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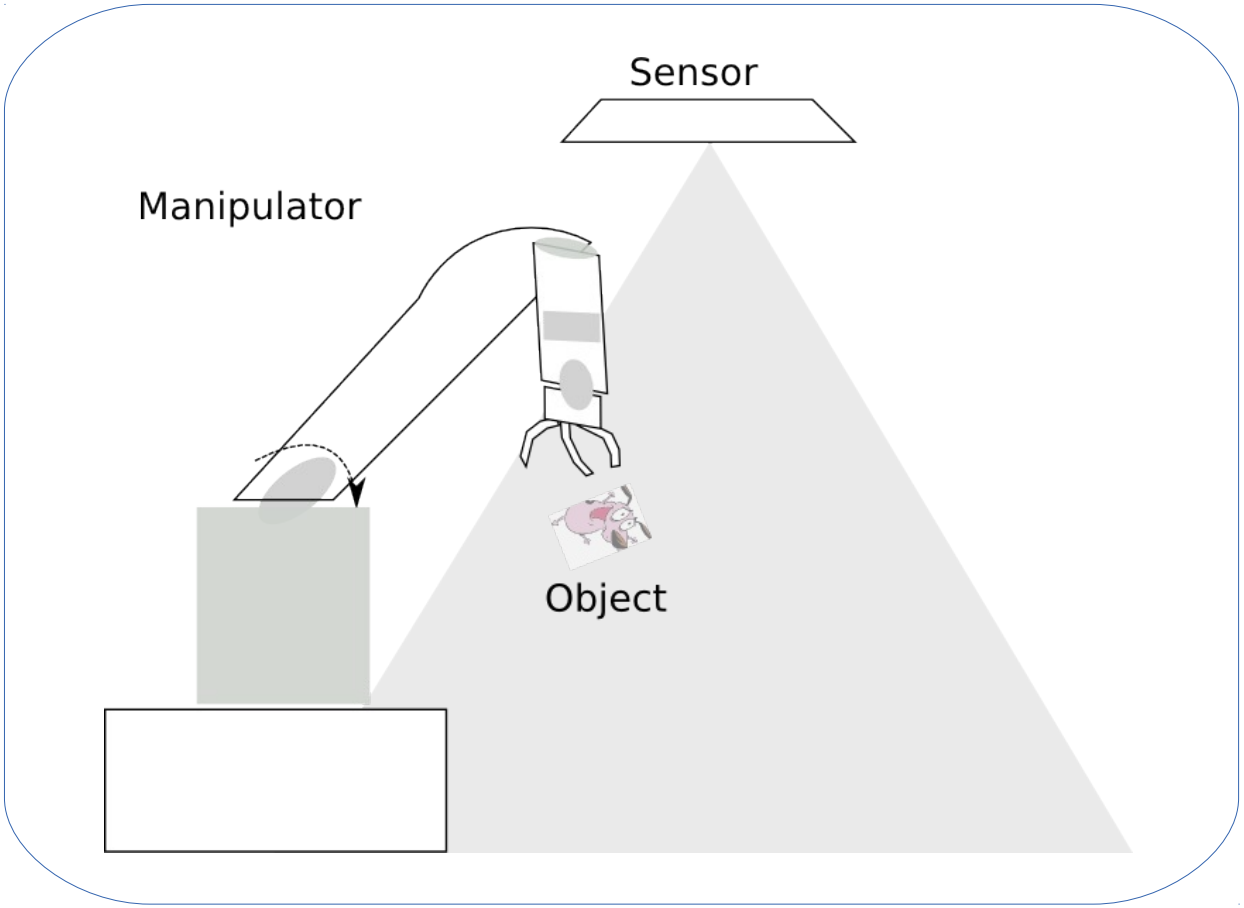
Realtime Tracking and Grasping of a Moving Object from Range Video

