

Localization of Mobile Robots

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Abstract

Objectives: To survey the different approaches and implementations proposed by various research papers for Localization of Mobile Robots Methods/Statistical analysis: Understand the pros and cons of various methods proposed in earlier research papers like Ultrasonic Hybrid Localization algorithm, Extended Kalman filter (using time domain), Oversampling algorithm, Low Pass filter (using frequency domain) and identify the cost effective and accurate methods for Mobile Robot localization. **Findings:** Usage of Oversampling algorithm along with Low Pass Filter would help in reducing the cost of implementation as well as increases the accuracy of predicting the robots position **Application / Improvements:** Accurate position of Mobile Robots will help to reduce human labour in complicated/dangerous tasks and environments.

Key Words : Localization, Mobile Robots, low pass Filter, Ultrasonic Sensors, Ultrasonic Hybrid Algorithms

1 INTRODUCTION

Three things are needed for a Robot to navigate in its environment 1. Knowing where it is, 2. Knowing where it is going, 3. Knowing how to get there. The scope of this paper is restricted to answering the first point. Localization is the determination of position and orientation of any object. Humans use reference points around them and a sense of distance relative to the reference point to know where they are located. Robot positioning and Orientation methods can broadly be classified into two Relative Positioning, Absolute Positioning¹. Relative positioning methods include using Odometers, Inertial navigation systems^{Fig.1}, etc. Absolute positioning methods include usage of beacons, artificial landmarks, natural landmarks, and Model matching. Locating the position and orientation of Robots requires application of various sensors, algorithms, and filters. Different kinds of Sensors like Odometer^{2,3,4,5,6}, gyroscopes⁷, accelerometer⁷, ultrasonic sensors^{8,9,10}, and Infrared sensors¹¹ have been proposed.

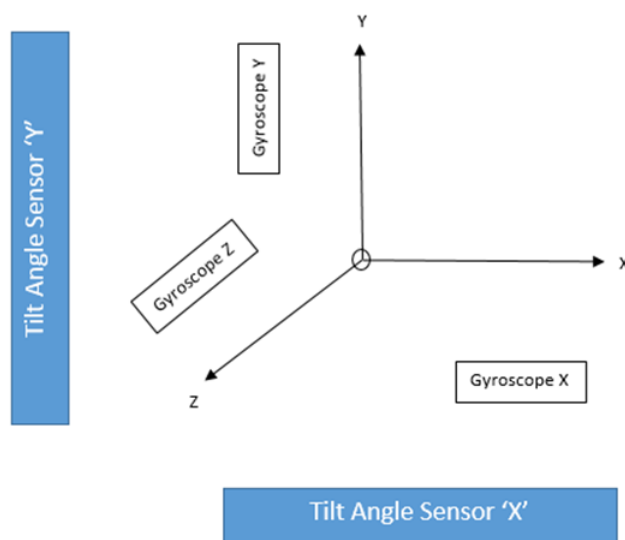


Figure 1: Localization of Mobile Robot using Inertial navigation systems

Algorithms proposed include Hybrid Static Posture for Global

Self-Localization⁸, Accurate Hybrid Global Self-Localization Algorithm^{9,12} and Dynamic Ultrasonic Hybrid Localization^{10,13}. Various kinds of filters like Kalman, Extended Kalman⁷, Hybrid Extended Kalman^{2,14}, and Particle filter¹⁵ have been proposed in various papers. Kalman filter can be used only for a system with linear measurements. It is not widely used for non-linear systems like the one that is being discussed. So Extended Kalman filter (EKF) and its variants, which support non-linear measurements is highly recommended^{2,7,16}. In association with EKF, error models are defined based on the sensor specification. Particle filters or Sequential Monte Carlo method compares existing data with latest data to calculate the current position. This method is heavy in computation, but provides more accurate results. We will look into the different proposed methods in greater detail in the below sections.

