Scene Representation and Object Grasping Using Active Vision

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Workshop on Defining and Solving Realistic Perception Problems in Personal Robotics, International Conference on Intelligent Robots and Systems 2010, Taipeh, Taiwan

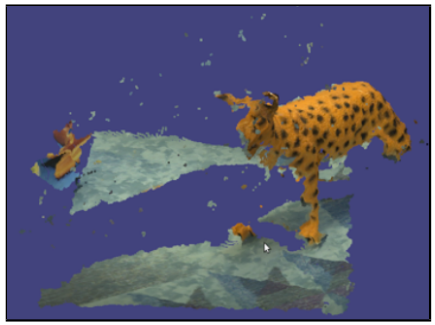
Introduction

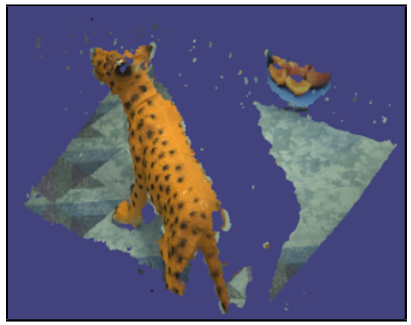
- Large research field:
  Object-Centered Grasp Inference
  $\longrightarrow$ affordances
- Given an Object o, which grasp g can be applied to it?

$$g = f(o) \qquad (1)$$

- o: known, unknown or familiar
- function f: stable grasp, imitation, task specific, heuristics, etc.

?





Questions in Grasp Inference and Executation

- How do we detect object hypotheses o ?
  - foreground/background segmentation $\rightarrow$ occlusions, viewing constraints
  - recognition & pose estimation
  - categorisation
- How to constrain f to obtain a grasp g feasible in a whole scene? $\rightarrow$ collision avoidance
- Given a task, how to plan a whole sequence of manipulation tasks?
  - Prepare the dinner table!
  - Pour me a cup of coffee!
  - Clean the table!
  - Unload the dishwasher!
- **Robot needs to understand the scene it is facing!**

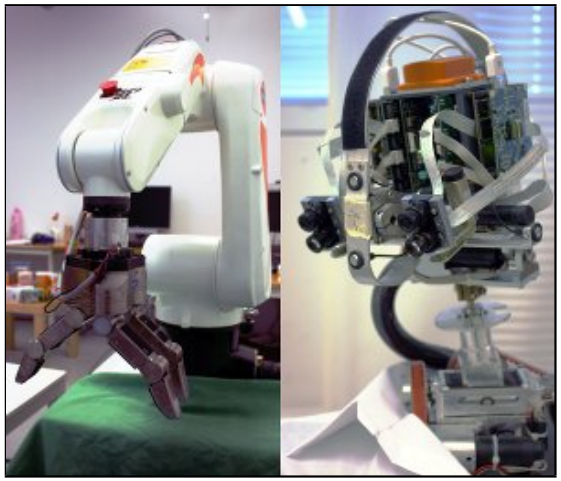
What do we mean by scene?

- Embodiment
- Obstacles (furnitures, supporting planes, ...)
- Object Hypotheses

Our Approach Towards Scene Understanding

Active Vision System integrating different **computational processes** for **incremental** scene understanding

- Hardware:
  Armar III Robotic Head (7 DoF), 4 Cameras
  Kuka Arm (6 DoF)
  Schunk 3-fingered Dexterous Hand (7 DoF)
- Scene:
  one supporting plane
  several object hypotheses