Farzad Husain, Adrià Colomé, Babette Dellen,
Guillem Alenyà and Carme Torras

Introduction

- We present an automated tracking and grasping system



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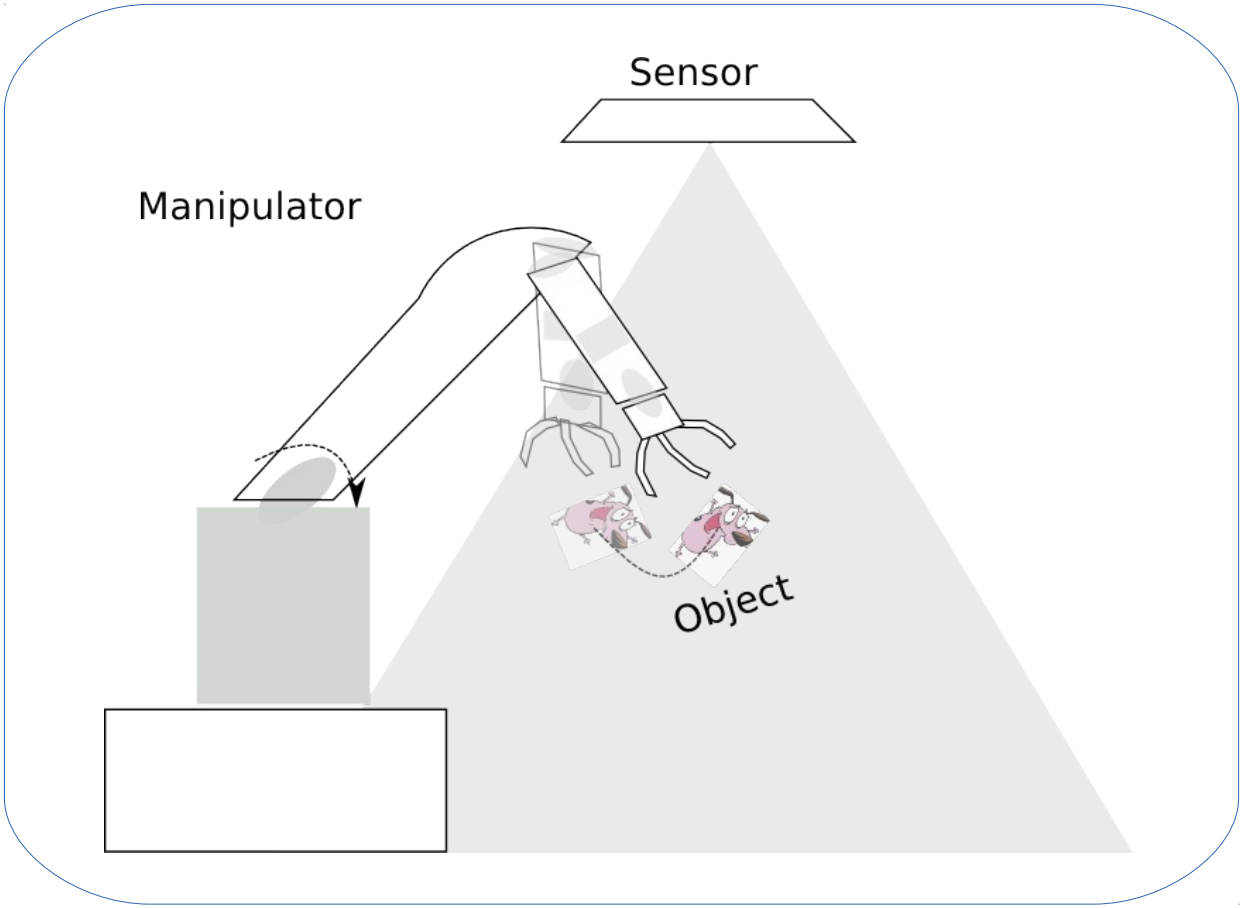

