Project 1

Kyle Jeffrey

Abstract—Robots are the summation of sensor data processing and response. Using sensor data Robots can track their surroundings but, this data is with respect to the Robot itself. To use data from multiple Robots or sensors then, a procedure must be used to put this data in respect to some common frame. This paper expolores linear algebra techniques to make multiple coordinate frames transform into a common coordinate frame.

1 Introduction

The project manual specifies the problem here:

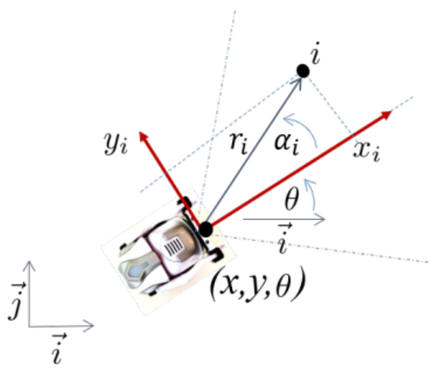

Figure 1:

Figure 1 depicts a Cozmo robot (top view). Using its camera we can measure the distance ri and the angular position α_i of a ground marker i. The distance ri is measured from the origin of the robot's reference frame (depicted in red) and the angular position α_i is measured from the x axis of the reference frame which is aligned with the robot's heading. The robot is capable of keeping track of the global position (x, y) and the heading angle θ of the robot's frame, i.e., its pose given by the triple (x, y, θ). The heading angle is measured with respect to the direction of $\vec{i}$ of the global coordinate system. The limits of the camera's angular range are depicted with the dashed-dot lines.

Fig. 1. Project Manual Guidelines

2 Solution

See below a figure of two Robots observing multiple markers. Some of the markers observed are the same but that is not easily identifiable from the raw data of the Robots.

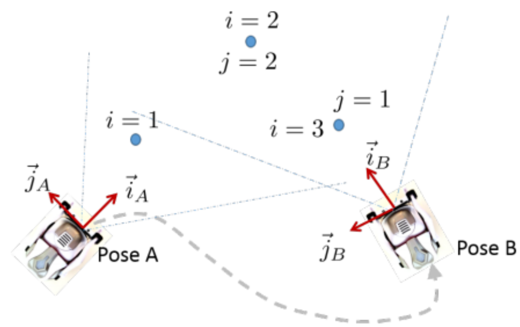

Fig. 2. Robot's Observing Markers

To put the data from these Robots into a common coordinate frame, a transformation matrix is needed. The matrix will need to rotate and then translate the basis vectors to match the global frame. This means applying the rotation matrix:

$$\begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix}$$

Fig. 3. Rotation Matrix

Applying this transformation, where θ is the angle of Pose of the Robot, followed by a translation of $\begin{bmatrix} x \\ y \end{bmatrix}$ gives the global coordinates of all points the Robots detect within there coordinate frames.

These Matrix transformations can be put into one Matrix that does both rotation and translation, shown here:

$$\begin{bmatrix} \cos(\theta) & -\sin(\theta) & x \\ \sin(\theta) & \cos(\theta) & y \\ 0 & 0 & 1 \end{bmatrix}$$

Fig. 4. Rotation and Translation Matrix

2.1 Finding Markers

Now we'll briefly discuss both parts of the project. The first part specified a data set of markers in the coordinate from of a Robot with Pose A and the same for another Robot with Pose B. The goal is to find how many independent markers exist between the measurements of both Robots in the coordinate frame of Pose A.

To transform the markers in Pose A to Pose B, transform the points to the global frame, and then use the inverse transform for Pose B. Here's a visual:

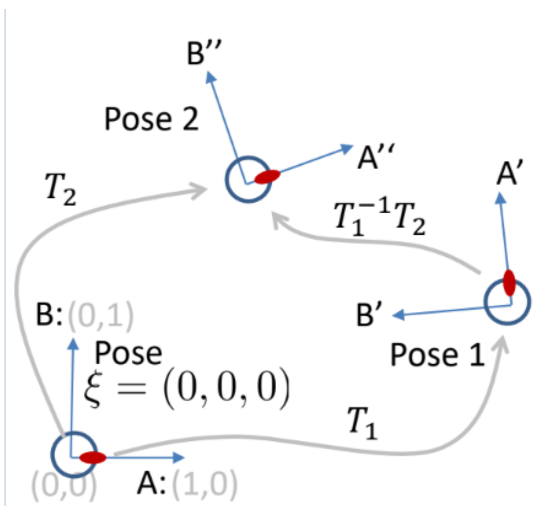

Fig. 5. Transformations between Coordinates

Once the markers are transformed through matrix multiplication of $T_A^{-1}T_B$, the markers are considered the same if they satisfy the equation: $\sqrt{(a_x - b_x)^2 + (a_y - b_y)^2} \leq 1$. Where a and b are points from the data sets for a and b, transformed into the a coordinate frame. Less than 1 is an arbitrarily defined constant.

Part 2 reserves no specifications for how to find duplicate markers. In my implementation, I converted both data sets into the global coordinate frame and checked for duplicates.

Kyle Jeffrey Kyle Jeffrey is a Senior Robotics Engineering Student at the University of California Santa Cruz. He is the Secretary of the Engineering Fraternity Tau Beta Pi and the lead Hardware Engineer at the on campus startup Yektasonics.