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Robotic mapping assisted by local magnetic field anomalies

Haiyang Zhang*, Fred Martin

hzhang@cs.uml.edu, fredm@cs.uml.edu
Computer Science Department, University of Massachusetts Lowell, One University Ave, Lowell MA 01854

*Corresponding author. Phone: 978-884-9278, Fax: 530-325-3887.

This paper presents a method to incorporate measurement of local magnetic field anomalies into SLAM (Simultaneous Localization And Mapping) algorithm. One of the key problems of SLAM is loop closure, which means to map the same place into the same location on the generated map, when the place is revisited by the robot. It is particularly important for large area map consistency. Steel structures, furniture and equipments inside a building disturb the natural magnetic field of the earth. These local anomalies of magnetic field are usually considered as noise when using an electronic compass on a robot. But, in this paper, we utilize these data to help solving the SLAM loop closure problem, since the magnetic anomaly patterns are different across a given building and stay relatively stable over time.

Introduction and objective of the work

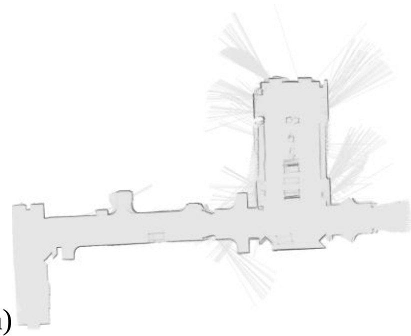
SLAM (Simultaneous Localization And Mapping) algorithm [1, 2] generates a map while a robot travels through an unknown space, and determines the current location simultaneously. The inputs to the SLAM algorithm are usually the odometry (encoder) and laser range data. Based on the historical data and current observations, the robot's most likely location is determined by a statistical model, such as Extended Kalman Filters, or Particle Filters. The map can be feature (landmark) based or occupancy grid based.

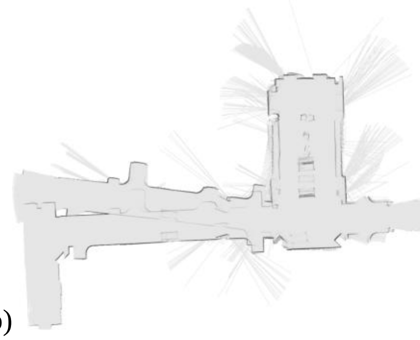
Since the introduction of SLAM algorithm, recent research has been done on alternative methods to sense the robot location and new algorithms for loop closure. Loop closure means to map the same place into the same location on the generated map, when the place is revisited by the robot. It is particularly important for large area map consistency. For example, machine learning [3] and active-SLAM [4] are used to detect loop closure based on laser data.

Local anomalies of the ambient magnetic field were used for 1D localization in building hallway [5]. In this paper, we propose to incorporate magnetic field anomaly data into the SLAM algorithm to assist loop closure in 2D localization and mapping.

Results and their significance

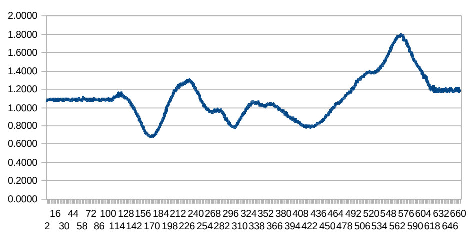
- SLAM results with regular electronic compass


(a)

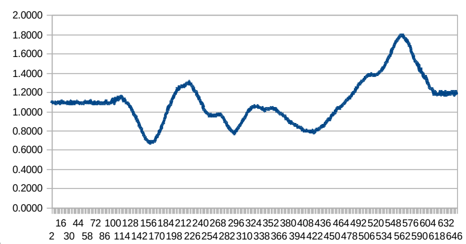

(b)

The two maps above were generated from our indoor experiments using DP-SLAM (Distributed Particle SLAM) algorithm [6]. The data were collected from a floor in our computer science building. We used electronic compass without considering local magnetic field anonymalies in this case. As shown on the map (a), the gray area is open space, the dark edges are obstacles, and the white area is unknown space. But, when the robot returning back to the original place, newly created map segments are not consistent – map (b). This demonstrates the loop closure problem.

- Measurements of local magnetic field anomalies



(a)



(b)

In the building hallway same as above, we measured magnetic field strength with PNI Macromag 3-axis magnetometer. The absolute value in the XY plane is shown in the diagrams above. Since the robot is only moving in XY plane, this value is rotational invariant. We have found the magnetic field anomalies are significant, but remain fairly stable between the first run (Diagram a), and the second run (Diagram b). This means it can assist solving the loop closure problem of SLAM.

- Incorporate measurements of magnetic field anomalies into SLAM

SLAM algorithms usually take laser range finder and encoder data. Probabilistic modes can remove most of the random errors in relatively short range. But, after the robot travels for an extended distance, the errors accumulate, and may prevent loop closure.

In our approach, magnetic values are overlaid on map grids, missing values are filled in by interpolation. We use particle filter based on importance sampling. The resampling weight (w) is calculated as the conditional probability of current laser data (l), current and recent magnetic values (m), and the (x,y) location represented by this particle:

$$w = p(l,m \mid x,y)$$

Detailed results will be on full paper.

How the paper fits the conference theme

This paper proposes a method that incorporates measurements of local magnetic field anomalies into SLAM algorithm. It is a low cost way to improve loop closure successful rates, thus enhances the consistency of robotic mapping, which is important for practical robot applications.

References

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