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Sim2Real transfer for Reinforcement Learning

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About me

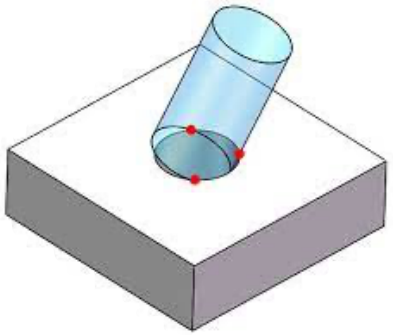
- BS (2017) and MS (2021) degree in electronics RTU
- Work experience:
  - Upholstery Specialist
  - Taxi driver
  - Carpenter
  - Sales person
  - Logistics Specialist/Purchasing Coordinator
  - **Research assistant at EDI (working since 2020)**

Current projects

- Currently working on two Horizon 2020 projects:
  - AI4CSM - Automotive Intelligence for/at Connected Shared Mobility (360 degree 3D perception system based on ToF sensor cameras)
  - IMOCO4.E - Intelligent Motion Control under Industry 4.E (Pick and Place Task with UR5e robotic arm) **The base project for PHD

PHD thesis and project tasks

- Main topic - Sim2Real transfer for Reinforcement Learning
- Pick and Place task with UR5e collaborative robot and Robotiq 2F-140 gripper:
  - Pick the bottle (randomly placed in pile)
  - Should be placed on to moving conveyor belt (Peg-in-hole)
- Demonstrator and evaluation at Madara Cosmetics premises



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Current situation with research

- Some troubles with environment setup:
  - ROS2 - newer version of Robot OS
  - Moveit2
  - Ignition Gazebo
  - Gym-Ignition

System architecture

- “System Architecture for Robotic Arm Adjustment to Different Objects in Pick-and-Place Tasks” - Extended Abstract (Jun’23)

Main objective and problem statement

Main objective - design a robotic system architecture that simplifies the process of adjusting a pick-and-place robot for different objects in a production line:

- Quickly adapt to new products is important in factory setting
- Aiming to achieve goal by using Reinforcement Learning (RL) methods and Generative Adversarial Network (GAN)
- Reduce dependance on the machine learning expert for every product change