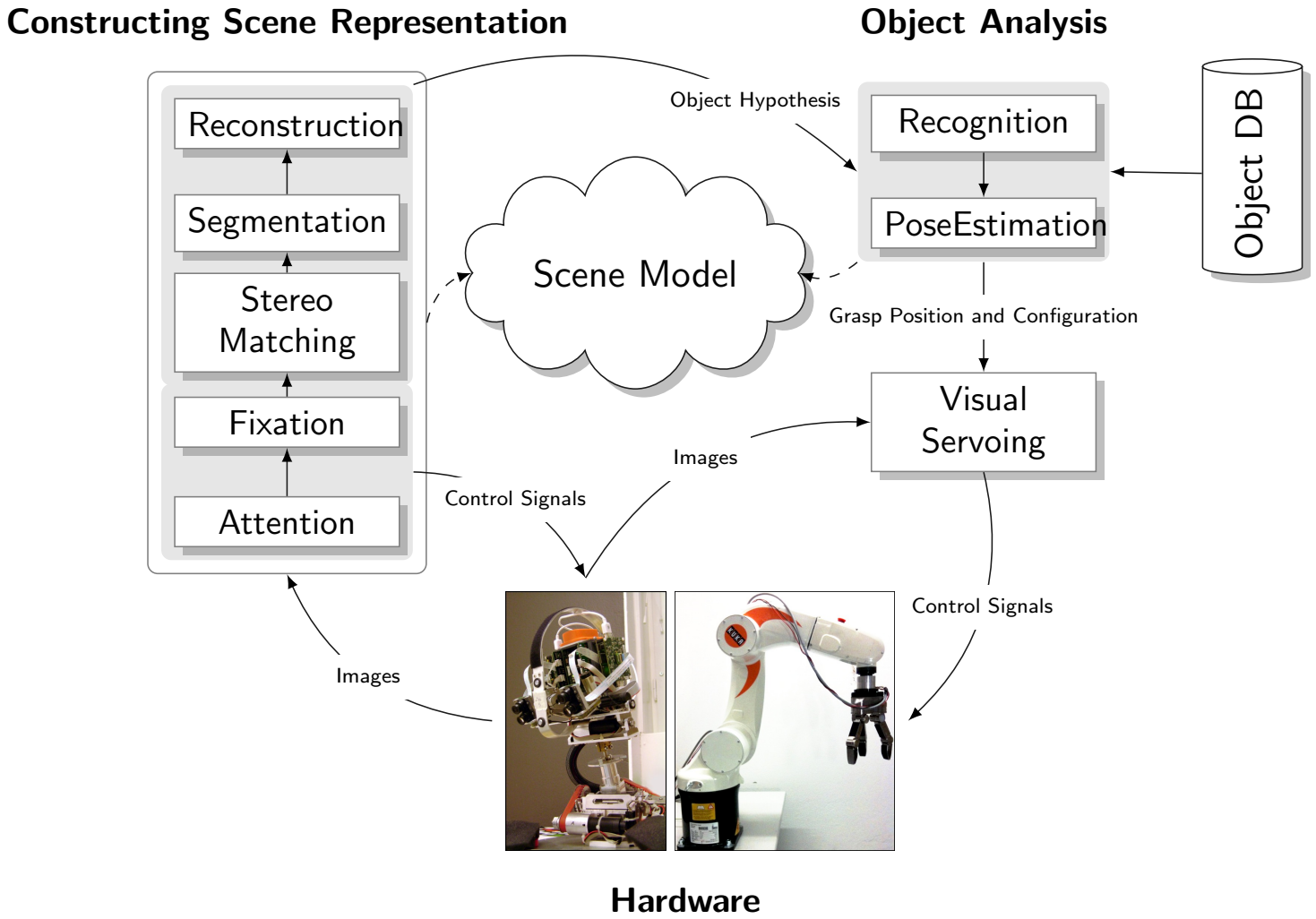
Why do we need four cameras?

- Wide field of view - scene oriented
  - Easier to find objects and their relations
  - Suitable for attention
- Narrow field of view - object oriented
  - Easier to analyze objects and perform learning
  - Suitable for recognition/categorization

Computational processes involved

Task: Grasping Known Objects

Building up scene model independent of object knowledge



Offline Calibration

- Neccessary for:
  - Stereo Calibration for image rectification prior to stereo matching
  - Head-Eye Calibration to bring an attention point in wide field cameras to center of foveal cameras
  - Hand-eye calibration for visual servoing
- Transformations to determine
  1. Between left & right camera for fixed joint configuration
  2. Between one camera system in two different joint configurations
  3. Between camera and arm

