2D Autonomous Mapping

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Design Concept

- **Need** - Autonomous vehicles are often used to explore difficult to reach places (i.e. Search and Rescue, Scientific Exploration).
- **Solution** - This project aims to create a low cost, educational demonstration of **autonomous mapping and navigation** by building a vehicle that explores a simulated environment.
- **Scope** - Eliminate mechanical design challenges by reducing a real, textured environment to a **static environment with smooth ground and flat walls.** We will build a ground vehicle capable of producing a **2D map of the maze**, traversing through it, and updating live changes to the maze
- **ECE Areas**: Software and Signals

System Specifications

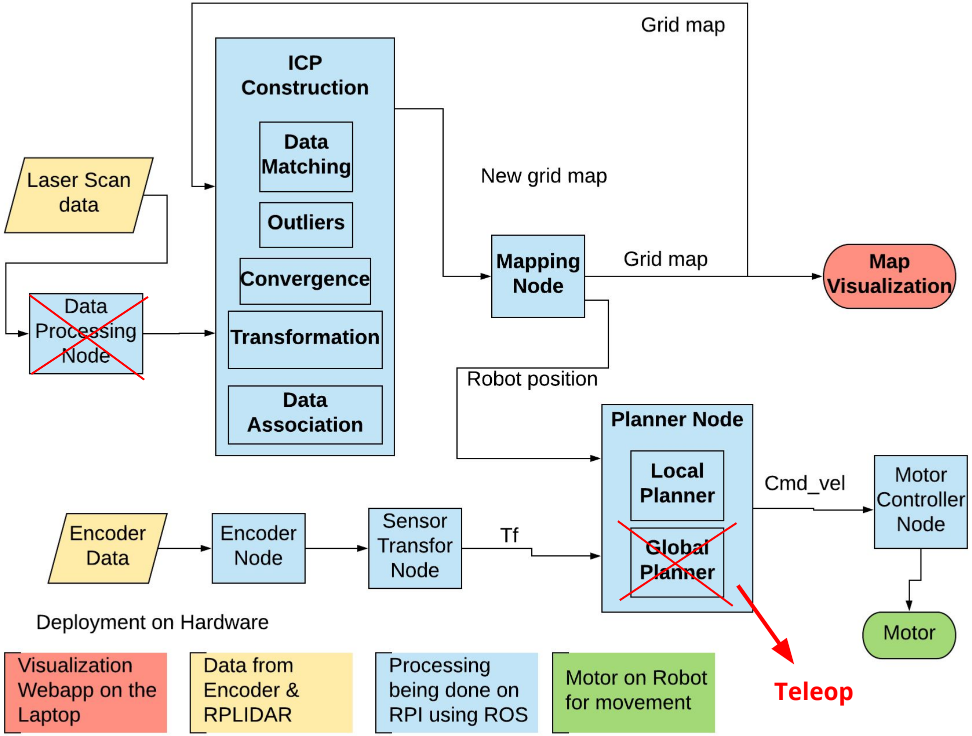
1. Small wheeled vehicle capable of exploring an area with smooth surface.
2. Vehicle needs to traverse area above a minimum decided speed.
3. Must have a battery life of at least 2 hours.
4. Vehicle should keep track of map coverage (previously decided).
5. Software should be able to simultaneously do localization and mapping of the area.
6. Vehicle should travel efficiently without hitting any walls.
7. User must be able to start the vehicle from a webapp on a laptop.
8. User must be able to see the map being updated as vehicle moves.

SLAM Solution:

SLAM (Simultaneous Localization and Mapping) built from ground up with these components:

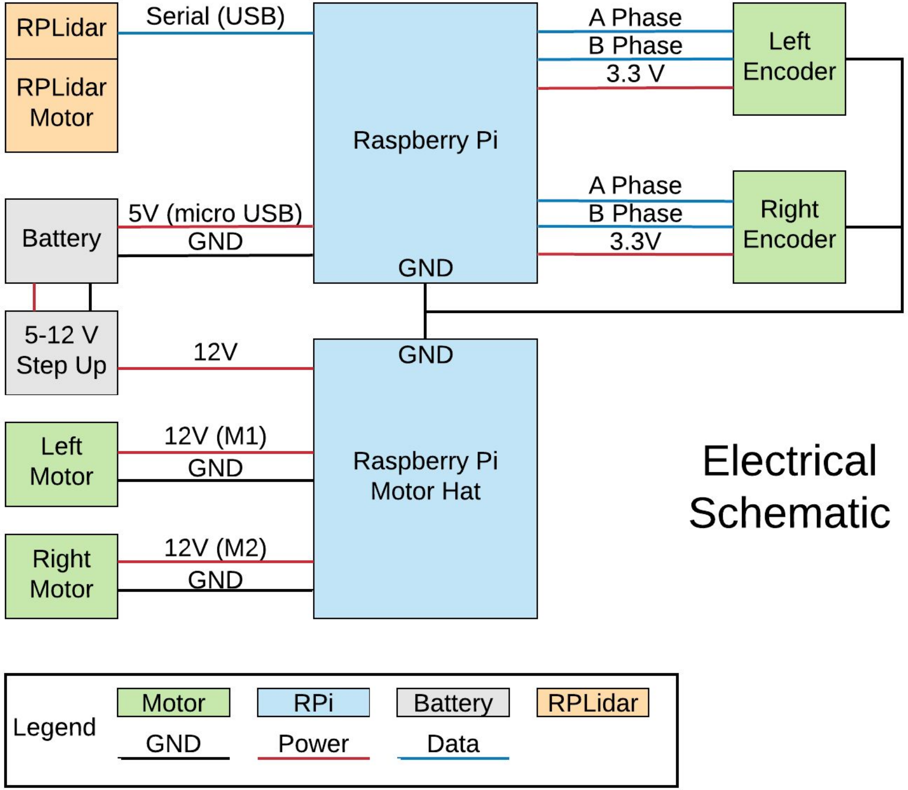
- **Mapping**: Occupancy Grid Maps; Use graph-based search to mark explored nodes
- **Sensing**: Single Point Lidar (RPLidar A1 ~$150)
- **Sensor mode**: Raw data aka 2D point cloud
- **Kinetics**: Previous commands given + odometry data
- **Loop closure**: Using kinetics data