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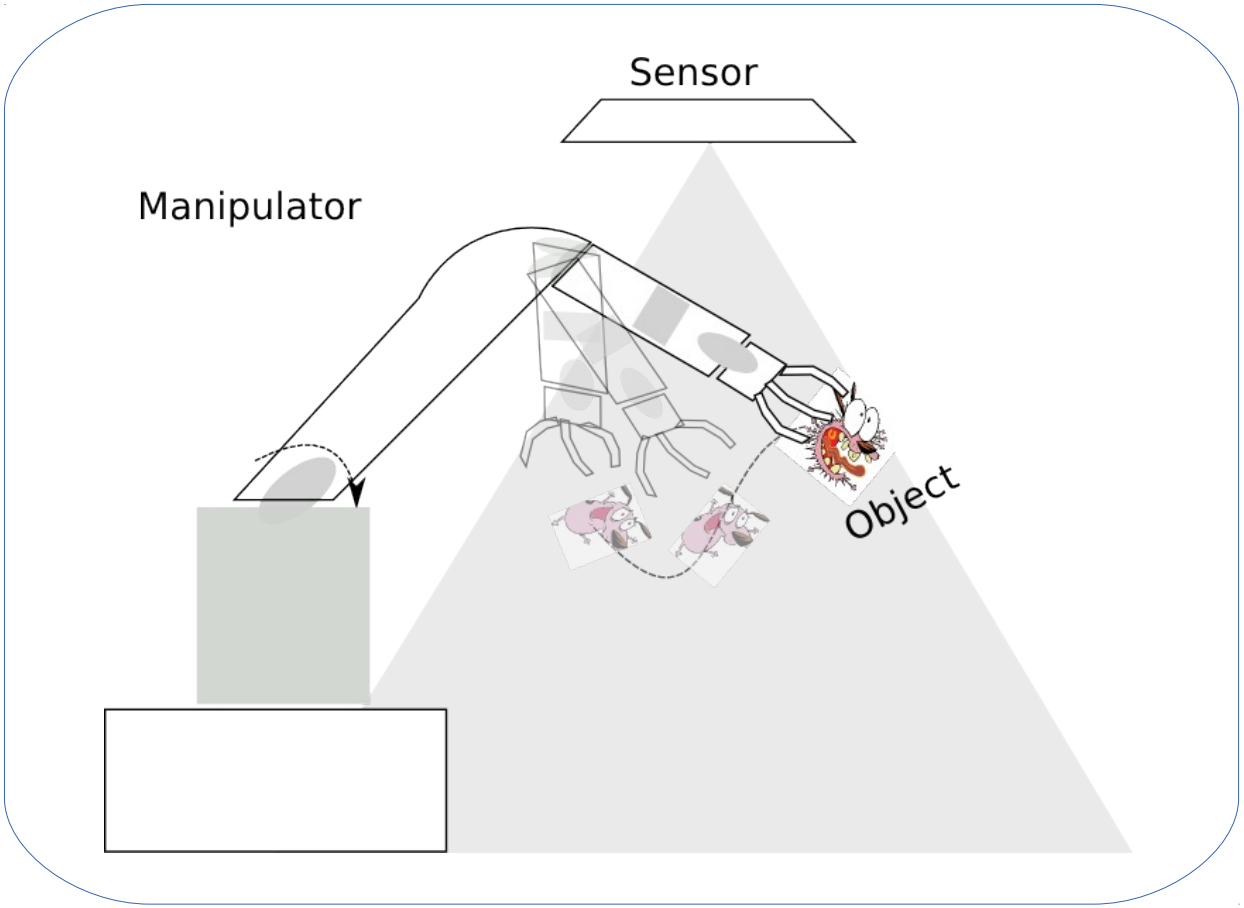
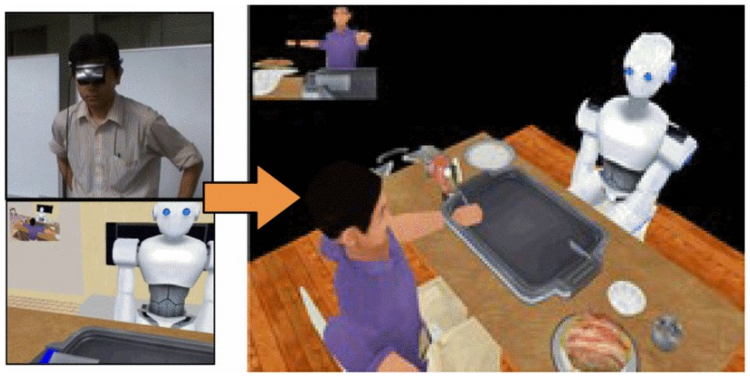
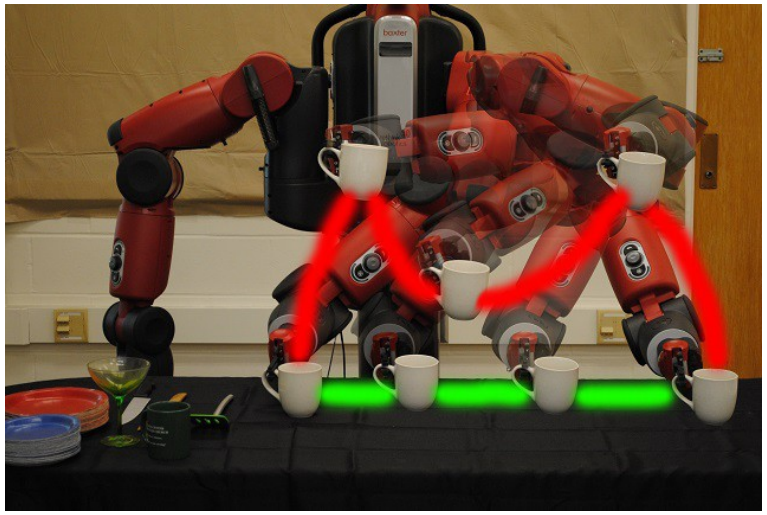


Motivation

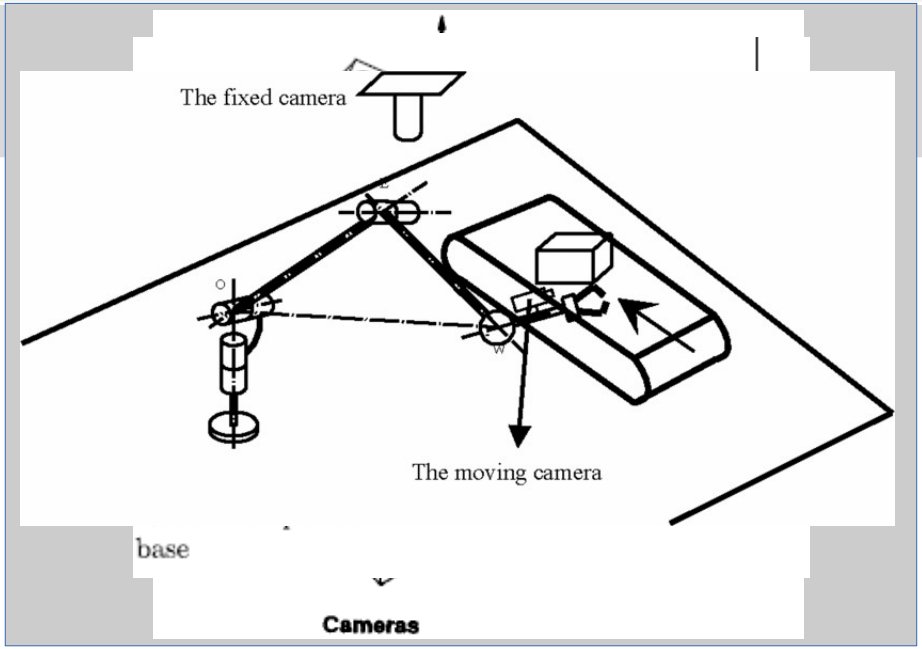
- Higher level of autonomy
  - Human-Robot Interaction: A Survey, Goodrich et al., *Found. Trends Hum.-Comput. Interact.*, 2007
  - Integration of Work Sequence and Embodied Interaction for Collaborative Work Based Human-Robot Interaction, Tan et al., *HRI*, 2013



