Screws, Nuts, and Bolts Sorting with Model-Based Top-down Grasping

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Abstract

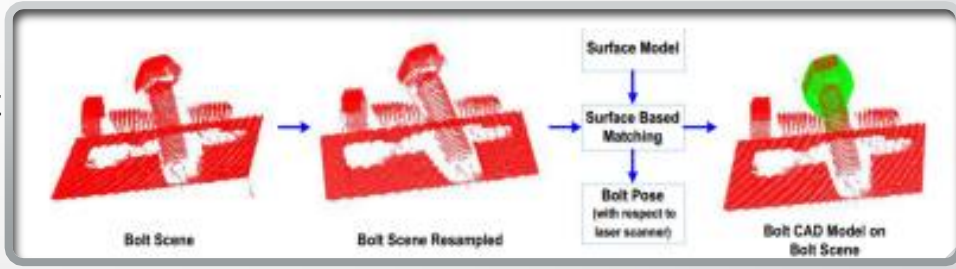
- Someone opens a package carelessly intermingled all the fasteners parts for an IKEA furniture.
- It can be difficult to figure out which part is which.
- The objective of this project is to implement a sorting robot that can sort screws, nuts, bolts, and other mechanical fasteners based on their characteristics like head shape and length and put them into a different bin from a single large bin stress that is associated with this household task.

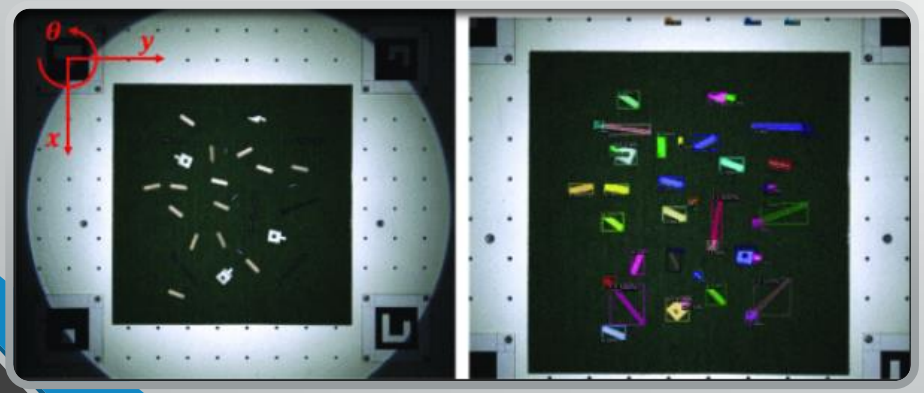
Introduction

- Like the iRobot that is currently in the market which is used to vacuum a house and automate basic chores. The motivation behind solving the sorting from 1 pile problem is also to automate and solve basic problems caused by human error.
- By having this sorting robot to provide an extra set of hands, it would increase the productivity of one by giving them the opportunity to focus and complete the objective. In this case it would be assembling the furniture using the correct fasteners instead of spending time finding it.
- By implementing a top-down view of the large bin, the robot will be able to pick up a fastener, identify its characteristics, and then place it into its associated bin.
- The proposed solution would be to implement an image classification model with a CNN neural network that will assist with the reinforcement learning of the sorting task that the robot will need to complete.

Related Work

- A Review of Motion Planning Algorithms for Robotic Arm Systems
  - Model-based learning using random sampling and generation of candidate viewpoints.
- Robotic Assembly of Threaded Fasteners in a Nonstructured Environment
  - Detecting bolt from the scene using surface matching after the CAD model gripping pose was pre-determined.



