Umgebungswahrnehmung und Verhaltensplanung für Kognitive Roboter

Sven Behnke
Universität Bonn
Institut für Informatik VI
Autonome Intelligente Systeme

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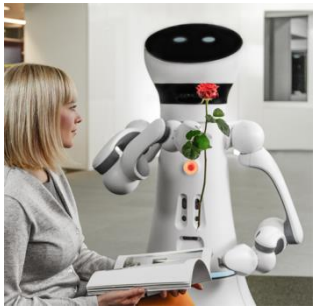
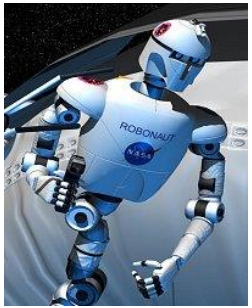
Neue Anwendungsgebiete für Roboter

- Autonomes Fahren
- Logistik
- Landwirtschaft
- Kollaborative Produktion
- Alltagsassistenz
- Weltraum, Suche&Rettung
- Medizin, Pflege
- Spielzeuge
- **Brauchen mehr Kognition!**



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Einige unserer Kognitiven Roboter

- Ausgestattet mit zahlreichen Sensoren und Gelenken
- Demonstration in komplexen Szenarien

Fußball

Serviceaufgaben

Griff in die Kiste

Mobile Manipulation

Inventur

RoboCup 2016 TeenSize-Finale

Visuelle Wahrnehmung der Spielsituation

[Farazi & Behnke, RoboCup 2016]

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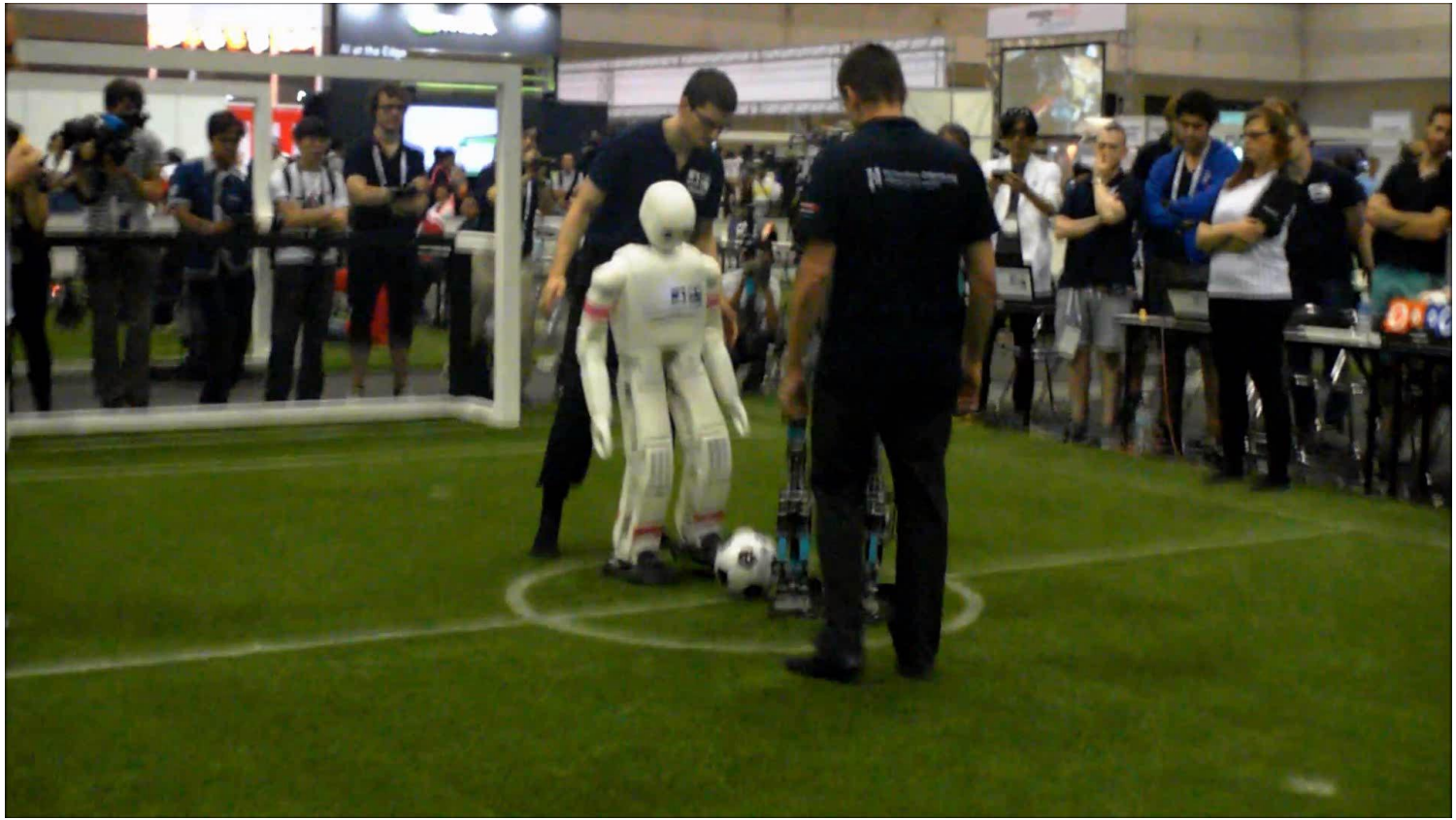
RoboCup 2017 AdultSize-Finale



Kognitiver Serviceroboter Cosero

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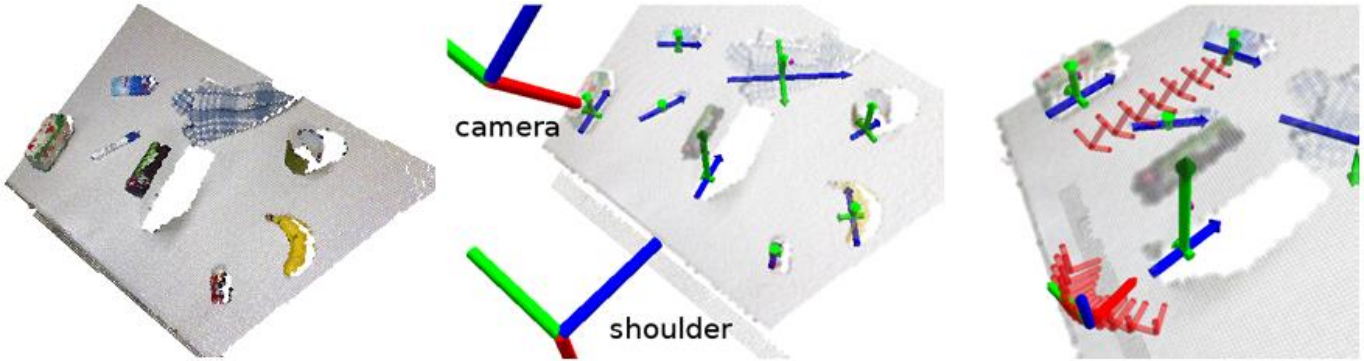
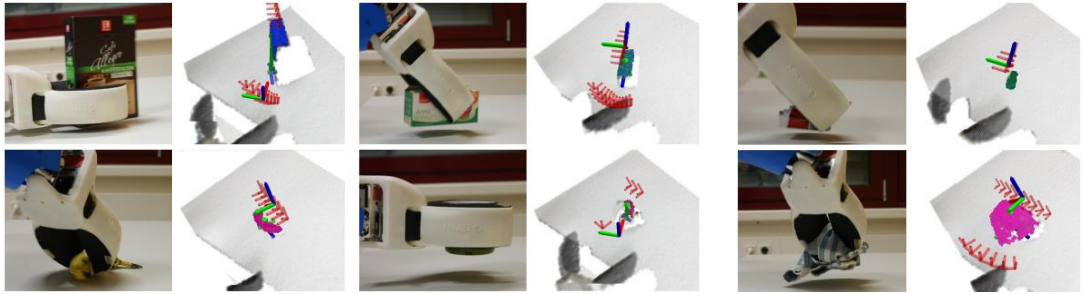
Table-top Analysis and Grasp Planning

- Detection of clusters above horizontal plane
- Two grasps (top, side)



- Flexible grasping of many unknown objects



[Stückler et al, Robotics and Autonomous Systems, 2013]

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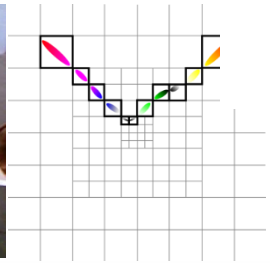
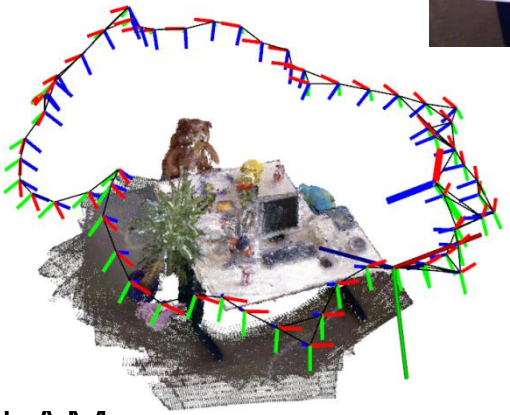
3D Mapping by RGB-D SLAM

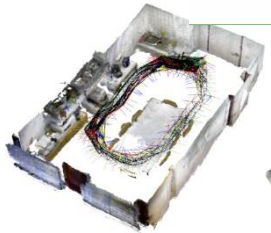
[Stückler, Behnke:
Journal of Visual Communication
and Image Representation 2013]

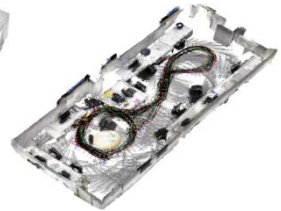
- Modelling of shape and color distributions in voxels
- Local multiresolution
- Efficient registration of views on CPU
- Global optimization





- Multi-camera SLAM





[Stoucken]

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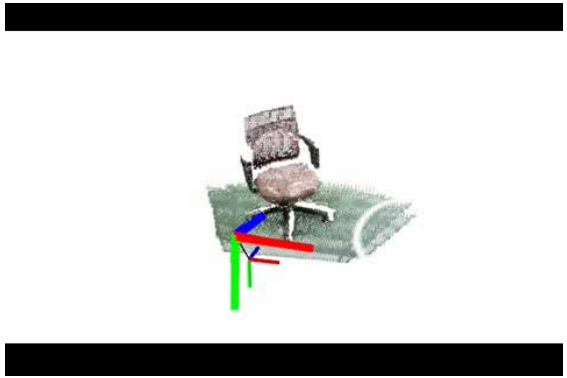
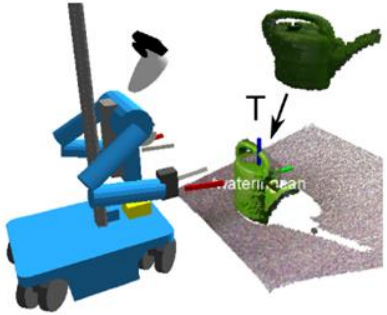
Learning and Tracking Object Models

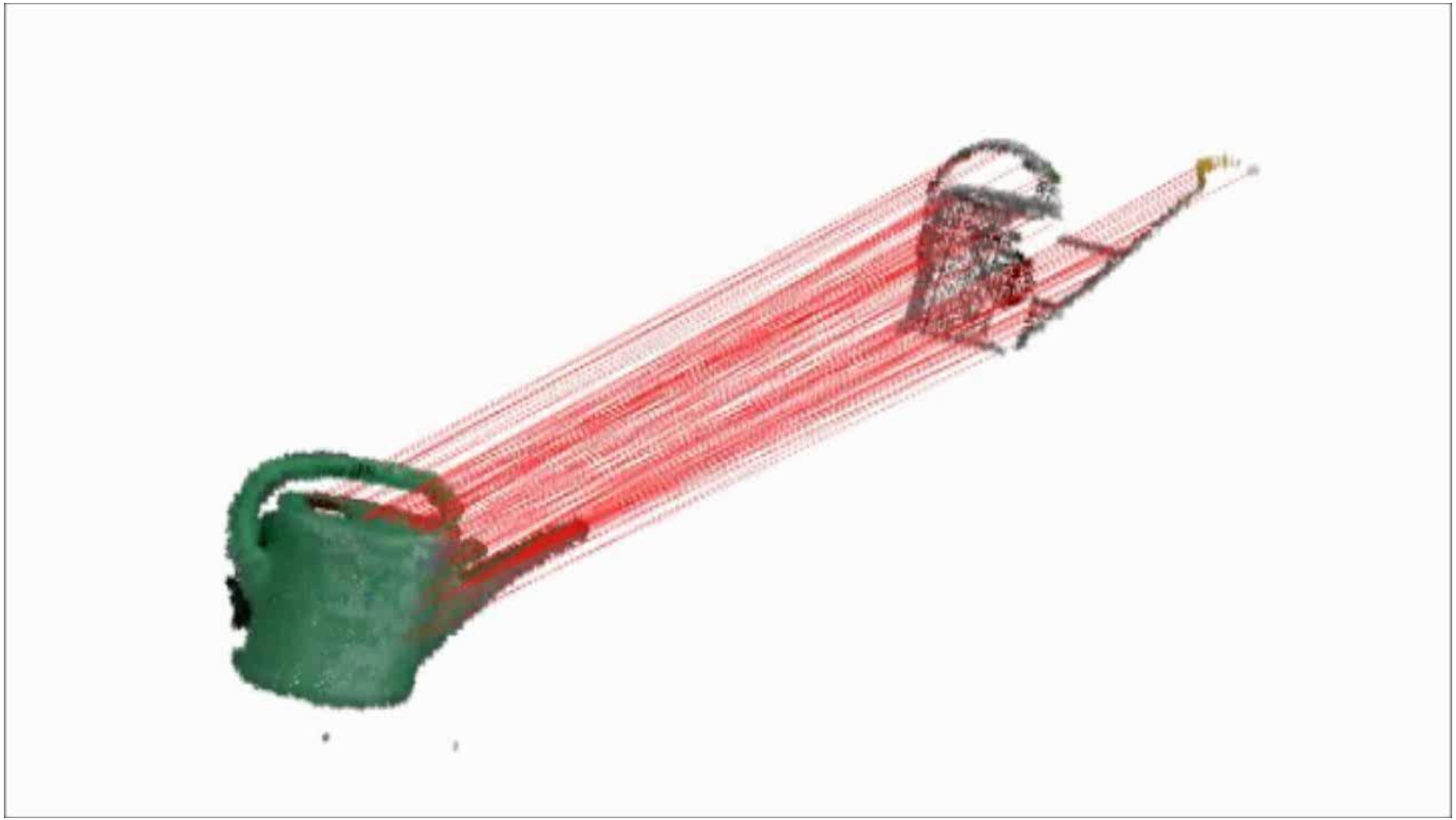
- Modeling of objects by RGB-D-SLAM



- Real-time registration with current RGB-D frame



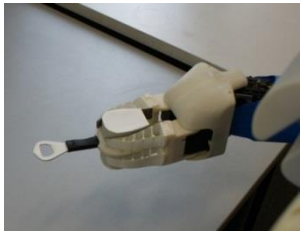
Grasp & Motion Skill Transfer

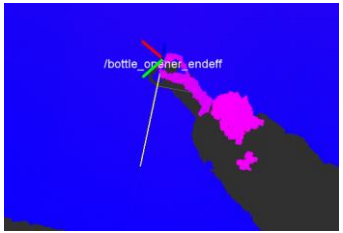


[Stückler, Behnke, ICRA2014]