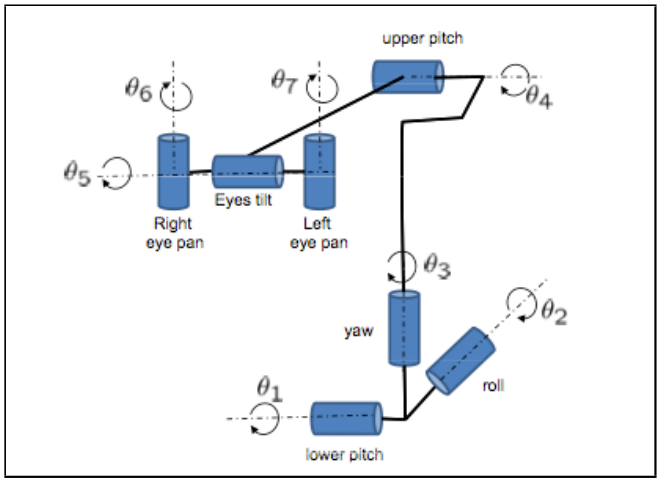
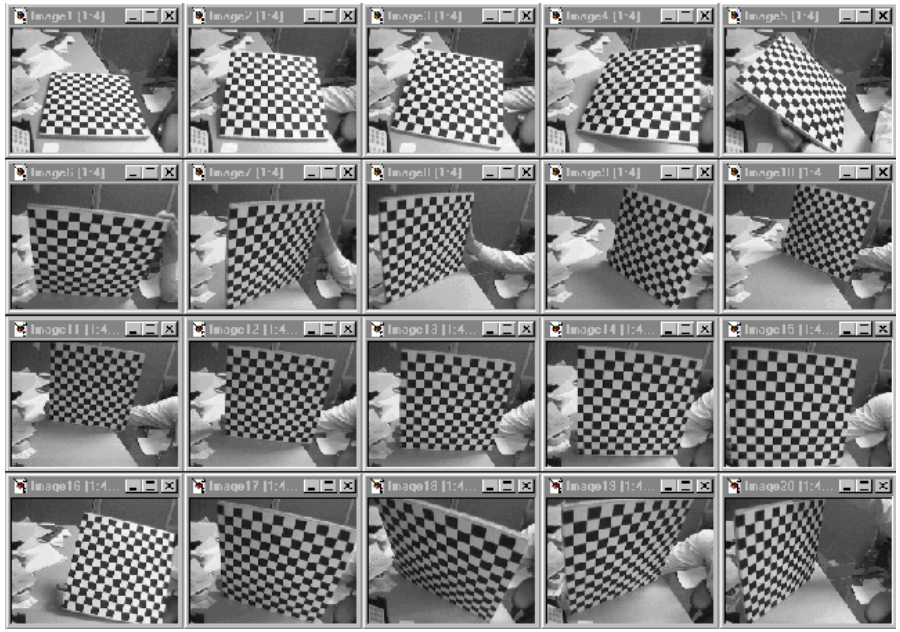


Figure: Armar III Head Kinematic Chain

Stereo Calibration - Classic

- checkboard pattern $\longrightarrow$ own coordinate system
- Each transformation between checkboard and left or right camera system determinable $\longrightarrow$ transformation between left and right camera



Stereo Calibration - Our Approach

- Kuka arm with high precision
- Tracking of LED attached to end effector
- Advantages:
  1. Camera-to-Arm transformation for free
  2. No restriction of point positioning $\longrightarrow$ Checkerboard has to be visible for both cameras
  3. Pattern uniform in image space

