Towards robust robotic manipulation through continuous object and arm tracking

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Research Question

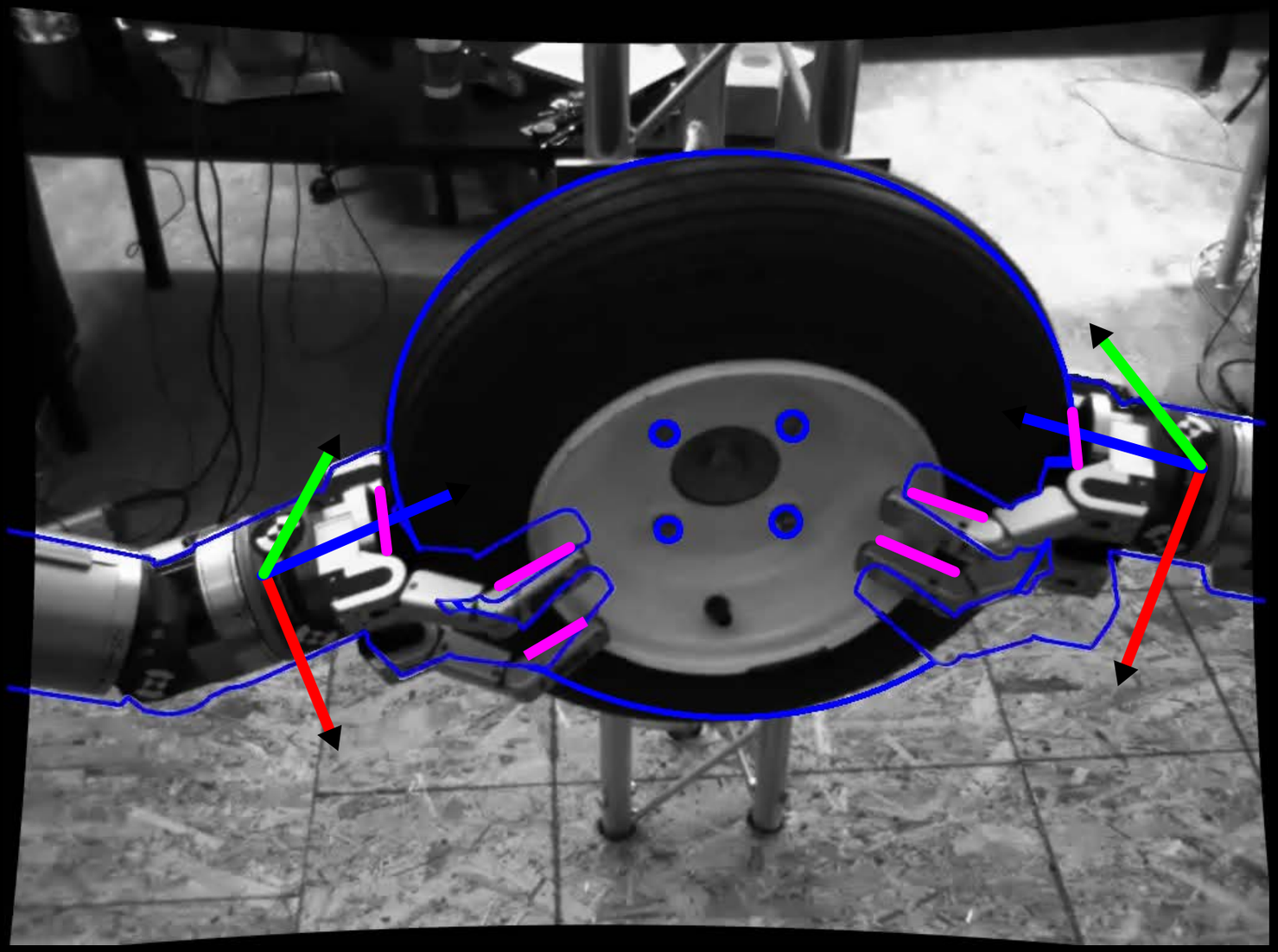
- How can we make a robot robustly perform dexterous grasping and manipulation of objects despite
  - uncertainty in sensing and actuation
  - complex and dynamic environments

How do we get there?

Get vision into the low-level control loop

- Gain robustness against dynamic scene changes and uncertainties through
  - real-time
  - processing of task-relevant features
  - cross-checking of beliefs in multiple modalities ⟶ Force Control
  - allowing viewpoint changes during execution
- Make extensive pre-planning obsolete

One example task: Mounting a wheel on a hub



Blue - Object and Arm Outline

Pink - Tactile Sensor Readings

Frames - Force Torque Readings

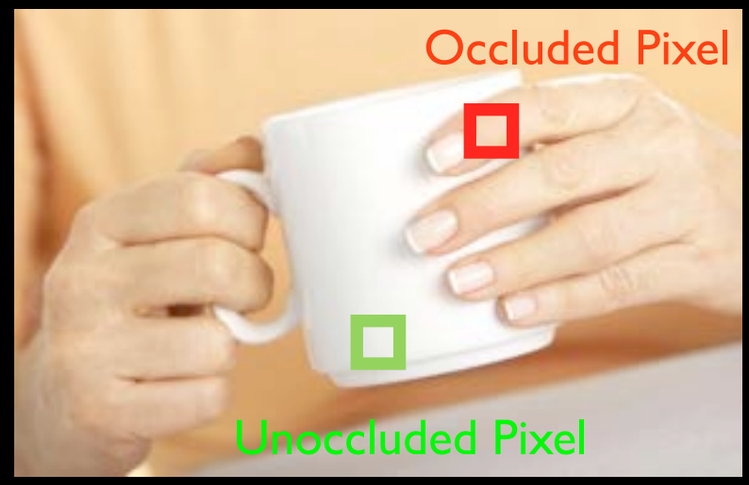
Object Tracking

- Challenge: Occlusion due to Manipulation

Manuel Wühtrich et al. “Probabilistic Object Tracking using a Depth Camera” IROS 2013

