Artificial Intelligence

Universität Bremen

Improving robot manipulation through fingertip perception

Alexis Maldonado[1,2] Humberto Alvarez[1,2] Michael Beetz[1,2]

[1]Institute for Artificial Intelligence
Universität Bremen
http://ai.uni-bremen.de

[2]Intelligent Autonomous Sytems
Technische Universität München
http://ias.in.tum.de
(Our lab is moving to Bremen!)

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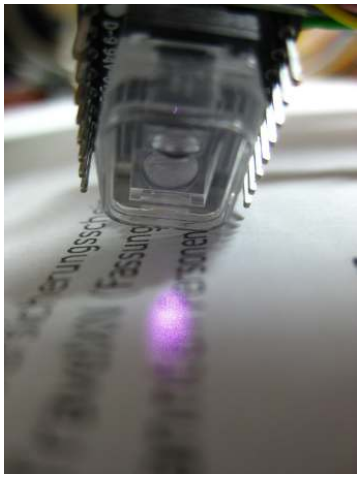
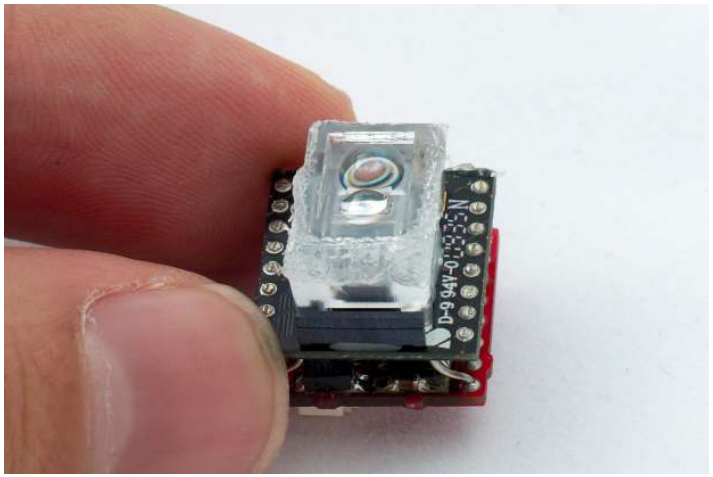
Robot manipulation benefits from sensors close to the action

- Sensors on end-effectors can perceive the objects without occlusions and get detailed information about them
- We present a low-cost but versatile sensor with three modalities and show how each is used in our robot





End-effector not only as Output Device

As an **input** device:

- capable of exploring the (local) environment and give haptic and external information
- Propriceptive vs Exteroceptive sensing

Two kinds of sensing in end-effectors

- Proprioceptive sensing: (Available in most robot hands/grippers)
  - Joint positions / velocities / accelerations
  - Force/Torque sensing
- **Exteroceptive sensing:** (Not very common. Our focus!)
  - Distance to objects (Pre-touch sensing)
  - Images of the object's surface
  - Tangential displacement (slip)
- The more sensing, the better! Limited by size / weight / cost / robustness constraints.

Outline

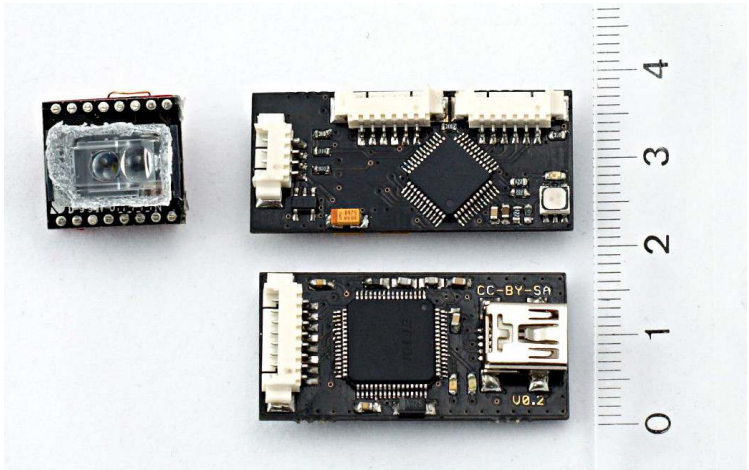
System

3D shape reconstruction

Surface material/texture recognition

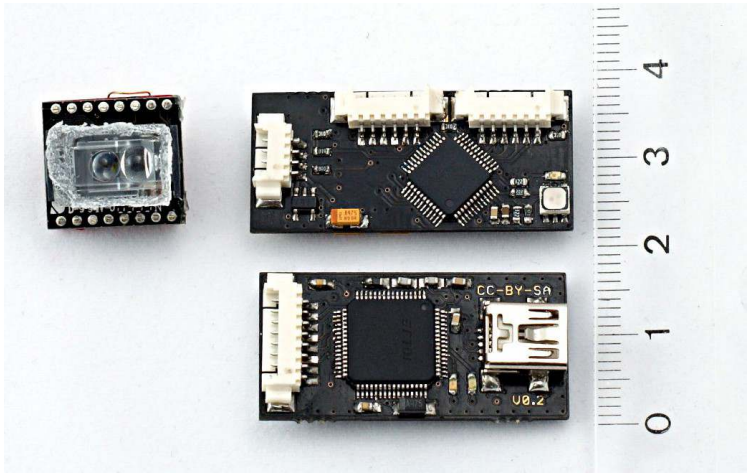
Object slip detection

Fingertip sensor - Capabilities



1. Proximity sensor: range 1-10mm.
2. Surface image acquisition: 30x30pixel image / area of the object ~ 1 mm^2.
3. Optical-flow measurement: The original use of the sensor: measure tangential displacement.

Fingertip sensor - Usage



1. 3D object shape reconstruction, specially the **occluded** parts.
2. Surface material/texture recognition (quickly and accurately).
3. Slip detection while manipulating (lifting/holding).

Related work

The idea of adding sensing to the manipulators is not new!

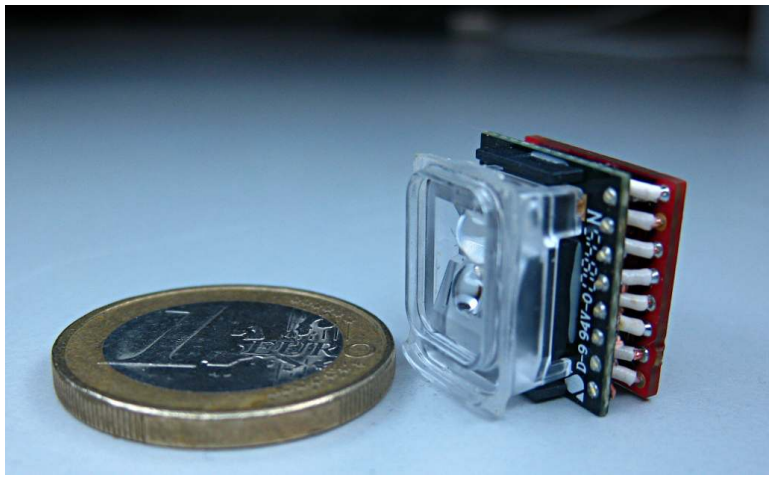
- Object shape reconstruction using tactile sensors[1]
- Infrared proximity sensors in end-effectors (Pre-touch sensing)[2]
- Stereo cameras on a gripper[3]
- Many more in the paper


P. K. Allen and P. Michelman, “Acquisition and interpretation of 3-D sensor data from touch,” *IEEE Transactions on Robotics and Automation*, vol. 6, no. 4, pp. 397–404, 1990.


