Exploring the Motion Manifold for an Articulated Arm

UGP Presentation

Avikalp Kumar Gupta

Supervised by: Amitabha Mukerjee
Department of Computer Science and Engineering
IIT Kanpur

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Outline

Introduction

Ultimate Aim of the Work

Plan paths of multiple robots.

Aim of this Project

Extension of motion planners to 3-D with the help of **simulations**

- This project is an extension of the M. Tech. thesis of Debojyoti Dey [Dey, 2015] from 2 dimensions to 3 dimensions
- Requires exploration of motion manifold using only visual input

Outline

Motion planning for planar robots

Have a look at the video demonstrations of Debojyoti's algorithm.

Motion planning for planar robots

- Visual Configuration Space
- Decoupled road-map composition
- Probabilistically resolution complete

3D Articulated Arm

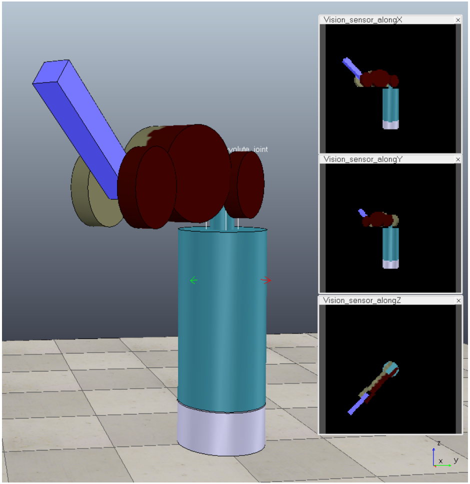
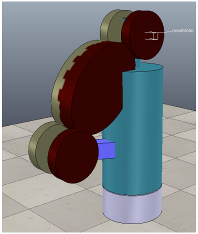
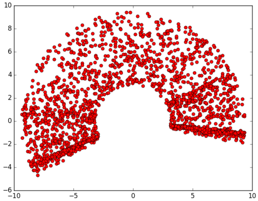


Figure: Robotic arm with 3 revolute joints - Created in v-rep. The 3 smaller windows show the image captured by the vision sensors installed in the scene *(image has been generated using v-rep software)*

Data Generation

Images captured during simulation.
Advantage: Avoids impossible poses
Disadvantage: Loss of uniformity in randomness



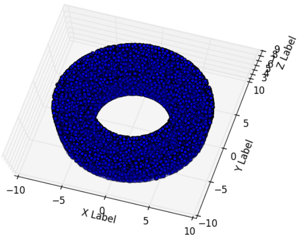


(a) An impossible pose generated by assigning random angles to all the joints

(b) Plot showing accumulation of data points on the boundaries (Details: Radial distance $= 2\pi + \theta_2$, and angle $= \theta_0$)

Outline

Ideal Motion Manifold



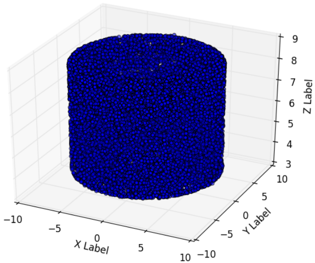
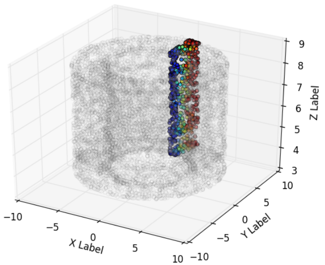
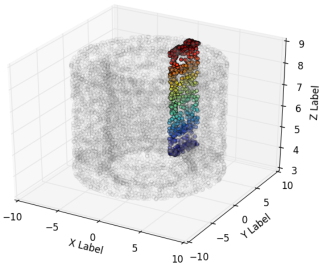


Figure: 3-D plot of θ_0, θ_1 and θ_2 is a hollow cylinder (*Details:* $2\pi + \theta_0$ *= distance from z-axis,* $2\pi + \theta_1$ *= distance from x-y plane &* θ_2 *= angular displacement along z-axis*)

Ideal Motion Manifold



(a) color changes as θ_0 increases



(b) color changes as θ_1 increases

Figure: 3-D plots explaining the structure of the hollow cylinder in figure 2 (*Details: The colored points only correspond to configurations which have* $0 < \theta_2 < 0.1$ *rad*)

Manifold Generated on Images

We used ISOMAP (Stanford University's MATLAB code) to generate this from the image data:

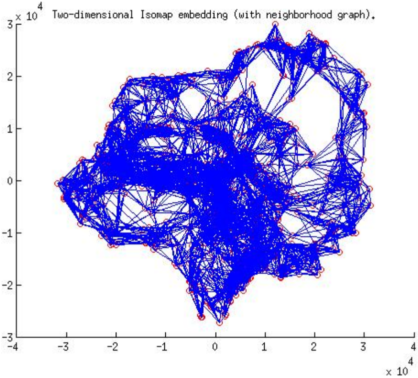


Figure: 2-D projection of the configuration-space of the robot, as deduced by dimensionality reduction using ISOMAP