Object Tracking

- Remedy: Model occlusion per pixel
- Add binary variable to state vector
- Factorize state for tractability
- Rao-blackwellized Particle Filter
  - One particle per object pose hypothesis
  - One occlusion map per object pose hypothesis



Manuel Wühtrich et al. “Probabilistic Object Tracking using a Depth Camera” IROS 2013

Probabilistic Object Tracking using a Depth Camera

Manuel Wüthrich[+], Peter Pastor[*], Mrinal Kalakrishnan[*],
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http://youtu.be/MBgggaJq1sY

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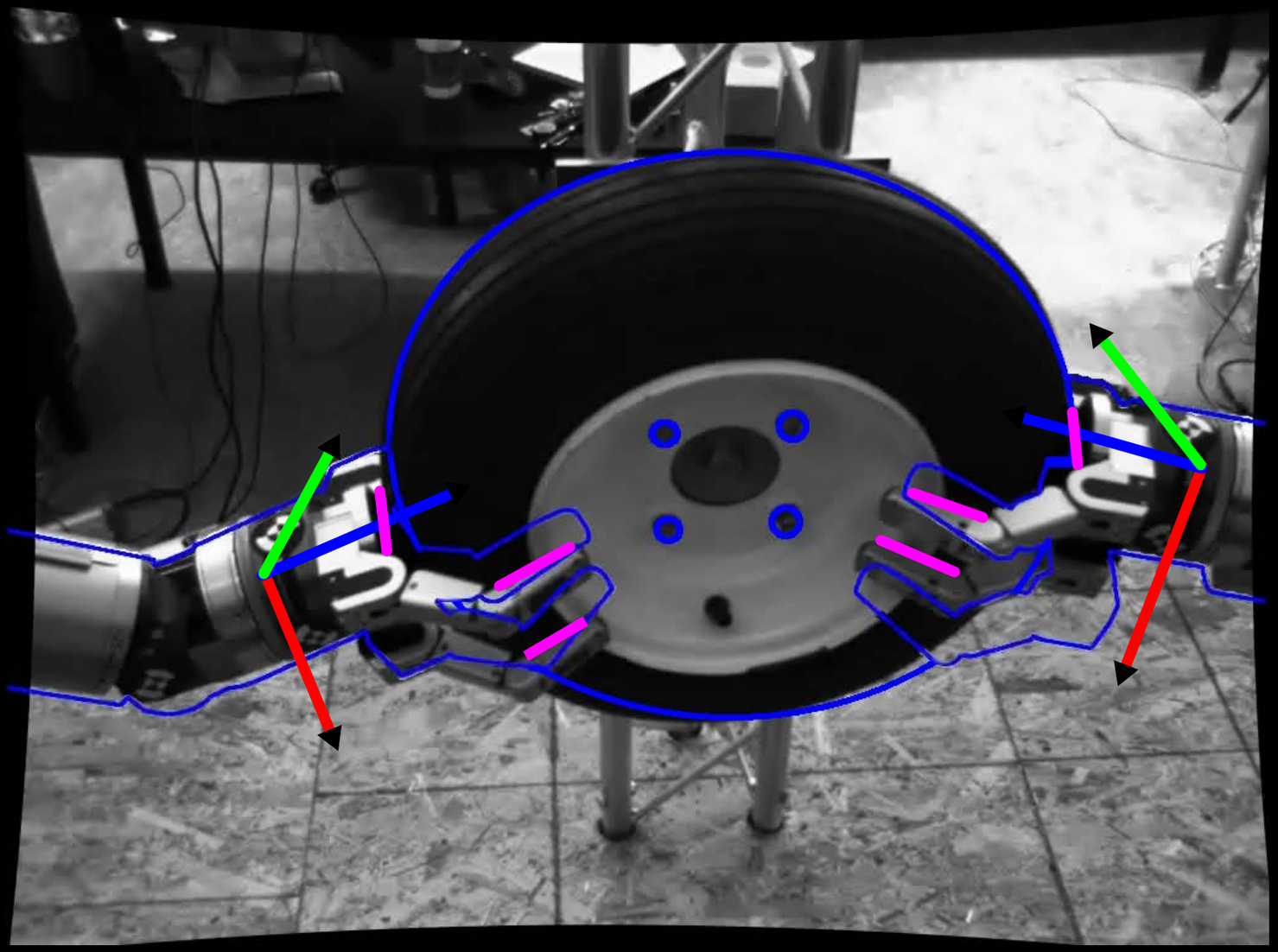

