ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

Microsoft Kinect and Sensory Data Fusion for Robust SLAM Using ROS

Amrutha Dilip Salunkhe[1], Prof. M. N. Kakatkar[2]

Post Graduate Student, Dept. of E&TC, Sinhgad College of Engineering, Pune, India [1]

Professor, Dept. of E&TC, Sinhgad College of Engineering, Pune, India [2]

ABSTRACT: The problem of Simultaneous Localization and Mapping (SLAM) has attracted many researchers in the field of indoor wireless mobile robotics. Localization and map building are two essential tasks for an autonomous mobile robot's indoor navigation in unknown environments. In general, SLAM algorithms use odometers information and measurements from sensors of robots. In this proposed work presents a hybrid algorithm for solving SLAM problems by employing advantages of respective algorithms. Simultaneous update of robot pose and linear feature estimates is performed through hybrid algorithm and this can be achieved by comparing two of the most important solutions in position. It implement the proposed SLAM by hybrid algorithm using low cost, ready-to-use, energy efficient Arduino microcontroller as embedded system and verify the feasibility of the proposed methods as a indoor wireless mobile robot. The aim of this paper is to acquaint with the kalman filter and the extended kalman filter algorithm for determining the position of a mobile robot. The performance of EKF and the quality of position estimation depends on the exact a priori information of process and measurement noise covariance matrices. Taking this problem into a account and to solve mistakes show in estimations the simulation results can be drawn with better accuracy of the filters in estimating the robot's localization.

KEYWORDS: Arduino microcontroller, Hybrid Algorithm, Estimation robot pose, Kalman filter

I. INTRODUCTION

The motive is to develop an autonomous mobile robot which localize and map of indoor environments. Accordingly, the robot should be intelligent to manage its sequence of action through specific perceptive process, rather than following a static, hardwired sequence of cursorily provided commands. The objective of this research is to build differential drive robotic platform from scratch. In addition, we have to implement an advanced algorithm for efficient mapping and localization of mobile robot. In this paper, localization and mapping of robot is plan using gmapping through ROS. The aim is to explore and improve the navigational and path planning algorithm performance for real time mobile robot. When an obstacle is detected on the path then robot should detect and localize it. Again to investigate the feasibility of the integration of ROS and the Microsoft Kinect on a mobile robot platform for SLAM.

II.RELATED WORK

In the beginning, a short history of robot slam for readers to well understand researcher's primary ideas on reducing noise in robot localization and mapping problem, and how these ideas formulate to solve the problem of slam when mapping and localization were introduced by researchers in the early 1980's, the work at that time focused on solving mapping and localization independently [1] [2].robot mapping is the problem of acquiring an accurate map of the environment given some knowledge of robot's position and motion. the work in robotic mapping typically assumes that the robot's localization in the environment is 100% certain [3] and focused mainly on analyzing the measurement data obtained from a noisy world to build up a map to present that environment on the other hand, robot localization is another problem of estimating robot pose (robot's position and heading) much work has been done on how to reduce the control error [10] and robot slip problem when a robot is running through an area. in this situation, a map of working environment with landmarks is required as a prior knowledge for robot to determine where it is smith et al.

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(1990) [1] first introduced the idea of solving both of the mapping and localization problems, simultaneously they developed a probabilistic method to indicate the spatial relationship between landmarks in an environment when robot is estimating its pose, currently the map is represented as a set of landmark position and a covariance matrix is used to present the uncertainty of either the landmark or the robot's pose this kind of map today is usually mentioned as feature-based map, and this problem is called cml (concurrent mapping and localization), but now more people would like to use slam (simultaneous localization and mapping) (thrun et al. 2005) [5].since then, a probabilistic approach [3] [4] [11] has become a standard way of solving the slam problem many issues associated with kalman filter approach have been approved and other experiments by using an improved method [5] [9] [12], particle filter technique, also accomplish the target successfully.

III.PROPOSED SYSTEM

The robot's movement is controlled by two Direct Current (DC) gear motors with an encoder. The two motors are driven using a motor driver. The motor driver is interfaced into an embedded controller board, which will send commands to the motor driver to control the motor movements. The encoder of the motor is interfaced into the controller board for counting the number of rotations of the Motor shaft. This data is the odometry data from the robot. There are kinect sensors, which are interfaced into the PC for taking 3D image.

