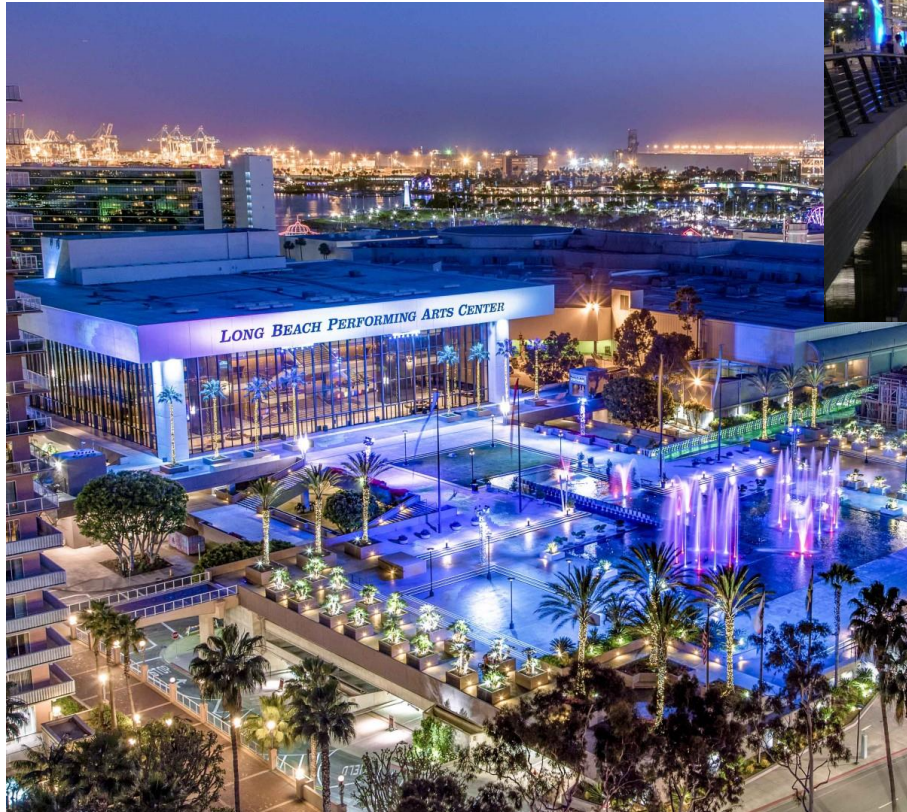


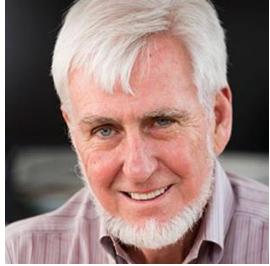
Grid Cell-Inspired Fragmentation and Recall for Efficient Map Building

Jaedong Hwang, Zhang-Wei Hong, Eric Chen,
Akhilan Boopathy, Pulkit Agrawal, Ila Fiete

Conferences are held in various locations and usually very complex



Place Cell and Grid Cell




John O'Keefe
(1971)



May-Britt & Edvard I. Moser
(2005)

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*The Nobel Assembly at Karolinska Institutet
has today decided to award the*

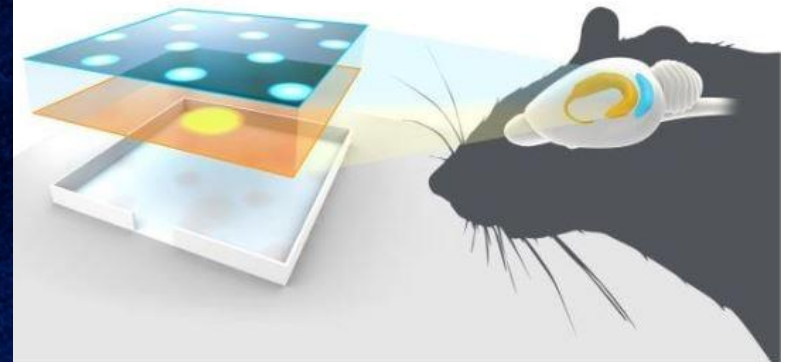
**2014 NOBEL PRIZE IN
PHYSIOLOGY OR MEDICINE**

to:

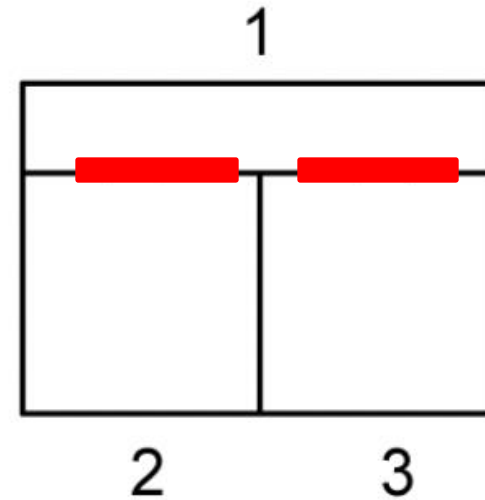
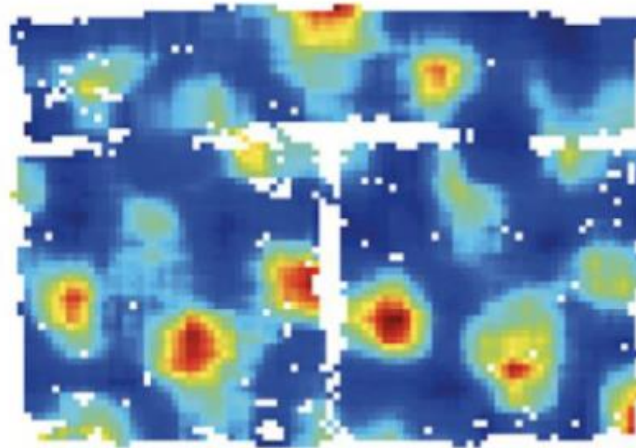
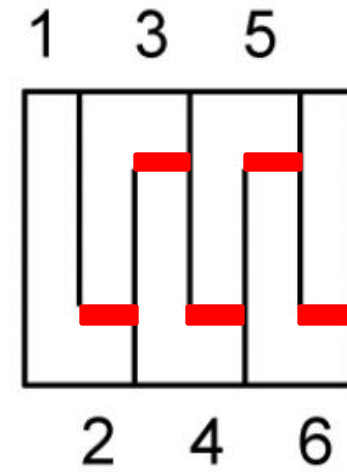
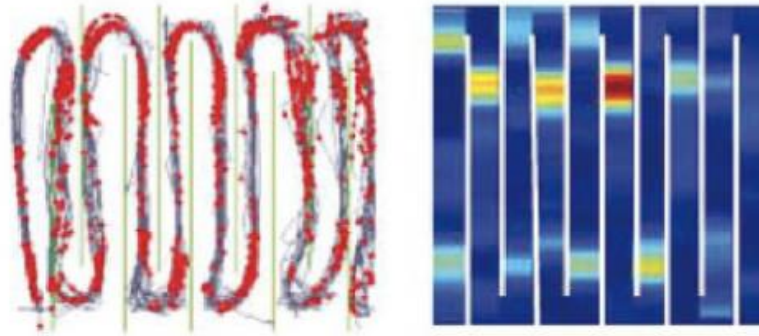
**John O'Keefe
May-Britt Moser
Edvard I. Moser**

