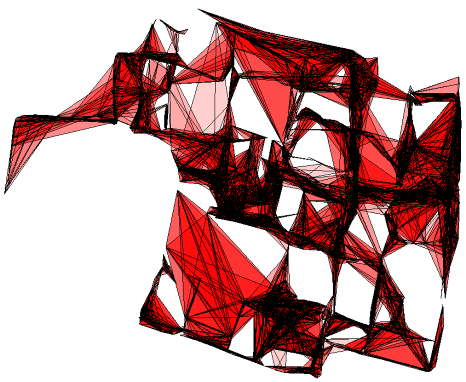
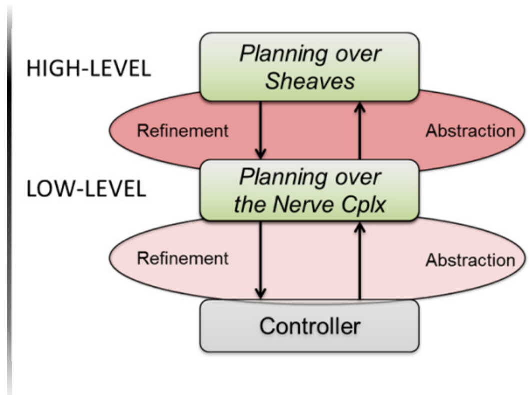
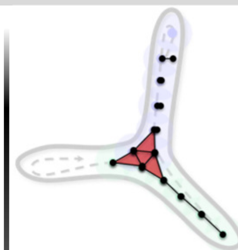
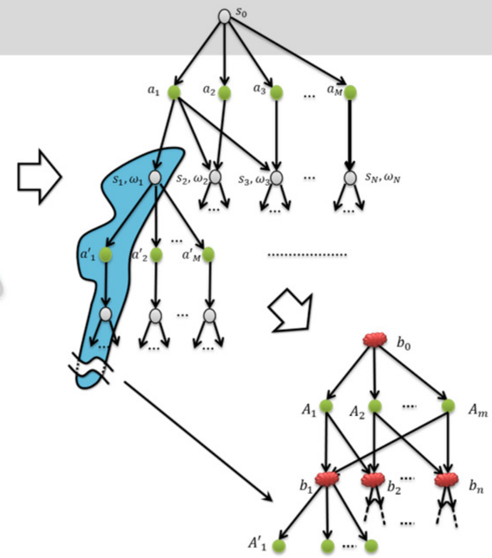
Localization and Planning For Autonomous Systems Via (Co)homology Computation









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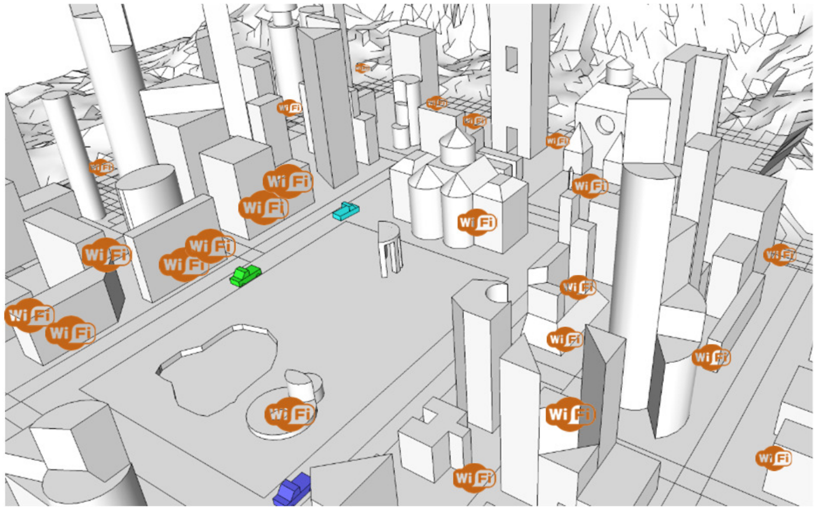
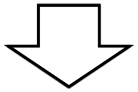
* Work done when at UTRC

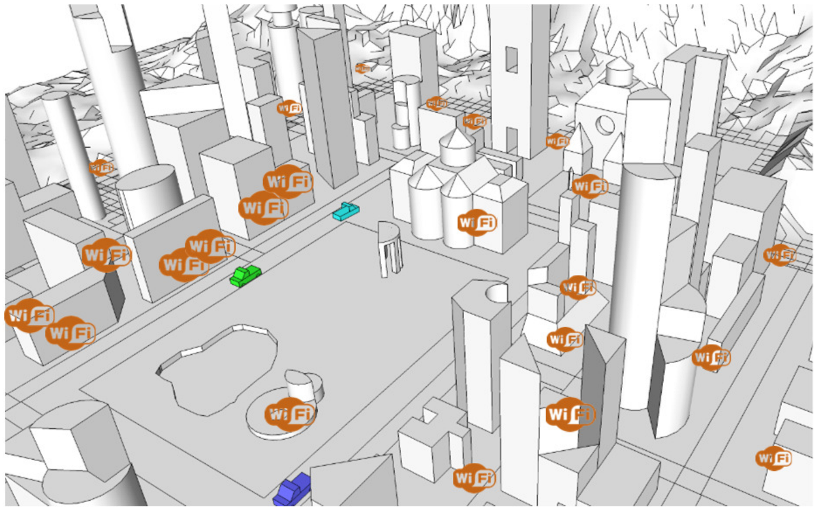
Leveraging Qualitative Information





- Uncoopertive environment
- No knowledge of location
- No knowledge of infrastructure
- Prior information

