

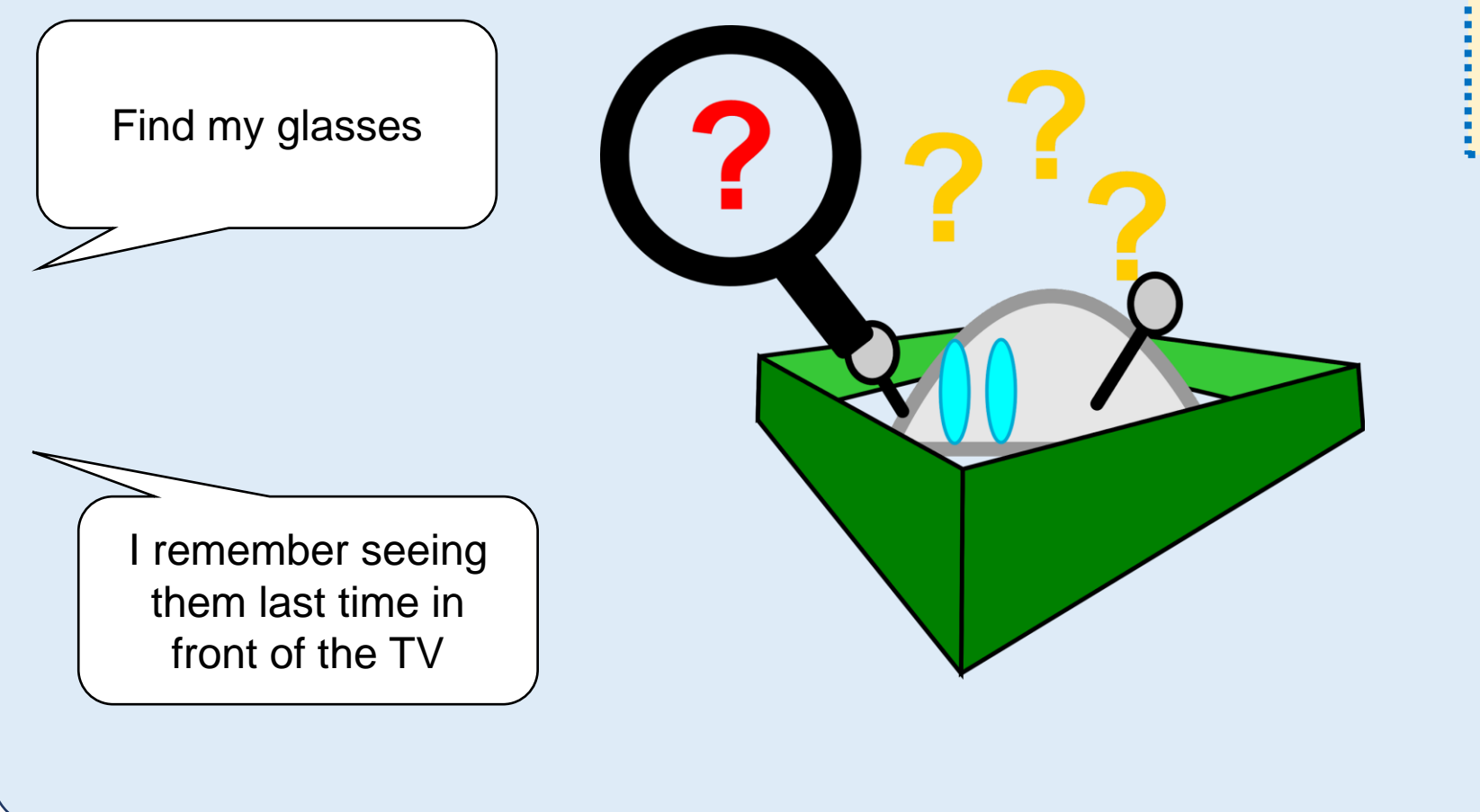
Robot Acting and Interacting Under Partial Observability and Perceptual Uncertainty

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Motivation

Uncertainty is a primary challenge that robots must handle to be competent in many complex, **human-centered** domains.

