ECHORD experiment ActReMa

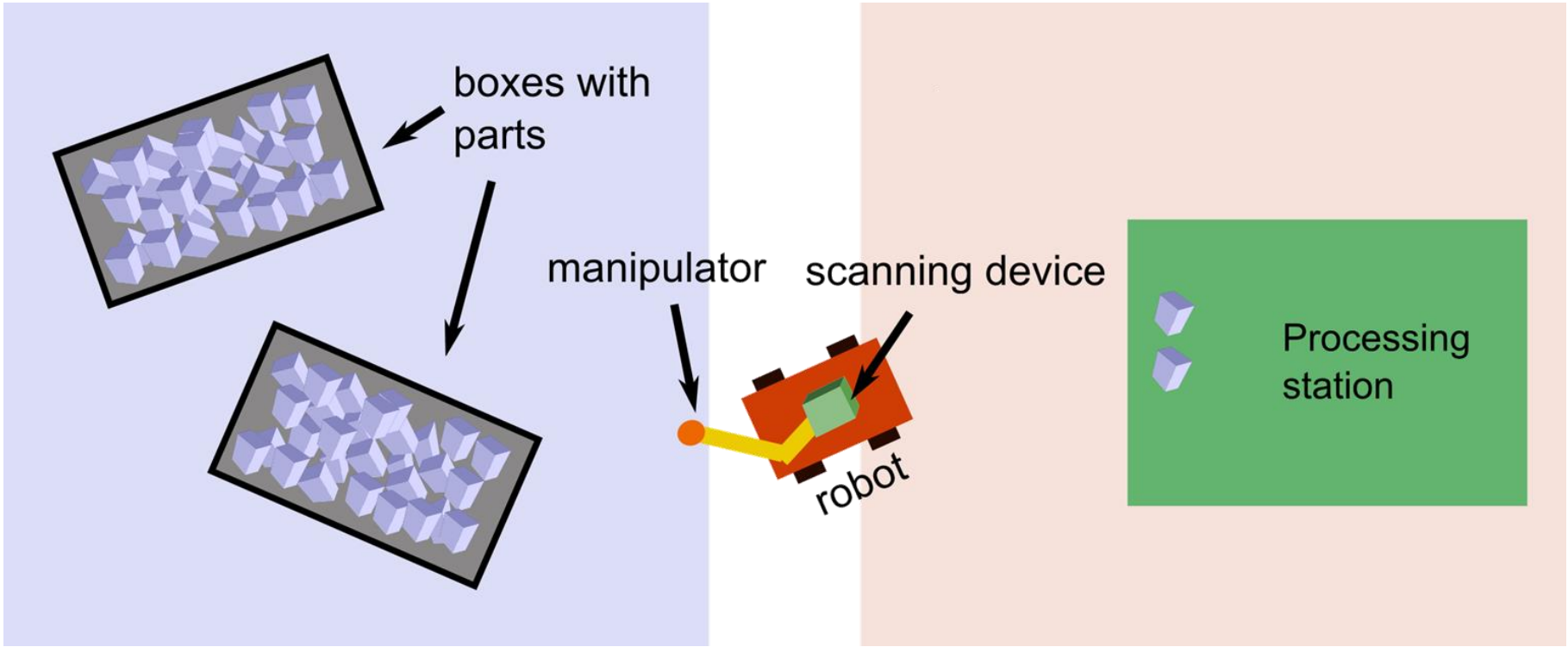
Active Recognition and Manipulation of Simple Parts Exploiting 3D Information

Experiment Partners:

- Rheinische Friedrich-Wilhelms-Universität Bonn
- Metronom Automation GmbH

Experiment Scenario

A robot grasps parts out of a transport box and delivers them to a processing station.



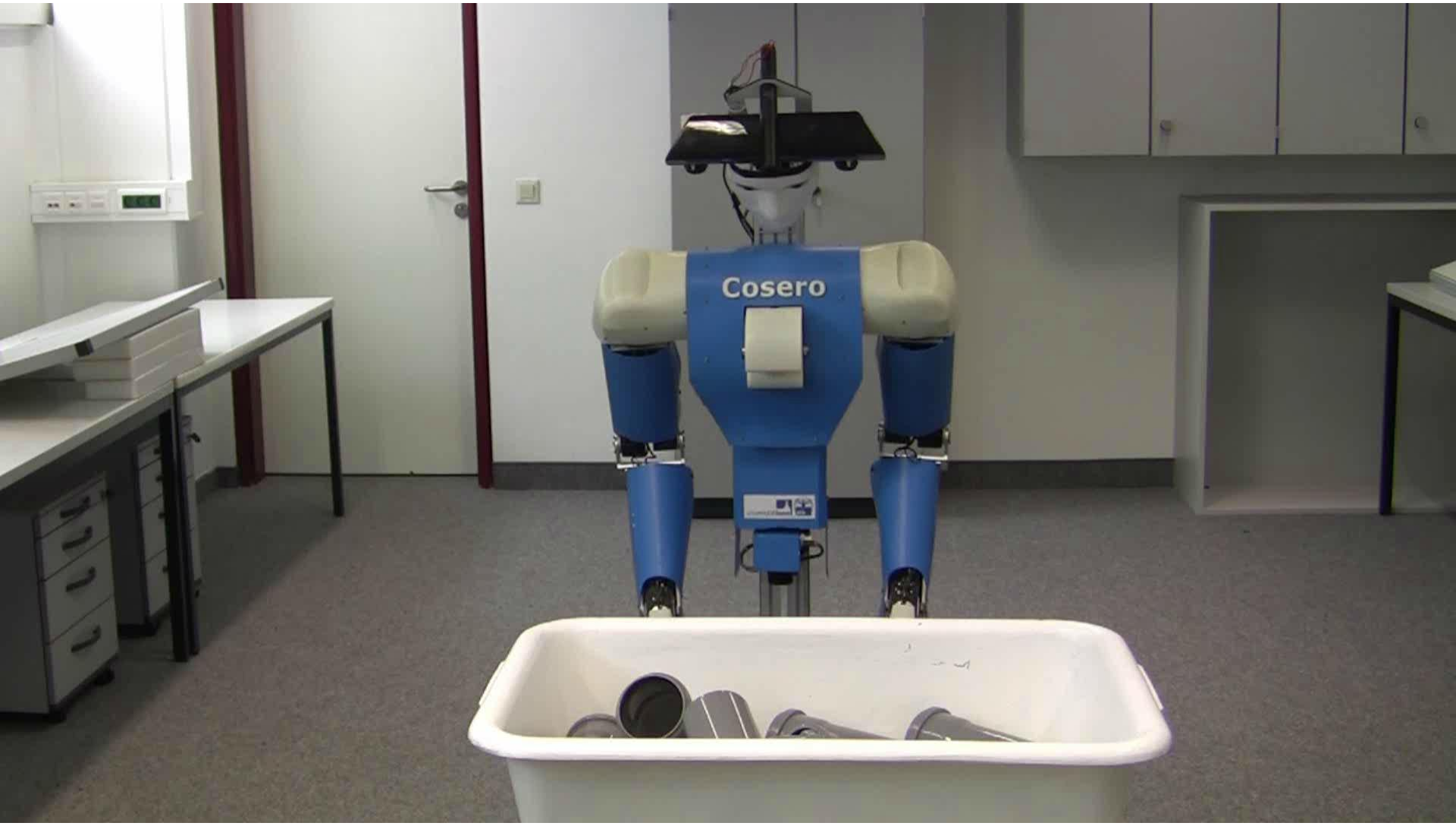
Objectives

- Robust and efficient detection and pose estimation of known objects from measurements of a 3D laser scanning device

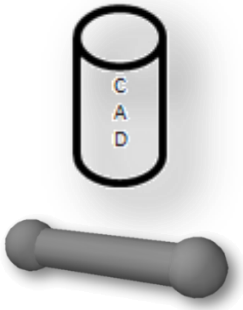
- Efficient exploration of the part arrangement in the transport boxes to handle occlusions

- Flexible grasp and motion planning for a robot in a semi-structured environment, i.e. when the arrangement of parts and transport boxes is variable

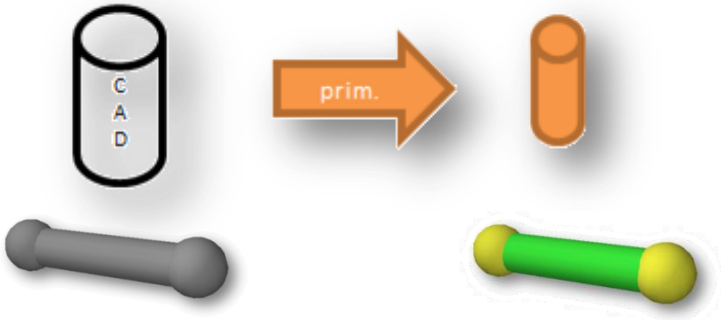
Acquisition of 3D Measurements



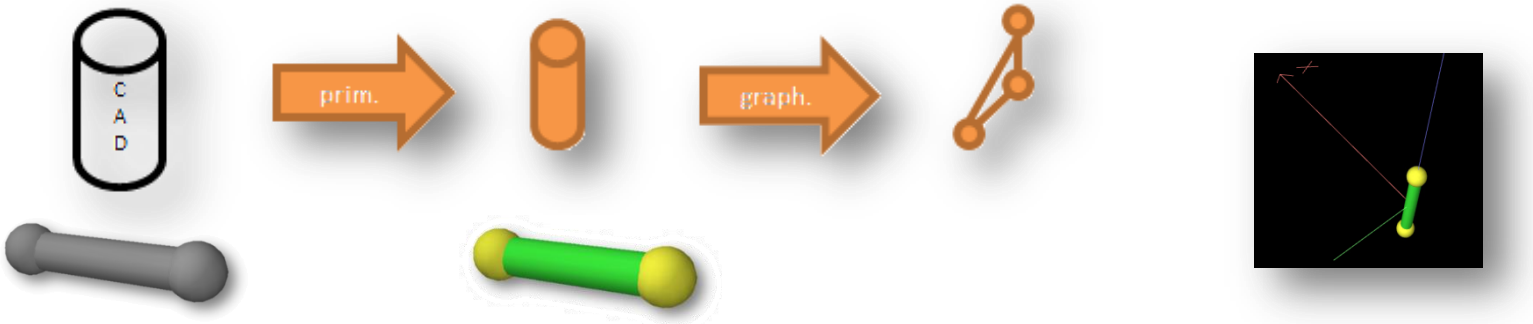
Graph-based Recognition



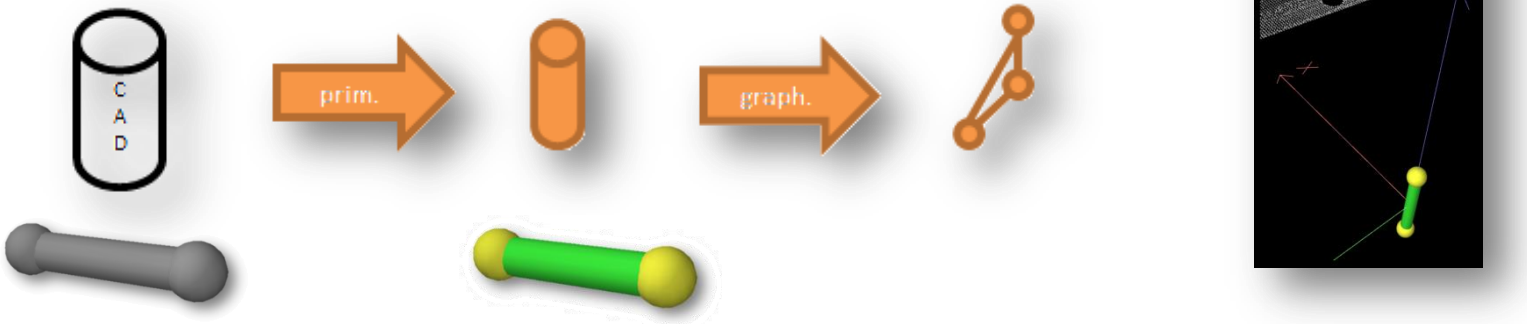
Graph-based Recognition



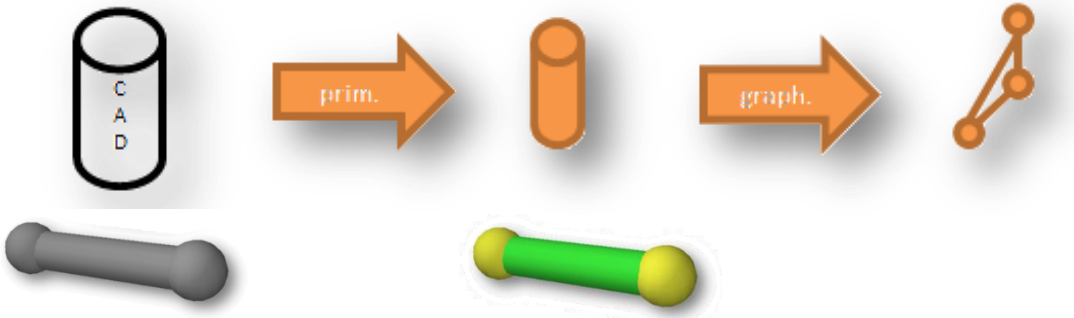
Graph-based Recognition

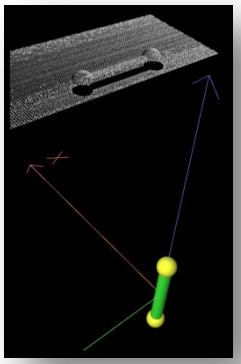


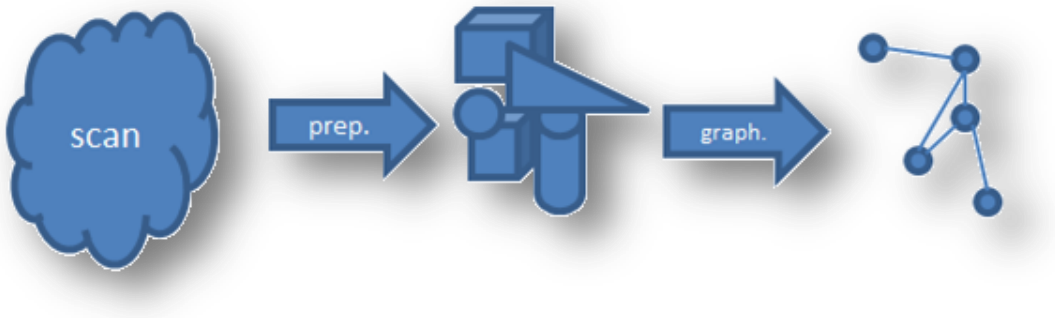
Graph-based Recognition



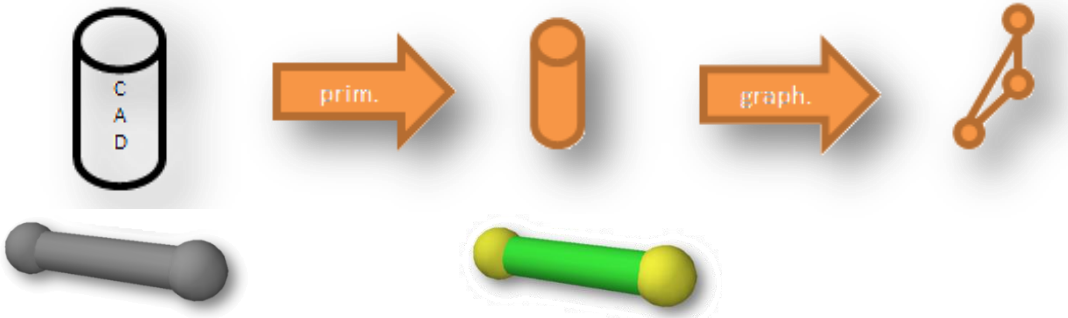
Graph-based Recognition

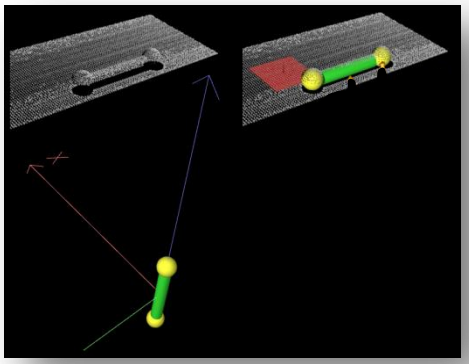


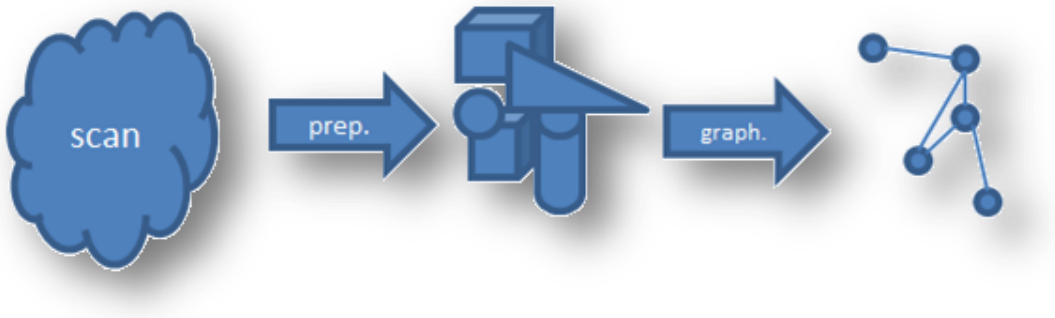




Graph-based Recognition







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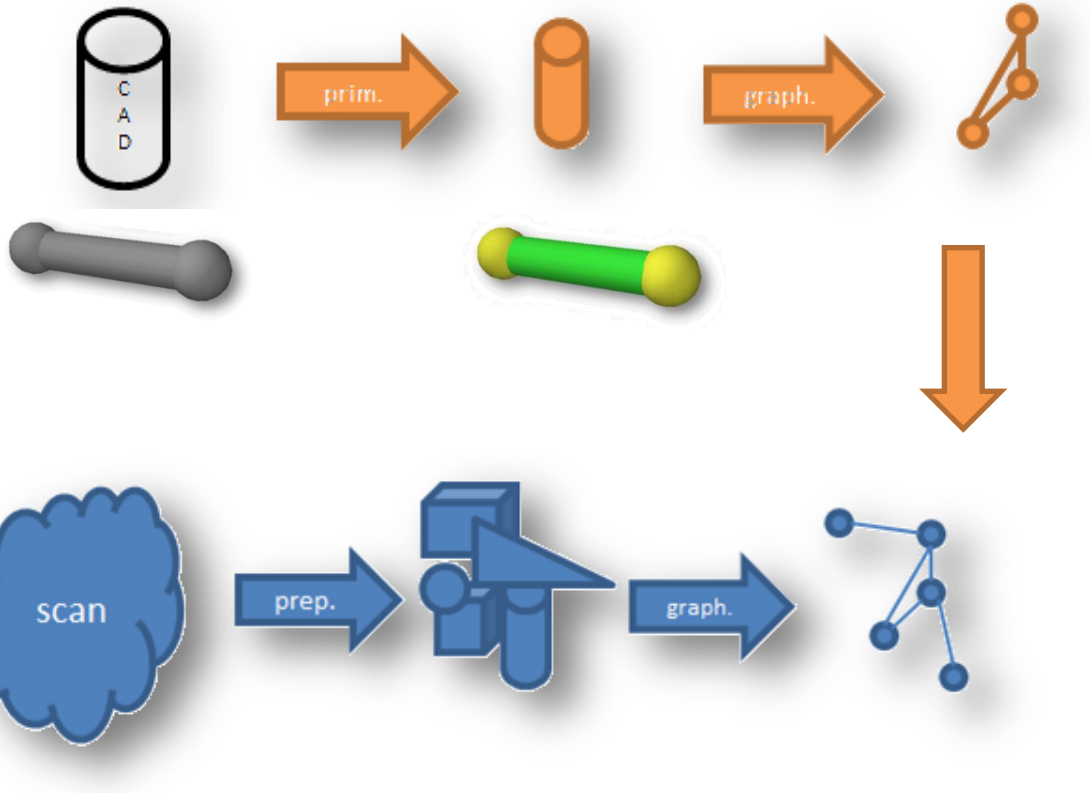