There is an IMU sensor to improve odometry calculation. The embedded controller board is interfaced into a PC, which does all the high-end processing in the robot. Vision and sound sensors are interfaced into the PC and Wi-Fi is attached for remote operations.

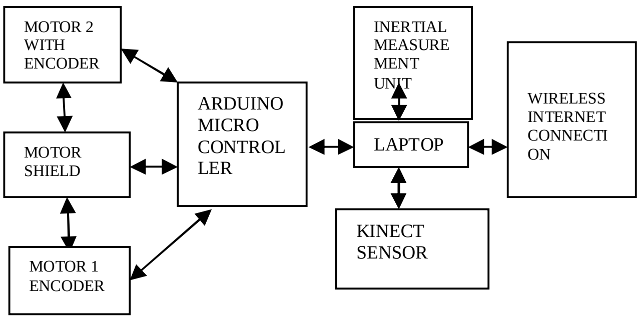

FIG 1: BLOCK DIAGRAM OF THE SYSTEM

IV.PROPOSED ALGORITHM

Extended Kalman Filter

In estimation theory, the extended Kalman filter (EKF) is the nonlinear version of the Kalman filter which linearizes about an estimate of the current mean and covariance. In something akin to a Taylor series, we can linearize the estimation around the current estimate using the partial derivatives of the process and measurement functions to compute estimates even in the face of non-linear relationships.

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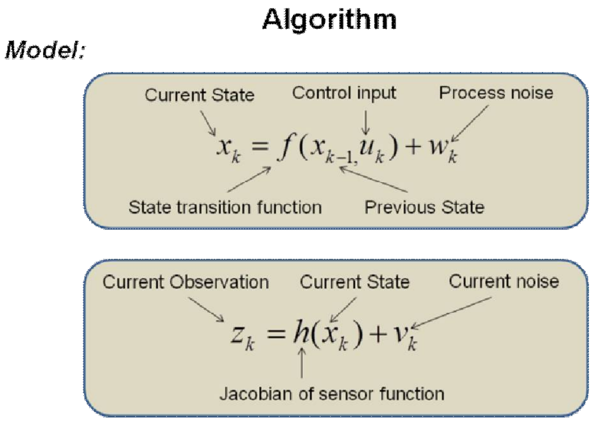
STEP-1: Model



Here again is our modified formula for system state:

$$x_k = Ax_{k-1}$$

Where *x* is a vector and *A* is a matrix. As you may recall, the original form of this equation was

$$x_k = Ax_{k-1} + Bu_k$$

where u_k is a control signal, and *b* is a coefficient to scale it. We also had the equation

$$z_k = Hx_k + v_k$$

STEP 2 - Start Prediction

If succeed to fit model into **Kalman Filter**, than the next step is to determine the necessary parameters and initial values of the filter.

We have two distinct set of equations: **Time Update** *(prediction)* and **Measurement Update** *(correction).* Both equation sets are applied at each **k**th state.

Time Update *(prediction)*	**Measurement Update** *(correction)*
$x_k = Ax_{k-1} + Bu_k$ $P_k = F_{k-1}P_{k-1}F^T{}_{k-1} + Q_{k-1}$	$G_k = P_k H_k^T (H_k P_k H_k^T + R)^{-1}$ $\hat{x}_k = \hat{x}_k + G_k(z_k - h(\hat{x}_k))$ $P_k = (I - G_k H_k)P_k$

STEP 3 – Predict

After we gathered all the information we need and started the process, now we can iterate through the estimates. Keep in mind that the previous estimates will be the input for the current state.

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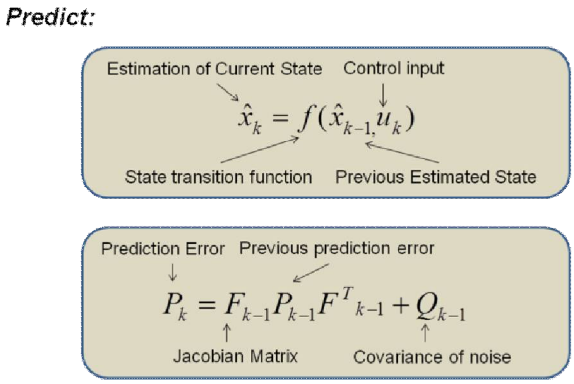

This research work, proposes a robot limitation framework taking into account the extended kalman filter to beat the issues of restriction in mobile robot. The exploratory consequence of this paper delineates the strong and precision of the proposed framework. MATLAB simulation of mobile robot is performed using Extended Kalman Filter.