- Learning from demonstration
  - Learning Trajectory Preferences, Jain et al., *NIPS*, 2013



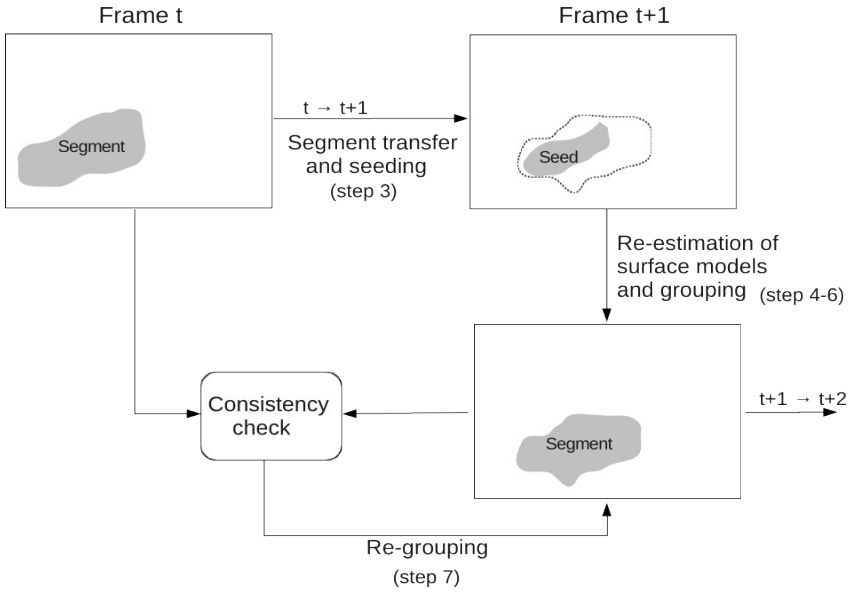
Related Work



Approach	Tracking & pose estimation →	Positioning the gripper
Allen et al., *T-RO*, 1993	Stereoscopic optic flow	Planar trajectories only
Kondak et al., *IROS*, 2001	Assume object trajectories provided already	Objects move on a conveyor belt
Smith et al., *IROS*, 1995	SSD based optical flow	Translation only
Bing et al., *M2VIP*, 2008; Benameur et al., 1998; Lei et al., *CDC*, 1993	Simulation only	
Siradjuddin et al., *IJCNN*, 2012	Blob detection algorithm	Position based visual tracking

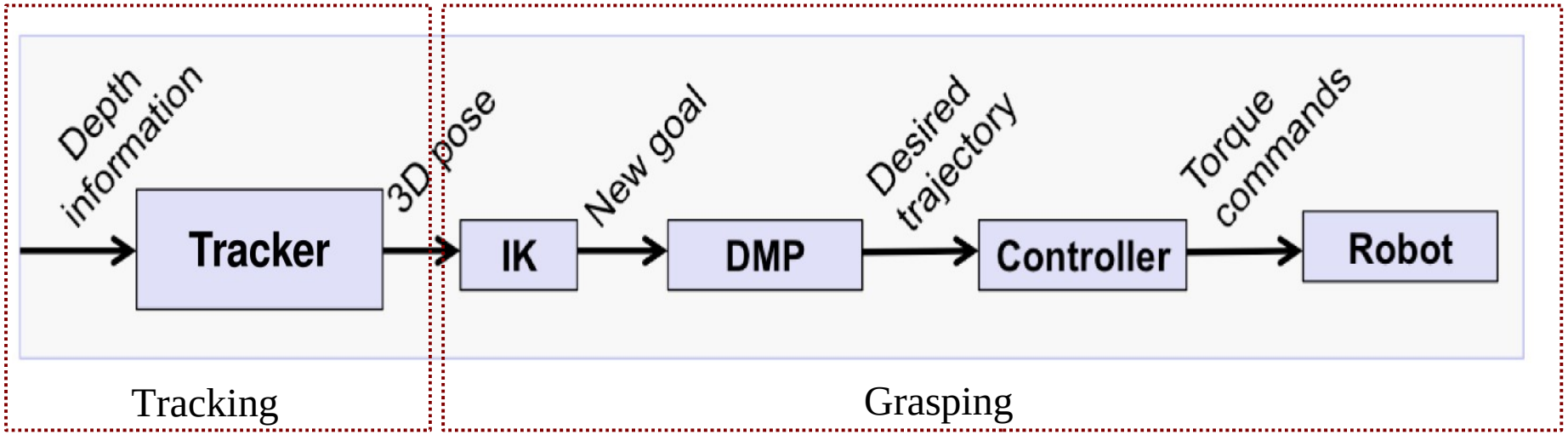
Related Work

- Tracking with range images
  - 3D tracker in the point cloud library
    http://www.pointclouds.org/
  - Seeding and region growing
    Dellen et al., *VISAPP*, 2013;
    Jiang et al., *3DIM*, 1999
  - Articulated motion only
    Ganapathi et al., *CVPR*, 2010;
    Knoop et al., *ICRA* 2006;
    Tsap et al., *DSP*, 2004