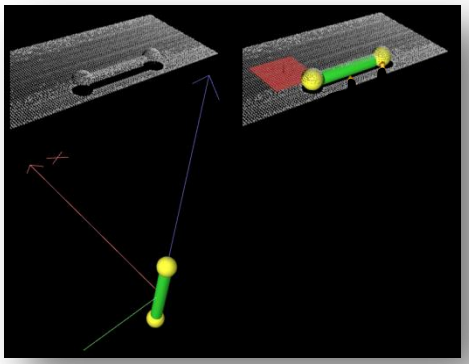

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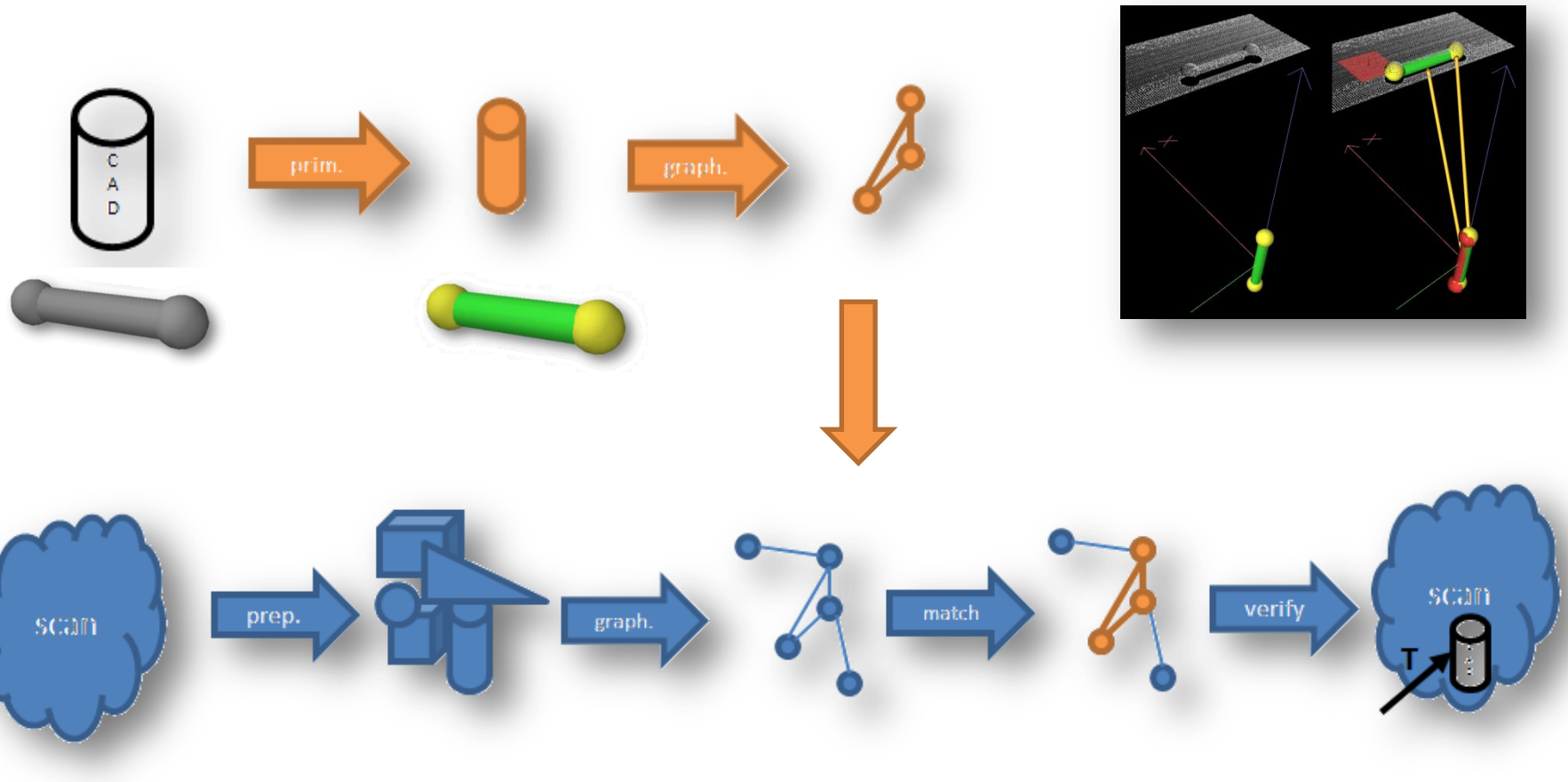
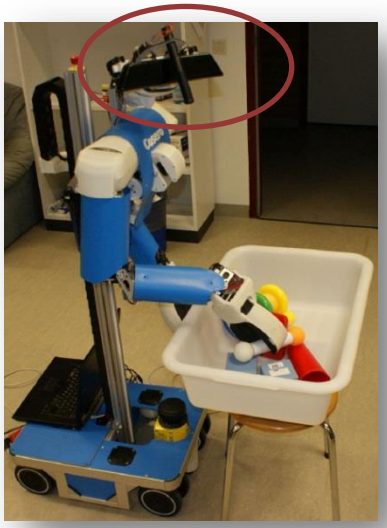
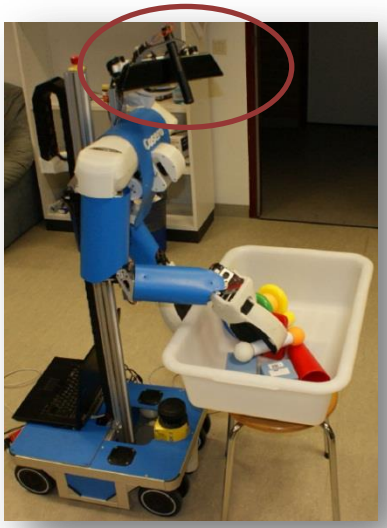


Microsoft Kinect Result

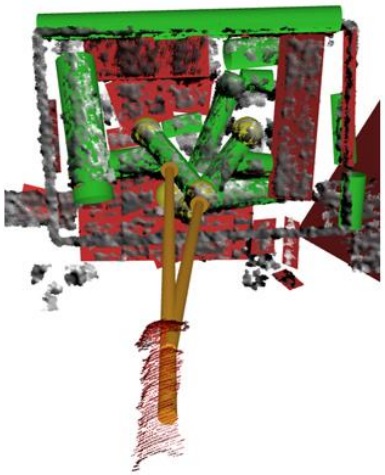


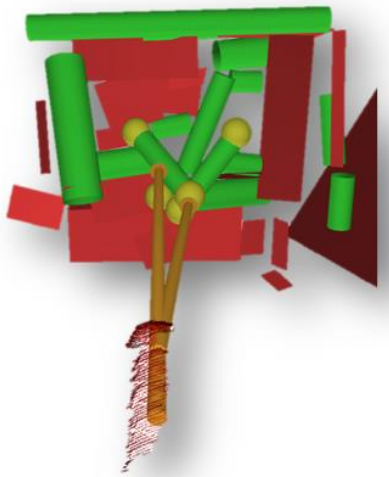
Model

Microsoft Kinect Result

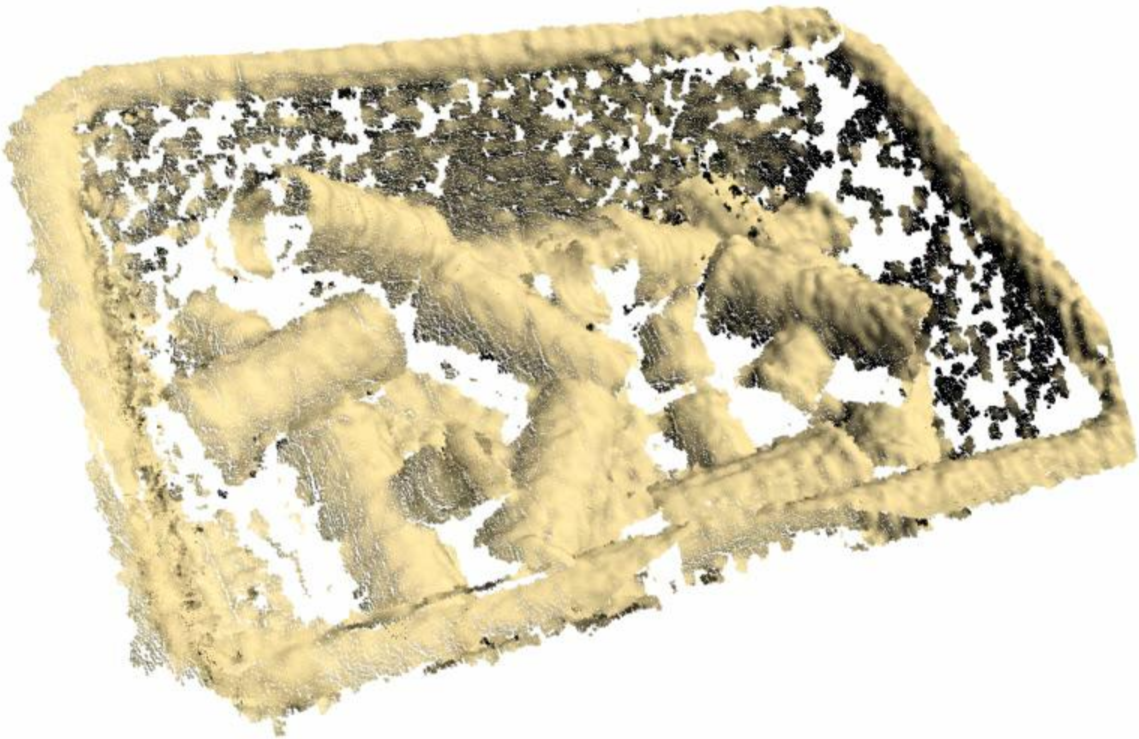


Model





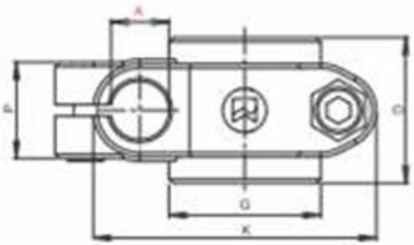
Pipe Connector Detection

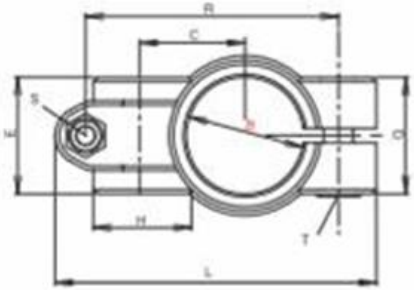


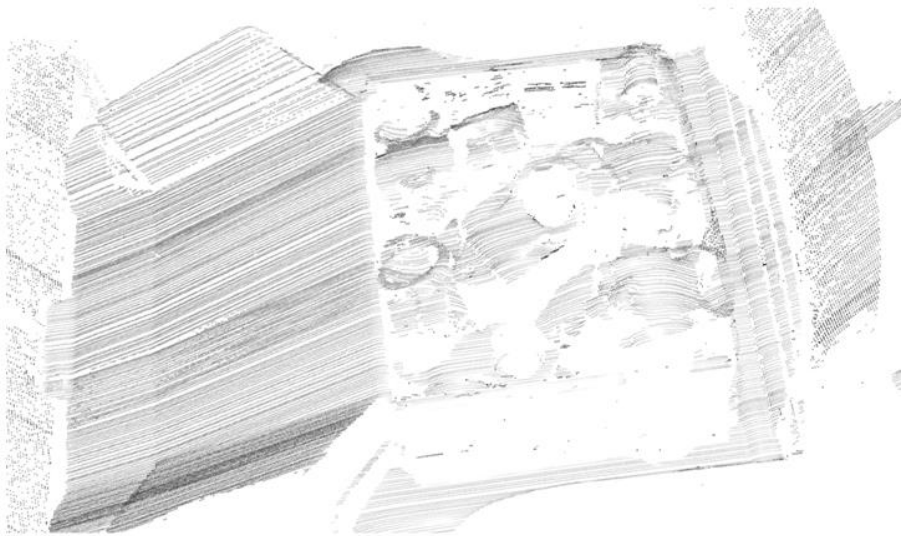
Input point cloud
Detected primitives
Detected objects