System Architecture Diagram



Electrical Schematic

- Lidar: RPLidar A1M8 (acquired)
  - 4 bytes per point (1 degree)
  - 1980 points / sec
  - Serial port baud rate 115200
- Motor: 12V, 350 rpm DC motor + encoder
  - 229 ft / m
- Battery: Portable phone charger, 5V USB



Validation Plan

Maze Design:

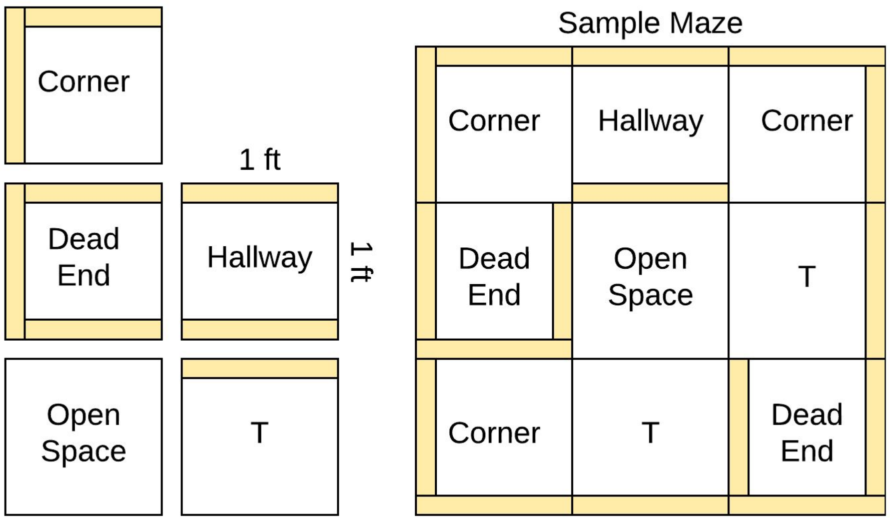
- 1 ft wide hallways
- Modular 1x1x1 ft sections, combined to form different maze configurations

Phase 1 Testing:

- Build small maze with 4-6 sections to test basic navigation (without autonomous mapping function)

Phase 2 Testing:

- Expand maze to 6x6 grid demo size
- Test map coverage on various configurations