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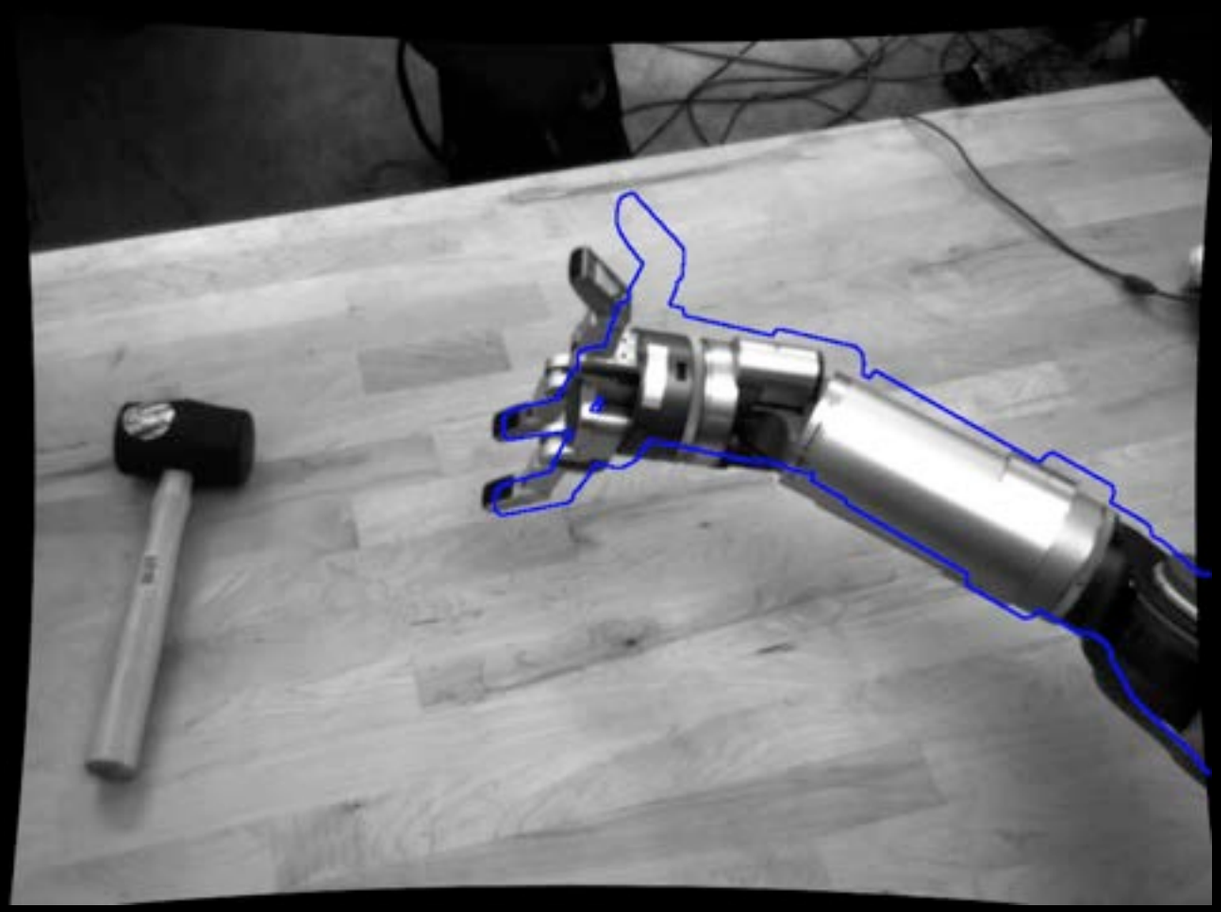
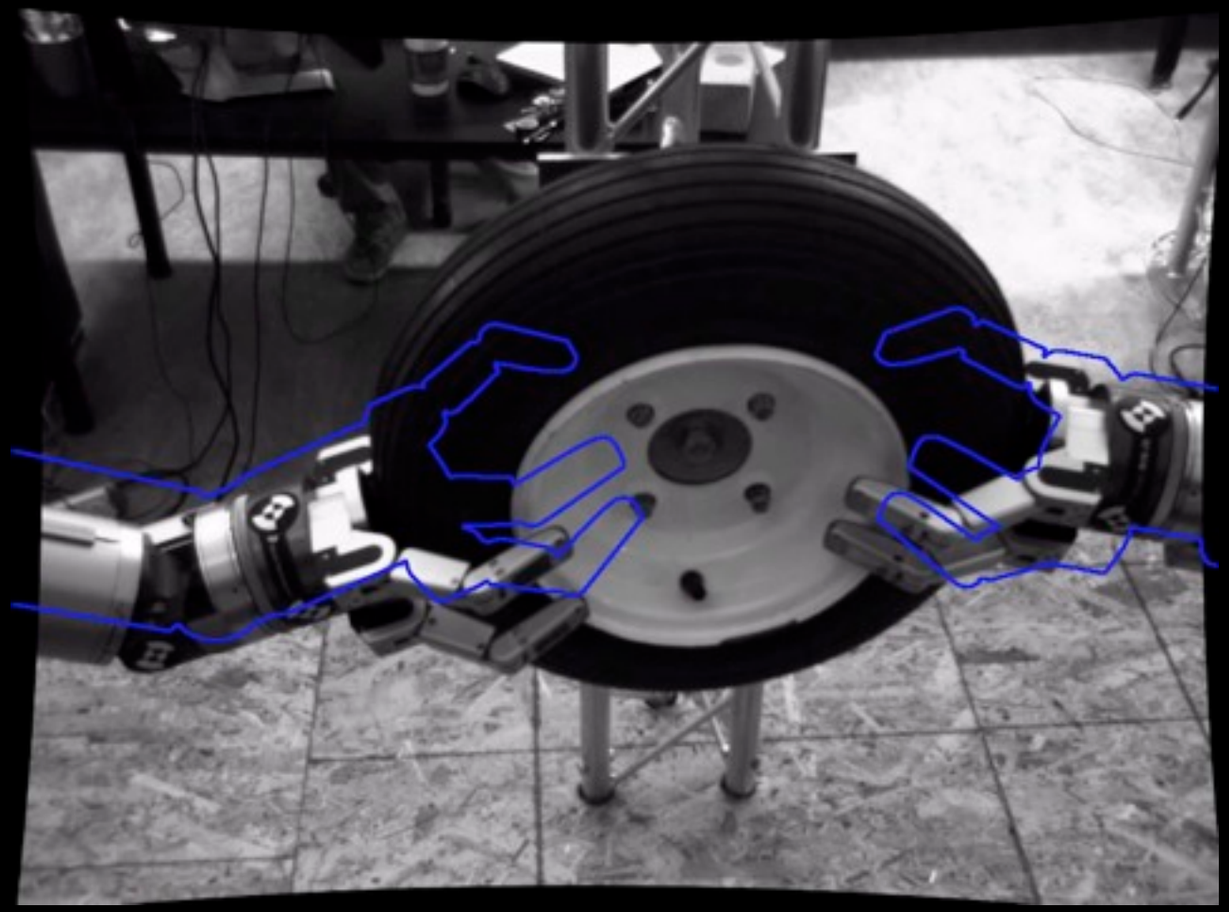
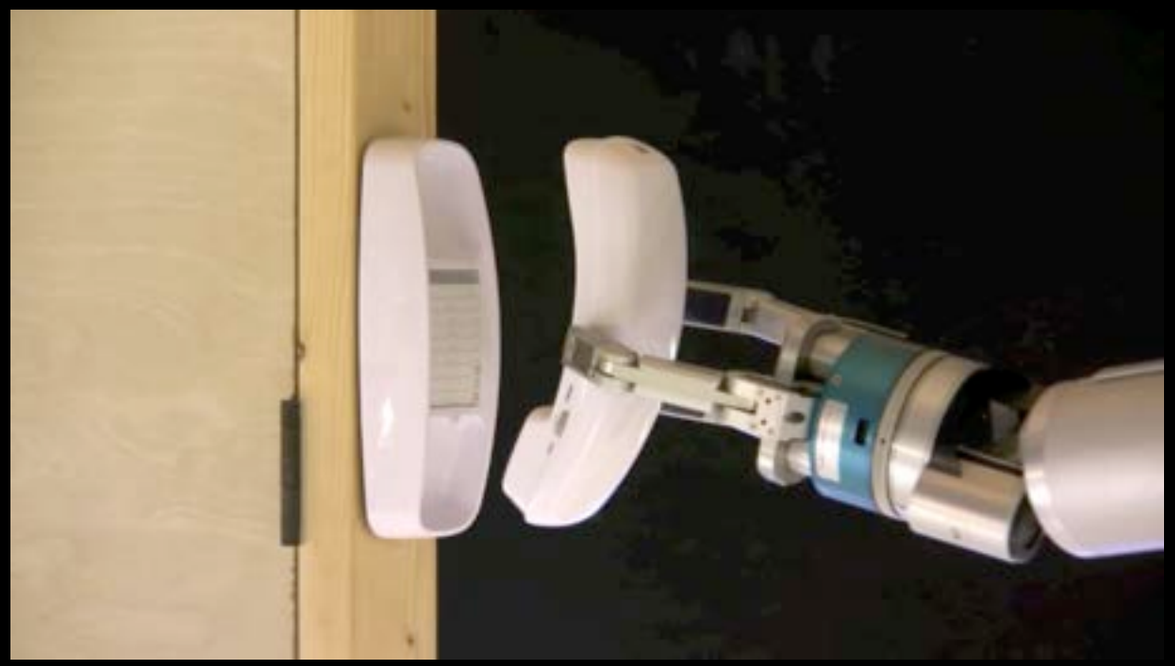




