IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Odometry Calibration

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ABSTRACT

Odometry is the most widely used method for determining a mobile robot's current position. Odometry gives conveniently accessible real-time positioning information in between periodic absolute location measurements in most practical applications. In differential-drive mobile robots, the most common sources of systematic error in odometry measurements are: a) uneven wheelbase and b) uncertainty about the effective wheelbase diameters. These errors are nearly constant and accumulate overtime. Therefore, there is need to calibrate the odometry sensor. In literature, it has been found that turn table method is widely adopted by the most of the researchers. In the proposed work, we are going to introduce hexagonal table for the calibration of odometry sensor. Finally, obtain result will compare with the traditional calibration methods.

INTRODUCTION

Vehicle's position in relation to a known starting position Odometry is simple, low-cost, and quick to do in real time, The limitless nature of odometry is one of its drawbacks. One of the most common techniques is odometry where the wheel encoder signals are used to find out the current position of a robot with reference to its starting point. But this technique is strongly influenced by the wrong parameter estimation and changes in environmental conditions like floor roughness, wheel slippages, etc. Odometry errors can be classified into two categories: systematic error and non-systematic error. Usually, internal systematic factors like wheel diameters, distance between two wheels, etc. cause systematic error and it shows biased characteristic. In contrast, non-systematic errors, which depend on robot environment interaction parameters like floor roughness, wheel slippages etc., are independent of systematic features and has an unbiased (random) characteristic.

Borenstein et al investigated the potential causes of Errors in odometry Borenstein and his colleagues based their findings on these studies. Fen popularized a geometric approach known as The UMB method is used to calibrate some systematic inaccuracies on closed rectangular paths Kelly proposed a general solution based on the linearized error equation.

Following the pioneering work of Arimoto et al., various learning algorithms for various types of repetitive systems have been developed during the last two decades.

Iterative learning control (ILC) is a novel feed-forward control method that was proposed. Zhang et al. came up with the idea. For discrete-time linear systems, an ILC approach is used. An example is seen in ILC is found for discrete-time nonlinear systems. Casalino& Bartolini devised a control learning algorithm for Manipulators for robots These methods for learning are based on the full trajectory's measurement signals However, in Sometimes, an actual system is used to obtain the measurements for the entire journey becomes extremely difficult and pricey. To address these issues, point-to-point ILC (also known as Terminal ILC (TILC) is a type of ILC that utilizes data from end points. A terminal ILC-based odometry calibration technique is provided in this paper. First, for discrete time-varying nonlinear systems, a terminal ILC algorithm is developed. The existence of the is a sufficient condition.

1.2 Problem Statement

We focus on systematic errors:

- Unequal wheel diameters
- Actual wheel base different from nominal wheel base

1.3 Objective of the project

Computation of systematic parameters in odometry using hexagonal turn table.

1.4 Limitations of existing work

Due to sharp turn in square turn table slippery floor can be create problem in computation of calibration parameters.

1.5 Organization of documentation

The reminder of the documentation has been organized as follows:

Chapter 2 has been devoted to the literature of odometry calibration. In these strengths and limitations of existing systems have been discussed. Additionally, the gaps in research have been identified and requirement of for the research towards development of odometry calibration has been explained.

Chapter 3 Introduces the technologies and their background theories which has been used and implemented towards achieving the research objective.

Chapter 4 proposes odometry calibration system; its designs, architecture, sensors, algorithms, and development. Further the flow-of-control within the system. Interfacing sensors and connectivity issues have been explained in this chapter.

Chapter 5 provides the obtained results and discussion.

Chapter 6 Includes the conclusion of the research work. It also summarizes the contribution of the research work and its future scope of the work.

Literature survey

For the calibration of specific systematic errors on rectangular shut directions, Feng presented the UMB technique, a typical mathematical strategy. At the point when a robot can assess its own position utilizing outside sensors, for example, ultrasonic, lasers and vision.