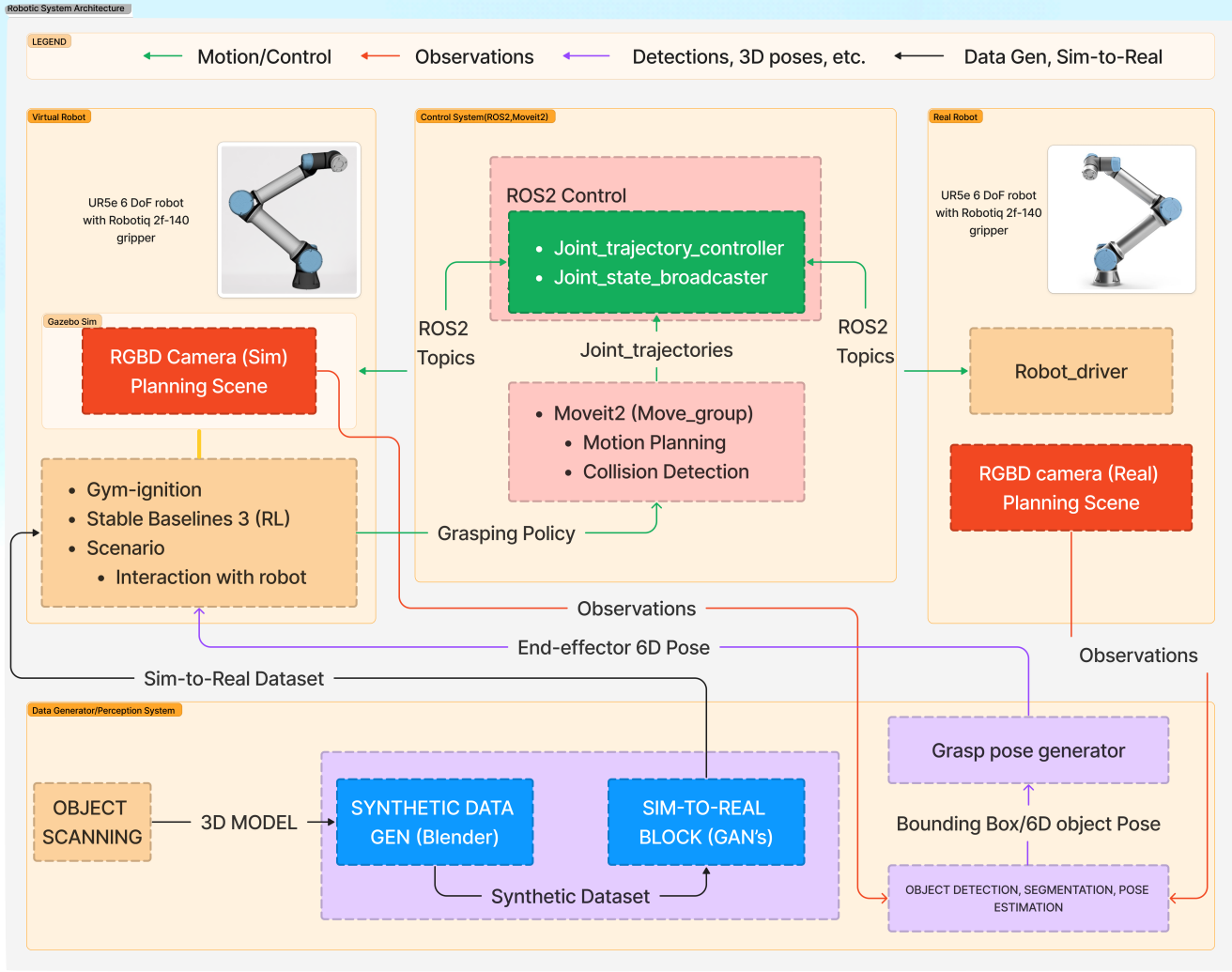
Main objective and problem statement

Specific requirements defined by the vendor:

- Real-time constraints
- Ease of operation
- High pick-and-place rate
- Adapt quickly to new products

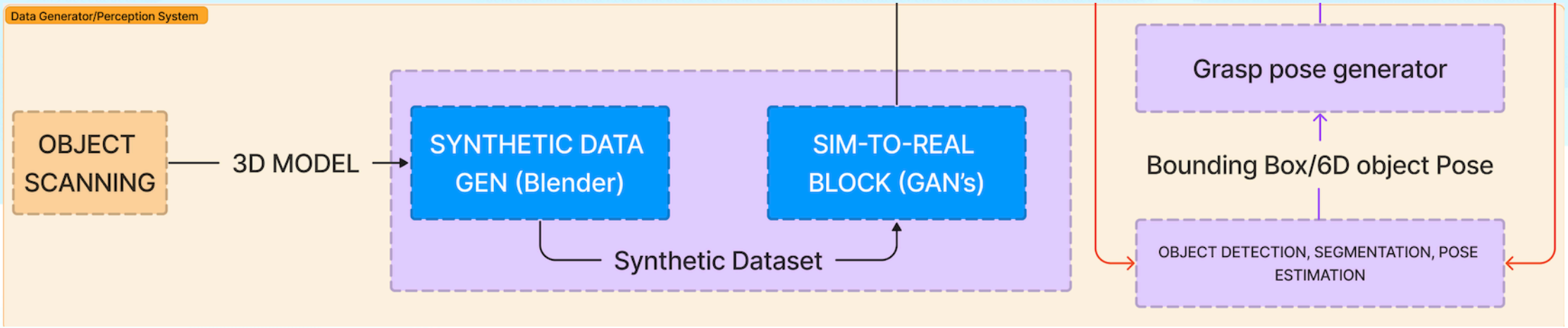
Architecture overview

- The primary goal - simplify the addition of new products to production line.
- Architecture incorporates Reinforcement Learning methods and Generative Adversarial Networks