Goal: Better Pose Detection for Construction Parts like These

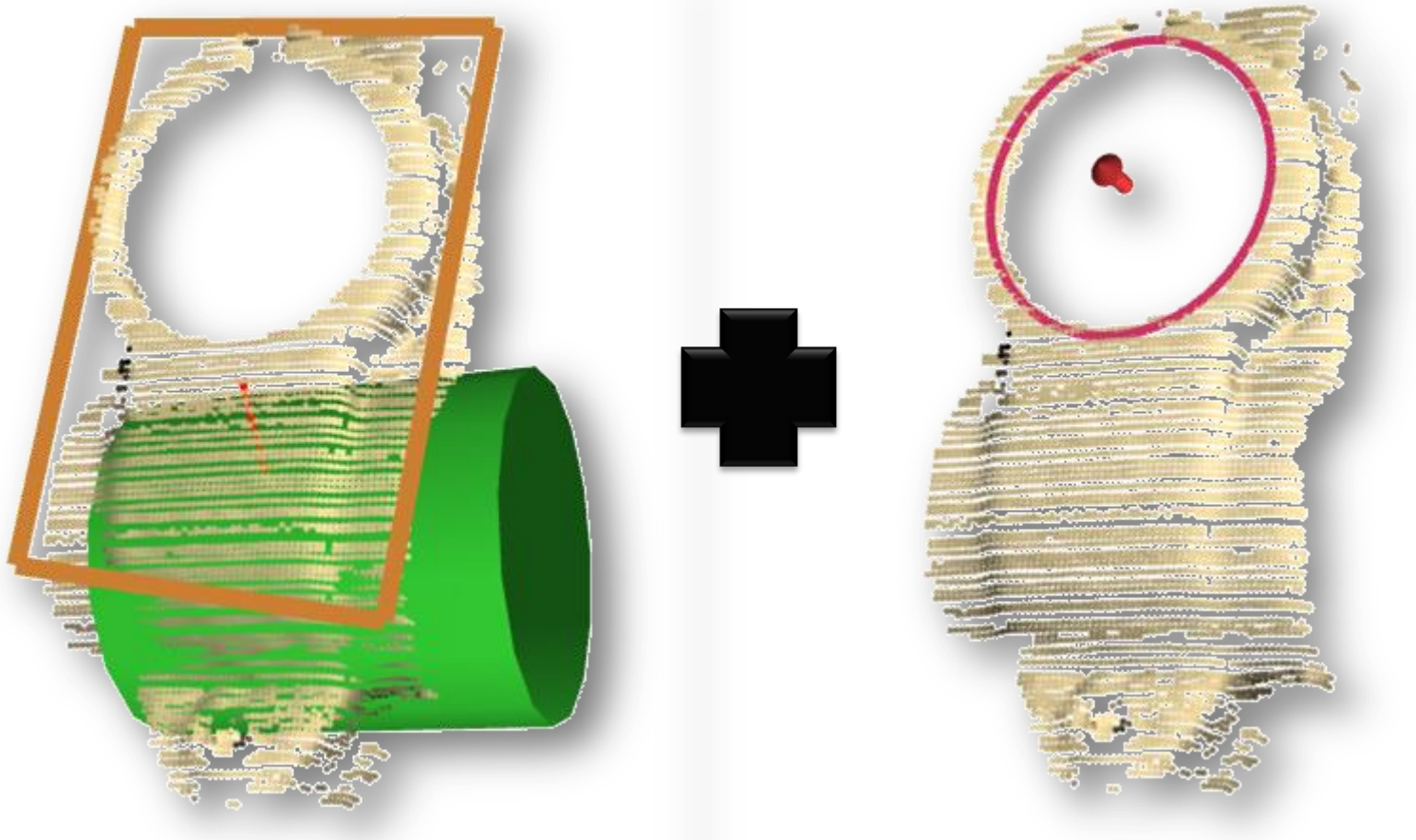
More Difficult Scenario



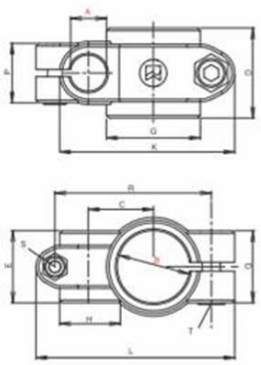


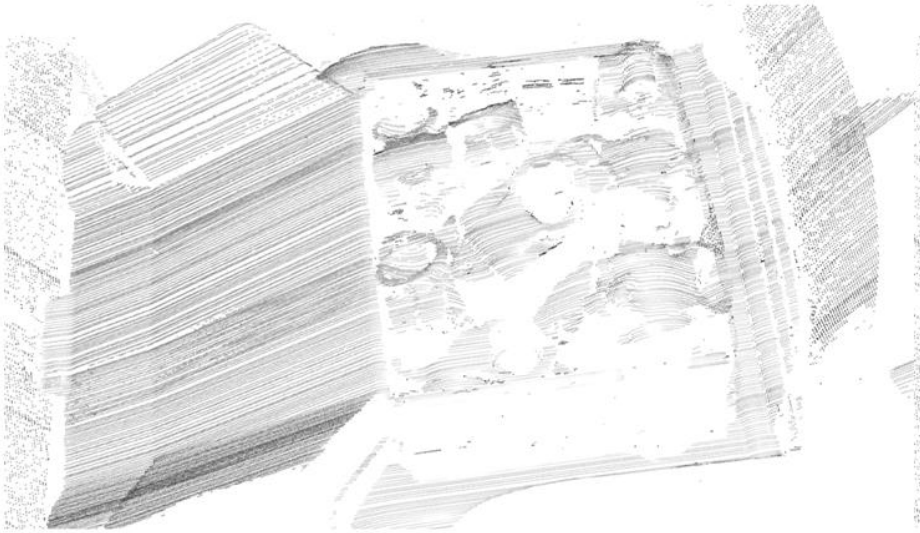


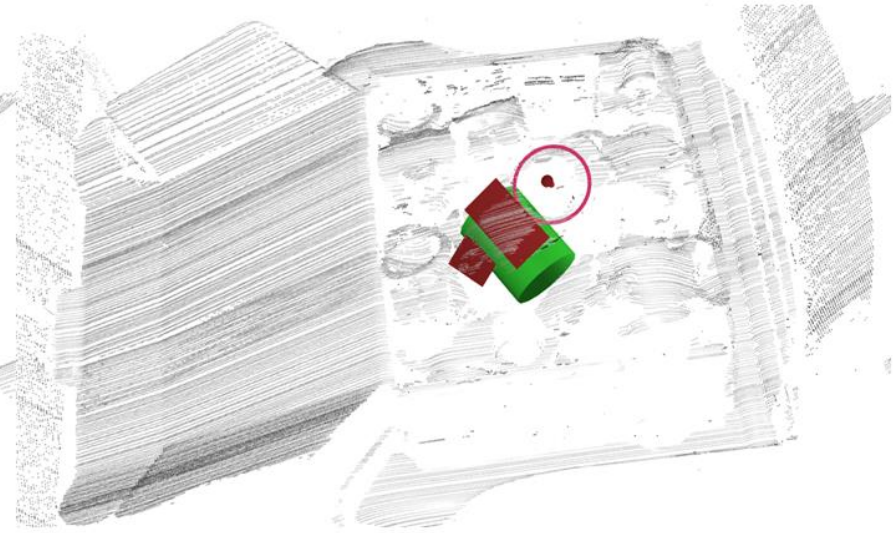
Idea: Combining 2D and 3D Shape Primitives for Object Detection and Pose Estimation



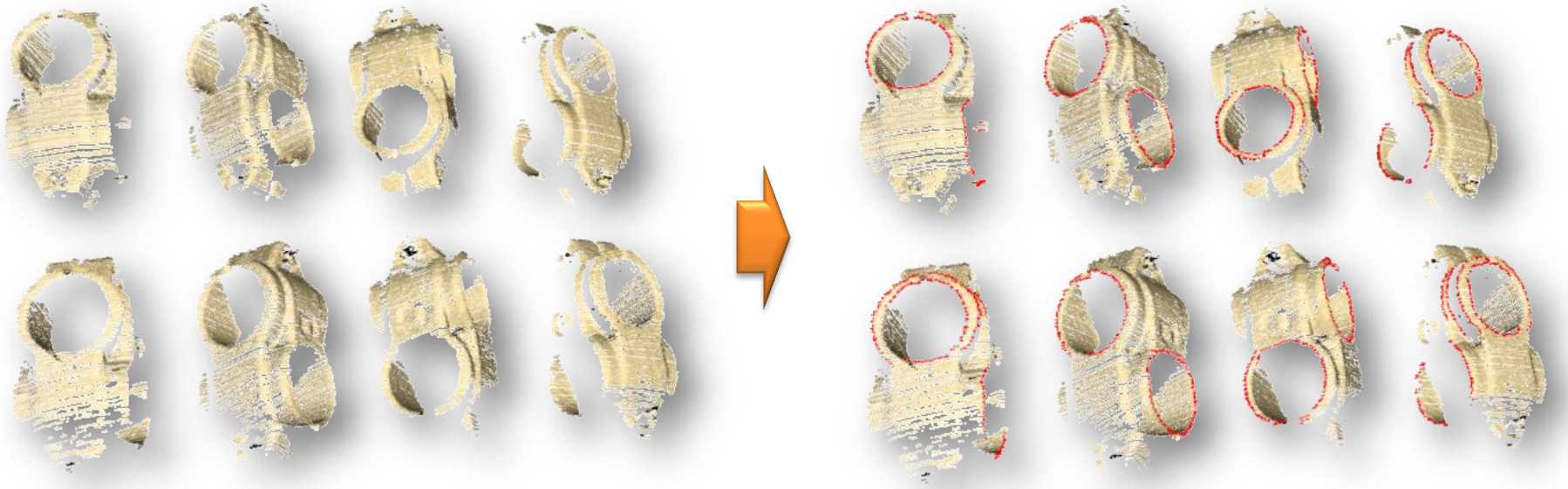
2D Primitives

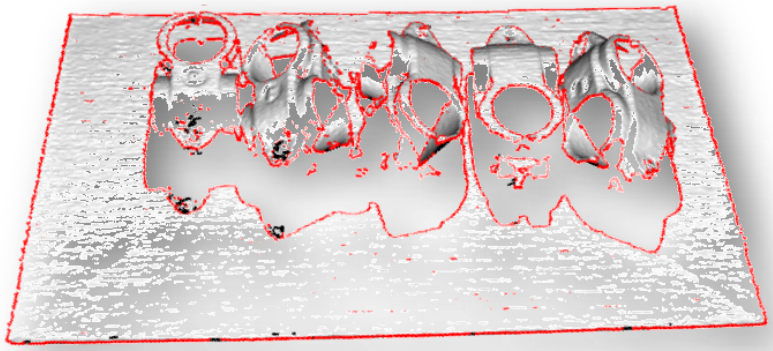


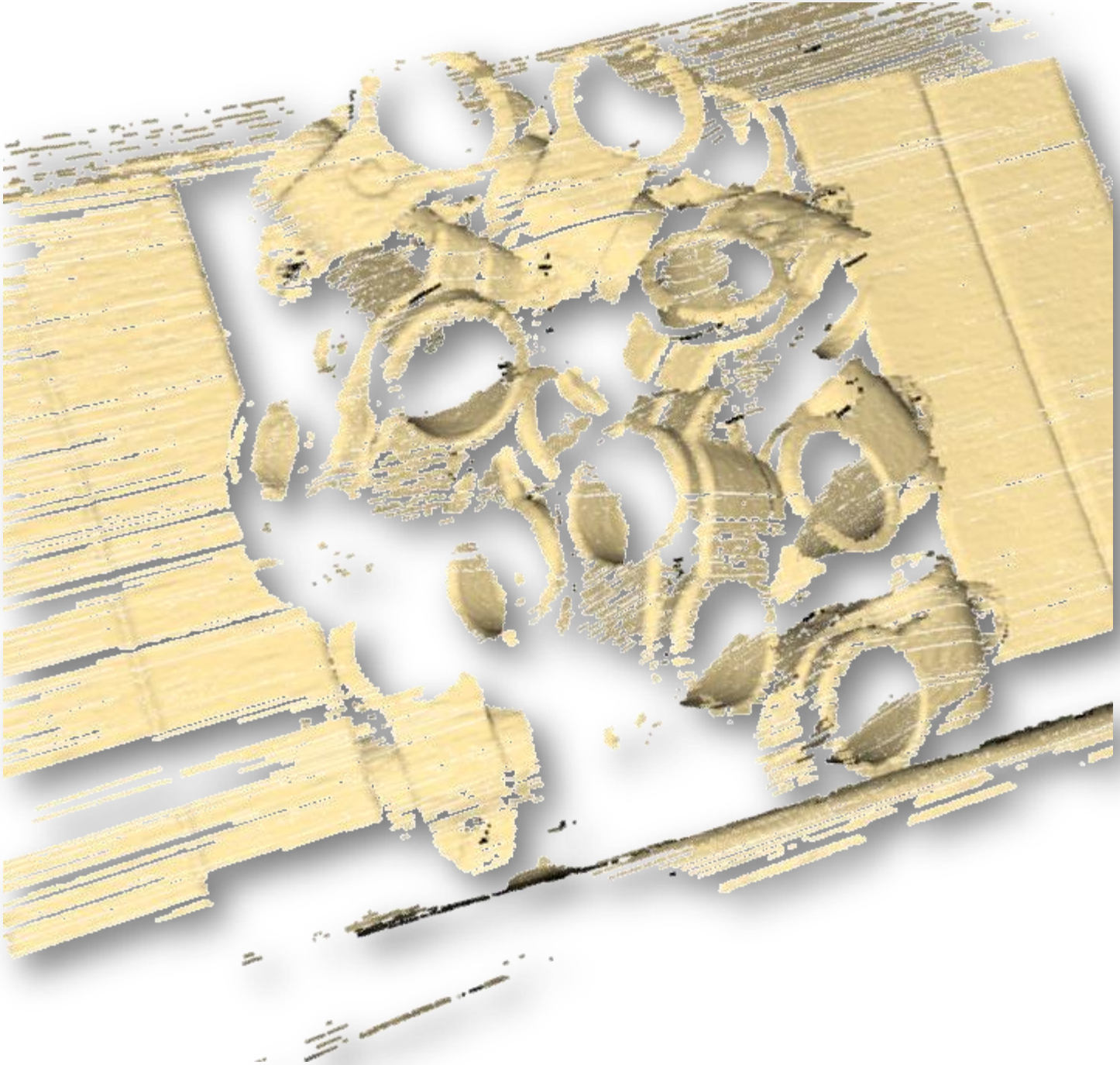


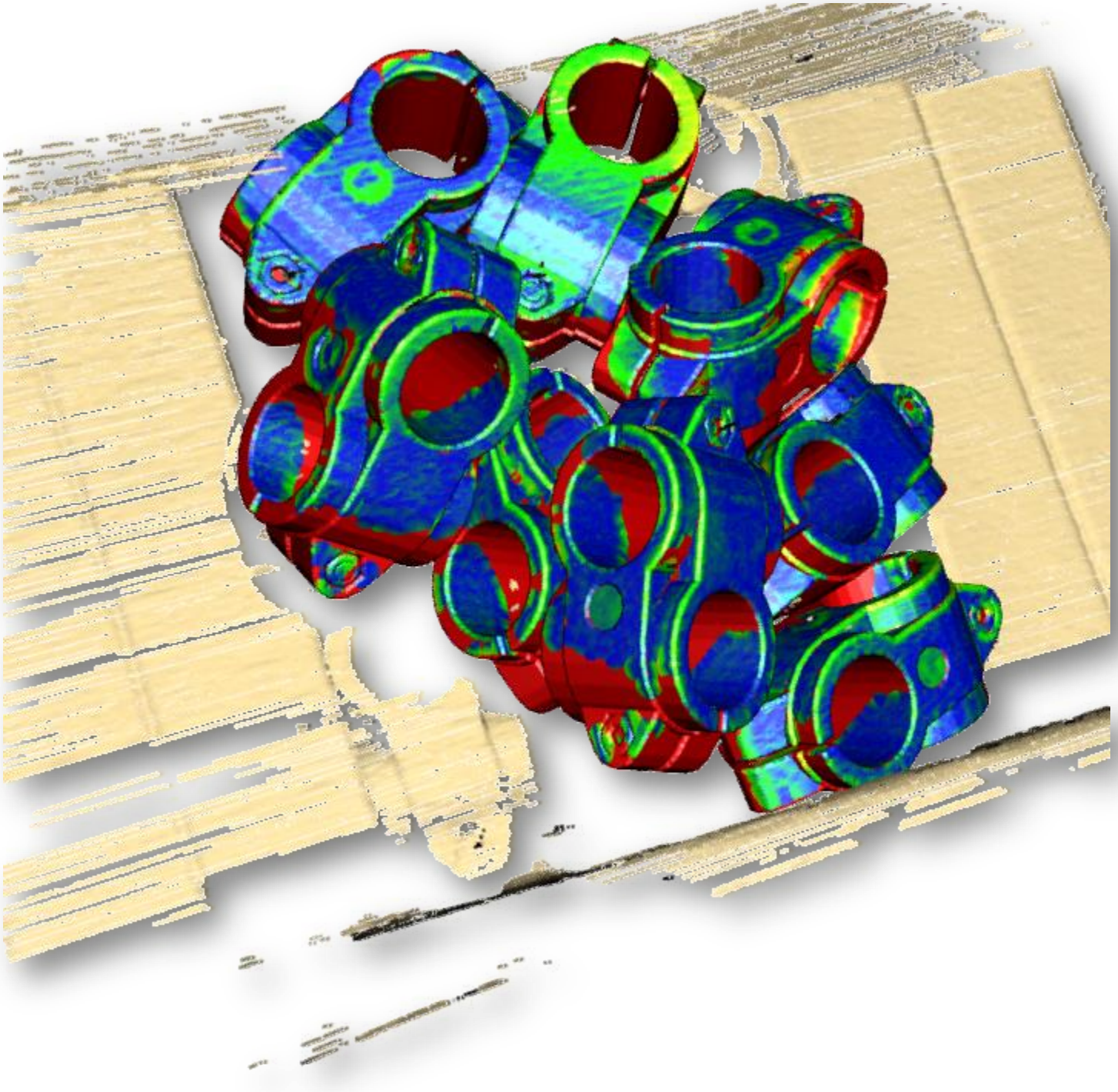


2D Primitives Improvements

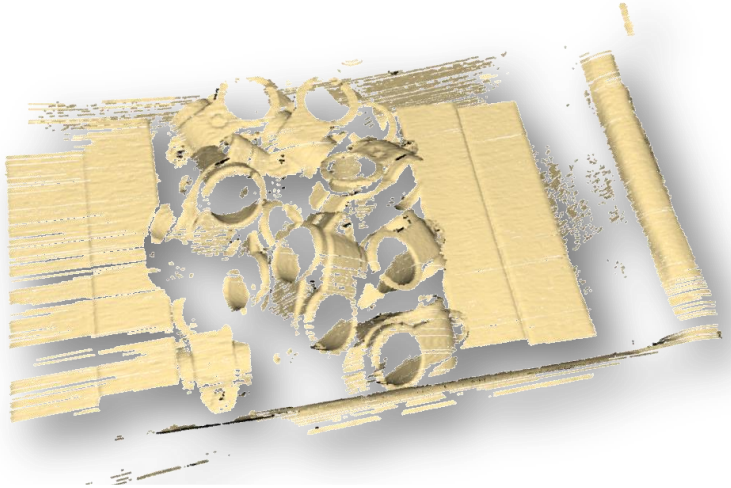


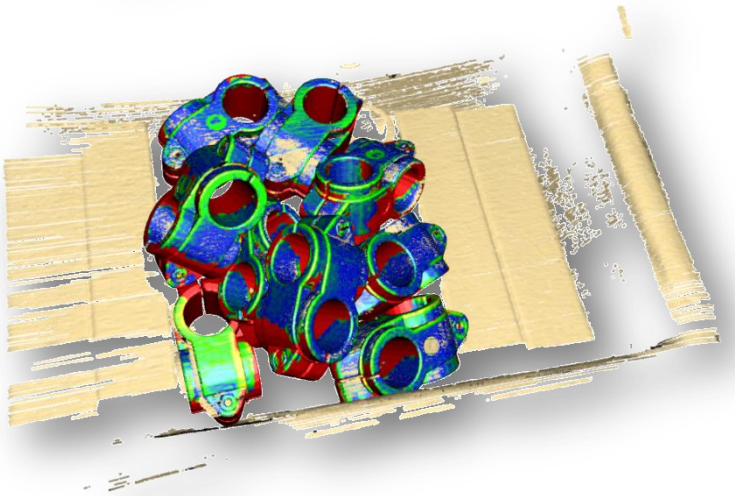






Comparison: Input, 3D only, PPF, Ours





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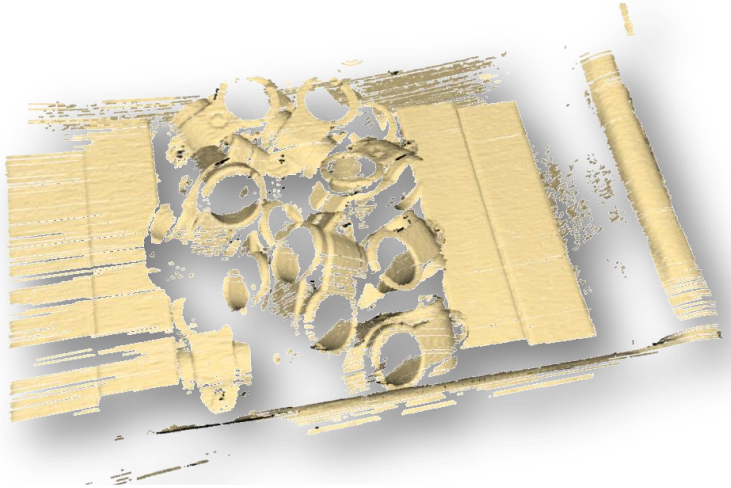