*"for their discoveries of cells that constitute a
positioning system in the brain"*

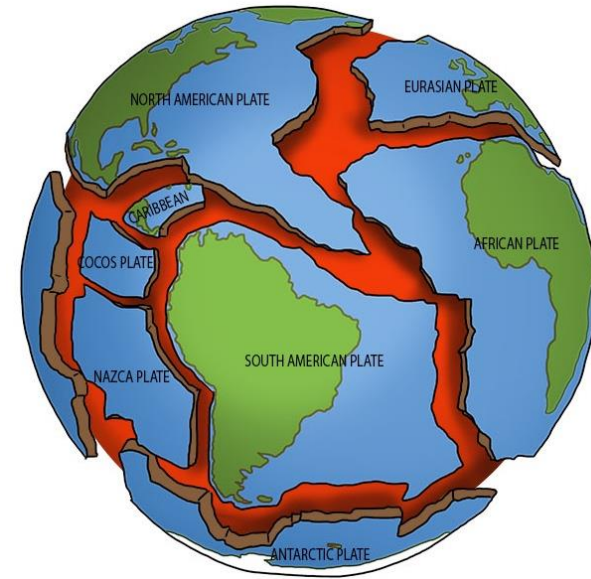
 **Nobelprize.org**
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Remapping



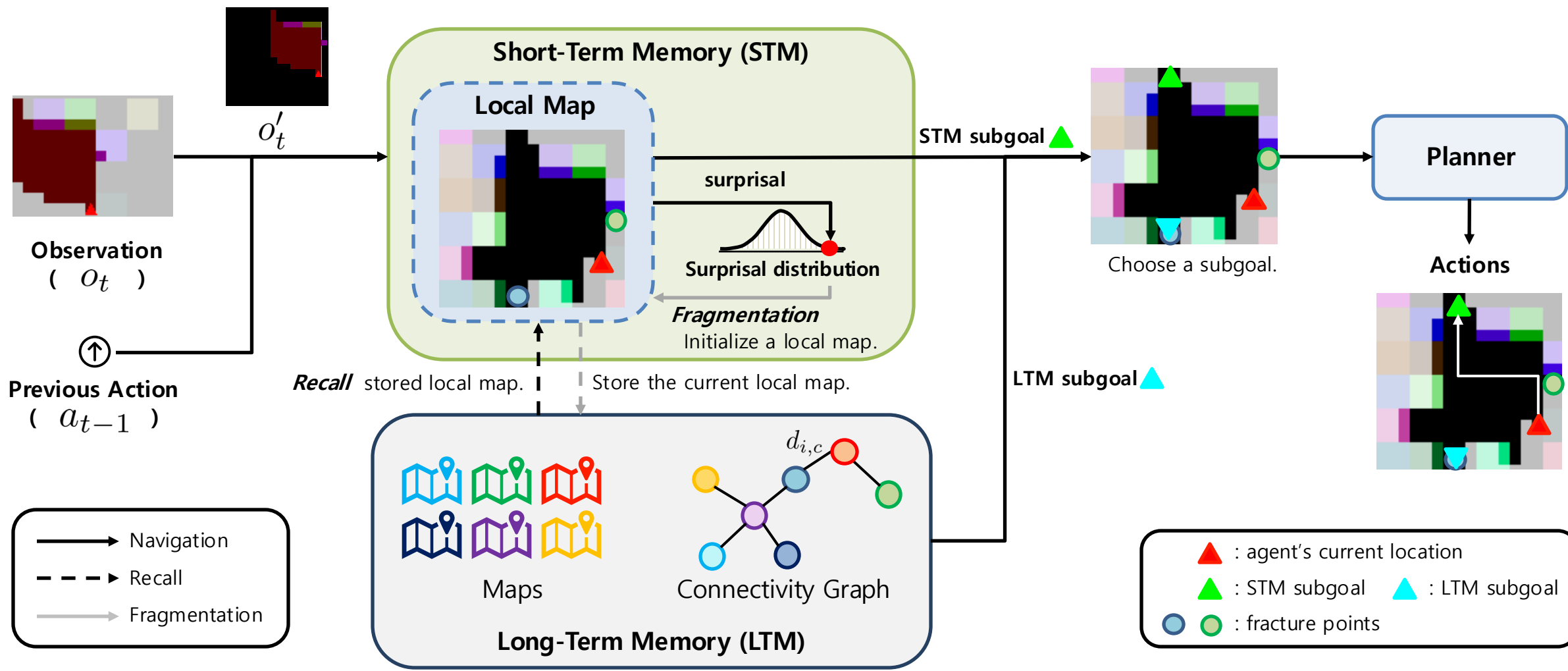
Fragmentation



Simultaneous Localization and Mapping (SLAM)



Fragmentation and Recall in Map Building (FARMap)



