Demo Abstract: Range-SLAM: UWB based Realtime Indoor Location and Mapping

Yi Liu[2,*], Zhuozhu Jian[1,*], Junbo Tan[1], Lunfei Liang[5], Houde Liu[1,†], Xinlei Chen[1,3,4,†]
[1]Shenzhen International Graduate School, Tsinghua University;
[2]School of Information Science and Engineering, Shandong University;
[3] Pengcheng Laboratory; [4] RISC-V International Open Source Laboratory;
[5]School of Mechatronics Engineering, Harbin Institute of Technology;
* contributed equally; † corresponding authors.

ABSTRACT

Simultaneous localization and mapping (SLAM) systems frequently employ LiDAR and cameras as essential sensing components. However, these sensors are proved to be unreliable in environments with poor visibility or reflective surfaces. And UWB (Ultra Wide Band) sensor with a longer wavelength shows better potential to achieve perception tasks. However, since UWB sensors can only obtain distance information from the anchors, it is difficult to densely construct the geometric structure of the environment. In this paper, We propose Range-SLAM, a method based on received signal strength indicator (RSSI) recognition and binary filtering to complete the mapping task and enhance positioning based on the map, and only require UWB as external perception sensor. Real-world experiments are conducted and prove the effectiveness, real-time performance and robustness of the Range-SLAM algorithm.

KEYWORDS

Simultaneous localization and mapping, RSSI, UWB

1 INTRODUCTION

LiDAR and camera are commonly used external sensors for agent positioning and mapping. However, in challenging scenes filled with smoke or containing large numbers of mirrors, the relatively low signal-to-noise ratio of these optical measurement devices allows SLAM algorithms that rely on such devices to malfunction, significantly reducing the capabilities of autonomous systems [1][2][3] . However, the frequency bands at which both LiDAR and camera light sources operate are close to the visible frequency range within the electromagnetic spectrum.

Over the few years, there have been various studies to explore radio frequency (RF) bands instead of dedicated sensors for SLAM, given the RF signals' robustness against harsh and extreme environmental conditions. While novel RF devices such as UWB radar and micro-Doppler radar are capable of initially accomplishing SLAM tasks in challenging environments, their relatively high cost makes it difficult for them to be widely adopted. The position of robot based on UWB systems has been extensively researched due to the frequency characteristic advantages of RF signals and the relative affordability of anchor-tag systems[4] [5] [6] . As far as we know, there is currently a lack of work that relies on only a UWB device as an external sensor to complete mapping task and integrate it into the SLAM system.

This paper first presents a SLAM system that relies on only a UWB device as external perception to complete real-time localization and mapping. First, using support vector machine (SVM) to to classify RSSI data, we develope a low complexity and real-time NLOS Identification module to identify obstacle between the anchor and the label. Then we use a 2D probabilistic grid map to construct environment and design a map update strategy based on Binary Filter and Raycasting algorithm. Finally, we integrate the map and the Extended Kalman filter-based (EKF) positioning system and enhance the positioning accuracy.

2 SYSTEM ARCHITECTURE

As shown in figure 1, the range-SLAM framework is divided into three modules, receives high-frequency UWB (50Hz) and IMU (100Hz) data, outputs real-time label position (100hz) and updates the occupied grid map (10Hz).

2.1 NLOS Identification Module

The observation data are derived from UWB signals collected from the UWB tag affixed to a mobile robot. At each timestamp, the real-time data consists of the measured distance d, RxRssi Rx, and FpRssi Fp, which serve as criterias for identifying NLOS conditions. The data within the UWB window will perform pre-processing operation for following LOS/NLOS identification including: normalization, exception and smooth. Take signal strength and distance information to identify LOS/NLOS conditions as a classification problem, the SVM classifier is employed to address the problem.

2.2 Location Module

In this module, the Weighted Least Squares (WLS) based positioning method is introduced to mitigate the detrimental impact of NLOS ranging data. we combine IMU data with position from UWB, loosely coupled through the Extended Kalman Filter (EKF) to solve cumulative error drift of IMU and optimizes UWB positioning deviation in NLOS scenarios.