Leveraging Qualitative Information



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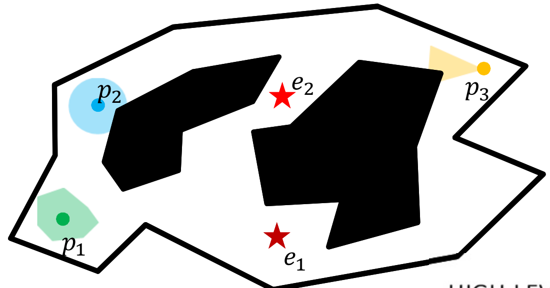
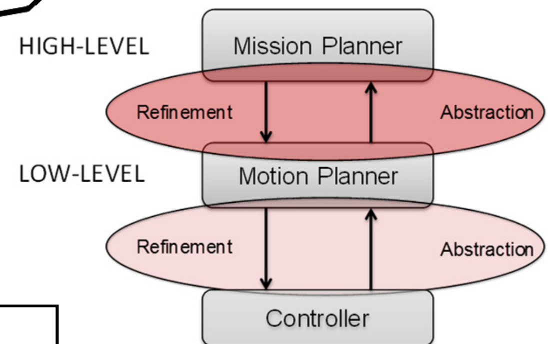
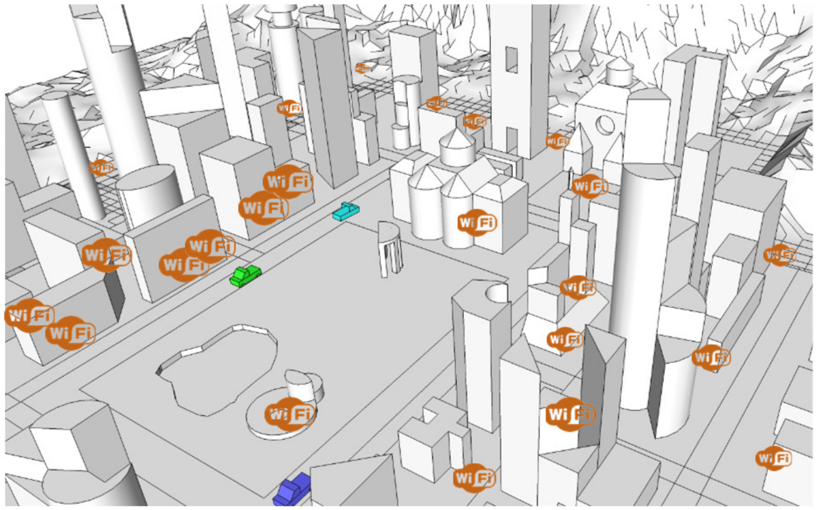


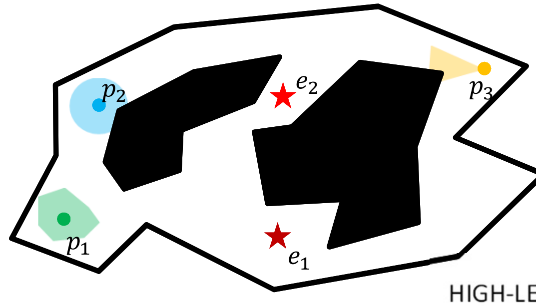
Pursuit evasion Planning



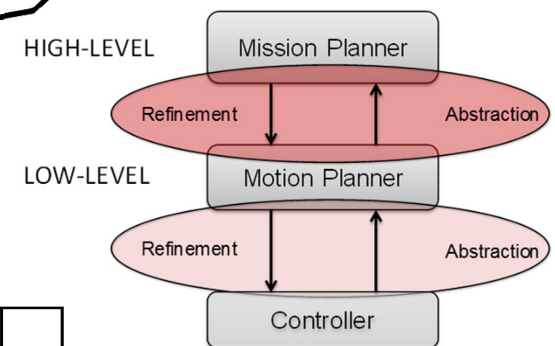
- Qualitative & compressed abstraction of domain at high level
- Combinatorial representation that capture sensing capabilities