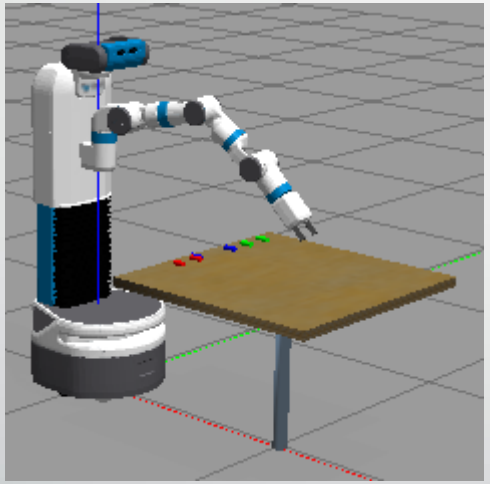


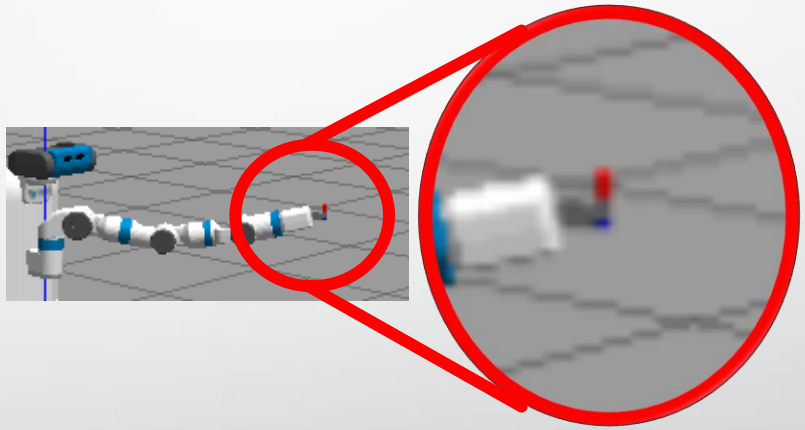
- Estimation of the Gripping Position and Orientation of Fasteners in Camera Images
  - Identifying gripping pose of mechanical fasteners in 2-D space used to construct an IKEA chair

General Method

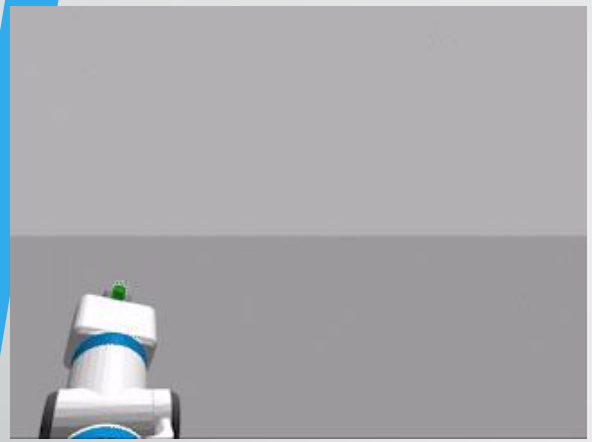
Method from a process and application point of view.

First step: Grasp mechanical fastener
with robot arm and gripper.





Second step: Bring grasped fastener close to the camera to look at finer details



Third step: Use image classification neural network to determine type of fastener

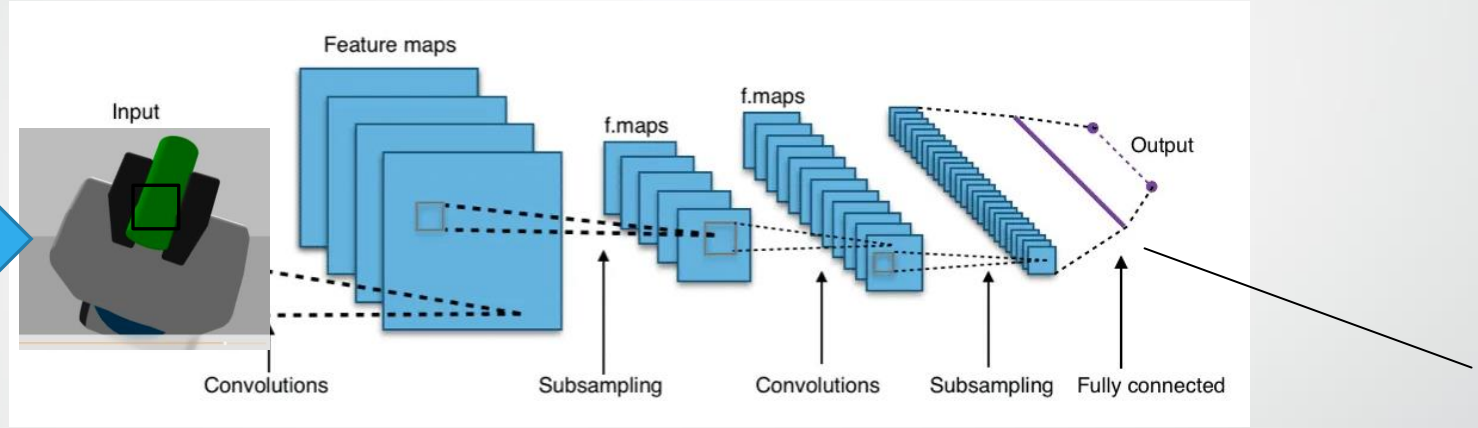
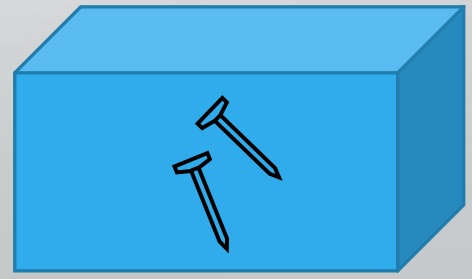


