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Identification of Mobile Robot Using Ultrasonic Waves

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Abstract— *Robots play a major role in present world to minimize human labour and to accomplish complicated/dangerous tasks. The pre-requisite for a motilerobot to perform its activities in a given environment is for it to know its current location, which would help it to know the degree and distance to move to perform its tasks., Different techniques have been suggested over the years to solve the problem of the Robot knowing its own location. This document presents a survey on the different approaches and implementations proposed by various research scientists. In this paper, 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 and measurements to accurately track the posture of the motile robot. The proposed solution is designed to be more cost effective but also provides reliable solution to the problem of Mobile Robot localization.*

Keywords— *Localization, Mobile Robots, Filters, Sensors, Algorithms, Where am I?*

I. 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 limited to answering the first point. Localization is the determination of posture and orientation of any object. Humans use reference points around them and sense of distance relative to the reference point to know where they are located.

Robot positioning and Orientation type can broadly be categorized into two – Relative Positioning, Absolute Positioning [1]. Relative positioning methods consist using Odometers, Inertial navigation systems 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.

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Different kinds of Sensors like Odometer [3], gyroscopes [2], accelerometer [2], ultrasonic sensors [5][6][10], and Infrared sensors [12] have been proposed. Algorithms proposed include Hybrid Static Posture for Global Self-Localization [5], Accurate Hybrid Global Self-Localization Algorithm [6][11] and Dynamic Ultrasonic Hybrid Localization [10][15].Various kinds of filters like Kalman, Extended Kalman [2], Hybrid Extended Kalman [3][18], and Particle filter [4] 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] [3][13]. 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.

II. PROPOSED SYSTEM

In most papers studied, the basic concept used for localization of Mobile Robots is distance and angle measurement, the main difference being usage of reference points, sensors and measuring devices used.

In the paper "*Inertial Navigation Systems for Mobile Robots*" by Billur Barshan, Hugh F. Durrant-Whyte [2], 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 acquires INS Sensor measurements as Input and generates calculations for the posture, orientation, and rate of drift.

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) inertial sensors error models are developed and comprehended for the estimation of physical place and orientation of a mobile robot vehicle. Gyroscopes performance with error models is correlated to the accomplishment when the error models eliminated in the design. Same error models were designed for every axis of a solid-state tri-axial accelerometer and for a conducting-bubble tilt sensor which perform alternative function as a affordable accelerometer. Three gyroscopes were included in integrated inertial platform, a tri-axial accelerometer and two sensors for tilting explained.

The circuit concept involves the accelerometer. The orientation estimates calculated using this method was stable for prolonged time period. When the position estimates acquired were stable for a less time frame.

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 360^o laser sensor scan. Hybrid Extended Kalman Filter is implemented to model error and provide accurate estimate of location by comparing the actual and estimated location of the beacons. Separating and Sequence Updating (SSU) algorithm (Figure 2) is used to decide on the best measurement.