K. Hsiao, P. Nangeroni, M. Huber, A. Saxena, and A. Y. Ng, “Reactive grasping using optical proximity sensors,” in *International Conference on Robotics and Automation (ICRA)*, 2009.

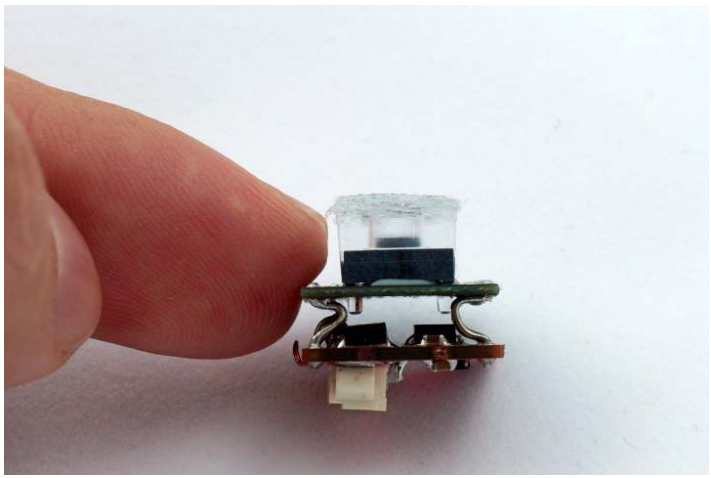

A. Leeper, K. Hsiao, E. Chu, and K. Salisbury, “Using Near-Field stereo vision for robotic grasping in cluttered environments,” *12th International Symposium on Experimental Robotics*, Dec. 2010.

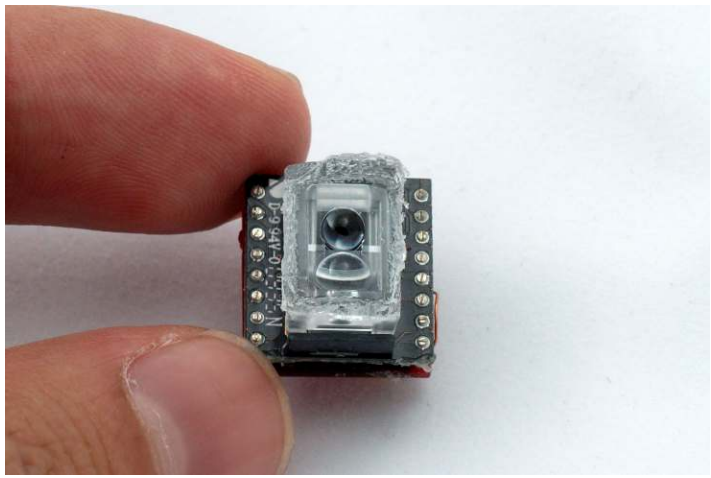
Fingertip sensor - Internals



- Small size (fingertip vs wrist)
- Versatile (3 operating modes)
- Robust (no contact necessary)
- Low cost (< 200EUR including 4 sensors)

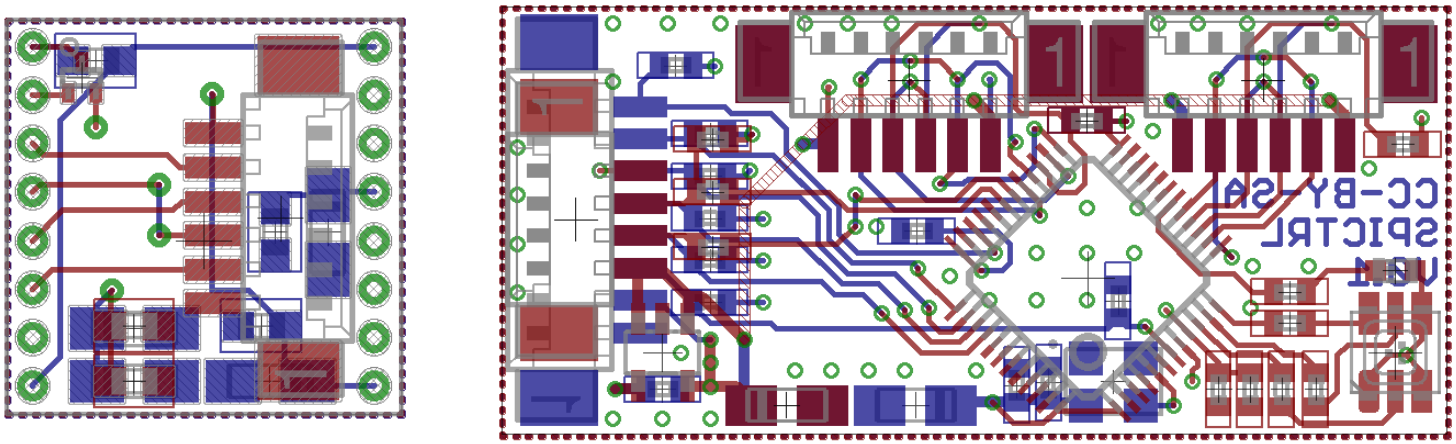
Fingertip sensor - Internals





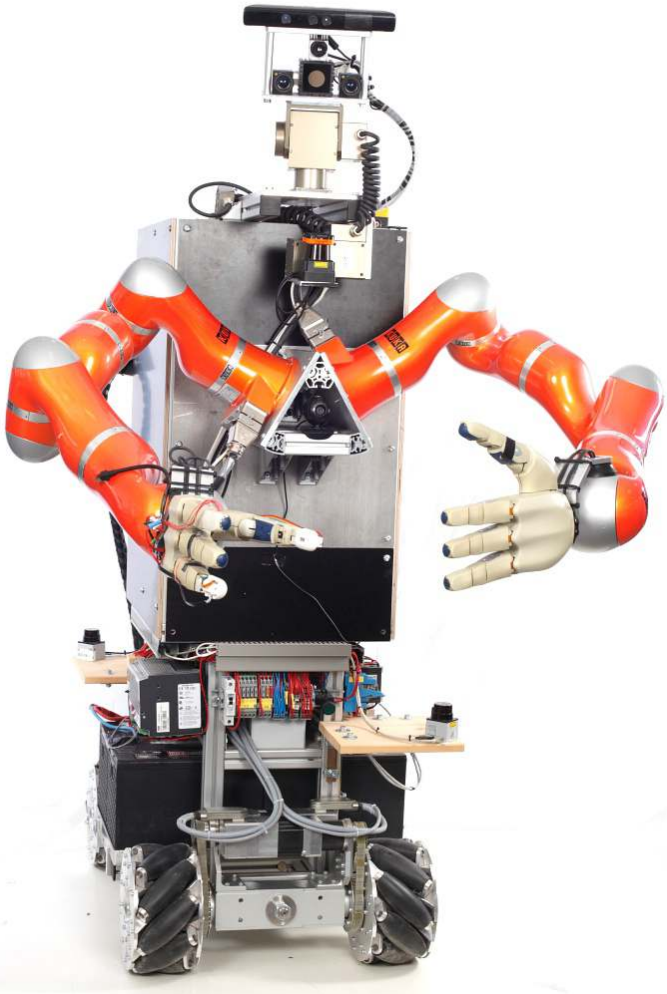
- Based on the Avago ADNS-9500 mouse sensor
- Microcontroller board based on a STM32 @ 72MHz
- USB connection for communication and programming
- Easy to use: ROS drivers and nodes available