Image Classification: { Nail }

Arm Pose for Nail Bin

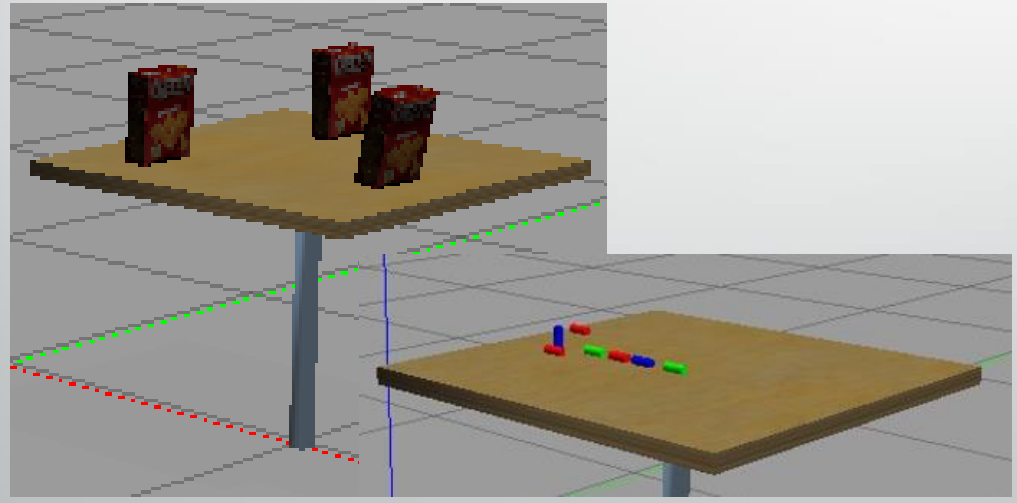


Fourth step: Move grasped fastener to a labeled bin separate from the location of fastener (off the table).

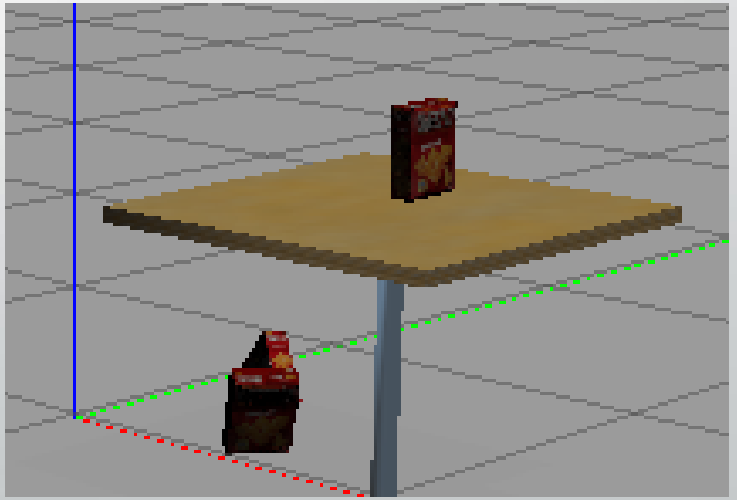
Experiments and Problems

How to create random environments and poses?
- Using the Population tag in a .sdf randomly places objects in a defined area.
- Problem: All objects have the same orientation. Uniform distribution is not random enough, but random distribution doesn't account for model clipping