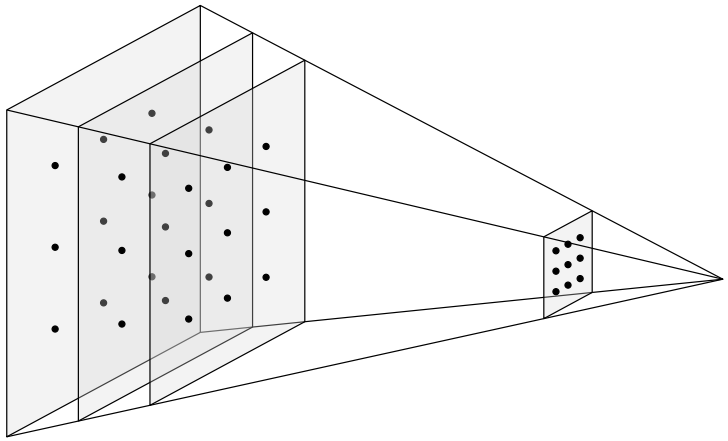


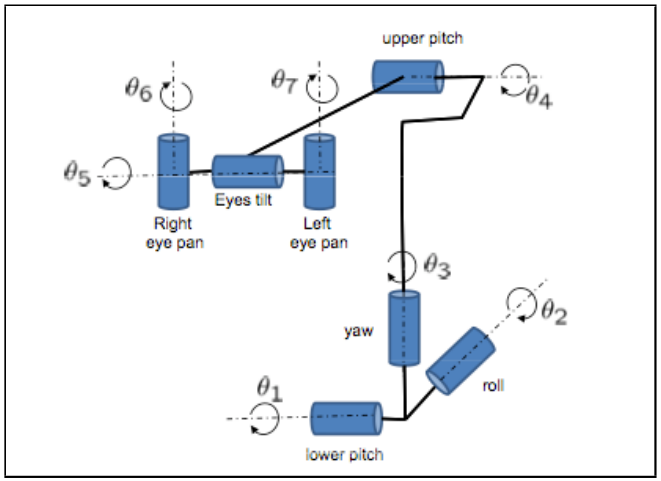
Figure: Movement pattern of end effector.

Stereo Calibration - Example Video

See `www.csc.kth.se/~bohg/calibVideo.mp4`

Head-Eye Calibration

- Head with 7 DoF $\longrightarrow$ 3 change epipolar geometry, 4 change pose of cameras relative to neck
- Mechanical inaccuracies affect center and axis of rotation
- repeatability issues remain $\longrightarrow$ online calibration & visual servoing