Tool use: Bottle Opener

- Tool tip perception



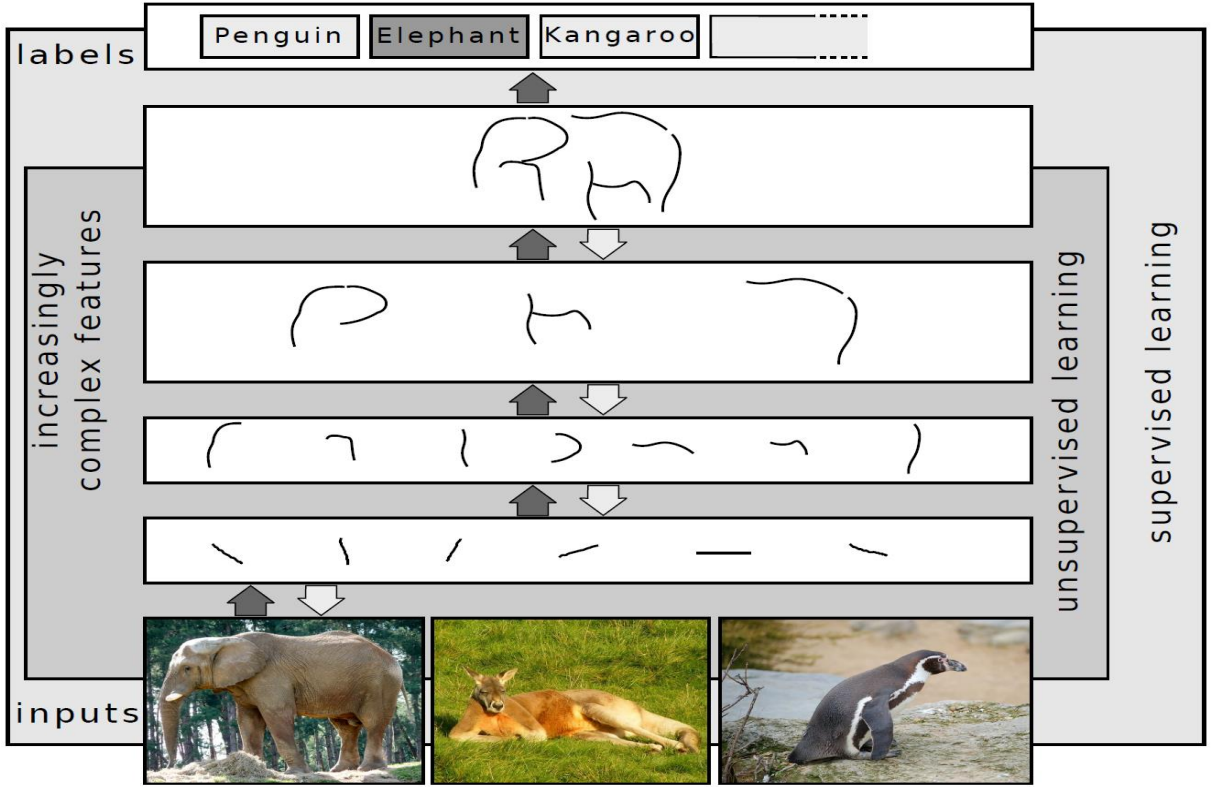


- Extension of arm kinematics
- Perception of crown cap
- Motion adaptation

[Stückler, Behnke, Humanoids 2014]

Deep Learning

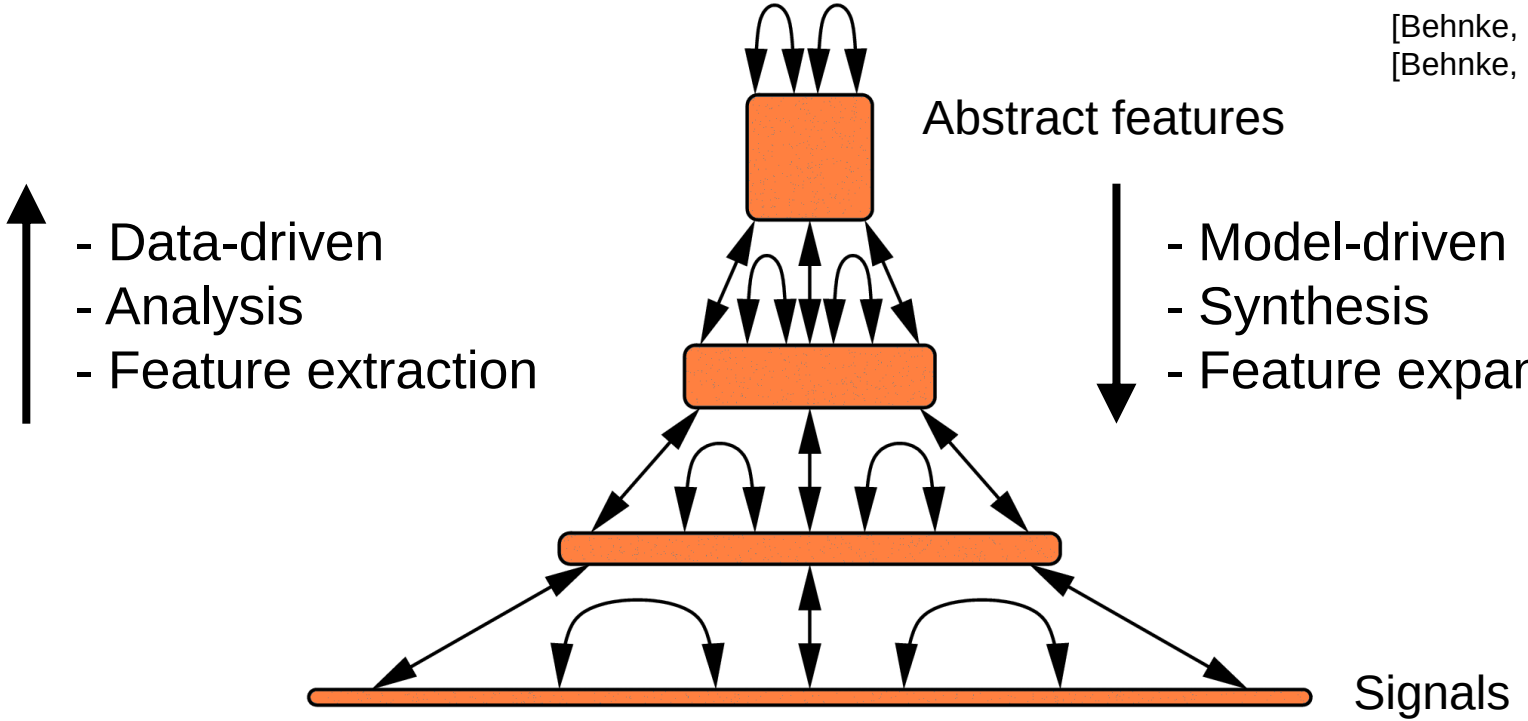
- Learning layered representations



[Schulz; Behnke, KI 2012]

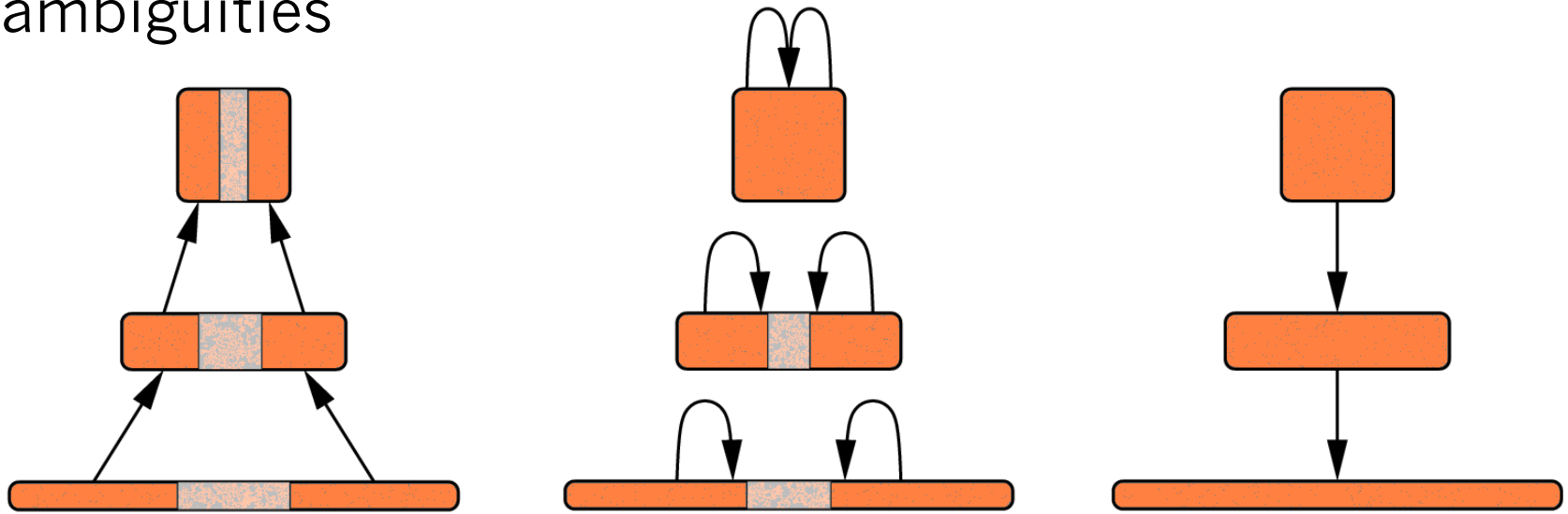
Neural Abstraction Pyramid

[Behnke, Rojas, IJCNN 1998]
[Behnke, LNCS 2766, 2003]



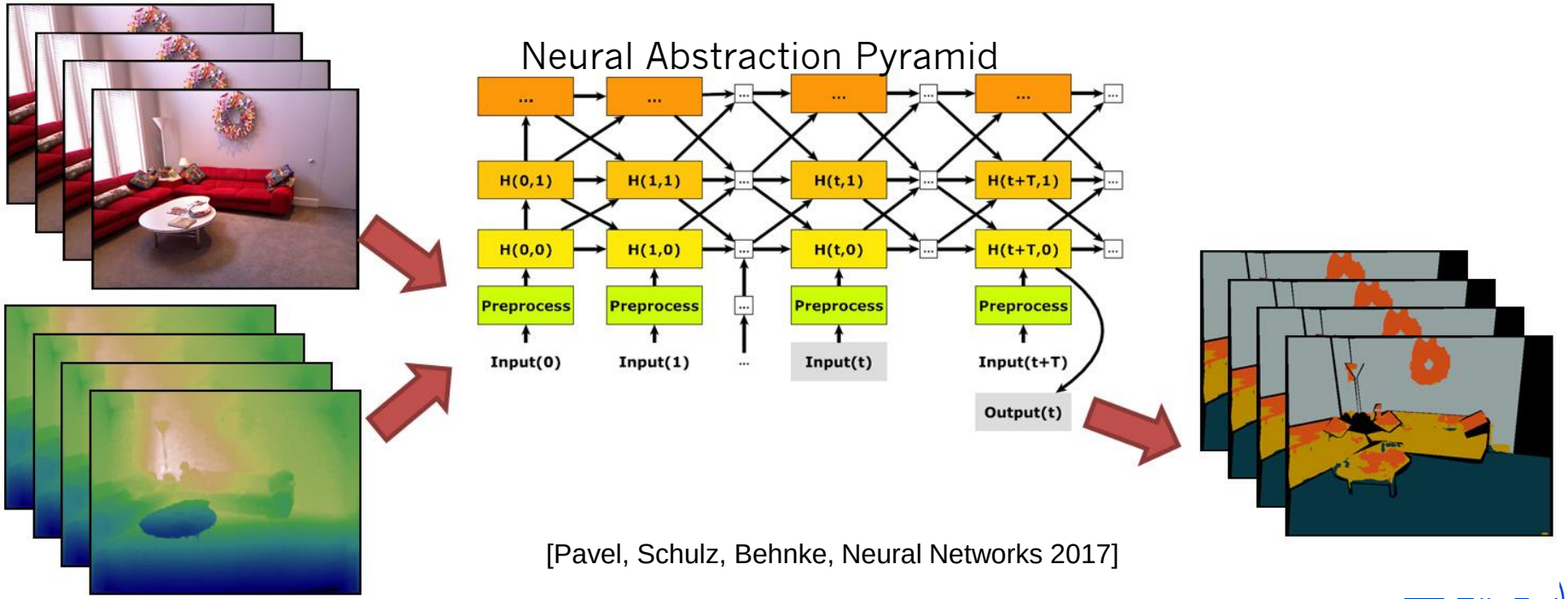
Iterative Image Interpretation

- Interpret most obvious parts first
- Use partial interpretation as context to resolve local ambiguities



Neural Abstraction Pyramid for RGB-D Video Object-class Segmentation

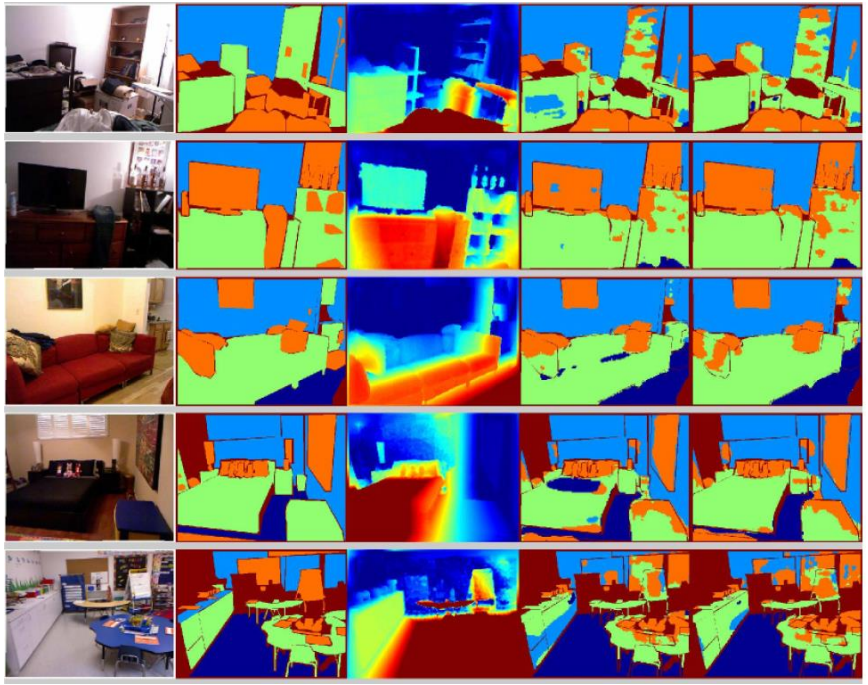
- Recursive computation is efficient for temporal integration



[Pavel, Schulz, Behnke, Neural Networks 2017]

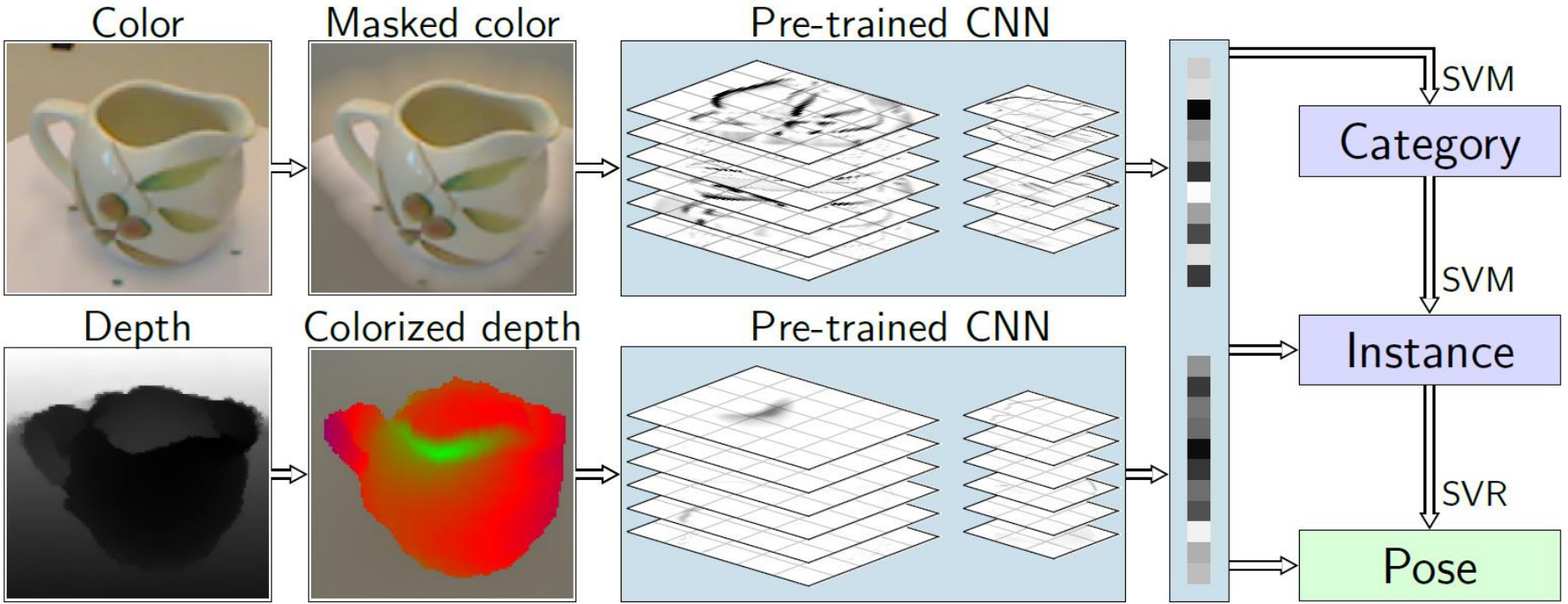
Geometric and Semantic Features for RGB-D Object-class Segmentation

- New **geometric** feature: distance from wall
- **Semantic** features pretrained from ImageNet
- Both help significantly



[Husain et al. RA-L 2017]