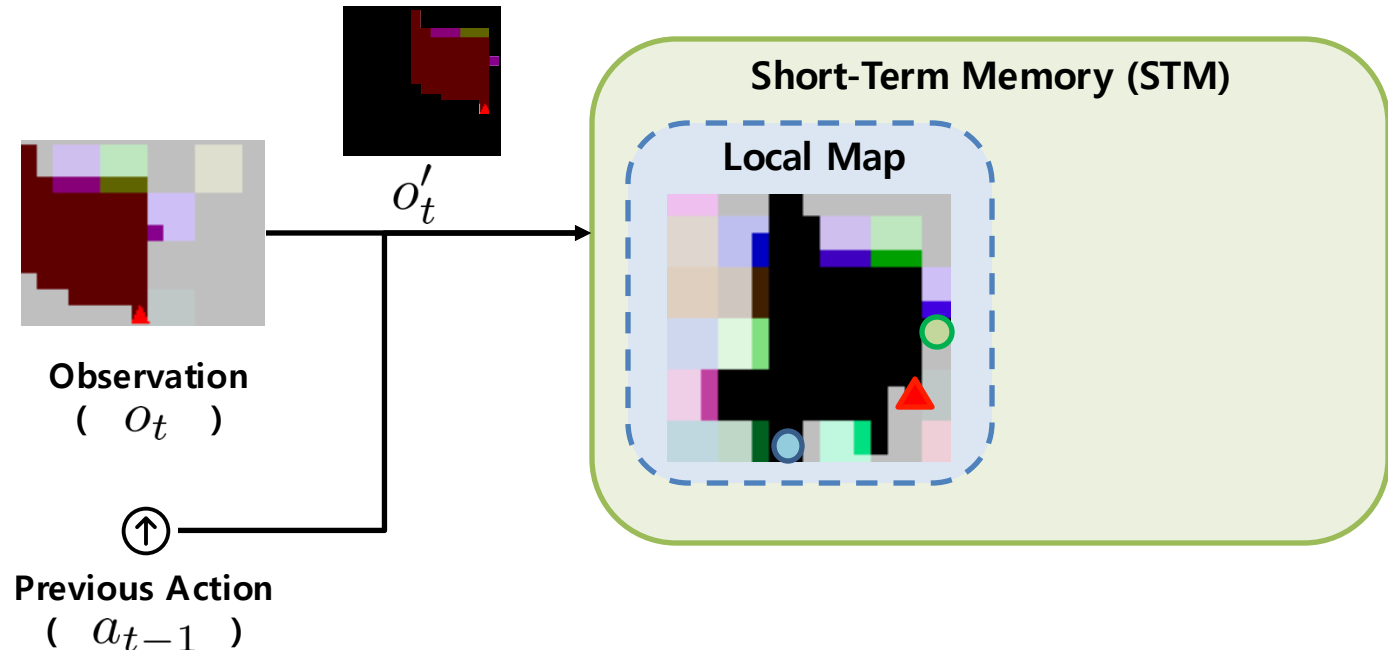
Short-Term Memory (STM)

- Short-Term Memory builds a local predictive map.
- The map is defined as temporally decaying trace of recent sensory observations.

$$\mathbf{M}_{t,C}^{\text{cur}} = \gamma \cdot \mathbf{M}_{t-1,C}^{\text{cur}} + (1 - \gamma) \cdot o'_{t,C}$$

γ : discount factor

o'_t : spatially transformed
current observation.



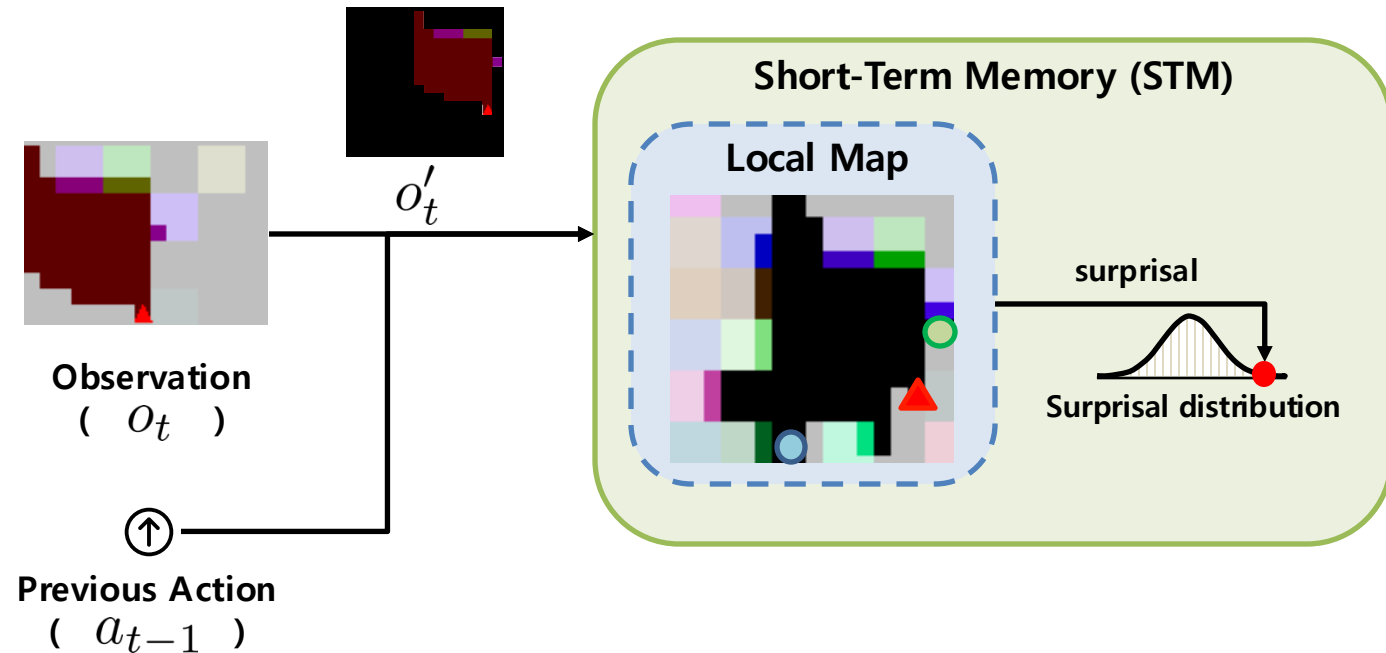
Confidence and Surprisal

- Confidence at time t is defined as average confidence of visible cells:

