

Mobile Robots Lab Report

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Abstract

The robot localization problem is a key problem faced in modern day mobile robots. This problem involves obtaining “clean” data about the robot’s environment, determining the current location of the robot, and deciding on an optimal travel path towards a desired location. The robot receives information from its environment via robotic sensors (wheel encoders and sonar range finders). The robot then uses the sensor data and information about its previous location to determine its current location.

Mobile robot simulation software is a useful tool for designing and testing localization algorithms. Aria is a C++ SDK used for developing and testing mobile robot software. MobileSim is a simulation software for testing mobile robot software which uses Aria. Both Aria and MobileSim were used to develop and test mobile robot software.

Contents

1	Introduction	2
1.1	Dead Reckoning	2
1.2	Wheel Encoders	3
2	Methods	5
2.1	Square Path Robot	5
2.2	Sonar Measure Robot	5
2.3	S-Curve Robot	5
3	Results	5
4	Conclusion	5

List of Tables

1	Phases of Quadrature Encoder	4
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List of Figures

1	2 Wheeled Robot (Side view)	2
2	Robot Motion Model from $t = 0 - \Delta t$	2
3	Quadrature Encoder	4
4	Quadrature Encoder Signals (90° phase shift)	4

1 Introduction

1.1 Dead Reckoning

Robot localization is crucial to effective robot locomotion. Various methods are used to determine the current and future locations of robot; each unique to the available sensors, robot structure and environment. Dead reckoning is one of the simpler methods used. It requires as few sensors as possible and relies mostly on known motion models and states. Dead reckoning is a method of finding the location of an object based on a known motion model and current state information. Once the current state of an object is known then its motion model can be used to predict future motion states. For example, one can predict the future position of a robot if it is known that that the robot is moving in a straight line and at a constant speed and its current position.

A two wheeled robot as shown in Figure 1 will be used for our analysis of dead reckoning. Two wheeled odometry is used to create a motion model of the robot which is then used to predict future locations of the robot. In this study only the x and y coordinates are of interest although velocity can easily derived.

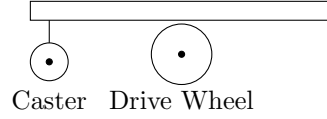


Figure 1: 2 Wheeled Robot (Side view)

We will begin our analysis with the odometry model of the two wheeled robot. The odometry model is as follows (its derivation is beyond the scope of this report):

$$P(t) = \begin{bmatrix} S \\ \theta \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & \frac{1}{2} \\ \frac{1}{w} & -\frac{1}{w} \end{bmatrix} \begin{bmatrix} S_R(t) \\ S_L(t) \end{bmatrix} \quad (1)$$

Where S and θ respectively are the robot distance travelled and heading of the robot. S_L and S_R are the distances traveled by each wheel (left and right respectively). w is the distance between the contact points of the wheels of the robot.

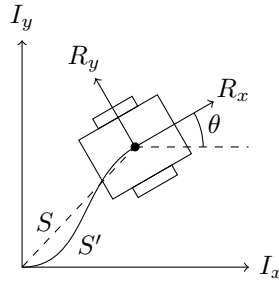


Figure 2: Robot Motion Model from $t = 0 - \Delta t$

From Equation 1 we can create a motion model relative to the inertial frame of reference I (as shown in Figure 2). To simplify our analysis the following is assumed:

- The robot's motion model is measured on a time differential Δt that is small with respect to the total time (T) the robot performs its motion.
- The robot's wheel encoders are error-less and no wheel slipping occurs.
- Δt is chosen to be small enough so that $S' - S \approx 0$ and thus $S' = S$.