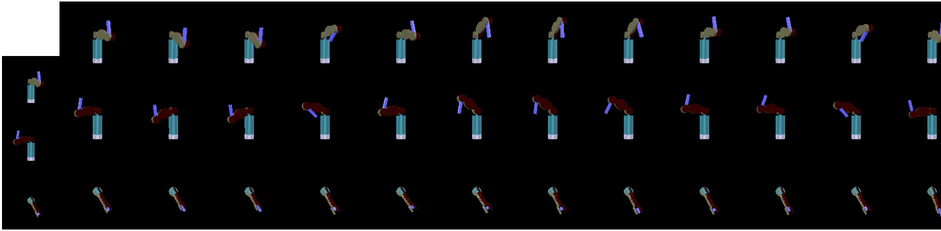
Outline

Analysis

Major reasons of these short-circuits:

- a jump when 2nd link and the base cylinder are in the same spatial region (Figure 5).
- the opposite faces of the middle link get inter-changed (θ_1 change by 180^o, and θ_2 and θ_3 change signs) (6).

Short-circuits: Type 1



(a) Pose

(b) its neighbors

Figure: *Illustration of a short-circuit*: Poses in which the 3rd link is in the same spatial region, but the angles are far off, also become neighbours [$\Delta\theta_2 \sim 0$; $\Delta\theta_1 \sim 60^\circ - 100^\circ$; $\Delta\theta_0 \sim 180^\circ$]

Short-circuits: Type 2

(a) Pose

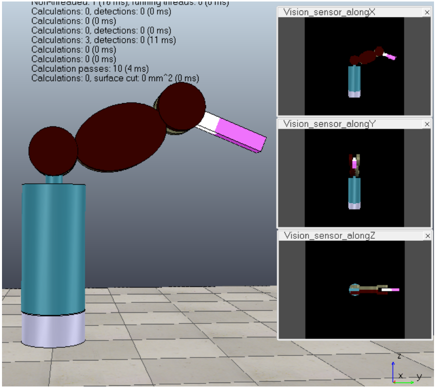
(b) its neighbors

Figure: *Illustration of a short-circuit*: Poses which occupy approximately the same space, but are far off in the actual manifold become neighbours [$\Delta\theta_2 = 180^\circ$, $\Delta\theta_1 = -2\theta_1$ & $\Delta\theta_0 = -2\theta_0$]

Outline

Proposals

- Changes in input image
- Change in distance metric (use of Ideal Track Points [Ramaiah et al., 2015])



Bibliography I

Dey, D. (2015).
Visual Motion Planning of Multiple Robots by Composing Roadmaps.
Master's thesis, IIT Kanpur, India.

Ramaiah, M. S., Mukerjee, A., Chakraborty, A., and Sharma, S. (2015).
Visual generalized coordinates.
CoRR, abs/1509.05636.

APPENDIX - A

Explanation of the key traits of Debojyoti's algorithm

Visual Configuration Space

Traditional methods used Motion configuration Space.

- Planning path on a configuration space defined in terms of motion parameters becomes intractable when the dimension of the configuration space grows up
- Dimension of visual configuration space is independent of degrees of freedom of the robots.

Multi-robot Motion Planning

- Centralized Path Planning
- Decoupled Path Planning

Multi-robot Motion Planning

- Centralized Path Planning
- Decoupled Path Planning
  - Prioritized planning
  - Fixed-path coordination
  - Semi centralized model
  - *Fixed road-map coordination*

Probabilistically Resolution Complete

- Completeness

Probabilistically Resolution Complete

- Completeness
- Probabilistic completeness

Probabilistically Resolution Complete

- Completeness
- Probabilistic completeness
- Resolution completeness

APPENDIX - B

Another Major Challenge: Completeness

Outline

- Completeness

Challenge: Correctness and Completeness

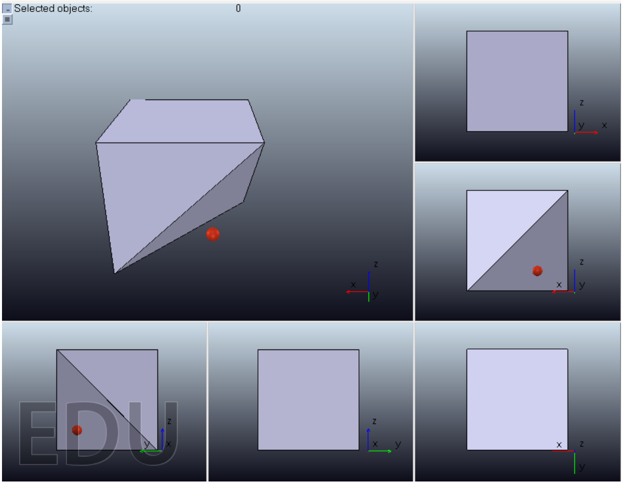


Figure: (left-top)A small sphere near a truncated cube; (others) all 5 cameras (placed at orthogonal positions) detect "false" collision *(image has been generated using v-rep software)*