Our Approach

- Tracking with range images
  - Geometric Particle Filtering on the Affine Group (Kwon et al., *CVPR*, 2009)
  - Originally proposed for color images
- Reposition WAM arm
  - We use a robust online inverse kinematics algorithm (Colome et al., *IROS*, 2012)



Tracking

- Particle filtering on the Affine group (Kwon et al., *CVPR*, 2009)

1. Sample $X_t^{(i)} \sim p(X_t|X_{t-1}^{(i)}, y_t)$
2. Compute weights $w_t^{(i)} = w_{t-1}^{(i)} \frac{p\left(y_t|X_t^{(i)}\right)p\left(X_t^{(i)}|X_{t-1}^{(i)}\right)}{\pi(X_t^{(i)}|X_{0:t-1}^{(i)}, y_{0:t})}$
3. Resample $X_t^{(i)}$ according to $w_t^{(i)}$

- Constant velocity model for the state dynamics

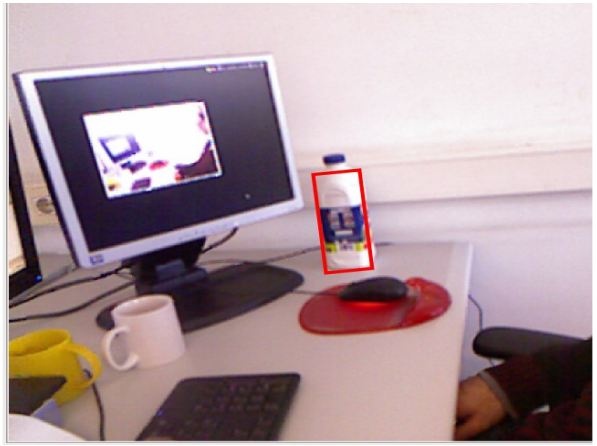
$$X_t = X_{t-1} e^{[a \ \log(X_{t-2}^{-1} X_{t-1}) + W_t]}$$

$$y_t = h[X_t, I_{t=0}(P)] + v_t$$

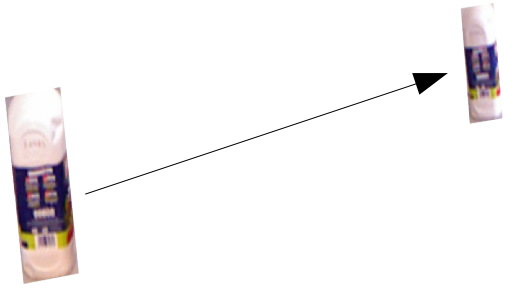
- We create a texture independent tracker by using only range images

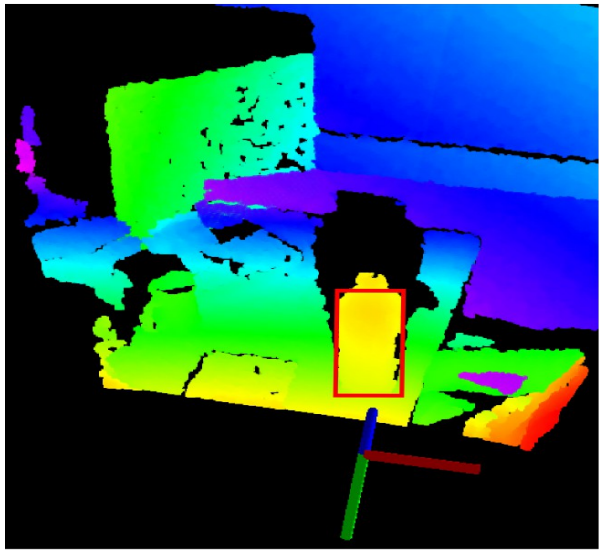
Tracking

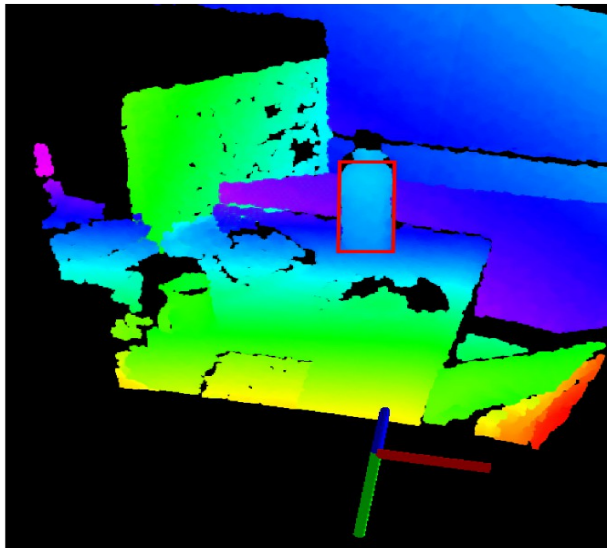
- We use a different measurement function



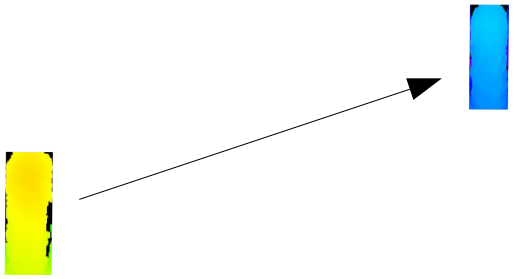
$$h(X_t, I_{t=0}(P)) = \left\| I_{t=0}(P) - I_t(P'_t) \right\|_1$$







