POSE-BASED SLAM WITH PROBABILISTIC SCAN MATCHING ALGORITHM USING A MECHANICAL SCANNED IMAGING SONAR

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Abstract - This paper proposes a pose-based algorithm to solve the full SLAM problem for an Autonomous Underwater Vehicle (AUV), navigating in an unknown and possibly unstructured environment. The technique incorporate probabilistic scan matching with range scans gathered from a Mechanical Scanned Imaging Sonar (MSIS) and the robot dead-reckoning displacements estimated from a Doppler Velocity Log (DVL) and a Motion Reference Unit (MRU). The raw data from the sensors are processed and fused in-line. No priory structural information or initial pose are considered. The algorithm has been tested on an AUV guided along a 600m path within a marina environment, showing the viability of the proposed approach.

Keywords - Underwater Navigation, AUV, EKF, SLAM, Imaging Sonar.

I. INTRODUCTION

In spite of the recent advances in AUV navigation techniques, robustly solving their localization in unstructured and unconstrained areas is still a challenging problem. The last decades, a number of studies in mobile robotics had developed techniques to address the localization problem with very promising results. In particular, the so-called Simultaneous Localization and Mapping (SLAM) techniques have been broadly and successfully applied to indoor and outdoor environments [1].

This paper is proposing an extension of the MSISpIC [2] algorithm in the pose-based SLAM framework. MSISpIC incorporate scan matching techniques to estimate the robot relative displacement between two configurations, by maximizing the overlap between the range scans gathered by a MSIS sensor.

II. SLAM ALGORITHM

A DVL and a low cost gyrocompass are used for dead reckoning while a MSIS is used for sensing the environment. The MSIS needs few seconds to complete a 360o sonar scan but in that time, the vehicle is moving giving deformed scans as a result. Two Extended Kalman Filters (EKFs) are used, one for tracking the robot position during the image grabbing and another to estimate the past history of the poses occupied by the robot at the end of each scan.

The first EKF using a constant velocity model with acceleration noise and updated with the velocity and attitude readings from the DVL and the gyrocompass respectively, is used to track the AUV position during the few seconds needed to gather a full polar image with the MSIS. This trajectory is used to remove the motion induced distortion of the acoustic image as well as to predict the uncertainty of the range scans prior to register them through the pIC [3] algorithm.

Then the initial robot pose is stored in a second augmented state extend Kalman Filter (ASEKF) used to estimate the full robot trajectory, while the first EKF is reset to start a second scan. Once the second scan has been completed, the probabilistic scan matching algorithm adapted to the MSIS sensor is used to register both scans, improving the estimation of the robot displacement between the scans. The corrected robot displacement is then compounded with previous scan pose (from the ASEKF) to get the current scan pose, which is used to augment the state. Each new pose of a scan is compared with previous scans that are in the nearby area and if there is enough data overlapping, a new scan match will put a constrain between the poses updating the ASEKF. These constrains help to identify and close the loops which correct the entire previously trajectory bounding the drift.

III. EXPERIMENTAL RESULTS

The method described in this paper has been used with a dataset obtained in an abandoned marina located in Sant Pere Pescador, on the Catalan coast [4]. This dataset is in a structured environment but our algorithm does not take into account any structural information neither features.

The survey mission was carried out using ICTINEUAUV [5] traveling along a 600m path equipped among others with DVL, MRU and MSIS sensors. Fig. 1a, shows the trajectory and the map estimated using the dead-reckoning method. Fig.1b, shows the trajectory and the map estimated with our SLAM algorithm. In these figures, the estimated trajectory is plotted on an ortophotomap together with the DGPS ground truth for comparison. It can be appreciated that the dead-reckoning estimated trajectory suffers from an important drift which is drastically reduced when our algorithm is used.

IV. CONCLUSIONS

This paper proposes an extension to the MSISpIC algorithm in the pose-based SLAM framework. MSISpIC is able to perform underwater scan matching using a MSIS. To deal with the motion induced distortion of the acoustic image, an EKF is used to estimate the robot motion during the scan. Each full scan pose is maintained in a second filter, an augment EKF and is cross registered with all the previous scan posses that are in a certain range applying the pIC algorithm. The proposed method has been tested with a real world dataset including DGPS for ground truth. The results show substantial improvements in trajectory correction and map reconstruction.

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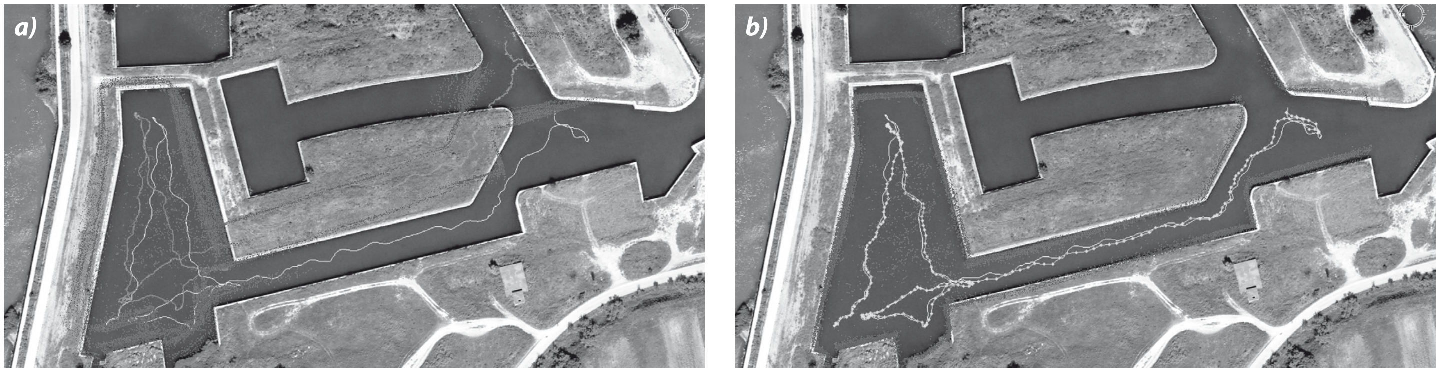

Fig 1: Results: a) Trajectory and map generated with dead reckoning (red). DGPS trajectory (yellow) used as a ground truth. b) Map and trajectory (dotted cyan) generated with the SLAM algorithm.