SCAR Project Proposal

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Introduction

The SCAR (SCanning And Reconstruction) project is an attempt to use the Neato as a 3D scanner by driving around an object and using the LIDAR and camera to recreate it digitally. We are treating this as a simpler, though still well within scope, implementation of a SLAM algorithm, operating with the constraint of an isolated and deterministic environment.

Topics

In general, the topics covered will include the following:

- 2D/3D Scanning and Reconstruction
    - Using the LIDAR (2D and 3D) and camera (3D) to generate point clouds which will be processed and used to form rough (or precise) contours and shells digitally.
- Exploration of *classical* algorithms
    - Identification of which object is the subject in a frame and filtering out of background. Simplified implementation of SLAM algorithms through combination of sensors and movement.
- Integration of simulation (SITL) & real-world development
    - Utilizing RVIZ during development of our program before porting it to Neato hardware
- Lidar signal-processing
- Bundle Adjustment
    - Knowledge of errors/noise in both the LIDAR and movement and using this knowledge to correct/improve each other for an overall better output.
- Multisensor fusion and registration

More description on the distinction between the MVP and stretch-goal objectives will be provided later.

Timeline

Our advantage in tackling this problem is that the scalability of the various layers of features as we dynamically adjust how ambitious the scope of the project will be.

First pass (**11/29**): Drive in a circle around the object and use the LIDAR to create a contour of a single layer of the object from LIDAR scans. We would like to have this working bare bones by the end of November, as the problem definition is intentionally constructed such that it is tractable and mostly sets up the interactions and the framework on which to base further development.

Second pass (**12/6**): Drive in any continuous path (of approximately the same (counter)clockwise direction) around the object and create a contour of a single layer of the object from LIDAR scans. We would like to have this working by early December.

Third pass (**12/14**): Drive any continuous path (of approximately the same (counter)clockwise direction) and recreate the shell of the object from LIDAR scans and camera images. This would have a deadline of the project's finale on December 14th.

Stretch Goal (∞): Correct features / noise in sensors based on other sensors (Bundle Adjustment) for a more accurate scan.

Risks

One of the biggest risks we have identified in pursuit of this project is sensor noise. Given we are basing most of the reaction on the movement of the Neato and the LIDAR, noise in these sensors (and we know there exists noise in these systems) will affect our outcome, especially if they compound. One of our learning topics, bundle adjustment, attempts to mitigate this.

Another risk (but also point of learning) is dealing with and processing the point clouds we will be generating - the objective is to strike the balance between familiarizing with the frameworks and achieving compelling performance.

Goals

Ben

Goal 1: I would like to take advantage of and learn to use simulations (Rviz) more effectively. Often it seems unfeasible or tedious to test code with physical hardware, especially in the field of robotics so having the knowledge and confidence to build a simulation and run code on it would be a huge boon to future project I work on. To do this, a simulation will be part of the final project, such that we can create and place an object in Rviz and have the robot create it's contour from the LIDAR scan. This project feels like a good fit for this goal as it can be replicated in simulation and developed there and then ported to the hardware with minimal differences.

Goal 2: I would like to learn how to go better go about researching and implementing a classical algorithm, in this case simplified SLAM and point cloud processing. I learned a lot about utilizing the Neato and sensors from the robot localization project while the particle filter algorithm felt fairly scaffolded. With this project being open ended there's a lot more freedom. I will check my progress in this goal as SLAM and point clouds are implemented and checking each step of the way that I understand them as individual components. Given that the plan is to implement two different algorithms, our project seems to fit well for this goal.

Goal 3: Finally learning to use sensor data in conjunction with other sensor data is something I want to explore more in depth. With robotics platforms increasing housing more and more sensors, moving forward and knowing how to effectively and efficiently use that data, not just as separate data streams but fusing them to have more reliable and precise information about the world. This project suits this goal as we plan to first combine movement control (encoders/odometry) and LIDAR, and as we go further, the camera, to create better scans.

Jamie

In considering object reconstruction as a minimalistic SLAM problem, the project presents itself as a good opportunity to tackle a foundational robotics problem with a classical approach, which is aligned with the desire to explore this area more in depth.
Another natural extension of the project is how it is faced with the problem of seamless multisensor fusion in trying to incorporate different sensor measurements towards the single reconstructed target, as well as using such information to rectify the noise and the errors introduced in any one of the sensors.
Finally, which a rich and scalable feature set in the project, it requires efficient and effective collaboration on a multi-part problem, which is another one of the learning goals coming into the project.

Resources

Mastering OpenCV with Practical Computer Vision Projects
Scan Matching
Homography
Iterative Closest Points for Scan Alignment
Lidar-Camera Registration via Intensity
LIDAR Odometry (with 2 planar LIDAR)

Tasks

- Build Simulation
    - Robot(?)
    - Spawn Object to scan
    - Generate bag file
- Aggregating scans to a single point cloud
    - 11/13 - run Neato around object, record all relevant data
    - /tf, /tf_static, /camera/image_raw, /odom, /stable_scan, /cmd_vel
        - Compress Image
- Scan Matching
    - ICP?
- Modify Camera Mount
- Sensor Fusion
    - Camera-Lidar extrinsic registration
- Image Matching
    - + Homography (→ Point Cloud)
- Bundle Adjustment
- Blog