Jaguar Lite Point Tracking

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***Abstract*—This paper describes the implementation of point tracking for the *Jaguar Lite Mobile Robot Platform*. Motion control of the autonomous vehicle is achieved using a Proportional-Integral-Derivative controller. In both simulation and hardware mode, the control law parameters and control gains have been tuned to demonstrate stable, precise motion towards desired goal states.**

I. Introduction

Point Tracking refers to a robot's ability to transition from one pose to another on a known map of its environment. By modeling the robot's drive train with a motion model and by incorporating odometric sensor reading into this motion model, the robot can develop a trajectory between points. In the following paper, we incorporate both a differential drive-train motion model with a PID-controlled differential drive train to designate the Jaguar Lite robotic platform to track points on a two-dimensional environment.

A. Hardware Platform

The hardware platform of choice is a Jaguar Lite autonomous vehicle, sourced by Dr. Robot. This differential-drive platform is fairly rugged, and features a suite of sensory inputs: a 9 DOF Inertial measurement unit (IMU), two rotary encoders, a 240° field-of-view laser range finder, and an on-board webcam [**?**]. With a wireless wifi interface, the designer can implement navigation algorithms in *C#* within Microsoft Visual Studio to communicate with the Jaguar platform. Most importantly, the platform can be driven both indoors and outdoors.

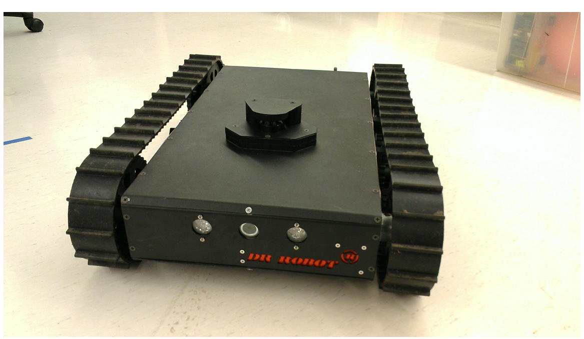

Figure 1.

B. Terminology

This paper refers to specific definitions and usage of the following terms:

- **Pose** represents the robot's position: $[x, y, \theta]$ relative to a coordinate frame fixed to the environment that the robot navigates.
- **Nonholonomic Constraints** refers to a restricted motion path constrained by the physcial construction of the robot. On a two-dimensional coordinate frame, a robot that can freely rotate and translate is considered a holonomic robot.
- **Point Tracking** refers to the Jaguar Lite's ability to transfer from one pose to another on a navigable coordinate frame.

II. Method

A. Motion Model

To determine the robot's motor outputs, an effective motion model which reflects the robot's holonomic constraints must first be developed. The Jaguar Lite moves with a differential drive train. For this reason, the motion model cannot incorporate direct translation of the robot in a direction normal to the sides of the robot. Figure XXXX illustrates possible trajectories, each of which is governed by the speed of the right wheel, ω_1 and the left wheel, ω_2.

Given a differential drive train, we can have chosen the following motion model [**?**]:

$$\rho = \sqrt{\Delta x^2 + \Delta y^2} \tag{1}$$

$$\alpha = -\theta + atan2(\Delta y, \Delta x) \tag{2}$$

$$\beta = -\theta - \alpha \tag{3}$$

In the equations above, x and y define the horizontal and vertical displacements respectively, relative to a fixed initial coordinate frame. θ defines the angular displacement of of the robot normal vector relative to the x axis. ρ defines the magnitude of the displacement from the robot pose to the desired pose. α defines the error of the robot normal vector relative to the desired angle relative to the goal. β defines the angle of the goal vector relative to the horizontal. These angles are depicted in the illustration below:

The above equations are sufficient to determine the error in the robot's pose from the desired pose, as well as the linear and angular corrections that must be made. Next, by weighing the errors, two more equations can be produced, which define the Jaguar Lite's *linear*, v, and *angular*, ω, velocities as a function of the error values: ρ, α, and β.

$$v = k_\rho \tag{4}$$

$$\omega = k_\alpha \alpha + k_\beta \beta \tag{5}$$

where k_ρ, k_α, and k_β are constants.

Therefore, given that equations [4] and [5] model the Jaguar Lite's desired change in displacement over time, the equations below must ultimately be solely determined from the rotations of the left and right wheels. Equations [6] and [7] fulfill this requirement.

$$\omega(t) = \omega_1 + \omega_2 \tag{6}$$

$$v(t) = L\left(\omega_1 - \omega_2\right) \tag{7}$$

where L is the radius of the robot. Thus, the overall left and right angular velocities, ω_1 and ω_2, may be determined by combining the previous equations to produce:

$$\omega_1 = \frac{v}{2L} + \frac{\omega}{2} \tag{8}$$

$$\omega_2 = -\frac{v}{2L} + \frac{\omega}{2} \tag{9}$$

Assuming the robot is travelling on a circular arc of constant radius, we can apply basic circle geometry to calculate the distance traveled Δs and the change in orientation $\Delta\theta$ of each tread of the Jaguar Lite robot for time step Δt. These changes in displacement are within the local coordinate frame of the robot. To convert the position change of the robot into the global coordinate frame, we assume that the robot's motion is small in a given time step. As a result, the robot's trajectory can be approximated to be a straight path, and using trigonometry we derived the following equations to determine the change in position within a global coordinate frame, where L is the radius of the robot.

III. Results

IV. Conclusion

Acknowledgment

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