

# Sketching Geometry and Physics Informed Inference for Mobile Robot Manipulation in Cluttered Scenes

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ICE  
Interactive Computing Experiences  
Research Cluster of Excellence



Can we make your  
**world programmable ?**



Use  $x$  robot

to perform task  $y$

in  $z$  environment



# Learning from Demonstration

# (Kinesthetic) Learning from Demonstration



[Ijspeert et al. 2002]



[Jenkins, Mataric 2004]



[Cakmak et al. 2015]



[Abbeel et al. 2007]



[Niekum et al. 2013]



# (Kinesthetic) Learning from Demonstration

Generalization limited to:

- Proprioceptive perception
- Configuration space demonstrations
- Procedural programming
- Replay robot behavior

[Ijspeert et al. 2002] [Abbeel et al. 2007]



[Cakmak et al. 2015]



[Niekum et al. 2013]

# Kinesthetic LfD

~~Proprioceptive perception~~

~~Configuration space  
demonstrations~~

~~Procedural programming~~

~~Replay robot behavior~~

# Next Gen LfD

Scene perception

Workspace  
demonstrations

Declarative programming

Goal-directed robot behavior

# Next Gen LfD

## **Semantic Mapping**

[Kuipers 2000]  
[Rusu et al. 2008]  
[Xiang et al. 2017]

Workspace  
demonstrations

## **Planning-based Programming**

[Fikes and Nilsson 1971]  
[Laird et al. 1987]  
[Kaelbling et al. 1998]

Goal-directed Robot behavior

# Semantic Robot Programming

# Semantic Robot Programming

[Zeng, Jenkins, et al. ICRA 2018]

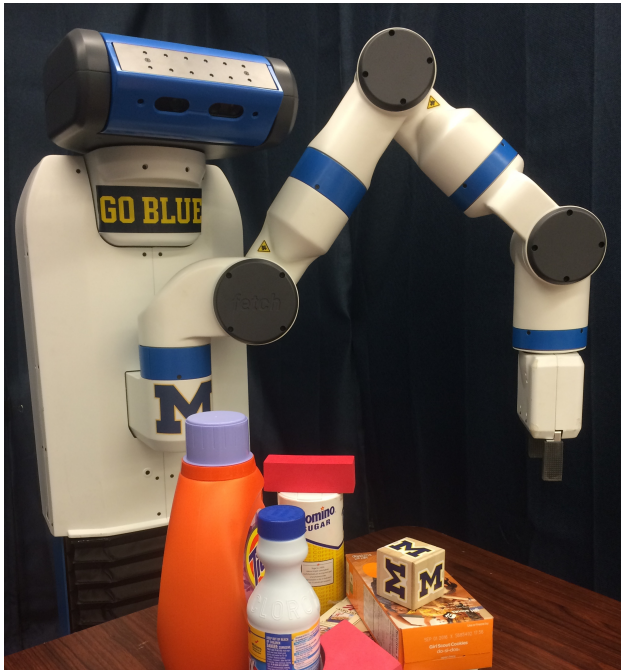


Enable natural user programming of robots  
by demonstration of intended goal scenes



# Scene Estimation in Clutter

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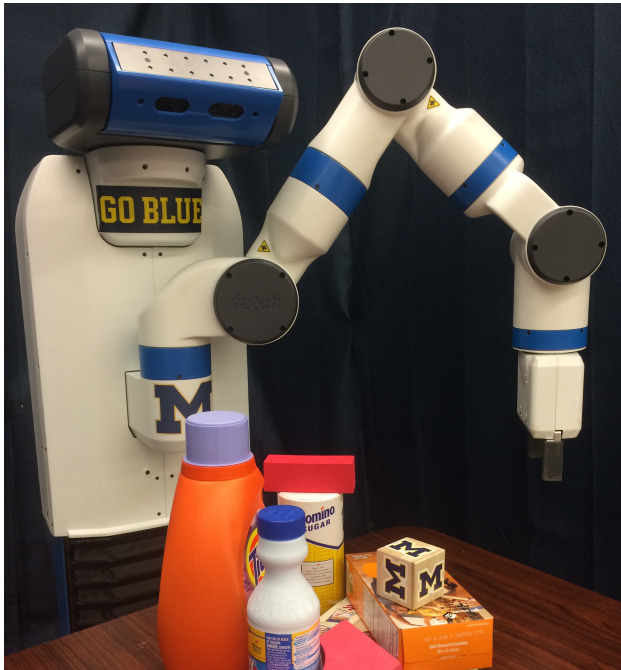
**Assume:**  
object geometries

