

SCIENTIFIC EXPERIMENTATION AND
EVALUATION
ASSIGNMENT: 05

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1 Relevant Aspects of Experiment

1.1 Apparatus

1.1.1 Hardware

- KUKA youBot arm.
- Objects of three different sizes and weights, with ArUco markers attached to the top.
- Camera (Microsoft LifeCam).
- Two computers, one to run the robot and other for data gathering from the camera.
- A fixed container or marker on the table to ensure that the initial object position is kept constant.

1.1.2 Software and Libraries used

- KUKA youBot drivers.
- Control scripts for the arm to pick and move the objects in one of the three predefined placing poses.
- Marker pose subscribed script, to gather pose of the object.
- **LibreOffice Calc** for data management.
- **Python** for data visualization and calculations
- Python libraries:
 - pandas
 - numpy
 - matplotlib
 - seaborn
 - scipy.stats

1.2 Procedure

- First we run the script to get the arm in the pre-grasp position.
- We then place the object in the container, keeping the marker's orientation constant throughout the experiment.
- We then run the script to move the arm in one of the three pre-defined positions; and repeat this twenty times for each weight and pose combination. Thus, giving us 180 readings of pose coming from three different objects in three different orientations.
- Once the object is placed and the arm moves back to a stationary position, we run the subscriber script to collect pose readings of 50 frames from the camera. This is repeated after each motion.

1.3 Expected Problems and Performance

- The picking position of the arm might differ from the ground truth, because of vibrations, motion in the table and a variety of other physical conditions.
- The placement of the object in the container might not always be aligned properly.
- The marker on top of the object might move during movement and thus will lead to improper pose data.
- After placing the object, the gripper might touch it while moving away, which will introduce distortions in data.
- The light might not always be uniform, which might also cause some distortions in observation.

2 Observations and Data

2.1 Visualization

2.1.1 Data Visualization

- The raw data with fifty reading for each run has been filtered and saved as an average. This data is used for further visualization.
- The first visualization shows the pose distribution of large, medium and small objects in three directions including the initial and expected pose.
- The upper right hand corner is the left run plot and the lower left hand corner is right run plot.

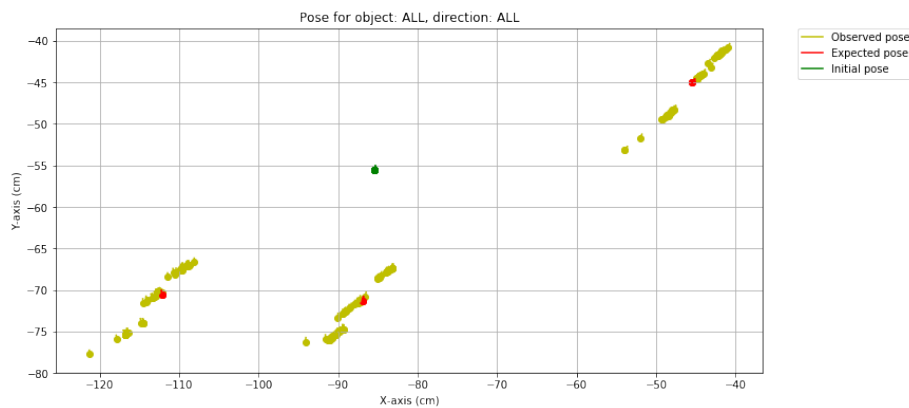


Figure 1: poses for all objects in straight, left and right direction

2.1.2 Outlier Detection and Removal

We filtered the noisy raw data by removing all records with x, y or theta value outside the range of $\mu_x \pm 2\sigma_x$, $\mu_y \pm 2\sigma_y$, $\mu_\theta \pm 2\sigma_\theta$ respectively. We used the filtered raw data to calculate mean for each experimental trial. Total number of outlier is 495 and outlier per experimental run is 2.75

2.1.3 Pose Visualization

- The first section shows the pose plots of small, medium and large objects in straight path.
- It shows the initial pose, the expected(ground truth) and observed pose(twenty points).
- The same process is repeated for left followed by right run.