Fingertip sensor - Internals

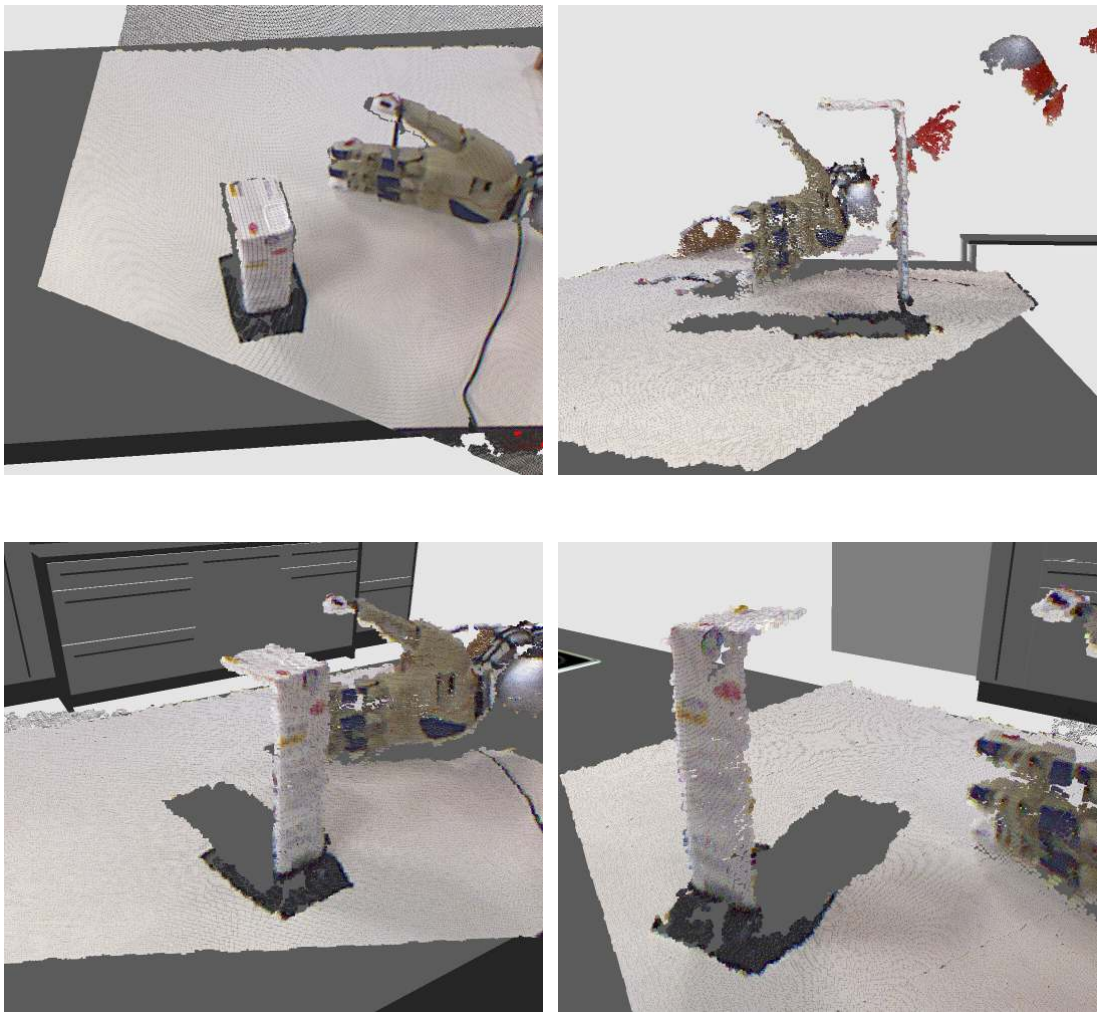


- COTS components
- Open Hardware (Creative Commons) / Free Software (GPL)
- Schematics / Components / Software:
  http://toychest.in.tum.de/wiki/projects:fingertip

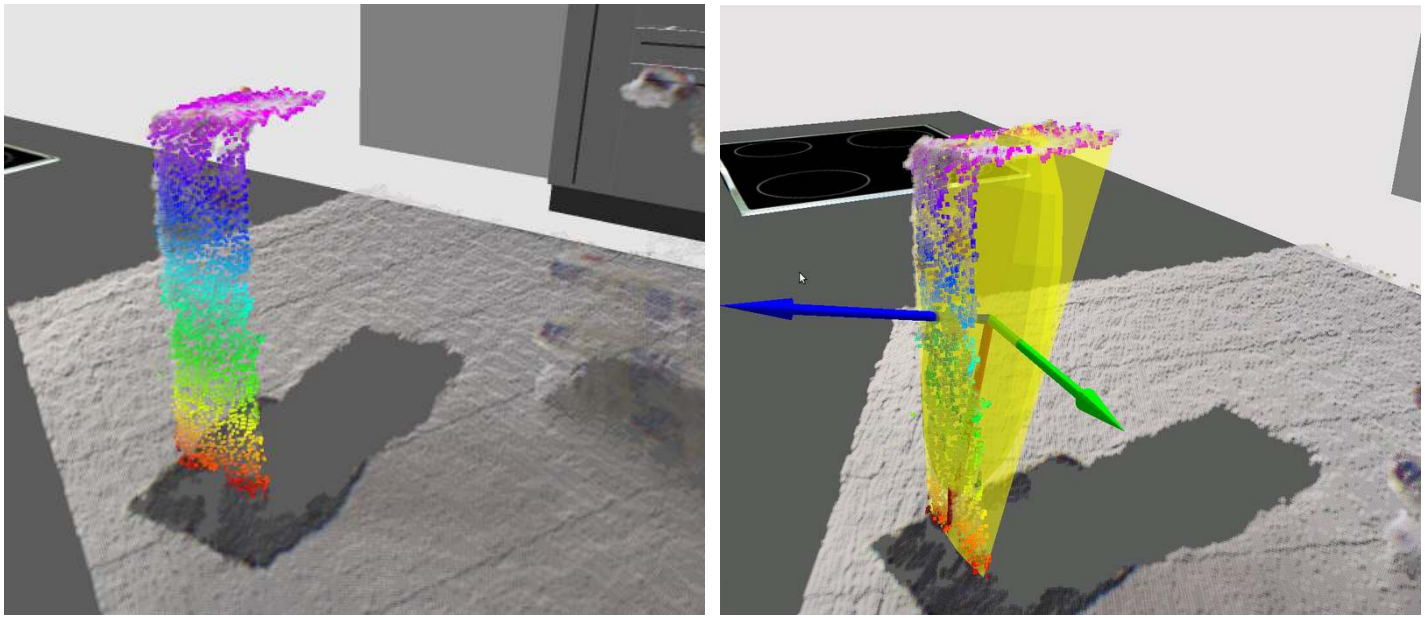
Installed in our robot



Typical robot perception (PrimeSense)