IV. DIFFERENTIAL DRIVE MECHANISM

Kinematics is the relationships between the positions, velocities, and accelerations of the links of a manipulator, where a manipulator is an arm, finger, or leg. Robot kinematics is the study of the mathematics of motion without considering the forces that affect motion. It mainly deals with the geometric relationships that govern the system. Kinematic is mainly divided into two types i.e. forward and reverse kinematics. Forward kinematics uses the kinematic equations of a robot to compute the position of the end-effectors from specified values for the joint parameters. The reverse process that computes the joint parameters that achieve a specified position of the end-effector is known as inverse kinematics.

A mobile robot or vehicle has six degrees of freedom (DOF) expressed by the pose (x, y, z, roll, pitch, and yaw). It consists of position (x, y, z) and attitude (roll, pitch, and yaw). Roll refers to sidewise rotation, pitch refers to forward and backward rotation, and yaw (called the heading or orientation) refers to the direction in which the robot moves in the x-y plane. The differential-drive robot moves from x-y in the plane, so the 2D pose consists mainly of x, y, and θ, where θ is the head of the robot that points in the forward direction of the robot. This much information is sufficient to describe a differential robot pose.

Many mobile robots use a drive mechanism known as Differential drive. It consists of 2 drive wheels mounted on a common axis, And each wheel can independently being driven either forward or backward. While we can vary the velocity of each wheel, for the robot to perform rolling motion, the robot must rotate about a point that lies along their common left and right wheel axis. The point that the robot rotates about is known as the ICC –instantaneous Center of Curvature .By varying the velocities of the two wheels, we can vary the trajectories that the robot takes. Because the rate of rotation! About the ICC must be the same for both wheels, we can write the following equations

$$\omega\left(R + \frac{l}{2}\right) = V_r$$
$$\omega\left(R - \frac{l}{2}\right) = V_l$$

where l is the distance between the centers of the two wheels, Vr ; Vl are the right and left wheel velocities along the ground , and R is the signed distance from the ICC to the midpoint between the wheels. At any instance in time we can solve for R and ω:

$$R = \frac{1}{2}\left(\frac{V_l + V_r}{V_l - V_r}\right)$$
$$\omega = \frac{V_l - V_r}{l}$$

There are three interesting cases with these kinds of drives.

1. If V_l = Vr, then we have forward linear motion in a straight line. R becomes infinite, and there

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is effectively no rotation ω is zero.
2. If V_l = -Vr, then R = 0, and we have rotation about the midpoint of the wheel axis - we rotate in place.
3. If V_l = 0, then we have rotation about the left wheel. In this case R = l/2Same is true if Vr = 0.

Note that a differential drive robot cannot move in the direction along the axis - this is a singularity. Differential drive vehicles are very sensitive to slight changes in velocity in each of the wheels and Small errors in the relative velocities between the wheels can affect the robot trajectory and they are also very sensitive to small variations in the ground plane, and may need extra wheels (castor wheels) for support.

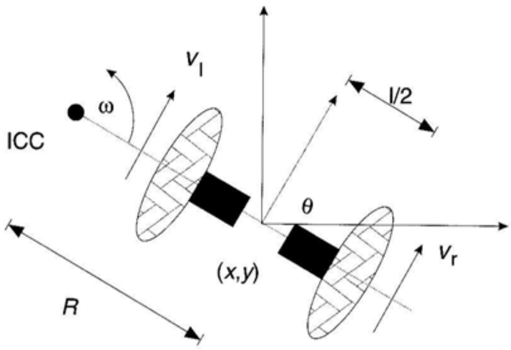

Fig 2: Differential Drive kinematics

Forward Kinematics for Differential Drive Robots

In figure, assume the robot is at some position(x;y),headed in a direction making an angle with the X axis assume the robot is centered at a Point midway along the wheel axle. By manipulating the control parameters Vl;Vr we can get the robot to move to different positions and orientations.(note:Vl;Vr) are wheel velocities along the ground).Knowing velocities Vl;Vr and using equation 3,we can find the ICC location:

Inverse kinematics

Inverse kinematics refers to the reverse process. Given a desired location for the tip of the robotic arm, what should the angles of the joints be so as to locate the tip of the arm at the desired location that means given a desired end-effector pose (position +orientation), find the values of the joint variables that will realize it.

V.SIMULATION RESULTS

Mapping using ultrasonic sensor and Matlab software.

