives:

1. The map doesn’t exist in the database.
2. An error message is displayed to the user.

4.3.5 View Current Map

Use case name: View Current Map

Actors: User

Detailed Use Case:

1. The user initiates a new scan.
2. The system begins mapping the space.
3. Map data is displayed live to the user.

Alternatives:

4.3.6 Take manual control.

Use case name: Take manual control.

Actors: User

Detailed Use Case:

1. User requests manual control of the UV
2. User inputs direction for the drone via keyboard

5. Metrics

This section will be discussing the viability of the project and the hurdles that must be met to consider it a completed project. I will know if this project has succeeded if the following criteria are met:

- The UV will be able to navigate a space successfully.
- A comprehensive 2D map of the space is generated.
- The end-user can view live map data via a remote connection to the drone.
- Map data is properly processed and stored in a database for further use.

6. Existing Projects

LiDAR is a relatively new technology. It has not found its footing in many industries yet. Despite this, there are some well-known products and services that do use it. The most similar product to this project is the Roomba. If the vacuum aspect is removed its core functionality of navigating space is quite similar. A LiDAR scanner in a Roomba is rare and mainly in the more expensive models. They incorporate a mix of sensors such as bumper sensors or proximity sensors etc. Given the LiDAR's precision, I feel it is a necessity to include it in this use case. My project differs by using LiDAR as the sole source of navigation. I feel the technology is precise enough the navigate a space efficiently and safely on its own.

Another industry where Lidar has seen heavy use is the autonomous car industry. Lidar has made its way into Self-driving cars as it is much better at judging distances than traditional sensors and cameras (Domke, n.d.).

7. Bibliography

Domke, C., n.d. *LiDARs for self-driving vehicles: a technological arms race | Automotive World*. [online] Automotive World. Available at: <https://www.automotiveworld.com/articles/lidars-for-self-driving-vehicles-a-technological-arms-race/#:~:text=LiDAR%2C%20typically%20used%20as%20an,navigate%20environments%20in%20real%20time.>