2 CONCEPTUAL STUDY

In most papers studied, the basic concept used for localization of Mobile Robots is distance and angle measurement, the main difference being the usage of reference points, sensors and measuring devices used. In the paper Inertial Navigation Systems for Mobile Robots by Billur Barshan, Hugh F. Durrant-Whyte⁷, three solid state gyroscopes (for measuring angular movement in relation to gravity axis), tri-axial accelerometer (for approximating the position based on velocity) and tilt sensors (for measuring the tilt angles in uneven surface). Inertial navigation systems (INS) is a kind of dead reckoning system which does not depend on external reference points but makes use of self-contained measurement devices to identify their location. Error modelling is done using Extended Kalman Filter (EKF) which takes INS Sensor measurements as Input and produces estimates for the position, orientation, and drift rates.

A cost effective system for inertial navigation is described for the application of the mobile robots. Estimation of the robot orientation is done by two different solid-state gyroscopes. Along with the extended Kalman filter (EKF) error models for inertial sensors are developed and comprehended for the estimation of physical place

and orientation of a mobile robot vehicle. Performance of the gyroscopes with error models is correlated to the accomplishment when the error models are removed from the system. Similar error models have been developed for each axis of a solid-state tri-axial accelerometer and for a conducting-bubble tilt sensor which may also be used as a low-cost accelerometer. An integrated inertial platform consisting of three gyroscopes, a tri-axial accelerometer and two tilt sensors is described. The circuit concept involves the accelerometer. The orientation estimates calculated using this method was reliable over quite long periods of time, while the position estimates obtained were reliable over shorter periods.

In Localization Based on the Hybrid Extended Kalman Filter with a Highly Accurate Odometry Model of a Mobile Robot by Tran Huu Cong, Young Joong Kim, Myo-Taeg Lim, Odometer reading based on Dead Reckoning and Artificial beacons are used along with 360⁰ laser sensor scan. Hybrid Extended Kalman Filter (HEKF) is used to model error and provide accurate estimate of location by comparing the real and estimated location of the beacons. Separating and Sequence Updating (SSU) algorithm ^{Fig.2} is used to decide on the best measurement.

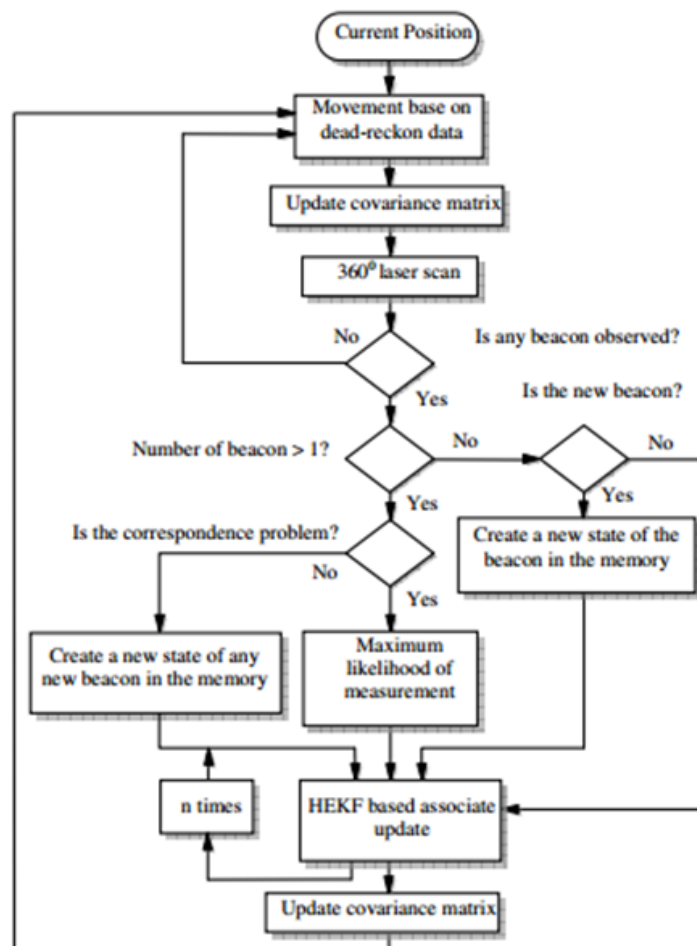


Figure 2: Flow chart of SSU Algorithm

Starting at the current position, the robot takes a movement step base on dead-reckoning data. At the new position, the error covariance matrix is updated. Then by 360⁰ laser sensor, an observation is taken. If no beacon observed, the mobile robot continuously changes to next step or the position and orientation will be updated. The robot decides whether that beacon has been saved in the memory or a new state will be created in the memory. The

maximum likelihood strategy is used to decide which beacon is the best confident and only one beacon is selected for updating the robots pose.