Initial mapping of robot is done using low cost ultrasonic sensor and Matlab software. Range of Ultrasonic sensor is from 2 cm to 4 m. Ultrasonic sensor is used to measure real time distance of obstacle from robot using Arduino microcontroller and servo motor is used to rotate ultrasonic sensor from 0^0 to 180^0 and again from 180^0 to 0^0 . Confined space is created using thick paper sheets. These real time data is taken from Arduino port to Matlab and map is plotted as shown below. Serial data logger of Ultrasonic sensor with time is also shown below. Also distance data that we got was not smooth and linear. So here we used Kalman filter to to filter that data and we got smooth readings and ultimately map. We also placed some dynamic obstacles that was also detected in map.

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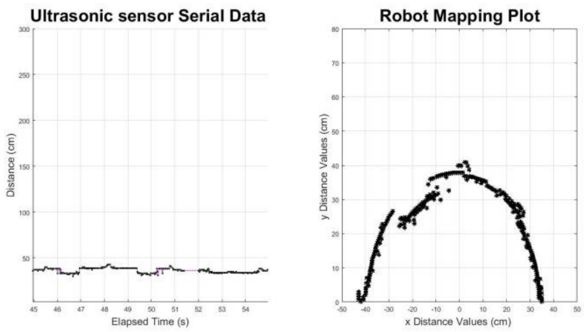

Fig 3: Robot mapping without object inside

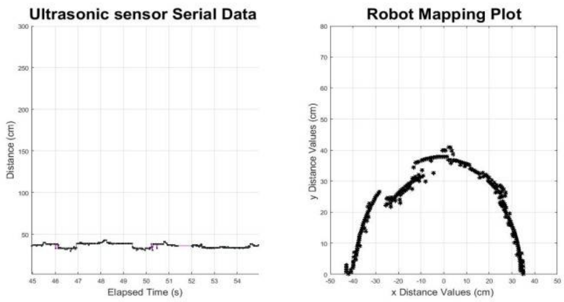

Fig 4: Robot mapping with object inside

Robot mapping plot with and without filter

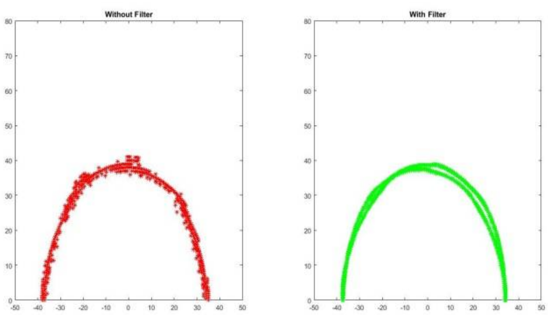

Fig 5: Robot mapping without object inside

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Robot mapping plot with and without filter object inside

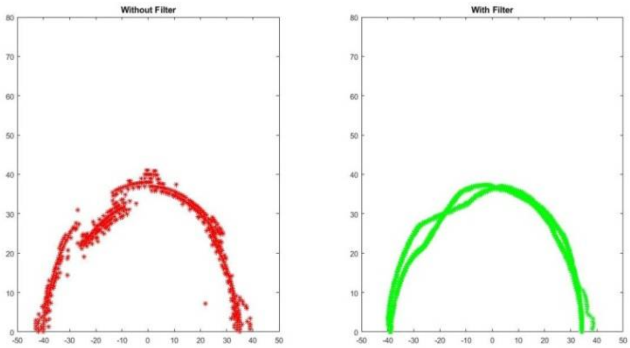

Fig 6: Robot mapping with object inside

VI. CONCLUSION

The processes of the integration of ROS with the mobile robot platform and the Microsoft Kinect depth sensor to conduct SLAM in an unknown and dynamic environment were investigated. The SLAM components were tested as the mobile Robot was wirelessly tele operated from keyboard commands, creating a map of the unknown environment. Normally high cost laser scanner is used for SLAM but we replaced it with low cost 3D Kinect sensor. ROS, with its modular architecture and object-oriented programming, provided a simple, yet robust, framework for the mobile robot platform, depth sensors, map construction packages to work harmoniously together in order to accomplish the objectives. And finally, with the integration of ROS and the Microsoft Kinect, Simultaneous Localization and Mapping of an unknown environment were successfully conducted resulting in the robot achieving its goal while identifying and mapping obstacles. Three-dimensional SLAM could be another interesting way ahead with this platform.

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