

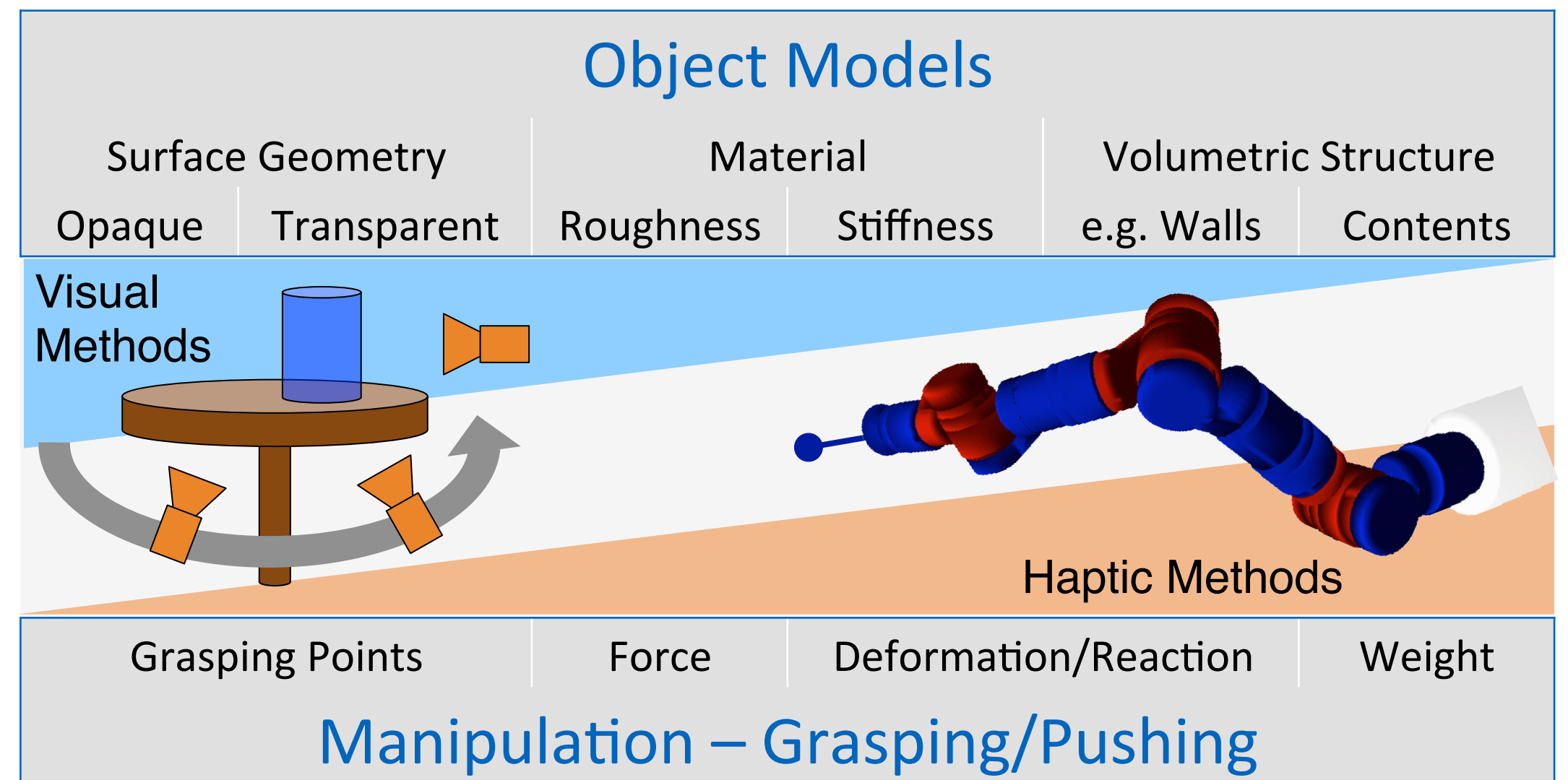
# VISUO-HAPTIC MODELING FOR MANIPULATION

Alt, N.; Steinbach, E. · n.alt@tum.de · Technische Universität München

non-final version

2014-05

**Abstract** – Cognitive robotic systems require multilayered models of objects in their environment. For detection and manipulation tasks, appearance, geometry, material roughness, stiffness and weight are of relevance. Appropriate models build on established visual reconstruction techniques, yet they must also integrate haptic properties, which can only be learned by exploration. We propose two approaches of visuo-haptic modeling for grasping and navigation, which are adapted for object-level or room-level representations, respectively. Visual reconstruction, transparency detection and haptic exploration are combined to create a model suitable for stable manipulation tasks. Visually similar objects – such as paper/plastic/glass cups – are successfully distinguished. Furthermore, a camera-based sensor is presented, which visually obtains haptic/tactile data during manipulation.