RGB-D Object Recognition and Pose Estimation

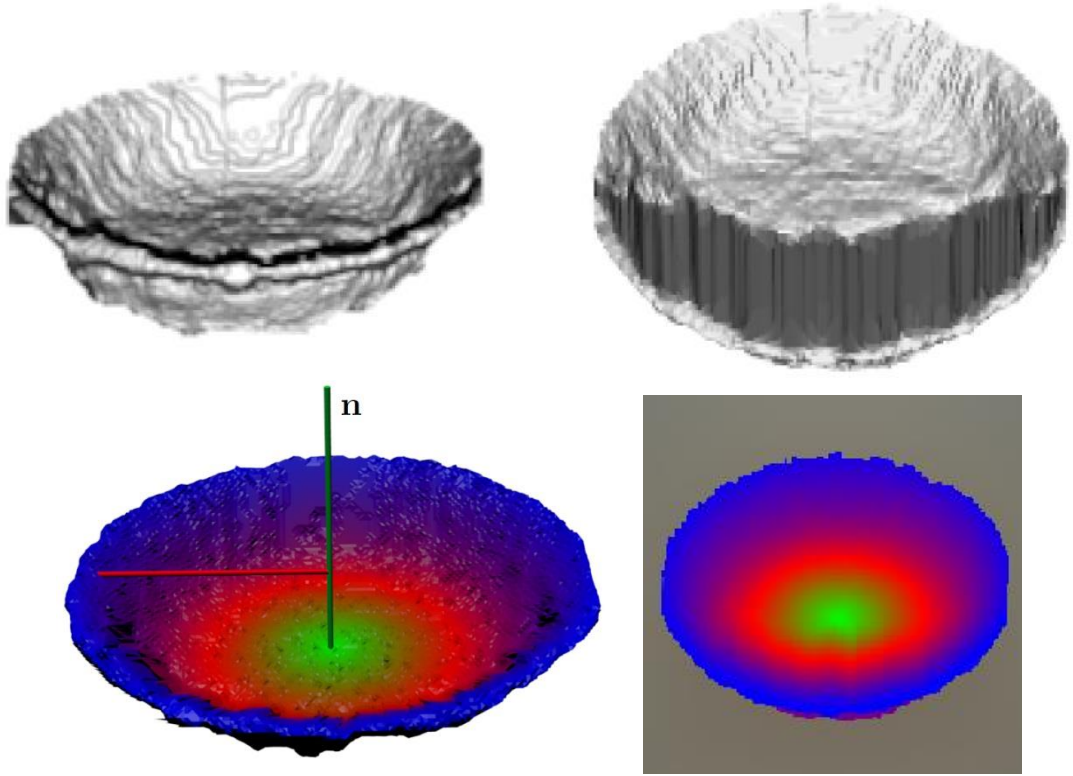


[Schwarz, Schulz, Behnke, ICRA2015]

Canonical View, Colorization

- Objects viewed from different elevation
- Render canonical view

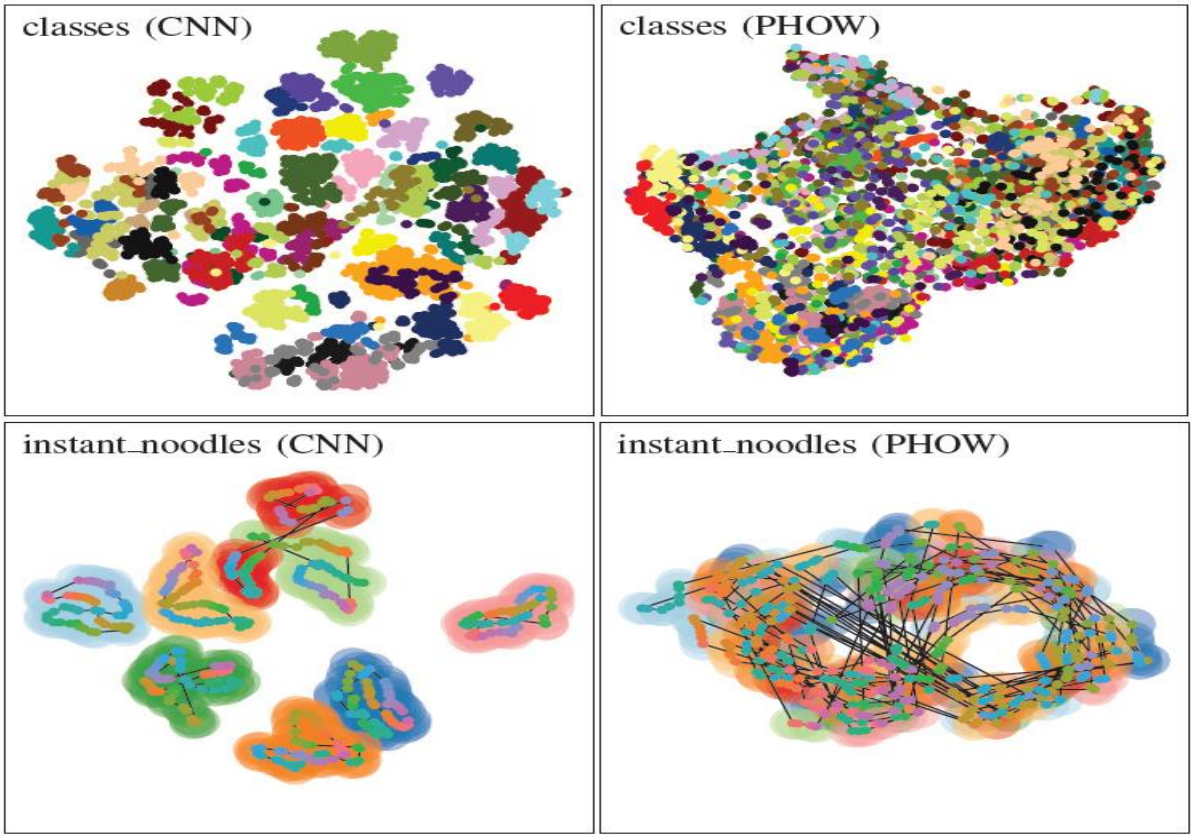
- Colorization based on distance from center vertical



[Schwarz, Schulz, Behnke, ICRA2015]

Pretrained Features Disentangle Data

- t-SNE embedding



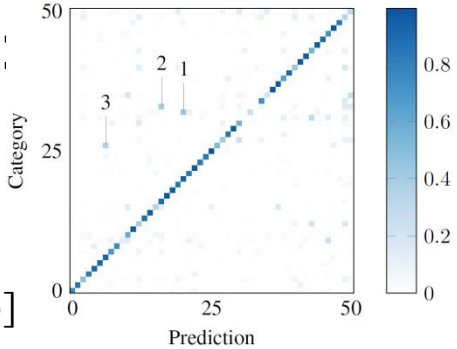
[Schwarz, Schulz, Behnke ICRA2015]

Recognition Accuracy

- Improved both category and instance recognition

Method	Category Accuracy (%)		Instance Accuracy (%)	
	RGB	RGB-D	RGB	RGB-D
Lai *et al.* [1]	74.3 ± 3.3	81.9 ± 2.8	59.3	73.9
Bo *et al.* [2]	82.4 ± 3.1	87.5 ± 2.9	**92.1**	92.8
PHOW[3]	80.2 ± 1.8	—	62.8	—
Ours	$\mathbf{83.1 \pm 2.0}$	88.3 ± 1.5	92.0	**94.1**
Ours	$\mathbf{83.1 \pm 2.0}$	$\mathbf{89.4 \pm 1.3}$	92.0	**94.1**

- Confusion:



[Schwarz, Schulz, Behnke ICRA2015]

1: pitcher / coffe mug

2: peach / sponge

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Amazon Picking Challenge

- Large variety of objects
- Unordered in shelf or tote
- Picking and stowing tasks

[Schwarz et al. ICRA 2017]

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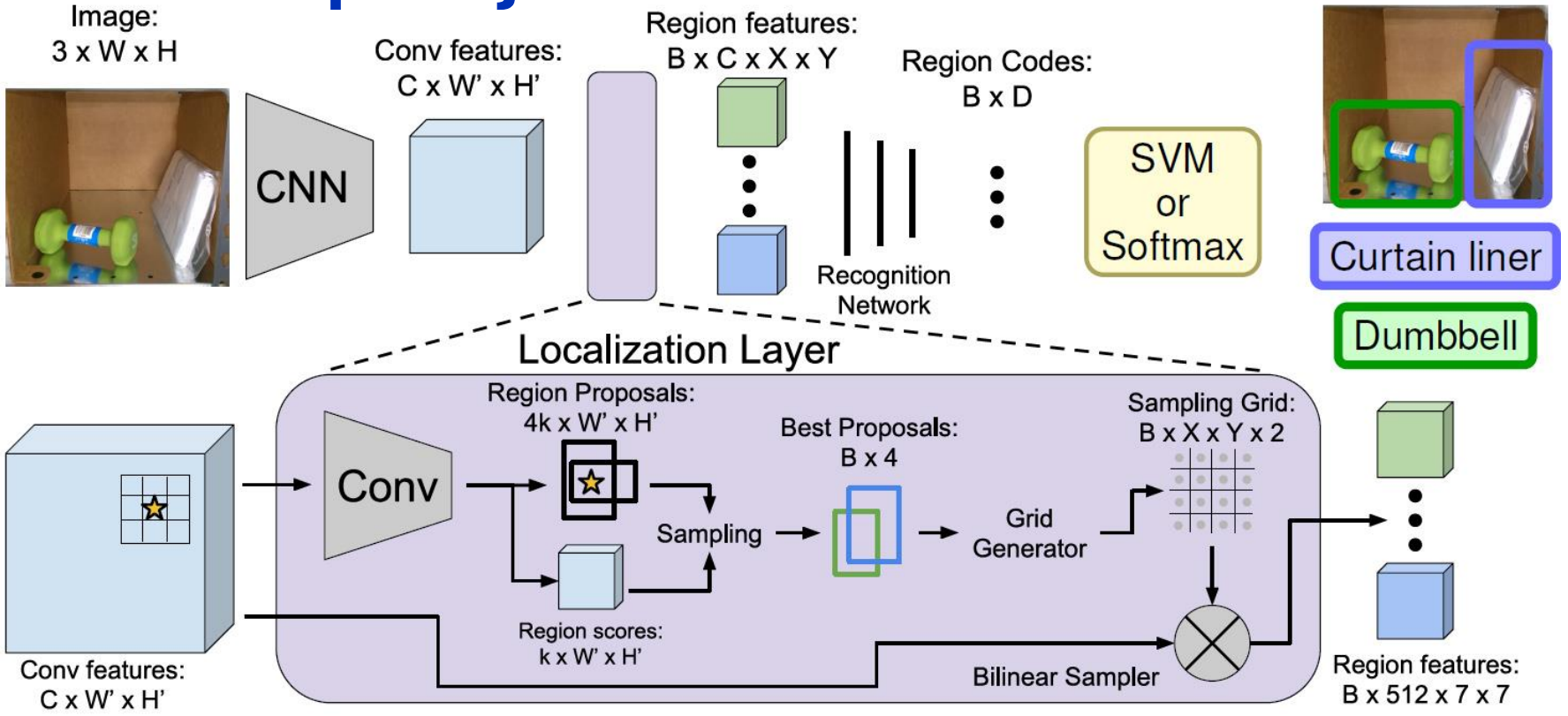
Deep Learning Semantic Segmentation

- Adapted from our segmentation of indoor scenes [Husain et al. RA-L 2016]

[Schwarz et al. ICRA 2017]

DenseCap Object Detection

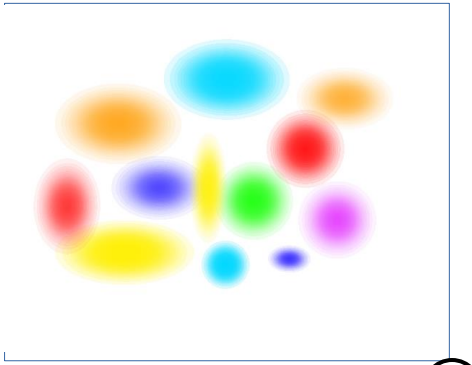


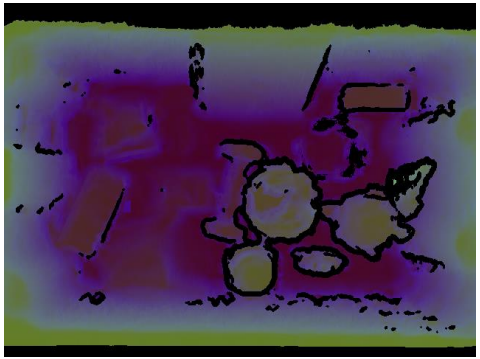
[Schwarz et al. ICRA 2017]

[Johnson et a CVPR 2016]

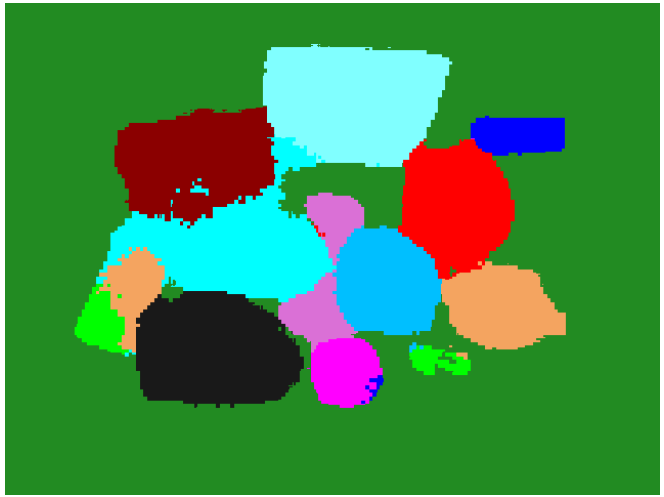
Combined Detection and Segmentation

Detection



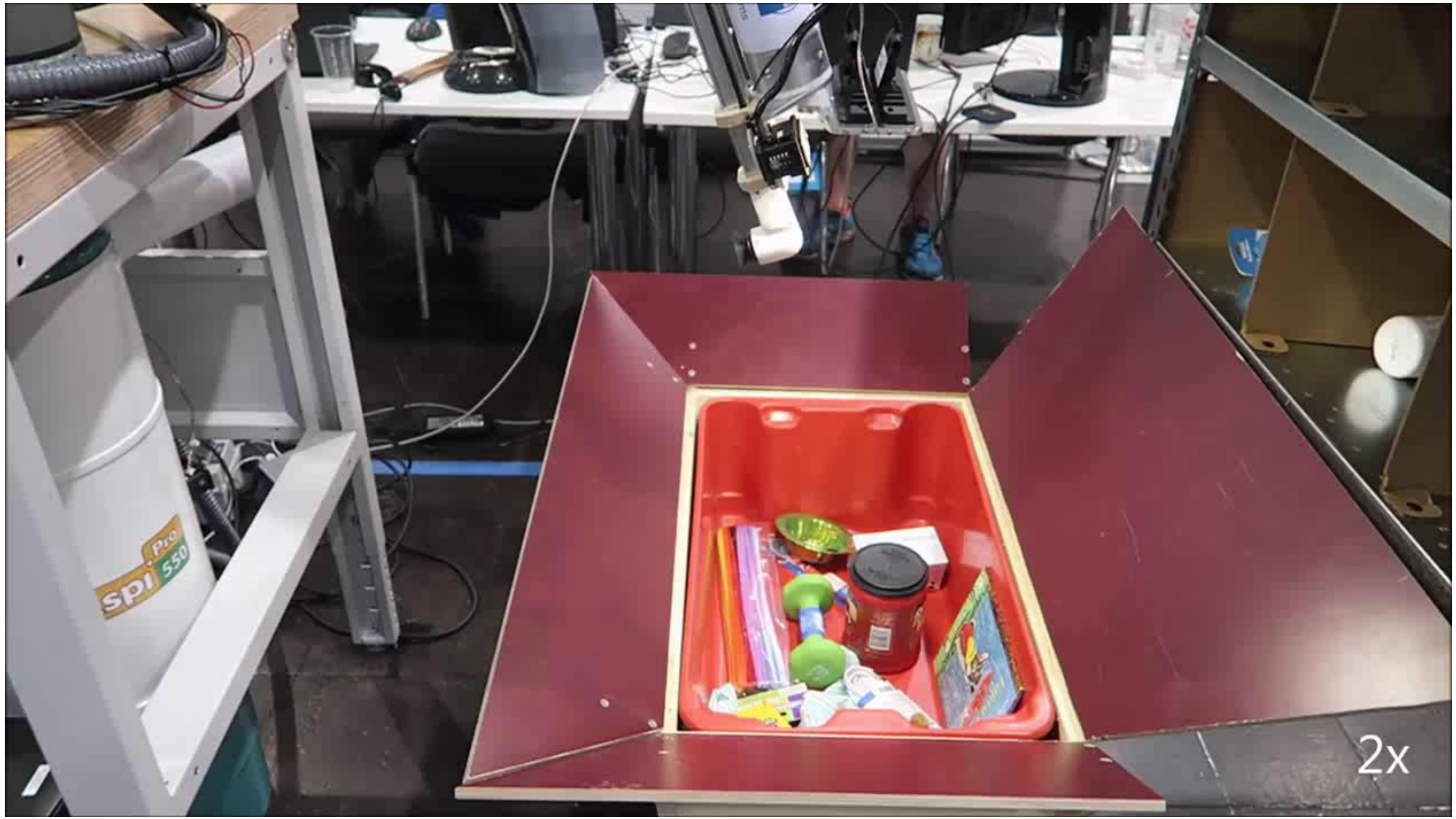


Segmentation



[Schwarz et al. IJRR 2017]