The results of the tests show that there has been an impressive improvement in contrast with UMB mark, odometry exhibitions are better and show better execution in correcting precise missteps proposed a two-wheel differential drive robot odometry alignment strategy that produces into account the consolidated results of jumbled wheel breadths and wheelbase mistake. The chip is remembered for the remote-controlled model auto versatile. The turning encoder RE12D17 is utilized for restriction, while the ATmega12815,16 is utilized for movement control. for the estimation of outright situating, and the business outright situating sensor Stargazer18 the vehicle's position. The Stargazer is an area sensor that is monetarily accessible. utilizes man-made land denotes the consequences of the trials gave uncover that the result. The UMB mark method5 takes with the understanding that the wheel width blunder and the wheelbase mistake are autonomous. By and by, this supposition that is invalid in light of the fact that the wheel distance across blunder and the wheelbase mistakes at the same time happen. Likewise, estimation accepts that the wheel measurement blunder and wheelbase mistake are autonomous. Considering the coupled impact of two mistake sources works on the odometry alignment exactness.

Jung [5], proposed an odometry alignment plot for a two-wheel differential drive robot that includes estimating the last direction mistakes after a trial. Utilizing these direction blunder estimations, guess mistakes are killed, and the alignment exactness I gotten to the next level . The traditional UMB mark method5 includes estimate mistakes related with the little point approximations utilized. It is challenging to track down odometry adjustment plans for vehicle like portable robots.

McKerrow [6] proposed an alignment conspire for controlling point and kinematic boundaries of vehicle like versatile robots. In this scheme, the odometry mistake is demonstrated by acquainting three boundaries with describe the controlling point and the wheel breadths. Every boundary of McKerrow's odometry model is characterized utilizing left and right wheel encoder data. For McKerrow's method,12 extra reach sensor data and reach sensor alignment are required. Lee13,14 proposed an odometry alignment conspire for a vehicle like portable robot that includes estimating the last position mistakes after bear witness to run. The test track is comparative in shape to a 400-m running track.

Lee [7] checked that the limitation exactness of the plan is moved along by utilizing the EKF to join the encoder information from the front wheel sand back tires. It has been checked that the odometry adjustment precision can be improved by utilizing the last direction mistakes rather than the last position errors.10,11 Lee's technique for a vehicle like versatile robot is a valuable strategy for alignment of vehicle like portable robots. In any case, Lee's method additionally includes estimate blunders related with little point approximations, since Lee's strategy utilizes the last position.

As indicated by Marlon G. Boar net (Ross, 2014, p. 90), an expert in transportation and metropolitan development at the University of Southern California "Around each two ages, we modify the transportation foundation in our urban areas in manners that shape the imperativeness of neighborhoods; the settlement designs in our urban communities and open country; and our economy, society and culture" and as many accept, independent driving vehicles are this new huge change everybody is discussing. Driving not exclusively to high effect natural advantages, for example, the improvement of mileage.

Zhang et al. created an ILC strategy for discrete-time direct frameworks. In [4], an ILC for discrete-time nonlinear frameworks is determined. Casalino what's more Bartolini fostered a learning control calculation for robot controllers. These learning calculations work based on the estimation signs of a whole direction. Yet, in a genuine framework, once in a while, getting the estimations for the whole direction turns out to be truly challenging and furthermore expensive. To conquer these issues, highlight point ILC (likewise known as terminal ILC (TILC)), which utilizes the information of end focuses

just, has come into picture.

Chapter-3

Background Theory

3.1 Introduction

Odometry is the utilization of information from movement sensors to assess change ready after some time. The details of odometry estimation varies by vehicle design. In the context of mobile robots perhaps the simplest vehicle for odometry estimation is the differential drive vehicle. Odometry utilizing wheel encoders gives essential posture assessment for wheeled versatile robots.

Odometry is used for navigation purposes, it is used in advanced mechanics by a few legged or wheeled robots to assess their position comparative with a beginning area. There are many sources of error in the odometry calculations and can be partitioned into two gatherings. One is the systematic errors the other is nonsystematic error. Systematic error is not determined by chance but is introduced by an inaccuracy. To demonstrate the systematic errors definitively utilizing square way test, the experimenter needs to put a lot of work to program the robot to follow square way, to carry out the regulator and afterward to record beginning and last positions cautiously. Lee proposed an odometry calibration scheme for a two-wheel differential drive robot that considers the coupled effect of unequal wheel diameters and wheelbase error. Jung proposed a odometry calibration method for a two-wheel differential drive robot. In this technique, only the end heading error was used for the odometry calibration. heading errors are used to eliminate approximation errors and improve calibration accuracy. Borenstein al investigated the potential causes of Errors in odometry Borenstein and his colleagues based their findings on these studies. Fen popularized a geometric approach known as The UMB method is used to calibrate some systematic inaccuracies. Objective of project is to computation of systematic parameters in odometry using hexagonal turn table. In this proposed work we will utilize a differential drive robot on a hexagonal path to obtained calibration parameter. Optical encoder will be used to measure the position velocity of robot. Optical encoders are attached to wheels of robot.