Uniform distribution

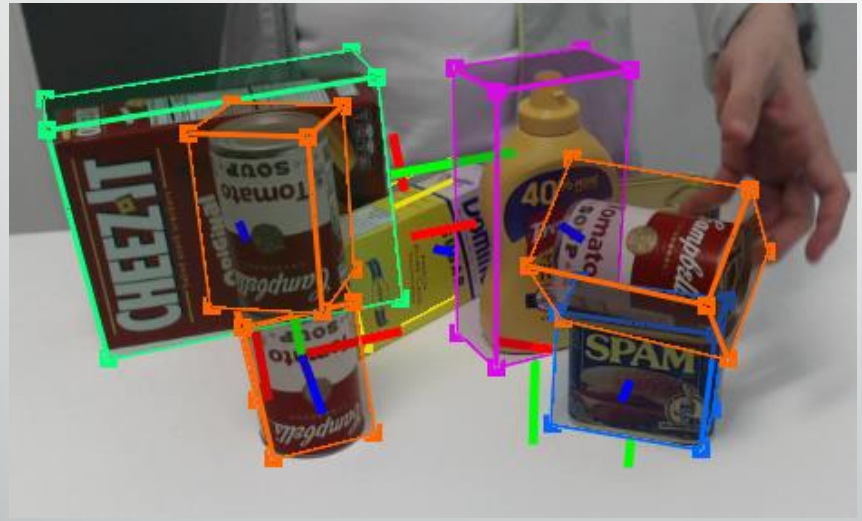


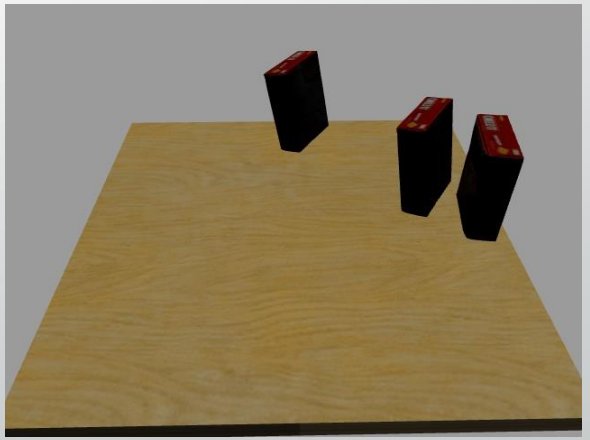
Random distribution



How to detect poses without knowing beforehand?