Stowing



Picking

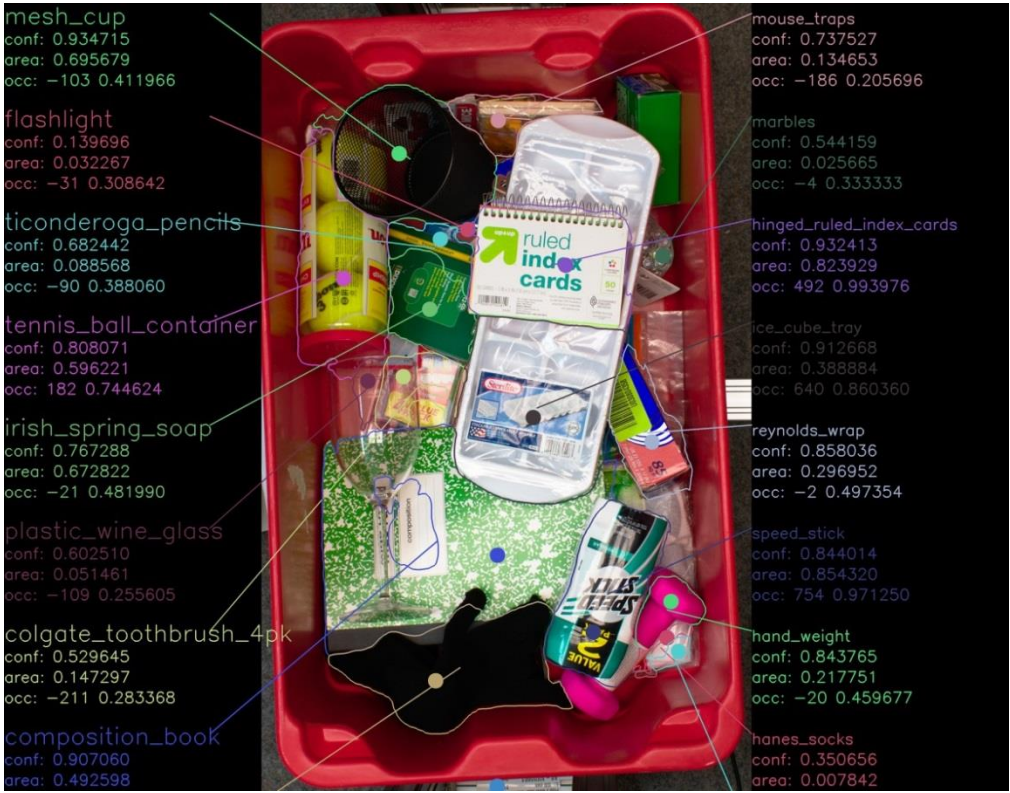
NimbRo Picking APC 2016 Results

- 2nd Place Stowing (186 points)
- 3rd Place Picking (97 points)

[Schwarz et al. IJRR 2017]

Amazon Robotics Challenge 2017

- Quick learning of novel objects
- Training with rendered scenes



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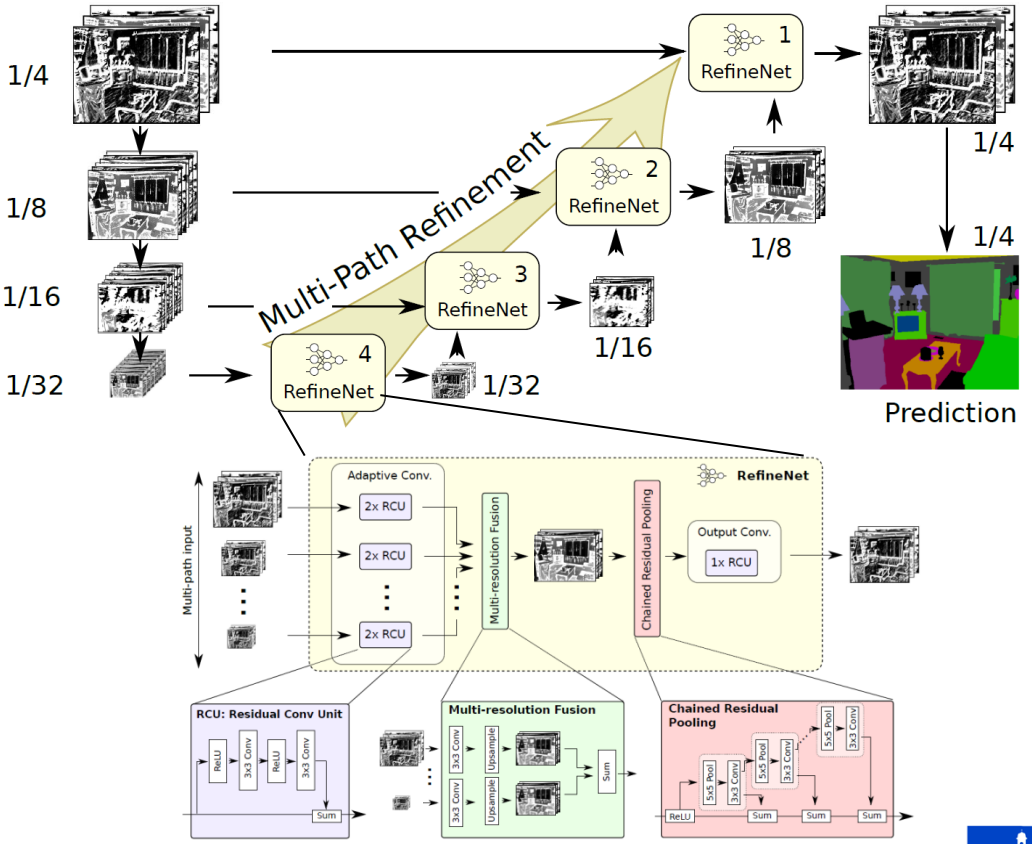
RefineNet

[Lin et al. CVPR 2017]

- Increase reso-lution by using features from the higher resolution
- Corse-to-fine semantic segmentation

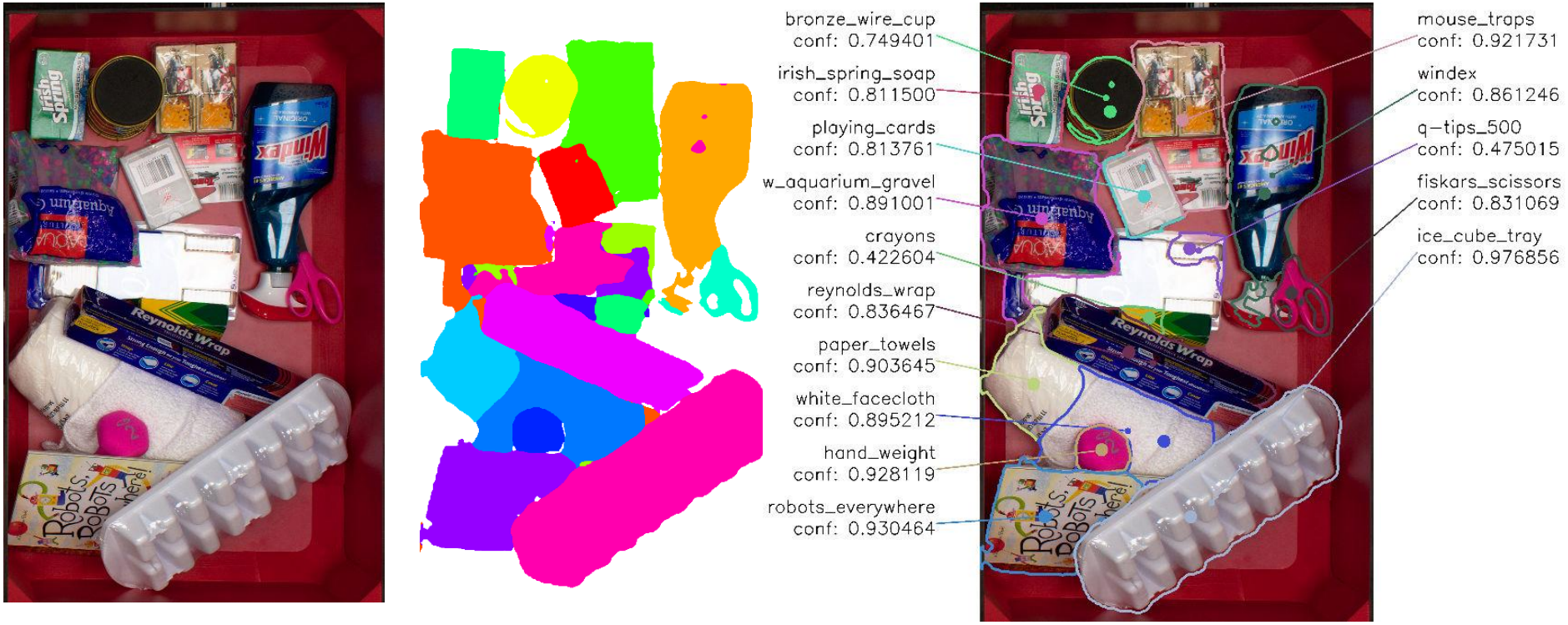


Object Capture and Scene Rendering

- Turn table + DLSR

Rendered scenes

ARC 2017 Perception Example



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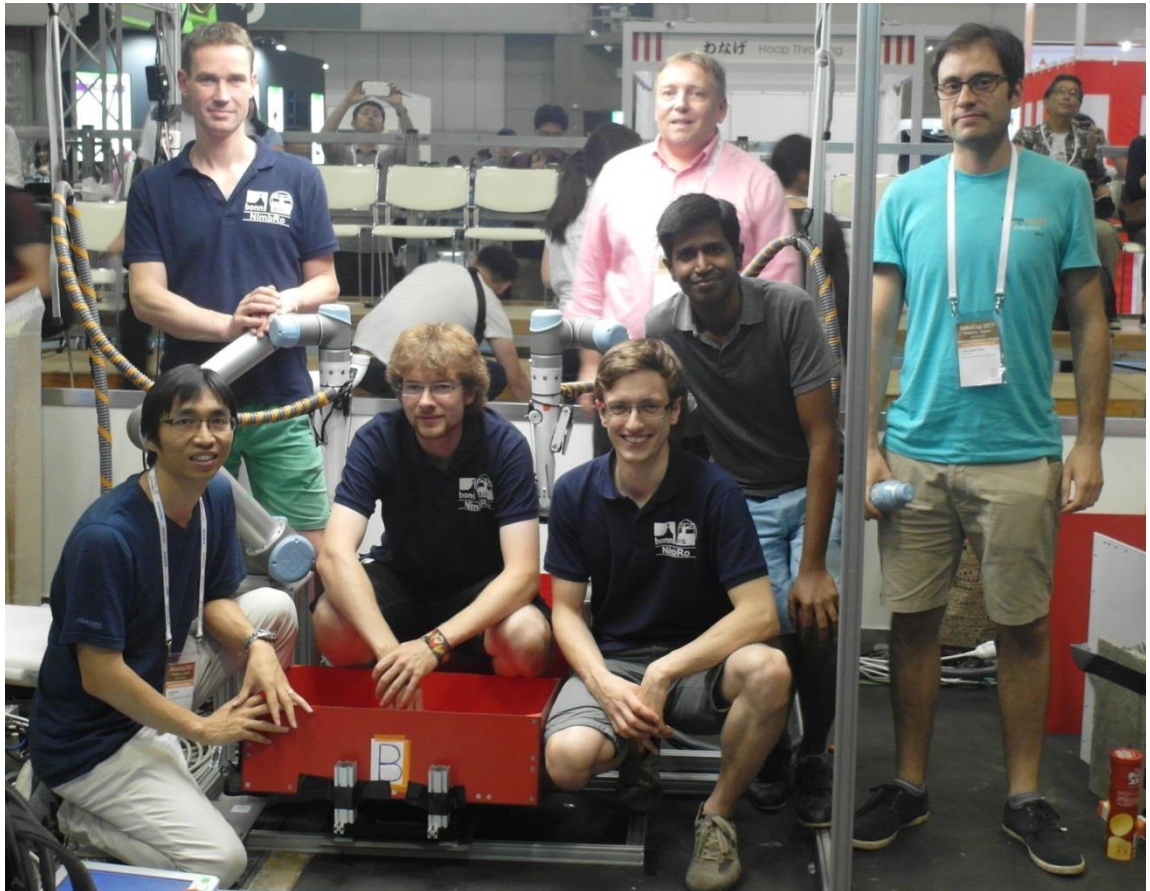
Amazon Robotics Challenge 2017 Final

NimbRo Picking 2017 Team

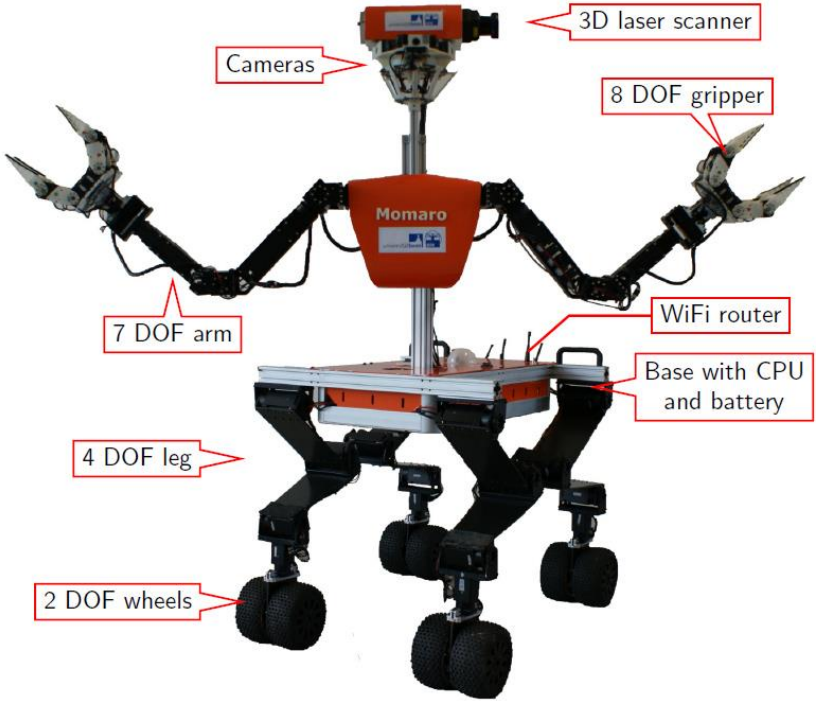
- 2nd place Pick
- 2nd place Stow-and-Pick Final



Mobiler Manipulations-Roboter Momaro

DARPA ROBOTICS CHALLENGE

- Vier nachgiebige Beine mit lenkbaren Radpaaren
- Menschenähnlicher Oberkörper
- Sensorkopf
  - 3D-Laserscanner
  - IMU, Kameras



[Schwarz et al. Journal of Field Robotics 2017]

