Learning to Singulate Objects using a Push Proposal Network

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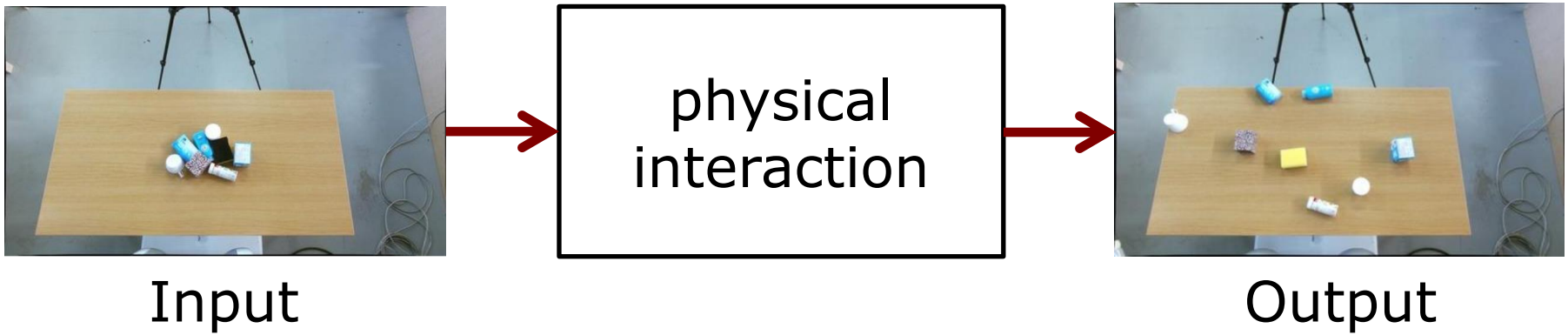
AiS Autonomous Intelligent Systems

Removing Clutter is Hard

Manipulation of objects in unstructured scenes is challenging due to uncertainty from perception

Motivation



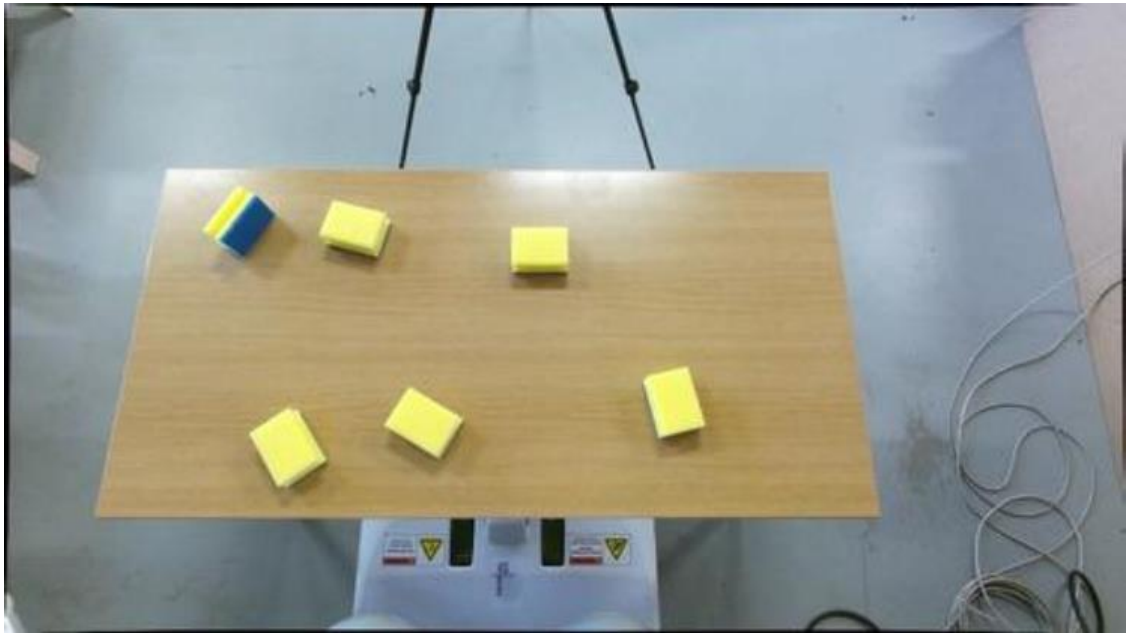
Object singulation = physically separating objects in cluttered tabletop scenes

Singulation and Interactive Object Perception

How many objects are in the image?