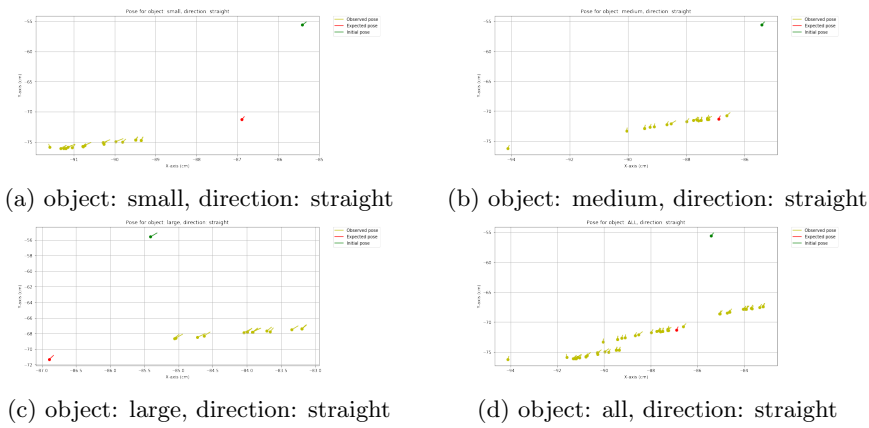


Figure 2: pose in straight direction

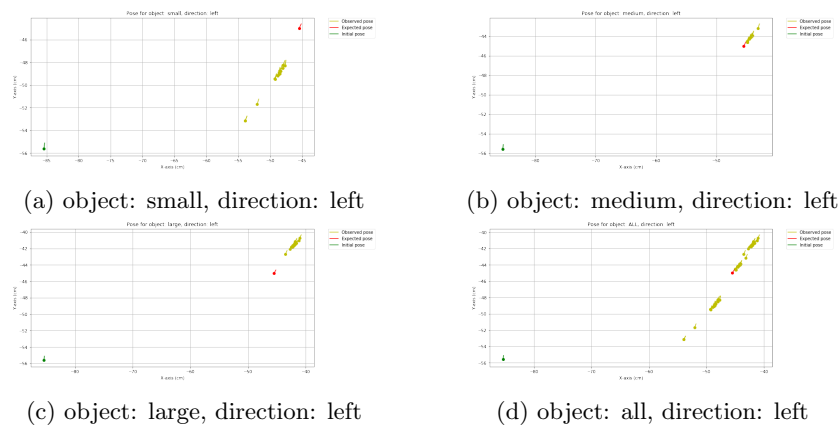


Figure 3: pose in left direction

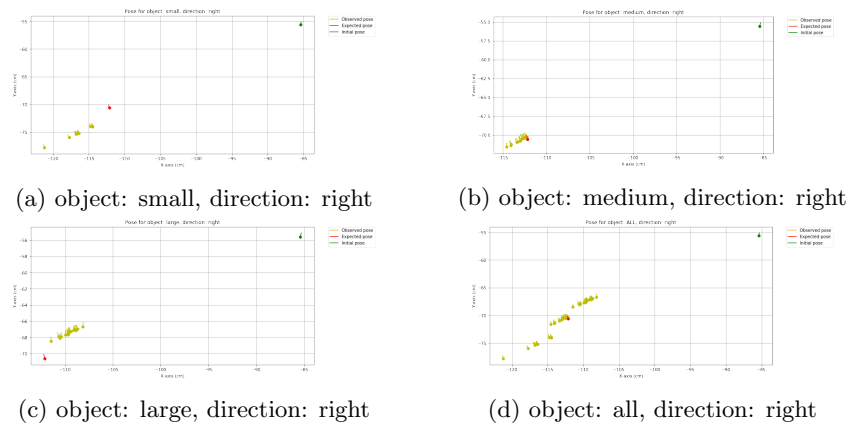


Figure 4: pose in right direction

2.1.4 Numerical Results

- By taking mean of all the all the points for straight, left and right gave us the following numbers.
- Straight:
 - X-axis: -87.54
 - Y-axis: -71.77
 - Angle: 1.42
- Left:
 - X-axis: -45.27
 - Y-axis: -45.10
 - Angle: 0.98
- Right:
 - X-axis: -113.04
 - Y-axis: -71.08
 - Angle: 1.76