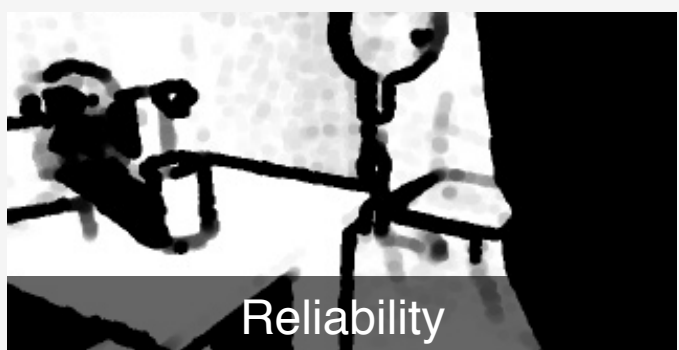
## VISUO-HAPTIC OBJECT MODELS

### Multi-View Reconstruction

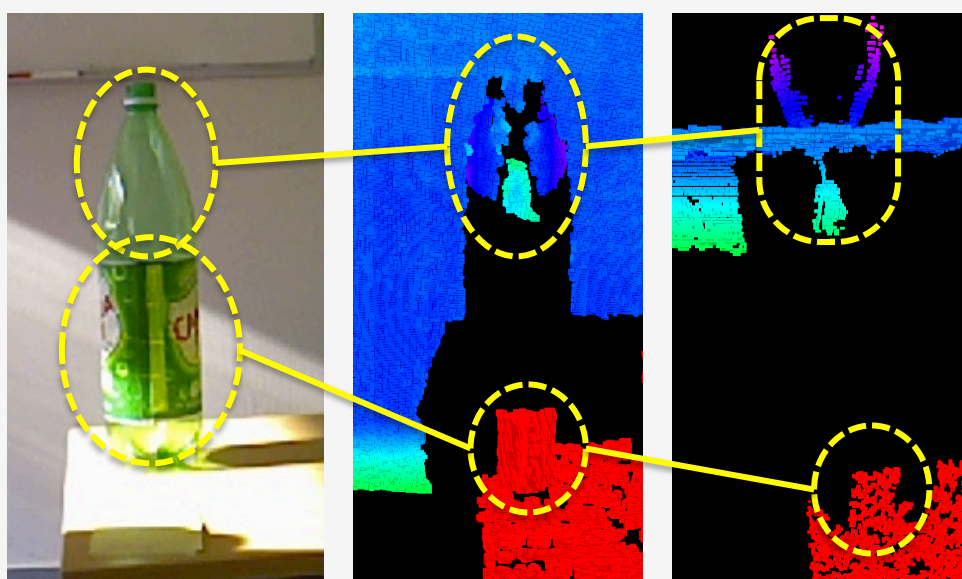
e.g. KinectFusion [5], Octomap [6] + Robot Arm

