Indirect Object Search based on Qualitative Spatial Relations

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### How can autonomous mobile robots find objects in largescale environments?





BHAM Computer Science Building (upper ground floor)



Combining semantic environment maps, common sense knowledge about object locations, and utilities in a decision theoretic approach *[IROS 11, ICRA 12]* 



Semantic map of Engineering Building No 2 (University of Tokyo)



Probabilities of objects in rooms extracted from the Open Mind Indoor Commen Sense (OMICS) database



## Where to search for an object in a given room? *Where to stand? Where to look?*







Assumption: Objects rest on surfaces

3D map of the environment



Extracted supporting planes based on normal estimations





# Weighting of view cones lets the robot face supporting planes



Search at three poses







low



## Can we exploit the structure of real-world office environments?







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### What are Qualitative Spatial Relations (QSRs)?







QSR models capture the relation of objects in space

 $scene(Monitor, Keyboard, Laptop, Cup, Bottle) \Leftrightarrow$   $in-front-of(Keyboard, Monitor) \land$   $left-of(Laptop, Keyboard) \land$   $right-of(Cup, Keyboard) \land$   $behind-of(Bottle, Cup) \land$ close-to(Bottle, Cup).



## From QSRs back to metric positions

Given a set of qualitative scene descriptions:



We generate object positions using the *Ternary Point Calculus [Moratz et al 2003]* by sampling a **relative angle** and **distance** 





Gaussian mixture models represent relative positions of an object

$$P_{QSR_{rel}}(\mathbf{x}|\lambda) = \sum_{i=1}^{m} w_i \mathcal{N}(\mathbf{x}|\mu_i, \Sigma_i)$$

Cup wrt Monitor

Cup wrt Keyboard





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### Using QSR models improves weighting of view cones



$$\underset{\psi \in \Psi}{\operatorname{argmax}} \sum P_{QSR}(v_i) In(v_i, Viewcone(\psi))$$







## Supporting planes







QSR







### Object search experiments in simulation

Search method	#found	avg time (sec)	avg #poses
Random	6/10	68.5	4.8
Supporting planes	10/10	33.6	2.3
QSR	10/10	15.7	1.1
QSR (partially correct)	8/10	55.0	3.1





## Integration on the real robot [ICRA 14, under review]













### Conclusions & Future work

- QSR-models can improve the search for objects
- Logical queries can also prune the GMM models at query-time

#### QSRs

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#### **Future Work**

- Planning for next view
- Exploration vs Exploitation



Thank you for your attention! Questions?



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