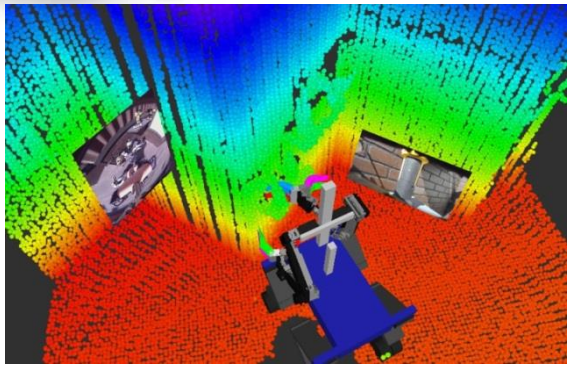
Führen eines Fahrzeugs

Ausstieg

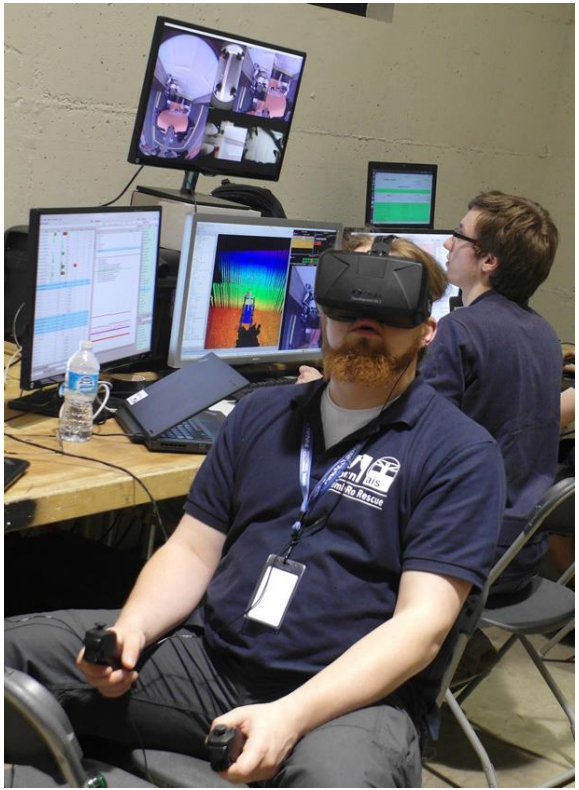
Operator-Interface für die Manipulation

- 3D-Head-mounted Display

- 3D-Umgebungs-modell + Bilder

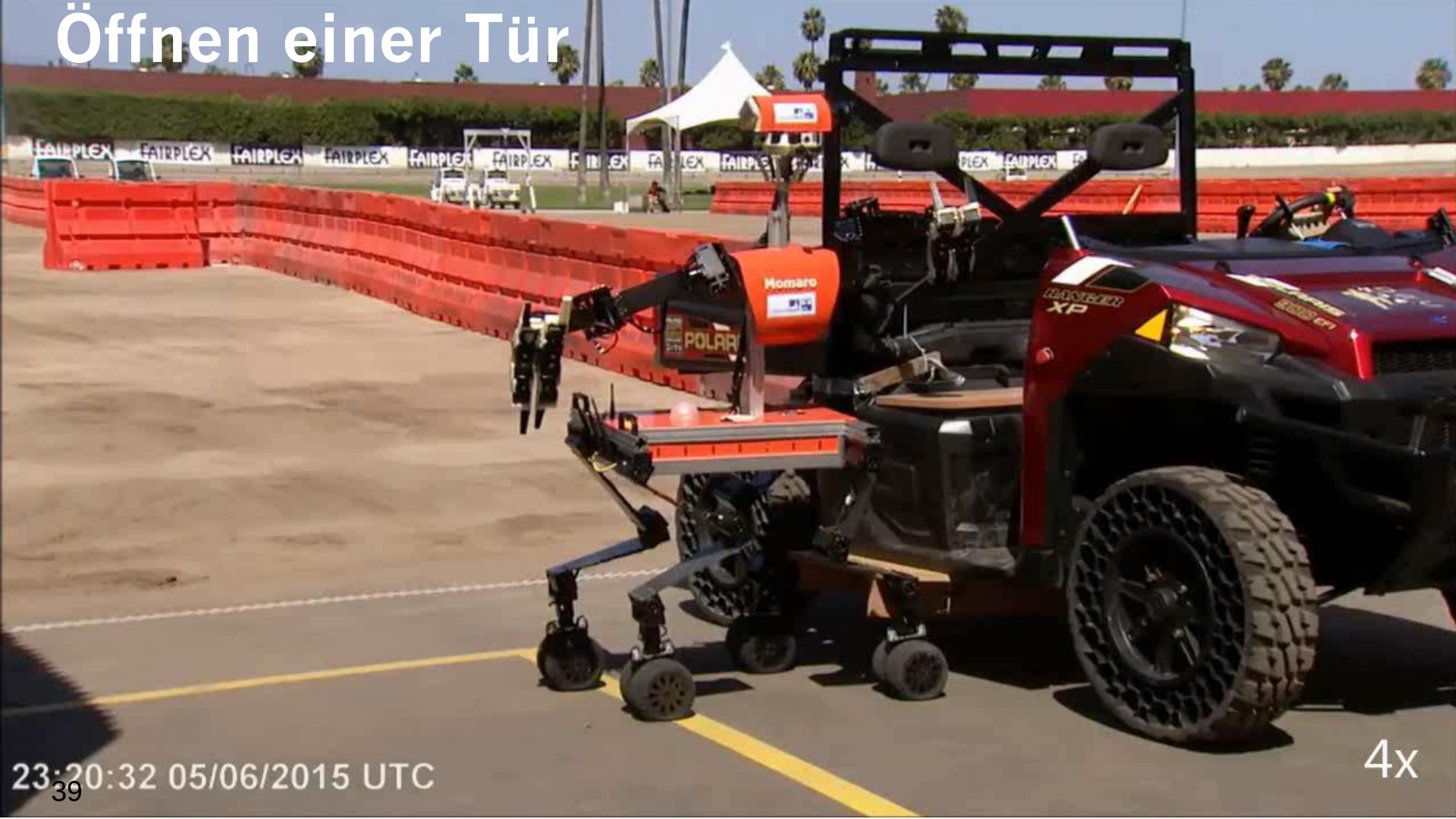


- 6D-Magnet-Tracker



[Rodehutskors et al., Humanoids 2015]

Öffnen einer Tür

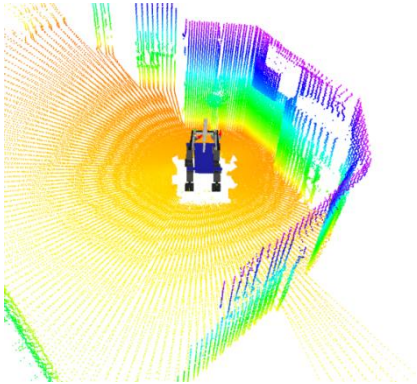


Lokale Multiresolutions-Surfel-Karten

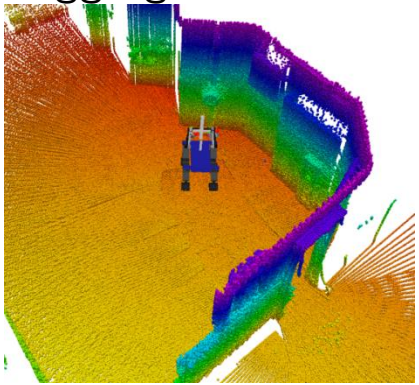
- Registrierung und Aggregation von 3D-Laserscans
- Lokales Multiresolutionsgrid
- Surfel in den Zellen

[Droeschel et al., Robotics and Autonomous Systems 2017]

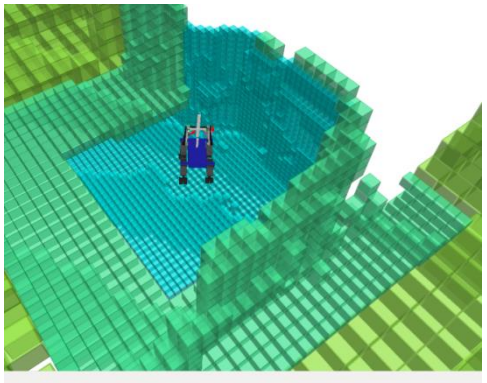
3D scan



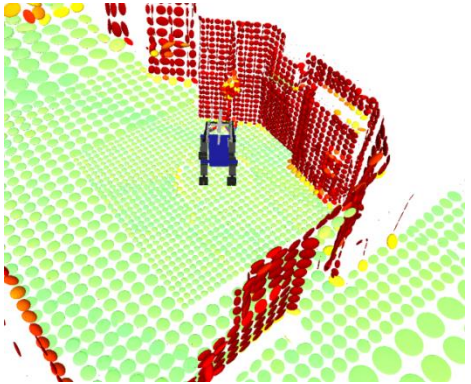
Aggregated scans



Multiresolution grid



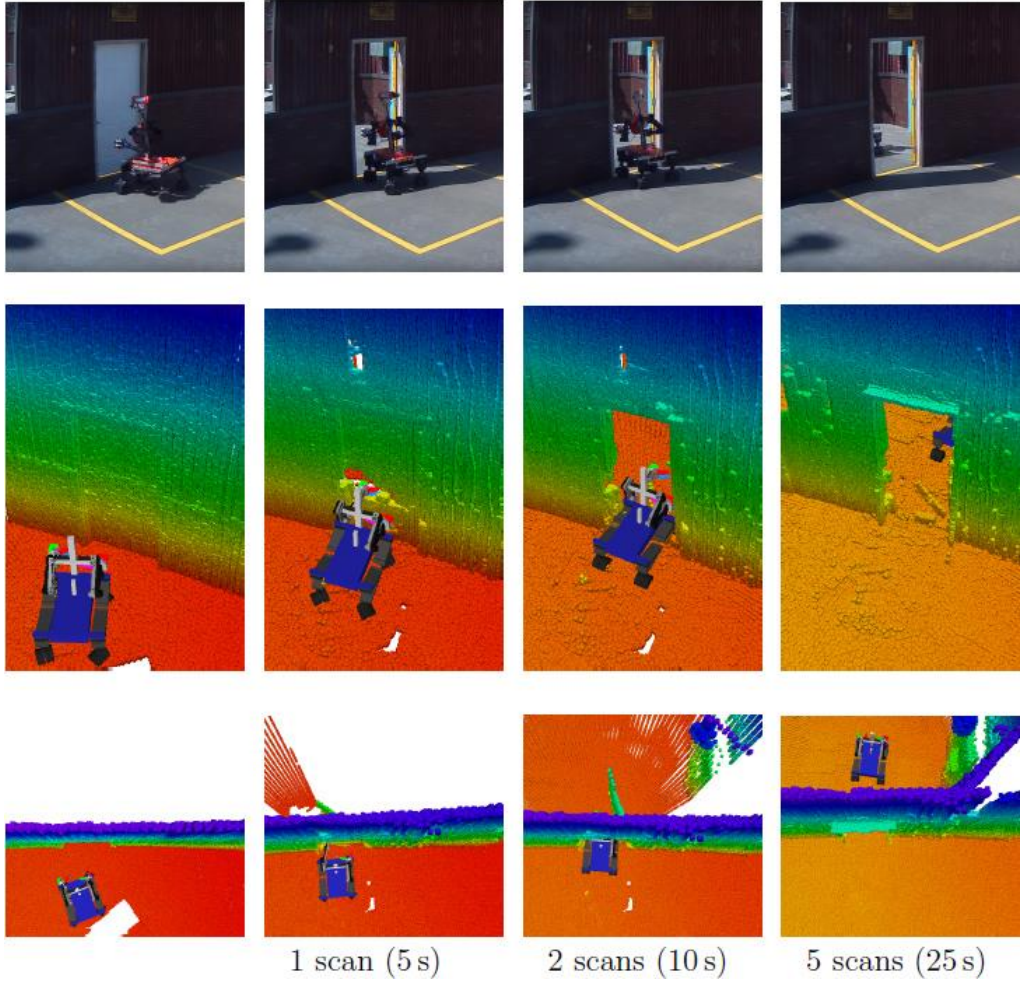
Surfels



Filterung beweglicher Objekte

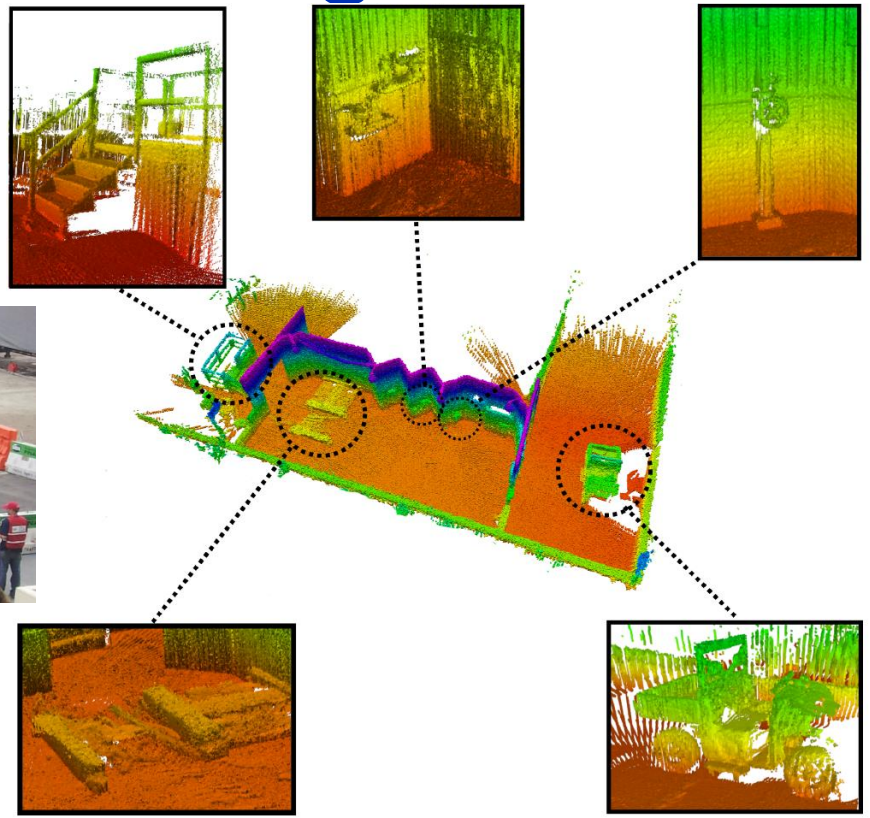
- Distanzmessungen sind auch Freimessungen
- Aktualisierung der Belegtheitsschätzung in jeder Zelle

[Droeschel et al., Robotics and Autonomous Systems 2017]