Motivating example: helping an elderly person find a missing pair of glasses



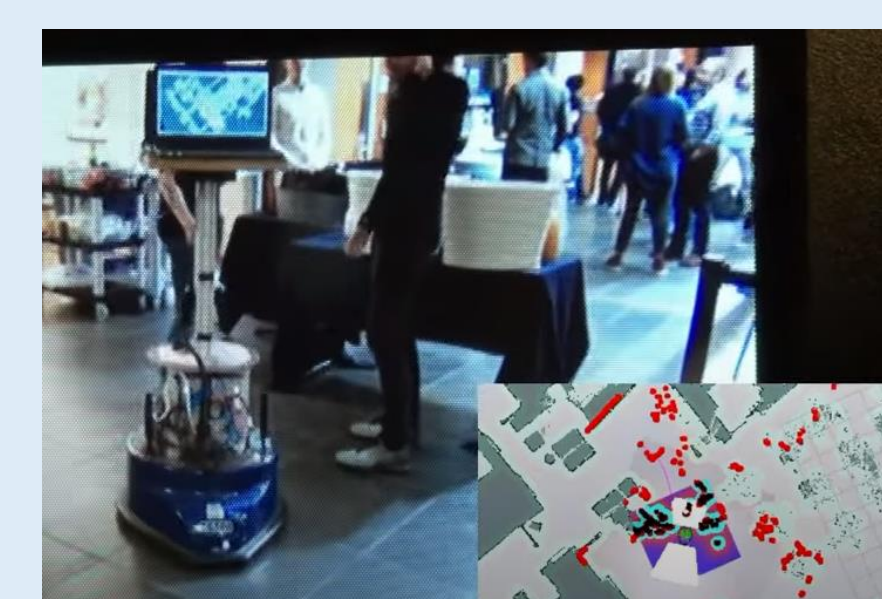
requires

Act under [constantly present] uncertainty about where are the glasses? (partial observability)
what is the robot looking at now? (perceptual uncertainty)
what will the robot observe if it performs an action? (perceptual uncertainty)

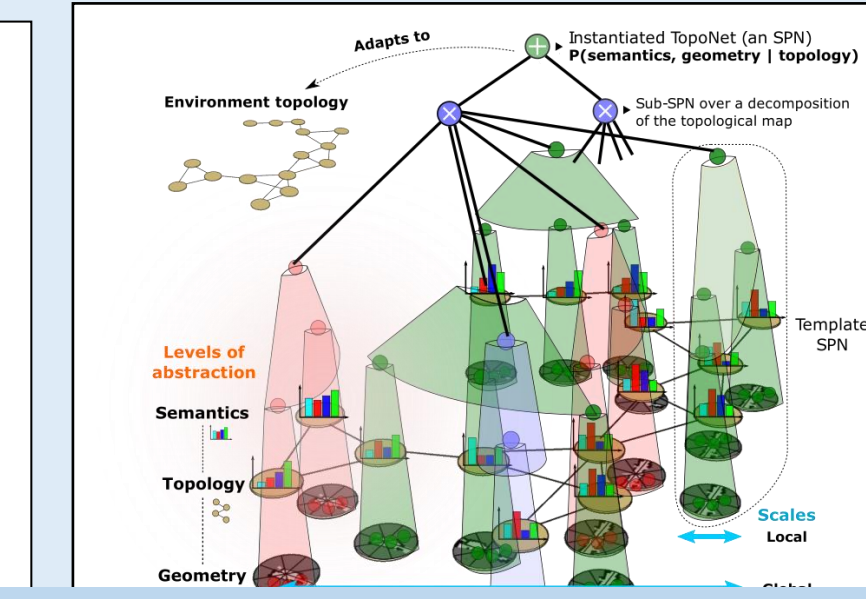
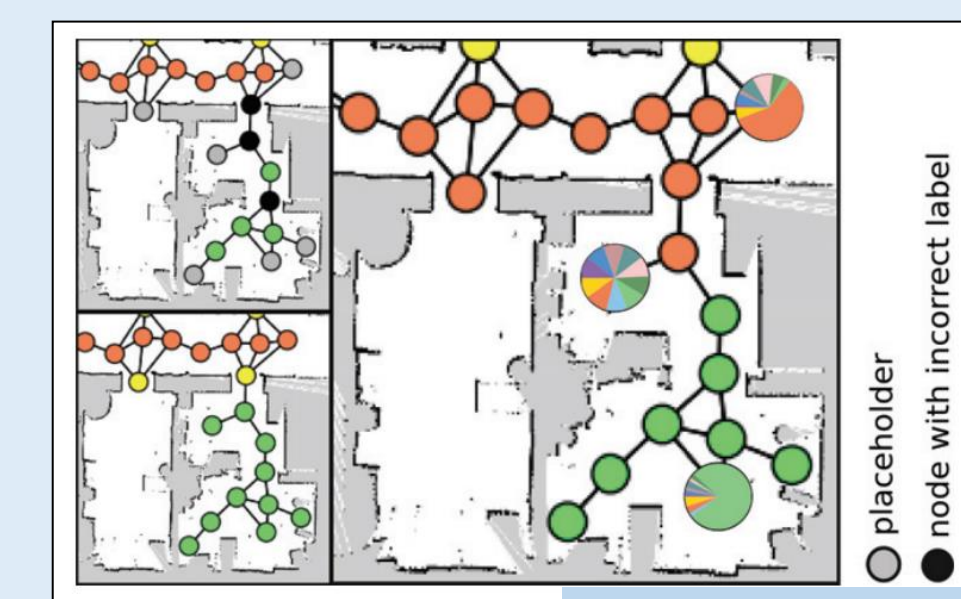
Interact with humans through natural language [subjective, ambiguous]

My long-term research goal is to enable robots to **act in the human world** and **interact with humans in a principled manner**.