Singulation and Interactive Object Perception

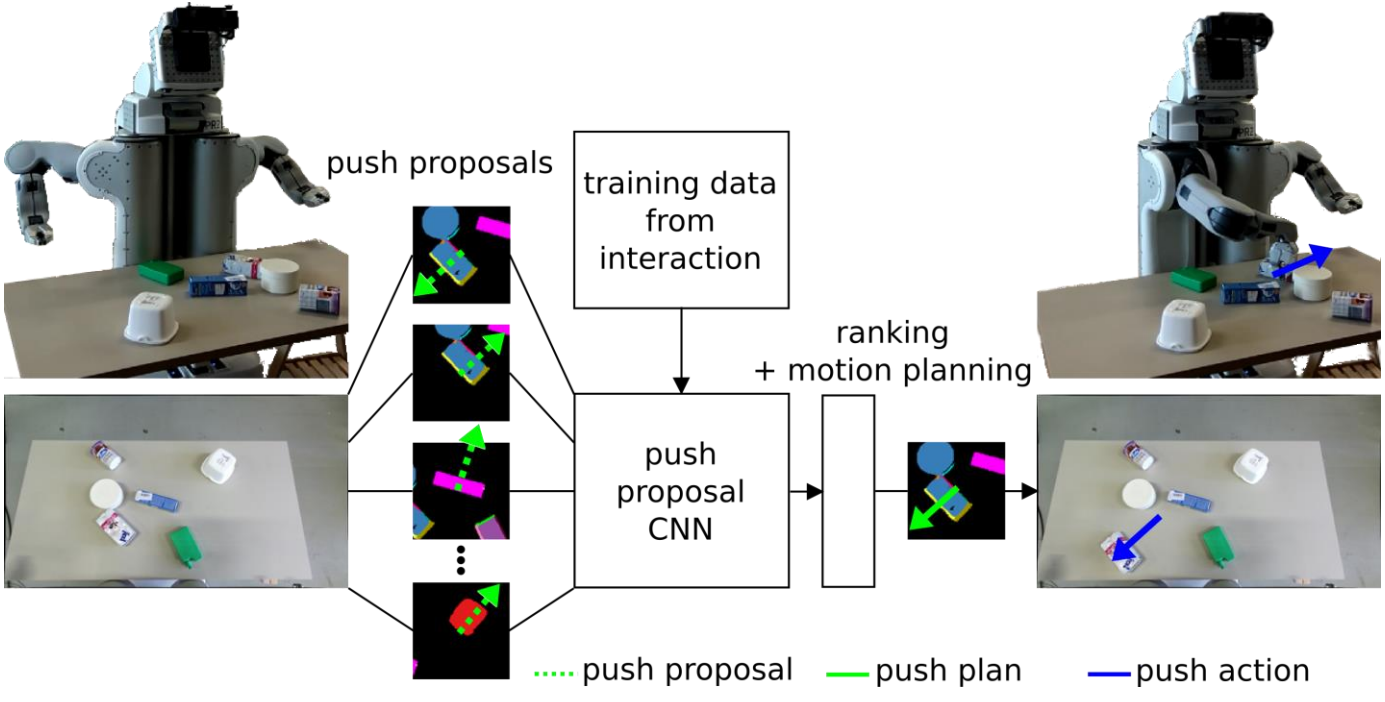
Singulation facilitates perception



Contributions

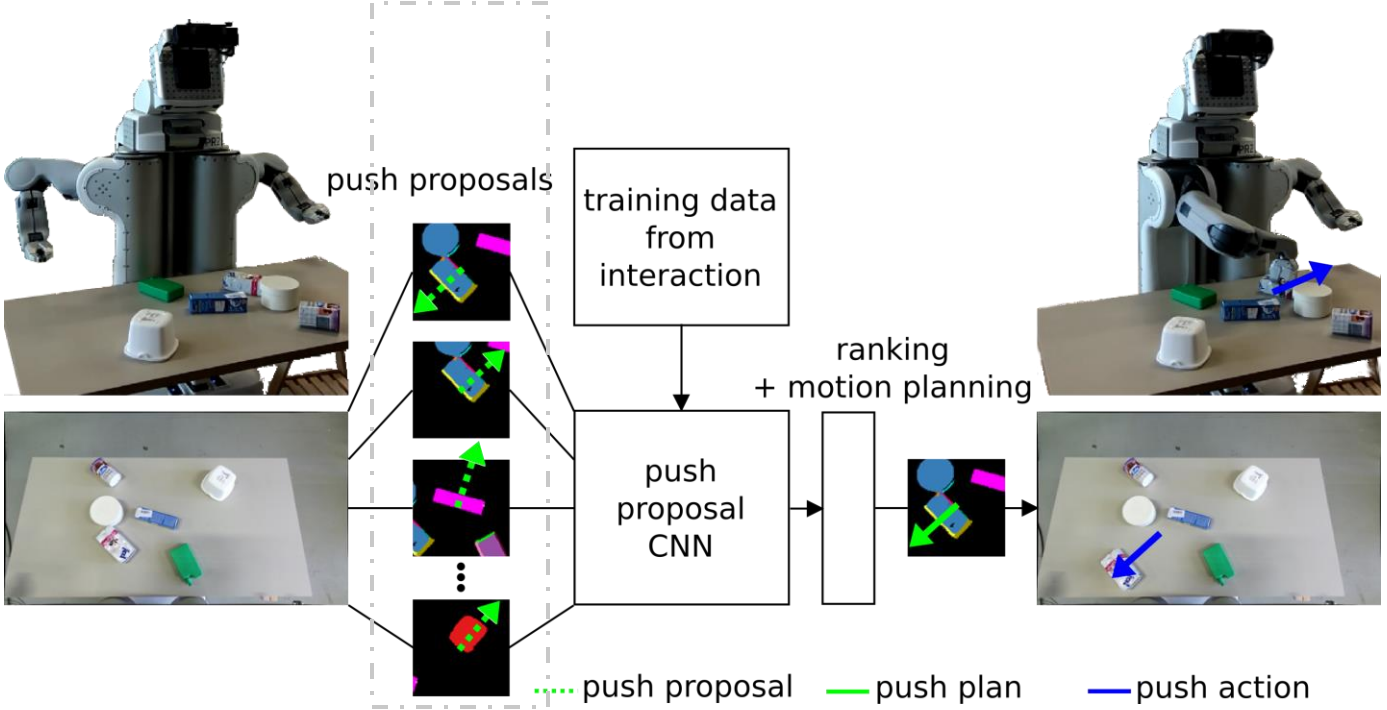
- We train a CNN to detect favourable push actions from over-segmented images in order to clear clutter
- In comparison to previous work
  1. Model-free approach, no physics simulator, no object knowledge
  2. Learn features automatically

Approach


push proposals
training data from interaction
ranking + motion planning
push proposal CNN
push proposal
push plan
push action