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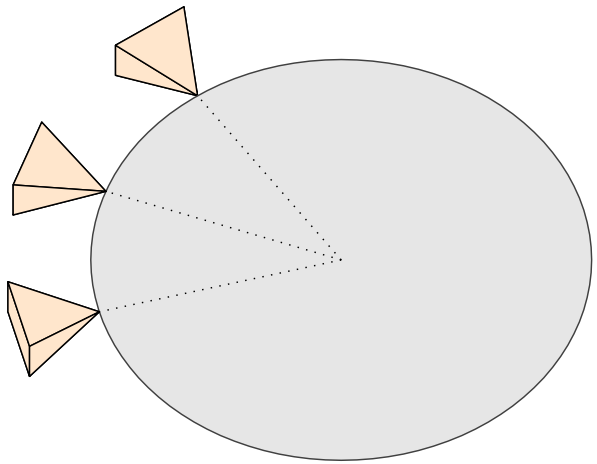
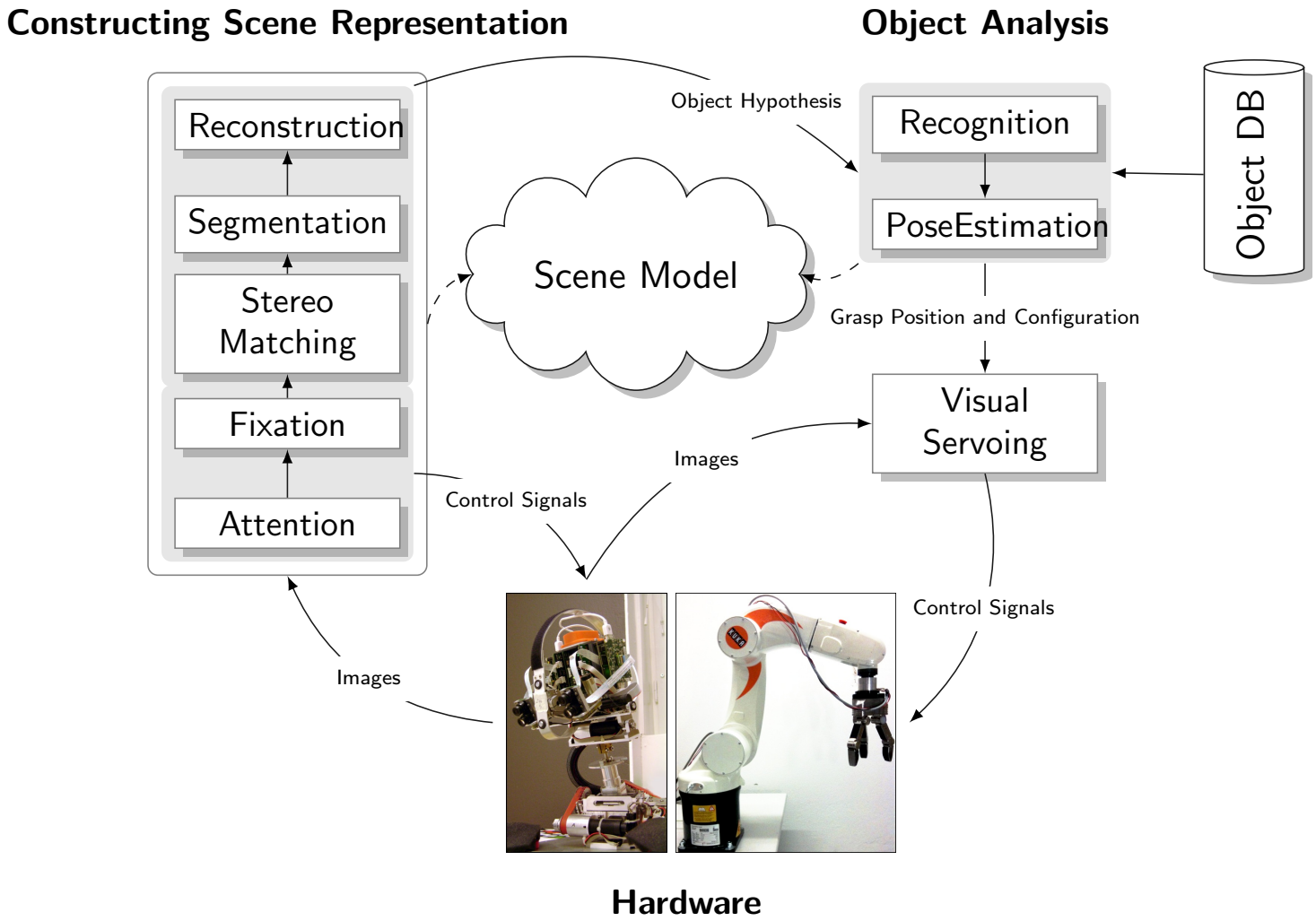


Figure: Three viewing directions of a camera rotated around one axis.

Computational processes involved

Task: Grasping Known Objects