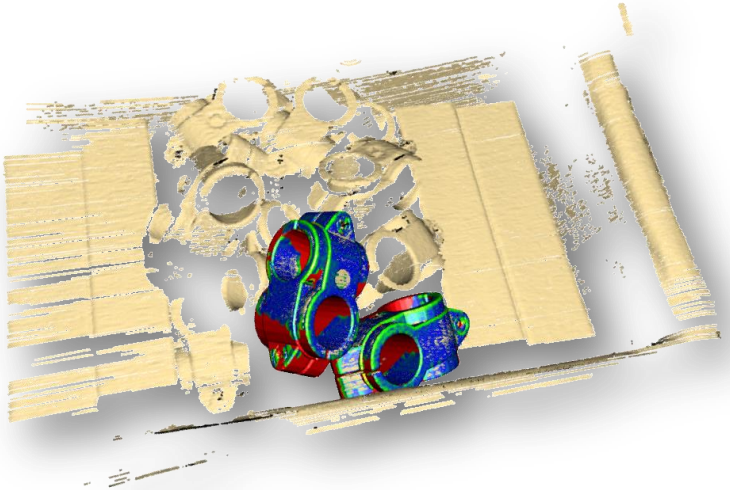

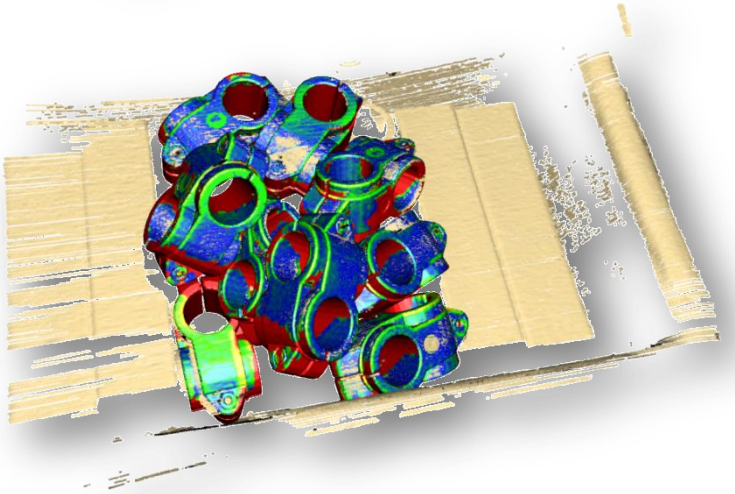

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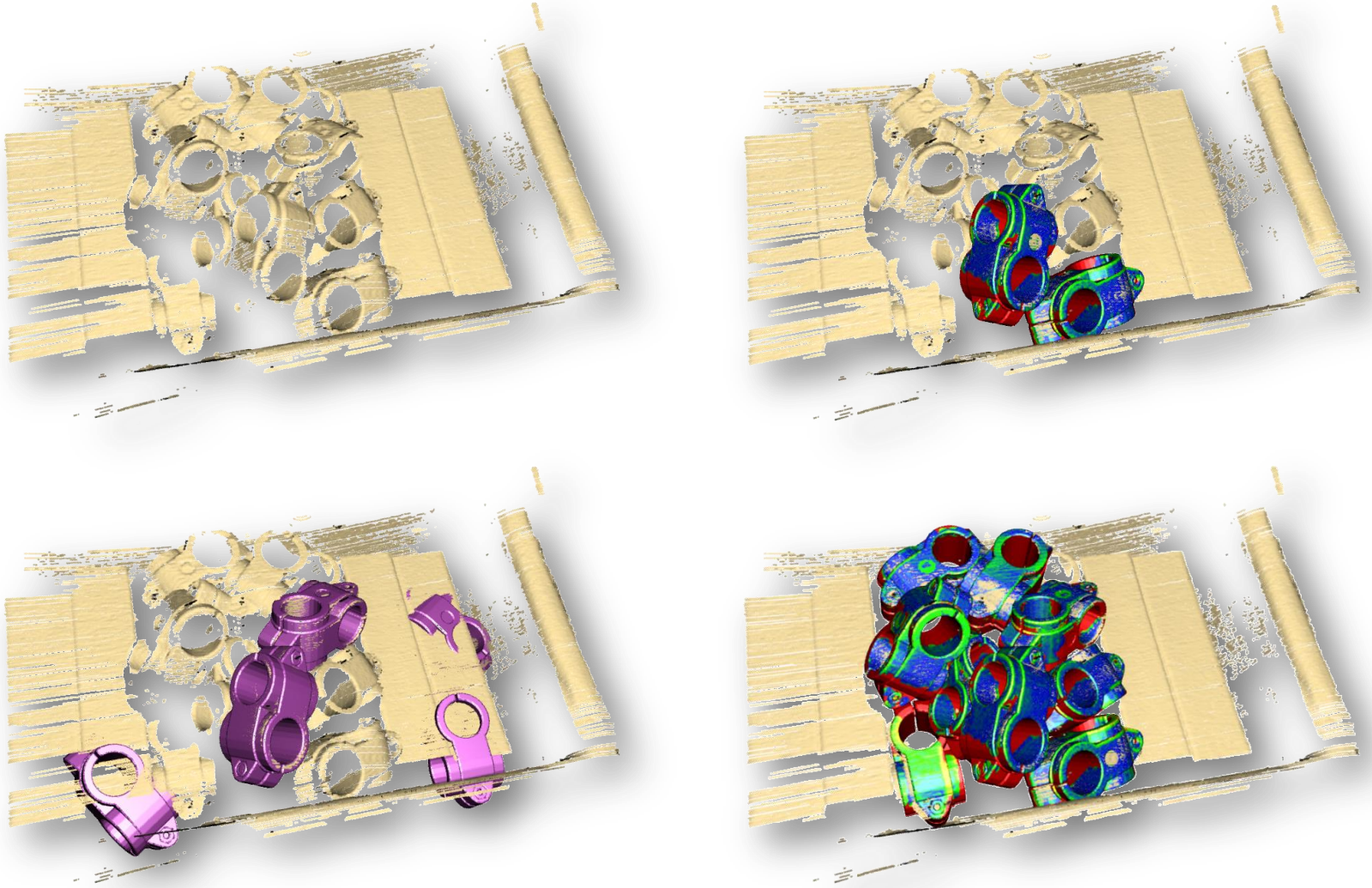

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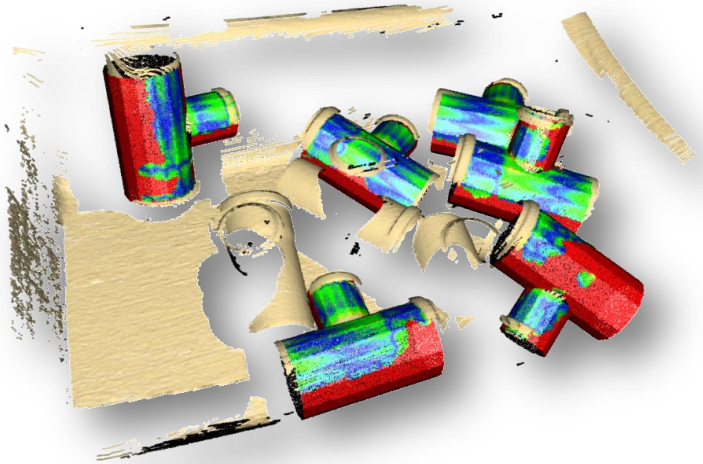

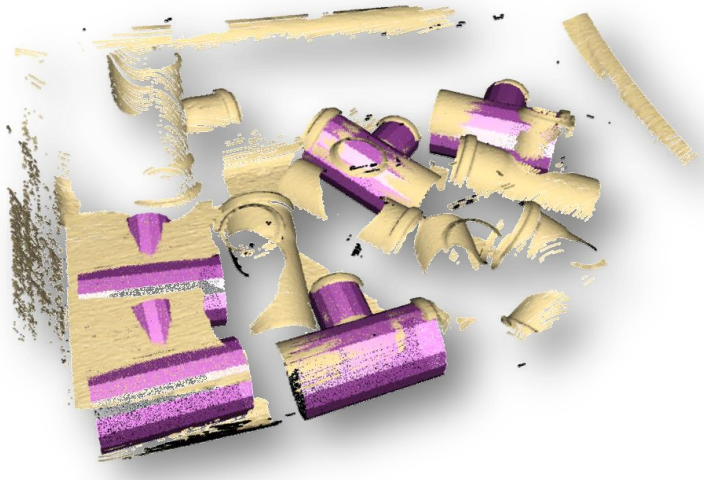

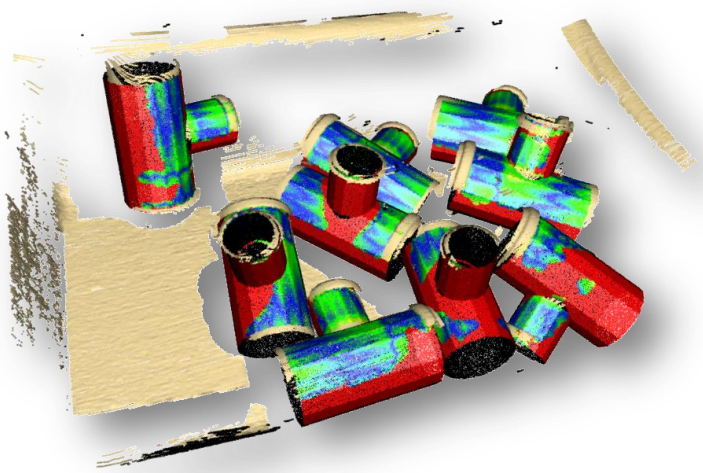

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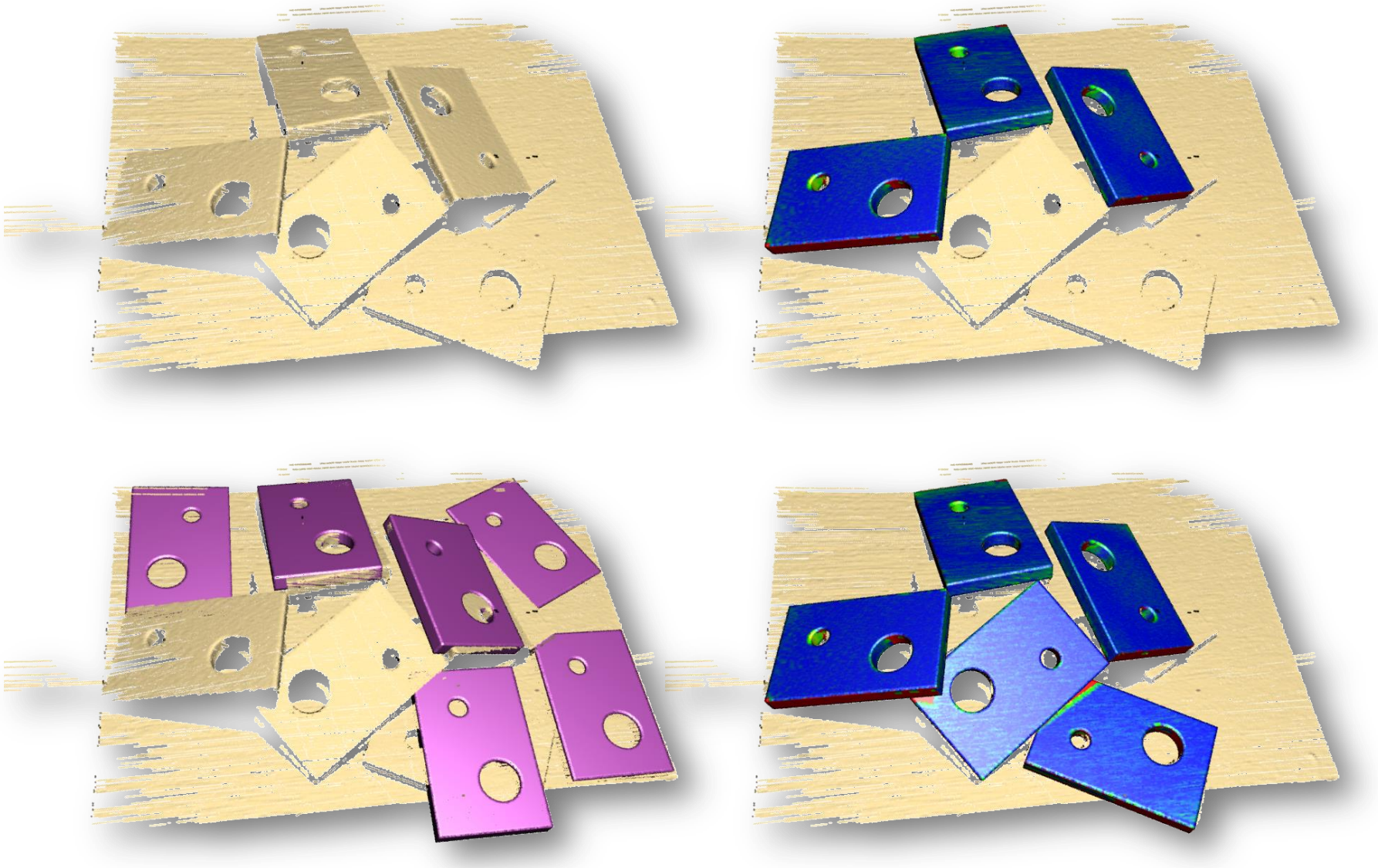
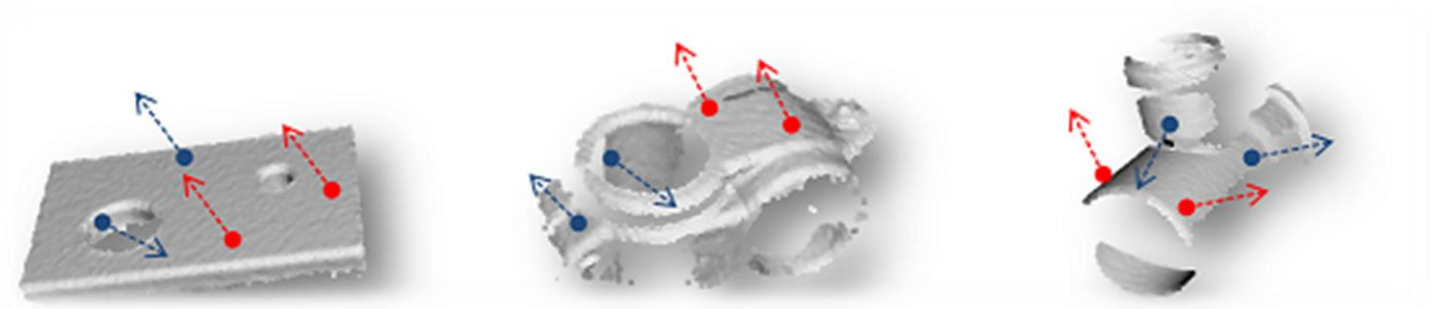


Quantitative Results

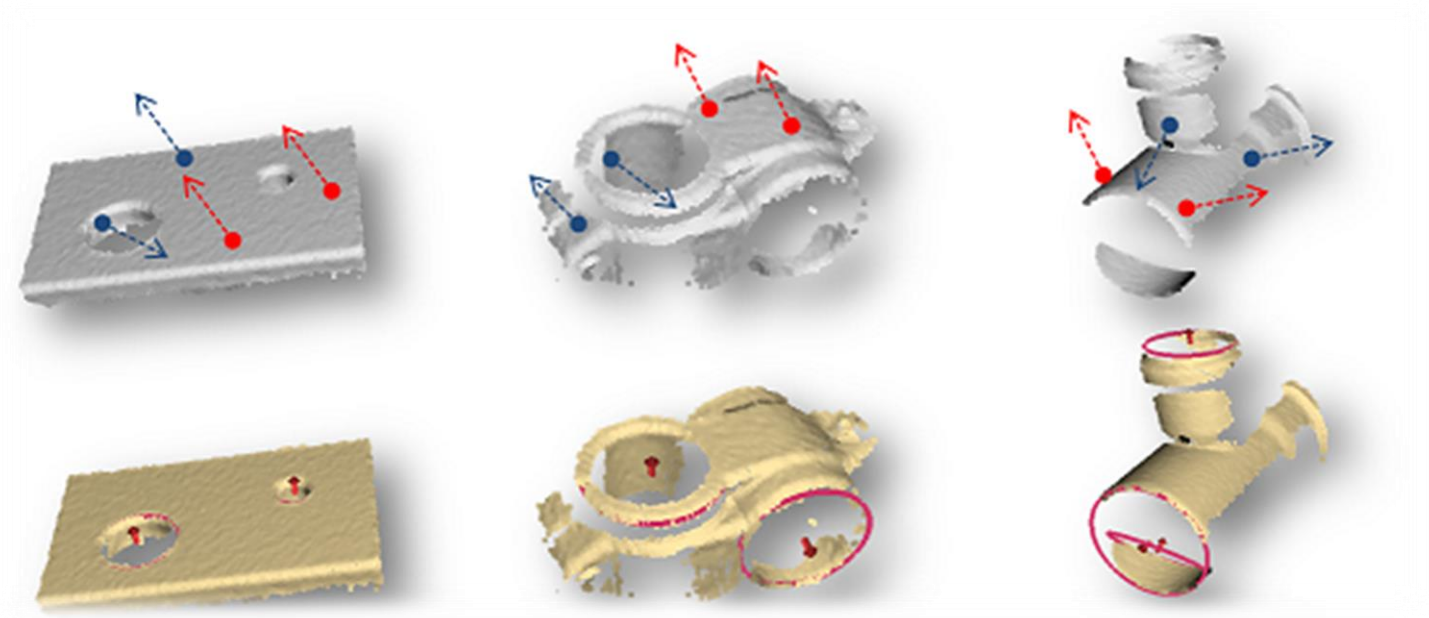
AVERAGE ACCURACY OF THE DETECTION

Average accuracy	Ours	Without 2D	PPF
CCP	0.81	0.23	0.29
Pipe	0.89	0.47	0.27
Wood	0.82	0.21	0.08
Overall average	0.84	0.30	0.22