### Transparency Detection [4]

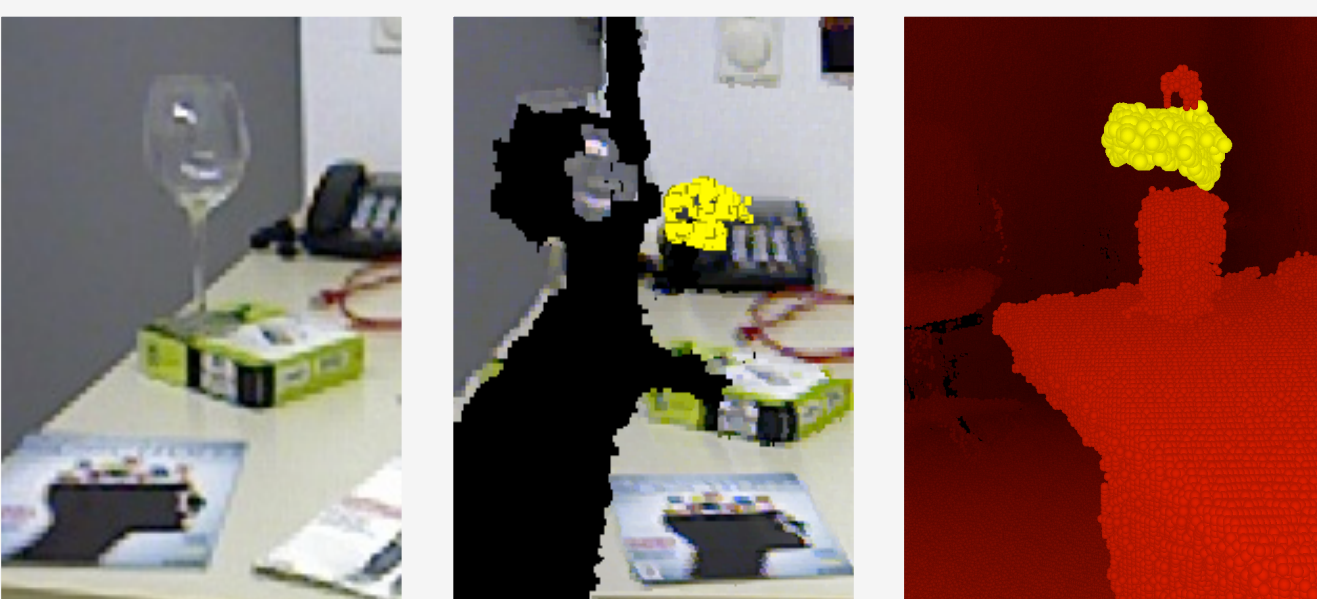
- Local background model



- Refraction detection

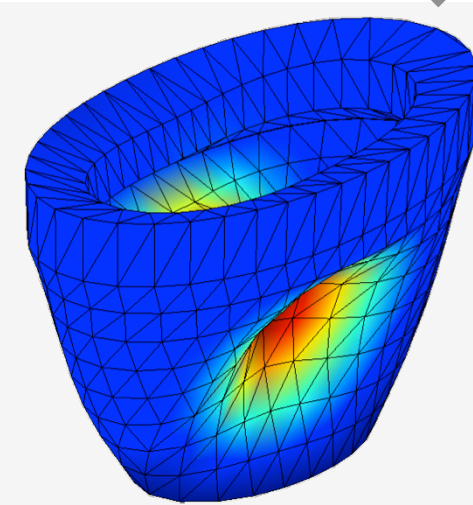


- 3D reconstruction of transparency



### Grasp Simulation

- Create local stiffness map
- Identify representative grasp points
  - PCA of deformation shapes
  - Extrema of stiffness map



### Modeling Layers

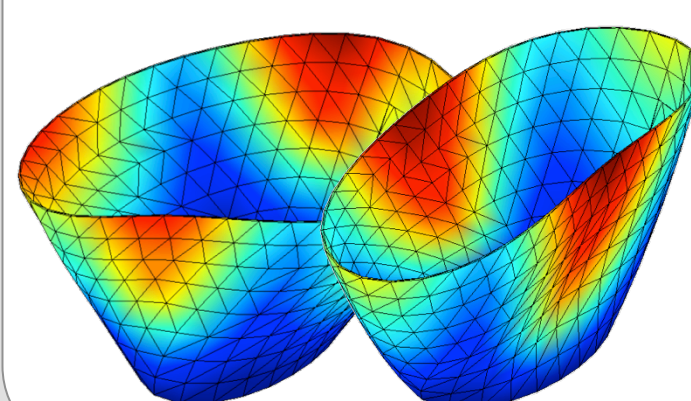
3D Geometry  
(Surface Model)

Transparency  
(Reconstruction Error)

Visuo-Haptic  
Geometry

FEM  
(Stiffness)

Deformation Modes  
(Characteristic shapes)



### Exploration of Geometry

- Geometry of unknown regions by touching
- Touch planning
  - Largest unknown cone
  - Highest extrapolation uncertainty
- Create fused mesh, extrapolation with RBF