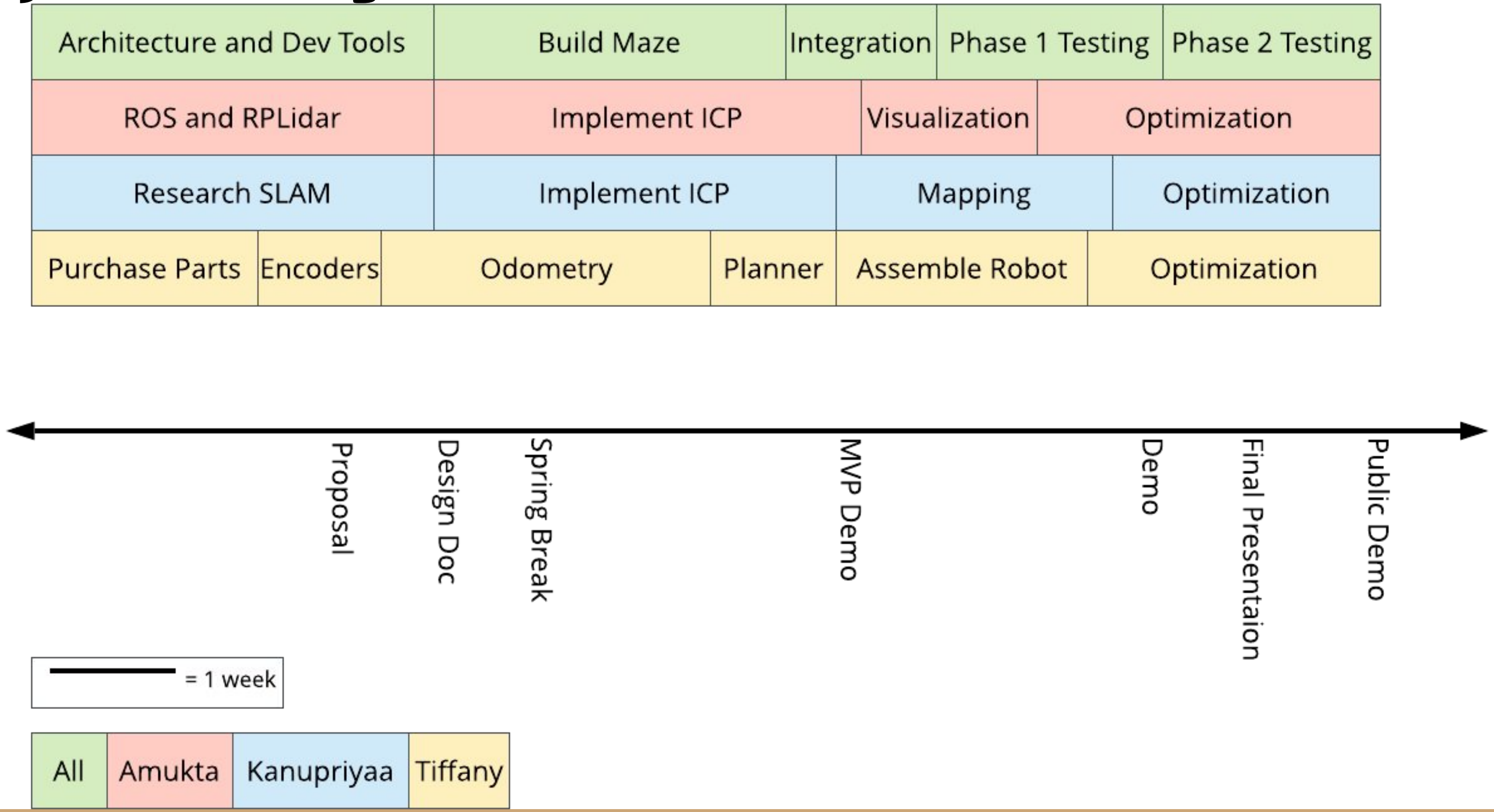
Performance Metrics

Metric	Measurement Indicator	Target
Vehicle Speed	Encoder, # map segments explored	> 20ft/min
Map coverage	Grid map completeness (pixels)	> 95% of map explored
Efficiency	# dead ends, # unnecessary paths revisited	< 0, 2 maze segments
Efficiency	Time to complete maze mapping	< 5 mins
Localization accuracy	Estimated to actual position distance	< 1 in
Battery Life	Time passed with robot operating continuously	2 hours

Performance

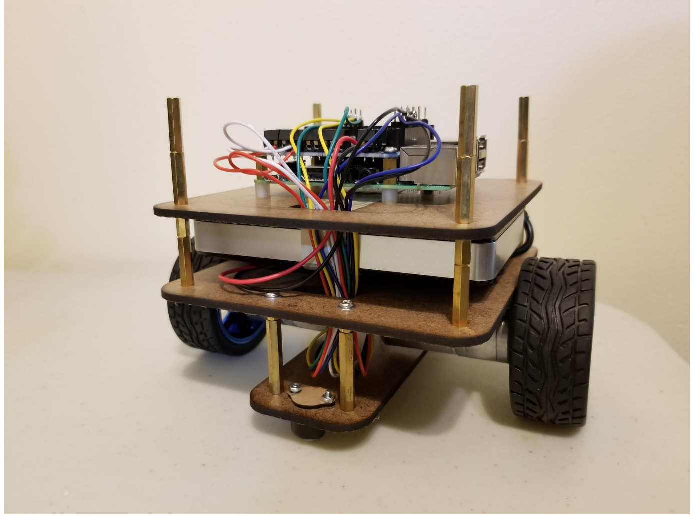
Metric	Results	Target
Vehicle Speed	Max physical speed 234.5 ft/m Mapping speed 5.5”/sec -> 27.5 ft/min	> 20ft/min
Map coverage	NA	> 95% of map explored
Efficiency	NA	< 0, 2 maze segments
Efficiency	< 5 mins	< 5 mins
Localization accuracy	Accuracy under 1 inch, based on map resolution. Resolution can be higher but causes unnecessary use of memory.	< 1 in
Battery Life	> 4 hours motors + rviz running	2 hours

Project Management



Final Solution

- 6x6 ft configurable maze
  - 11 3-sided “corner” segments
  - 25 2-sided “T” segments
- Modular, compact design
- Completely wireless
- Live map visualization
  - Rviz
  - Custom web application
- Wireless teleoperated vehicle control



Lessons Learned

- Order parts ASAP
- Start integrating sooner
- PID motor control and calibrating odometry is hard