$$c_t = \frac{\mathbf{M}_{t-1,C}^{\text{cur}} \cdot o'_{t,C}}{\|o'_{t,C}\|_1}$$

- Surprisal is defined as

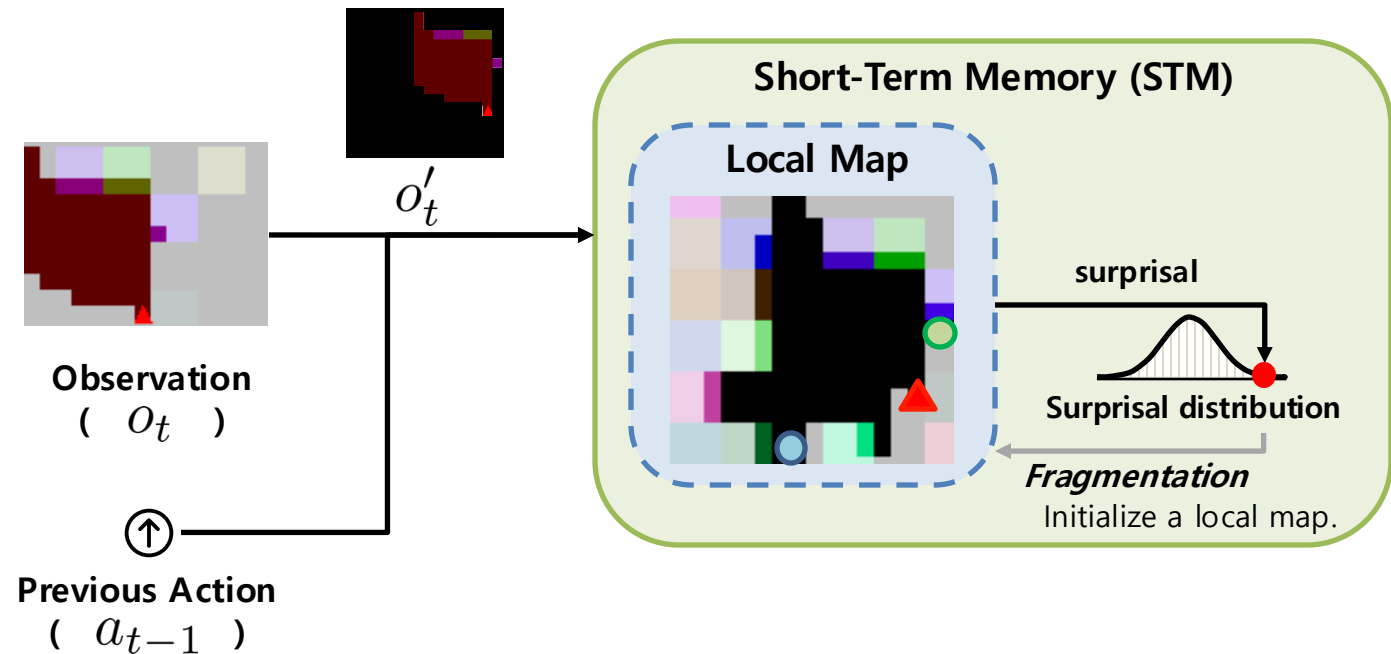
$$s_t = 1 - c_t$$



Fragmentation

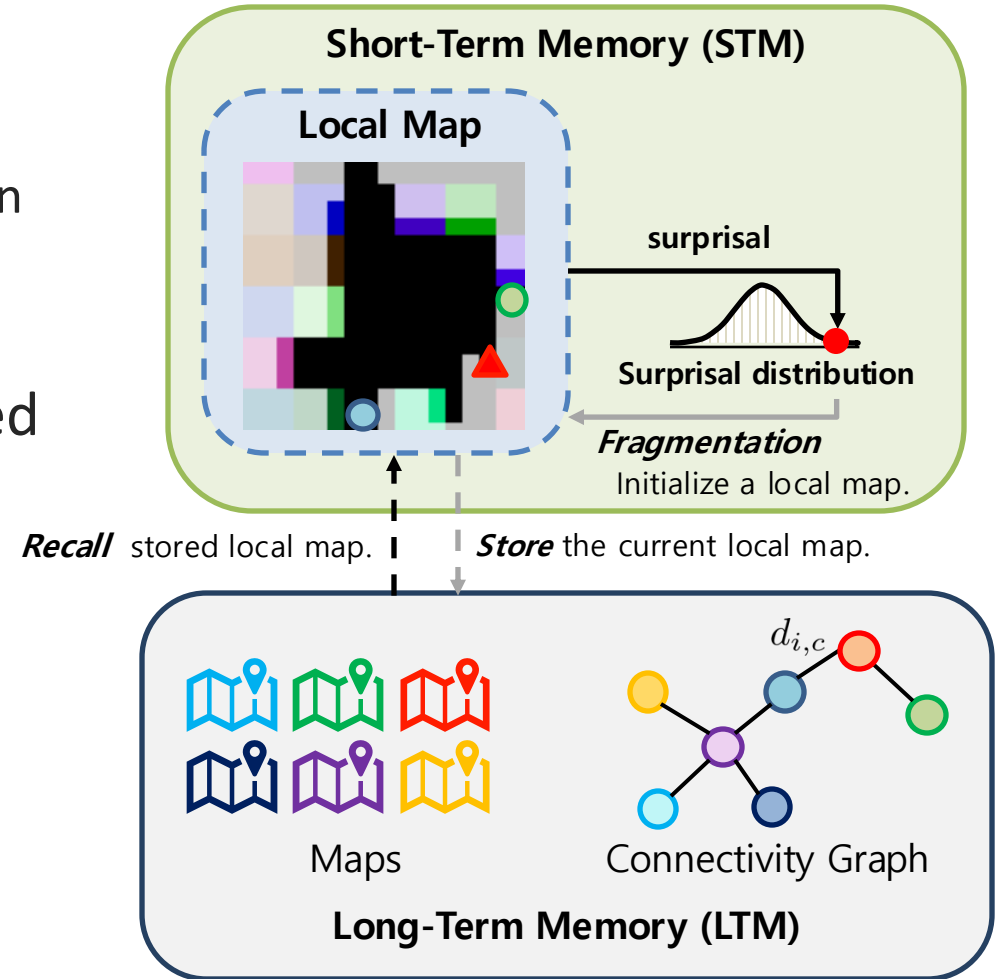
- We calculate running average and standard deviation of surprisal in the local map.
- If z-score for the current surprisal is bigger than a threshold, the fragmentation happens.