Leveraging Qualitative Information





Pursuit evasion Planning



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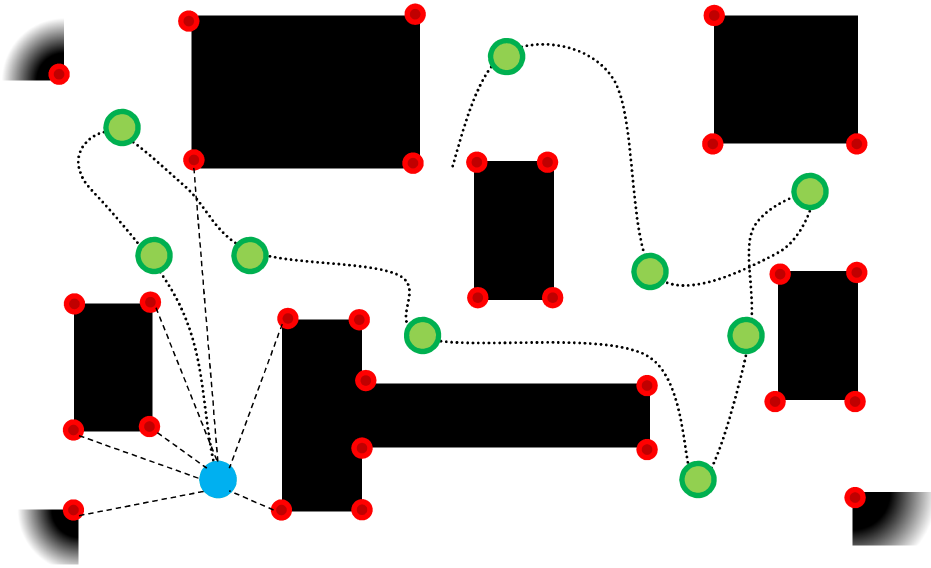
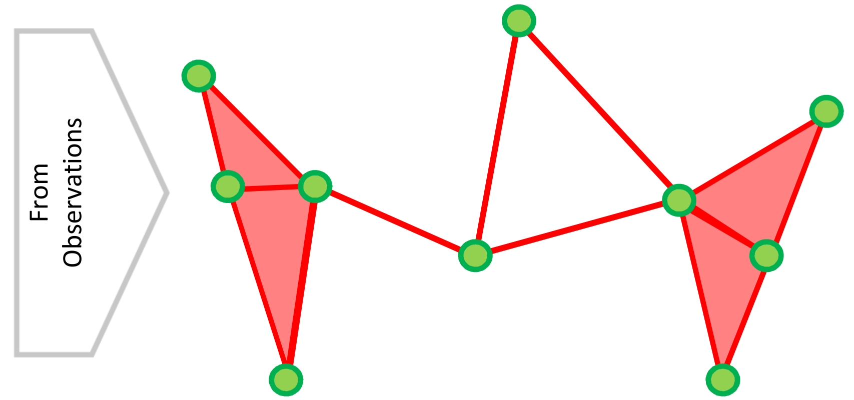
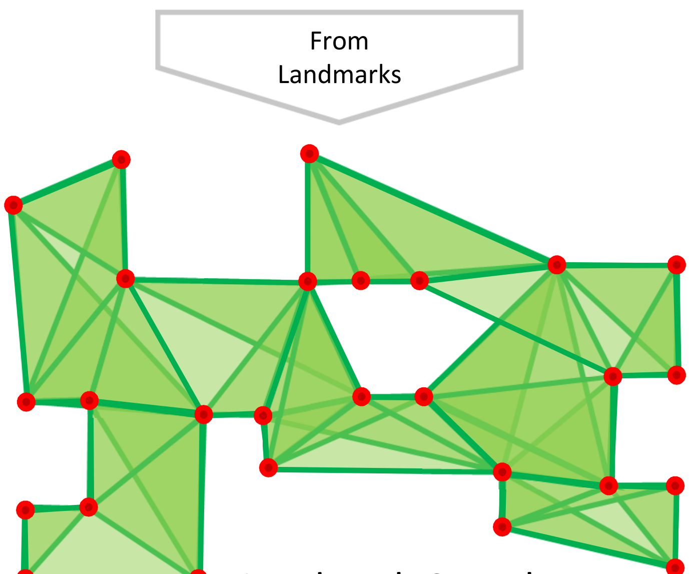
Simplicial Complex
Sheaves
(Co)Homology