Error between the real arm pose and the arm pose according to the joint encoders



Robot Arm Tracking

- Goal: Compute an estimate $\hat{\theta}$ of the true joint angles θ

Bohg et al. “Robot Arm Pose Estimation through Pixel-Wise Part Classification” ICRA 2014

Robot Arm Tracking

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- Common Approach:
  - Minimize distance between robot arm surface and some features ⟶ Correspondence Problem

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Robot Arm Tracking

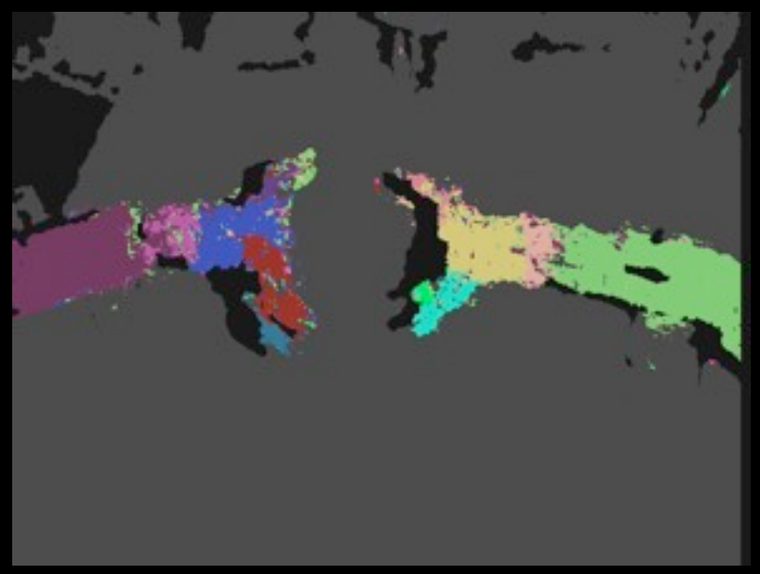
- Goal: Compute an estimate $\hat{\theta}$ of the true joint angles θ
- Common Approach:
  - Minimize distance between robot arm surface and some features ⟶ Correspondence Problem
- Our Approach:
  - Estimate 3D position of joint axes directly + inverse kinematics

Bohg et al. “Robot Arm Pose Estimation through Pixel-Wise Part Classification” ICRA 2014