$$\frac{s_t - \mu_t}{\sigma_t} > \rho$$



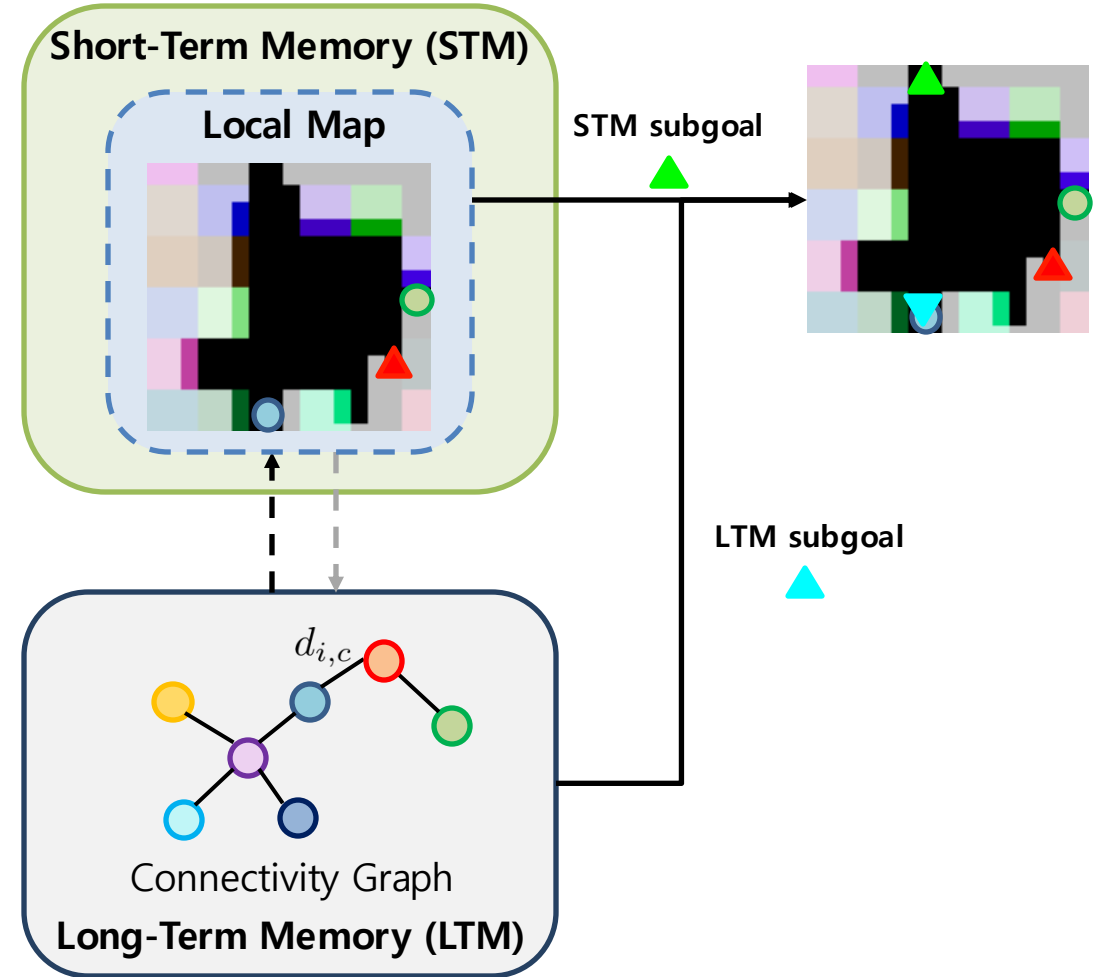
Long-Term Memory (LTM)

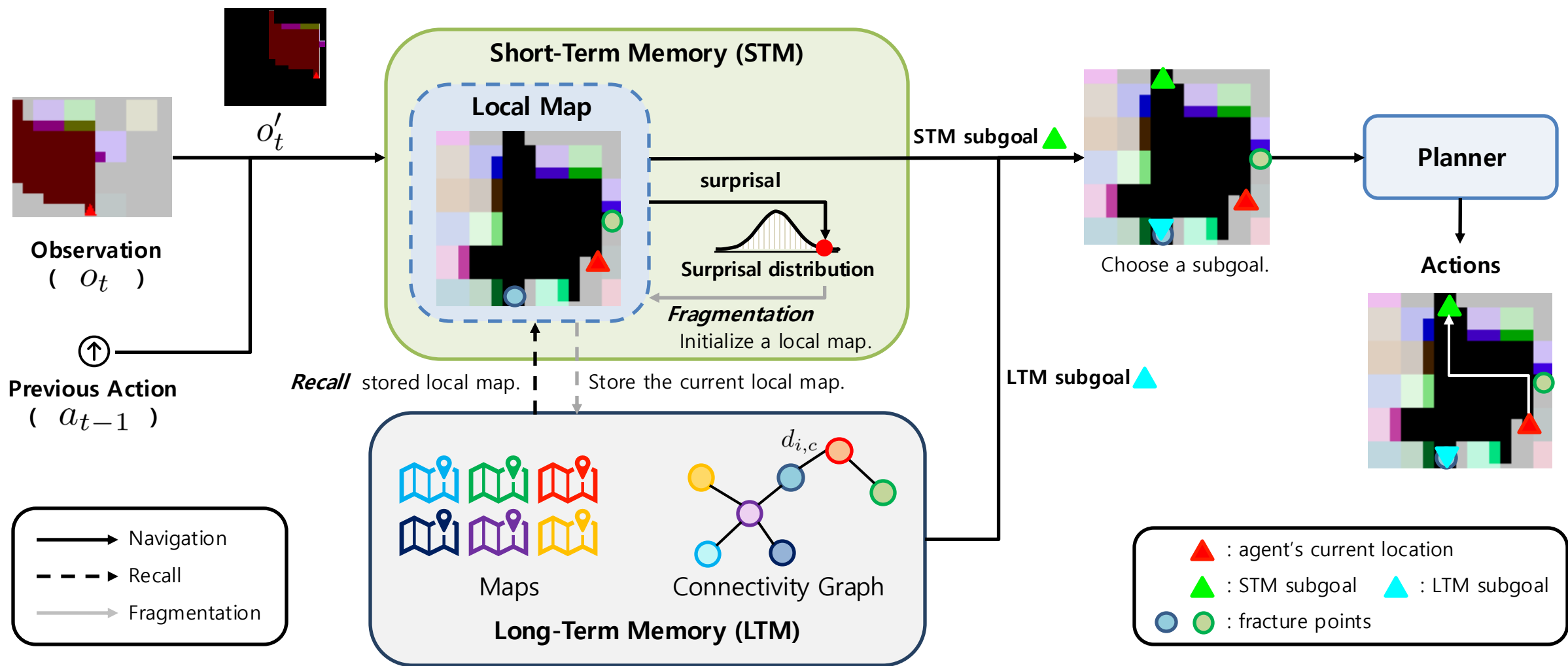
- Store – when the fragmentation event happens.
 - Local map
 - the ratio of the number of frontier and the number of known cells in the map
- Recall – when the agent approaches to the fragmented location (overlap with another local map)
 - Recall corresponding local map.
 - Store current local map in LTM.



Subgoal

- Two sources of subgoal; STM and LTM.
- From the current local map, the agent sets frontier-based subgoal.
- By using connectivity graph of maps in LTM, the agent decides that which local region is less explored.