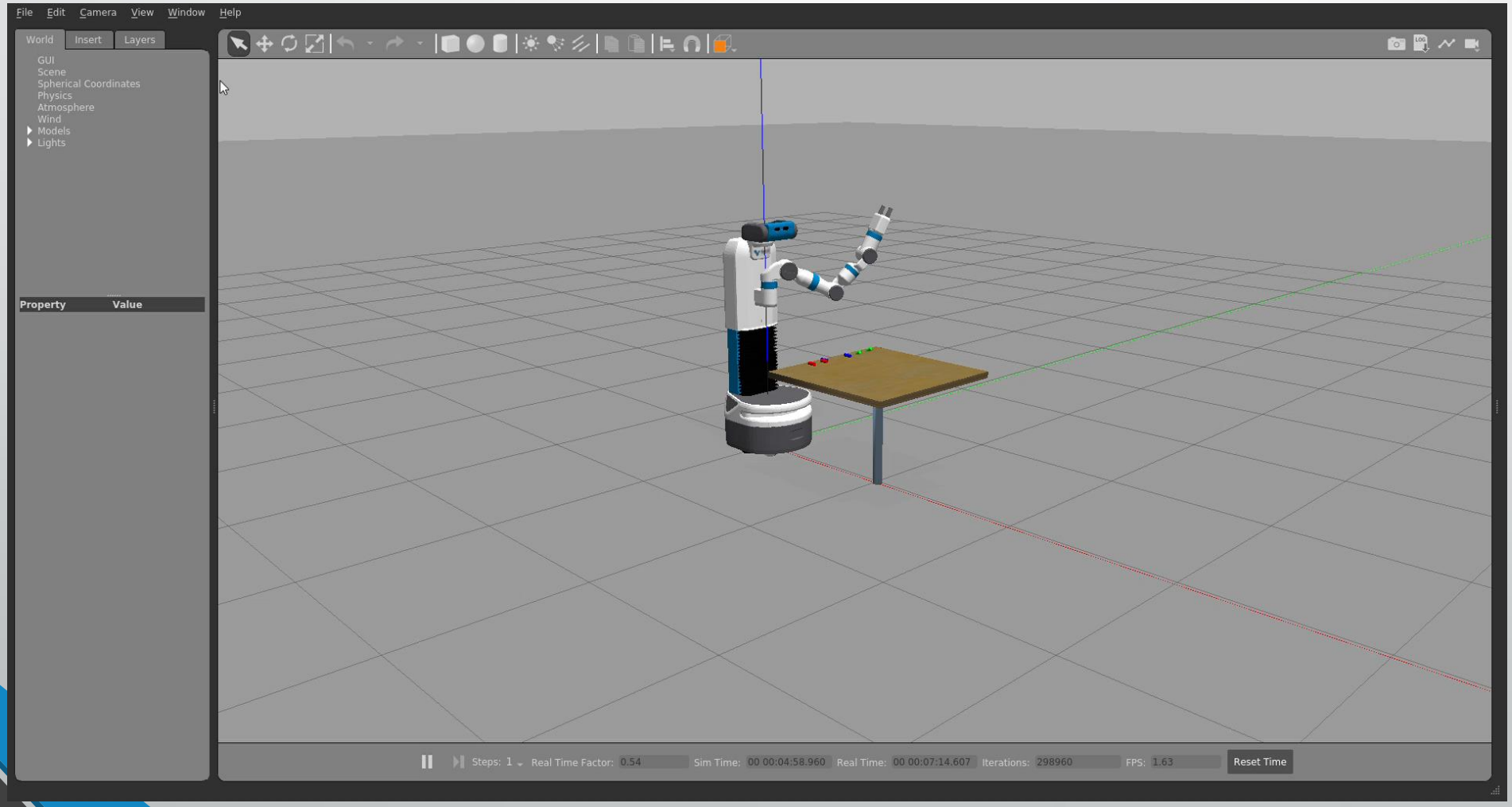
- Use a model-based pose estimator on pretrained object
- Deep Object Pose Estimation (DOPE)
- Problem: Trouble connecting camera topics (expects usb camera) to DOPE.
- Had to settle for colored cylinders where poses are received from Gazebo Simulator