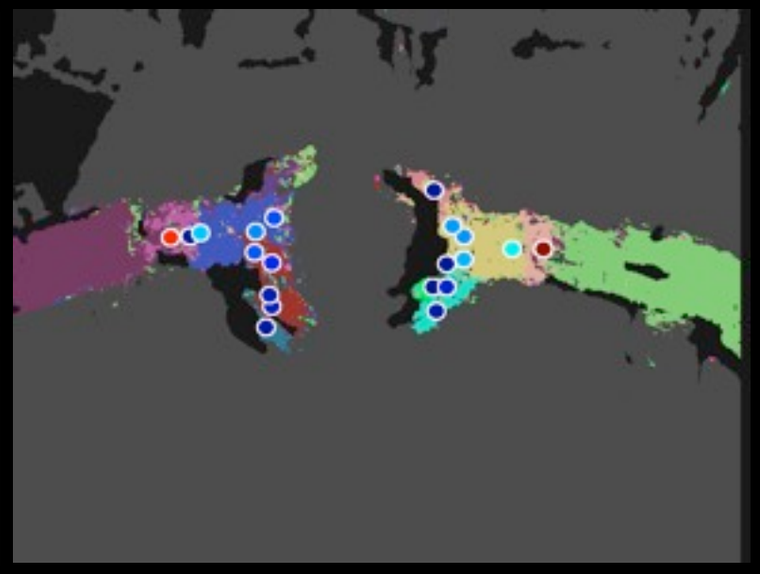
Robot Arm Tracking

- Pixel-wise Part Classification
- Voting-based Joint Axis Position Estimates

Real Depth Data



Classified Pixels

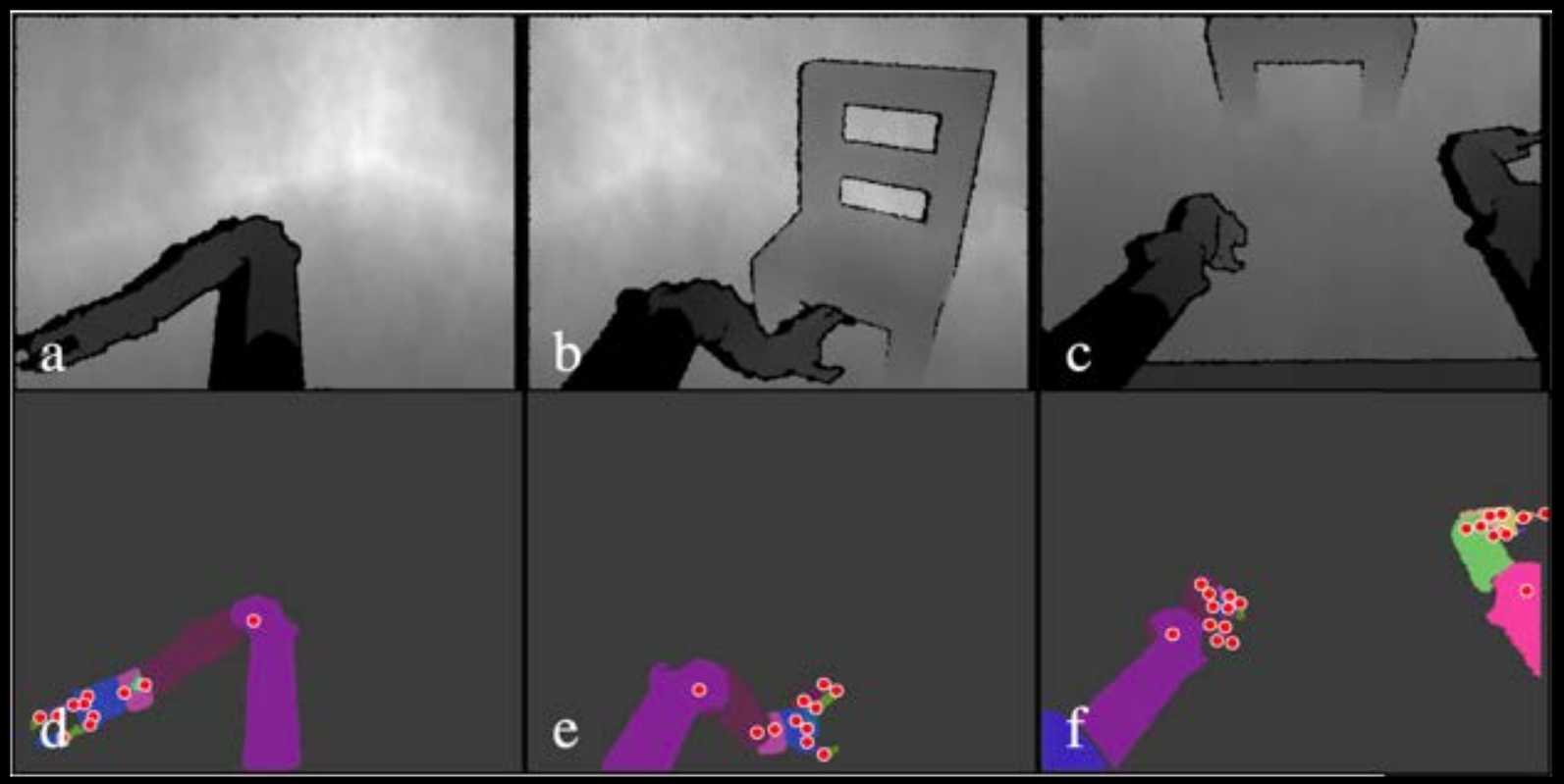


Joint Axes Position Estimates

Bohg et al. “Robot Arm Pose Estimation through Pixel-Wise Part Classification” ICRA 2014

Pixel-wise Part Classification

- Synthetic training data for supervised training
- Random Decision Forest Classifier