Building up scene model independent of object knowledge



Attention for Scene Search

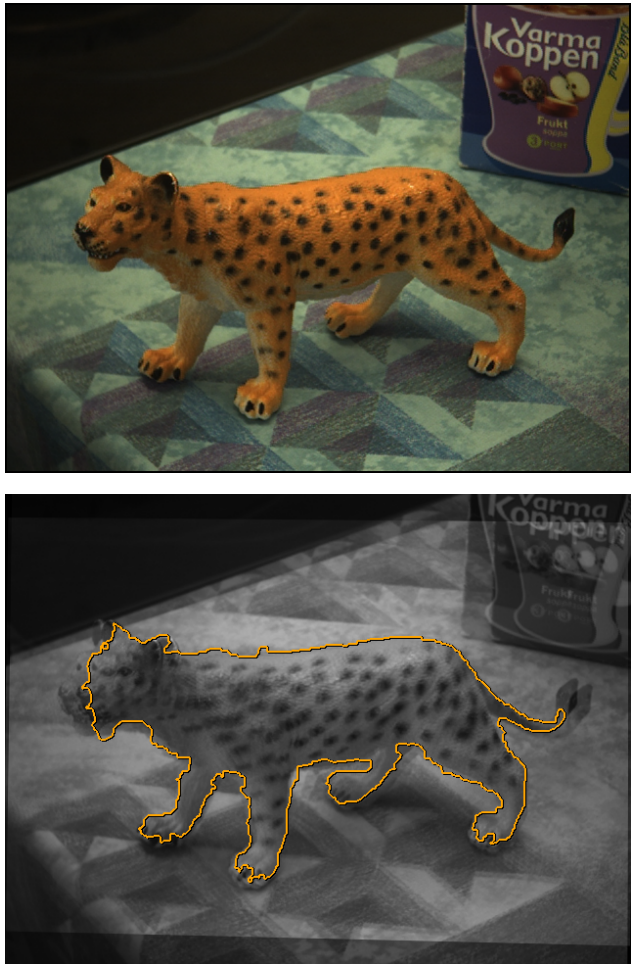
- Saliency Map on Wide-Field View (Itti & Koch Model)
- Peaks in the map = object hypotheses
- Gaze shift and Fixation triggered
- B. Rasolzadeh et al., IJRR 2009

