CS-365A Course Project
Visual Odometry in a 2D environment

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ABSTRACT

Odometry finds many applications in navigation and obstacle aversion. In our project, we implement Manifold learning to construct the image space of a 2-D environment and find out the configurations corresponding to the neighbours of a given image.

INTRODUCTION

Visual Odometry is the process of estimating the position and orientation of the robot using the camera images associated with it. Our project involves collecting images as seen from a robotic arm with 3 links and 2 links having 2 cameras and 1 camera respectively. The images obtained by the camera comprise as our dataset. We make use of manifold learning to determine the configuration of the arm given a new image.

METHODOLOGY

We have a 2-D enclosure as our environment, with all walls painted with varying shades of red, blue, pink and green. The corners are painted black.
In case of 3 link robot arm, we have used 2 cameras mounted on the end effector and at the end of the second link. While for 2 link robot arm, we have used only 1 camera mounted on the top of the end effector.
APPROACH:

Robot arm(having 2/3 links) kept at center of the box with camera

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Camera emit rays at angular difference of 0.2° generating 180° field of view

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2 Images obtained appended side to side to make one single image

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Dataset generated for different robot configurations(θ_1, θ_2 & θ_3)

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Isomap Algorithm is applied to get the reduced dimensionality

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Applied KNN search algorithm to find the nearest neighbours in image dataset and mapped them to corresponding robot configurations

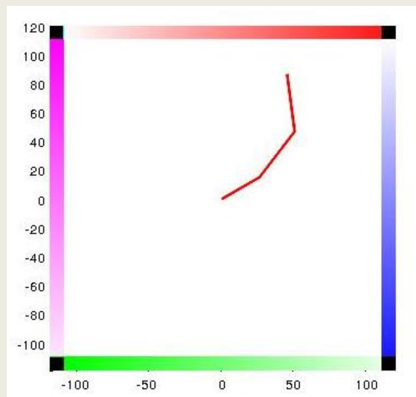


Figure 1. Environment with robot

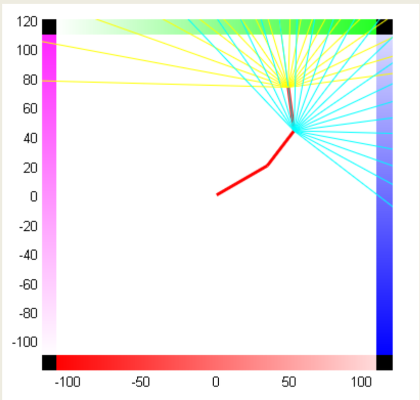


Figure 2. Camera emitting rays with 0.2° least count

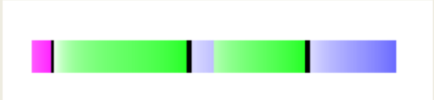


Figure 3. Appended images obtained from cameras

RESULTS

- Generated 10,000 images (1 * 1800 * 3) as seen by 2 cameras in case of 3 link robot
- Generated 10,000 images (1*900*3) as seen by 1 camera in case of 2 link robot
- Isomap results when applied on images for 3 link robot arm :

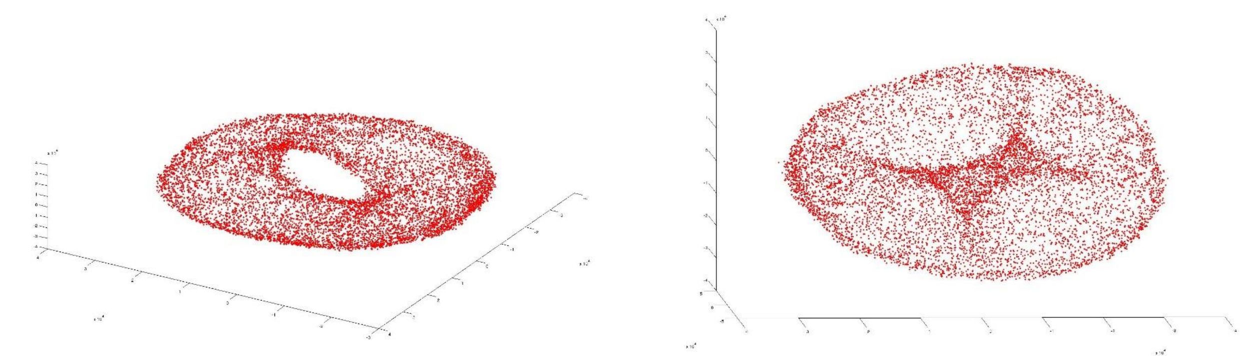


Figure 4. 3-D embedding for 3-DOF robotic arm after applying Isomap (view from different angles)

