Implementation of Dynamic Environment Localization

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***Abstract*— Although discussed in class and throughout the readings, the localization of a robotic system in dynamic environments is an important aspect of probabilistic robotics yet to be covered in any amount of depth through practical hands-on learning experiences. In this paper we detail how we implement a version of dynamic system localization using real hardware sensor data.**

I. Introduction

The challenge of mapping a robot's location within a given environment can already be a difficult one. It can be even more difficult when the environment includes dynamic elements. Beyond transforming raw sensor data into useful information that can be used to approximate the robot's location, in a dynamic environment, the algorithms at work must now consider obstacles that move. Small dynamic obstacles, or obstacles that do not persist for very long can be less impactful, but large obstacles, such as a moved shelf or storage container, can drastically alter the map for longer periods of time. This differs from simultaneous localization and mapping (SLAM) because a pre-existing map is used as a baseline, even if some objects within said map have changed.

We will overcome this challenge by implementing a form of dynamic mapping which allows the localization of the robot to be separate from the mapping of the environment. Because map updates are independent from the localization of the robot, we should be able to use already (or very similar) implemented localization techniques that we have created. This approach draws heavily from the paper *Towards Effective Localization in Dynamic Environments* by Dalu Sun, Florian Geiβer, and Bernhard Nebel [1] and the method which they created described in said paper. A major deviation from this paper will be the use of much more inexpensive sonar rangefinders as opposed to the laser rangefinders that were used in the experiments of that paper.

II. Related Work

The Sun, et al paper described in the previous section summarizes several works of research that are related to dynamic localization. Two such approaches rely on an EM-algorithm to create object models for dynamic objects [2, 3]. Another research work mentioned in the paper implements a method termed SLAMMOT, where localization, mapping, and moving object tracking is implemented all together [4]. However, the author mentions that all these algorithms are computationally intensive and not suitable for real-time localization. One approach that was appropriate for online localization used a static occupancy grid map with lists of dynamic objects [5]. The Sun et al method incorporates the dynamic object detection directly into the occupancy grid map.

Extensive research has also been performed in localization using sonar sensors. One of the earliest efforts of robotic localization using sonar was conducted in 1987 by M. Drumheller [6]. He used a low-resolution sonar rangefinder and claimed adequate results in single room environments, even in the presence of noise and dynamic objects. A more recent experiment reported by J. Choi et al demonstrated a successful implementation of EKF-based SLAM using cheap sonar sensors [7]. Aspects of these implementations may be incorporated into our work.

III. Problem Formulation

In Sun, et al, a solution is addressed and validated for the problem of localization in dynamic and complex environments. They ran localization experiments in two real production halls and proved that their results were more accurate than other common methods of the time for environments with rapid, large, and irregular changes in the map.

However, all the experiments used in the paper were executed using laser range finders, which are particularly expensive. Such an expense would deem this solution unfit for many consumer applications in which the market would be unwilling to pay such a large price for certain products. We will instead use a cheaper sonar sensor and show that adequate results can still be achieved. We will additionally overcome the problem of dynamic environments with a solution that could easily be applied to other static only algorithms.

IV. Proposed Solution

We will implement a similar method as proposed in Sun, et al for localization in dynamic environments. However, instead of implementing the algorithm using data from laser range finders as they did in this work, we will use data that was collected from one or more sonar sensors, as sonar sensors are substantially less expensive than laser range finders. We will however use their idea of keeping separate the mapping and localization processes within the robot algorithm.

Because the method proposed separates the mapping of an environment and the localization methods, it carries the added benefit of being able to re-use previously developed algorithms. We plan on combing the methods used by Sun, et al into one of our own previously developed localization algorithms. We will borrow their application of dynamic map updating into a normal localization algorithm. This should demonstrate and easy to add method that could be ported into other static algorithms.

V. PROPOSED EVALUATION

To validate the proposed solution for inexpensive localization in dynamic environments, we will purchase one or more inexpensive sonar sensors which we will place on large toy cars with encoders on the wheels (?). These cars will be our "robots" and will be manually pushed through the environments.

Validation of our implementation will be based on comparison of three separate runs:

1. A base line run where our robot moves through a static environment and localizes itself based on a known map. In this case, the known map will align with the environment the robot moves through. We would expect good localization in this case.
2. A run where the robot moves through a dynamic (some things have moved but are not currently moving) environment and localizes itself based on a known map that DOES NOT match the environment it navigates through (because of the changes). In this case the dynamic mapping principles from Sun, et al have not yet been implemented (or are disables). This will give us a baseline to see how a robot can encounter problems win navigating through a dynamic environment without the needed changes to its algorithms.
3. A final case where the robot moves through a dynamic environment and localizes itself against known map, while also making dynamic corrections to the map in order to effectively localize. This will allow us to compare what we would expect to be a better performance than run 2.

The prior known map will consist of an occupancy grid map with cells tagged as either static (walls or objects which never move) or dynamic (boxes, chairs, shelving, etc...). This will allow the robot to know what objects it is allowed to edit in its occupancy grid map.

Performance will be measured by the average error, meaning the average difference between the actual and computed poses over a series of time steps, $|\mathbf{x}-\hat{\mathbf{x}}|$. The actual position will be marked up on the floor with masking tape so that we have something to compare to the theoretical position.

VI. CONCLUSION

This paper will show whether cheaper sensors such as sonar can still be used in place of more sensitive, but costly sensors like laser range finders. It also demonstrates that using the basic ideas of the method described in Sun, et al, existing algorithms can be augmented to work in dynamic environments. Much of the ideas behind this paper must be attributed to Sun, et al, but it also shows how partial changes to existing algorithms, using those methods, can be implemented into any static localization algorithms to enlarge the situations in which they can be applied.

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