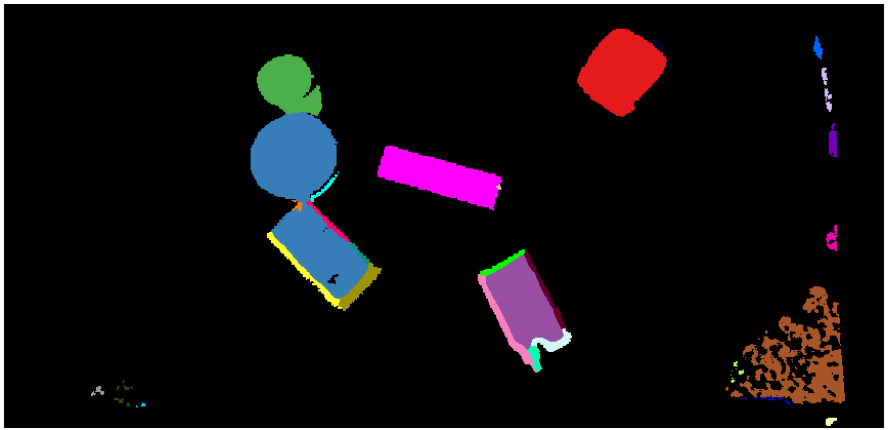
Approach

1. Sample push proposals from over-segmented RGB-D image



Over-segmentation

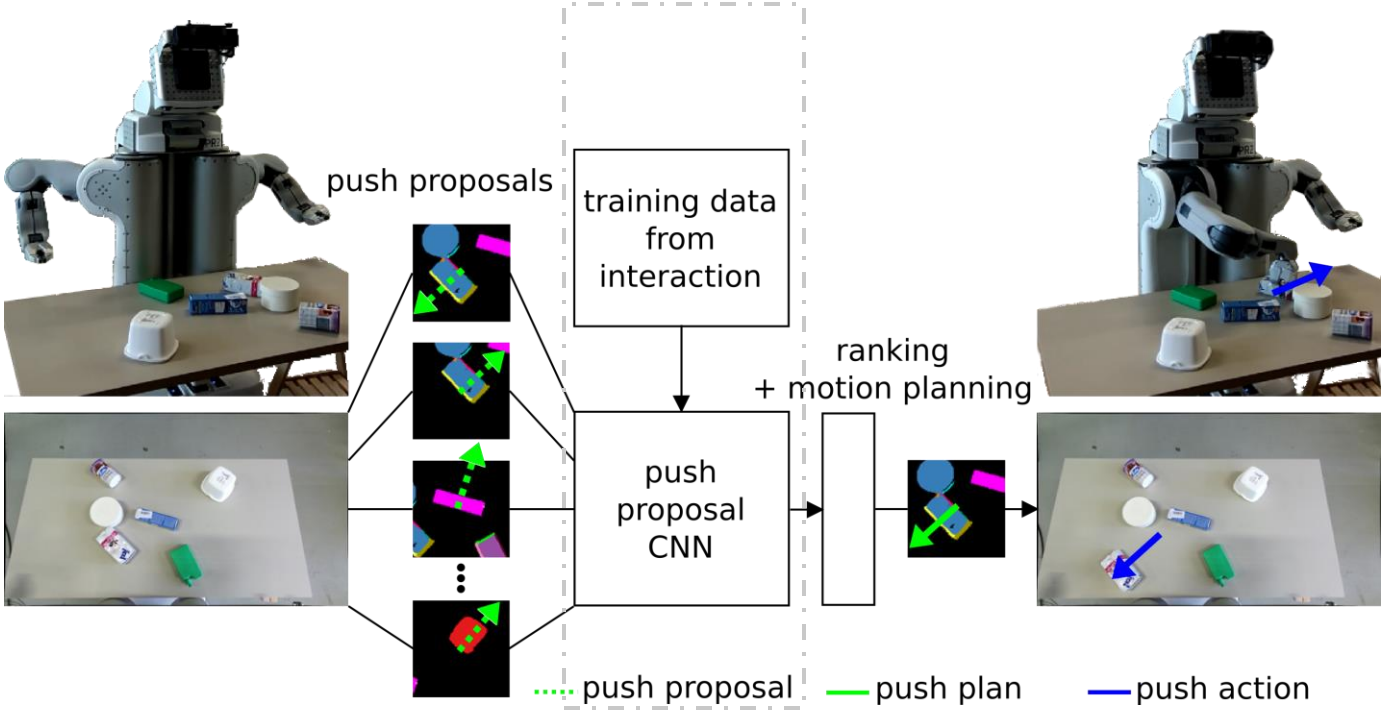
Objects get segmented into multiple facets using RGB-D Segmenter [1]