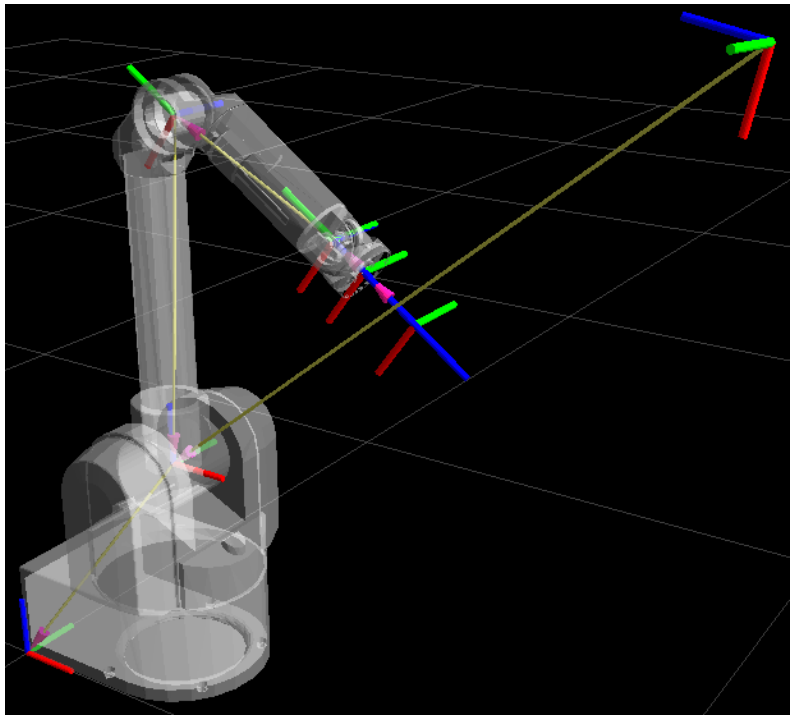
$$h(X_t, I_{t=0}(P)) = \left\| I_{t=0}(P) - I'_t(P'_t) \right\|_1$$



Grasping

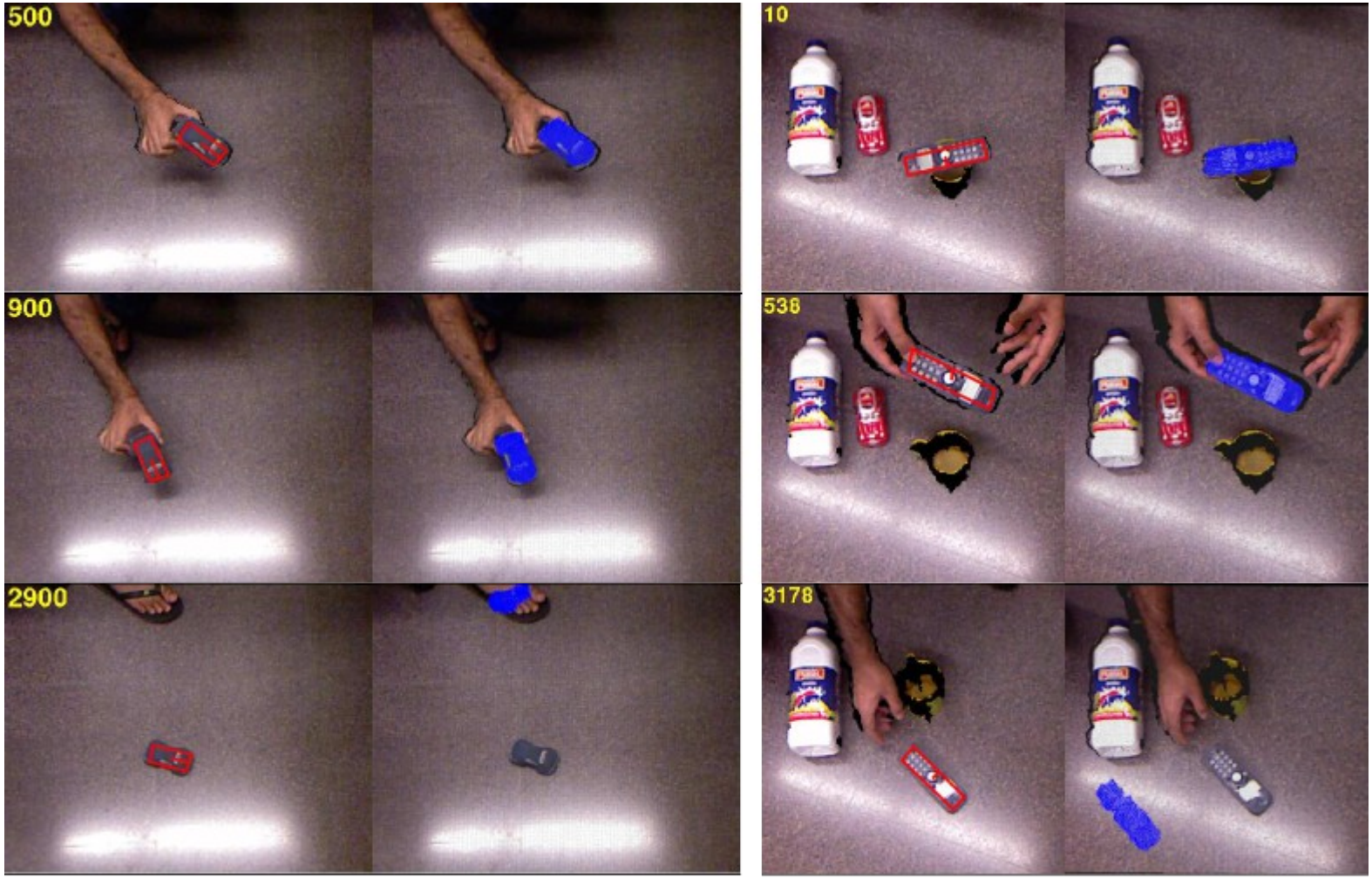
- WAM arm with 7-DoF
- Online update using Dynamic Motor Primitives
- Update the goal pose of the WAM end effector