With reference from the Measurement and correction of systematic odometry errors in mobile robots, Odometry is the most extensively used method of concluding the fleeting position of a mobile robot. It introduces practical methods to measure and reduce odometry errors that are caused by the two dominant error sources in differential-drive mobile robots:

1. Ambiguity about wheel base effectiveness; and
2. Dissimilar wheel diameters. These errors stay almost constant over prolonged periods of time. Performing an occasional calibration as proposed here will increase the odometric accuracy of the robot and reduce operation cost because an accurate mobile robot requires fewer absolute positioning updates. Many manufacturers or end-users calibrate their robot, usually in a time-consuming and non-systematic trial and error approach ¹⁷. By contrast, the method described in this paper is systematic, provides near-optimal results, and it can be performed easily and without complicated equipment. Experimental results are presented that show a consistent improvement of at least one order of magnitude in odometric accuracy for a mobile robot calibrated with our method.

In Hybrid Localization of Micro Robotic Endoscopic Capsule Inside Small Intestine by Data Fusion of Vision and RF Sensors, a hybrid localization technique, camera motion tracking algorithm to support the existing RF localization infrastructure for the WCE application. The major contribution of this work is that we demonstrated the potential of using video source to aid the RF localization of the WCE. The proposed motion tracking technique is purely based on the image sequence that captured by the video camera which is already equipped on the capsule, thus, no extra system components such as IMUs or magnetic coils are needed. The performance of the proposed method is validated under a virtual emulation environment. Experimental results show that by combining the motion information with RF measurements, the proposed hybrid localization algorithm is able to provide accurate, smooth and

continuous localization results that meet the requirement of WCE application. In the future, we will focus on refining this algorithm according to the clinical data and testing this algorithm with real human object.

In Probabilistic Localization Methods of a Mobile Robot Using Ultrasonic Perception System by Lei Zhang and Rene Zapata, Hybrid Grid-MCL algorithm ^{Fig.3} along with Monte Carlo Localization (MCL) and grid localization, sampling in similar energy regions and both these combined together are the three approaches carried out in this paper. The heavier computation burden due to need of large number of samples was found to be the drawback of the system which in turn was overcome by the pre-caching technique.

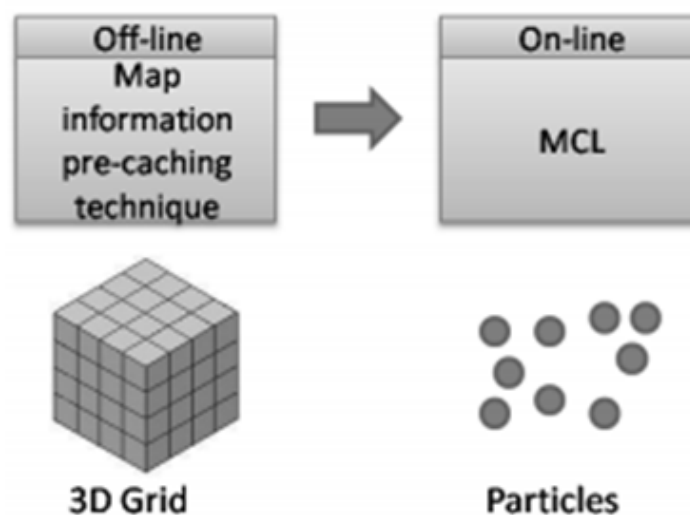


Figure 3: Hybrid Grid-MCL Algorithm

Effective localization ¹⁸ is a fundamental prerequisite for achieving autonomous mobile robot. In this paper, we propose three probabilistic approaches to solve the global localization problem and the kidnapped robot problem. The first approach named the hybrid Grid-MCL algorithm merges Monte Carlo Localization (MCL) and grid localization. It can solve the global localization problem with very low on-line computational costs. The second approach, sampling in Similar Energy Regions (SER), is used to conquer the

kidnapped robot problem. The third approach is a combination of previous two approaches with adaptive samples, which solves the global localization problem and the kidnapped robot problem together. The validity of our approaches is verified through extensive simulations employing ultrasonic Perception System.