Research Overview



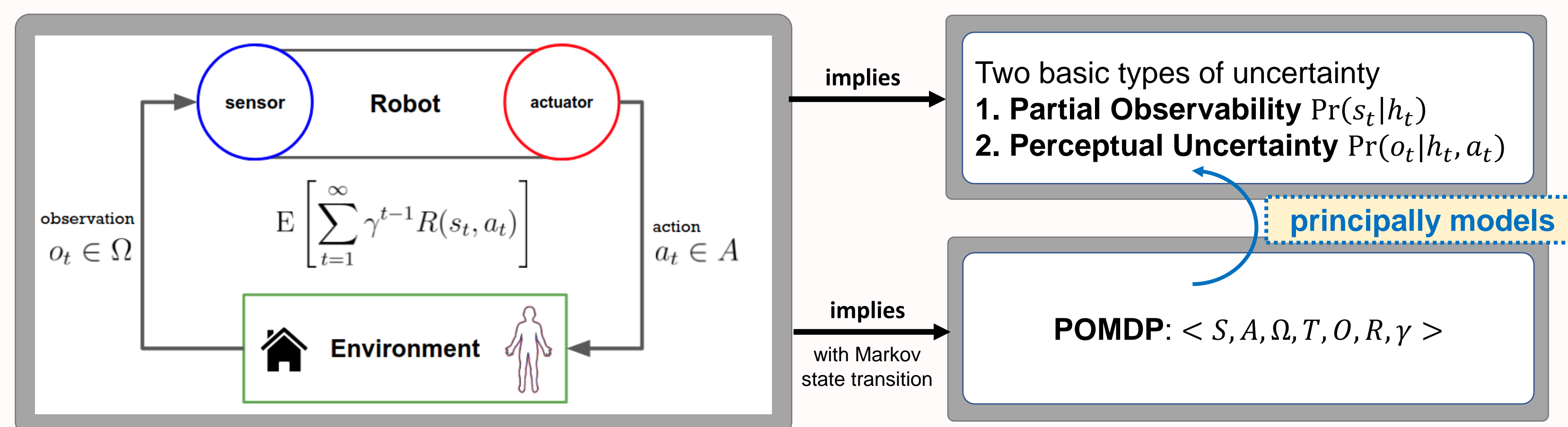
Mobile robot navigation [Z ROS Book'21]



Large-scale semantic mapping and probabilistic modeling of spatial knowledge [ZP IROS'19] [ZPR AAAI'18]

Uncertainty in robot perception (earlier work)