3.2 Errors Modeling

3.2.1 SYSTEMATIC ERRORS

Systematic errors are generated by imperfections in the robot's kinematics and are particularly dangerous since they build over time. Uneven wheel diameter and wheelbase uncertainty plays a bigger role. The issue of mismatched wheel sizes because of the unequal weight distribution and the softness of the material. The wheels are made of compressible material, yet they are soft to avoid slipping.

Observing actual state covariance is not as simple as it is in the systematic situation. We'll look at the parameters of a random process to see what they are Undoubtedly, you'll need to follow various paths and make use to quantify the variation of a point or locations along the way the actual variation to repeatedly execute the same path Occasionally, the condition that we ensure would be introduced. The following methods can be used to reduce random error: Increasing sample size or using an average measurement from a set of measurements.

Systematic mistake is difficult to detect – and so prevent. To avoid making these kinds of mistakes, be aware of your equipment's limitations and how the experiment works. This can assist you in identifying places where systematic errors are likely to occur. Several studies have considered this issue and proposed solutions. Among these, the UMB mark method is widely used. In the UMB mark method, a differential-drive robot was controlled to follow a square path, where the odometry was calibrated based on the error between the final pose and the predicted pose.

Versatile robots utilize elastic tires to further develop footing. However, these tires are hard to be produced precisely in something similar breadth. This will cause significant odometry mistakes. Indicating this mistake as E_d also characterizing it as:

$$E_d = \frac{D_R}{D_L}$$

where D_R and D_L are the actual wheel diameters.

Dubious of the powerful wheelbase is brought about by the reality that elastic tires contact the floor not in a point, yet rather in a contact region. Indicating this blunder as E_b and characterizing it as:

$$E_b = \frac{b_{actual}}{b_{no\min al}}$$

where actual b is the actual wheelbase of the robot, no al min b is the nominal wheelbase of the robot. On the off chance that the normal of the genuine wheel widths D_a contrasts

from the ostensible width D_n, the robot will encounter an extra odometry mistake, which is called scaling blunder E_s:

$$E_s = \frac{D_a}{D_n}$$

A. The Source of Linear Motion Error

The scaling blunder E_s incorporates the sidelong dislodging blunder and direction mistake. The unidirectional square way incorporates four 90 degrees fixed-point pivot, the horizontal uprooting mistake can be redressed, so the impacts of E_s on direct movement can be overlooked All in all, main the wheel measurement blunder E_d has an impact on direct movement. It is equivalent to ordinary UMB mark technique. The inconsistent width of the wheels lead to a genuine direction of straight portable robot movement turning into a bend with a specific curve.

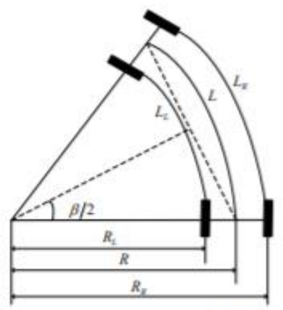


Fig. 1. The effects of E_d on linear motion.

Fig.3.1 The effects of E_d on linear motion

B. The Source of Fixed-Point Rotation Error

The impacts of E_d on fixed-point pivot from area A, we realize that the inconsistent distance across of the wheels lead to the real direction transforming into a curve with certain bend. It makes the portable robot produce a certain direction blunder before the fixed-point pivot, so the wheel distance across blunder E_d additionally affects fixed-point turn movement. Characterize α_d as a direction blunder that brought about by the

wheel distance across blunder E_d. The decay chart of fixed-point turn after straight movement is displayed in fig 2,

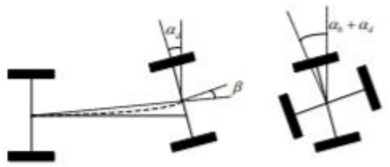


Fig. 2. Orientation error caused by two kinds of errors.