**Infer: scene graph**  
object poses  
inter-object relations

**Address uncertainty due to physical interaction:**  
occlusion, stacking  
contacts, multiple supports



# Scene Estimation in Clutter



**GemSketch:**  
object geometries  
*BY SKETCHING*

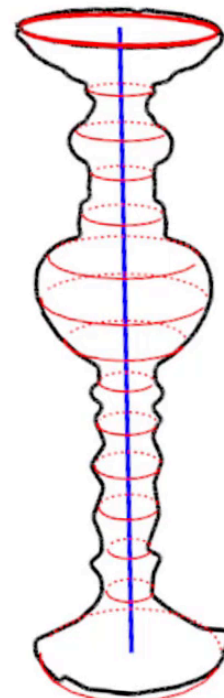
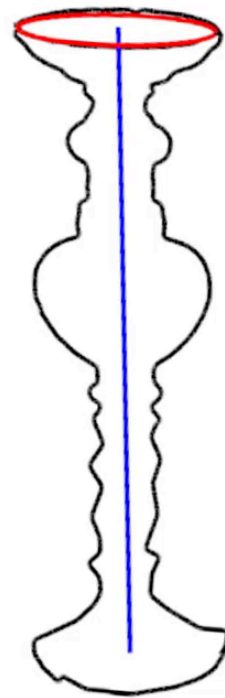
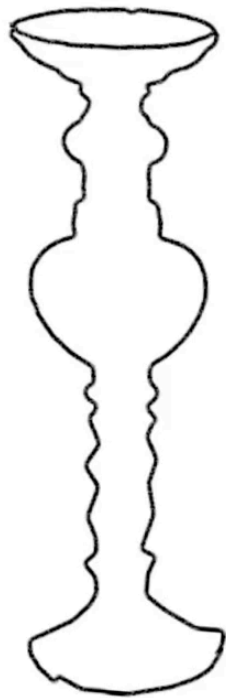
**PMPNBP:**  
object poses  
inter-object relations

*BY NONPARAMETRIC BELIEF PROPAGATION*



# GemSketch

[Maghouni, LaViola, Desingh, Jenkins ICRA 2018]





# GemSketch

[Maghoumi, LaViola, Desingh, Jenkins ICRA 2018]

