# Project Report

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## Visual Odometry in 2-D environment

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**Abstract**

In our project,we run a 2-D simulation which has a four-walled enclosure,each wall being coloured by shades of one particular colour.In the center of the enclosure,lies a robotic arm.The DOF for the arm is 2 in one instance and we have implemented the 3-DOF case as well.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.

## Acknowledgement of Sources

We hereby acknowledge that all ideas taken from other sources (books, articles, internet), the source of the ideas is mentioned in the main text and fully referenced at the end of the report.

All material which is quoted essentially word-for-word from other sources is given in quotation marks and referenced.

Pictures and diagrams copied from the internet or other sources are labelled with a reference to the web page or book, article etc.

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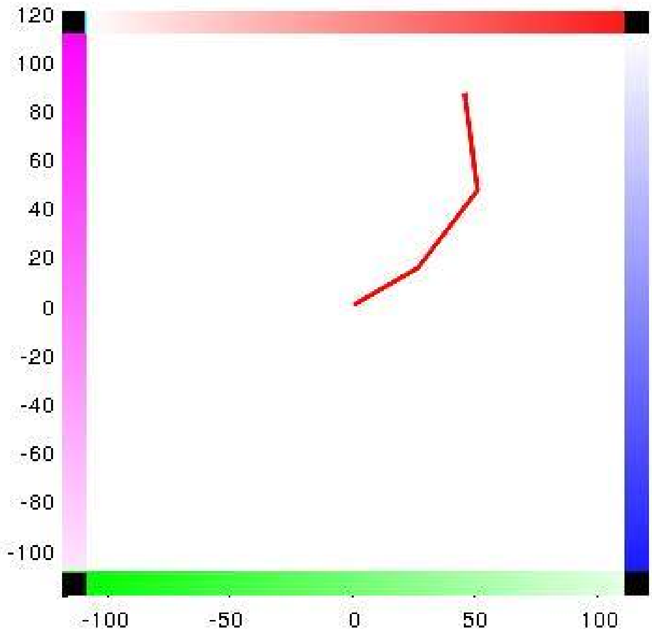
# 1 Introduction

Visual Odometry is the technique of estimating the position and orientation of the robot using the camera images as seen by it.In simpler words,it is a method we make use of to make sense of our surroundings,based on what we see.( [3])The image space is the dataset obtained by the camera placed at the end effector of the robot. We will also try to find the position of the obstacle placed in the environment by comparing its images taken from different angles. Visual Odometry(VO) improves navigation accuracy.




3-DOF Arm in the middle of the 4-walled enclosure.

# 2 Motivation

Let us take the instance of the Mars Land Rover mission. Now, we all know that GPS does not exist on Mars. Then, how do we tackle the problem of navigation and determination of the Robots position. Estimating position using the outputs of Inertial Measurement Unit and primitive odometry techniques produces significant amount of error so in this scenario Visual Odometry allows us to overcome this hurdle. Also, it is very much accurate, as compared to the traditional odometric techniques. It can be easily applied to unfamiliar terrains as well, something which GPS does not allow.( [1])

## 3 Previous Work

**Construction of Ego-model of Robot Arm by Swati** A CS365A project which involved "analyzing the visual intelligence in a robotic arm which has 2 links and a camera attached to its tip."(from [4])
Her project also made use of tactical senses for obstacle detection.

**Research Done by others** In a paper by Nister, D. on Visual Odometry for Ground Vehicle Applications, they tried to estimate the motion of a vehicle using images obtained from the video captured by the camera placed over it. They extracted feature points from the images and compared the pair of images to track the image trajectory and then used this to estimate motion of the vehicle by applying geometric tranformations.(from [2]) Our work is a preliminary work in this direction where we have tried to estimate the robots configuration using the static environment.

# 4 Methodology

To study the robotic motion in the 2 d environment we first created a 2-D environment which consisted of 4 walls having varying shades of four different colours namely red, pink, green and blue. The robot having 2 or 3 links was kept at the centre of the box with one end pivoted at the centre and the other left free. In order to capture image of the environment it had one and two cameras for 2 links and 3 links robot respectively. In case of 2 links robot camera was placed at the end effector of the robot while for the 3 links robot 2 cameras were present, one at the end effector and one at the top of the second link. For capturing images, camera emitted rays in 180° field of view with 0.2° angular deviation. In this way we obtained the image of the background as seen by the robot.

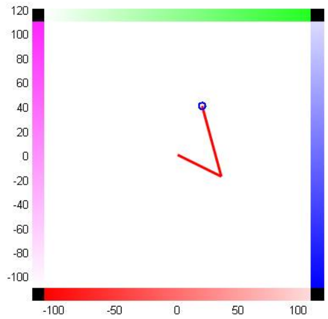



Figure 1: 2-DOF Arm with camera mounted on top

Figure 2: Image as seen by the camera

In this way we obtained the entire dataset for 2 links and 3 links robot. After obtaining this image dataset, we applied isomap algorithm to get their intrinsic dimensionality, observed their embedding in 2-D and 3-D space. We also used KNN search algorithm to obtain nearest neighbours of a given image in the dataset and then mapped it to its robotic configuration. Thus given an image we can get the nearest robotic configuration it might belong to. For 3 links robot we obtained 2 images using 2 cameras and then we appended them side to side to get one image.