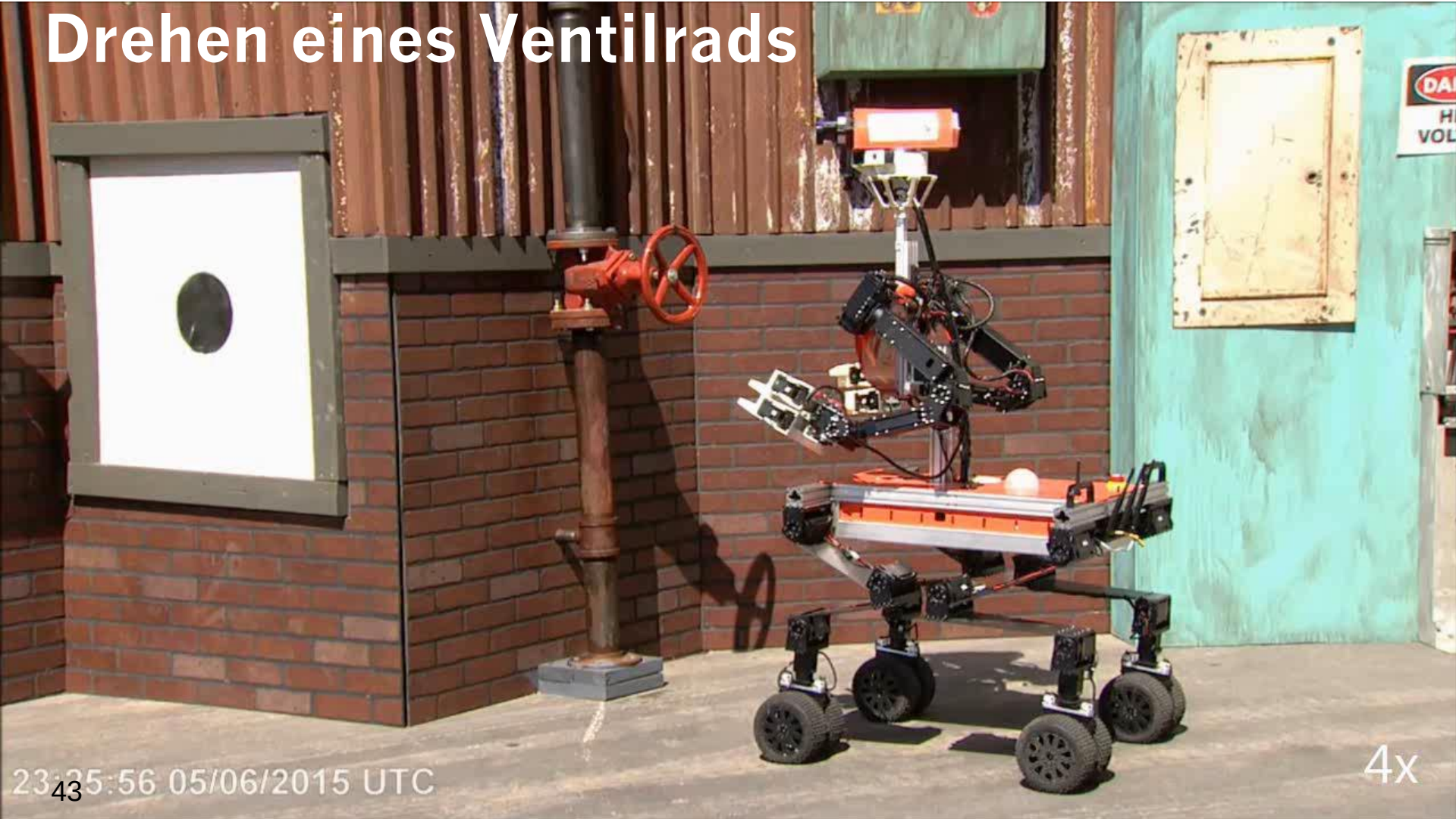
Allozentrische 3D-Kartierung

- Registrierung egozentrischer Karten durch Graphoptimierung



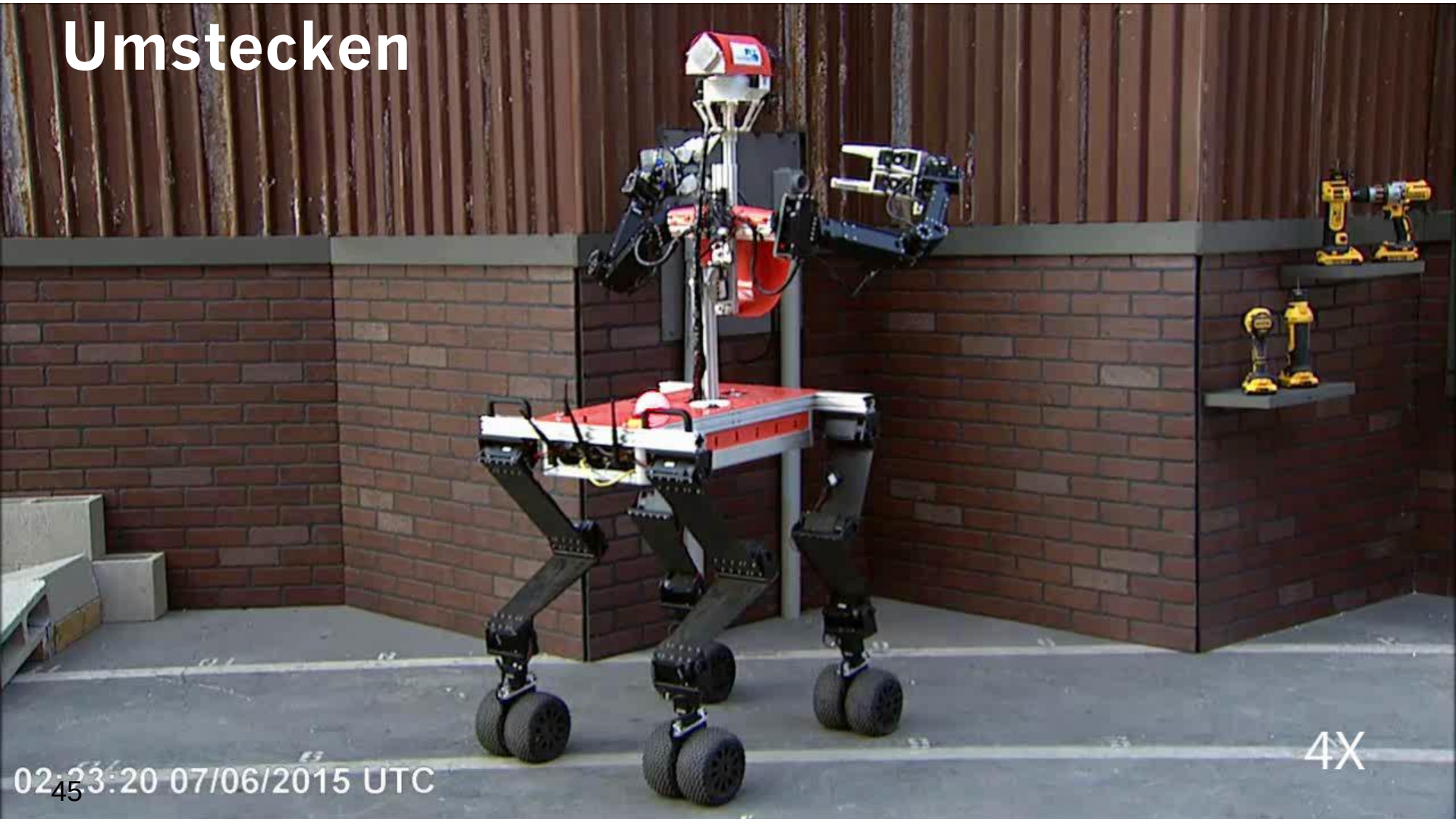
[Droeschel et al., Robotics and Autonomous Systems 2017]

Drehen eines Ventilrads



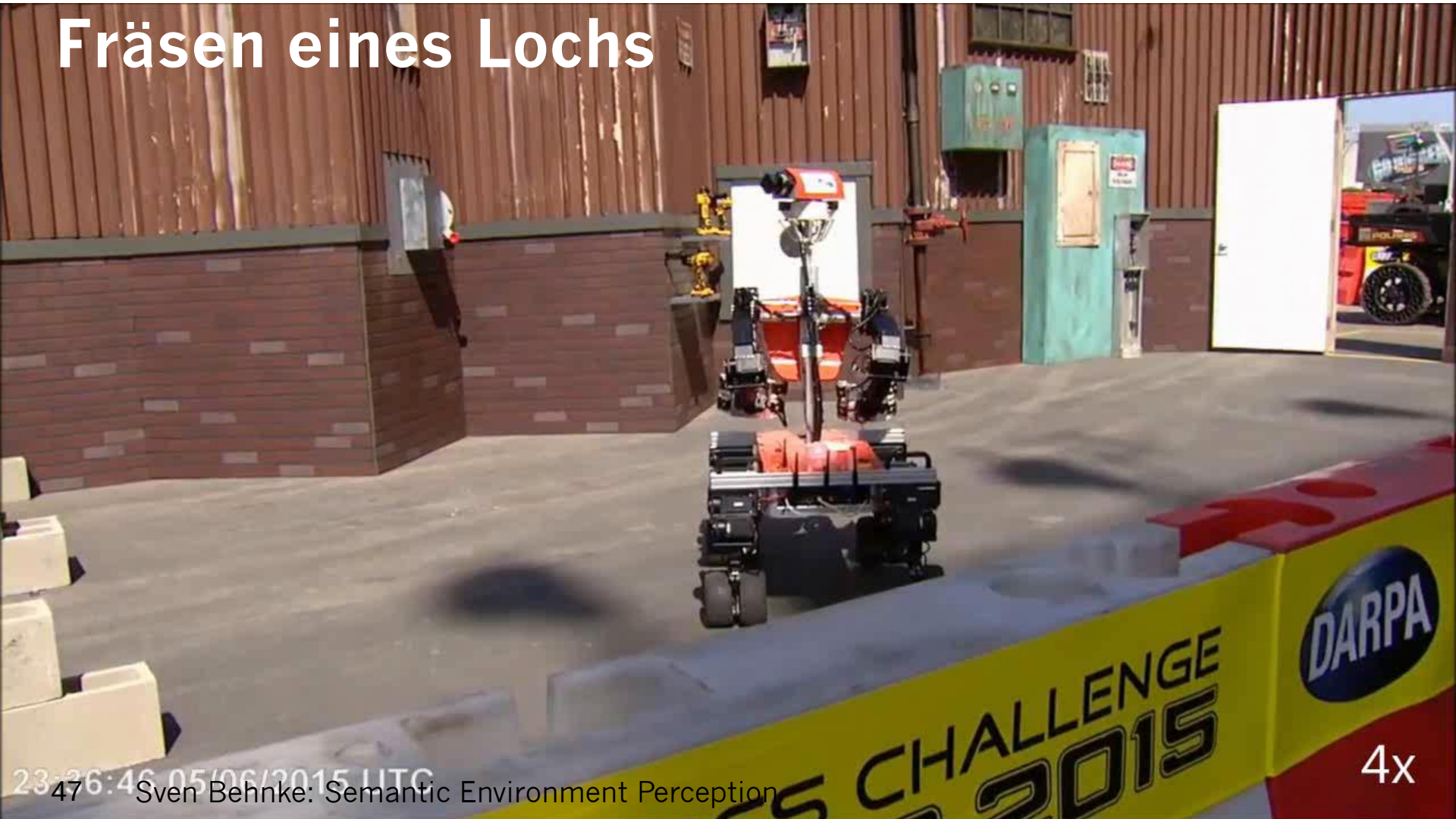
Umlegen eines Schalters

Umstecken



Überwindung von Hindernissen

Fräsen eines Lochs



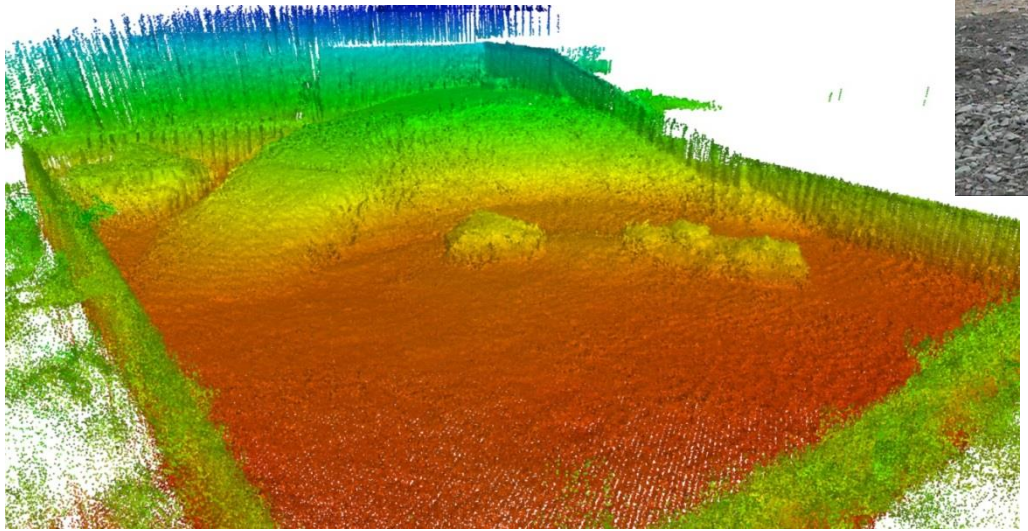
Team NimbRo Rescue

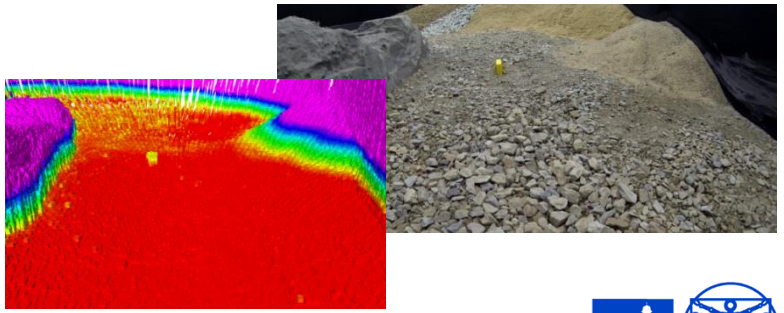
Bestes Europäisches Team (4. Platz)
Sieben von acht Aufgaben in 34 Min. gelöst

DLR SpaceBot Cup 2015

- Mobile Manipulation im Gelände

[Schwarz et al., Frontiers on Robotics and AI 2016]

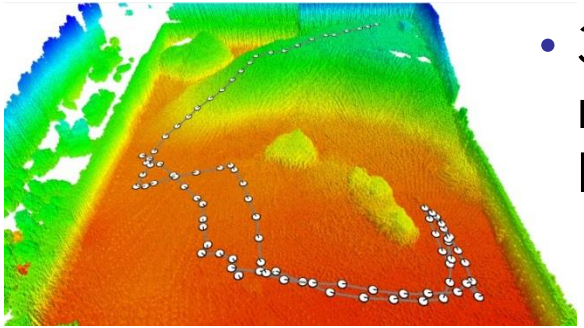


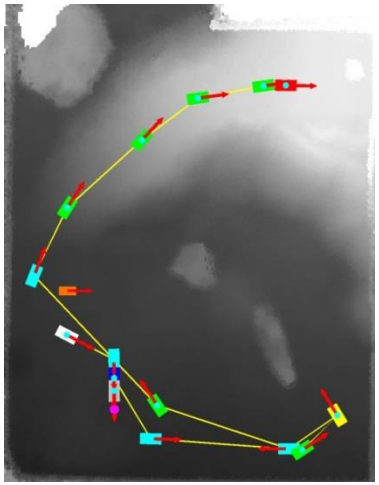


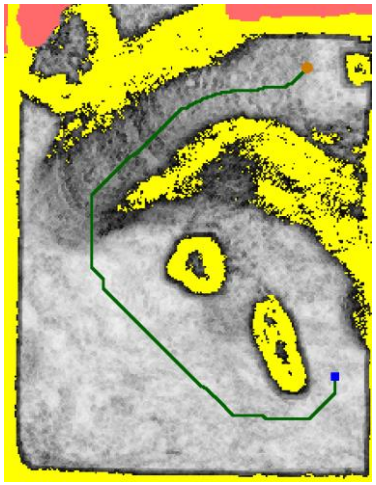
DLR SpaceBot Camp 2015

Autonome Missionsausführung

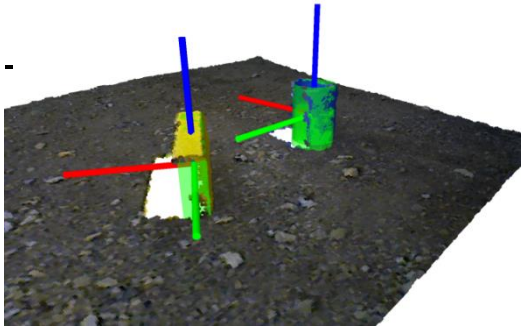
- 3D-Kartierung, Lokalisierung, Missions- und Navigations-planung

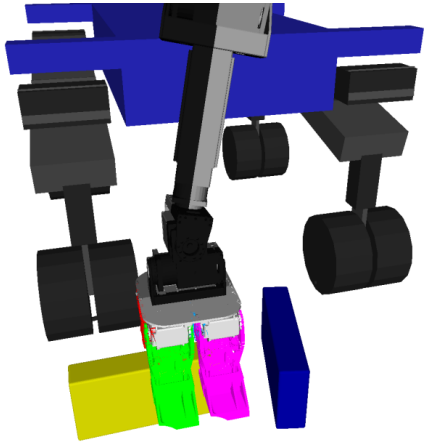






- 3D-Objektwahr-nehmung und Handhabung





[Schwarz et al. Frontiers 2016]

H2020 Project CENTAURO

Robust Mobility and Dexterous Manipulation in Disaster Response by Fullbody Telepresence in a Centaur-like Robot

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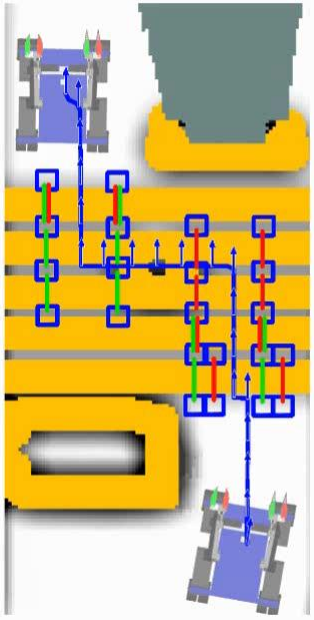
Expanding Abstract Steps to Detailed Motion Sequences

[Klamt and Behnke: IROS 2017]

Planning for Challenging Scenarios



[Klamt and Behnke: IROS 2017]

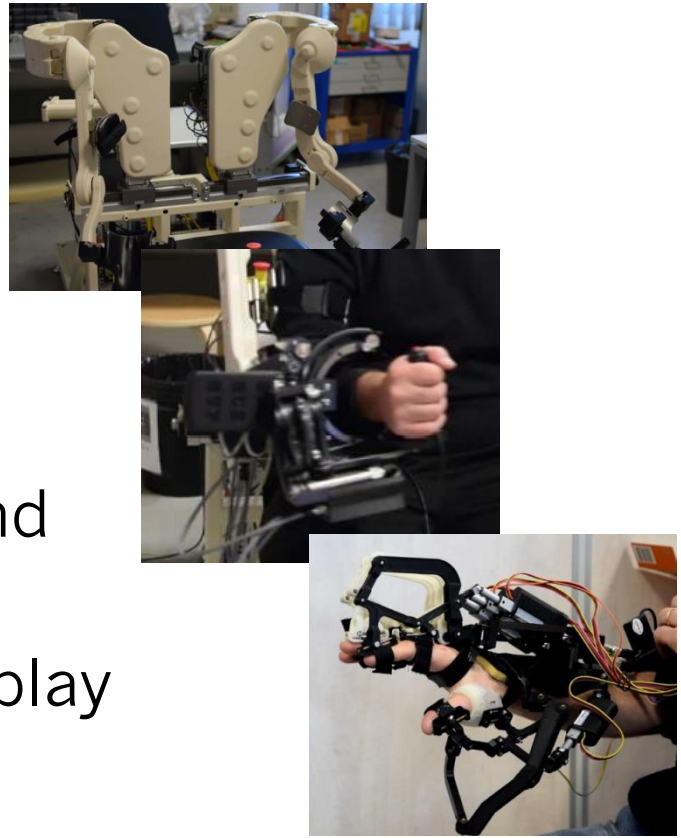
1st Centauro Robot

- Serial elastic actuators
- 42 main DoFs
- Schunk hand
- 3D laser
- RGB-D camera
- Color cameras
- Two GPU PCs

[Tsagarakis et al., IIT 2017]