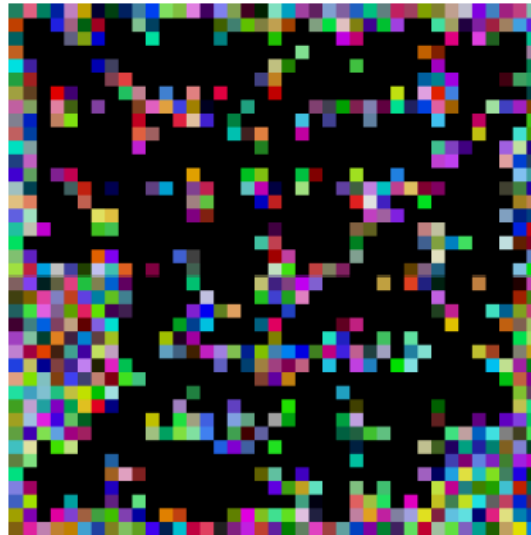


Procedurally-Generated Environments

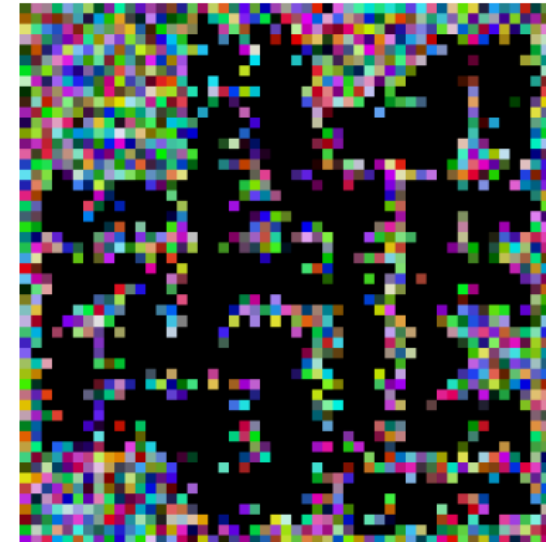
- 1500 environments
 - 300 maps with 5 different colors and starting locations.
 - Depending on the size of environment, we divide into three groups; small, medium, large.



(b) Small (size: 3249)



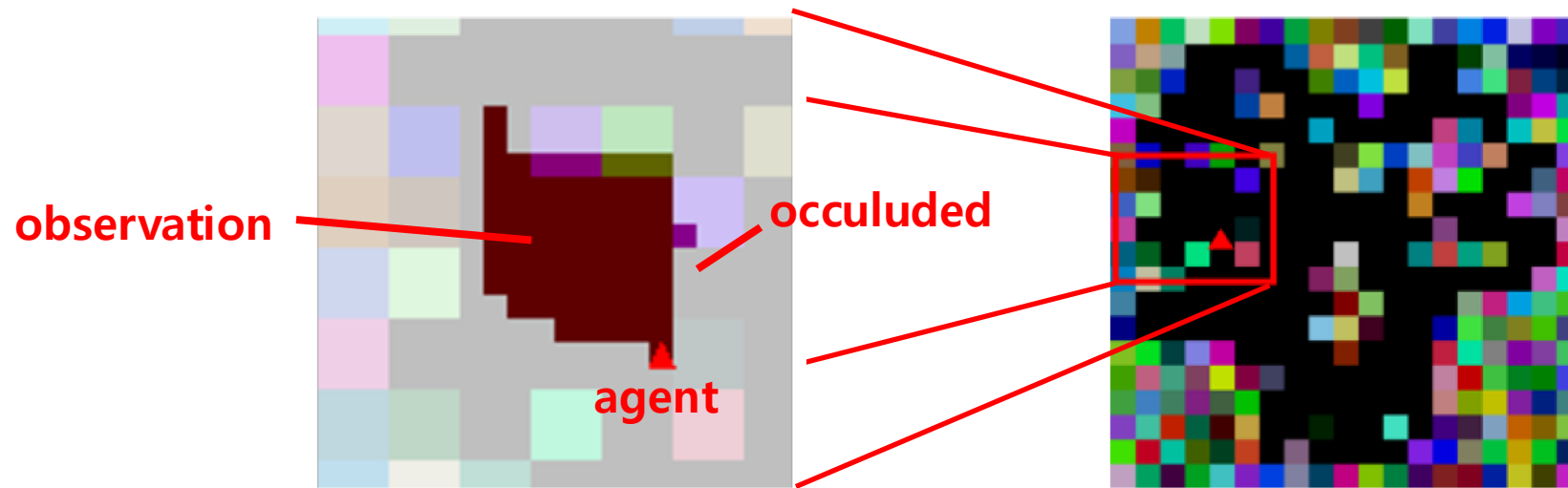
(c) Medium (size: 13689)



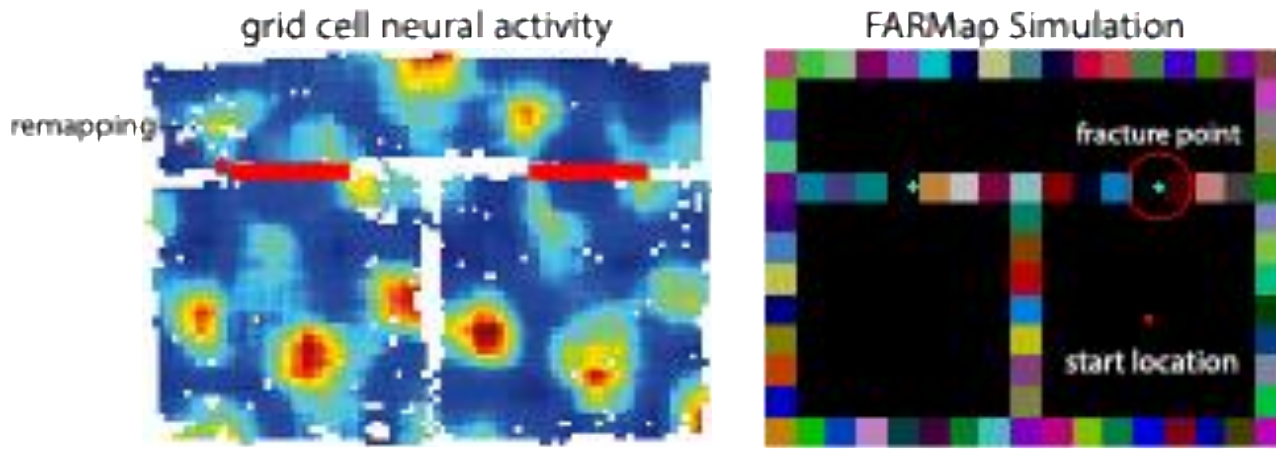
(d) Large (size: 23868)