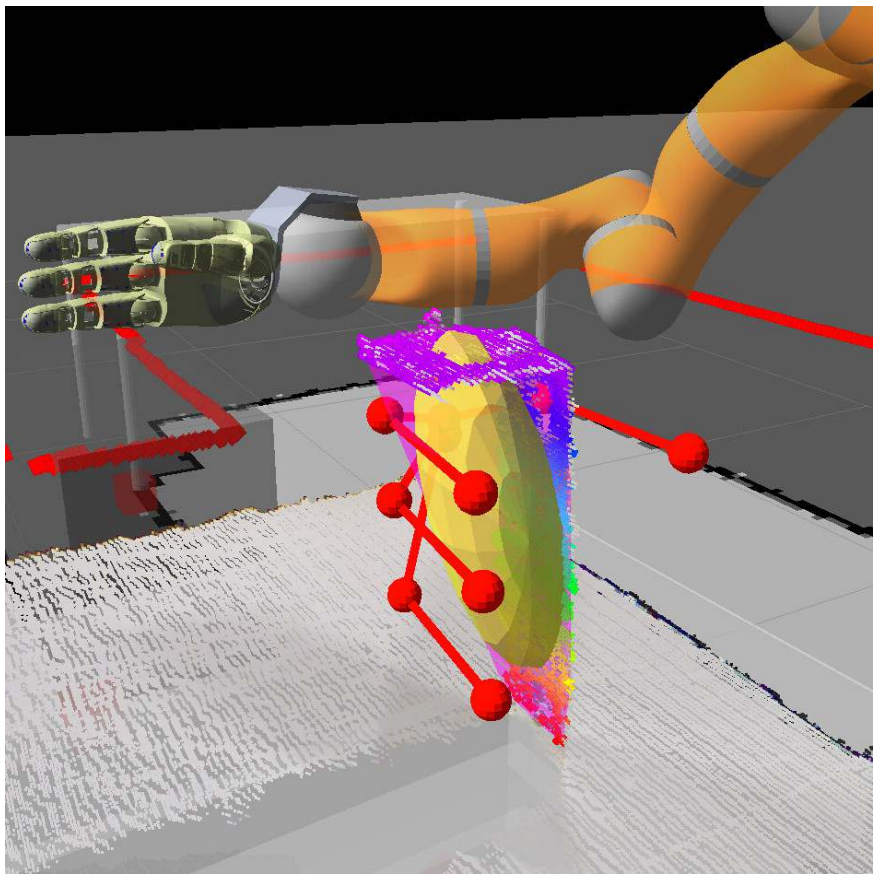


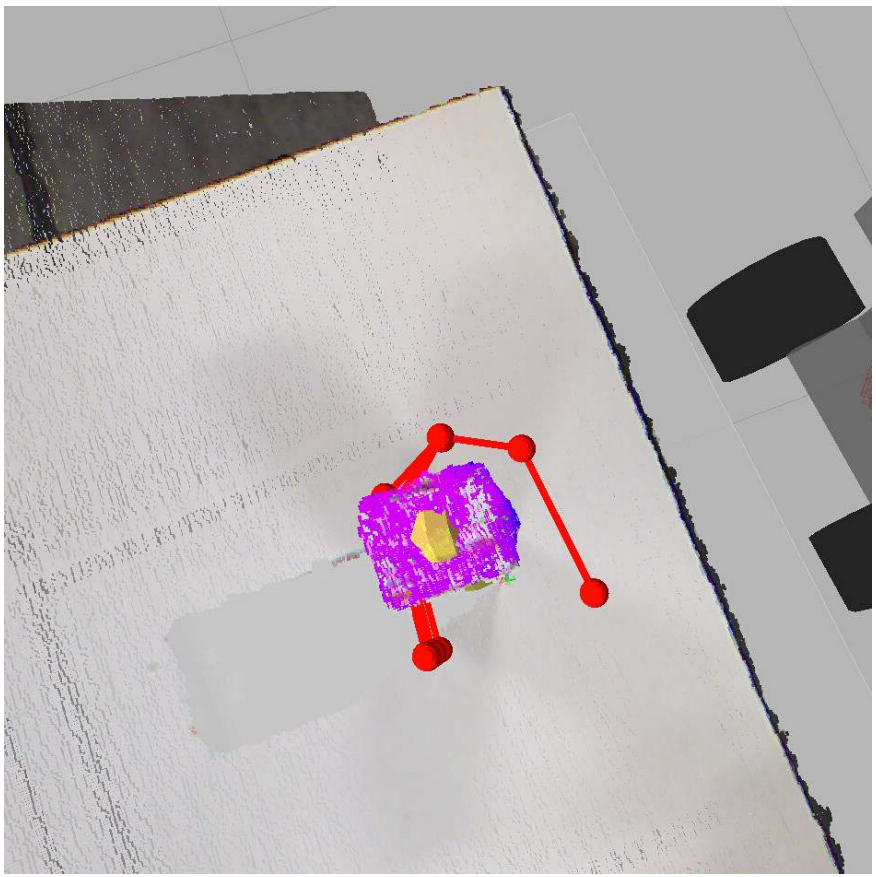
Perception for grasping



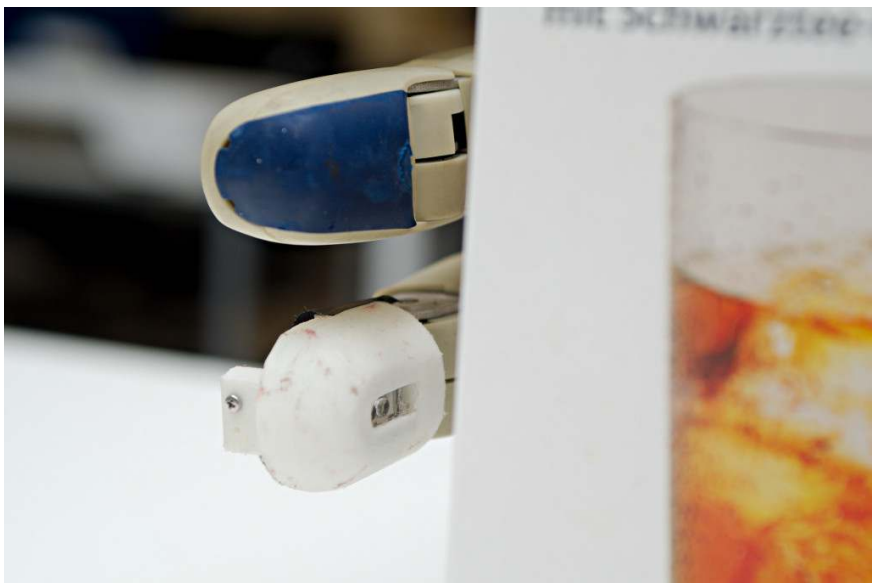
Left: Segmented points representing the object
Right: We represent the object as a gaussian point model (position + covariance matrix)