Fig. 3.2 Orientation error caused by two kinds of errors

Where α_b is the orientation error caused by E_b, α_d and β satisfy the following relation [12]:

$$\alpha_d = \frac{\pi \cdot b_{nominal}}{4L} \cdot \beta$$

where no al min b is the nominal wheelbase of the mobile robot;

L is the side length of the square way; β is the direction mistake created in the direct movement

2. The effects of Es on fixed-point rotation

The versatile robot turns at a decent point, the rakish speeds of the wheels on the left and right sides are equivalent what's more inverse, so when the wheel width is inconsistent, the genuine straight speed of the wheel is in direct extent to the genuine measurement of the wheel. Since the direct speed of the two wheels is inconsistent, the quick focal point of speed ' O won't match with the focal point of the wheel hub O. Expecting that the real measurement of right wheel is greater than the real measurement of left wheel, the revolution of the versatile robot is displayed in fig 3:

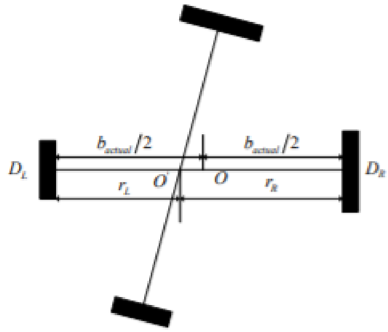


Fig. 3. The fixed-rotation with unequal diameters.

Fig.3.3 The fixed rotation with unequal diameters

The actual rotation angle of the mobile robot is assumed to be τ , it can be deduced from Fig. 3:

$$\frac{D_R}{D_L} = \frac{r_R}{r_L}$$

where r_R and r_L are the distance from O to the right and left wheel.

Further derivation shows that the normal of the genuine breadth D_a, the normal of the ostensible measurement D_n, the real revolution point τ and the ostensible turn point τ_n fulfil the accompanying relations:

$$\frac{D_a}{D_n} = \frac{\tau}{\tau_n}$$

If $D_a \neq D_n$, then $\tau \neq \tau_n$. This is to say, mistake will happen whenever the normal measurement of the wheel is inconsistent to the ostensible distance across, it is characterized as E_s, so, the blunder brought about by E_s cannot be ignored for the fixed-point pivot movement. In this paper, the direction blunder brought about by E_s is characterized as α_s:

$$\alpha_s = \tau - \tau_n \qquad (7)$$

The orientation error caused by E_b is as follows:

$$\alpha_b = \alpha - (\alpha_d + \alpha_s) = \frac{x_{c.g.CW} + x_{c.g.CCW}}{-4L} \cdot \frac{180^\circ}{\pi} - \left[\frac{\pi \cdot b_{nominal}}{4L} \cdot \beta + (\tau - \tau_n)\right]$$

$$E_b = \frac{90^\circ}{90^\circ - \alpha_b} = \frac{90^\circ}{90^\circ - [\alpha - (\alpha_d + \alpha_s)]} \qquad (8)$$

where $X_{c.g.\ CW}$ and $X_{C.\ g.CCW}$ is the abscissa of the focal point off each bunch as agent for the orderly odometry blunders in CW and CCW bearings. Taking everything into account, inconsistent wheel distances across, normal of both wheel measurement

vary from ostensible distance across and unsure about the powerful wheelbase all have consequences for the fixed-point turn movement of versatile robot.

Types of systematic errors:

- Wheels with different diameters
- The actual diameter differs from the standard diameter
- The actual wheel base is not the same as the standard one
- Encoder resolution is limited

NON-SYSTEMATIC ERRORS

Non-systematic errors are more common than systematic errors. Errors that are made on a regular basis are likewise a problem. Identify the position's uncertainty. A characteristic error ellipse surrounds each position, indicating a region of uncertainty The size of the error ellipse grows in proportion to the travel direction until absolute position measurement resets the size of the error ellipse. Only systemic errors are taken into account. so, the spread is the same poses computed at corresponding places would be purely based We're attempting to calibrate owing to a measurement inaccuracy However, in the absence of solid fixtures to direct the movement It is essential for a robot to be able to do repetitive motions to a recurrent position estimation Unless there is an exception truth on the ground.