### Generic FEM Models

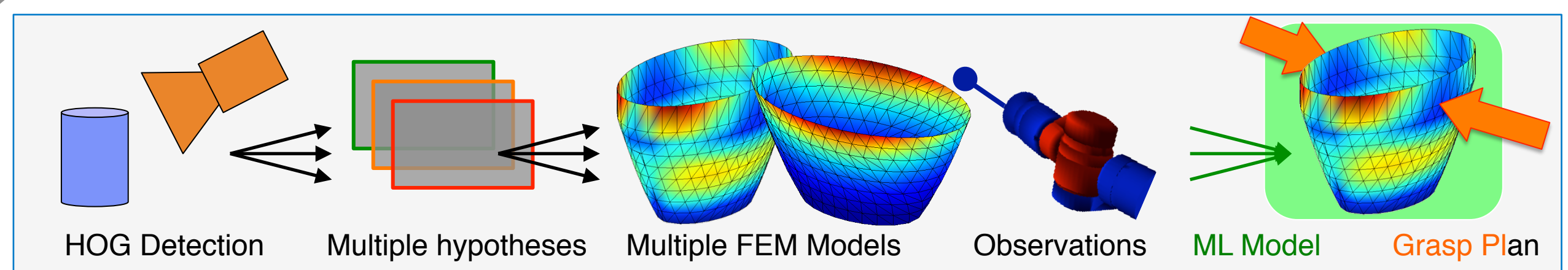
- Database of pre-learned generic geometries
- Selection by visual detection (SIFT/HOG)
- Multiple candidates
- Visual Ambiguities: Plastic/paper/glass bottle/cup

### Model parameters

- Structure: thin-walled, reinforcements
- Elastic modulus (material)
- Contents: enclosed air, open, liquid

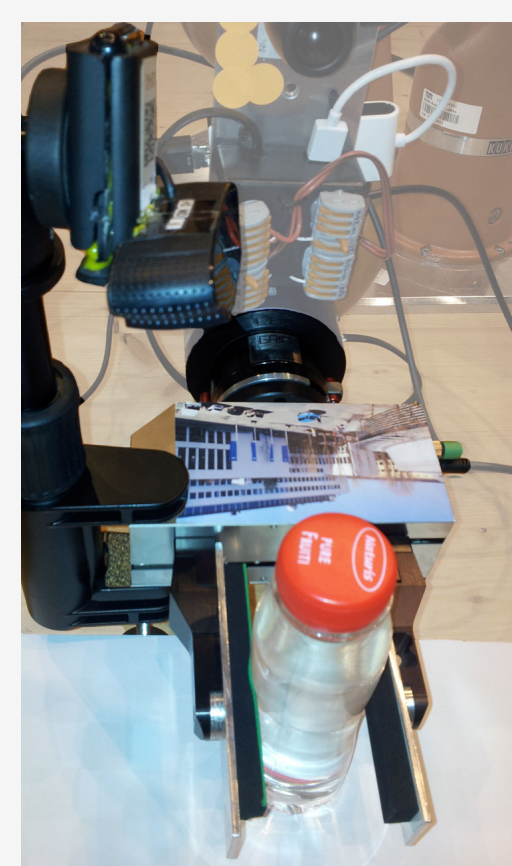
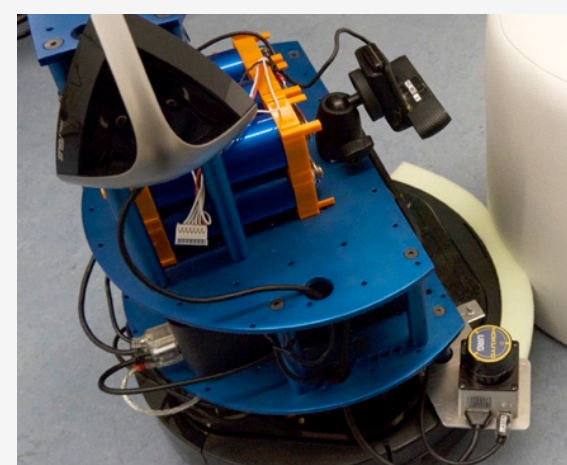
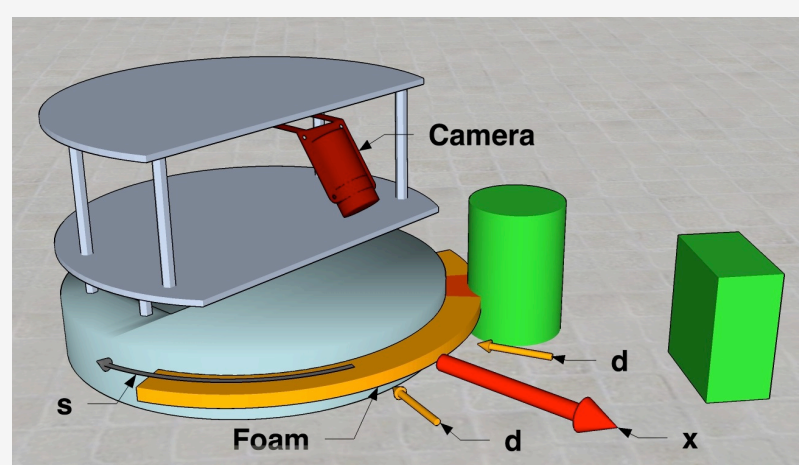
### Exploration of Stiffness