In A Hybrid Algorithm for Global Self-Localization of Indoor Mobile Robots with 2-D Isotropic Ultrasonic Receivers by Seong Jin Kim and Byung Kook Kim, several ultrasonic transmitters are fixed at reference positions and 2-D isotropic ultrasonic receiver array composed of three receivers is mounted on top of the Mobile Robot *Fig.4*.

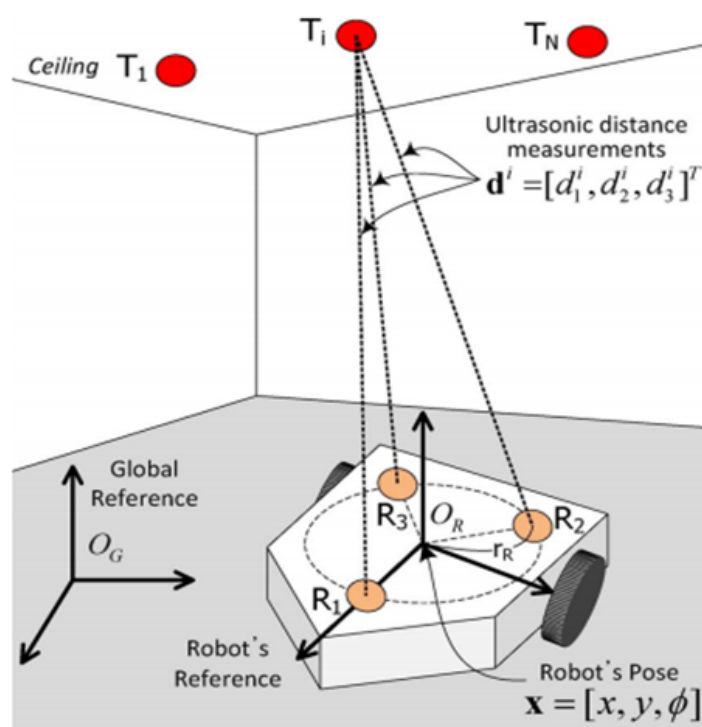


Figure 4: Localization of Mobile Robot using Ultrasonic sensors

Direct and Indirect methods are used to locate the position of the Robot. In the Direct methods, the exact position is located when proper signal is obtained from the transmitters, whereas when

the position cannot be exactly located, the Indirect method detects the position within the range. Hybrid static posture estimation algorithm is used to identify initial position of the Robot at start-up. Performance index is the key for positioning. Trilateration and triangulation are obtained using significant points from the performance index.

In Accurate Hybrid Global Self-Localization Algorithm for Indoor Mobile Robots with Two-Dimensional Isotropic Ultrasonic Receivers by Seong Jin Kim and Byung Kook Kim, which is advancement on the previous paper, Direct and Indirect methods are used. Only significant points are considered for the performance index which reduces the complexity of the previous method. In Dynamic Ultrasonic Hybrid Localization System for Indoor Mobile Robots by Seong Jin Kim and Byung Kook Kim, a further advancement on the previous two methods, Extended Kalman Filter (EKF) algorithm with a state/observation vector composed of Robot pose is presented using odometer and ultrasonic distance measurements. Ultrasonic Hybrid Localization (UHL) algorithm which identifies the best of Direct and Indirect measurements to accurately locate the position and posture of the Mobile Robot.

A competent DUHL algorithm¹⁸ system based on an EKF with a robot pose state/observation vector and a UHL algorithm using ultrasonic distance information dynamic estimates has been presented. The DUHL used odometric and ultrasonic distance measurements using ultrasonic sensors localization subsystem. The system uses ultrasonic sensors consisting of disparate ultrasonic Tx's fixed at reference positions and an equilateral ultrasonic Rx array with three Rx's on the top of the robot in global coordinates. It was demonstrated how the self-localization algorithm i.e., the UHL algorithm) could be used in conjunction with the EKF. To enable the persistent use of the UHL algorithm in the framework of the EKF, a dynamic distance estimation method was presented to track the estimates of ultrasonic distance information from feasible Tx's of interest and changeableness in estimates.

