Redundancy Resolution of An Autonomous Holonomic Drive Robot

Via Moore-Penrose Generalized Inverse

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Abstract

Often in hazardous or distant exploratory missions, humans may be substituted with robots to reduce injury or to communicate across far distances. While robots are often built to withstand extreme conditions, human input based on observations made either visually or electronically. This can be classified as a low level “open-loop” control system. Improving on this system, a higher level “closed-loop” system can be introduced, making the robot entirely autonomous.

Purpose

For this project, we aim to design and build a robot that can be represented by a Moore-Penrose Generalized Inverse Matrix that utilizes CAN communication technology and holonomic motion to allow for an autonomous robotics platform.

Introduction

Often in mathematics and engineering, systems of equations show up when dealing with m amount of equations with n unknowns. These equations can often be represented by a matrix with n columns and m rows. This method allows for the solution of a system of linear equations, where an inverse of this matrix is not possible and does not provide an exact solution. Therefore the Moore-Penrose Generalized Inverse Matrix is used to provide an approximate solution to a non-square matrix that has the dimensions n x m.

The Moore-Penrose Generalized Inverse Matrix is a unique technique used to solve complex matrices, even if it is not a square matrix. The Moore-Penrose inverse satisfies the following four conditions called the Penrose Conditions (Yoshikio, 1990):

\[ A^* = (A^TA)^{-1}A^T \]

Similarly in research done by Hanai, Marani, Choi, and Rosa (2009), they utilized a weighted Pseudo-Inverse matrix to detect thrust fault detection for underwater vehicles as shown below:

\[ A = \frac{1}{m} \sum_{i=1}^{m} a_i \]

Where m is the number of measurements and a_i is the individual measurement.

From our research from the previous semester, the traction coefficients that were determined will now be used as an input to the program to help aid the robot during autonomous mode. We can represent these values in the matrix W where 0 ≤ R_i ≤ 1. Combining the fixed body forces to the fixed wheel forces, based on the robots symmetry, we get the matrix A.

\[ W = \begin{bmatrix} R_1 & 0 & 0 & 0 \\ R_2 & 0 & 0 & 0 \\ R_3 & 0 & 0 & 0 \\ R_4 & 0 & 0 & 0 \\ \end{bmatrix} \]

\[ \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} = \begin{bmatrix} R_1 \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \\ R_2 \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \\ R_3 \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \\ R_4 \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \sqrt{\frac{1}{2}} \end{bmatrix} \]

Results

As demonstrated in the methods section, we were able to represent our robot by using the Moore-Penrose Generalized Inverse Matrix, more specifically a Weighted Pseudo-Inverse to include the weights or our Traction Control System project. Also during this project, we also showed that a Wheatstone Bridge circuit can represent our robot in which the mah mimics the behavior of the robot, allowing us to program and test our mathematical formulas by means of Hardware-In-The-Loop (HIL).

References