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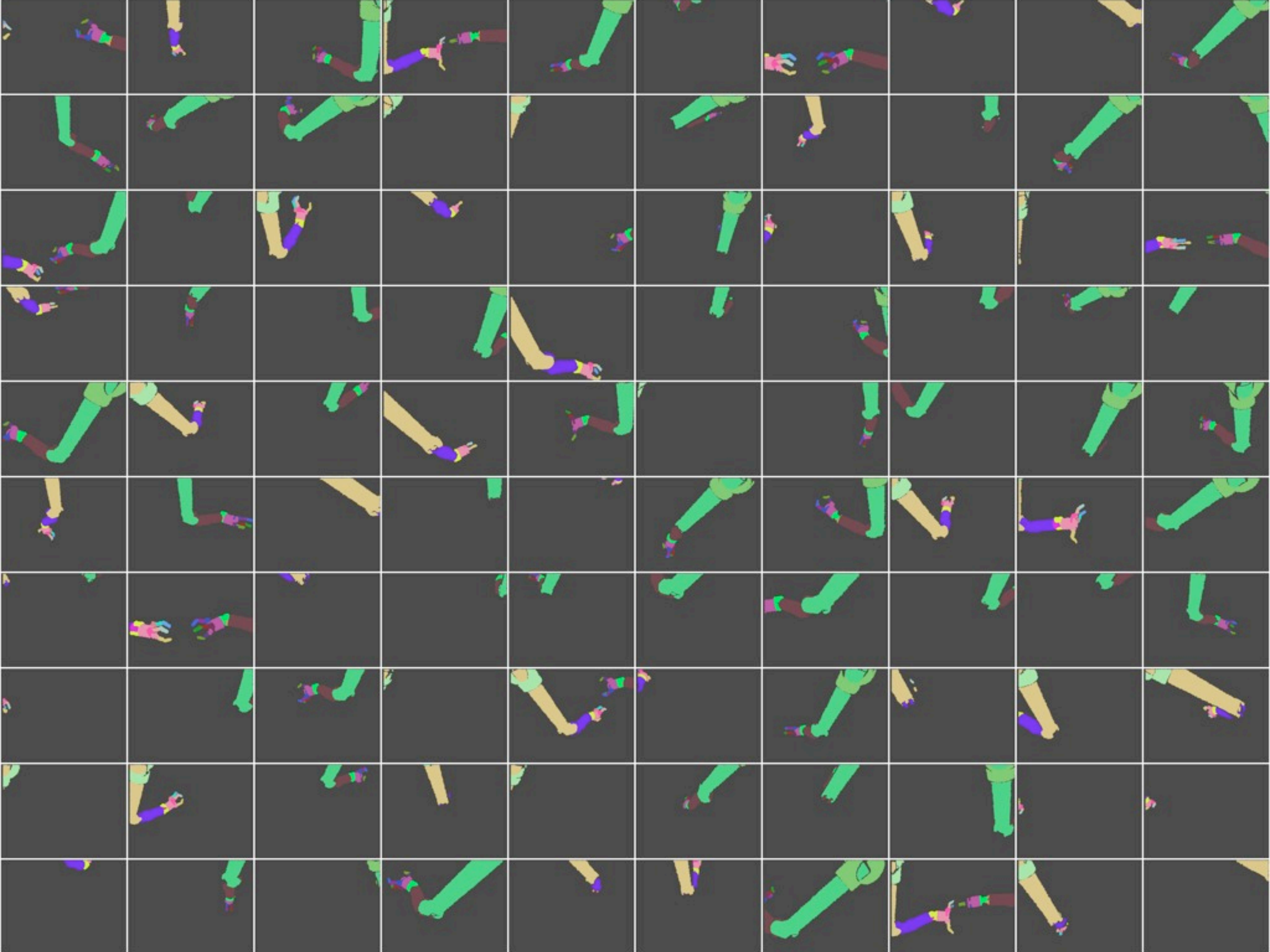