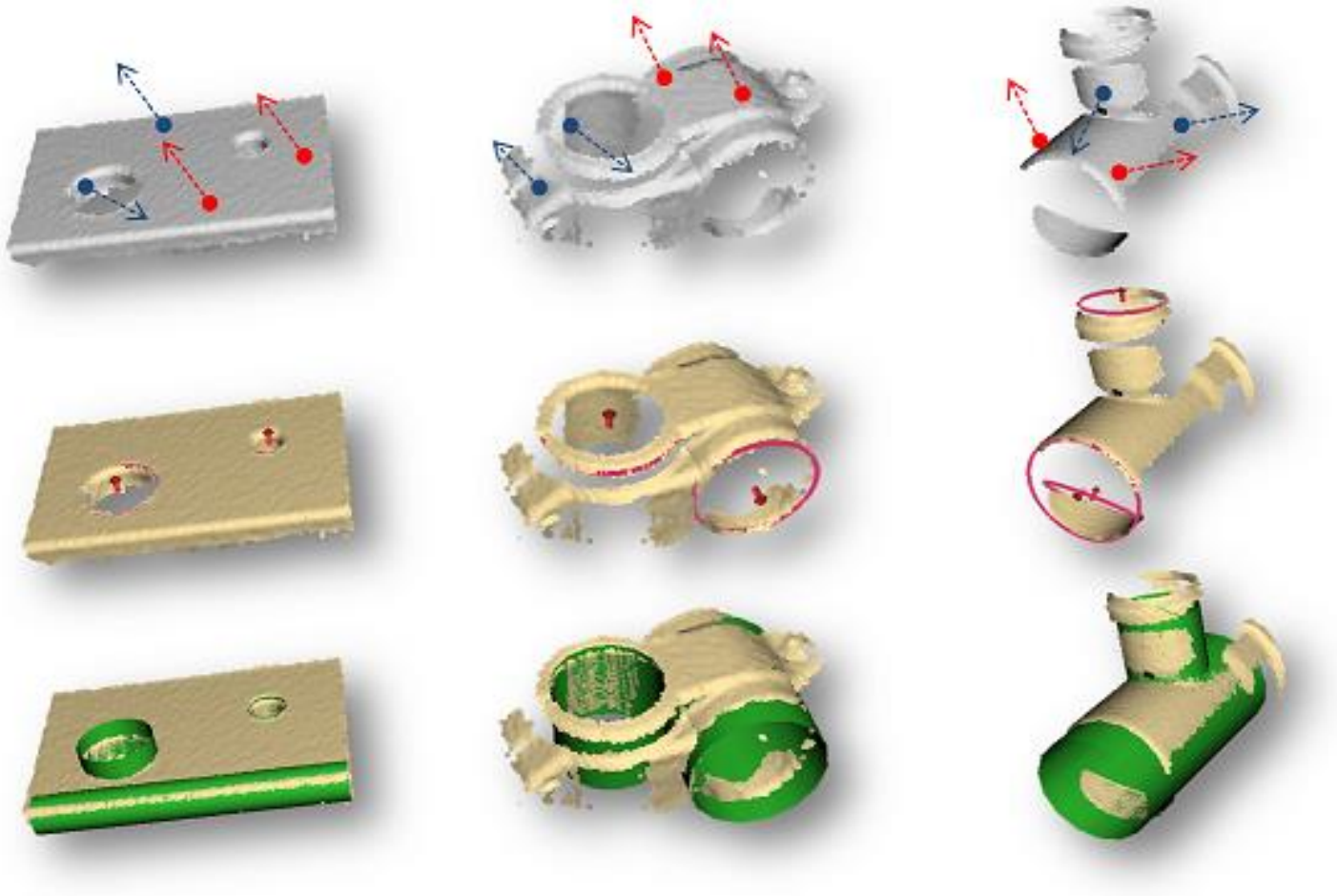
Point-Pair-Feature Compare



Point-Pair-Feature Compare

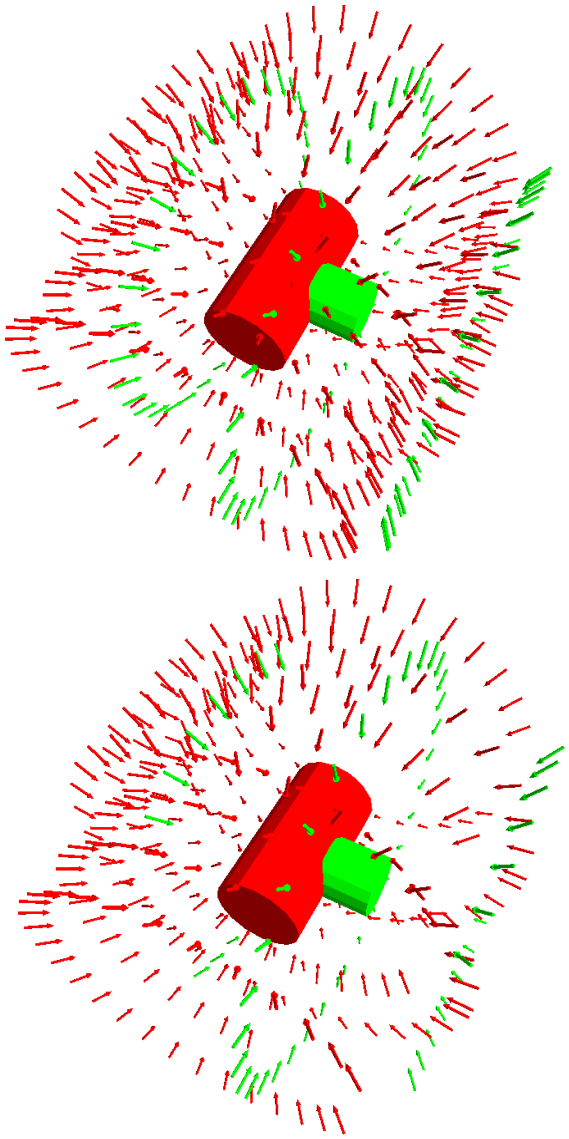


Point-Pair-Feature Compare



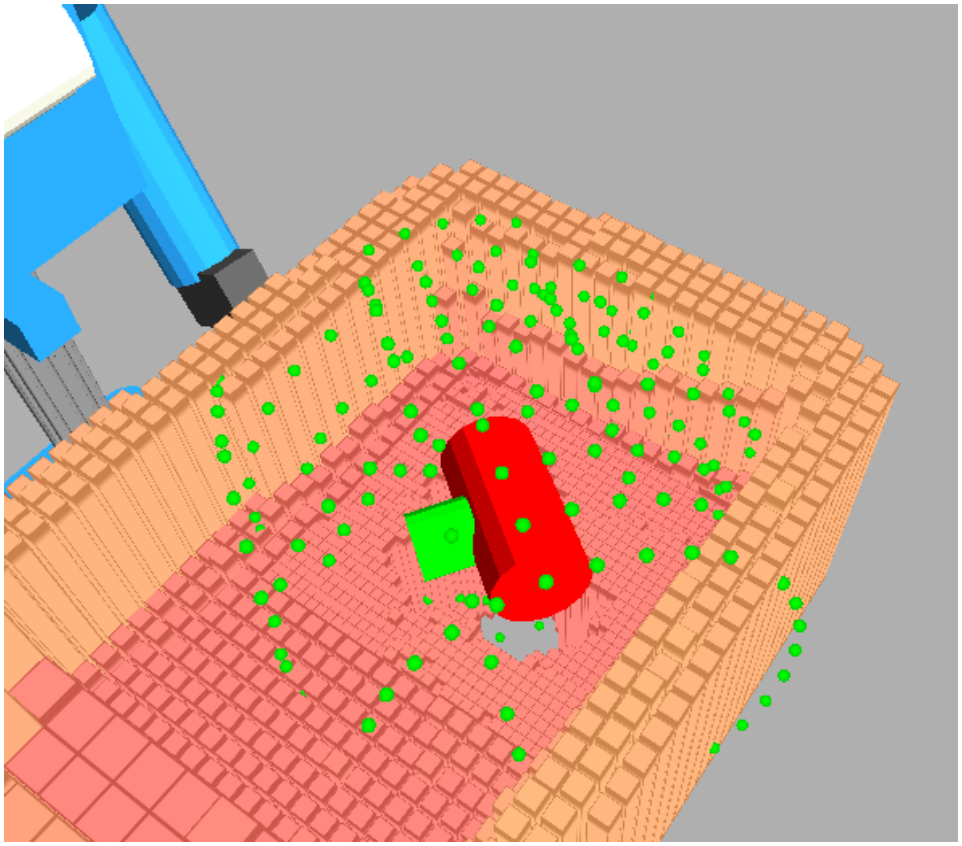
Grasp Planning – Offline Phase

- Preprocessing that is independant of the object pose
- Calculation of a set of possible grasps for each primitive
- Fast pruning of grasps that are infeasible on the primitive compound
- Verification of grasps with an endeffector model

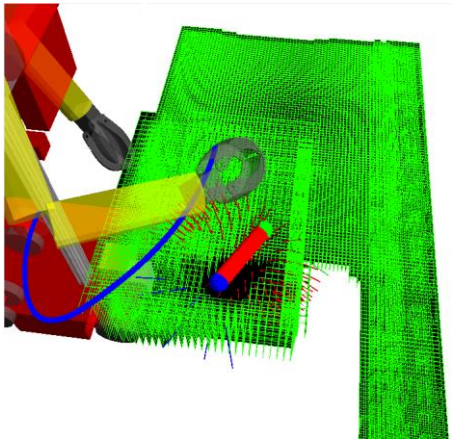


Grasp Planning – Online Phase

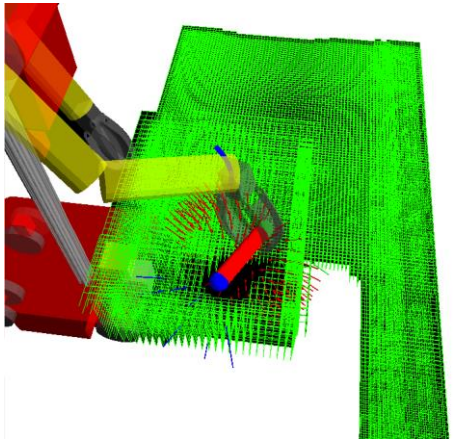
- Preprocessed grasps are evaluated in the current scene
- Fast pruning of grasps below the object and height map
- Inverse kinematics for the remaining grasps
- Collision free endeffector trajectories
- Heuristic ranking of grasps



Motion Planning



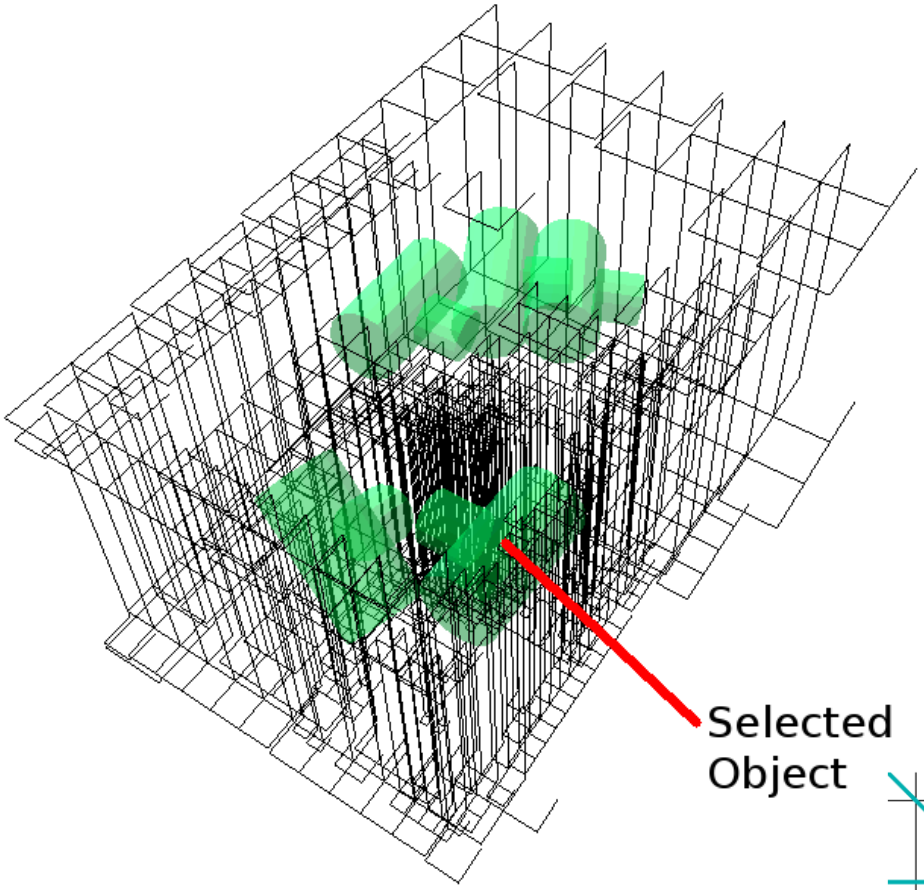
reaching pre-grasp pose above the box



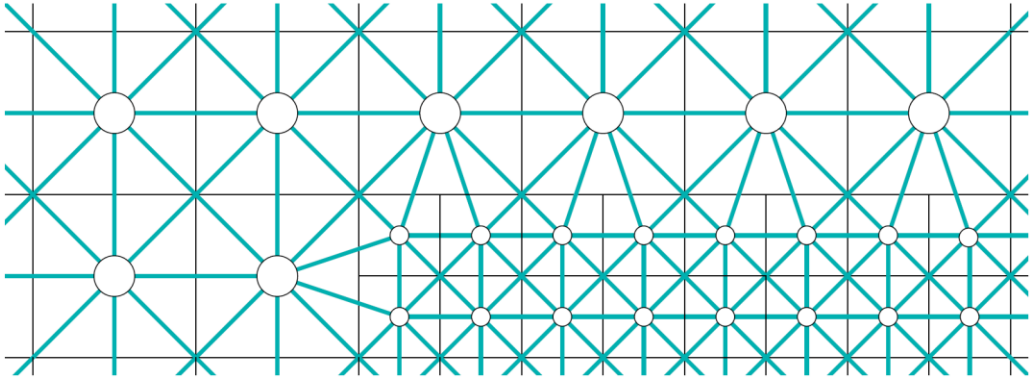
grasping the object

- Sampling-based multiresolution trajectory planner (LBKPIECE)
- Planning of trajectory parts in descending order of failure probability

Motion Planning

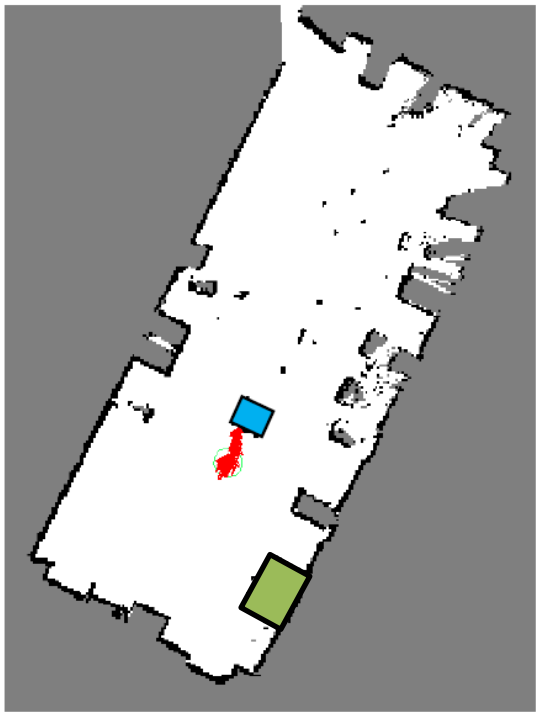


- Object-centric local multiresolution height map
- Space efficient grid representation
- Implicit modeling of safety margins



Robot Demonstration of Part Grasping and Delivery

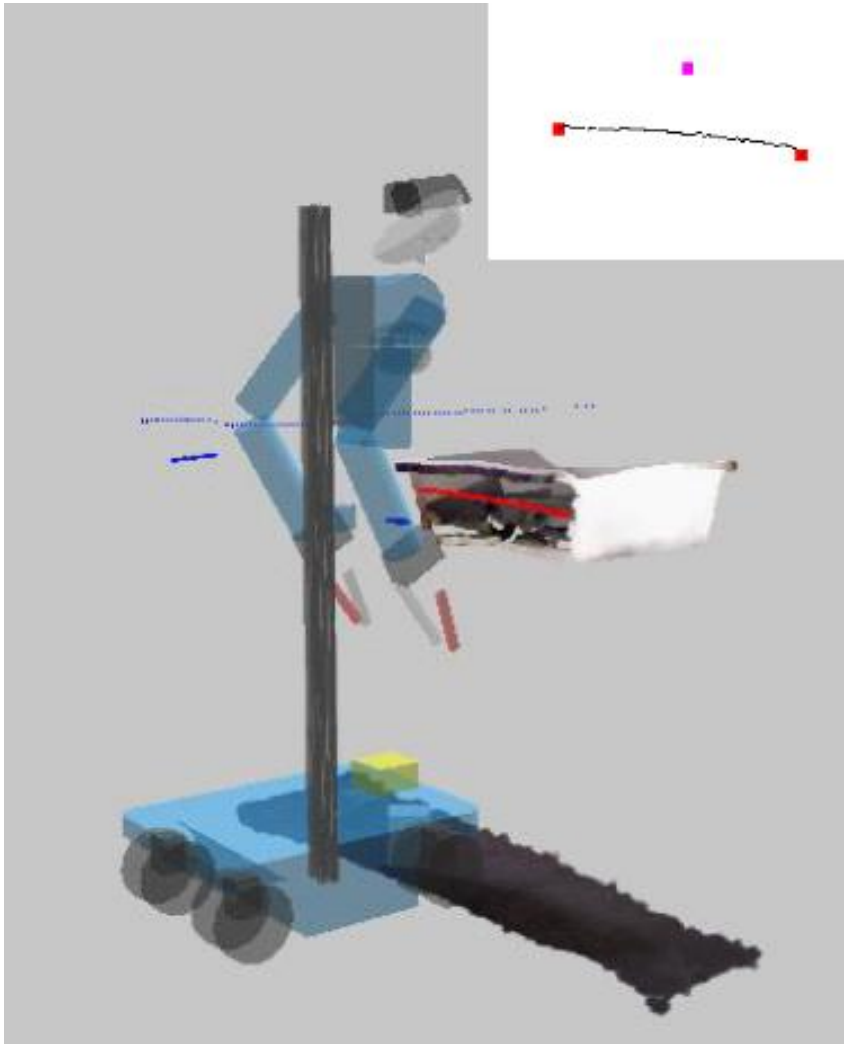
Global Navigation



- Adaptive Monte Carlo Localization to estimate the robot's pose in occupancy grid map
- A* search to plan short obstacle-avoiding path