The estimates of the aforementioned ultrasonic distance information are updated during robot motion and distance observation from the set of available Tx's. The approximate calculation and corresponding Tx can also be discarded due to a large uncertainty, if necessary. The proposed DUHL algorithm was compared against

the UHL algorithm using distances from the last two Tx's for four different trajectories. Using this algorithm, the tracking results of the robot were more accurate than those of the UHL algorithm using the last two Tx's. The operation mode based on a sequential RF synchronization with successive Tx's allowed the Barker code to work suitably, as described in Section II-A. However, orthogonal codes for faster localization process complementary sets of sequences may be used, on account of only one RF synchronization signal necessary to measure distances between Tx's and the Rx's on a robot. Reduced computational complexity is observed.

In visual SLAM choosing useful landmarks makes tracking easy, stability over multiple frames, and easy to redetect a previously visited location during the robots return path¹⁹. Hence loop closing is vital in SLAM. Loop closing decreases accumulated errors by distributing information from areas with lower uncertainty to those with higher. In addition to that the number of landmarks should be kept under control since the complexity of SLAM is typically a function of the number of landmarks in the map. Landmarks should also be well distributed over the environment.

1. the tracking of landmarks that enable a better pose estimation
2. the exploration of regions without landmarks to obtain a better distribution of landmarks in the environment, and
3. the active redetection of landmarks to enable loop closing in situations in which a fixed camera fails to close the loop. When two nodes, i and j are within a given range and sensor F.O.V. to each other, a range observation is generated which is represented by $z[i, j, t]$ ²⁰. This observation depends on the position of the two nodes i and j .

3 CURRENT SCOPE OF WORK

In current scope of work, the Ultrasonic sensors are used for distance measurement and the Speedometer for knowing the speed in which the Robot travels. Low Pass Filter is used for error reduction in measurements and to provide accurate localization of posture and orientation. The overall process of measuring based on the sensor

inputs and guiding the Robot to the desired position is performed by a PIC microcontroller (Model: PIC16F877A). The Ultrasonic Hybrid Localization algorithm proposed in an earlier work, allows for up to 500 measurements beyond which the error level is significant. The oversampling algorithm proposed in this work allows much more measurements to be taken to locate a robot in motion more accurately. Extended Kalman Filter is based on time domain, while Low Pass Filter is based on Frequency domain, which helps in covering greater distance along with the model of the ultrasonic sensor being used and measurements to accurately track the position of the mobile robot. The proposed solution is designed to be more cost effective but also provides reliable solution to the problem of Mobile Robot localization ^{Fig.5}.

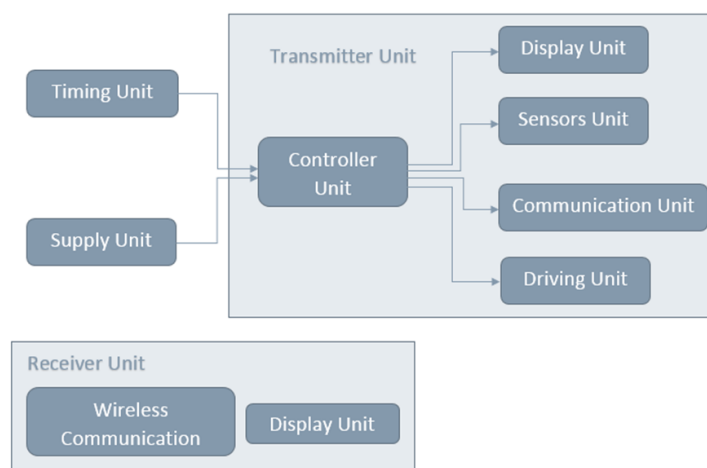


Figure 5: Circuit diagram of current scope of work

4 CONCLUSION

Identification of the exact position and orientation of the Mobile Robot is important for the Robot to move to the required destination and perform its activities. In this survey paper, the study of the varied concepts applied to solve the problem has been analyzed. Each method uses different measurement techniques, algorithms

and filters to determine the location as accurately as possible. Each method has its own advantages and disadvantages. Future work in this area is to further reduce the cost and increase the accuracy of locating the Mobile Robots.

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