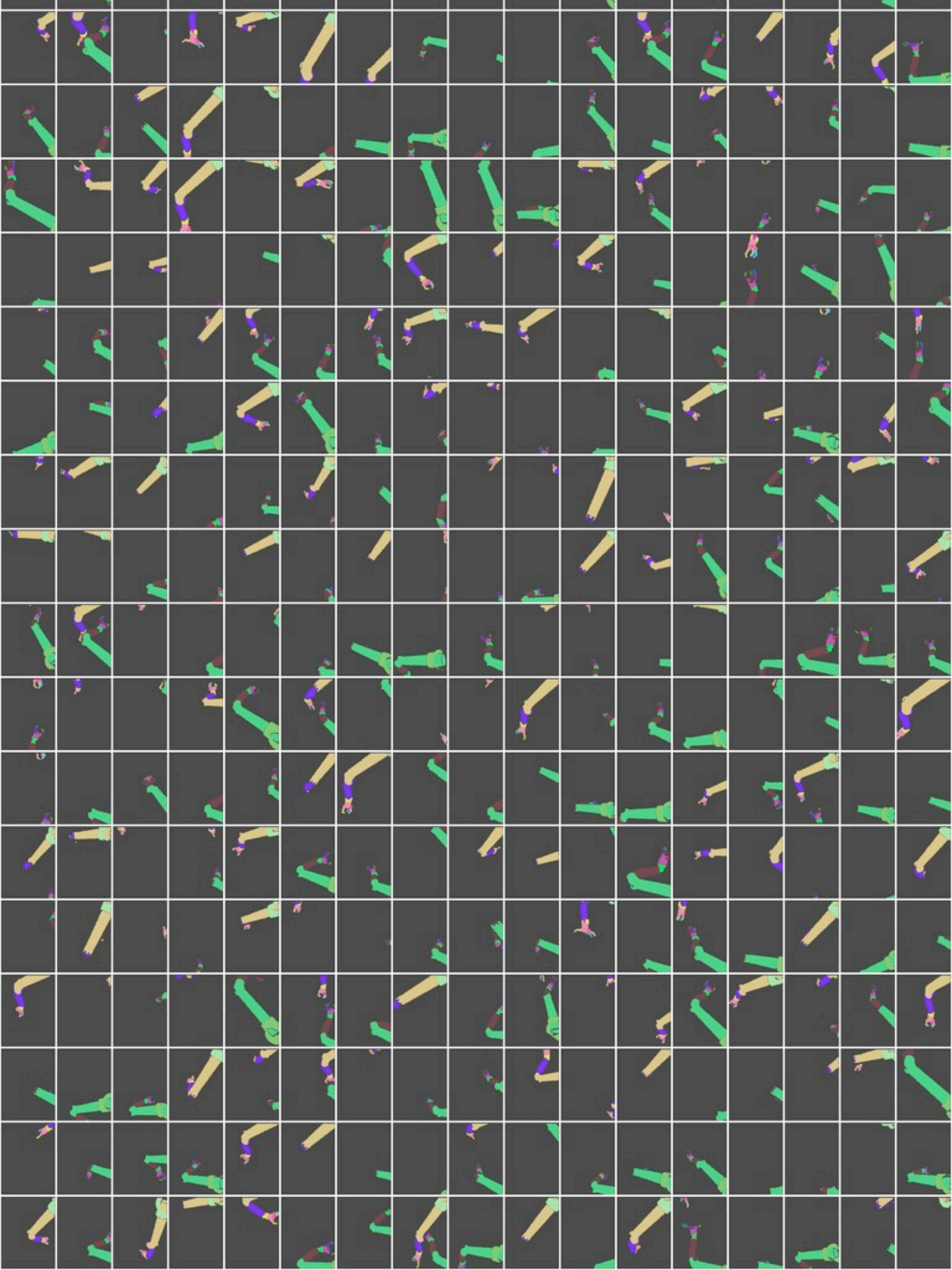
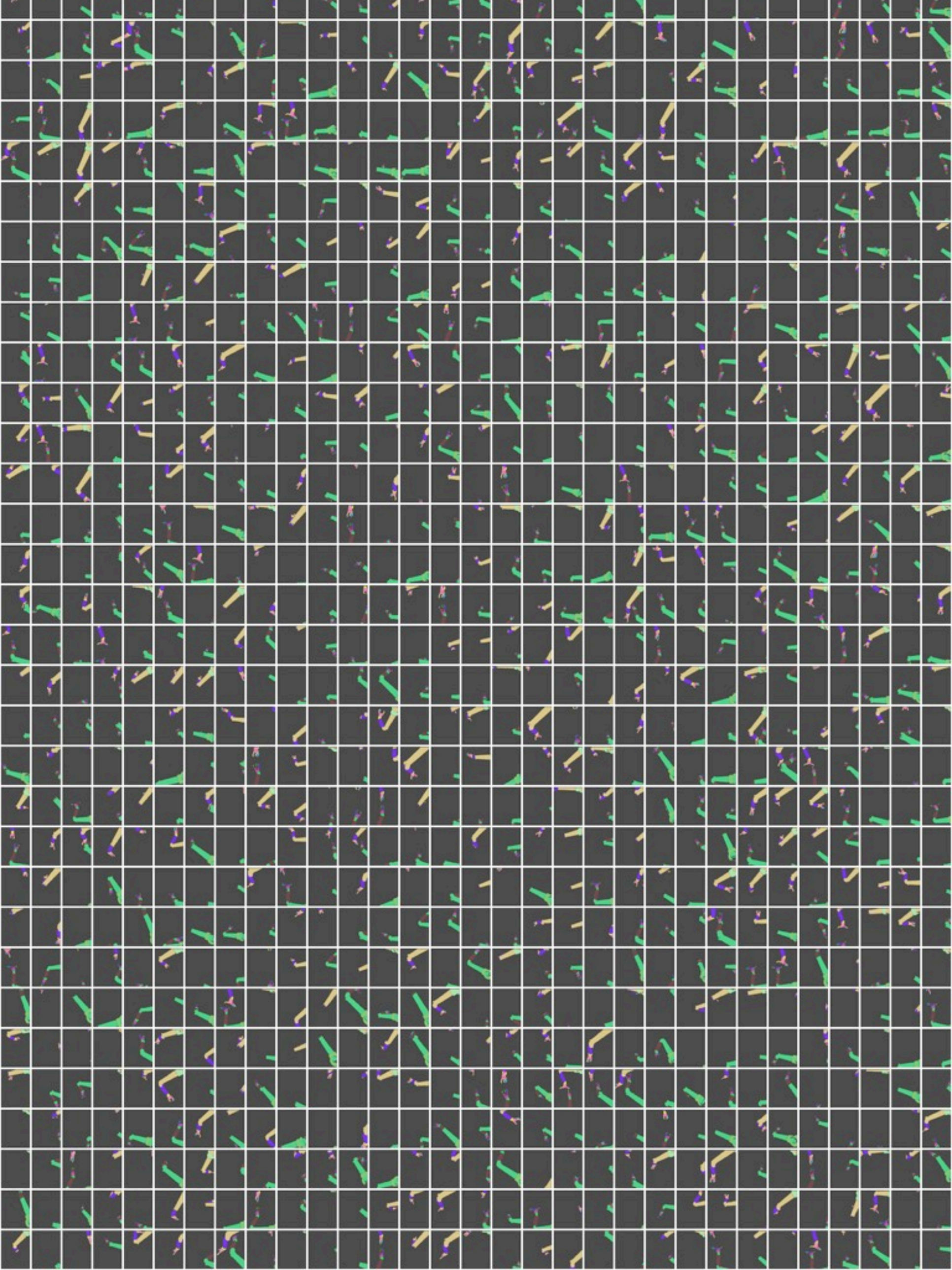
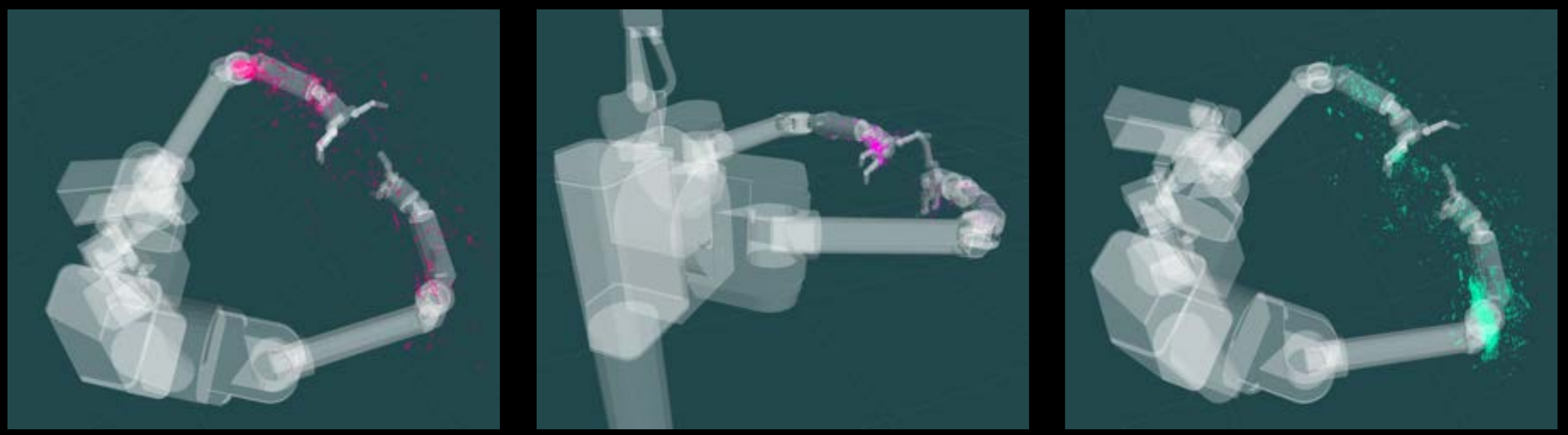