Fixation, Online Calibration and Stereo Matching

- After gaze shift fixation to improve reconstruction
- Adjustment of vergence angle
- Goal: Highest density of points close to the center of images is at zero disparity
- Initial rectification from offline calibration
- Parallel to Fixation: Refinement through online calibration
  - Matching of Harris Corner features in left and right images
  - Affine essential matrix
- Stereo Matching with OpenCV
- B. Rasolzadeh et al., IJRR 2009, `www.csc.kth.se/~celle`

Foveated Segmentation of unknown objects

- Hard to segregate unknown object from supporting surface
  - In household environment, objects commonly placed on flat surfaces
  - Three hypotheses for each pixel: Foreground, background or surface
- Object Model: 3D shape and colour distribution
- Iterative process to strengthen hypotheses over time
- Similar to Expectation-Maximisation; approximate technique for real-time capability
- Initialisation through fixation point
- Björkman and Kragic, ICRA 2010, BMVC 2010

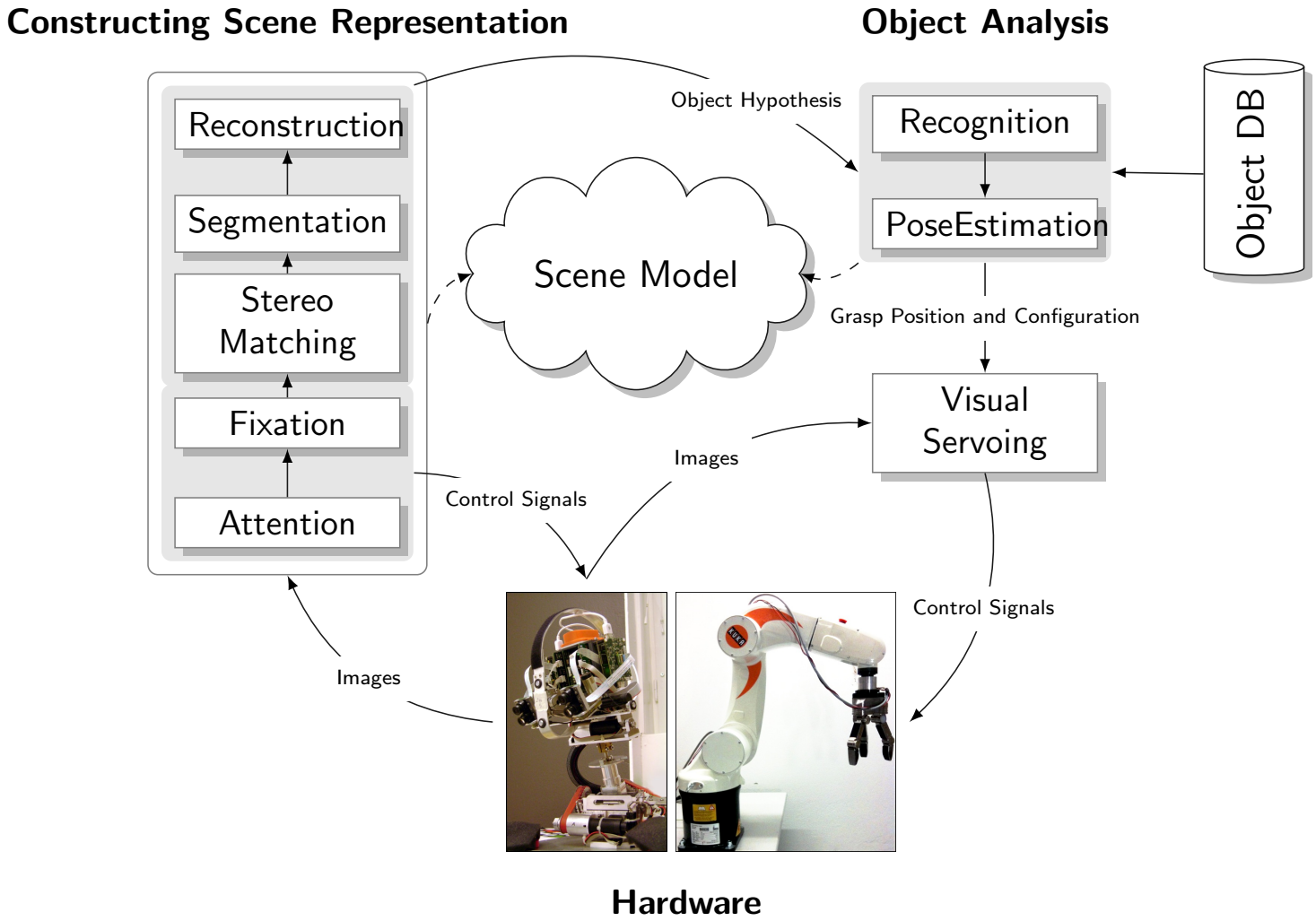


Resulting Scene Model

Five views merged together

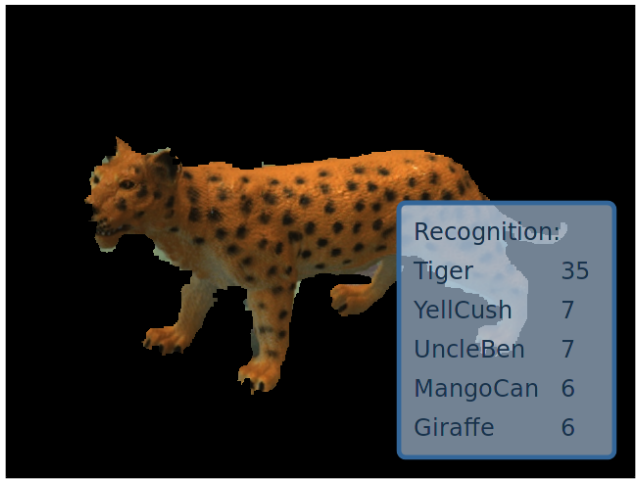
Initial Scene Model

Task: Grasping Known Objects



Recognition of Objects

- Two complementory cues: Color Co-occurence Histogram (CCH) and SIFT features (Bag-of-Words model)
- Object model learned offline from several viewpoints
- Online: Model matched against database with 25 objects
- M. Björkman and J-O. Eklundh, International Journal of Imaging Systems and Technology, 2006 and BMVC 2005