[1] Richtsfeld et al. 2012

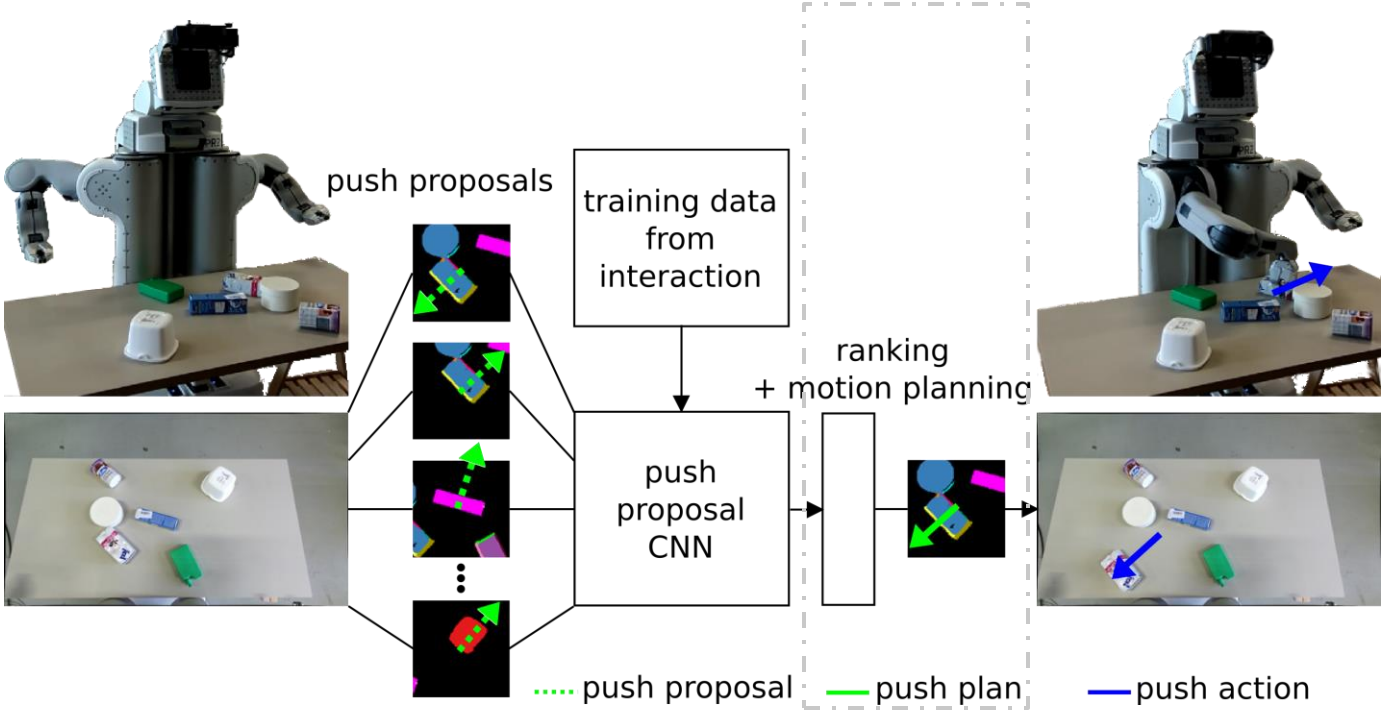
Approach

2. Classify set of sampled push proposals with push proposal network



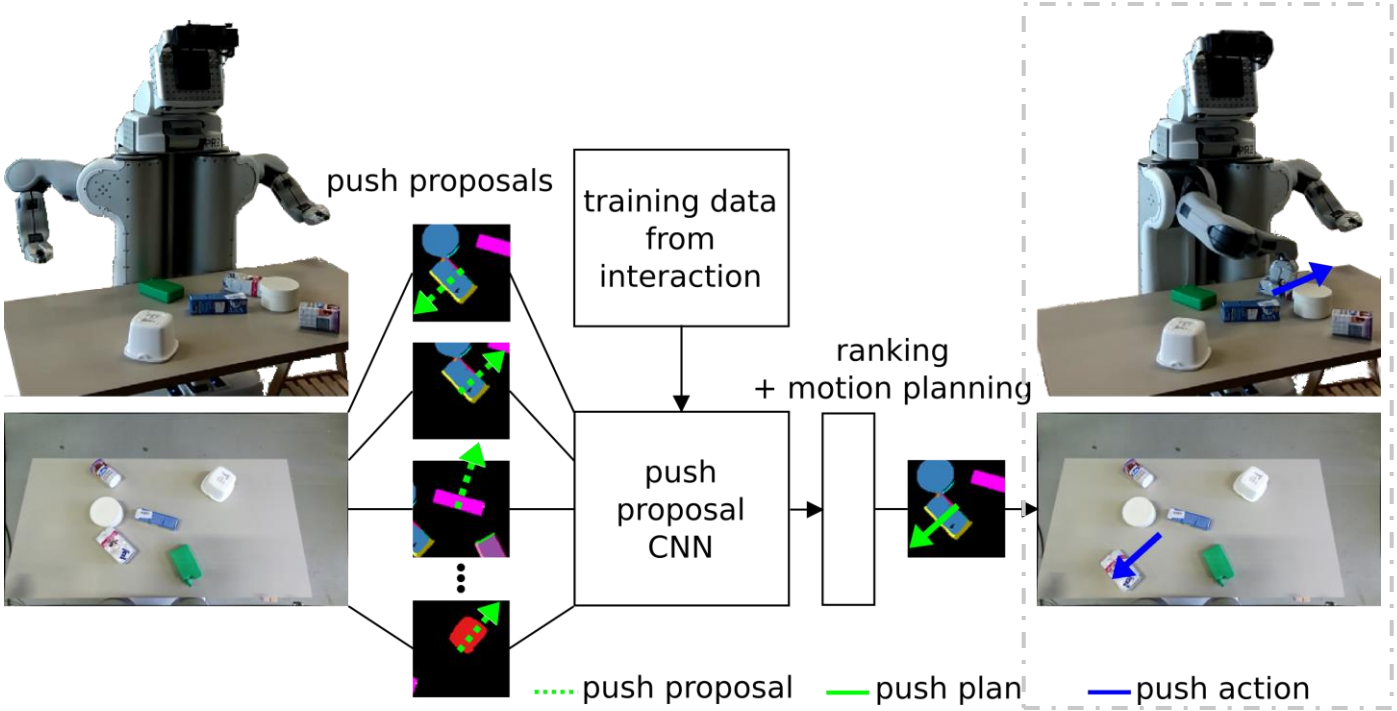
Approach

3. Perform motion planning



Approach

4. Execute first successful motion plan

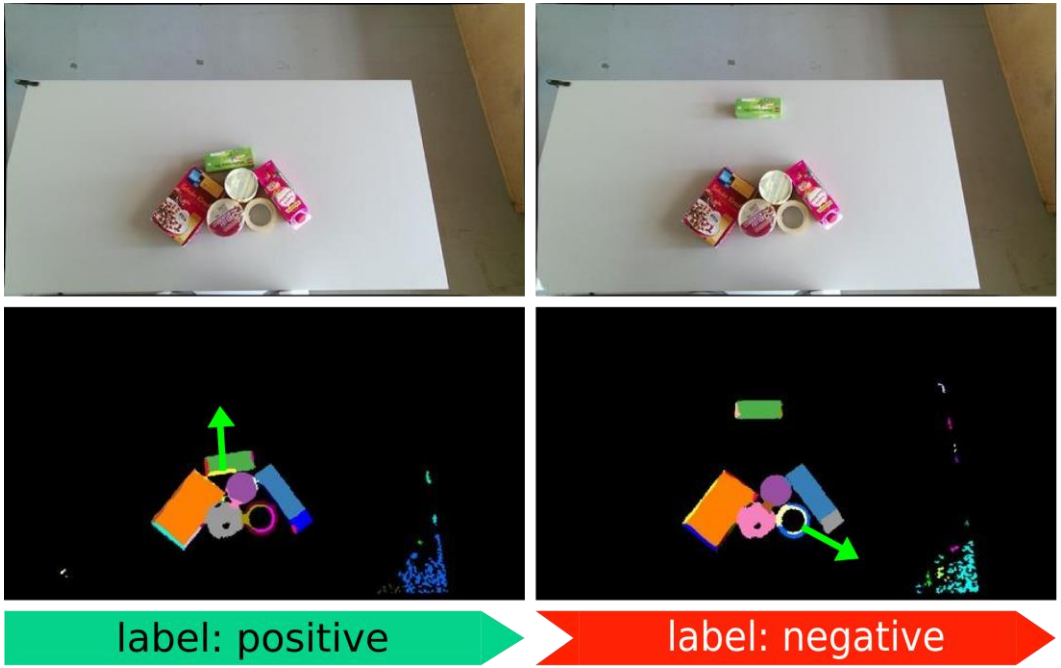


Definitions

- Neural network $F(\mathbf{o}, \mathbf{a}; \theta)$ with parameters θ