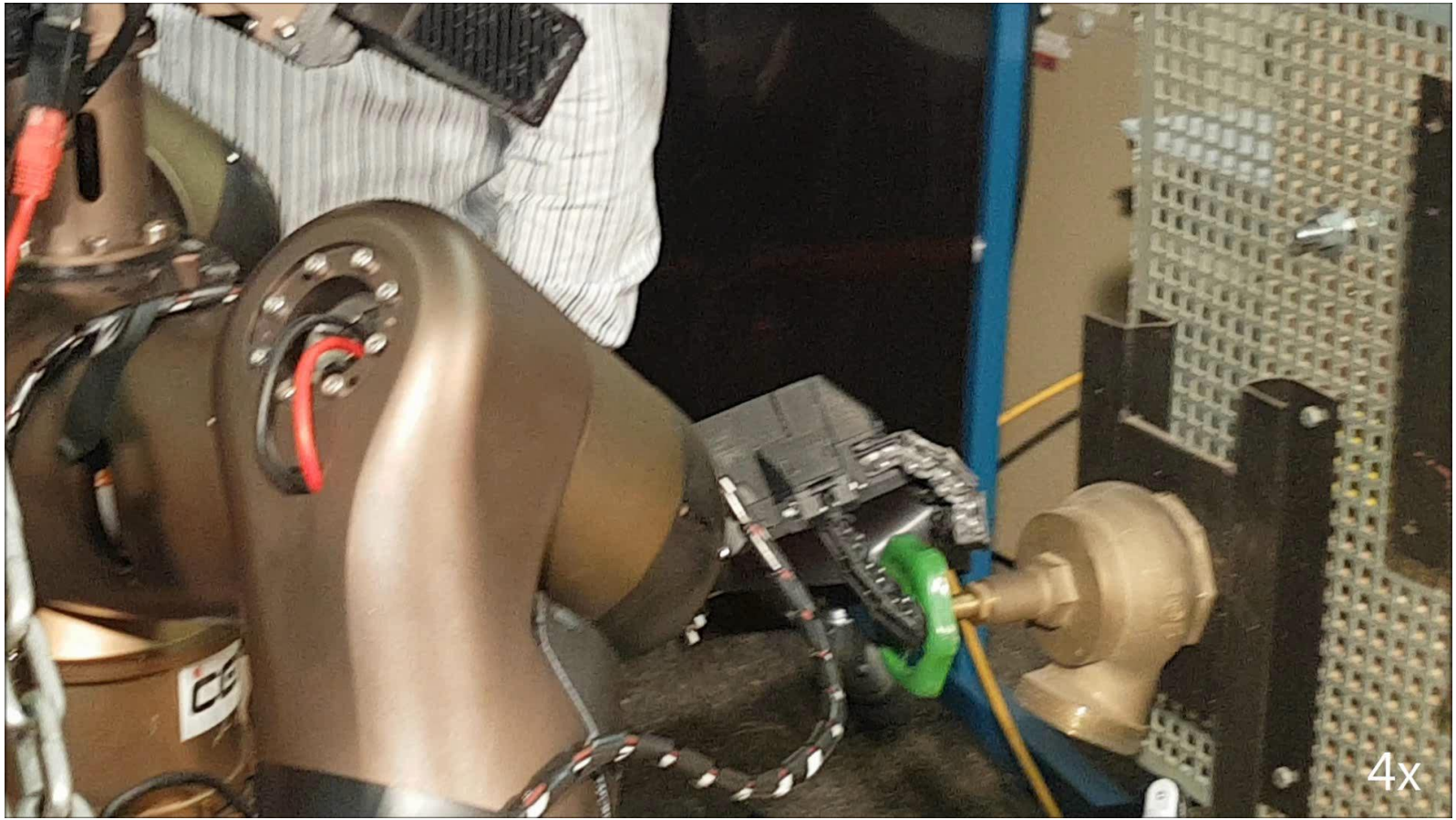
Main Operator Telepresence Interface

- Tendon-driven dual-arm exoskeleton
- Active wrist with differential tendon transmission
- Underactuated hand exoskeleton
- Head-mounted display
- Foot pedals

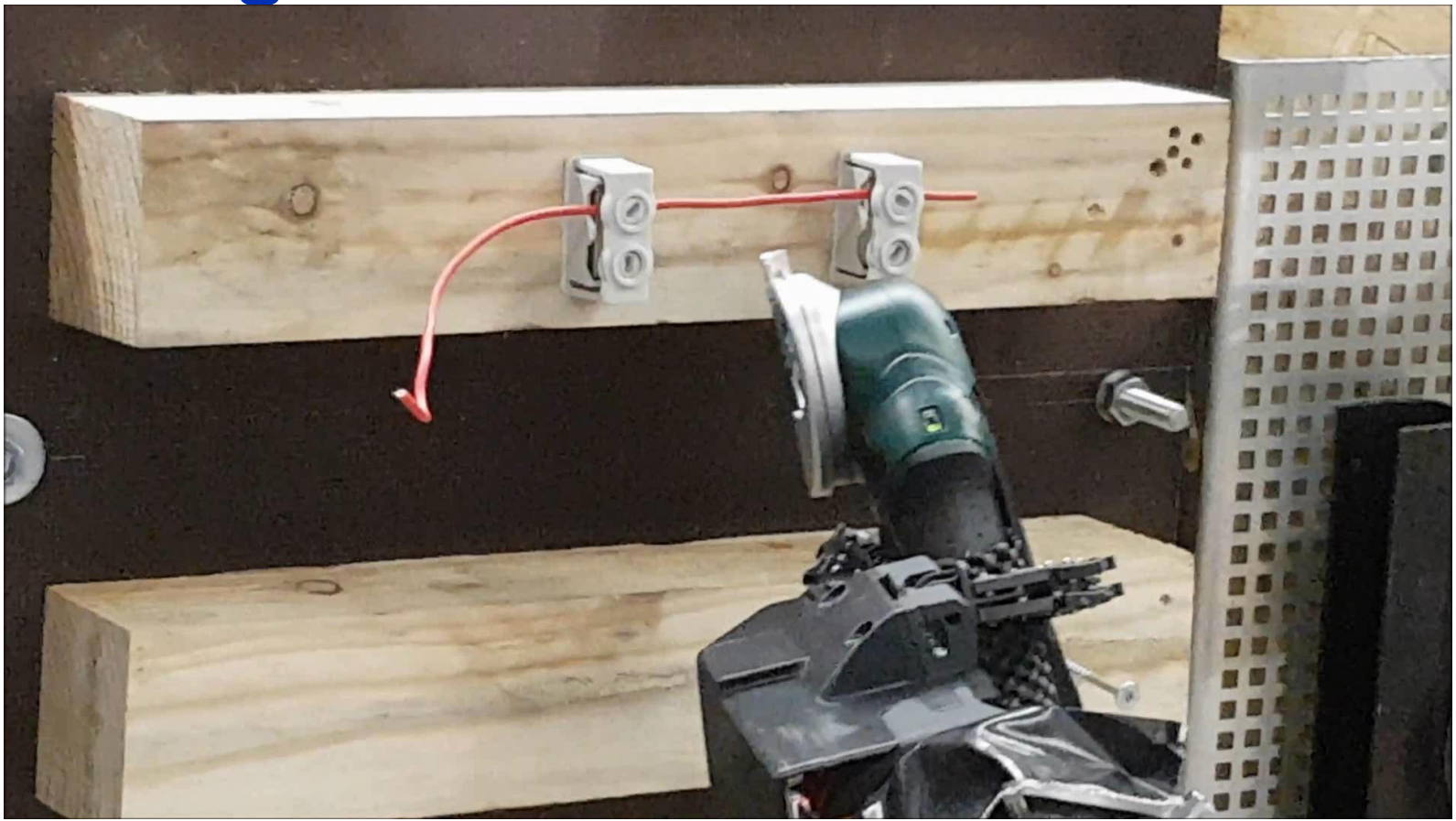


[Frisoli et al., SSSA 2017]

Turning a Valve



Cutting a Wire



Climbing over a Gap

Walking over a Step Field

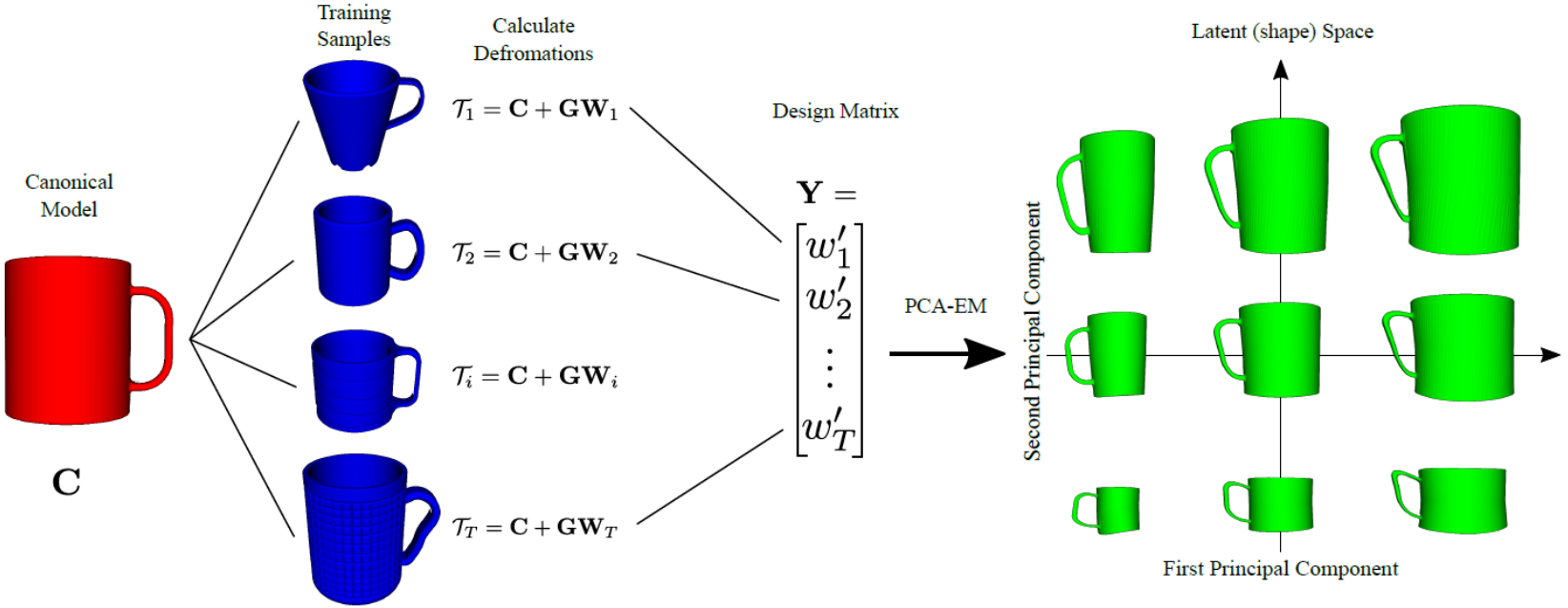
Transfer of Manipulation Skills

Knowledge Transfer

[Rodriguez et al. ICRA 2018]

Learning a Latent Shape Space

- Non-rigid registration of instances and canonical model
- Principal component analysis of deformations



[Rodriguez et al. ICRA 2018]

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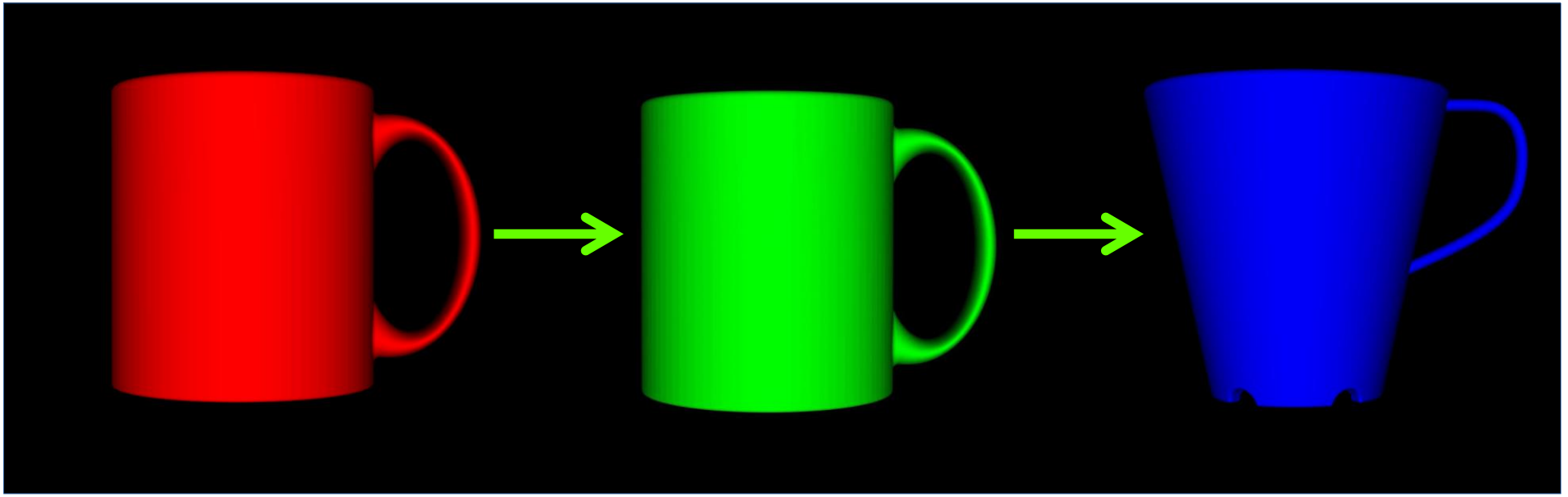
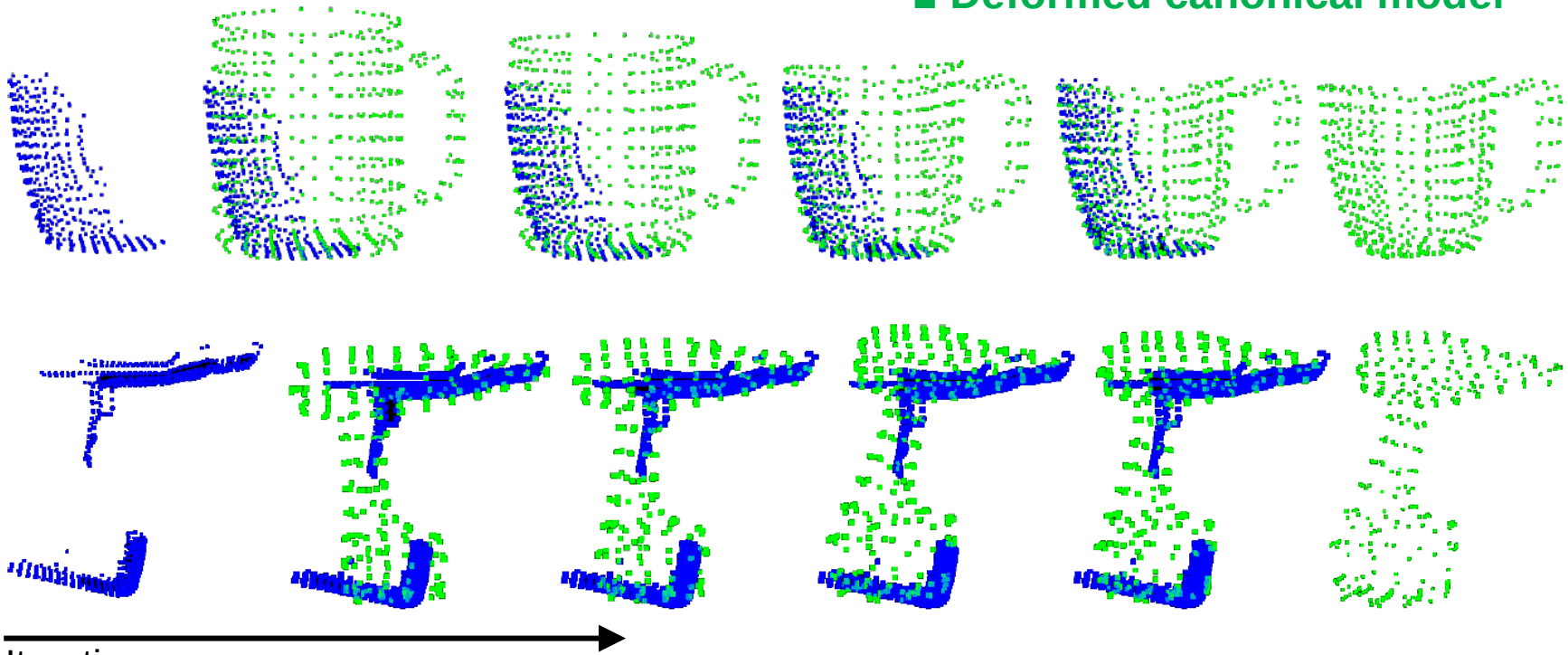
Interpolation in Shape Space



[Rodriguez et al. ICRA 2018]

Shape-aware Non-rigid Registration

- Partial view of novel instance
- Deformed canonical model

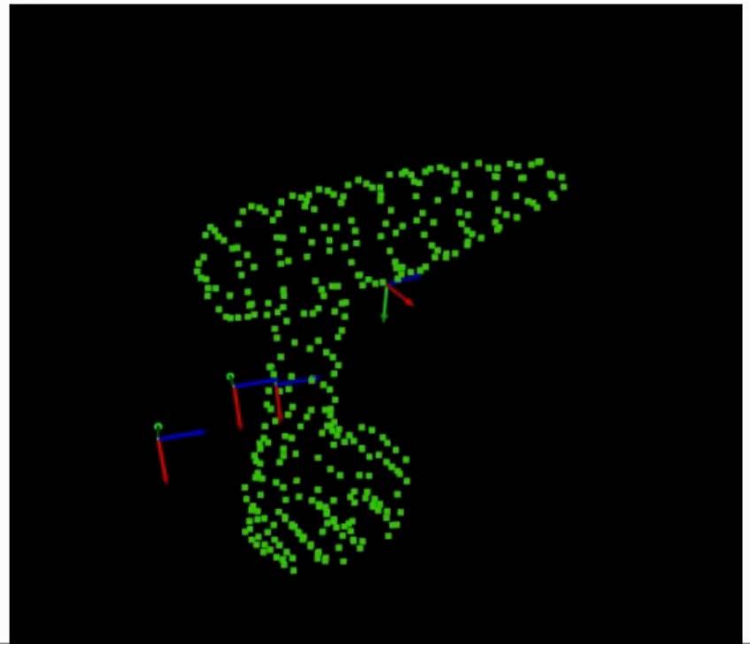


Iterations

[Rodriguez et al. ICRA 2018]