From these assumptions we have a motion model for the robot:

$$\xi_i = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix} = \begin{bmatrix} \cos \theta & 0 \\ \sin \theta & 0 \\ 0 & 1 \end{bmatrix} P(t_i + \Delta t) - P(t_i) \quad (2)$$

ξ_i is the position of the robot after some time lapse Δt . Thus to get the current position of the robot after some time T simply sum the interval position changes¹:

$$\xi(T) = \xi_0 + \sum_{i=0}^n \xi_i : n = \frac{T}{\Delta t} \quad (3)$$

Equation 3 simply means that given the robots initial position (ξ_0) and a sequence of wheel distance measurements for $t = \{\Delta t, 2\Delta t, \dots, T\}$ the position of the robot at T can be predicted. This of course is only valid for the above assumptions.

Dead reckoning is not practical when used alone. Sensor noise, wheel slippage, and distance estimation error ($S - S'$) all affect the outcome of Equation 3. However dead reckoning is not completely useless. In fact it forms the base motion model for other filter and motion estimation algorithms (such as the Kalman filter²).

1.2 Wheel Encoders

As seen in Equation 1 the robot's motion model is dependent on wheel distance travelled. Sensors that can translate rotational wheel motion to linear distance traveled are called wheel encoders. Different types of encoders are available each with their advantages and disadvantages. In this study we will examine a quadrature wheel encoder.

A quadrature encoder uses a disk (as shown in Figure 3) and two optical sensors to track the position of a wheel. The disk is patterned with alternating opaque and transparent wedges. As the disk spins the optical sensors produce a logic signal (0 or 1) respective to the wedge type it is over. The two sensors are placed in such a manner that their output waves are 90° out of phase (see Figure 4). The encoder coupled with the wheel in such a manner that the disk spins with an angular velocity that is proportional to that of the wheel.

¹A continuous form of Equation 3 is beyond the scope of this lab and is not needed computationally.

²https://en.wikipedia.org/wiki/Kalman_filter

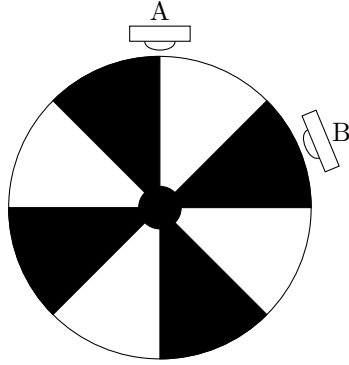


Figure 3: Quadrature Encoder

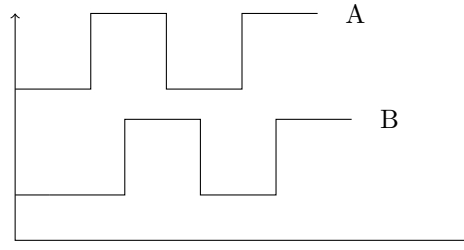


Figure 4: Quadrature Encoder Signals (90° phase shift)

The output from the encoder is read by software (via interrupts) and mapped to encoder positions and the directions the encoder rotated. The encoder output can be mapped to 4 different phases as shown in Table 1. The direction of the encoder can be determined by two successive phase changes. For example if the current phase is 2 and on the next encoder reading the phase is now 1 the encoder is rotating clockwise.

Phase	A Signal	B signal
0	0	0
1	1	0
2	1	1
3	0	1

Table 1: Phases of Quadrature Encoder

To determine the acceleration and velocity of the wheels the encoder signals are simply

sampled over time. That is software can determine the number of phase changes per second (the velocity) by counting the time between phase changes.

Quadrature encoders provide the robot with an interface with its lateral movement. The lateral distance that each wheel travels is:

$$S_{L,R} = Rn\mu \quad (4)$$

Where $s_{L,R}$ is the lateral distance of the wheel traveled, μ is a constant in units of $[\frac{radians}{pulse}]$, n is the number of pulses, R is the radius of the wheel. The translational velocity of the wheels can be found from Equation 4:

$$\dot{S}_{L,R} = \frac{S_{L,R}}{\Delta t} \quad (5)$$

Note that Δt is the same as that in section §1.1.

2 Methods

2.1 Square Path Robot

2.2 Sonar Measure Robot

2.3 S-Curve Robot

3 Results

4 Conclusion