Occlusion leads to understimation of size

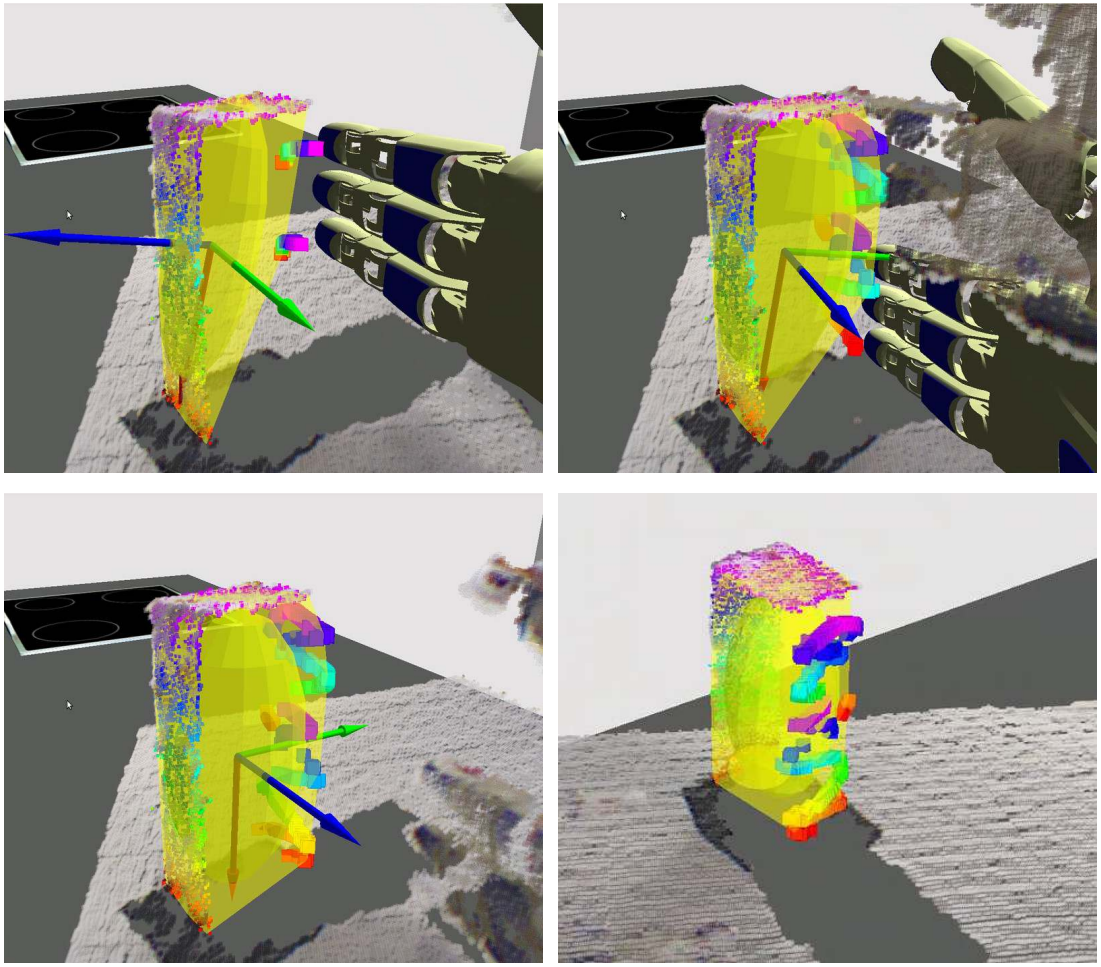




Obtaining a point cloud using proximity data

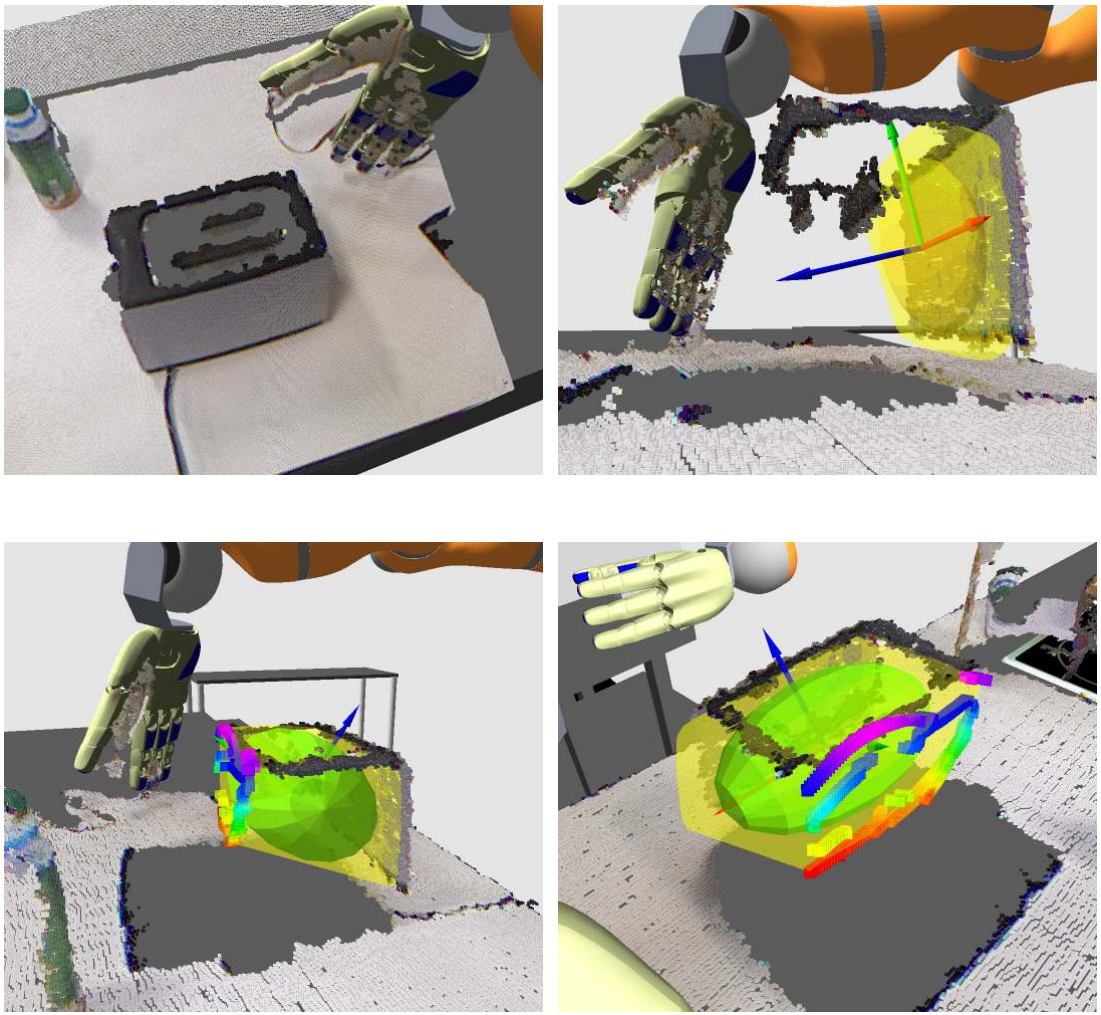


Shape reconstruction

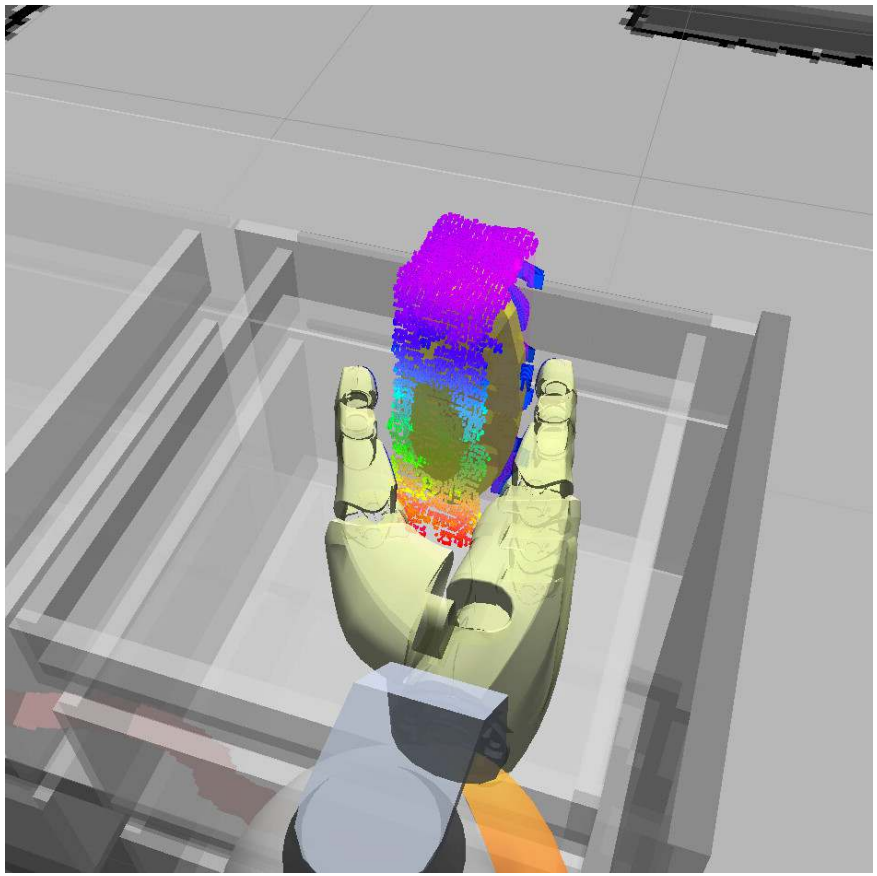


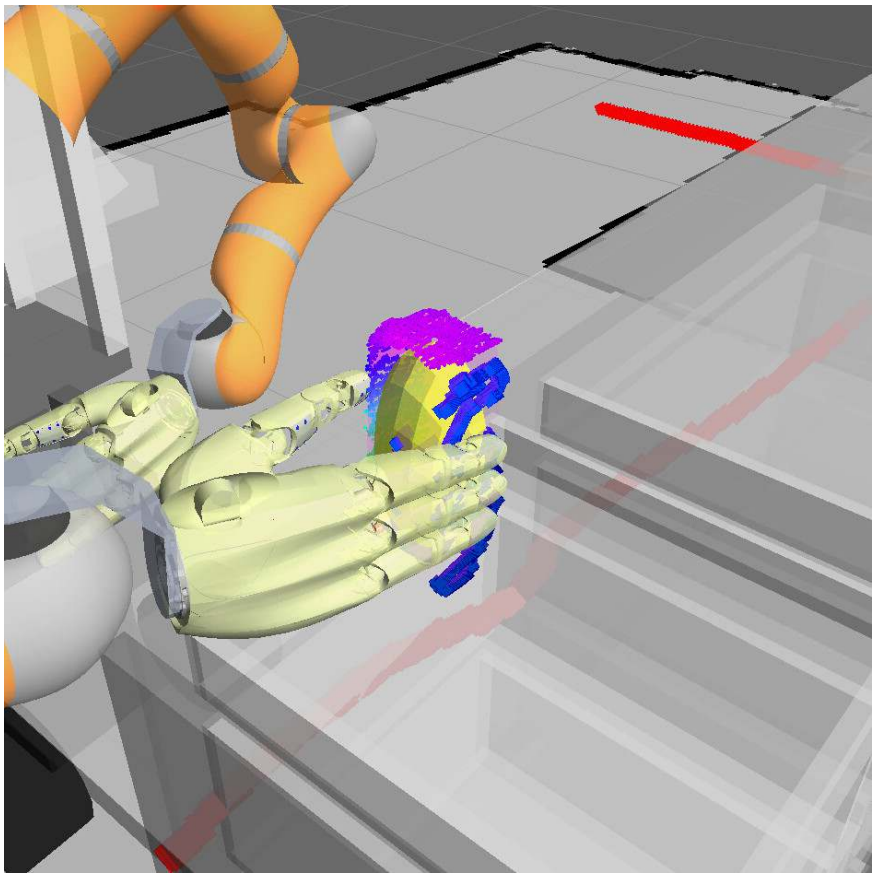
Video

Another example



Better results from grasp planning