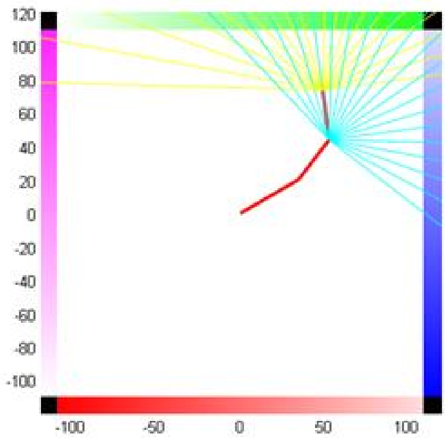



Figure 3: 3-DOF Arm with the two cameras emitting rays

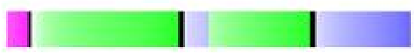
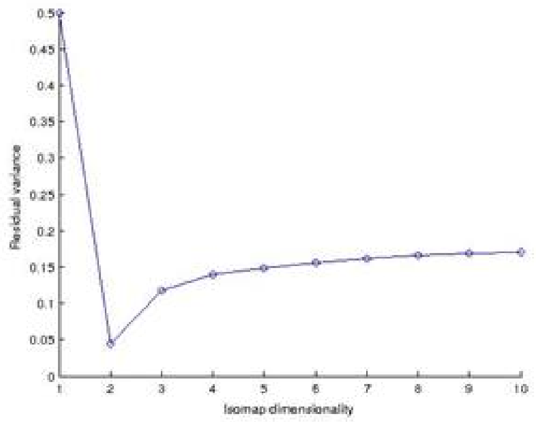


Figure 4: Images obtained by the two cameras,appended side to side

# 5 Results

We generated 10,000 random images for 2 links robot and then applied isomap algorithm to the same.




The plot between residual variance and dimensionality clearly shows that dataset has 2 dimensionality as was expected because the robot also had 2 degrees of freedom. The 3-D embedding of the same gave the following results

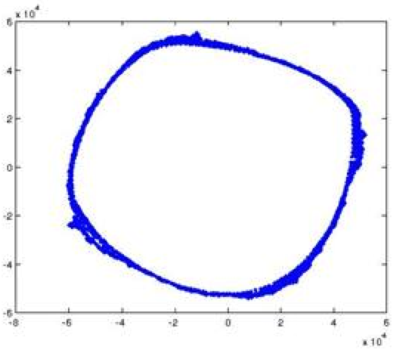



Figure 5: 2-D embedding for the images obtained by 2DOF arm

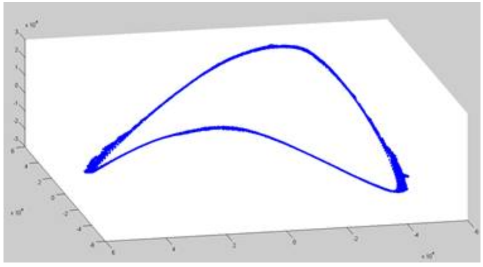


Figure 6: 3-D embedding for the same images

When we applied the same procedure on images having same $\theta_1$ but different $\theta_2$ the red and green graphs were obtained while when we gave $\theta_1$ randomly and $\theta_2$ fixed then blue graph was obtained.

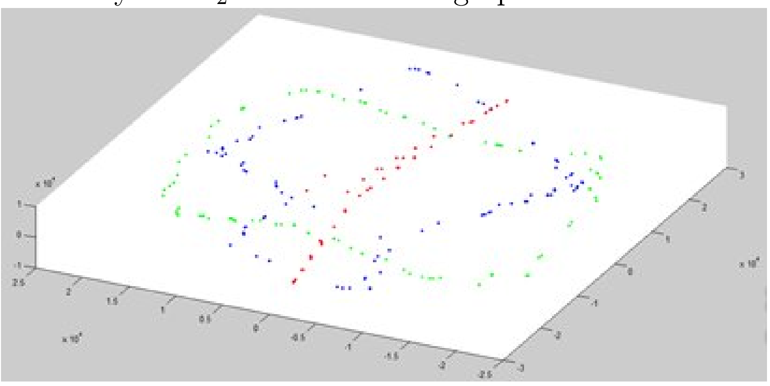


Figure 7: Blue dots correspond to fixed $\theta_1$,while red ones and green ones are for fixed $\theta_2$

The results for knn search algorithm when applied on a given image were:

Figure 8: An arbitrarily chosen sample image

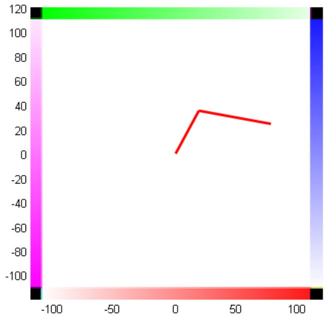



Figure 9: Corresponding configuration

Figure 10: First Neighbour

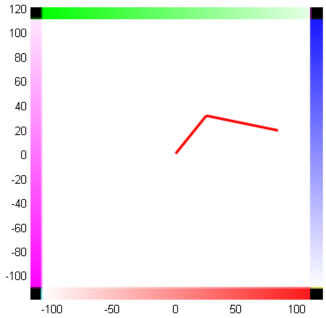



Figure 11: Corresponding configuration

Figure 12: Second Neighbour

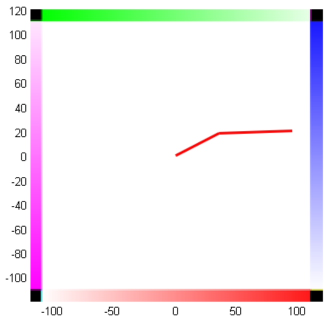



Figure 13: Corresponding configuration

Figure 14: Third Neighbour

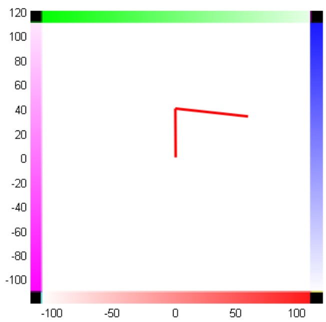



Figure 15: Corresponding configuration

The results obtained for the 3-DOF arm are as follows :

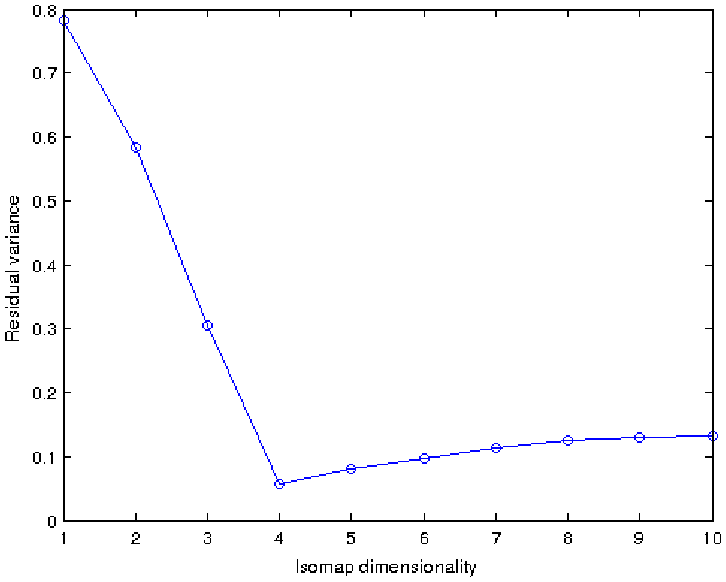



Figure 16: Plot for Residual Variance

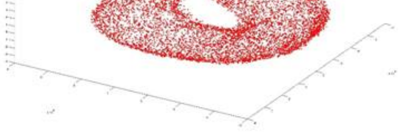


Figure 17: 3-D Embedding of the images for 3DOF arm

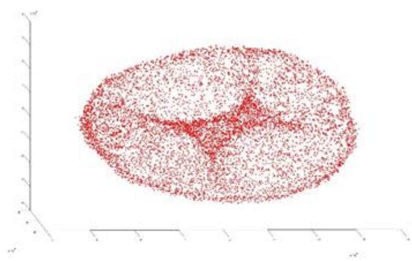


Figure 18: 3-D Embedding(different viewpoint)

## 6 Conclusions

The results for the 2-DOF case were as expected.The reduced dimensionality was 2.However,for the 3-DOF case,we get 4 as the reduced dimensionality.*Even,when we increased the data-set to 20,000 from 10,000,we got the same results.* One possible explanation could be that since the image that we are using is actually obtained by appending two independent images having 2 dimensionality. So when we combined these two images the dimensionality of the final image possibly became a product of their individual dimensionality. The nearest neighbours for one arbitrarily chosen image,suggests that close images are obtained with nearby configurations.

**Error Acknowledgement:** ***In the poster presentation,we had suggested otherwise,that different configurations could lead to same images,but when we corrected our code and examined the nearest neighbours,we found that the closest images to a given image are almost always a manifestation of closer configurations.***

## References


[1] Yang Cheng, Mark Maimone, and Larry Matthies. Visual odometry on the mars exploration rovers. In *Systems, Man and Cybernetics, 2005 IEEE International Conference on*, volume 1, pages 903–910. IEEE, 2005.

[2] David Nistér, Oleg Naroditsky, and James Bergen. Visual odometry. In *Computer Vision and Pattern Recognition, 2004. CVPR 2004. Proceedings of the 2004 IEEE Computer Society Conference on*, volume 1, pages I–652. IEEE, 2004.

[3] Davide Scaramuzza and Friedrich Fraundorfer. Visual odometry [tutorial]. *Robotics & Automation Magazine, IEEE*, 18(4):80–92, 2011.

[4] Swati. Construction of ego-model for a robotic arm, 2013.