- Verify local stiffness
- Verify deformation modes by pointcloud matching
- Select best model
- Refine model parameters



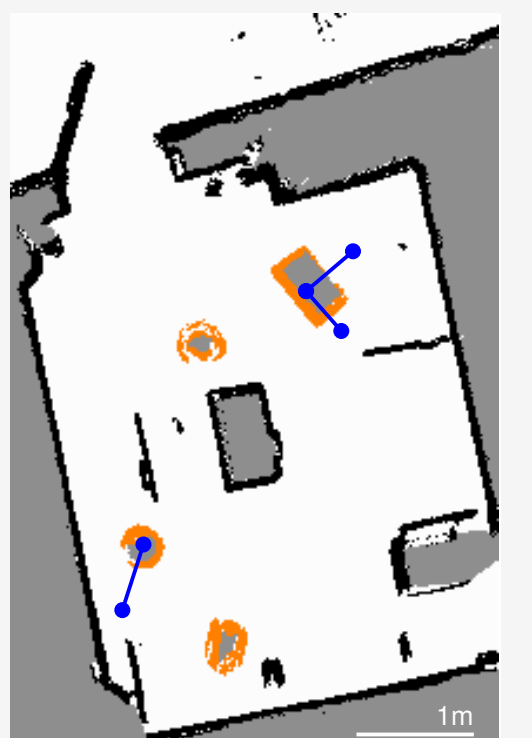
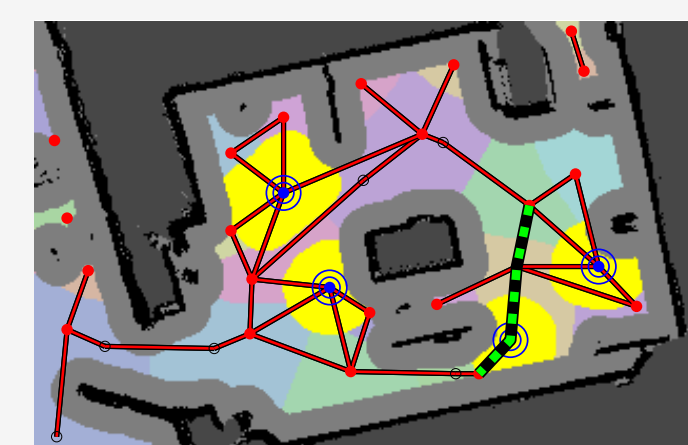
## VISUO-HAPTIC SENSOR [2,3]

- Camera-based sensor
- Measures impression of deformable foam
- Obtain haptic data visually: Force, movement, stiffness, shape
- Reduces system complexity, reuse of cameras



## NAVIGATION MODELS FOR MOBILE PLATFORMS [1]

- Visual model: Occupancy grid maps
- Haptic exploration of obstacles
- Integrated graph-based representation for navigation & manipulation planning



Left: Detour around obstacle; Center: Shorter path with manipulation (push); Right: Map

[1] N. Alt, E. Steinbach: Navigation and Manipulation Planning using a Visuo-haptic Sensor on a Mobile Platform. *IEEE Transactions on Instrumentation and Measurement*, vol. 63, 2014.  
 [2] N. Alt, E. Steinbach: A Visuo-haptic Sensor for the Exploration of Deformable Objects. *ICRA Workshop on Autonomous Grasping and Manipulation*, Hong Kong, Mai 2014.  
 [3] N. Alt, E. Steinbach: Visuo-haptic sensor for force measurement and contact shape estimation. *IEEE Int. Symposium on Haptic Audio-Visual Environments and Games (HAVE)*, Istanbul, Turkey, Oktober 2013.  
 [4] N. Alt, P. Rives, E. Steinbach: Reconstruction of transparent objects in unstructured scenes with a depth camera. *IEEE International Conference on Image Processing (ICIP)*, Melbourne, Australia, September 2013.  
 [5] S. Izadi et al.: KinectFusion: real-time dynamic 3D surface reconstruction and interaction. *ACM SIGGRAPH 2011 Talks*, New York, NY, USA, 2011.  
 [6] K. M. Wurm et al.: A probabilistic, flexible, and compact 3D map representation for robotic systems. *ICRA workshop on Best Practice in 3D Perception and Modeling for Mobile Manipulation*, Anchorage, AK, USA, 2010.