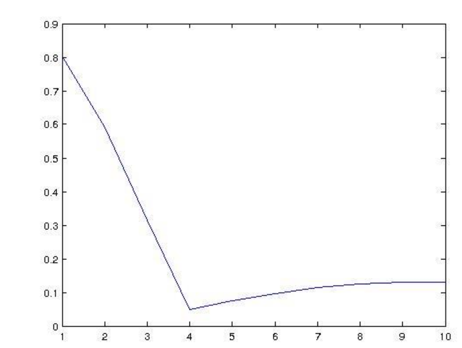


Figure 5. Isomap plot (Residual variance vs Dimensionality)

- Isomap results when applied on images for 2 link robot arm:

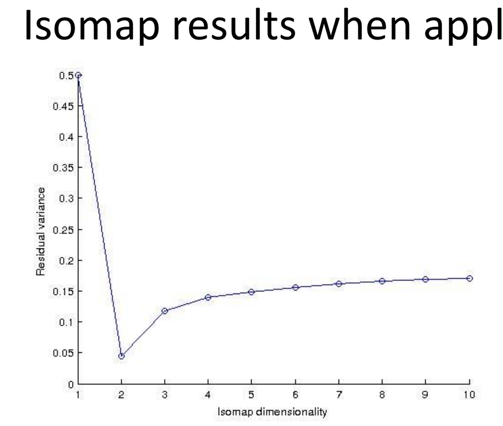


Figure 6. Isomap plot (Residual variance vs Dimensionality)