Voting for Joint Positions

- Retro-fitting of forest leaf nodes to offset between 3D point and joint position
- Voting per pixel for each joint



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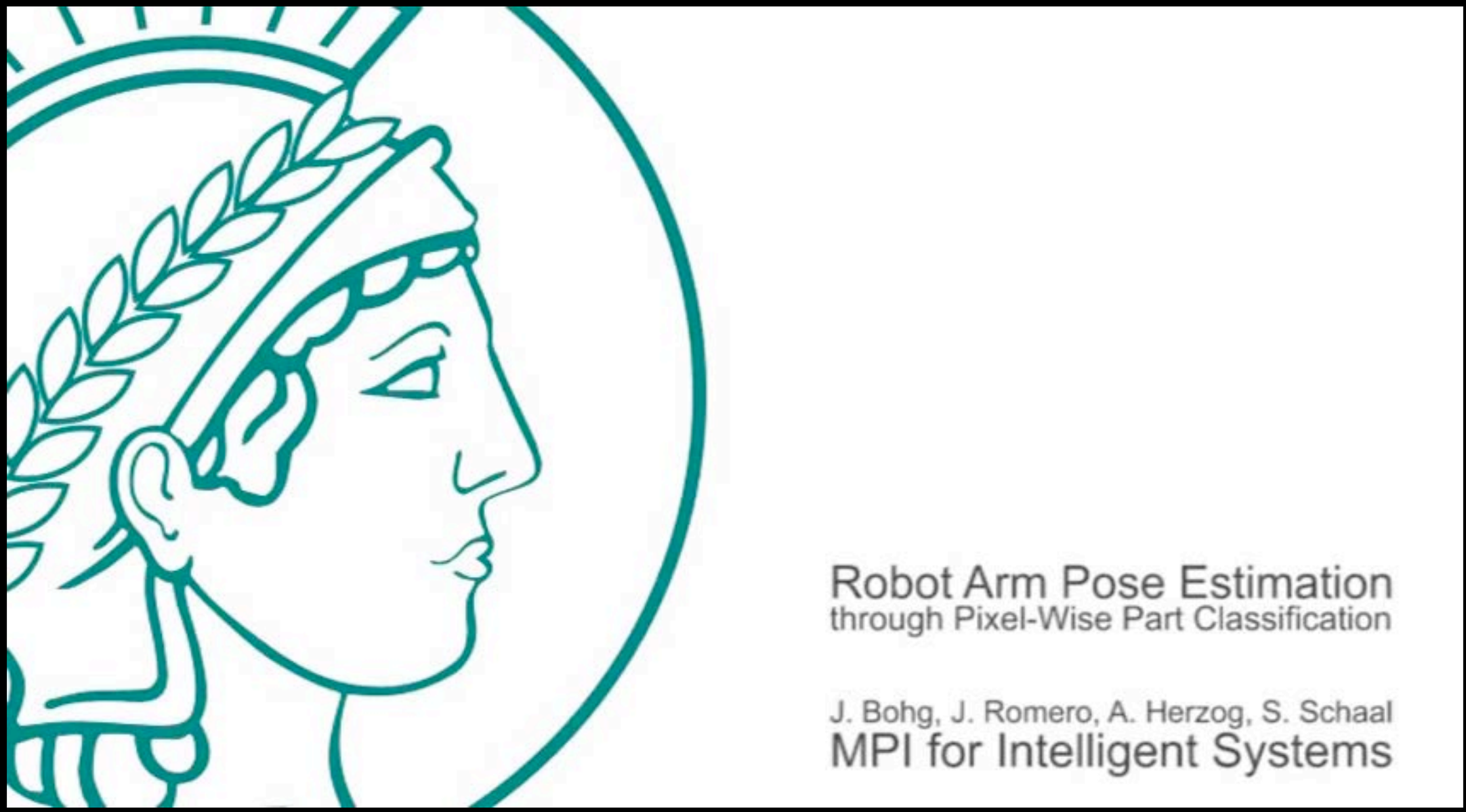

http://youtu.be/xXkV6UcMCqw

Conclusions

- New ideas for object and robot arm tracking
- Future Work:
  - Make them track simultaneously and include multi-modal features
  - Object tracking already real-time, arm tracking to become real-time soon
  - Object tracking already integrated in low-level controllers, arm tracking will soon be integrated