- Input is an over-segmented image $\mathbf{o}$ and a push proposal action $\mathbf{a} = (\mathbf{c}, \alpha)$
- The push proposal consists of a start position pixel $\mathbf{c} = (x, y)$ and a push angle α both defined in the image plane

Supervised Learning

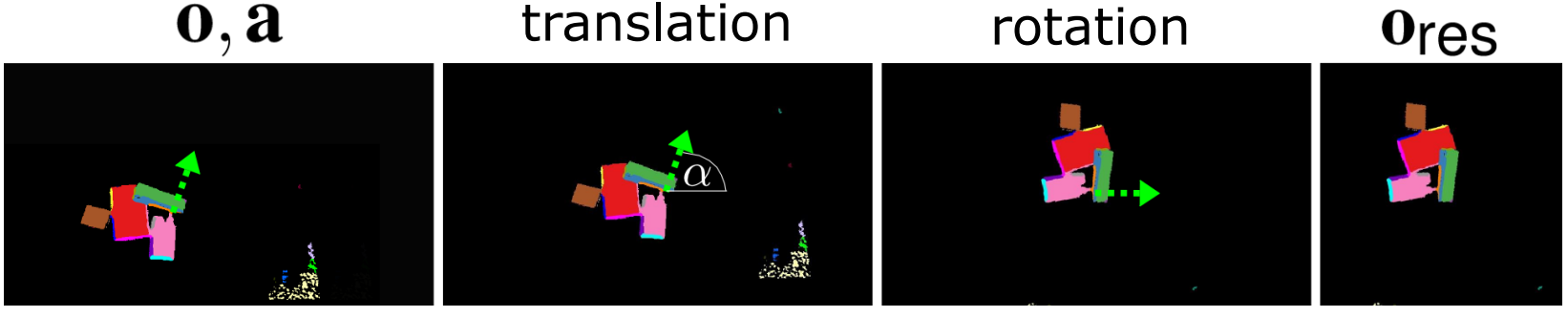
Training data is labeled by an expert user who gives a binary label for successful or unsuccessful push action