Better results from grasp planning (2)

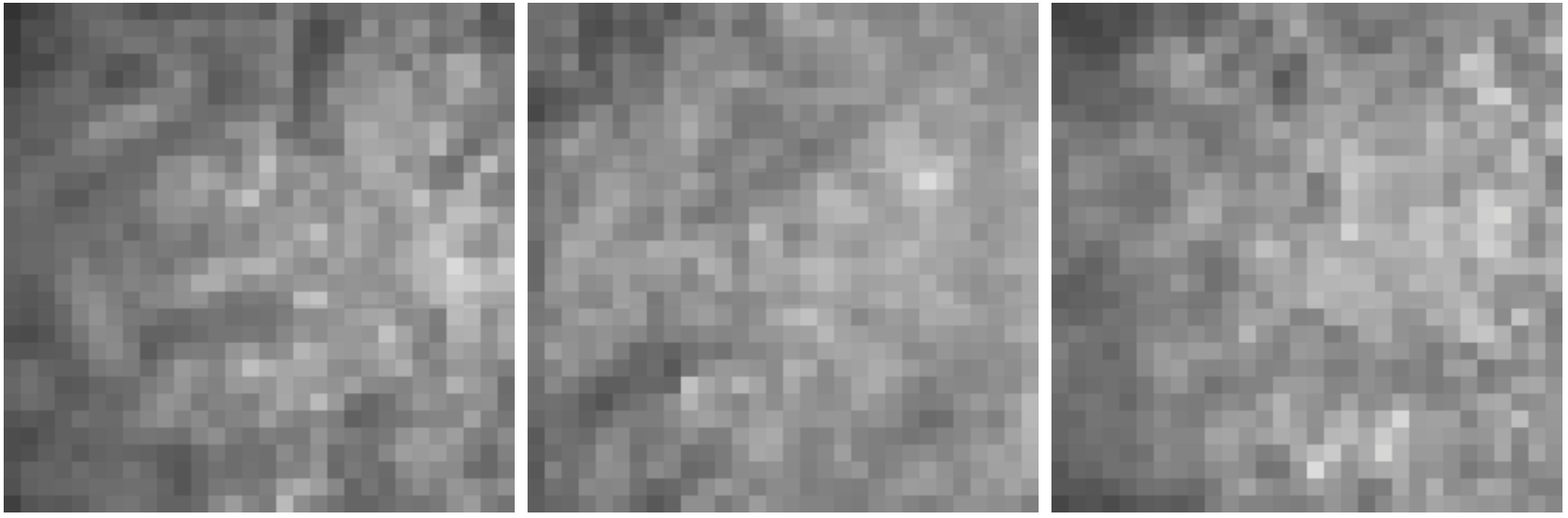
We use the Simple Grasp Planner or Statistical Grasp Planner (Presented at IROS2010)
Strategy:

- Estimate the position and size of the object (Point + Covariance)
- Find a grasp where the hand and fingers build a cage around the object