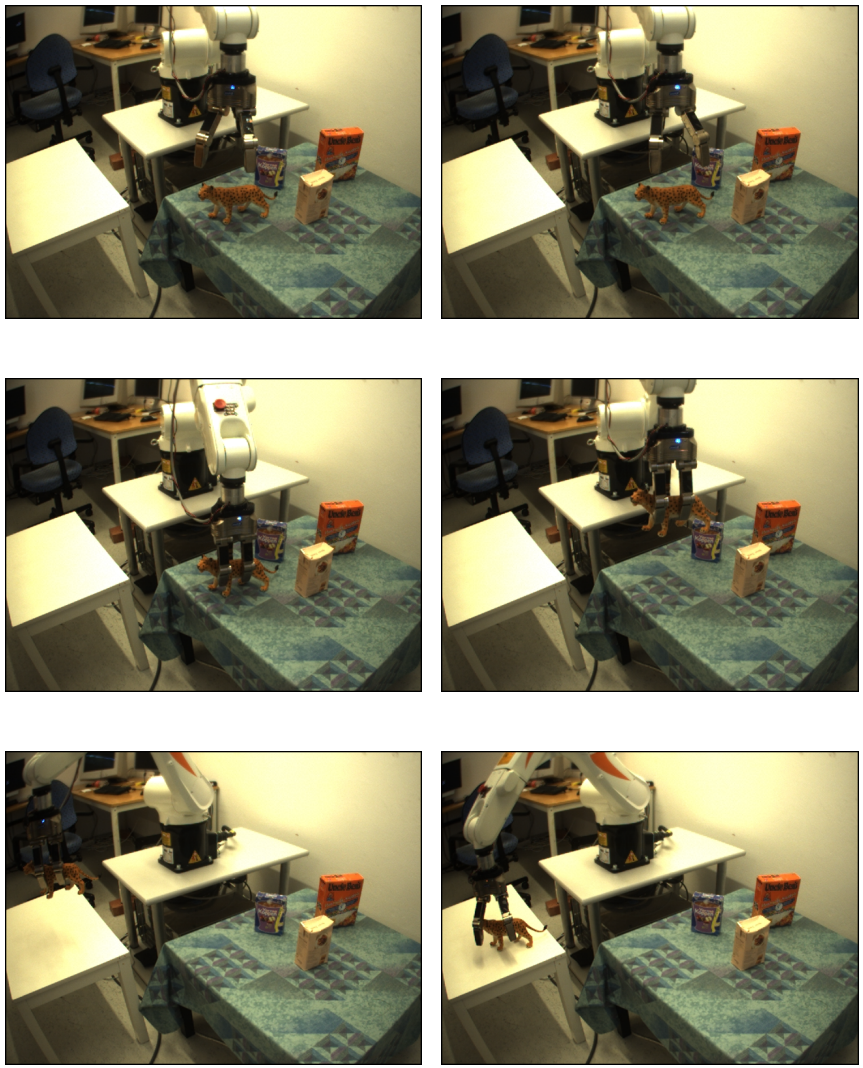
Pose Estimation

- Assumptions:
  - Objects can be approximated as either cylinders or boxes of known dimensions
  - Standing upright (cylinder) or on one of its surfaces (box)
- Given point cloud of a recognised object projected on the table $\rightarrow$ either rectangle or circle can be fitted to in 2D
- Initial guess with RANSAC
- refinement via minimisation of sum of absolute errors of each point to model (efficiently through a 2D distance map)
- another solution C. Papazov and D. Burschka, ISVC 2009, ACCV 2010

Figure: 3D Point Cloud (from two Viewpoints) and Estimated Object Pose.

Grasping the Objects

- Main focus of this talk: How to get to a scene representation suitable for grasping and manipulation?
- Grasping simplified to top grasps
- Pre-Shaping based on overall object shape
- position based visual servoing
  - LED on Hand aligned with desired position above object in the image
  - Hand lowered based on known object height
  - object is picked up and moved to side table



And now all together .....

See `www.csc.kth.se/~bohg/2010_IROS_WS.mpg`

Conclusions and Future Work

- We proposed an **Active Vision System** that **incrementally** builds up a **scene model** suitable for manipulation and grasping
- achieved through integrating different computational processes like
  - Attention
  - Fixation
  - Stereo Reconstruction
  - Segmentation
  - Recognition
  - Pose Estimation
  - Visual Servoing
- Initial scene model independent of object knowledge

Future Work - Grasping Unknown objects

- Really fresh work in collaboration with UJI Castellon, Spain
- Exploring the scene with the same processes
- Filling in the holes
- Manipulation planning in whole scene

Future Work - Augmenting Initial Scene Model with Haptic Information

- Talk on Thursday here at IROS 2010
- No Grasping, but haptic exploration to fill in the holes in the scene model
- See `www.csc.kth.se/~bohg/IROS2010Grasp.mp4`

Thank you for your attention!

This works has been supported by the EU project GRASP.