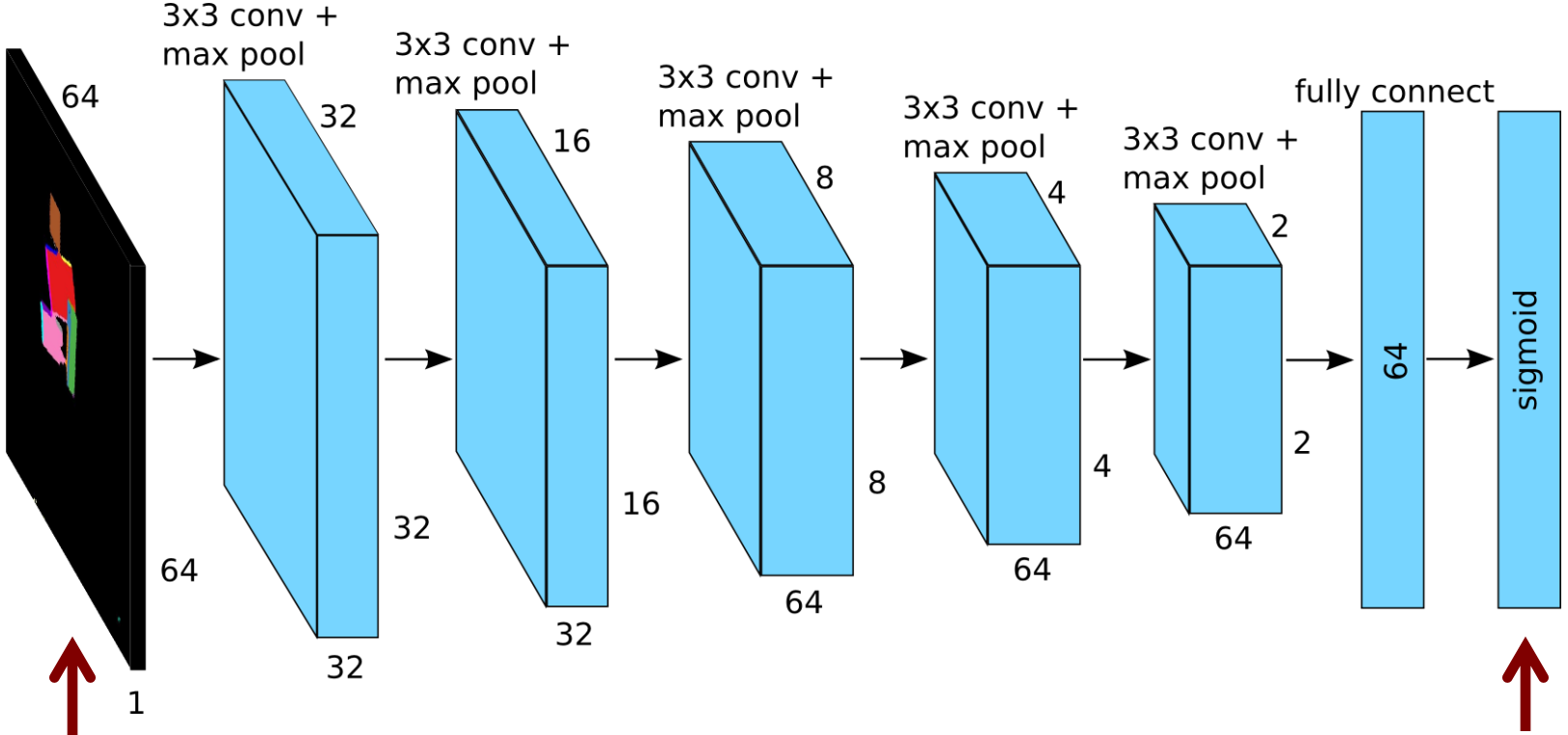
Iterative Training

How to Fuse Image and Push Proposal Action

- Key idea: only need to capture local context between objects, not global
- Fuse image $\mathbf{o}$ and push proposal action $\mathbf{a}$ using rigid image transformations
- Result is a local push-centric image $\mathbf{o}_{\text{res}}$