Observation

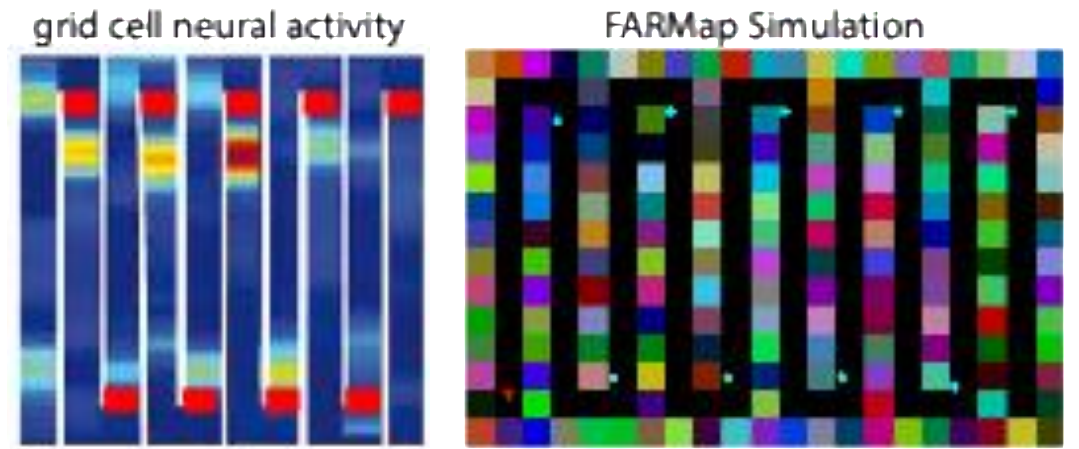
- Egocentric restricted field of view (130 degree) with occlusion.



FARMap Fragments where actual Remapping happens



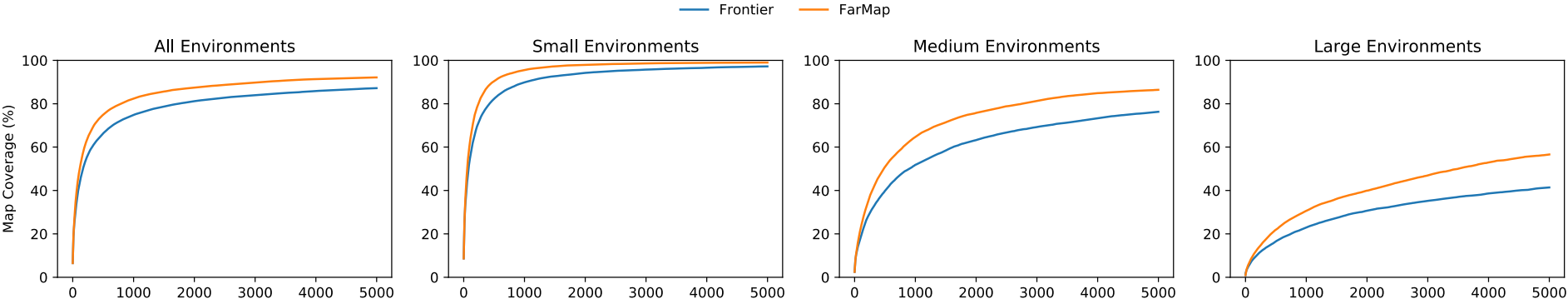
(a) Carpenter et al. (2015)



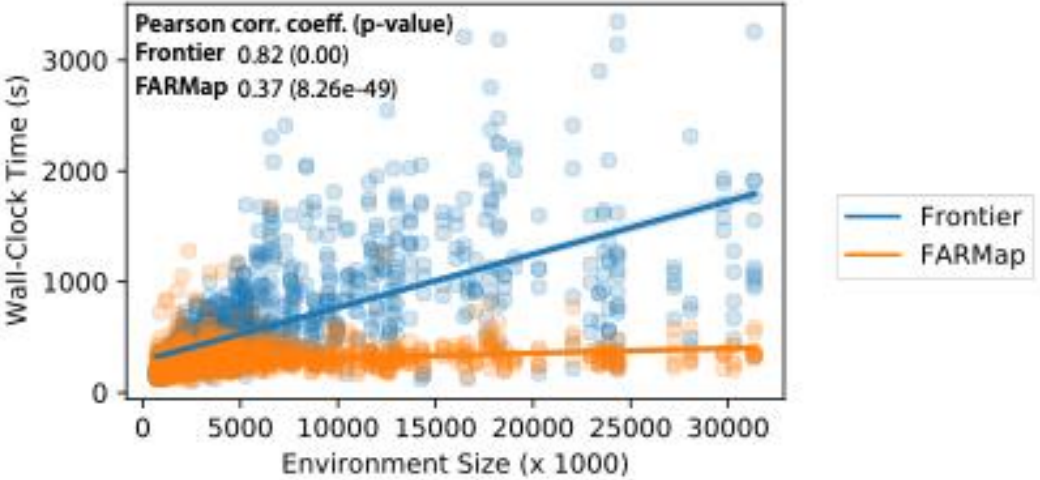
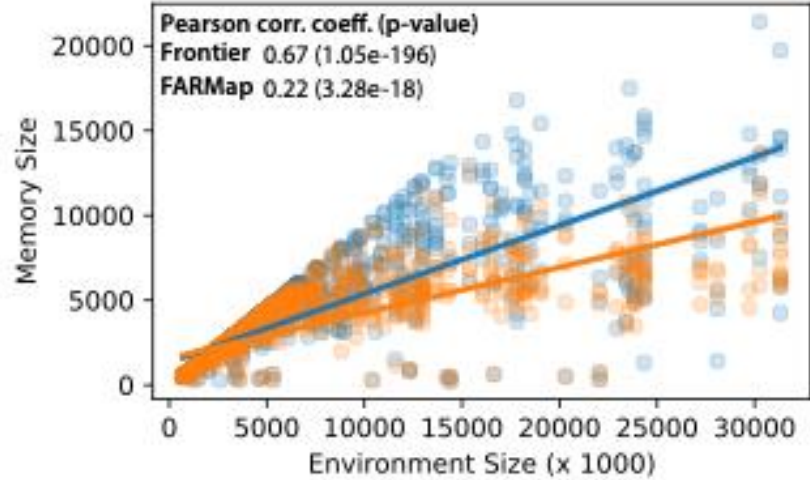
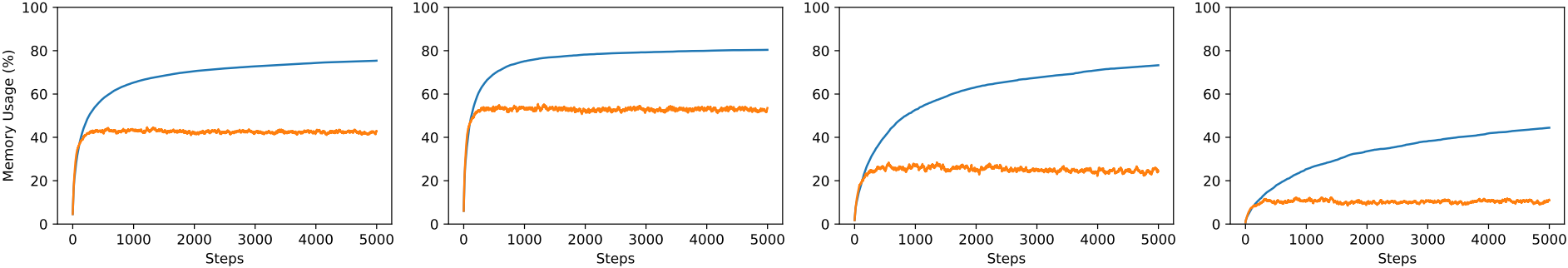
(b) Derdikman et al. (2009)