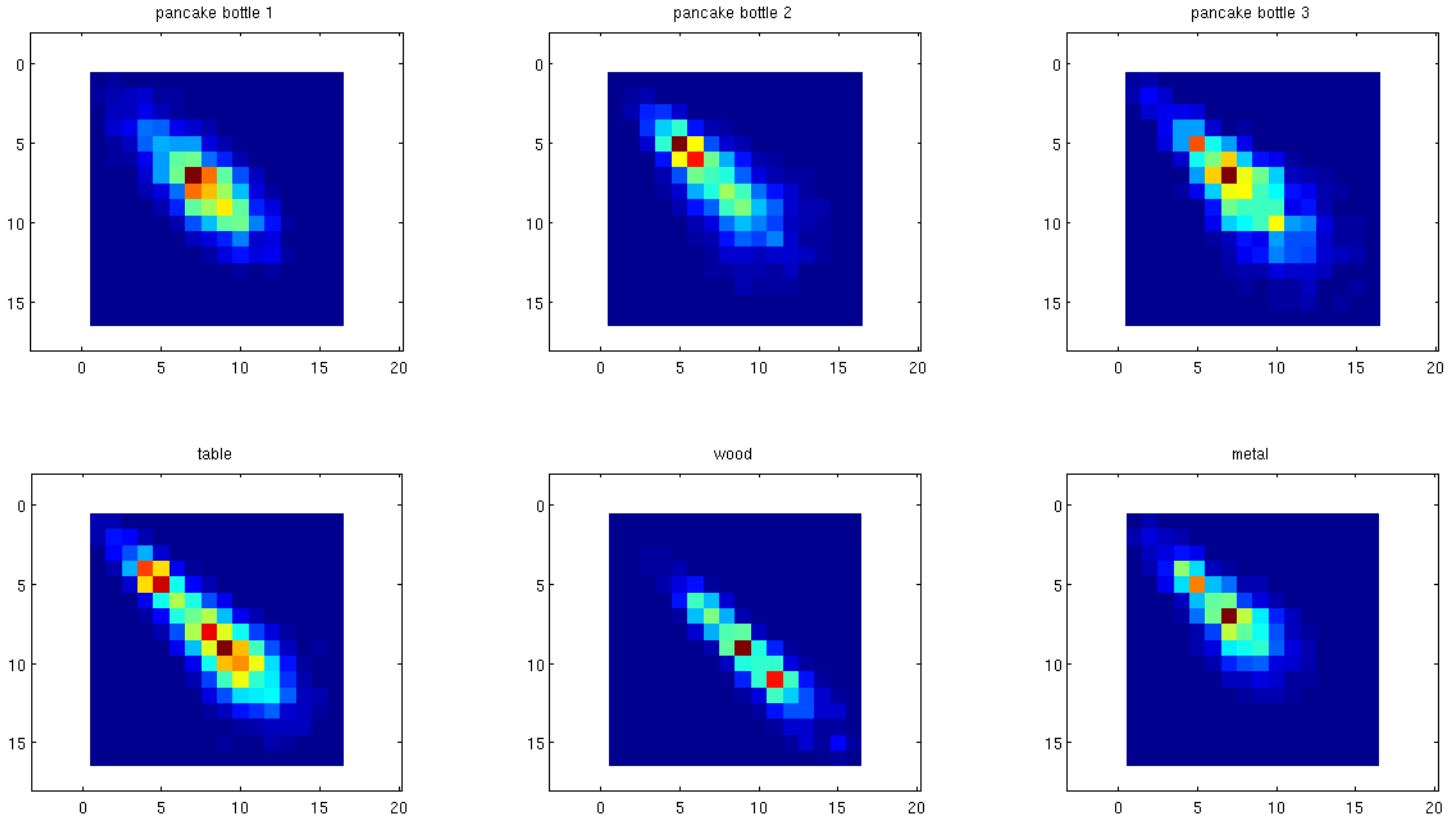
By having a much better estimate of the shape of the object, the SGP works much better. Other grasp planning algorithms for unknown/unmodelled objects would benefit too.

Micro-images

- We instruct the ADNS9500 sensor to deliver unprocessed images from the small CCD camera.
- Each image is 30x30pixels
- The infrared laser light reveals a lot of detail, even on glass or ceramics.

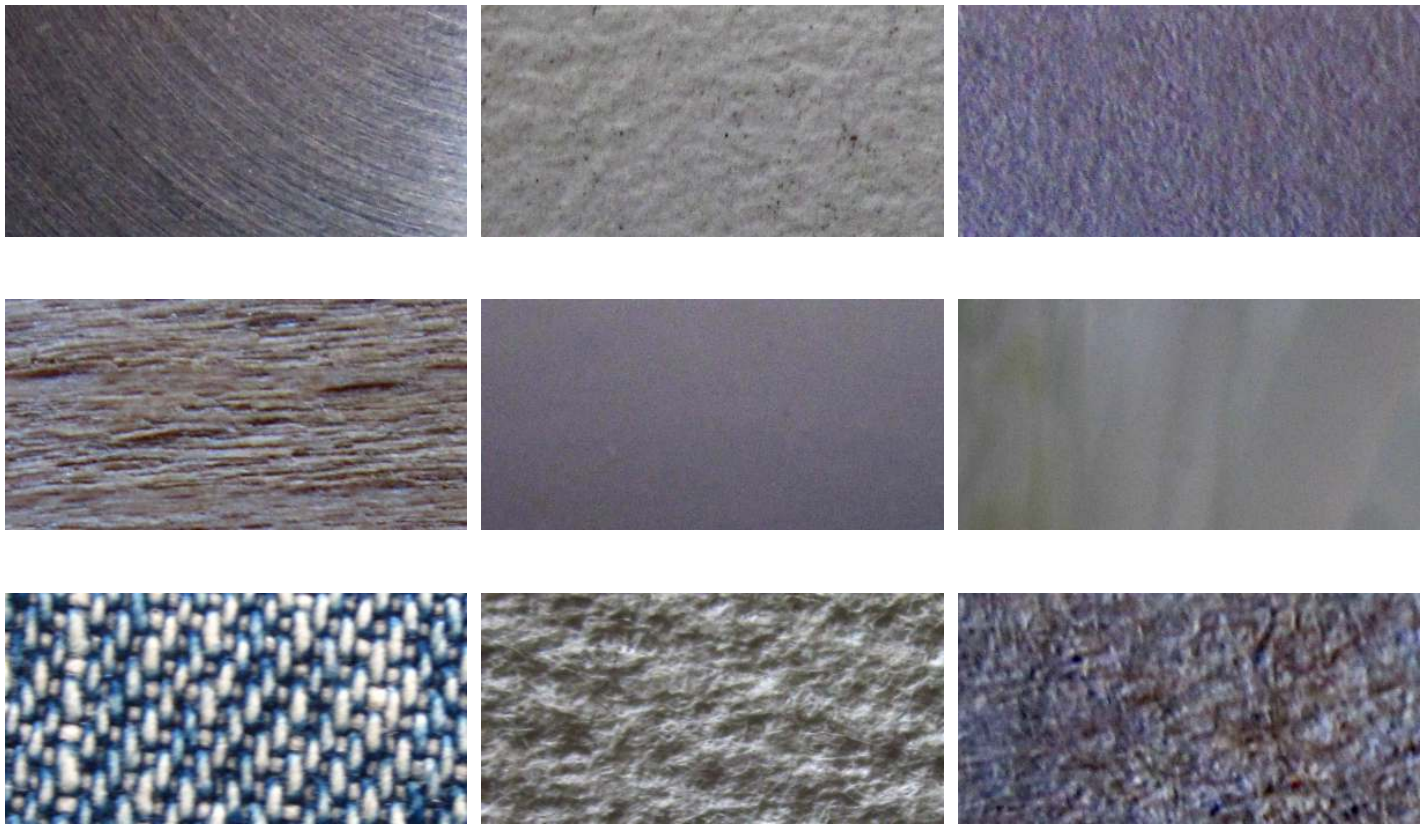


Classification algorithm



- Features from Gray Level Co-Occurrence Matrices (GLCM)
- SVM supervised learning classification