$$e = \left\| \begin{bmatrix} e_p \\ e_0 \end{bmatrix} \right\|_2 + \delta$$



Tracking Results

Our Approach | PCL (depth tracker) | Our Approach | PCL (depth tracker)



Tracking Results

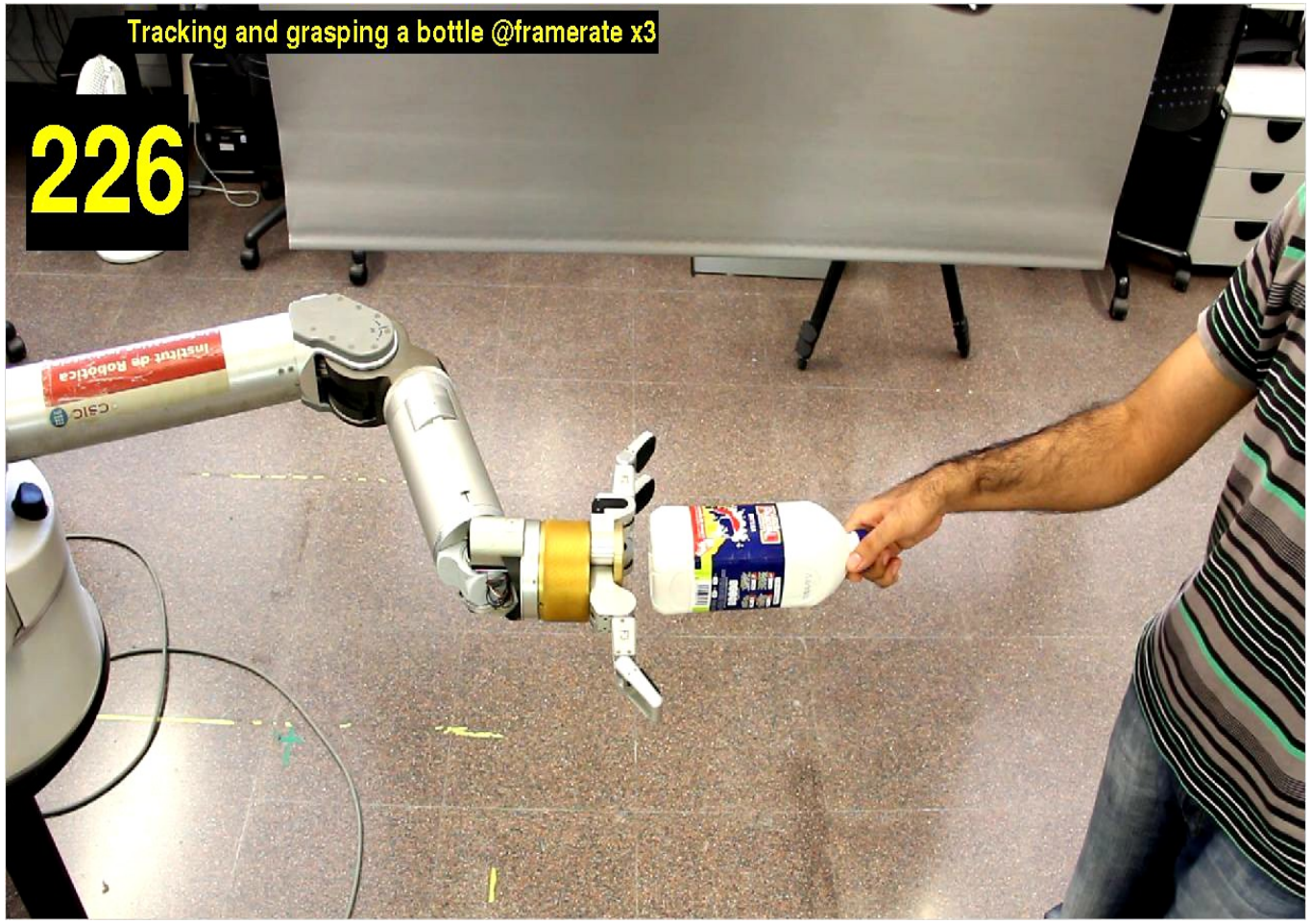
Comparison with depth tracker

Tracking Results

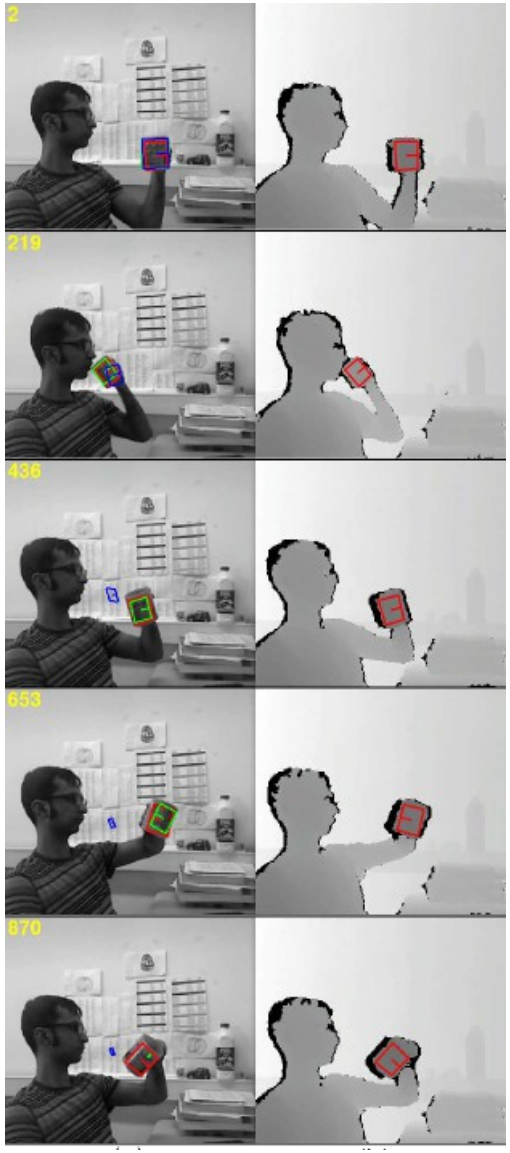
Comparison with color trackers

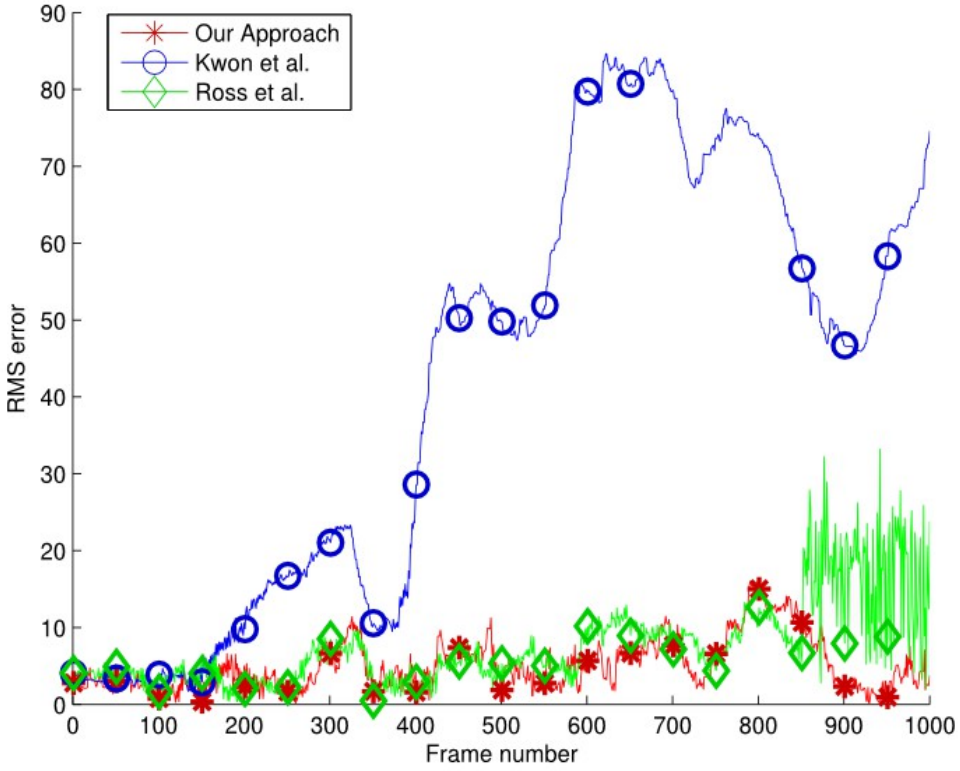
Results

Tracking and grasping system



Performance Evaluation: RMS error in tracking





Method	Mean RMS error
Kwon et al.	41.97
Ross et al.	7.37
Our Approach	5.06

Conclusion and Future work

- The system allowed us to track and grasp objects despite
  - Noise in depth data from Kinect camera
  - Partial occlusions
- For future
  - Our tracker processes ~20 fps
  - Efficient implementation
    - OpenMP
    - GPU
  - Depth differences between surfaces may become too small, resulting in assignment conflicts that cannot be resolved by the method as it is
    - Color image

Questions

- http://www.iri.upc.edu/groups/perception/#trackGrasp
- http://www.iri.upc.edu/people/shusain/index.html
- Thank You