Localization





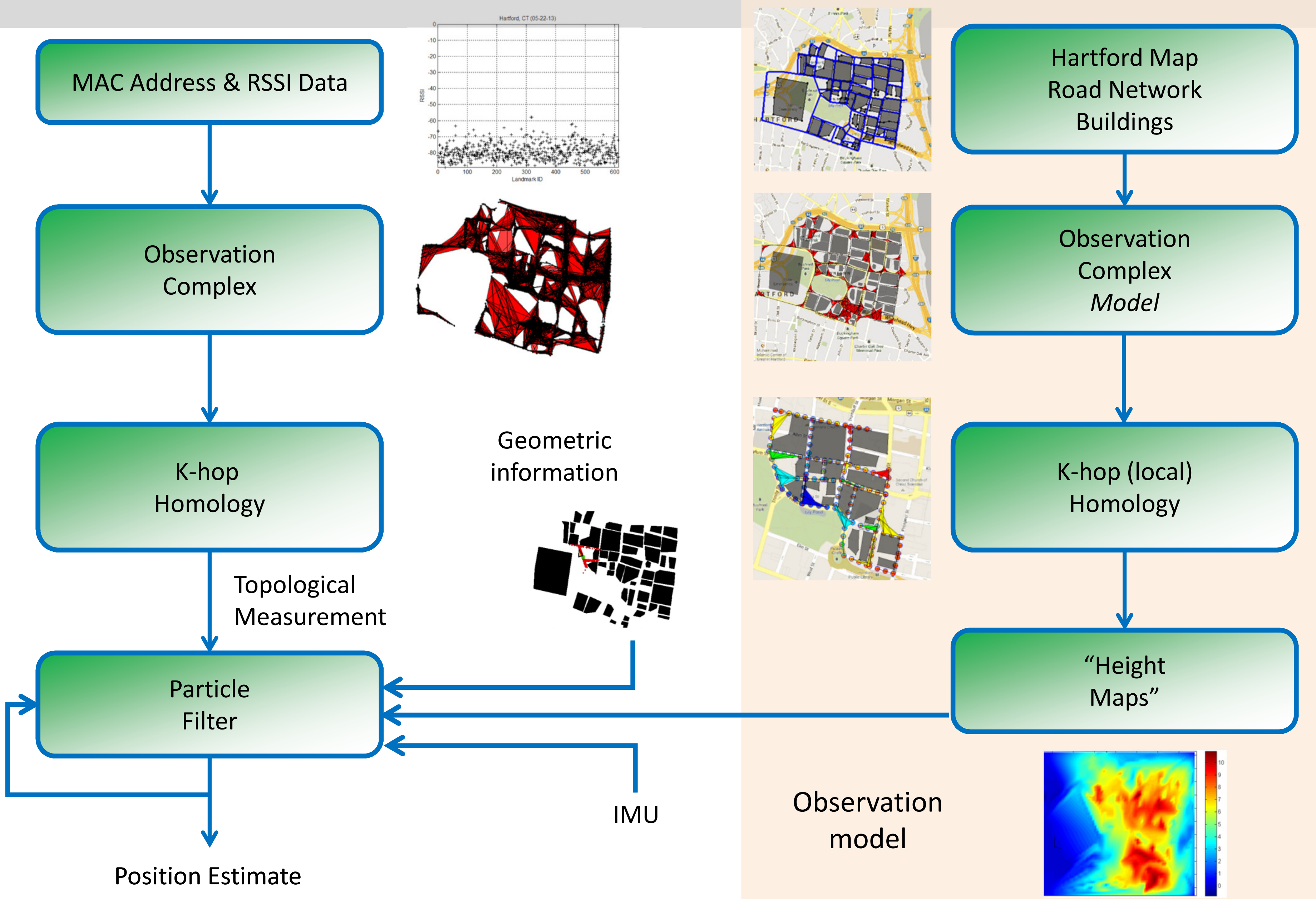
Observation Complex



Landmark Complex

- From local independent observations of landmarks, simplicial representations of the environment are created (*Dowker Complex*)
- Simplices are glued together by commonly sensed landmarks
- A topologically-faithful global representation of the environment is built from purely non-geometric observations