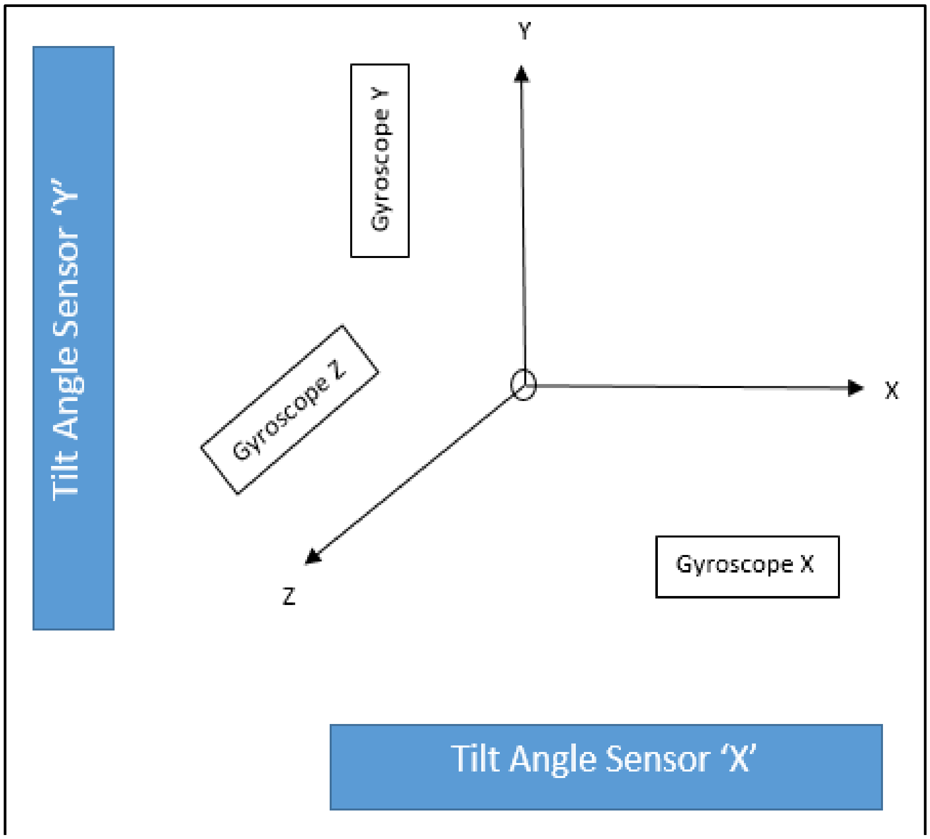


Fig.1 Localization of Mobile Robot using Inertial navigation systems

Depending on the present position, the robot performs a motion based on dead-reckoning data at the new position the error covariance matrix is modified. An observation is taken by 360 degree laser sensor. If there is no observation of beacon, the motile bot relentlessly changes to preceding step or the orientation and position will be modified. The conclusion was made by robot if the beacon must bestored in the memory or a new state will be generated. The maximum likelihood method is utilized to make decision which beacon is the most confident and for changing the robot's pose one beacon is selected.

With reference from the correction of systematic odometry errors and measurement in motile bots. The most frequently deployed method for concluding the fleeting position of a robot that is locomotive is Odometry. It proposes experimental ways to measure and reduce odometry errors that are produced by the two major error sources in differential-drive mobile robots:

1) Ambiguity about wheelbase effectiveness; and
2) Dissimilar diameter of wheels. These errors remain utmost stable over longer period of time. Infrequent calibration measurement proposed will improve the odometric precision of the robotand decrease operation cost because an precise motile bot needs less absolute positioning improvements. Most manufacturers or end-users validate their robot, typically in a time-consuming and non-systematic trial and error approach[14].

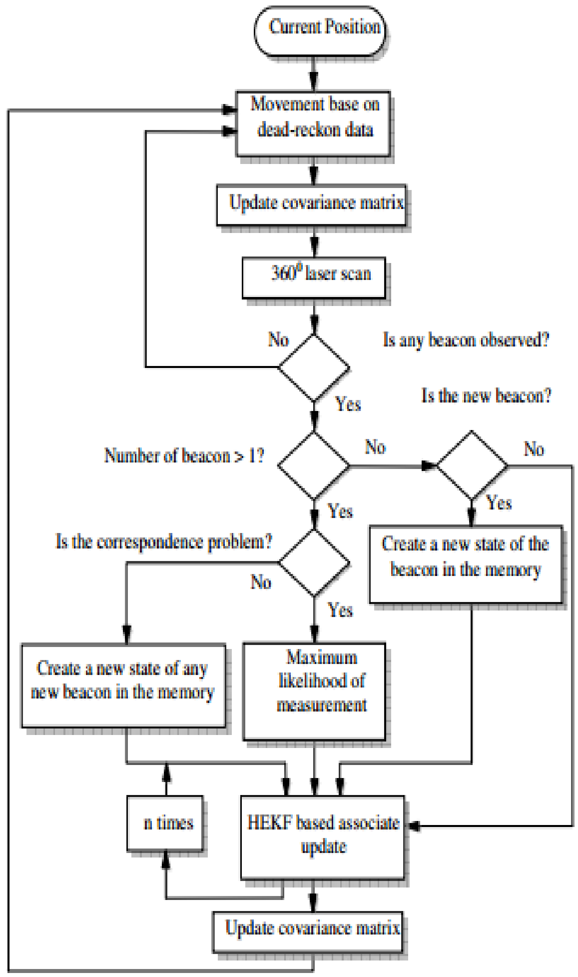


Fig. 2 Flow chart of SSU algorithm

In *"Hybrid Localization of Micro Robotic Endoscopic Capsule Inside Small Intestine by Data Fusion of Vision and RF Sensors"*, a mixed localization method, tracking algorithm for motion camera to support the existing radio frequency localization framework for the WCE application. The remarkable contribution of this work is that The ability of video source is exhibited to aid RF localization of the WCE. The motion tracking technique put forward is depends on the image sequence captured by video camera. which is equipped on the capsule previously, thus, no new system components like IMUs or magnetic coils are required. A virtual emulation environment is used for performance evaluation for the system put forward. The outcomes from experiments exhibit that by fusing the motion information with measurements of RF, the suggested hybrid localization algorithm has the ability to deliver precise, trouble free and continuous localization outcomes that meet the need of WCE application. Later the focus will be on algorithm refinement corresponding to the clinical data and algorithm testing with actual human object.