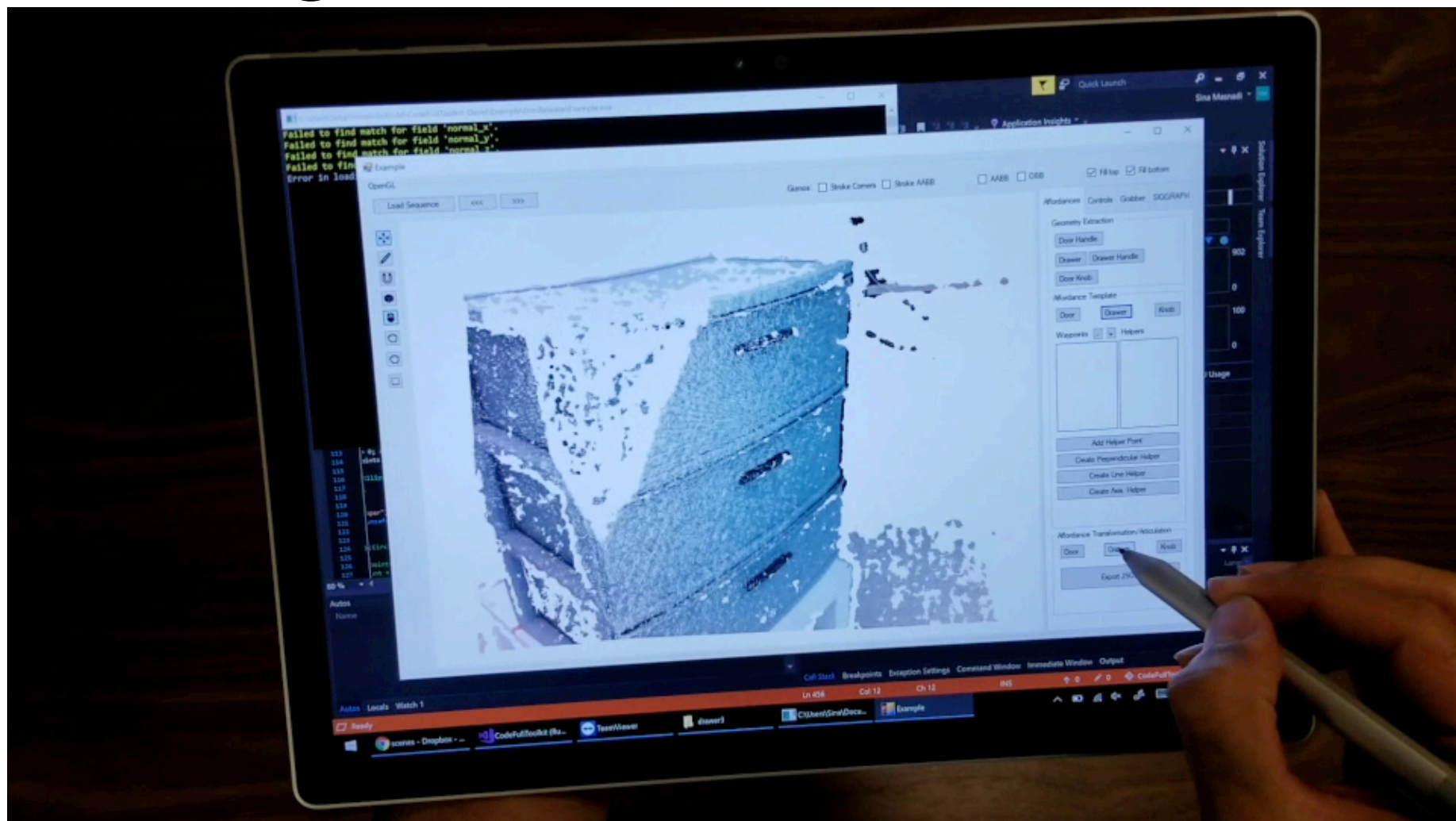
<https://youtu.be/z5oqfEmNIJE>

4x Speed



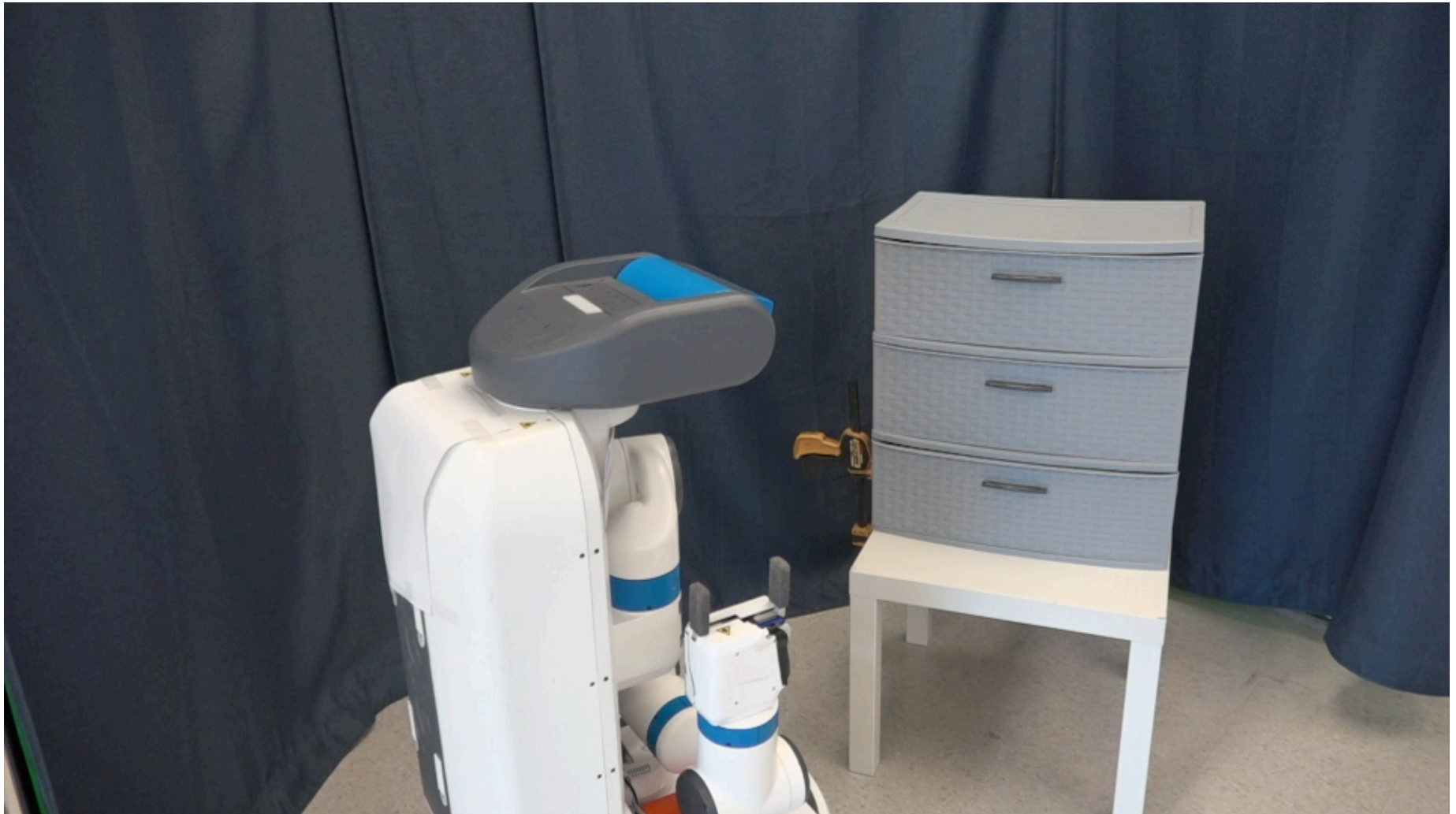
**Modeling objects in the presence of clutter**