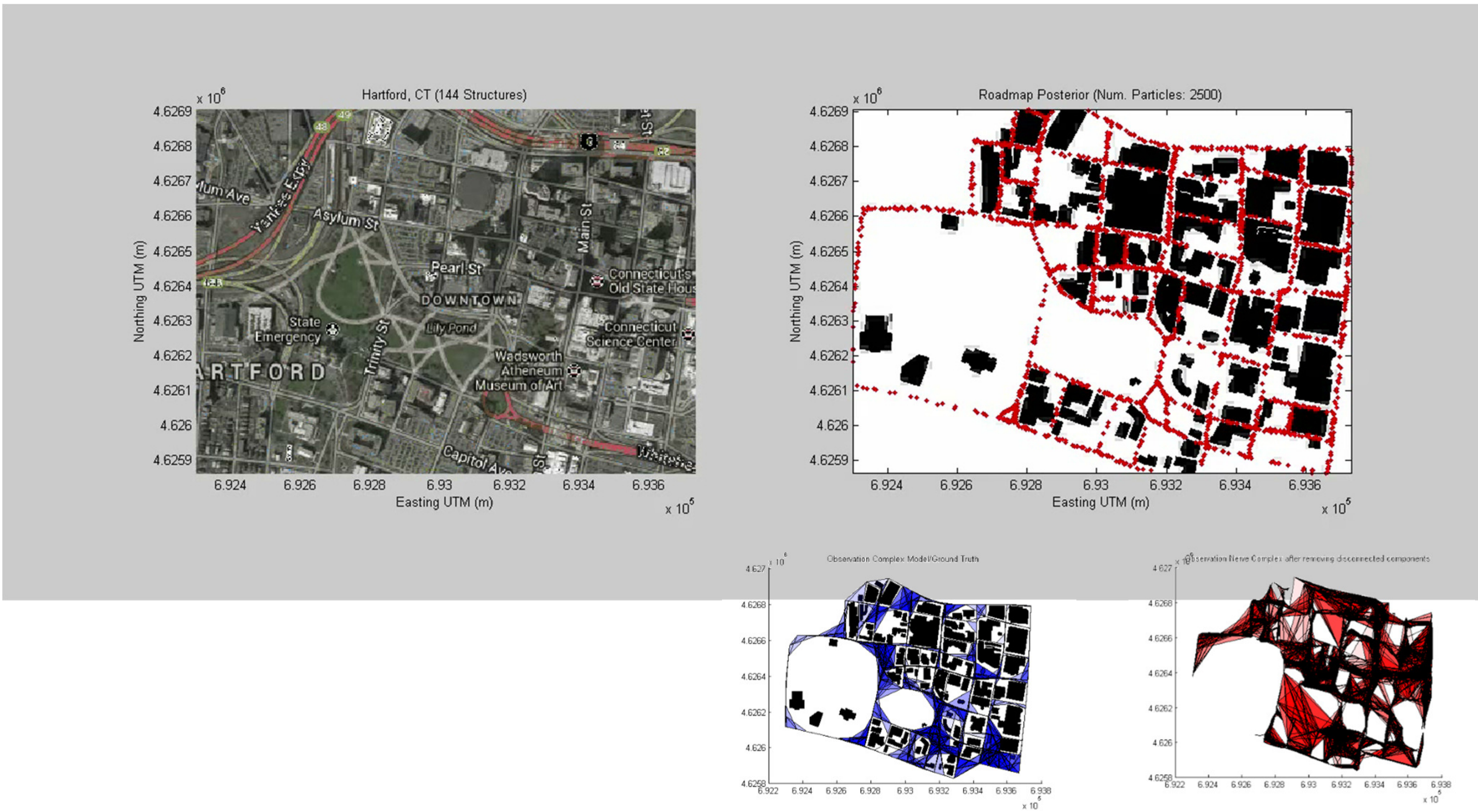
Filter Pipeline



Full Closed Loop w/ Real WiFi Local Homology

Particle Filter Status/Demo

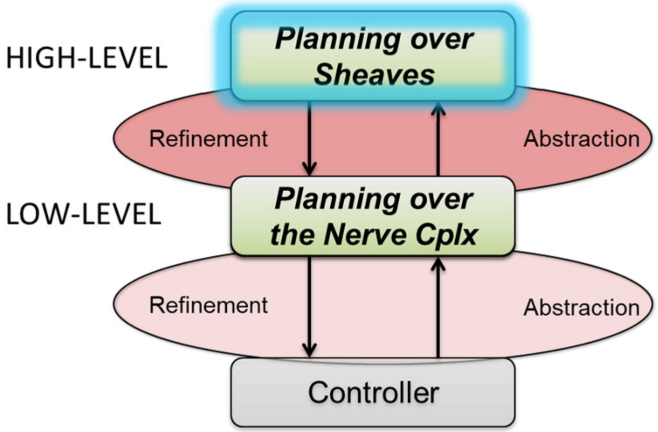
- **Prediction:** uStrain IMU (accels + gyros)
- **Correction:** Only WiFi Local Homology