In "*Probabilistic Localization Methods of a Mobile Robot Using Ultrasonic Perception System*" by Lei Zhang and Rene´ Zapata, Hybrid Grid-MCL algorithm along with Monte Carlo Localization 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.

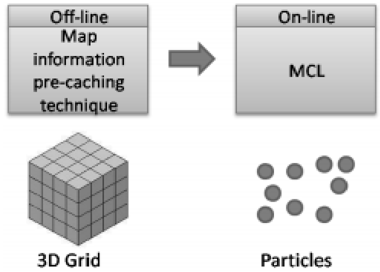


Fig. 3: Hybrid Grid-MCL algorithm

The basic requirement for accomplishing autonomous motile bot is effective localization. Three probliasitc approaches were proposed in this paper to resolute the global localization problem and the kidnapped robot problem. The first approach named the hybrid Grid-MCL algorithm fuses Monte Carlo Localization (MCL) and grid localization. The problem of global localization can be solved at less computational cost. Sampling in Similar Energy Regions (SER) is the second approach, The kidnapped robot problem can be overwhelmed with it. The fusion of two approaches mentioned with samples that are adaptive is the third approach, it resolute the global localization problem and the kidnapped robot problem combined. The approaches timeframe is checked via extensive simulations with Ultrasonic Perception System deployed.

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, Many ultrasonic transmitters are set at reference positions and 2-D isotropic ultrasonic receiver array composed of three receivers is mounted on top of the Motile Robot (Figure 4).

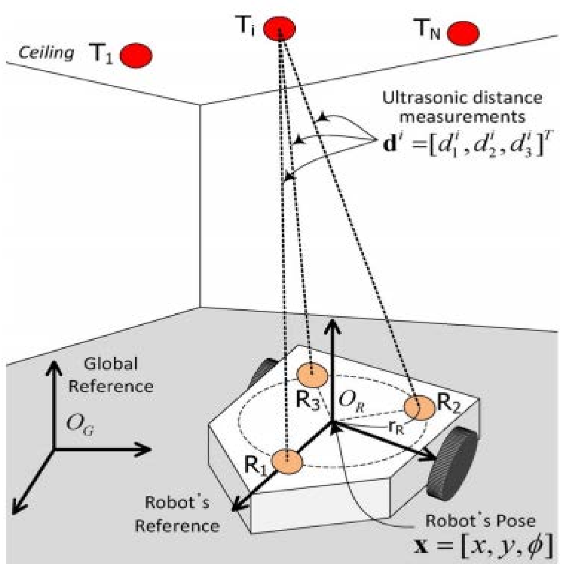


Fig. 4: Localization of Mobile Robot using Ultrasonic sensors

Straight and Indirect techniques 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 an 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 generated of Robot pose is shown using odometer and measurement of ultrasonic distance. Ultrasonic Hybrid Localization (UHL) algorithm which identifies the best of Direct and Indirect measurements to accurate locate the position and posture of the Motile bot.

A competent DUHL algorithm [8] design depends on an EKF with a robot pose state/observation vector and a UHL algorithm utilizing ultrasonic distance information dynamic evaluation was presented. The DUHL utilizes ultrasonic and odometric range measurements using ultrasonic sensors subsystem localization. The system uses ultrasonic sensors consisting of disparate ultrasonic (txs) set at reference positions and an equilateral ultrasonic array of receivers with receivers of three on the robot top in global coordinates. The usage of self-localization algorithm with the EKF is exhibited. the continuous use of the UHL algorithm is enabled in the framework of the EKF, a dynamic distance calculation method was depicted to keep track of the estimates of ultrasonic distance data from feasible Transmitters of interest and changeableness in estimates.

The calculation of the previously mentioned ultrasonic range data are revised at the time of robot movement and distance perceived from the group of present transmitters. The approximate calculation and related Transmitter can also be eradicated because of a great uncertainty, if essential. A comparison is performed with put forward DUHL algorithm with the UHL algorithm using space between last two transmitters for four non-similar trajectories. The mode of operation depend on a consecutive RF synchronization with next Transmitters permit the Barker code to perform it task appropriately, as explained in Section II-A. However, orthogonal codes for faster localization process supplementary sets of sequences may be used, on account of only one RF synchronization signal essential to calculate distances betwixt Transmitters and the Receivers on a bot. 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 path [21]. Hence c*losing of loops* is vital in SLAM. Loop closing reduces gathered errors by distributing in data from areas which are less certain to those with greater. In addition to that landmarks numbers must be maintained under control because the complications of SLAM is typically a function of the landmark numbers in the map. Landmarks must be distributed over the environment in appropriate manner.