2.3 Mapping Module

First, we design an algorithm based on raycasting [7] and SVM recognition to obtain the observation of each grid. Specifically, this process involves initiating from a designated tag viewpoint and tracing along a line segment pointing towards the center of an anchor point, calculating the positional relationship between this line segment and each pixel within the map, thereby determining the exact intersection points where the line segment crosses the

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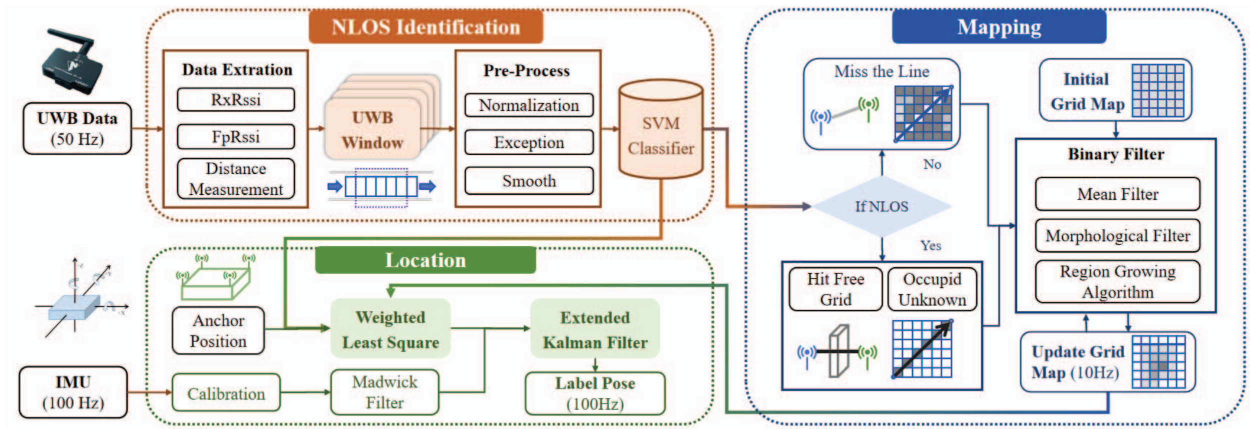

Figure 1: Range-SLAM framework

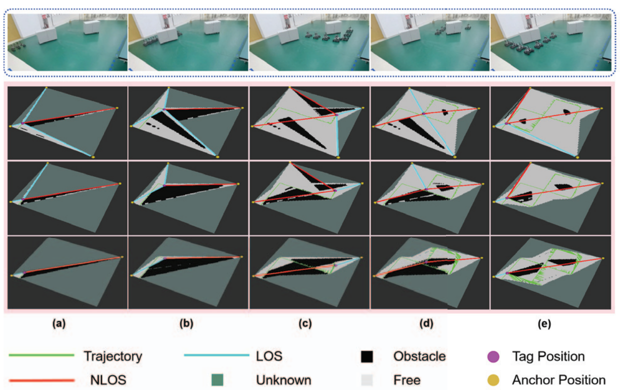

Figure 2: Experimental validation of the system on UGV

grid. Based on raycasting observations, we update each grid using binary filteringincluding three partsmean filter, morphological filter and region growing algorithm.

3 EVALUATION

We deployed four, three, and two UWB base stations indoors, respectively, and evaluated the system performance using a mobile robot (LinkTrack-a) equipped with UWB tags. Manually operated robots collect data and simultaneously complete positioning and mapping tasks. Figure 2 shows the mapping and positioning results of the robot going around the obstacle. The red line represents the NLOS area and the yellow represents the LOS area.

4 CONCLUSION AND FUTURE WORK

In this paper, we propose a novel Range-SLAM system leveraging UWB measurements for the purpose of accomplishing both localization and map construction tasks. This framework utilizes real-time label position and obstacle information to represent the environment with 2D grids map. The output occupancy grids map results under varying paths and different obstacle positions have been investigated, which can be the technical basis for robot navigation and obstacle avoidance. We would expand Range-SLAM to light-weight and multi-agent scenarios [8][9][10] in the future.

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