

Implementing Intelligent Electronic Traction Control Systems in Robotic Platforms

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Abstract

Automobiles have a unique way of distributing power to two or four wheels via a differential. This simple piece of automotive engineering has proven to be useful in contemporary vehicles when faced with tire slippage. Differentials solve this problem by means of a traction control system in order to distribute the power elsewhere to regain traction. Implementing an electronic traction control system onto a robotic platform can serve as an intelligent traction systems to control each individual wheel.

Purpose

In this project, we aim to supersede the concept of the differential by implementing an intelligent electronic traction control system onto our robotic vehicle. Our robot is outfitted with four mecanum wheels, each individually driven by a motor. By monitoring each wheel's angular velocity and current/torque, we can determine when a wheel is slipping and therefore adjust the slipping wheel in order to regain traction.

Introduction

Traction control is defined as a system that helps limit the tire slip due to acceleration on slippery platforms. Differentials are used to help tires regain traction by controlling the output level of torque in the motors which allows each wheel to rotate at different velocities. Figure 1 displays some of the components used in a traction control system.

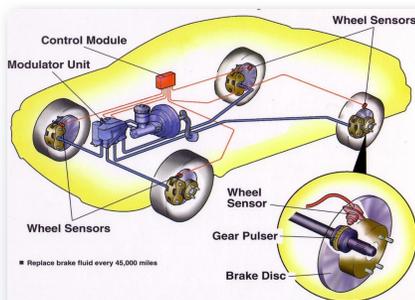


Figure 1: Traction Control System, <http://hdabob.com/the-vehicle/traction-control/>

According to research done by Hanai, Marani, and Choi (2010), they developed an automatic thrust redistribution algorithm for an underwater vehicle to generate a solution to help distribute the thruster forces to each motor when one is losing thrust while still trying to maintain the desired motion. In other research done by Hartani, Bourahla, Miloud, and Sekour (2009), they mentioned that by having a motor for each wheel on a vehicle, it increases the vehicle's power and weight distribution without the use of transmissions, drive shafts, and differentials by monitoring each wheel's drive torque and braking force. Because each wheel is individually driven by a motor, there is no power loss between the differential gear, thus the stability of the vehicle is increased.

For our research, our robot is outfitted with four mecanum wheels, each wheel individually driven by a motor. Similar to the research done by Dr. Hartani, we can measure each individual wheel's angular velocity through encoders as well as the amount of current being supplied to each motor through motor controllers. Equipping our robot with mecanum wheels allows our robot to achieve a special motion called holonomic motion. Holonomic motion is defined as being able to control all of the degrees of freedom (DOF) that a rigid body system has. These degrees of freedom can be shown in Figure 2. The uniqueness of holonomic motion allows our robot to maneuver in any direction without disrupting its orientation.

Introduction (Continued)



Figure 2: Degrees of Freedom, http://www.worldwidelflood.com/ark/anti_broaching/wave_yaw.htm



Figure 3: 10" Mecanum Wheel, <http://www.andymark.com/product-p/am-0583.htm>

Mecanum wheels are special wheels with rollers mounted at a 45° around the entire wheel. When the rollers are configured to look like an "X," this allows the robot to achieve holonomic motion.

Method

Before collecting data, our group brainstormed a list of possible scenarios where a wheel may lose traction and constructed a list of solutions to each scenario. These heuristic rules served as our foundation for our project.

To define a Traction Coefficient we performed three main experiments:

1. Run the robot under normal conditions.
2. Simulate one wheel slipping under normal conditions.
3. Adjust conditions to regained control of the robot.

Our experiments addressed a specific scenario where the front left wheel (wheel 3 in Figure 4) started to slip while we were driving forward approximately five meters along a straight path.

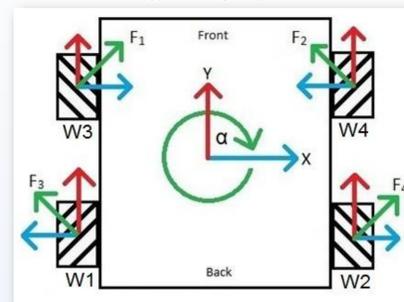


Figure 4: Vector components of our robot

Experiment 1

Experiment 1 served as our control in which the robot drove forward with all four mecanum wheels with good traction. This process was repeated 10 times, recording the current and angular velocity of each wheel.

Experiment 2

Experiment 2 served as a slipping condition where wheel 3 was slipping, therefore indicating there was no traction. Given the same forward input as the first experiment, the robot drove forward but consistently drifted off to the right due to the force vectors of each wheel. This process was repeated 10 times, recording the current and angular velocity of each wheel.

Experiment 3

According to our heuristic rules, we supplied more current to the third motor in order to compensate for the simulated slipping wheel of motor two. By applying extra current to the third motor the robot should have followed the straight path ending up in the same position as it did in the experiment 1. This process was repeated 10 times, recording the current and angular velocity of each wheel.