# Sketching Affordances

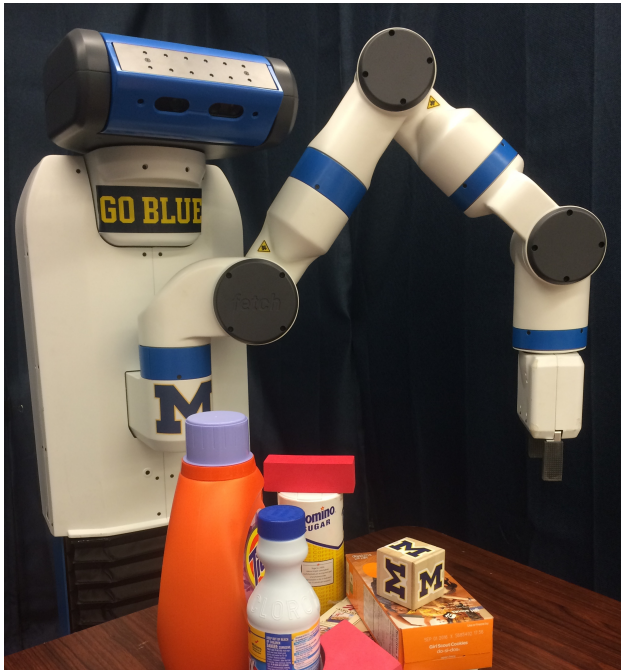




# Sketching Affordances



# Scene Estimation in Clutter



**GemSketch:**  
object geometries  
*BY SKETCHING*

**PMPNBP:**  
object poses  
inter-object relations

*BY NONPARAMETRIC BELIEF PROPAGATION*





# PMPNBP

Pull Message Products for Nonparametric Belief Propagation  
[Desingh, Jenkins arXiv 2018]