Early Attempt to use DOPE

Early Prototype Demo



Dataset

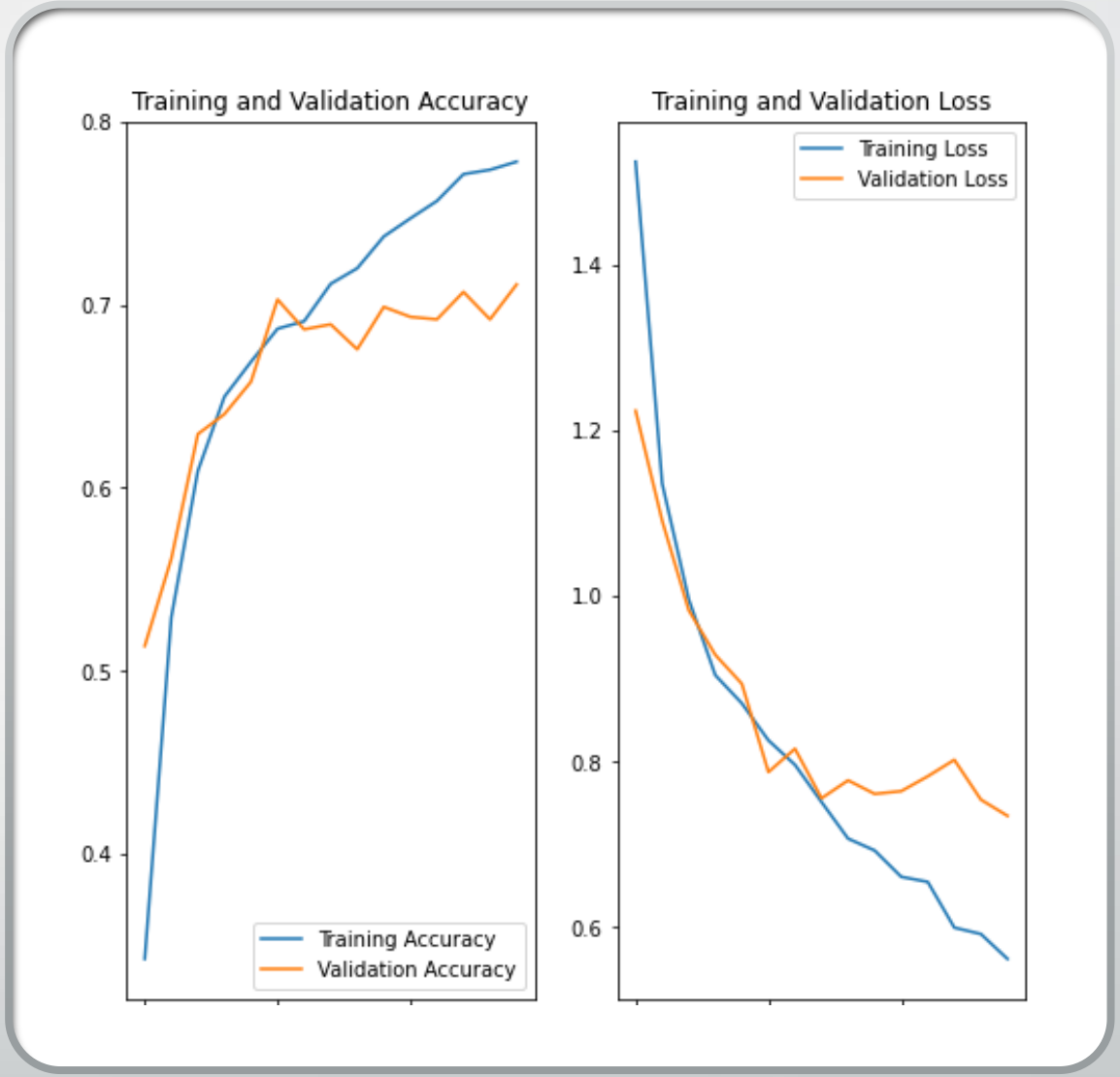
- The goal is to sort screws, bolts and similar objects.
- The dataset primarily consists of screws and bolts
- These screws and bolts are of different sizes and have some distinct characteristics.
  - Radius of screw and bolt
  - Length of screw
  - Shape of screw head

Image Classification

- The approach that is being opted for is to use the camera hardware present in the robot to take a picture of the object that is in the robot's hand and then use an image classification algorithm to categorize it, in this case the objects being screws and bolt
- A deep neural network classifier was built using convolutional neural networks (CNN)
- Due to training on a small custom dataset, a CNN model was opted for as they perform better on smaller datasets.

CNN Model Results

- The model has an approximate accuracy of 70 percent. The model also is well fitted to the training data.
- However, there is some room for improvement regarding the testing data
- The model pipeline will then be saved and loaded into another inference script.
- When the robot picks up new objects, a picture of that object will be taken using the inbuilt camera. This image will then be processed through the inference script and be classified into the according category.



Conclusion

To summarize the project:

- The goal was to create a robot that would sort fasteners using an image classification model and top-down grasping
- Areas for improvement:
  - Model accuracy is 70%, which can be improved through training the model with a larger data set of fine tuning the model
  - Work more on the perception of the simulation environment such as 6-D pose estimation
  - Determine the best way to grip each object such as gripping it vertically or from the side
    - Try it repeatedly and plug all the information into a deep neural network so the robot can learn from its previous attempts

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