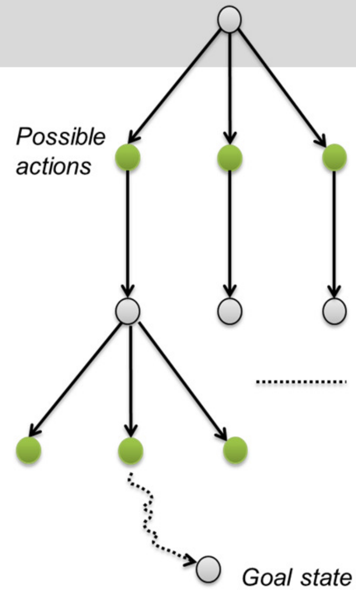


Higher-Level Planning

$$\mathcal{T} = (S, A, T, S_{goal}, S_{init})$$

- Hierarchical Planning

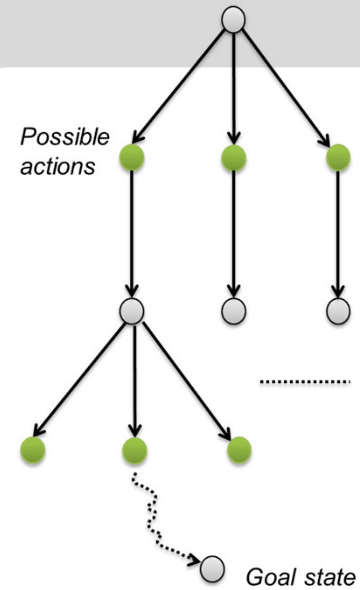




Markov Decision Process

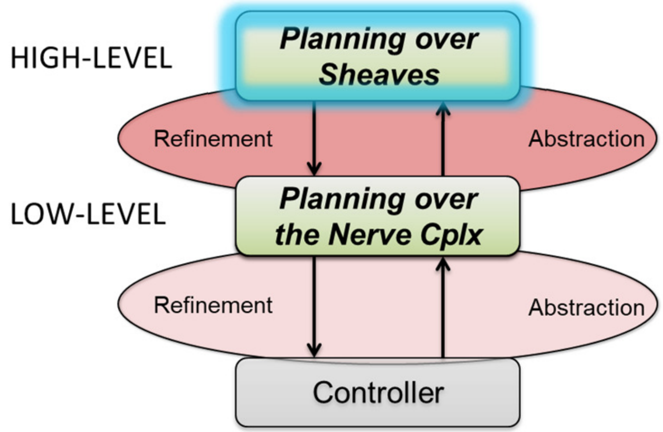
Higher-Level Planning

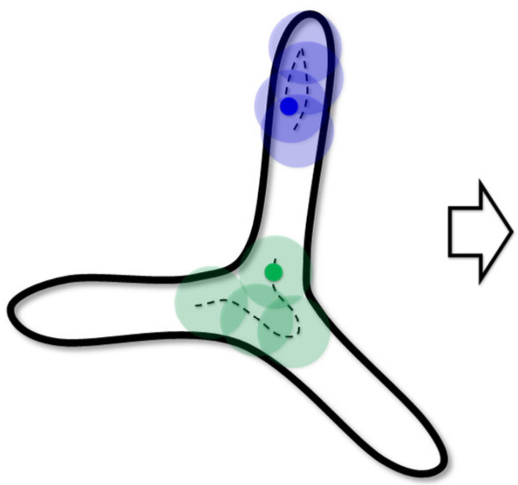
$$\mathcal{T} = (S, A, T, S_{goal}, S_{init})$$

