Implementation of Path Tracking On Lunar Robot

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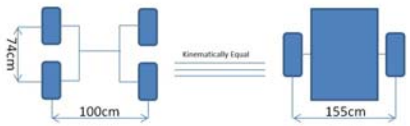
Introduction

Following a path under kinematic constraints – i.e. bounded velocity and acceleration – is a crucial element in mobile robotics that enables autonomous, goal-oriented exploration. Effective solutions to this problem are not readily apparent in lunar and planetary traverse, where soft soil may cause rovers to diverge significantly from intended paths. This project applies two classical path-tracking strategies and compares their performance on a lunar robot in high-slip scenario. Experimentation is conducted on the “RedRover P3” lunar robot platform.

Rover Model

Prototype 3

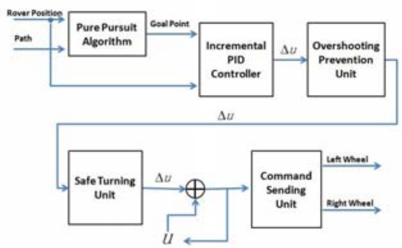
The experimental platform, Prototype 3, is a 4-wheel skid steer rover. Wheels on each side are coupled with a chain drive, and both sides can be driven independently. Skid steer rovers are similar to classical differential drive rovers, however, they turn by sliding wheels against the terrain. This sliding interaction, which is a function of geometry, terrain materials and frictional forces, is often too complex to model accurately in application. Fortunately, according to [1], there exists an approximate differential drive model kinematically equivalent to skid steer. For simplicity of development and testing, a differential drive approximation is utilized.



Kinematic equivalence between P3 and a differential drive vehicle

Methods

PID Control



Data flow diagram of path tracking algorithm based on PID(u is a control variable controlling how much rover should turn)

The procedure is described as follows:

(1) Using a predefined path and current rover position, a pure pursuit algorithm[2] calculates incremental goal points for the rover to follow.

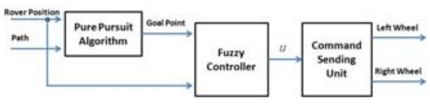
(2) A PID controller[3] computes heading error between the goal point and rover state and then outputs Δu that represents a value added to the current control variable u. The reason for choosing incremental PID is that it can be used to fit the acceleration limit naturally.

(3) An overshooting prevention module then catches the output of PID controller. This module compensates for overshooting by comparing the estimated time to decrease the angular velocity to zero and the estimated time to get onto the trajectory.

(4) A Safe turning unit limit the max turning speed in order to conform to the max speed limitation.

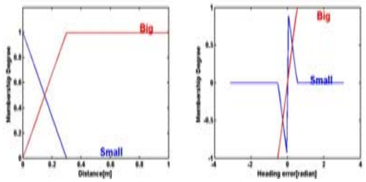
(5) A Command Sending unit translates the control variable to the speed of left and right wheels.

Fuzzy Control[4]



Data flow diagram of fuzzy control(u consists of the velocity of right and left wheel)

The linguistic rules of the fuzzy control method utilize the magnitude of distance and heading errors between the rover and goal point.



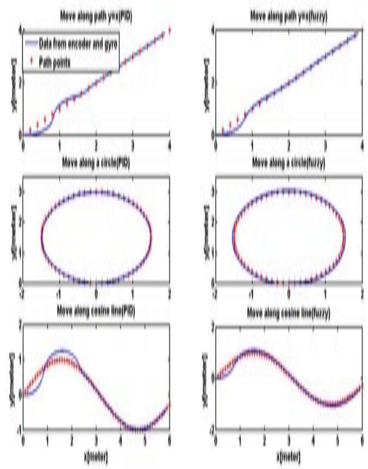
Membership functions

The fuzzy controller utilizes the degree from the membership functions shown above to calculate the left and right wheel velocities.

Experiments

Experiments on ideal plain ground

Several experiments are carried on the highbay ground in Gates Center before running in high-slip scenario. The experiment results are shown as follows:



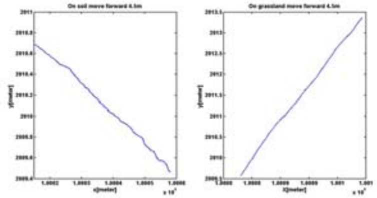
Experimental data collected from encoder and fabric optic gyro are shown in contrast with the predefined path. Left column is the results of PID controller and the Right column is the results of fuzzy controller.

From the pictures shown above, fuzzy controller shows less overshooting problem than PID controller. In the cosine line graph, Fuzzy controller converges more quickly and overshoots less. However, both controllers converge to the intended path at last for good experiment conditions(flat ground and no slippage).

Experiments on slippery ground

Running on the grassland and soil

Running environment is set on the grassland and soil to simulate the high-slip scenario. Only PID controller is tested in the field experiments. Straight line path is tested on both scenes.



Overview of the path when rover is commanded to move forward 4.5m

The graphs shows that P3 zigzags along a straight line.

This is mainly because the ground is not plain and slippery. PID controller needs to adjust the rover to the right direction all the time.

Another experiment is done on the grassland to move P3 along a 1m*3m rectangle. The rover did not finish the task for it sank at middle way.

References

[1] Mandow A, Martinez. J. L., Jesus M, Blanco J. L. . Garcia. C. A and Dpto.J.G, “Experimental kinematics for wheeled skid-steer mobile robots”, Intelligent Robots and Systems, 2007.IROS 2007. IEEE/RSJ

[2] Coulter, R. C. , ”Implementation of the Pure Pursuit Path Tracking Algorithm”, CMU-RI-TR-92-01. RI of Carnegie Mellon University

[3] Suresh Golconda, “Steering Control for a Skid-steered Autonomous Ground Vehicle at Varying Speed”, February 23, 2005

[4] Lee, T.H.. Univ., Kowloon, China Lam, H.K.; Leung, F.H.F.; Tam, P.K.S, “ A practical fuzzy logic controller for the path tracking of wheeled mobile robots” , Control Systems, IEEE(Volume:23, Issue:2)

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