1) better pose estimation is enabled by tracking landmarks
2) the area exploration with no landmarks to acquire a fine distribution of landmarks in the scenario, and
3) the active redetection of landmarks to enable closing of loops in environment in which a non-movable camera failedfor loop closing.

A range observation is generated When two nodes,i and j are within a range provided and sensor F.O.V. to each other which is exhibited by z[i,j,t][22]. This study depends on the position of the two nodes i and j.

III.RESULT ANALYSIS

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.

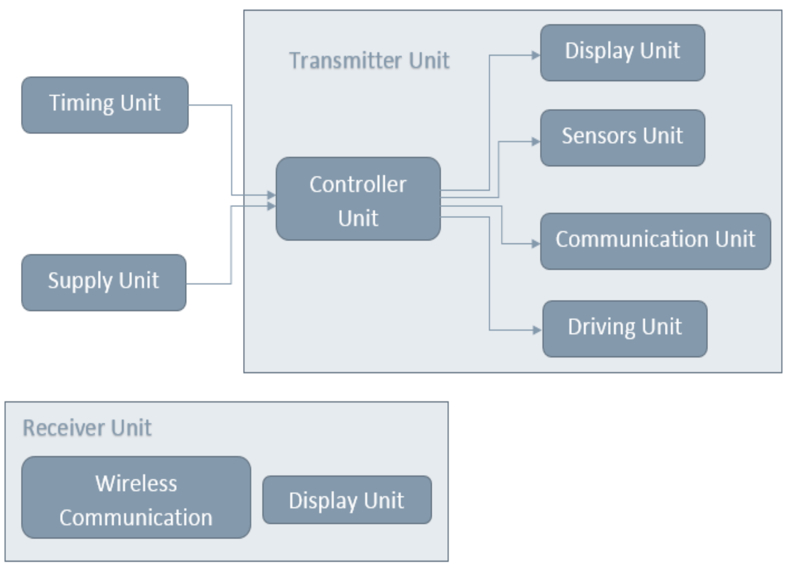
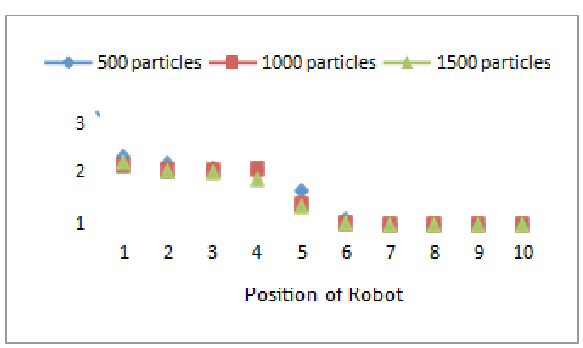


Fig. 5: Circuit diagram of current scope of work



(A)

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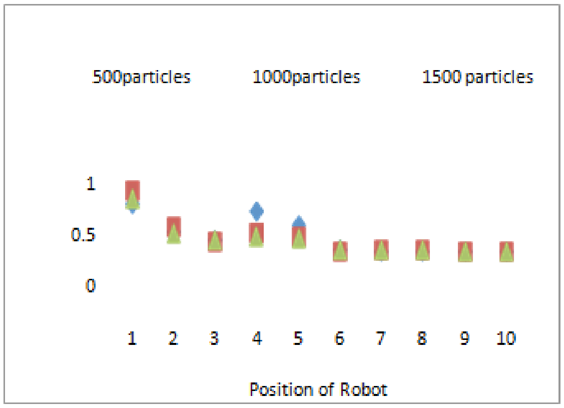
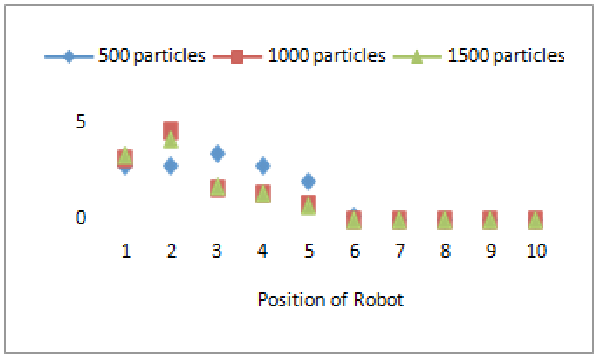


(B)



(c)

Fig. 6 Variance of particles(x, y, theta) in each position of Mobile Robot (a)variance of x-coordinate, (b)variance of y-coordinate, and (c)variance of theta

IV. CONCLUSION

Identification of the exact orientation and posture of the Mobile Robot is important for the Robot to move to the required destination and perform its activities. 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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