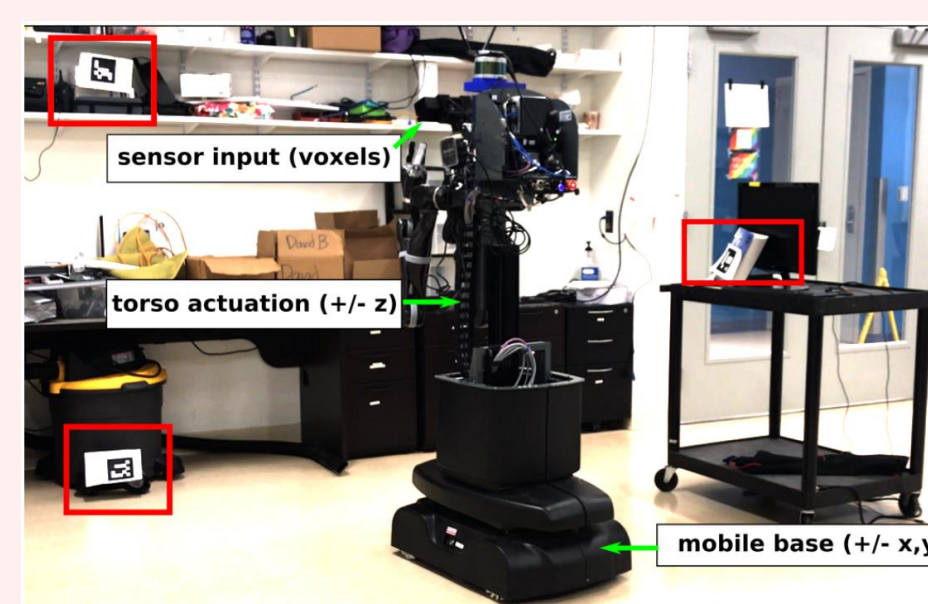
Current Methodology



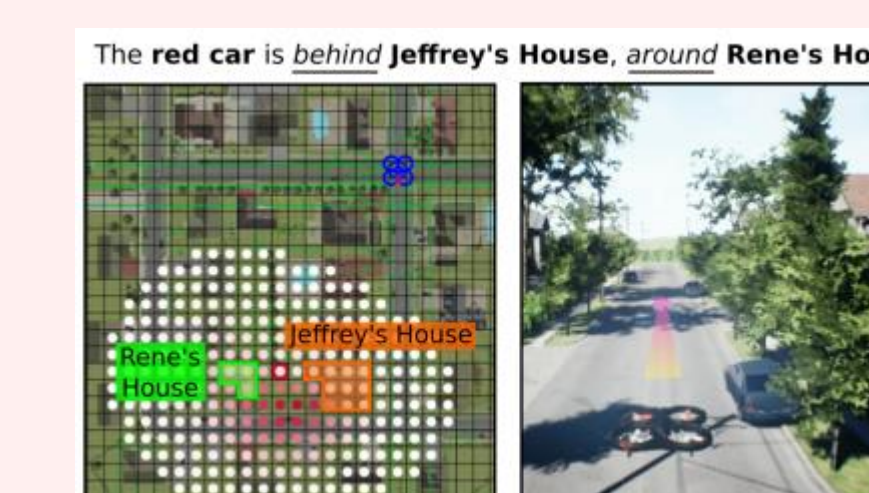
Solving POMDPs for real world problems is computationally prohibitive. Our **key idea** is to **exploit structures in the human world** (e.g., octrees, correlations) and **human-robot interaction** (e.g, spatial language), which significantly reduces unrealistic compromises that previous work make (such as constraining to 2D and object independence). Decision-making is primarily based on general-purpose online POMDP planning algorithms (e.g. POUCT) with problem-specific adaptations.

Hierarchical POMDP planning for Correlational object search

Multi-resolution POMDP planning for 3D object search based on **octrees**



Spatial language understanding for object search in urban areas



Dialogue object search



Interact

[ongoing; presented at RSS R4P Workshop 2021]

Act

[ZSKT IROS'21] IROS RoboCup Best Paper



[ZCSKT ICRA'22]

Uncertainty in robot decision making (PhD research)

Also: open-source library for POMDPs [ZT ICAPS WS'20]

pomdp_py

Selected Publications

Kaiyu Zheng, Rohan Chitnis, Yoonchang Sung, George Konidaris, Stefanie Tellex. "Towards Optimal Correlational Object Search." *IEEE International Conference on Robotics and Automation (ICRA)*, 2022.

Monica Roy*, **Kaiyu Zheng***, Jason Liu, Stefanie Tellex. "Dialogue Object Search." (Extended Abstract) *Robotics: Science and Systems (RSS) Workshop on Robotics for People: Perspectives on Interaction, Learning, and Safety*, 2021.

Kaiyu Zheng, Deniz Bayazit, Rebecca Mathew, Ellie Pavlick, Stefanie Tellex. "Spatial Language Understanding for Object Search in Partially Observed Cityscale Environments." *IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, 2021.

Kaiyu Zheng, Yoonchang Sung, George Konidaris, Stefanie Tellex. "Multi-Resolution POMDP Planning for Multi-Object Search in 3D." *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2021. **IROS RoboCup Best Paper Award**

Kaiyu Zheng. "ROS Navigation Tuning Guide." *Robot Operating System (ROS) - The Complete Reference (Volume 6)*, edited by Anis Koubaa, Springer, Cham, pp 197-226, July 2021.

Kaiyu Zheng, Stefanie Tellex. "pomdp_py: A Framework to Build and Solve POMDPs." *International Conference on Automated Planning and Scheduling (ICAPS) Workshop on Planning and Robotics (PlanRob)*, 2020. [Github: <https://github.com/h2r/pomdp-py>]

Kaiyu Zheng, Andrzej Pronobis. "From Pixels to Buildings: End-to-end Probabilistic Deep Networks for Large-scale Semantic Mapping." *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2019.

Kaiyu Zheng, Andrzej Pronobis, Rajesh P. N. Rao. "Learning GraphStructured Sum-product Networks for Probabilistic Semantic Maps." *AAAI Conference on Artificial Intelligence (AAAI)*, 2018.

Future Work

Short-term: Focus on the dialogue object search problem and develop a system capable of deciding what to say and how to act simultaneously, and conduct experiments with human subjects.

Long-term: Keep working on **human-centered domains** and the importance of interaction through natural language. Continue to address decision-making under **uncertainty** especially partial observability, with the intention to build real, practical systems; Expand solution methods to data-driven approaches and learning + planning. Expand to domains involving object interaction.