Architecture overview

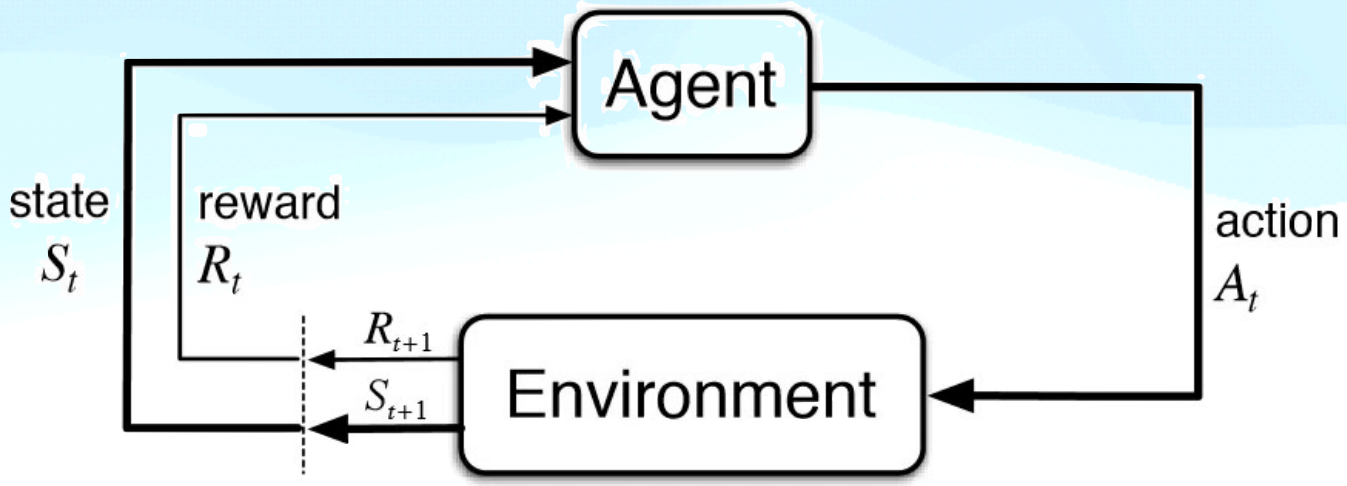
Dataset generator and perception



Architecture overview

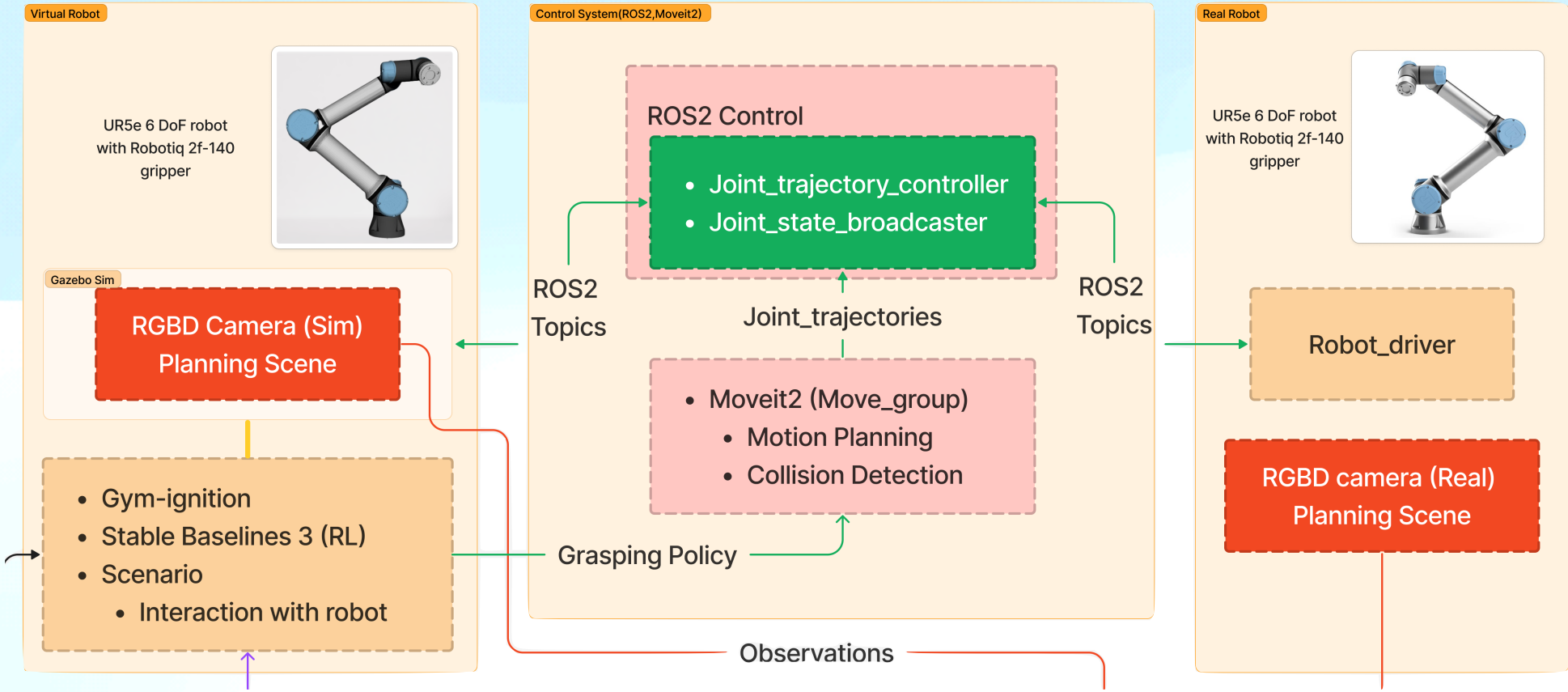
Reinforcement Learning:

- Gym-ignition[5]
- Stable Baselines 3[6]
- PyTorch
- Ignition Gazebo



Architecture overview

Planning and Control



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Architecture overview (Conclusion)

- Overview of architecture
- Adapting robot to new objects
- Reduce Sim2Real gap and improve system's performance
- Reduce dependency on the machine learning experts
- Next steps:
  - Implementation and evaluation of provided architecture for pick-and-place task
  - Further optimize the robotic system

Sim2Real with Cycle-GAN

- Sim2Real with Cycle-GAN - Article pending (Nov-Dec’23)

Sim2Real with Cycle-GAN

- Robot trained in a simulated environment and then this learned policy transferred to real robot.
- Performance decrease is observed - "reality gap”
- Cycle-GAN is designed to address "reality gap” issue
  - In our particular case processed images has the potential to enhance the quality of object detection

Sim2Real TESTS

- As a part of integration process (into proposed architecture) we have tested Sim2Real image translation with Cycle-GAN and object detector.
- We have set-up following environment in Ignition Gazebo simulator:
  - Camera set above the table
  - Bottles are placed randomly (qty., pos., orient.)
  - Camera stream passed to the Cycle-GAN using ROS2 topic
  - Translated image is passed to the object detector

Sim2Real TESTS

- For object detection we use YOLOv5m model, which is trained only on real data:
  - 6370 images for training
  - 1820 images for validation
- We assume that object detection works worser with simulated objects (bottles)
- The main objective of this tests to check if the Cycle-GAN improves simulated data (makes them more realistic)

Sim2Real TESTS

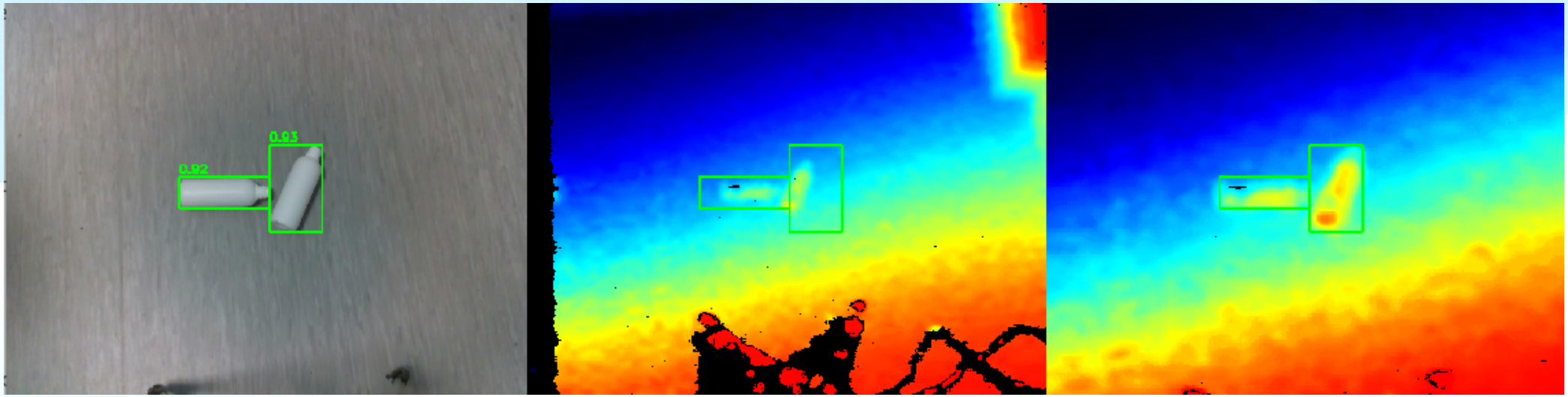
Sim2Real TESTS (results and conclusions)