The following two forms of non-systematic errors are the most common: due to the enormous contact area between the active wheels and the irregular floor surface, the wheelbase has a stochastic nature; Due to the over-acceleration, there is also slippage. The wheelbase is the length of the vehicle. Constantly altering during the robot's activity as the Because of this, the contact points do not remain the same during the test. Surface of the floor is uneven. Because the wheelbase is involved in the calculation, only when the robot executes a turn does the robot do odometrical computations. There is no longer any effectiveness on the strait line pathways. Overall effect of the wheelbase's stochastic character b when running on a path with a lot of twists and turns. As in the bi-directional square path test, the number of turns is there aren't enough to dampen the overall effect.

Types of unsystematic errors:

- Travel through unexpected locations
- Wheel slippage
- Slippery floor

System Architecture

The architecture of proposed system (the differential robot) as shown in figure 3…, we are using optical encoders at wheels of the robot. The proposed system will be consisted two wheels, encoder sensor and processor platform to carry hardware and Each encoder will be used to count the number of rotations of wheels of the robot. These encoders are internally connected to the interrupt pins of the processor. Encoder's measurements will be read and processed by the processor to compute the current position and velocity of the robot. The coming measurements are observed at frequency of 40Hz.

The working functionalities (as shown in figure 3.4) of proposed system are I) read encoder data, ii) process the data and iii) computation of navigation solution. The data from encoders will readout by making interrupts then it will process the data and it will compute the velocity and position of the robot.

Optical Encoder:

Encoders are utilized in electronic gadgets that need to work in fast and with high exactness. The strategy for controlling the engine revolution by identifying the engine turn speed. Encoder speed can be determined by two methods: pulse counting or pulse timing. Pulse counting is to measure the number of pulses per resolution for the encoder. Located directly behind each motor is a wheel encoder. Each wheel encoder is used to count the number of times the motor (left or right) has rotated.

Conclusion

In this chapter we have discussed the system architecture of differential robot by using the above-mentioned software and hardware components. The system is developed by the integrating processor with optical encoder sensor.

System Development

Introduction

The developed and proposed odometry calibration technique for pose estimation of wheeled drive robots using hexagonal path. odometry utilizing steady wheel encoder sensors is a key procedure for present assessment of wheeled drive robots. Odometry suggests the calculation of the general posture of a robot from the known introductory posture from collected encoder information. Adjustment is important to decrease the odometry errors that happen with expanding travel distance. Improved to the next level odometry can fundamentally lessen the functional expenses related with the establishment and upkeep of sensors and tourist spots. Gotten to the next level odometry additionally lessons the vulnerability of the assessed. These functionalities can be achieved by integrating all the technologies as mentioned in chapter 3. The system development will be achieved in three phases are as given below

i) Integration of processor with the encoder sensor
ii) Integration of processor-ESP32
iii) Integration of optical encoder with the hardware

System development

We are utilizing the wooden plate for to connect the differential drive robot.

Which is very cheapest material to run the differential drive robot.

Integration of processor and Encoder

This IR speed module sensor with the comparator LM393, we can ascertain the speed of pivot of the wheels of our robot. Assuming we place a ring gear that turns joined to our wheel. It could likewise be utilized as an optical switch. The essential activity of this sensor is as per the following; If anything is passed between the sensor space, it makes a computerized beat on the D0 pin. This heartbeat goes from 0V to 3.3V and is an advanced TTL signal. Then, at that point, with ESP32 we can peruse this heartbeat. The capacitor that has given the best outcome is the capacitor (562J 250v). This capacitor nearly doesn't misshape the advanced heartbeat produced by the comparator LM393.

For measure the speed of the robot, we can place just two encoders on two wheels or set 4 or 2 encoders on every one of the two wheels. For the optical encoder to work accurately with ESP32 Original. The VCC pin of the encoder should be provided with a voltage of 3.3V from the 3.3V pin of the ESP32. On the off chance that the VCC pin of the optical encoder is provided with a voltage of 3.3 Volts, it creates vortex flows in the computerized beat sign and processor doesn't peruse the encoder beats accurately. Perusing a larger number of heartbeats than they really produce.

