MapSweep

Dynamic mapping and path-planning for a robot vacuum

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ARTIFICIAL INTELLIGENCE

A Roomba recorded a woman on the toilet. How did screenshots end up on Facebook?

Use Case

- Have you ever been frustrated by your Roomba?
- We've identified a gap in the robot cleaning industry:
- 4 broad classes of traversal
  - "Bump and Turn" random navigation = SLOW, STATIC MAPPING
  - Gyroscope zigzag = SLOW, STATIC MAPPING
  - Camera-based visual mapping = GETS STUCK, LOSES MAP
  - Cost prohibitive advanced models are over $2000
- ECE AREAs: Software Systems & Signals

There's a need for a dynamic cleaning robot that is fast and precise

What is MapSweep?

We aim to make an autonomous cleaning robot that employs a 3D LiDAR for room mapping and collision avoidance. This contrasts from traditional collision-based mapping robots like Roomba. From this, we aim to achieve:

- Less collision with walls & furniture which could cause wear and tear
- Faster cleaning by more planning an efficient route to cover the entire area. This would save time and energy
- Superior mapping accuracy. 3D LiDARS can produce superior, more detailed room maps which can ensure a more thorough cleaning

Use-Case Requirements - Technical Considerations

Requirement	Justification
Mapping Accuracy: 95% coverage of the given testing space	Allowing for error in vehicle odometry as well as anticipating certain errors are not able to be reached
Precision: Be able to reach within a distance of 2 inches to an obstacle at the closest point	A distance of 2 inches allows for a slight bounding box around obstacles to increase safety while not giving up our mission of cleaning coverage
Minimal Collision: 0 Collisions	Objective of project surrounds the issue of household safety (knocking over things). We don't want collision.

Use Case Requirements - Real World Considerations

Requirement	Real World Considerations
Mapping Accuracy: 95% coverage of the given testing space	95% mapping accuracy gives good enough mapping for path planning while not having to spend additional energy for marginal gains.
Precision: Be able to reach within a distance of 2 inches to an obstacle at the closest point	Designed to accommodate for dynamic obstacles like pets, or children. Not getting too close is safer.
Minimal Collision: 0 Collisions	Prevent damage to household items, which can contribute to longevity of furniture and robot.

Technical Challenges

1. Real-time data processing and dynamically adjusting the path would be computationally intensive. How effectively we can avoid collision given potentially high latency could be an issue
2. Accurate odometry could also be difficult
3. Differentiating between permanent and temporary obstacles - how do we navigate around obstacles without unnecessary detours or even just completely halting the process
4. Battery duration is a concern. We will be running a lot of hardware off the battery so getting decent uptime could be a problem
5. Hardware integration will be sure to give some challenges

Solution Approach: Software

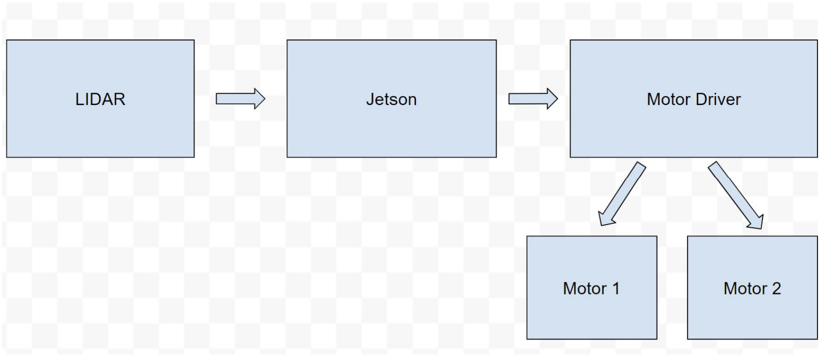
1. 3D LiDAR Room Mapping
   a. 360 degree View
   b. 30m scan distance with 43200 points/s , 11Hz circum scanning freq, 180Hz ver scanning freq
2. Path Planning Algorithm
   a. Separate 3D map into grids, then run A* Algorithm
3. Real-Time Path Adjustment Algorithm
   a. Use of SLAM techniques
4. Robot Location
   a. Use of Odometry from motor encoders
   b. Lidar localization within map of the room

Tools

- ROS
- Odometry with Motor encoders
- OpenCV for LiDAR data processing

Solution Approach: Hardware

1. Jetson for real-time path planning algorithm and map creation
2. Lidar for room mapping
3. DC motors with encoders for odometry
4. Battery pack for long lasting cleaning without downtime



Testing, Verification, and Metrics

Requirement	Testing
Mapping Accuracy: 95% coverage of the given testing space	Manual measurement of the room compared to the 3D mapping with measuring tape. Room size: 12’ x 20’ , Table size: 5’ x 5’ , 4 chairs or random arrangement
Precision: Be able to reach within a distance of 2 inches to an obstacle at the closest point	Taping a perimeter 2in off all the objects in the testing area and making sure it reaches these points
Minimal Collision: 0 Collisions	Analyze via visual inspection for any collisions.

Division of Labor

Task	Team Member
Path Planning	Kevin + Nick
Lidar Room Mapping	Nick + Kevin
Robot Design and Hardware	Matthew

Schedule

Task Number	TASK TITLE	DURATION
1	Hardware Selection & Purchase	5
2	LiDAR Mapping Research	2
2.1	LiDAR Data Acquisition Implementation	3
2.2	LiDAR Room Mapping Algorithm	5
3	Robot Design	4
3.1	Robot Base Assembly	2
3.2	Motor and Sensor Mounting	2
3.3	Microcontroller & Wiring	3
4	LiDAR Integration with Robot	7
5	Robot Odometry Fine Tuning	6
6	Path Planning Design	4
6.1	Initial Robot Navigation Integration	5
6.2	Obstacle Detection & Collision Avoidance	5
7	Testing & Optimization	7
8	Final Debugging & Documentation	3

Initial Creation															Integration															Optimization															DONE				
WEEK 1					WEEK 2					WEEK 3					WEEK 4					WEEK 5					WEEK 6					WEEK 7					WEEK 8					WEEK 9					WEEK 10				
M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F