Method (Continued)

To define our Traction Coefficient, we needed to convert the data into SI units. To do this, we use Equations 1 & 2. Then to find our Traction Coefficient, we use Equation 3.

$$\text{Normalized Velocity} = \frac{\text{Encoder Value}}{\text{Encoder CPR} \times \text{Free Motor Speed}} \quad (\text{Equation 1})$$

$$\text{Normalized Torque} = \frac{\text{Measured Amps} \times \text{Motor Constant}}{\text{Stall Torque}} \quad (\text{Equation 2})$$

$$\text{Normalized Traction Coefficient} = \frac{\text{Normalized Torque}}{\text{Normalized Velocity}} \quad (\text{Equation 3})$$

Results

Using encoders and motor controllers, we measured the velocity and current of each wheel in order to measure and determine when a wheel would be slipping.

We defined our normalized traction coefficient to be 10.3. This was calculated using Equations 1-3. This coefficient served as our control, meaning when all four wheels had perfectly even traction, the robot would move forward. If the coefficient were to be higher or lower than the normalized traction coefficient, then it would indicate that one of the wheels is either slipping or locked. In experiment 2, we calculated our slipping coefficient to be 9.6, which clearly indicates that wheel 3 is slipping. Figure 5 displays the relationship between these two numbers.

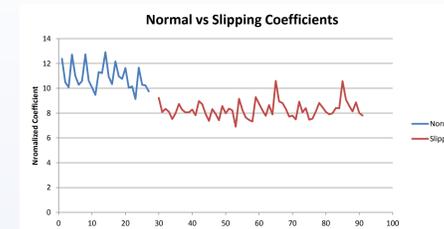


Figure 5

Figure 6 & 7 display the behaviors of motor 2 and motor 3.

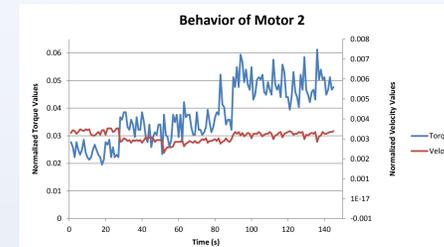


Figure 6

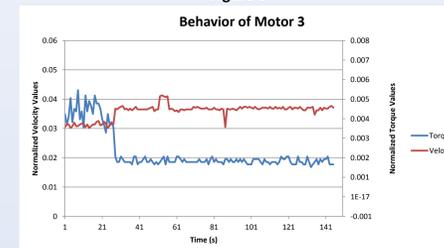


Figure 7

Future Research

In our current research, we utilized a low level "open-loop" traction control system where modifications to the robot were controlled through human input. In future research, we plan to implement a higher level "closed-loop" traction control system where the computer will be able make modifications based on given inputs from the encoders/sensors/and human input.

To expand our robot's capabilities, we plan to integrate an onboard GPS navigation system (Figure 8), gyros and accelerometers (Figure 9), as well as an anthropomorphic robotic arm, specifically the AX-18A robotic arm made by CrustCrawler Robotics (Figure 10). With these components, they will expand our robot's capabilities to better interact with, and be aware of its environment.

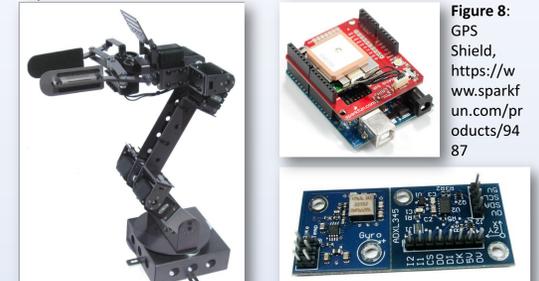


Figure 10: AX-18A Robotic Smart Arm, <http://www.crustcrawler.com/products/AX-18F%20Smart%20Robotic%20Arm/>

Figure 9: Gyro and Accelerometer, <http://www.andymark.com/product-p/am-2067.htm>

Conclusion

Throughout this project, we have demonstrated that our robot has achieved a electronic traction control system. By applying extra power to the wheel opposite of the slipping wheel, we were able to maintain a forward motion, even with a slipping wheel.

This type of electronic traction control system is already in use in automobiles, specifically electric vehicles. By being able to monitor each individual wheel, the onboard computer system is able adjust each wheel's velocity and current being supplied, therefore allowing for a stable ride. Benefits of this electronic system allow for mechanical systems to be replaced, therefore increasing the life span of the electronic traction system.

References

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2. Hartani, K., Bourahla, M., Miloud, Y., Sekour, M. "Electronic Differential with Direct Torque Fuzzy Control for Vehicle Propulsion System". Turk J Elec Eng & Comp Sci, Vol.17, No.1, pp 22, 2009.