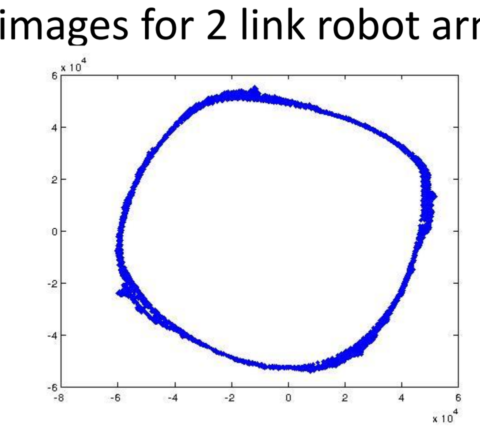


Figure 7. 2-D embedding for 2-DOF robot

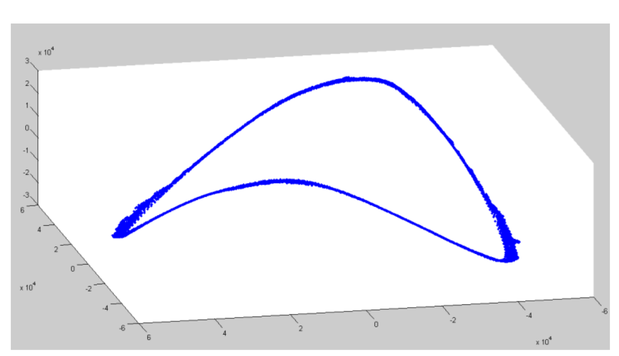


Figure 8. 3-D embedding for 2-DOF

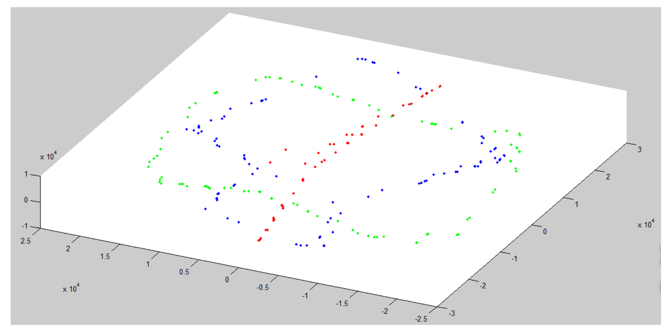
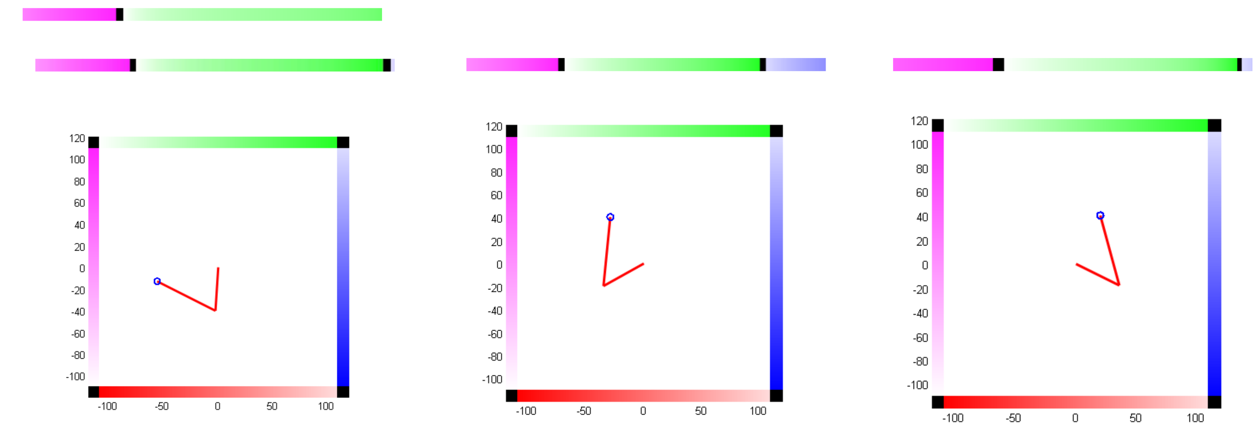


Figure 9. 3-D embedding for 2-DOF (blue for θ_2 constant, red and green for $\theta_1$constant (pi/2 and pi/4)

- Searching nearest neighbours of the given image and mapping the images obtained to the corresponding robot arm configurations



PREVIOUS WORK

Our work is partially based on Swati's work done in CS-365A course as her course project. Her project involved construction of an ego model for a 2-DOF arm. It involved taking images from a camera mounted on the top of the end effector as well as tactile sensors to detect obstacle collision.
We tried to construct similar environment for 3-DOF robot with 2 cameras and tried to analyze its images with further innovations.

CONCLUSIONS

- The dimensionality from 2-DOF robot came out to be 2 as was expected.
- The nearest neighbours in terms of images were quite correct but in terms of angle configurations it was not that right. The reason is probably because we have taken field of view to be 180° , with a smaller field of view more accurate neighbours could be find out.
- The dimensionality for 3-DOF robot came out to be 4 (as can be seen from the isomap plot).
- The probable reason for 4 dimensionality might be because the two images independently had 2 dimensionality and then they were concatenated to form 1 single image. Maybe some other method should be opted for concatenating the images or different approach to capture 3 dimensionality of the robot.

REFERENCES

1. Swati, Construction of ego-model of robot arm. http://home.iitk.ac.in/~swatim/cs365/project/report.pdf, 2013
2. R. Horaud, R. Mohr, F. Dornaika, and B. Boufama, The advantage of mounting a camera onto a robot arm, in In Proc. of the Europe-China Workshop on Geometrical Modelling and Invariants for Computer Vision, pp. 206-213
3. D. Nister, O. Naroditsky, and J. Bergen, Visual odometry, in Computer Vision and Pattern Recognition, 2004. CVPR 2004. Proceedings of the 2004 IEEE Computer Society Conference on, vol. 1, IEEE, 2004, pp. I-652
4. D. Scaramuzza and F. Fraundorfer, Visual odometry [tutorial], Robotics & Automation Magazine, IEEE, 18 (2011), pp. 80-92