Local Navigation

- Align to the transport box
- 2D laser range finder in the trunk at a height of 80 cm
- Line segments are extracted from the scan and checked for straightness



Results

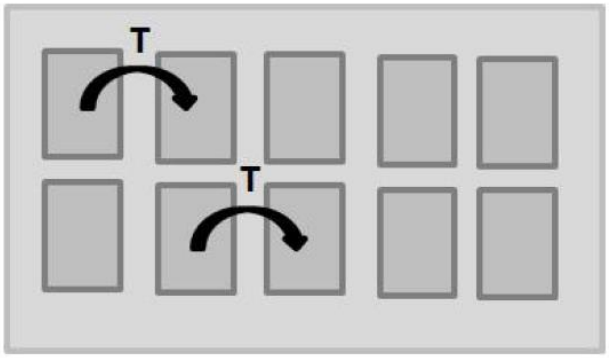
- 28 out of 32 runs successful

Phase	Mean duration (sec.)	Stddev of duration (sec.)
Navigation (transport box)	20	8
Approaching (transport box)	16	11
Cognition phase	83	41
Grasping	36	7
Navigation (processing station)	26	9
Approaching (processing station)	22	9
Putting the object on the processing station	18	2

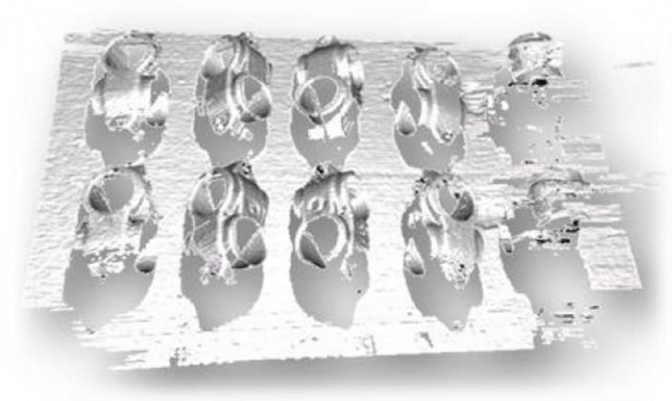
Introducing new Objects to the System

CAD model not available

Scan Board Technique

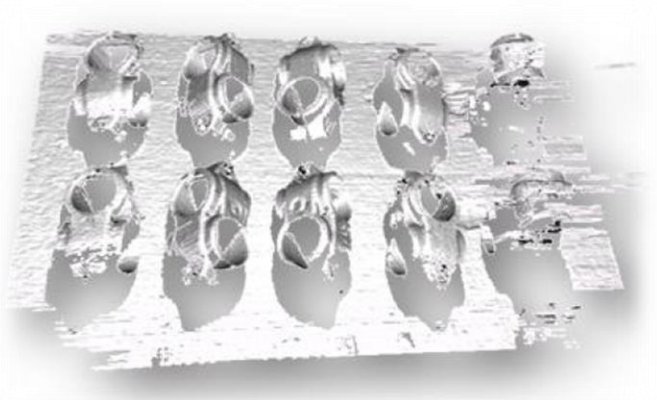


Board with known transformations



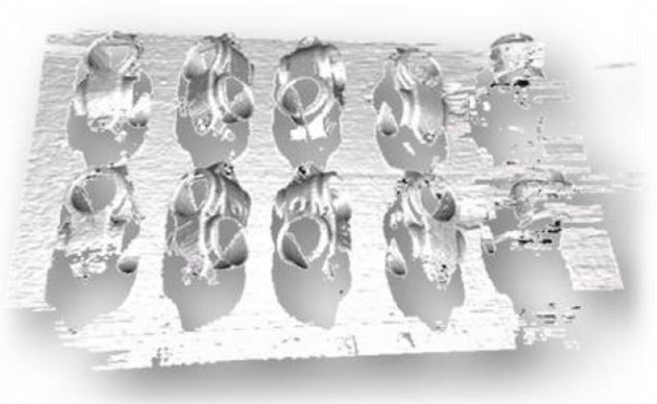
Several different views in one scan

Scan Segmentation

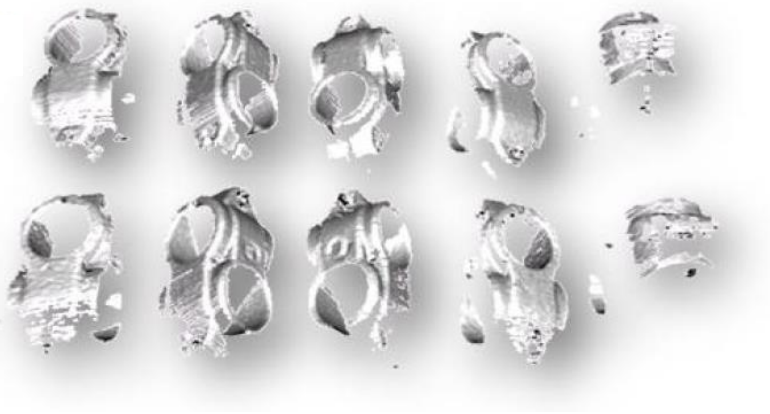


Raw measurements

Scan Segmentation

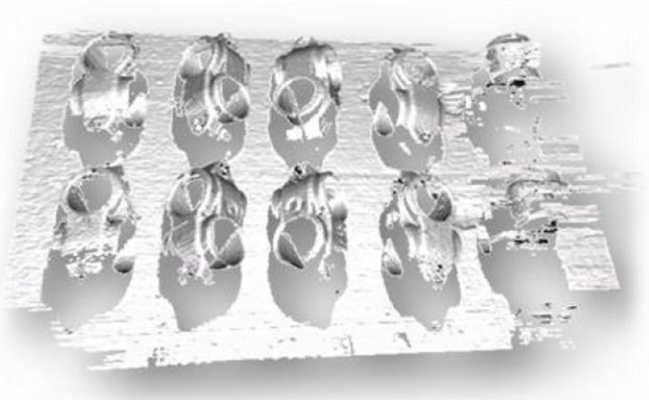


Raw measurements

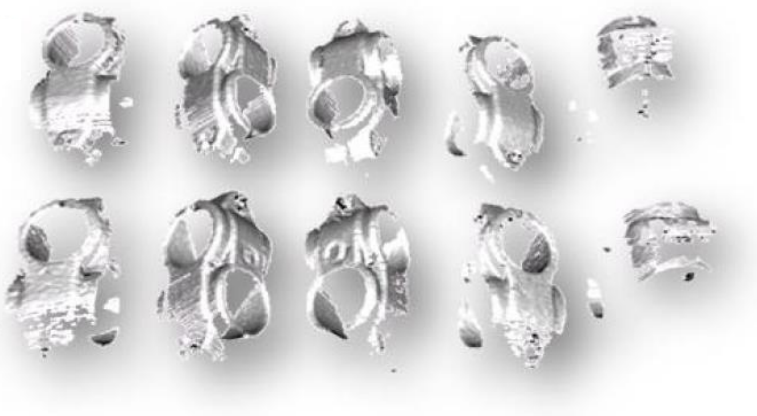


Removal of background

Scan Segmentation



Raw measurements

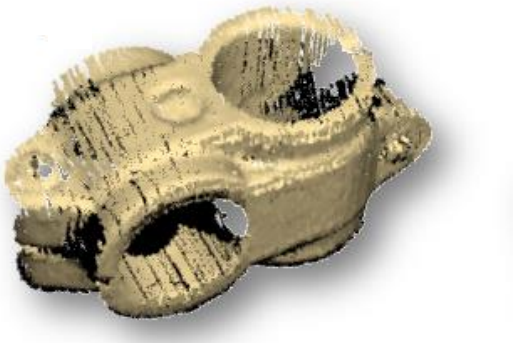