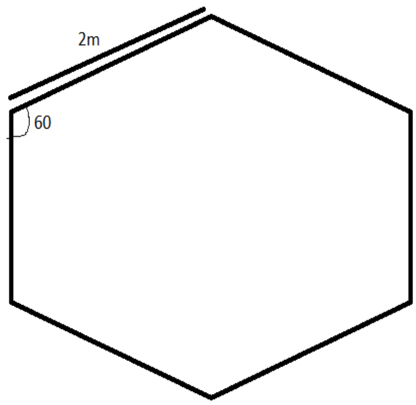
ESP32 Processor

ESP32 is a progression of minimal expense, low-power framework on a chip microcontroller with coordinated Wi-Fi and double mode Bluetooth. The ESP32 series utilizes a Ten silica extensa Deeply microchip or a solitary center RISC-V chip and incorporates worked in receiving wire switches, RF balun, power speaker, low-commotion get intensifier, channels, and power based Chinese organization, and is produced by TSMC utilizing 40nm cycle. It is a replacement to the ESP8266 microcontroller. This ESP32 component uses a debouncing state machine to track the position of an incremental rotary encoder such as the EC11 or LPD3806. ESP32 is a solitary chip 2.4Ghz Wi-Fi and Bluetooth combo chip planned with TSMC super low power 40nm innovation. It is planned and improved for the best power execution, RF execution, strength, flexibility, highlights, and unwavering quality, for a wide assortment of uses, and different power profiles.

Integration of processor and optical encoder

Testing Platform Development

To count the wheel rotations of a standard differential drive mobile robot, incremental encoders are installed on the two drive motors. A hexagonal path has been crated to obtained the calibration parameters. The length of each is about 2 m as shown in Figure 4.3. Robot will follow exact path as shown and measurements will recorded inside memory.

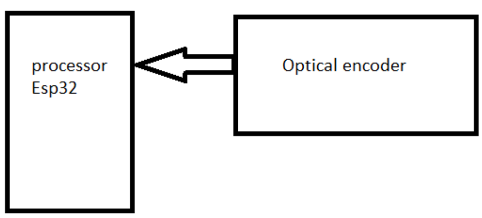


Hexagonal Path

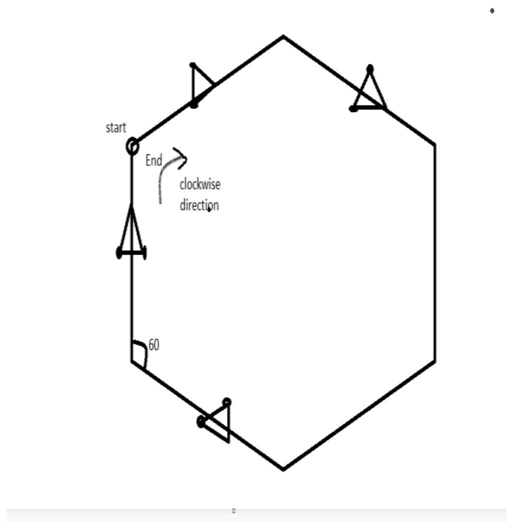
Testing and results

Introduction

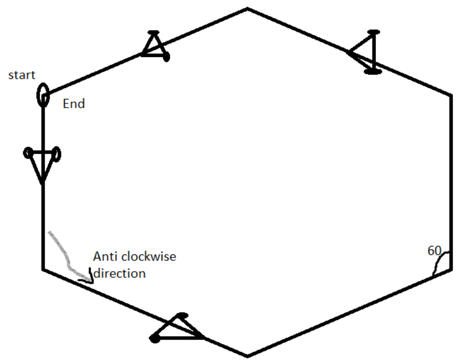
We are testing the robot in hexagonal path as we discussed in 4.3. To measure the length and position velocity of the robot. We are using least square method to measure the length and velocity of differential drive through robot.



Testing of robot



testing of robot in clockwise direction



testing of robot in anti-clock wise direction

Results

We have been successfully conducted the testing part. And took observation. The remaining part is analysis of the data and computation obile Robot,"

of base length and radius of wheels will do in future.

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