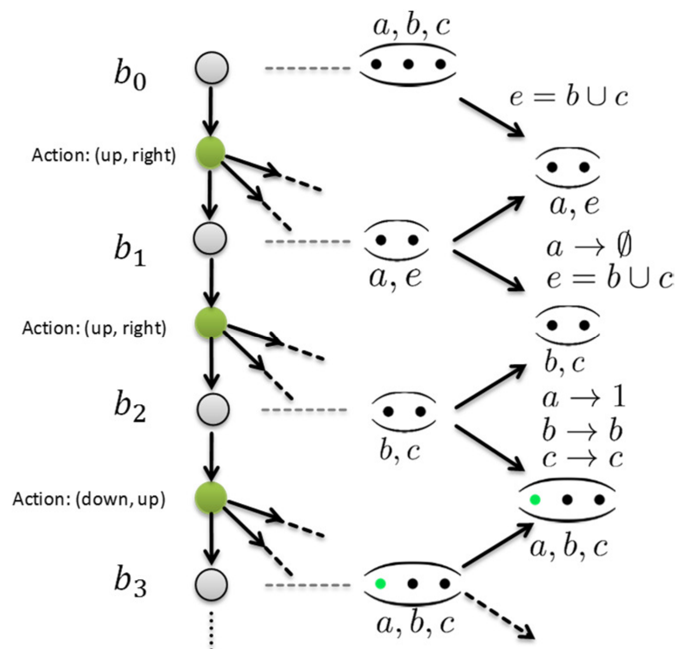


Markov Decision Process

- Hierarchical Planning





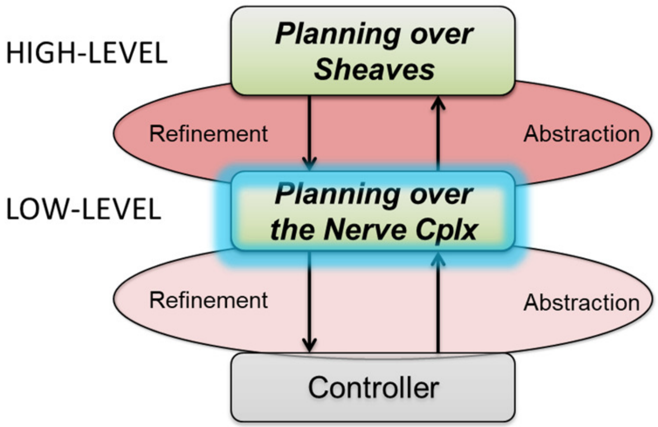


Sheaf "keeps track" of connective components over actions sequences

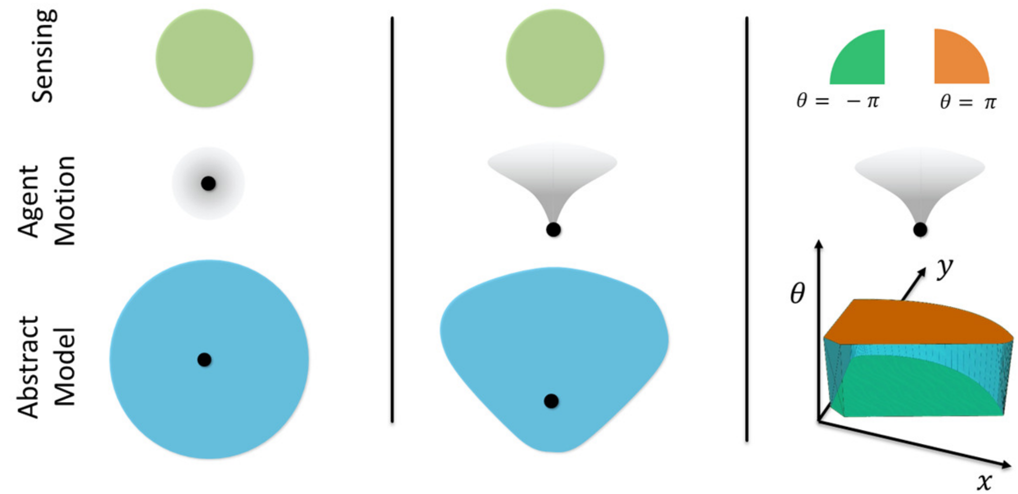
If global section then evader escapes

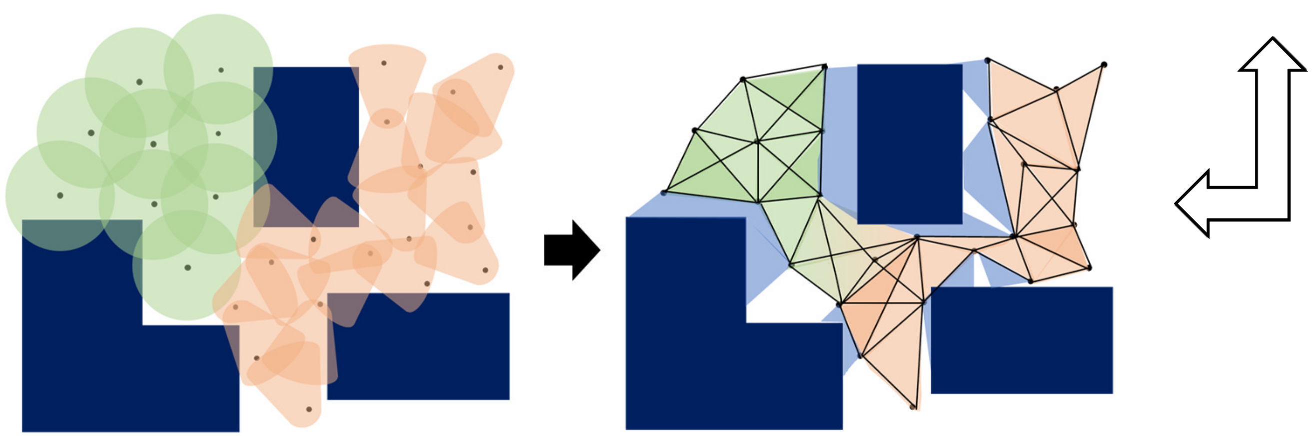
Lower-Level Planning

- Hierarchical Planner



- Given:
  - Sensing model of agents
  - Motion model of agents
- We can build low-level model that capture various details:

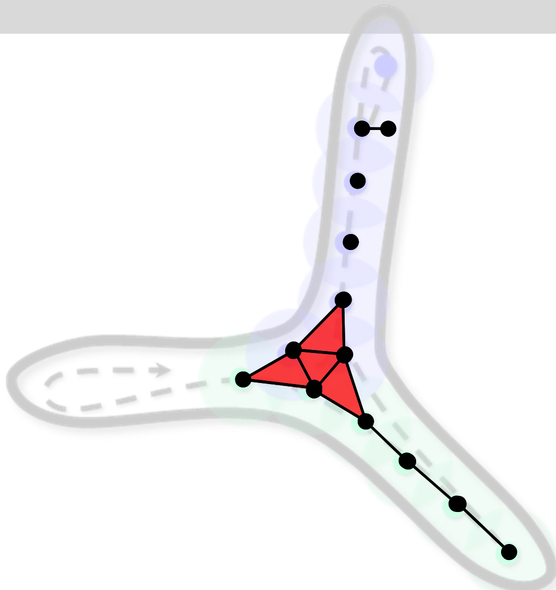


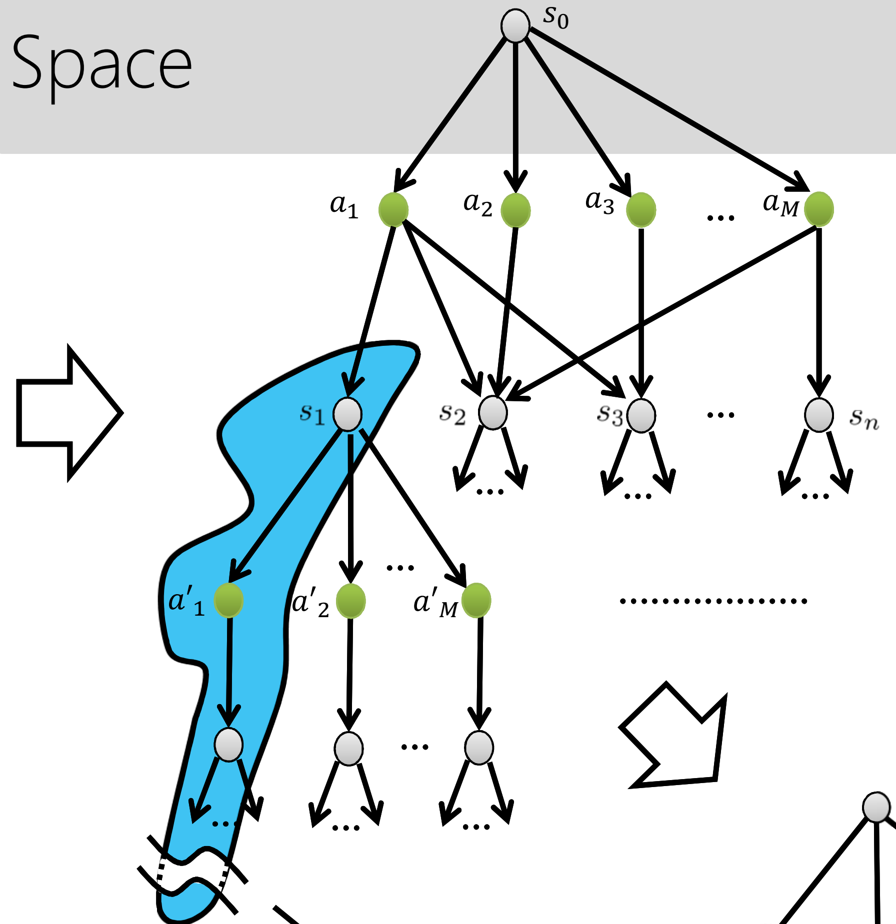


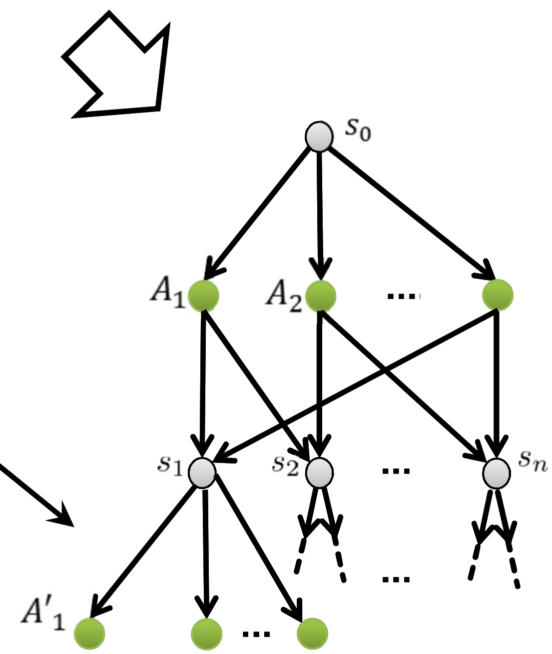
Space is sampled and motion-based sensor footprints of different vehicles are associated to different points

The nerve complex associated to the motion-based sensor cover is constructed including buildings

Compressed Search Space





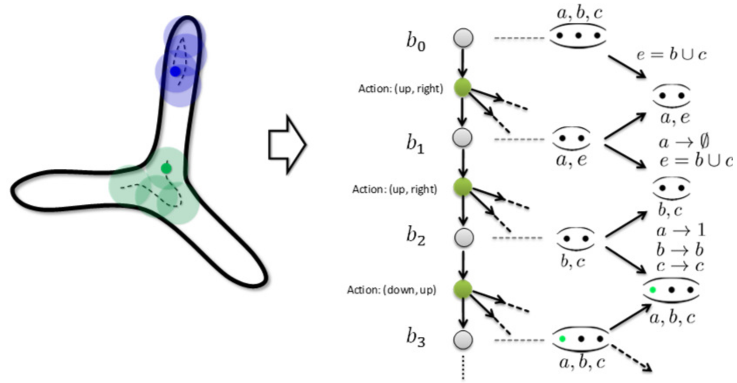


- Generate the transitions system T from action $\mathcal{A}$ and state $\mathcal{S}$ for a specific environment

- A sub-tree/sub-branch of the full T can be ‘collapsed’ into a single state and action based on the number of connected components obtained using the nerve construction: $A'_1 = \{a_{i_1}, a_{i_2}, a_{i_3}, \dots\}$

Encoding Challenge Scenarios

Domain Size
& Topology



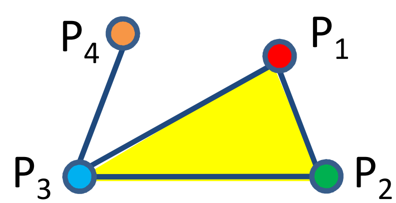
Sensing & evasion
sheaves

Evader Capture
Criteria

$E_1 = P_1P_2 + P_1P_3 + P_4$
$E_2 = P_2P_3 + P_2P_4$
$E_3 = P_1P_2P_3 + P_1P_3P_4$

Augment sheaf stalks;
build ***escape*** *and* ***capture complex***

Communication
Network



Factor into base space
as ***communication complex***