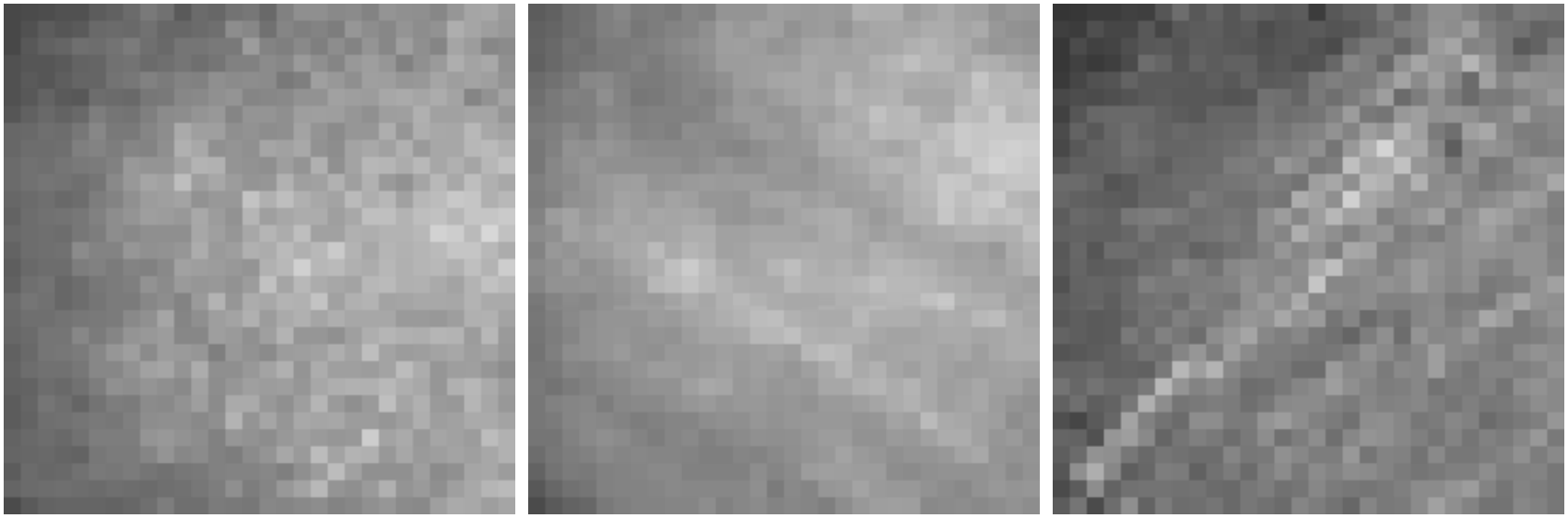
Material recognition experiment



Materials: metal, table melamine surface, paper, wood, plastic, glass, fabric, napkin paper and cardboard (Camera images)

Sensor images

Melamine, wood, metal:



Results

	1	2	3	4	5	6	7	8	9
1	**48**								
2		**47**		1					
3			**47**	1					
4				**47**					1
5					**48**				
6						**48**			
7							**47**		1
8								**46**	2
9				2			1	1	**44**

Household items experiment

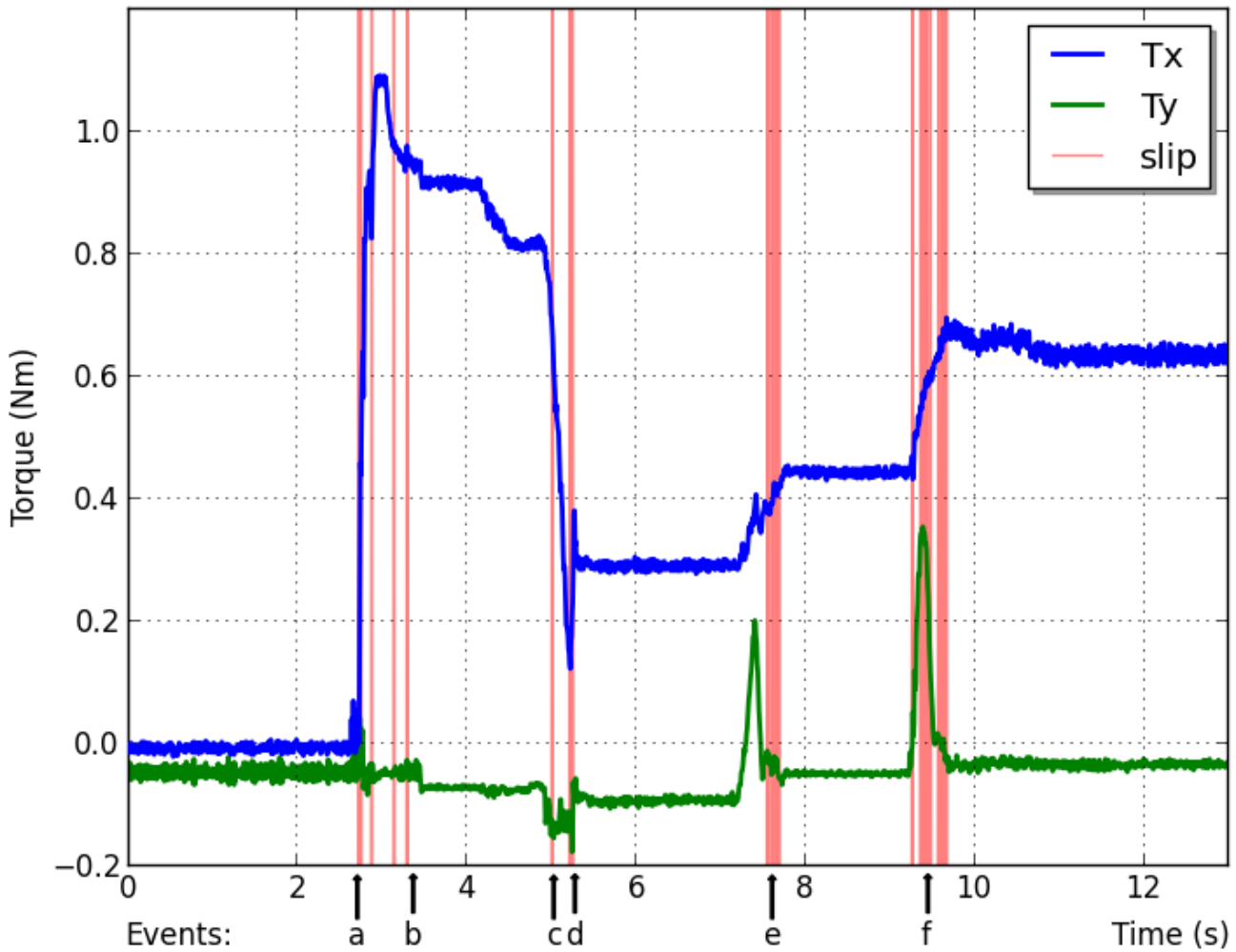
Results

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	**39**												1
2	1	**33**			3		1			1		1	
3			**40**										
4				**51**		10	2		7	2	8		
5		1			**36**			1			1	1	
6			1	7		**89**	1	2	4		12	2	2
7	2	5		4	1	1	**79**		7	5	6	6	4
8		1			1			**33**			1	4	
9				3		1	10		**66**				
10		2		1			1			**72**	2	2	
11		1		5		12		4		2	**66**	23	7
12	2	3	1		1	4	2	1	1	3	15	**79**	8
13	3	3		1		2	3				6	9	**93**

Use as a slip sensor

- Reliable slip data at approximately 50Hz per sensor or up to 200Hz if only one sensor is selected
- The robot can use this information to adjust the grasping force while carrying an object, or decide to hold the object with a second hand in order to keep it from falling.

Automatic adjustment of the grasping force



Summary

- We introduced an affordable and capable sensor for robotic fingertips
- We showed how the three different modalities of the sensor can improve robotic manipulation
  1. Reconstruct the 3D shape of objects
  2. Recognize the surface texture of objects
  3. Detect slip of the object while manipulating
- Please contact us if you are interested in board samples or integration into another robot!

Thank you for your attention

Questions?

More info: **http://toychest.in.tum.de**