Determining the Camera to Robot-body Transformation from Planar Mirror Reflections

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Abstract

This paper presents a method for estimating the six-degrees-of-freedom transformation between a camera and the body of the robot on which it is rigidly attached. The robot maneuvers in front of a planar mirror, allowing the camera to observe fiducial features on the robot from several vantage points. Exploiting these measurements, we form a maximum-likelihood estimate of the camera-to-body transformation, without assuming prior knowledge of the robot motion or of the mirror configuration. Additionally, we estimate the mirror configuration with respect to the camera for each image. We validate the accuracy and correctness of our method with simulations and real-world experiments.

Motivation

- Transformation essential for many common tasks (e.g., path planning)
- Typical methods (e.g., manual measurement) are unreliable, and transformation may need to be recomputed often
- CAD plots only determine transformation to camera housing

Requirements

- Compute precise transformation from camera to robot-body
- Do not require calibration equipment, or "lab" environment
- Do not assume knowledge of mirror size, or position
- Do not assume knowledge of robot's motion in front of the mirror

Contributions

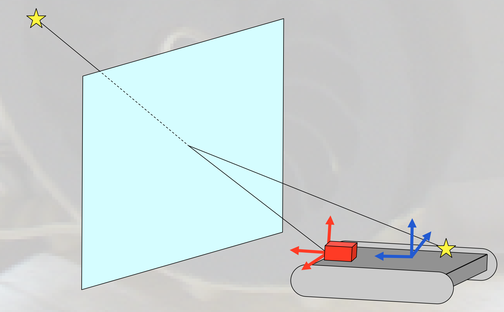
- Automated procedure to determine transformation from camera to robot-body
- Algebraic solution and insight into problem

Algorithm

- Collect images as robot moves in front of mirror
  - Robot-body only visible through reflection
  - Excite all degrees of rotation/translation
- Track point features through image sequence
- Compute initial guess
  - At least 3 points in 3 images needed
- Maximum Likelihood Estimator
  - Use all points in all images
  - Gauss-Newton minimization to solve Non-linear LS

Algebraic Solution

- 3 point pose estimation problem (up to 4 sols)
- Solve resulting non-linear set of equations



Properties of the System

- Number of unknowns: 6 + 3 x Nc
- Number of constraints: 2 x Nc x Np
- Views should differ by rotations about at least 2 axes

Website: mars.cs.umn.edu

Experimental Results

- 3 points in 1000 images (1024 x 768 px)
- Distances between 30 and 50 cm
- Rotations about horizontal and vertical axes by approx. 30 deg
- 3 sigma of the error: 2 mm, 0.2 deg per axis

Robot moving in front of a planar mirror with 3 fiducial points attached on a laser scanner.

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