Push Proposal CNN



Gets push-centric image $\mathbf{o}_{res}$ as input

Predicts probability of singulation success for one proposal

Experimental Setup

- PR2 robot with Kinect 2
- All experiments with unknown objects in cluttered initial configurations
- Increasing difficulty level 4-8 objects
- Singulation trial is successful if all objects are separated by at least 3cm

Results with 6 and 8 Objects

success

fail, two objects at top still touching

success

fail, no motion plan found objects too close to robot

Quantitative Results

- Success rate of our best network
  - 6 objects 70%, 25 trials
  - 8 objects 40%, 10 trials
- Improvement with respect to manual baseline method is 30%

Video

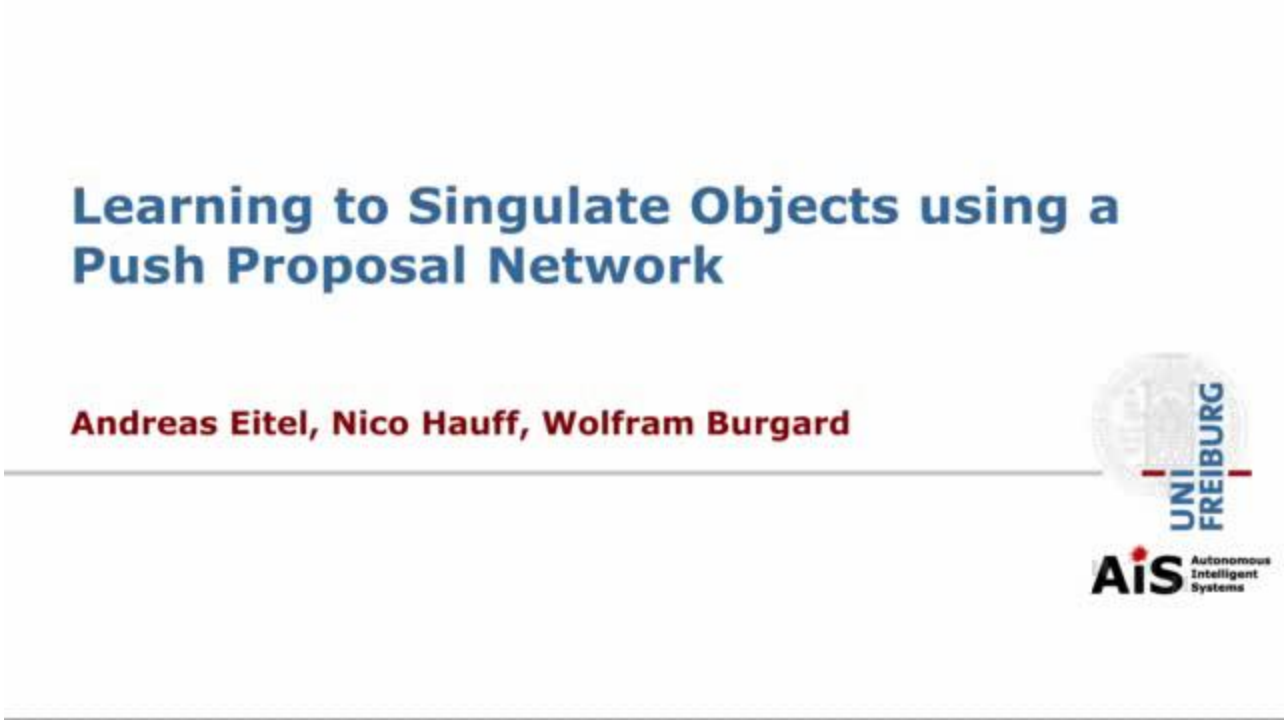
Conclusions

- Novel learning-based approach for clearing object clutter based on CNN
- Neural network generalizes well to novel objects and cluttered object configurations
- Novel method for fusing image and action representation into network
- Successful singulation experiments with up to 8 cluttered objects

Future Work

- Move from supervised to semi- and self-supervised learning
- Extension of network with multi-class output for prediction of varying push lengths

Thank you for your attention!



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http://robotpush.cs.uni-freiburg.de