	Gray value, %						
	10	25	35	45	55	65	75
SIM (accuracy, %)	91.86	92.36	**92.7**	**92.96**	**92.82**	**92.5**	**90.64**
SIM2REAL (accuracy, %)	**92.1**	**92.62**	**92.74**	**93.02**	92.42	90.22	85.98

- Bottles in training dataset look darker (greyish)
- Tests are made changing bottle colour in simulation
- Better results - 25-45% grey value
- Results are almost the same - possibly because of the object simplicity

Pose Estimation

- Another critical part of the proposed architecture
- First attempts in pose estimation for our particular case

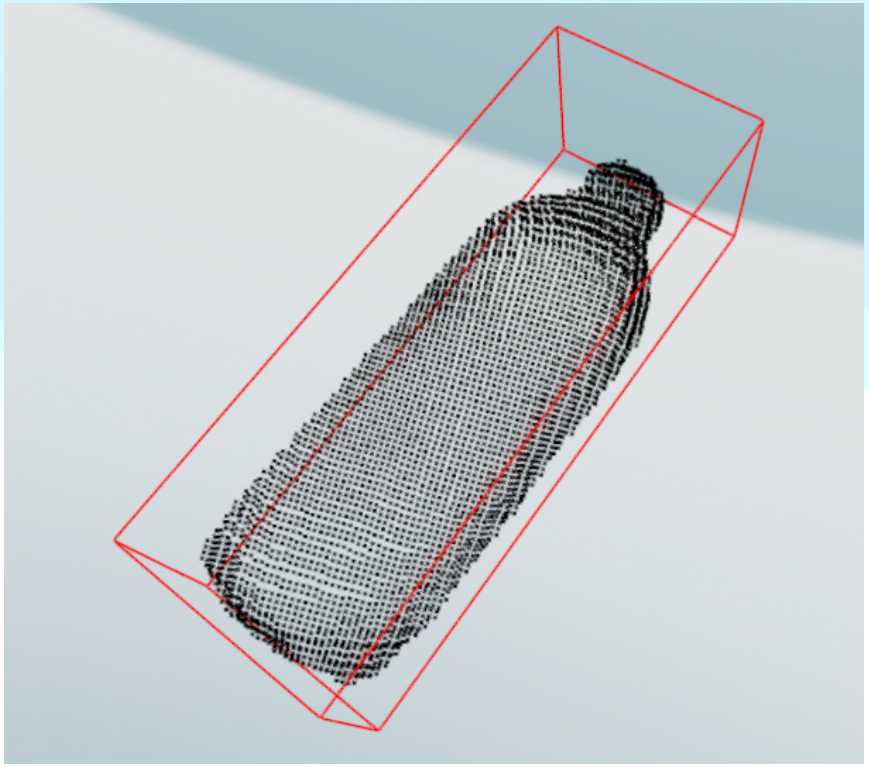


Pose Estimation

- Detected objects point cloud is segmented out from the depth image

Pose Estimation

- Open3D library to process point cloud
- “OrientedBoundingBox” function
- Compute oriented Bbox based on PCA
- Gives us the center of the bbox, rotation R and extent in x, y and z direction



Next steps

- Finish article
- Continue work with pose estimation
- Finally get started with RL experiments
- Once all blocks are ready make article from extended abstract about architecture.

Thank you!