Articulation



Occlusion

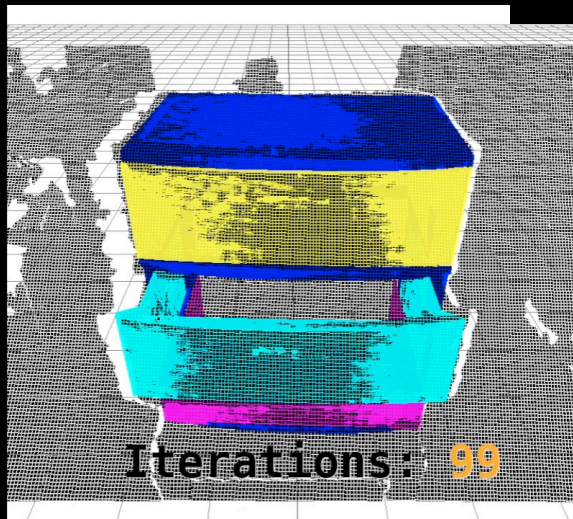


Self-filter

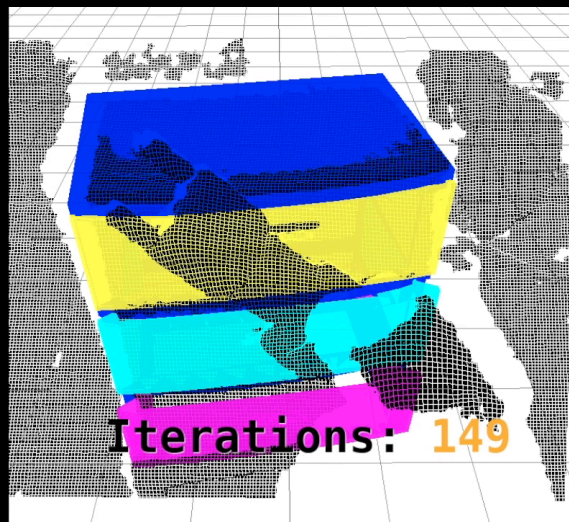
# PMPNBP

Pull Message Products for Nonparametric Belief Propagation  
[Desingh, Jenkins arXiv 2018]