Removal of background

Segmented scan

Reconstruction of the Object

Segmented scan

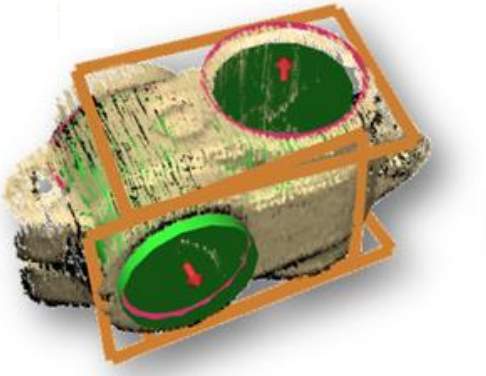


Aligned points of individual views

Reconstruction of the Object

Segmented scan

Aligned points of individual views

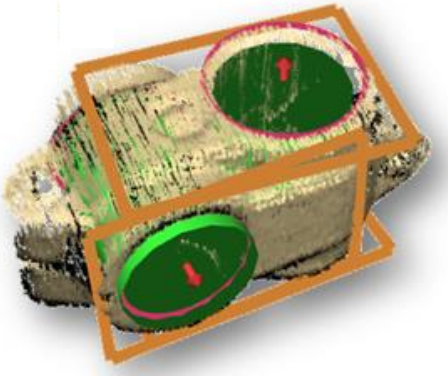


Detected primitives

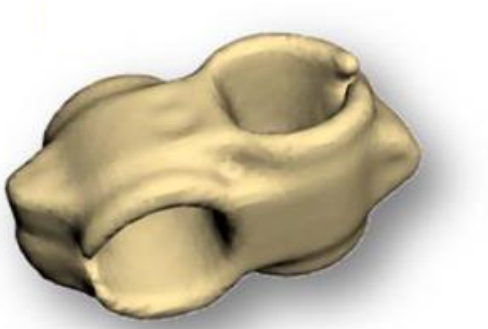
Reconstruction of the Object

Segmented scan

Aligned points of individual views



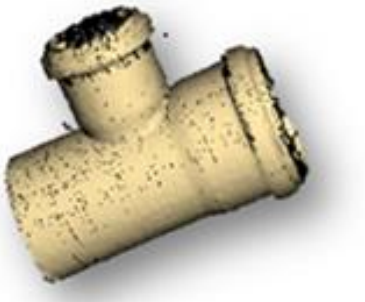
Detected primitives



Poisson reconstruction

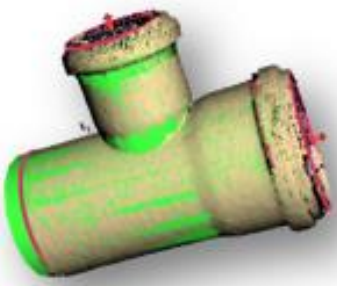
Another Result

Segmented scan



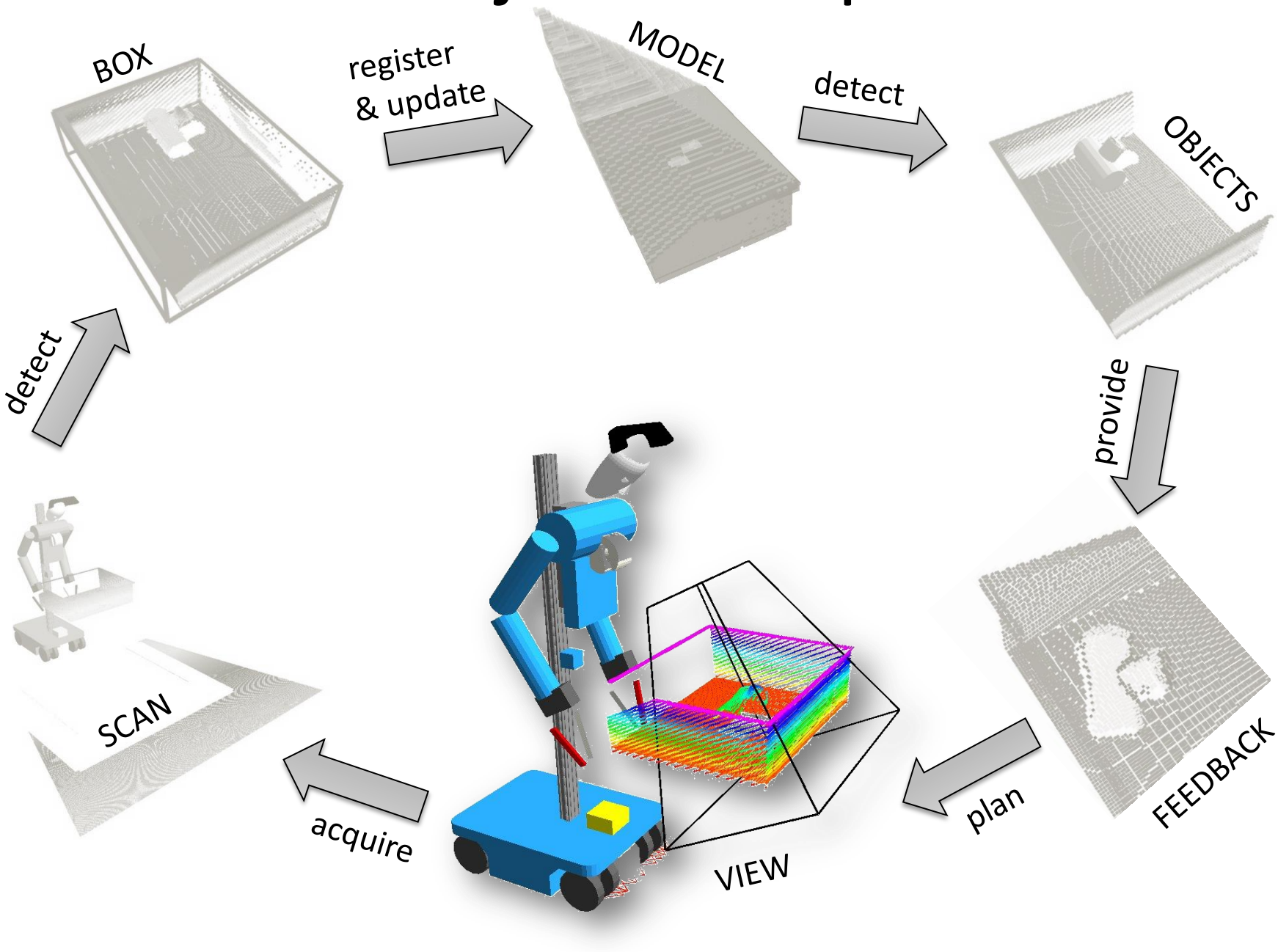
Aligned points

Poisson reconstruction

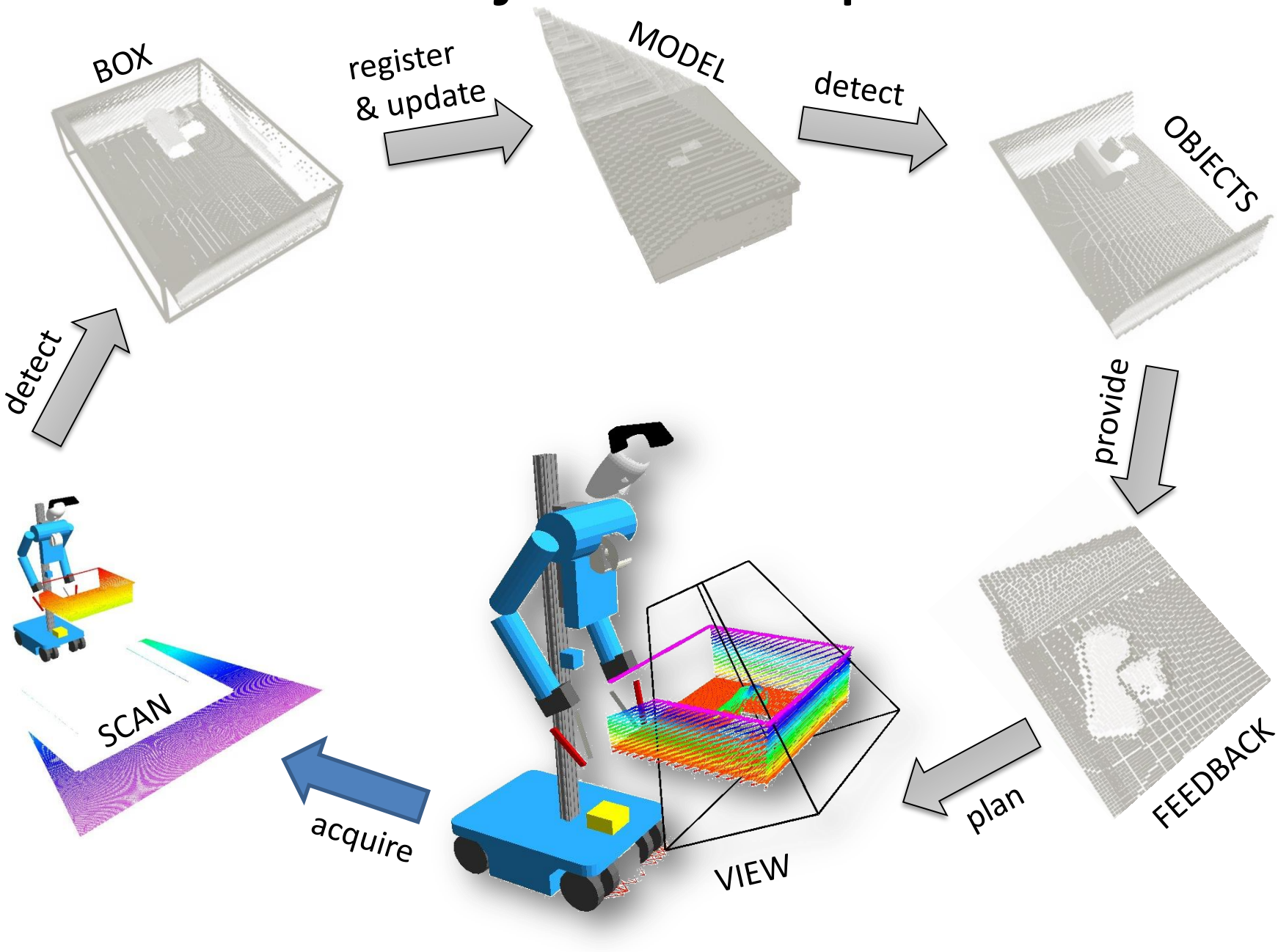


Detected primitives

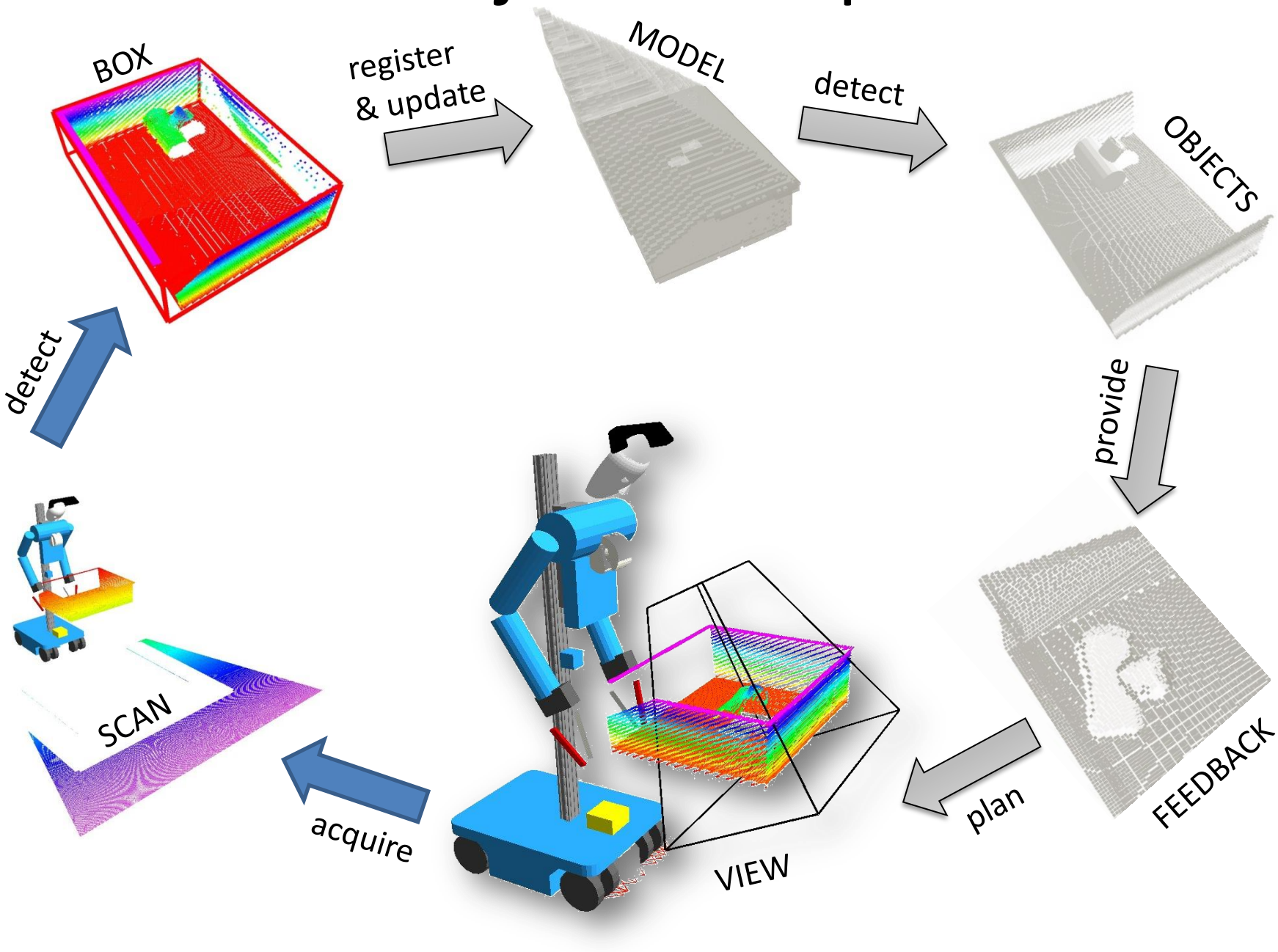
Active Object Perception



Active Object Perception



Active Object Perception



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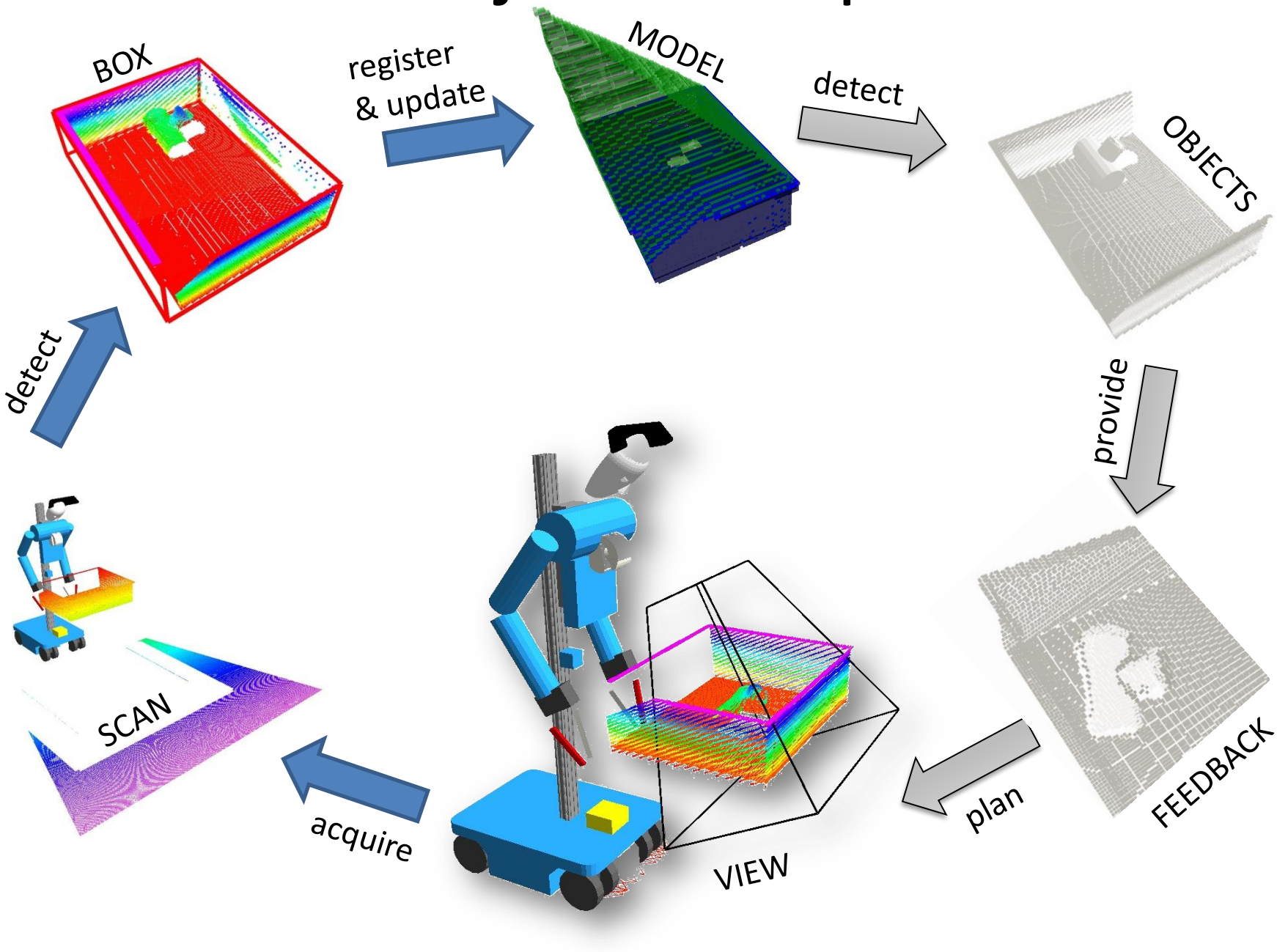

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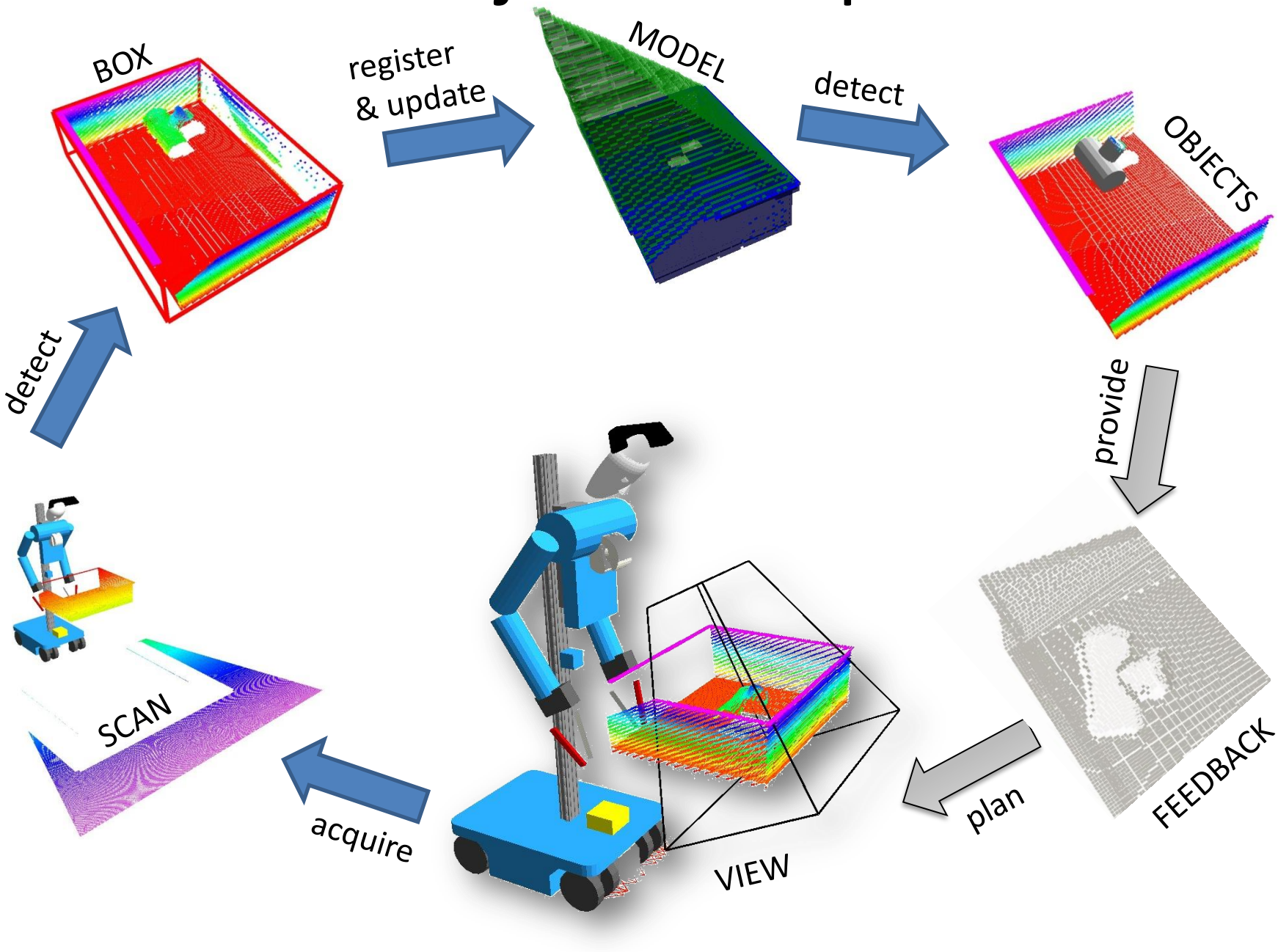

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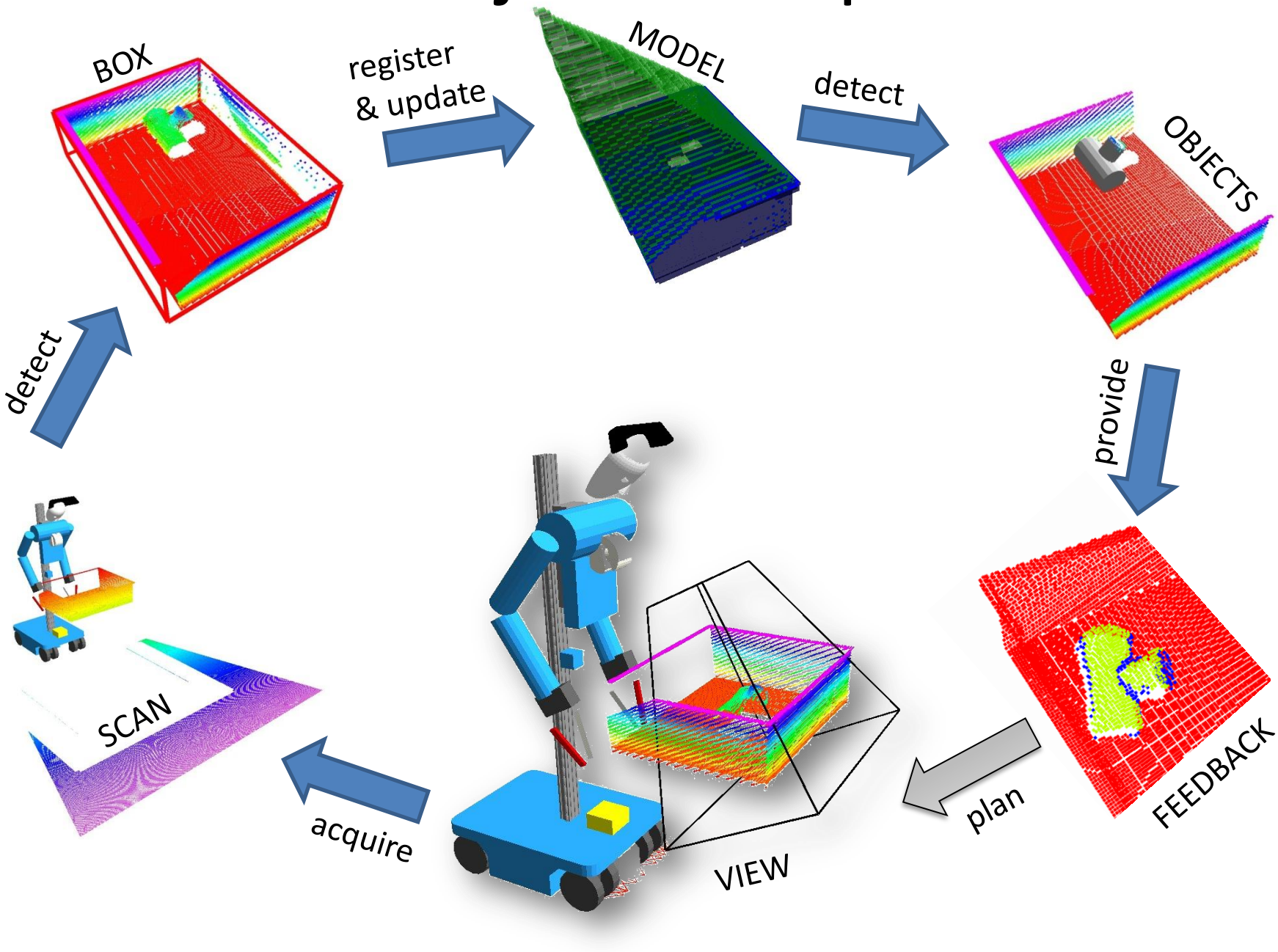