Transference of Grasping Skills

Warp grasping information



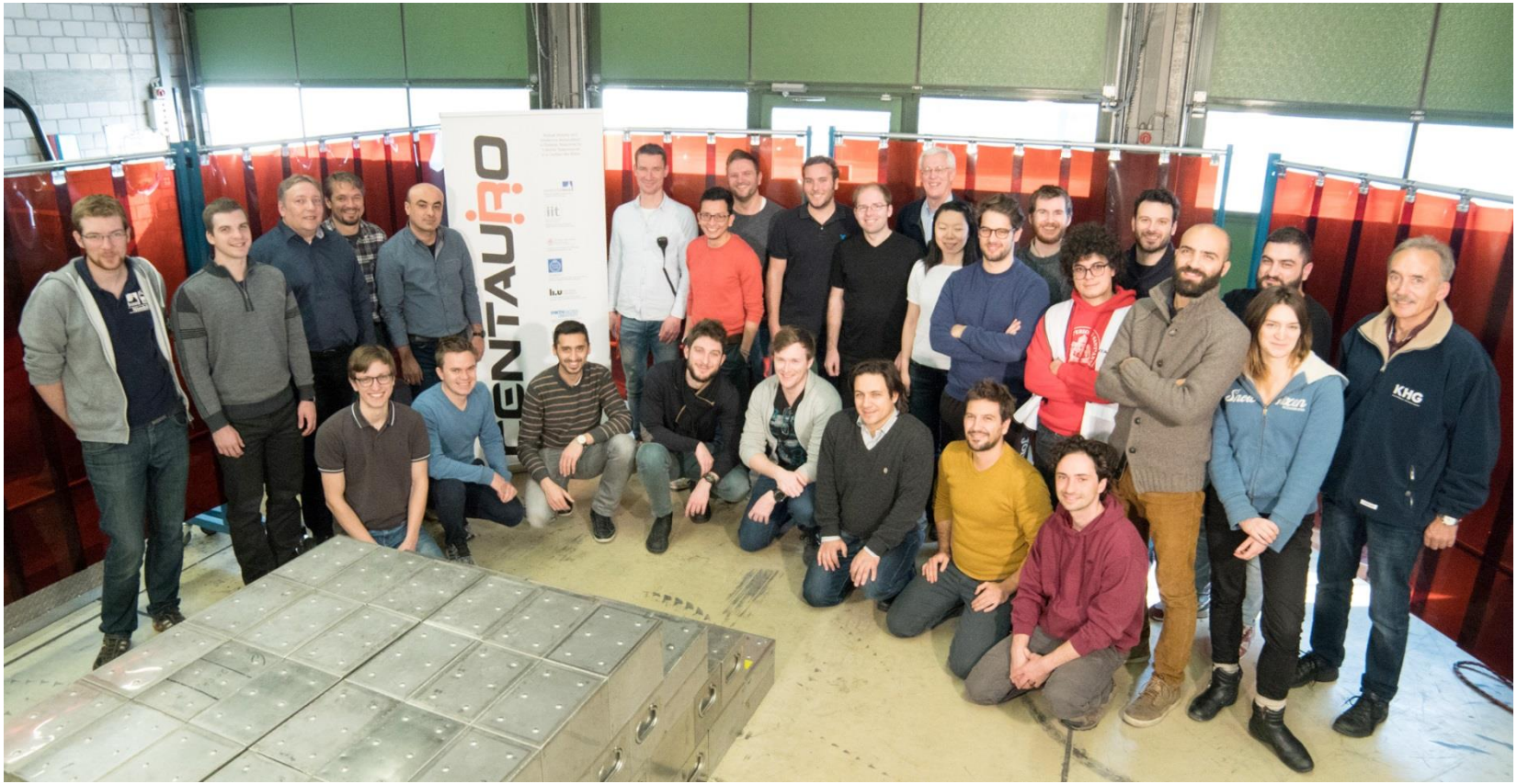
[Rodriguez et al. ICRA 2018]

Grasping an Unknown Power Drill

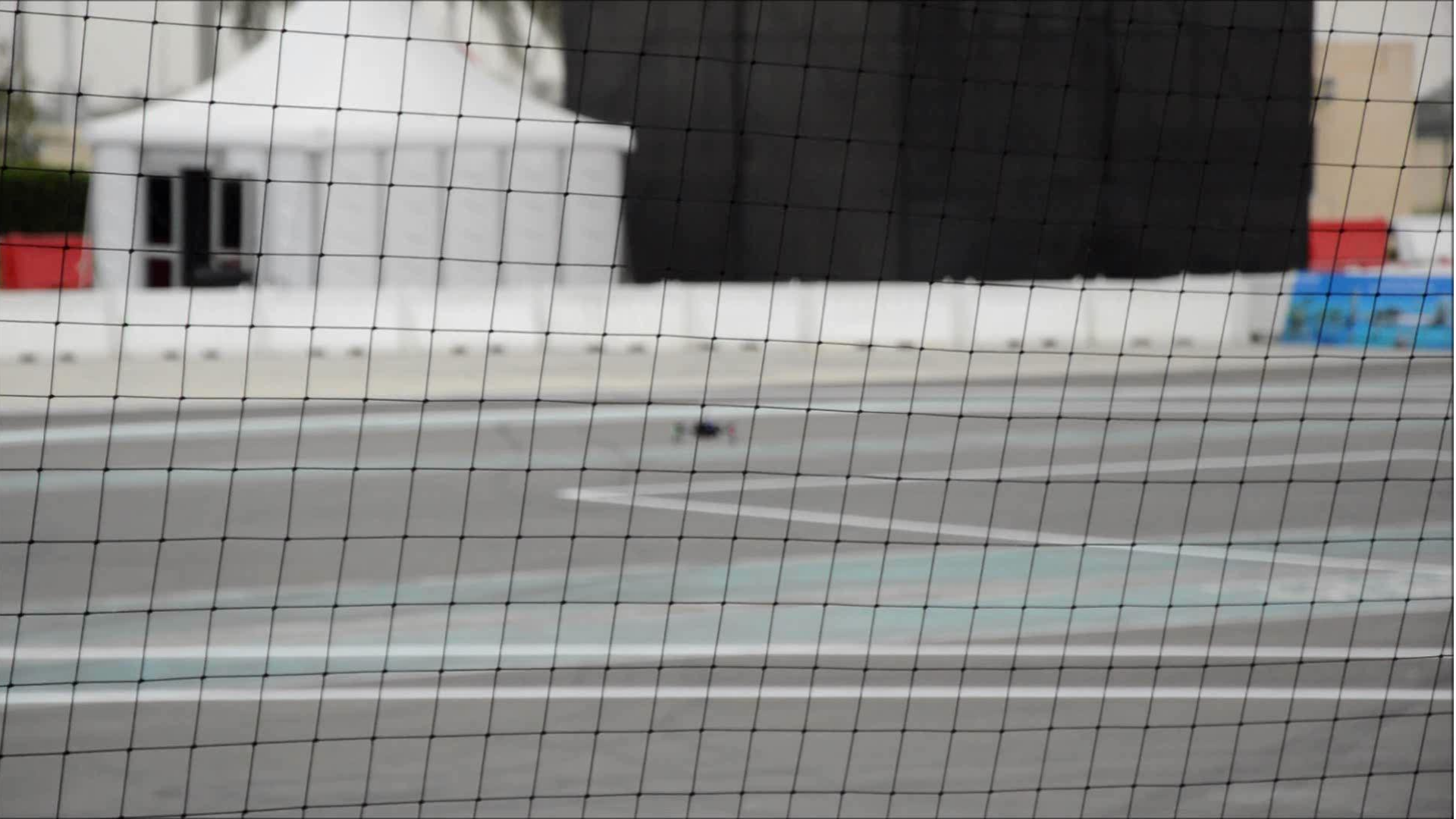
[Rodriguez et al. ICRA 2018]

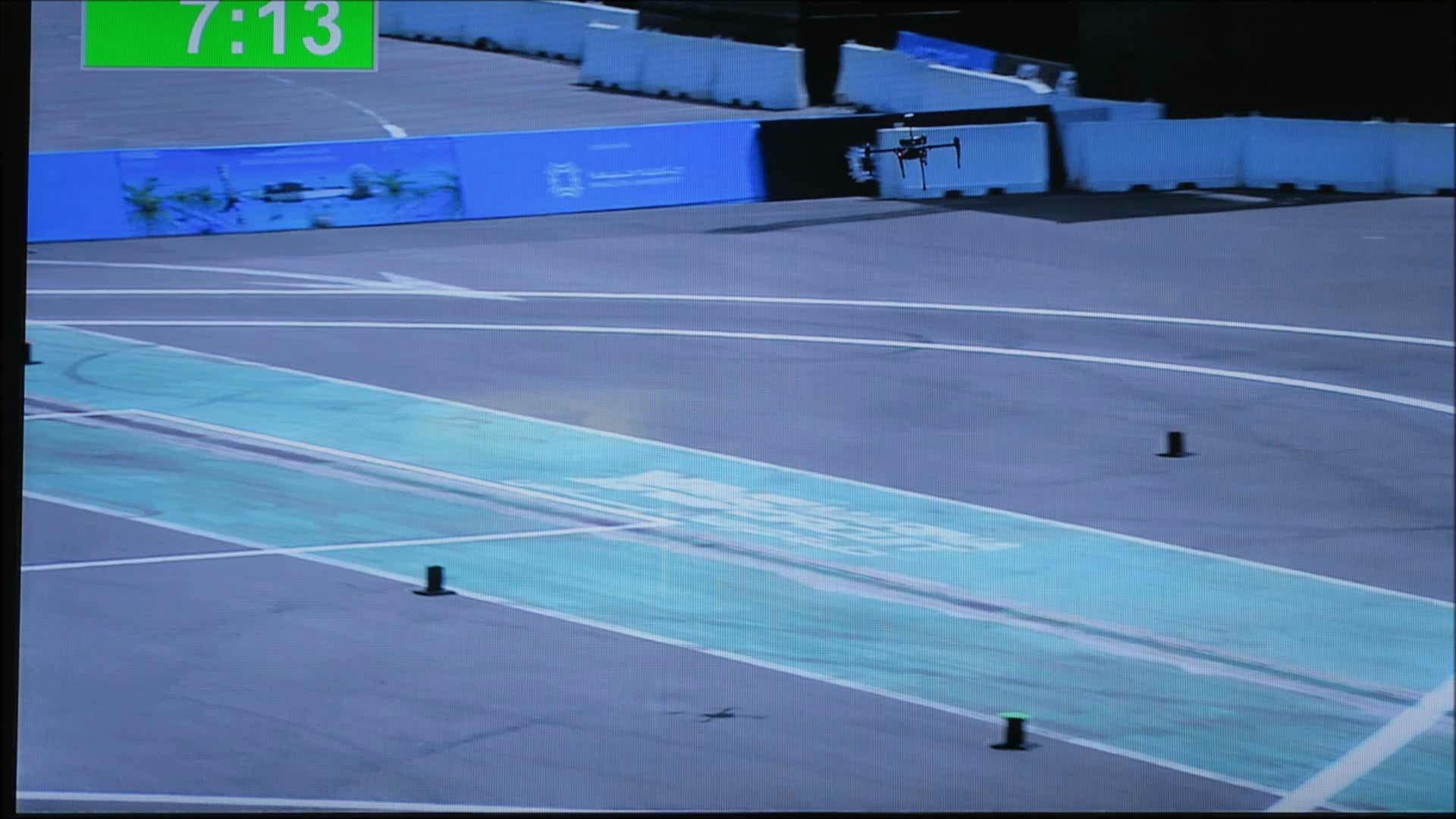
Fastening a Screw

CENTAURO Team



MBZIRC Challenge 2




7:13

MBZIRC Team NimbRo

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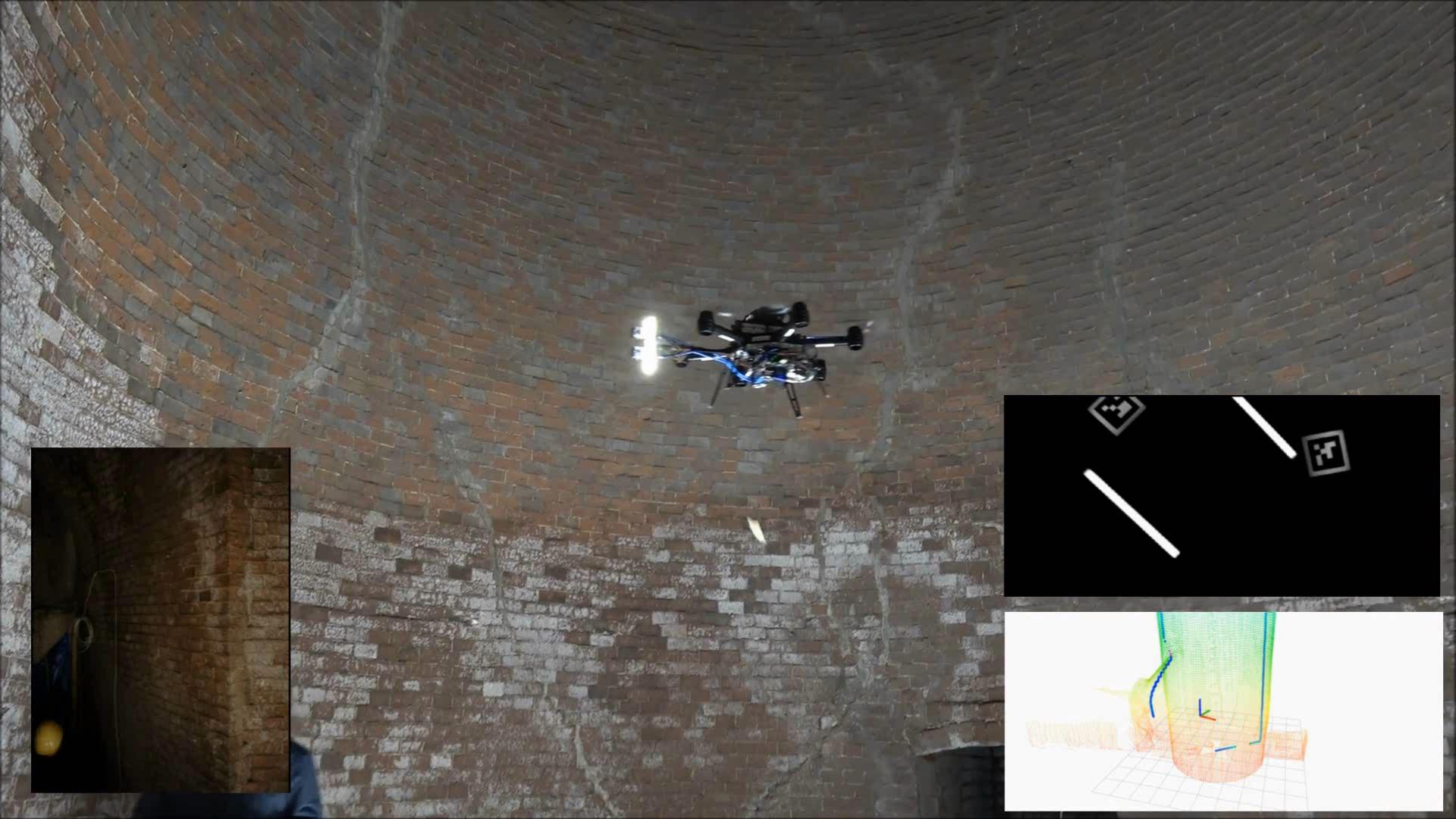
DJI Matrice 600 with Velodyne Puck

Autonomous Indoor Navigation

Fully Autonomous indoor flight without external tracking.



Zusammenfassung

- Beispiele für kognitive Roboter in komplexen Szenarien
  - Humanoide Fußballroboter
  - Serviceaufgaben im Haushalt
  - Griff in die Kiste
  - Menschenfeindliche Umgebungen
  - Flugroboter
- Herausforderungen beinhalten
  - 3D-Kartierung, semantische Szeneninterpretation
  - Hochdimensionale Bewegungsplanung, robuste Bewegungskontrolle
- Mögliche Lösungsansätze
  - Zusammenführen von Erfahrungen vieler Roboter
  - Kombination von menschlicher Intelligenz und Autonomie
  - Instrumentierte Umgebungen