Grid Cell-Inspired Fragmentation and Recall for Efficient Map Building

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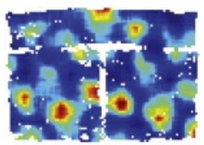
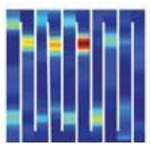
Fragmentation and Recall Framework

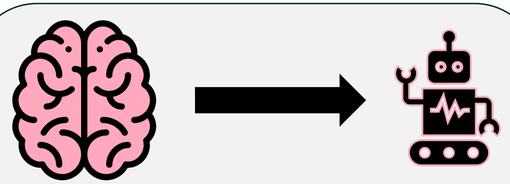
Grid Cell in Entorhinal Cortex



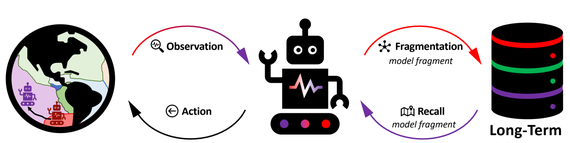
Carpenter et al. (2015)



Derdikman et al. (2009)



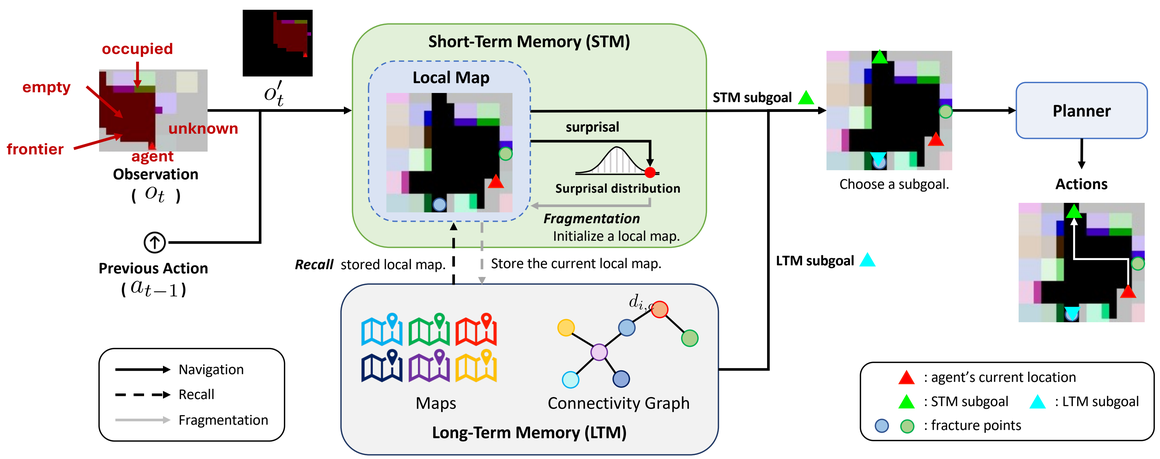
Fragmentation and Recall Framework for Map Building (FARMap) inspired by **Grid Cell** in the **Brain**



Fragmentation

- If surprisal is too **high**, $(s_t - \mu_t)/\sigma_t > \rho$
- Store the current local map in LTM.
- Initialize a new map in STM.

Fragmentation and Recall based Spatial Map Building (FARMap)



Short-Term Memory (STM)

- **Local predictive spatial map** $\mathbf{M}_t^{\text{cur}} \in \mathbb{R}^{(C+1)\times H\times W}$ is updated as with temporal decaying:

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

- **Surprisal** s_t : 1 – similarity between the predicted map and the current observation.

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

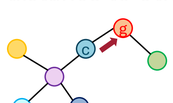
Recall

- If current location = fracture point (previously fragmented location)
- Recall the corresponding map from LTM.

Long-Term Memory (LTM)

- Storing currently unused model fragments building connectivity graph.
- Each node records discovery ratio q_i (# frontiers / # seen cells) and distance to others.

$$g = \arg\max_i \frac{q_i}{d_{i,c} + \epsilon}$$



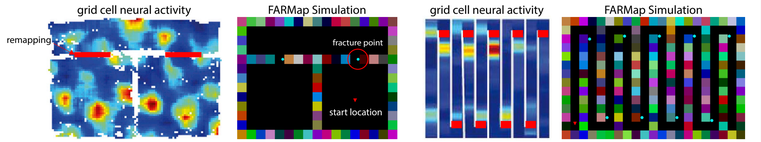
Subgoal

- **LTM subgoal:** stored map is less explored than the current one.

⇒ go to the corresponding fracture point and recall the map.

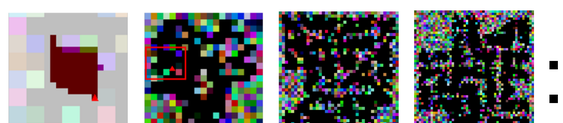
- **STM subgoal:** o.w., go to frontier in the current map similar to Yamauchi [4].

Comparison with Grid Cell Remapping



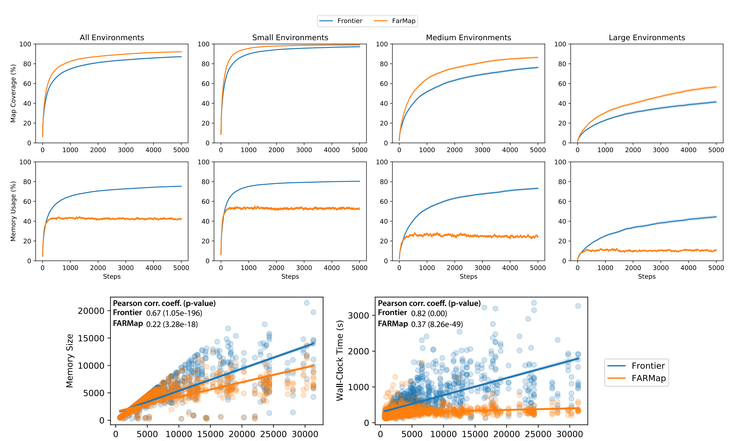
(a) Carpenter et al. (2015) (b) Derdikman et al. (2009)

FARMap in Procedurally-Generated Env.

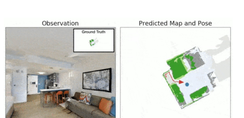


(a) Observation (b) Small (size: 3249) (c) Medium (size: 13689) (d) Large (size: 23868)

- 1500 Env.
- Restricted FoV



Active Neural SLAM [2] on Habitat Simulator



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**

Ref. **[1]** Carpenter et al. "Grid cells form a global representation of connected environments". Current Biology. 2015. **[2]** Chaplot et al. "Learning to explore using active neural slam". ICLR. 2020. **[3]** Derdikman et al. "Fragmentation of grid cell maps in a multicompartment environment." *Nature Neuroscience. 2009.* **[4]** Yamauchi, Brian. "A frontier-based approach for autonomous exploration." *CIRA*. 1997