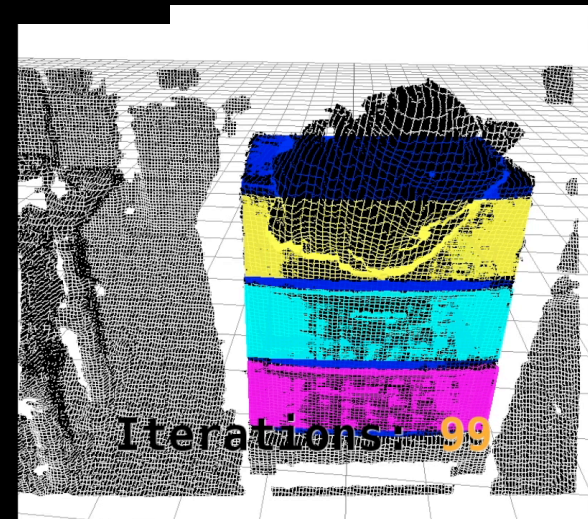
Articulation



Iterations: 149



Self-filter

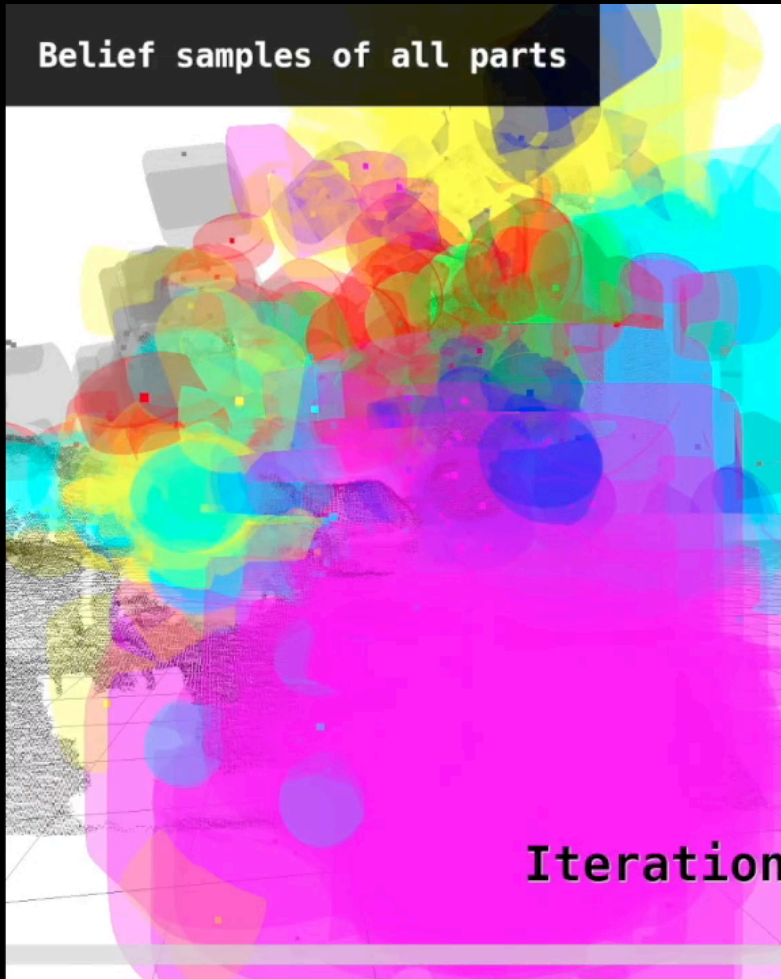


Occlusion

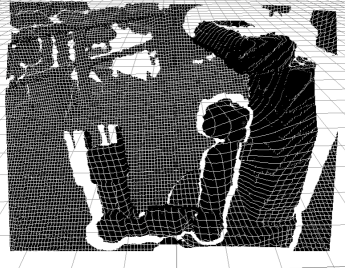
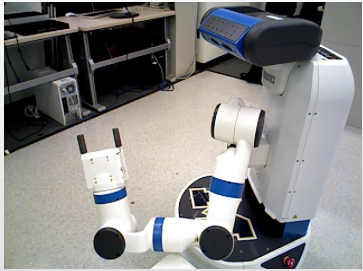
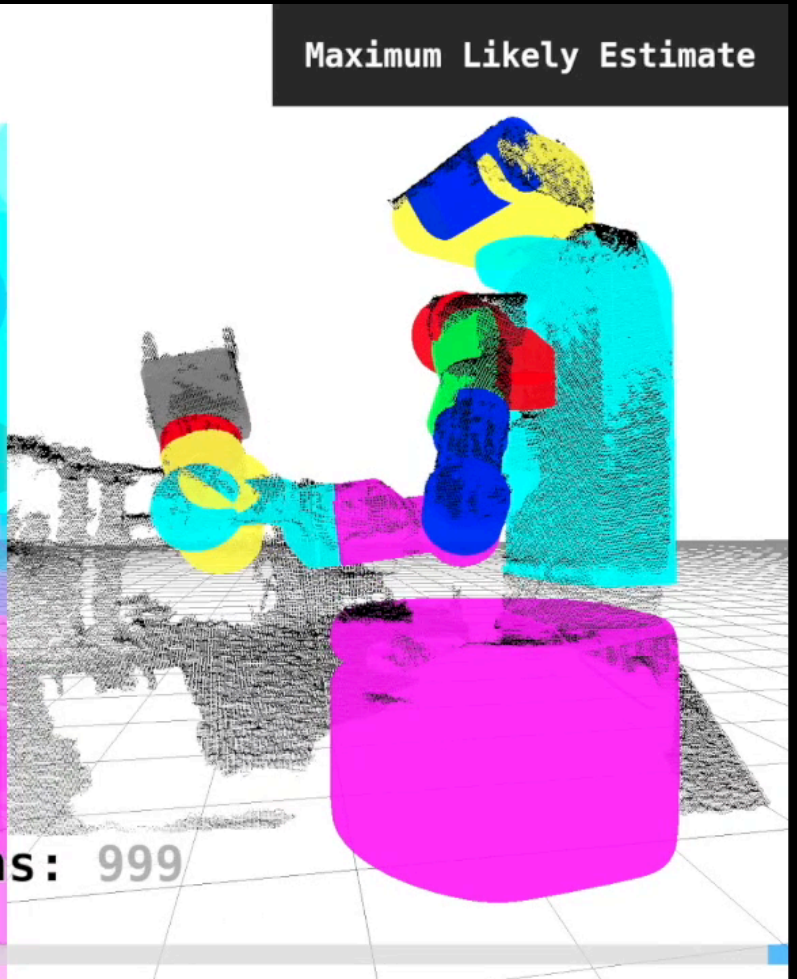


# Efficient high-dimensional inference

Belief samples of all parts



Maximum Likely Estimate



Observation

# Project Summary

Goal-directed dexterous manipulation in cluttered environments for scalability to greater numbers of objects with arbitrary geometries

## **Semantic Robot Programming:**

declarative robot programming by demonstration

## **GemSketch:**

object geometry acquisition in clutter by user sketching

## **PMPNBP:**

scene estimation through efficient high-dimensional inference

Thank you.