FARMap achieves better performance with less memory & wall-clock time

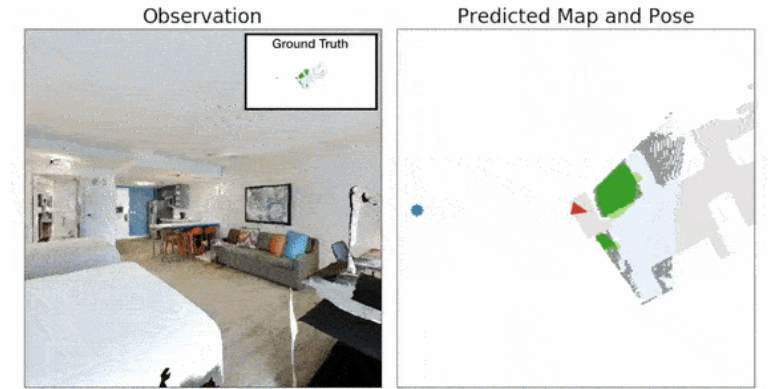
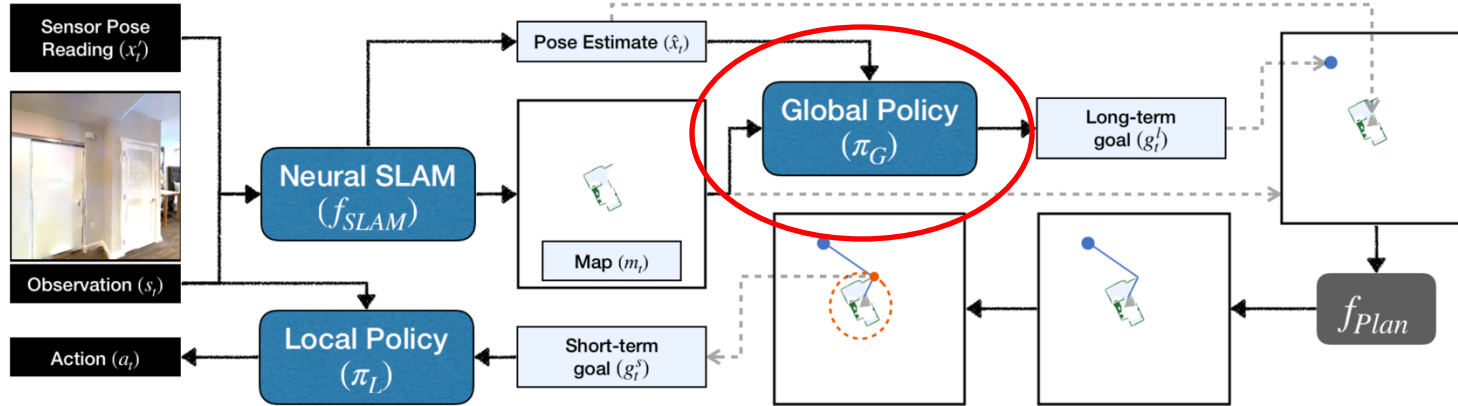
Map Coverage



Memory Usage



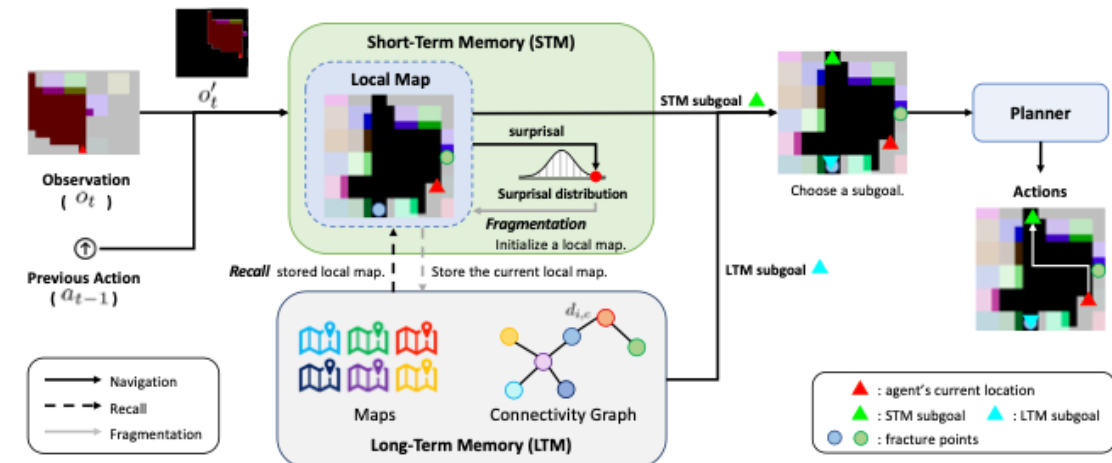
With Neural SLAM in Habitat Simulation



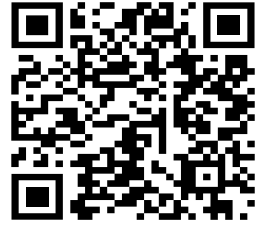
Model	% Cov.	Cov. (m ²)
Neural SLAM (Chaplot et al., 2020)	0.818	64.795
Neural SLAM w/o global policy + Frontier	0.733	58.103
Neural SLAM w/o global policy + FARMap	0.833	66.012

Summary

- We proposed Fragmentation-and-Recall framework for map building (FARMap).
- The fracture points match with the actual neuroscience experiments.
- FARMap explores a new environment faster with less memory compared to the baseline.
- FARMap can be combined with other spatial exploration methods.



Thank you



Project Page



Jaedong Hwang



Zhang-Wei Hong



Eric Chen



Akhilan Boopathy



Pulkit Agrawal



Ila Fiete

Contact: jdhwang@mit.edu