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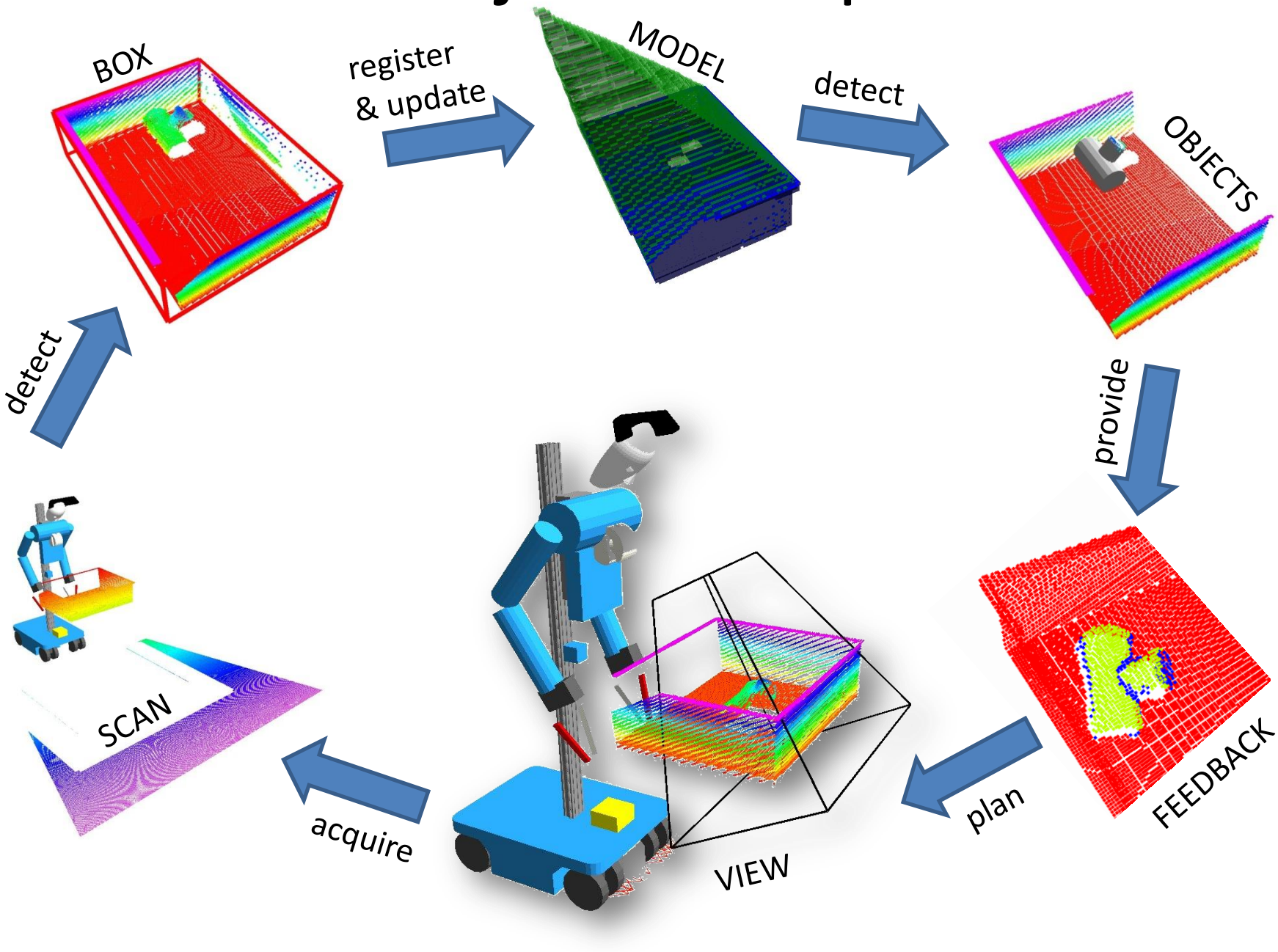
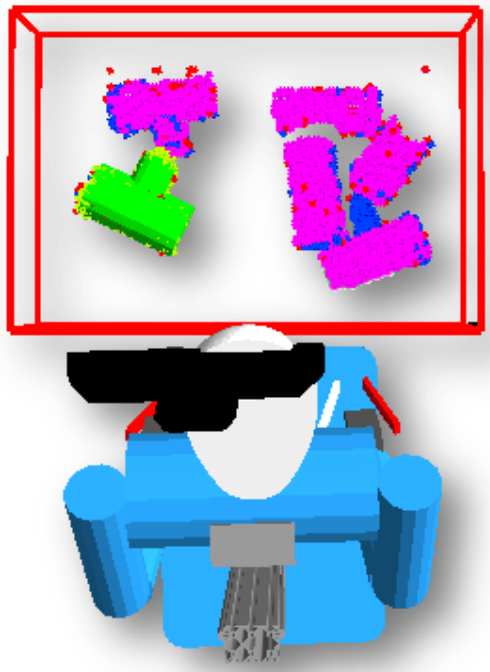
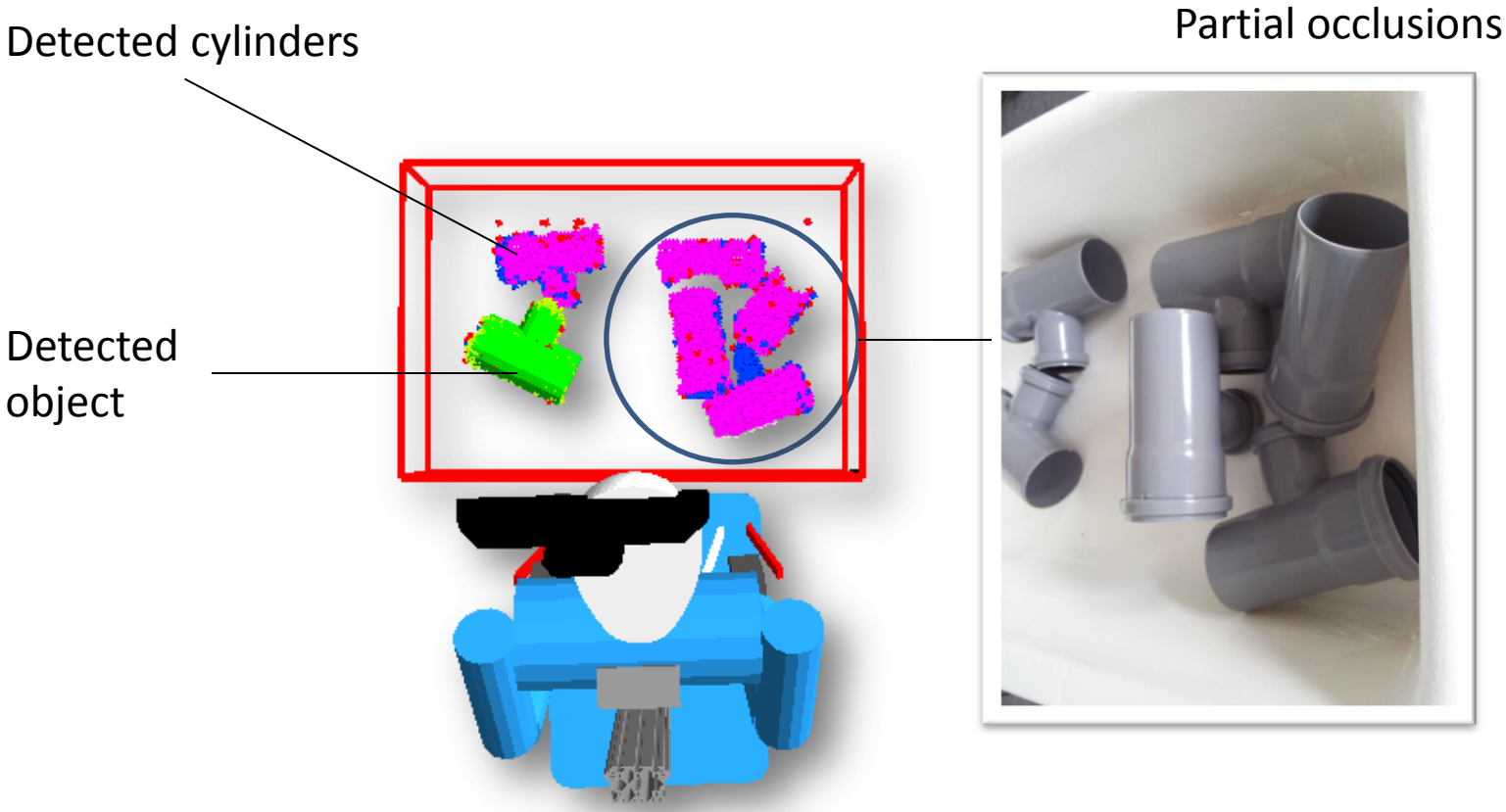


Active Object Perception



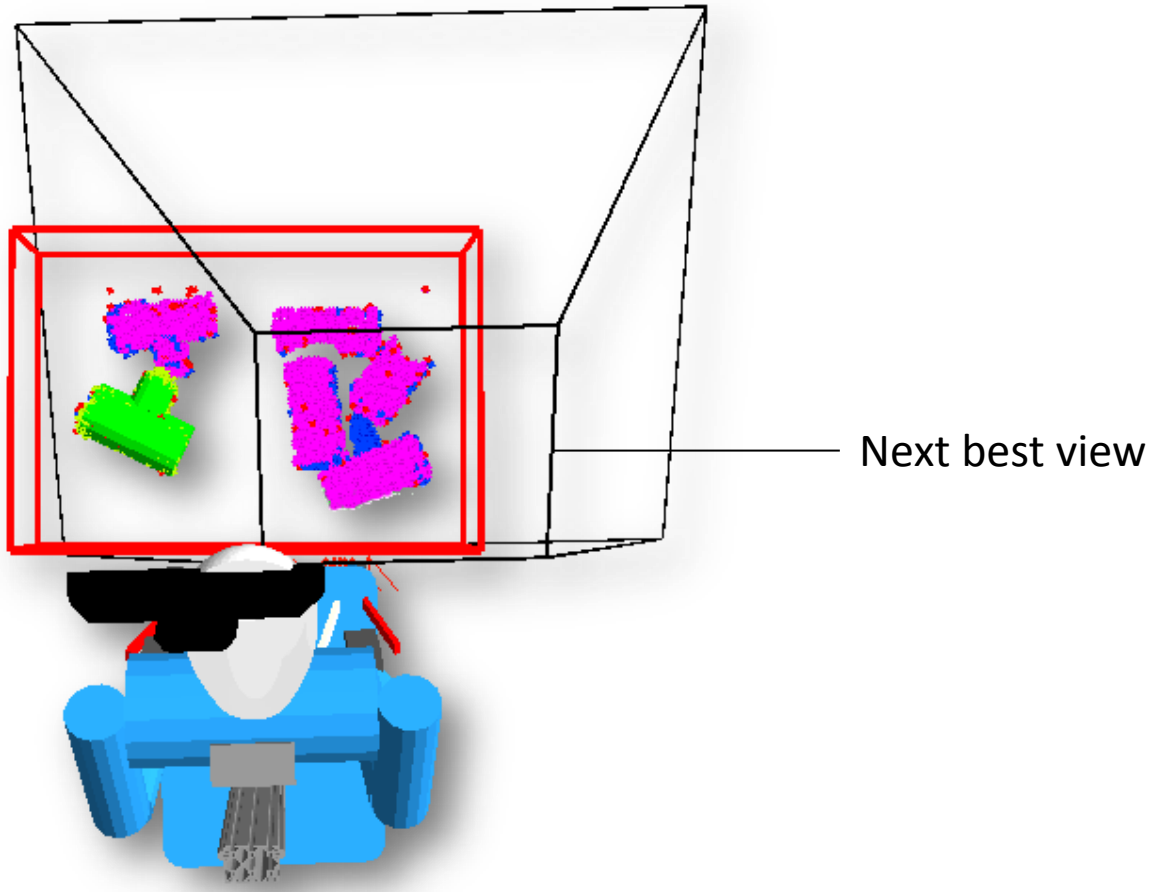
Efficient exploration of the part arrangement in the transport boxes to handle occlusions

Active Object Perception



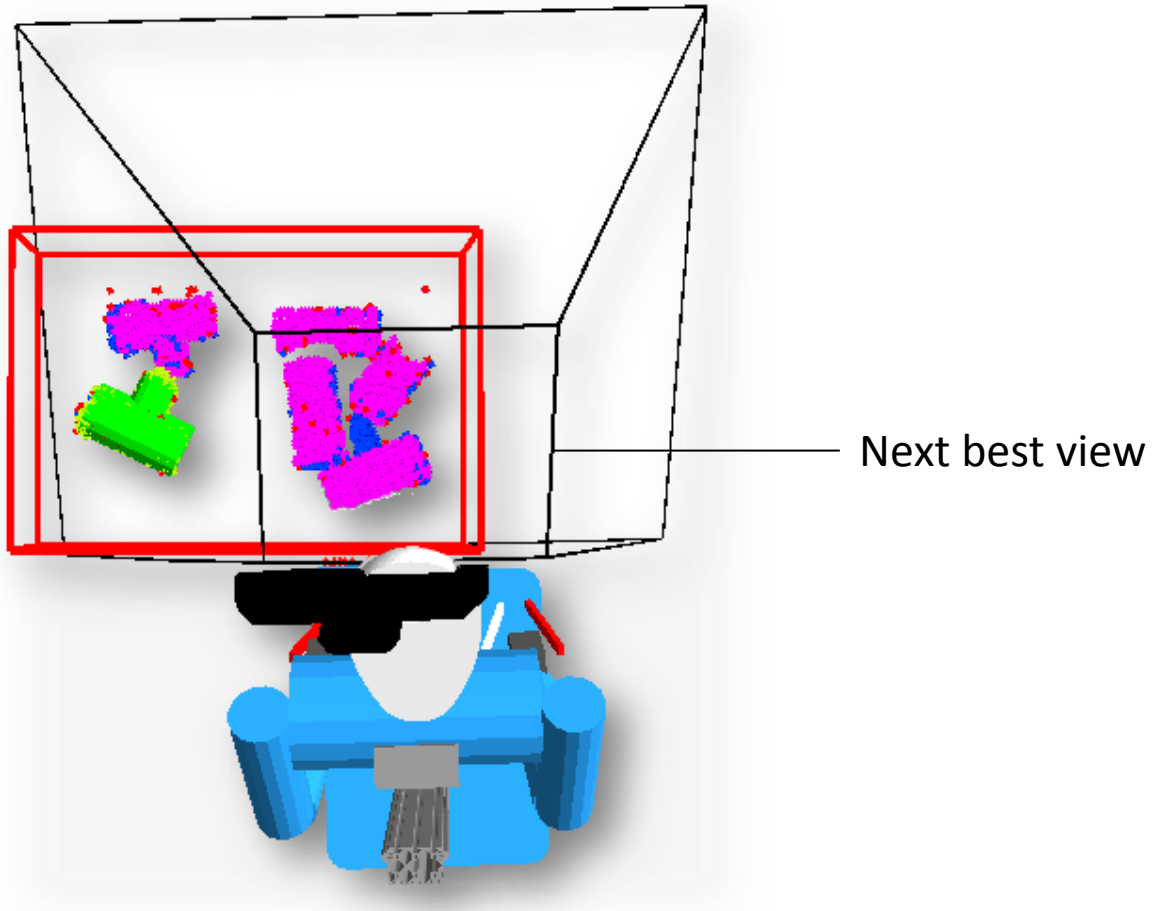
Efficient exploration of the part arrangement in the transport boxes to handle occlusions

Active Object Perception



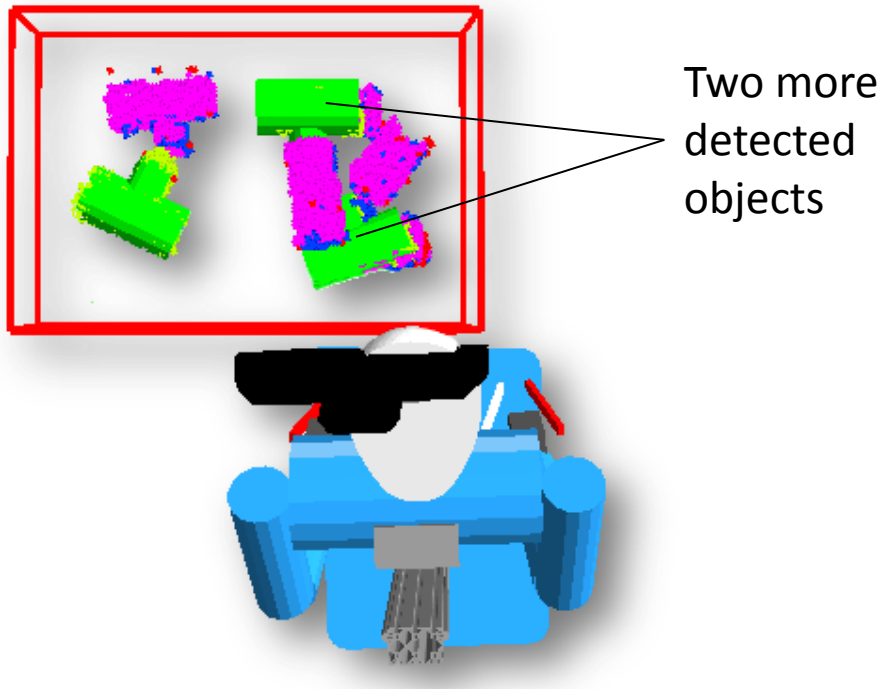
Efficient exploration of the part arrangement in the transport boxes to handle occlusions

Active Object Perception



Efficient exploration of the part arrangement in the transport boxes to handle occlusions

Active Object Perception



Efficient exploration of the part arrangement in the transport boxes to handle occlusions

Integration into Industrial System

pose estimation using basic primitives

bin picking with magnetic gripper

Conclusions

- Detection and localization of known objects
- Grasp and motion planning and execution
- Integration with global and local navigation
- Learning of object models from examples
- Active perception by view planning
- Industrial application

Acknowledgement:

FP7 ICT-2007.2.2 project ECHORD (grant agreement 231143) experiment ActReMa.

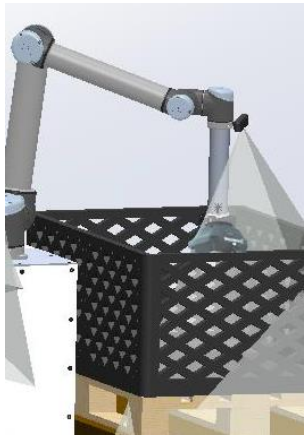
Publications

- D. Holz, M. Nieuwenhuisen, D. Droeschel, J. Stückler, A. Berner, J. Li, R. Klein, and S. Behnke:
  Active Recognition and Manipulation for Mobile Robot Bin Picking
  In: Gearing up and accelerating cross-fertilization between academic and industrial robotics research in Europe - Technology transfer experiments from the ECHORD project, vo. 94 of Springer Tracts in Advanced Robotics (STAR), pp. 133-153, 2014.
- A. Berner, J. Li, D. Holz, J. Stückler, S. Behnke, and R. Klein:
  Combining Contour and Shape Primitives for Object Detection and Pose Estimation of Prefabricated Parts
  In Proceedings of IEEE International Conference on Image Processing (ICIP), Melbourne, Australia, 2013.
- M. Nieuwenhuisen, D. Droeschel, D. Holz, J. Stückler, A. Berner, J. Li, R. Klein, and S. Behnke:
  Mobile Bin Picking with an Anthropomorphic Service Robot
  In Proceedings of IEEE International Conference on Robotics and Automation (ICRA), Karlsruhe, 2013.
- M. Nieuwenhuisen, J. Stückler, A. Berner, R. Klein, and S. Behnke:
  Shape-Primitive Based Object Recognition and Grasping
  In Proceedings of 7th German Conference on Robotics (ROBOTIK), Munich, 2012.

Follow-up Project: STAMINA
Sustainable and Reliable Robotics for Part Handling in Manufacturing Automation

Partners:

- Aalborg University (Coordinator), Denmark
- Peugot Citroen Automobiles S.A., France
- BA Systemes SAS, France
- University of Bonn, Germany
- University of Freiburg, Germany
- INESC Porto, Portugal
- University of Edinburgh, UK



Goal:

Develop a fleet of autonomous and mobile industrial robots for jointly solving three logistic and handling tasks:

- de-palletizing,
- bin-picking, and
- kitting.