Dataset for embodied learning

Habitat 2.0: Training Home Assistants to Rearrange their Habitat

Outline

1. Introduction to Embodied AI
2. Habitat
3. ReplicaCAD
4. Habitat 2.0
5. Pick Task - A base case of rearrangement
6. Home Assistant Benchmark (HAB)
7. Conclusion

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Introduction to Embodied AI

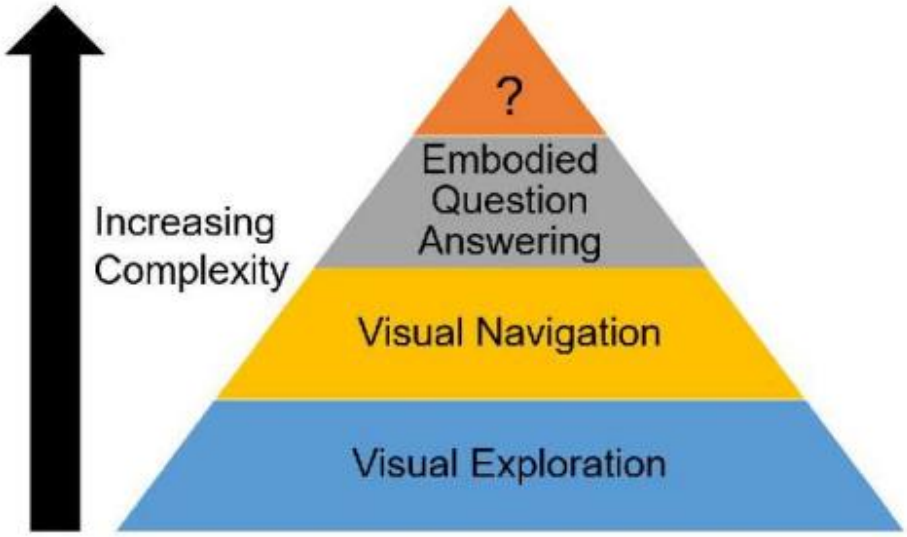
- Embodiment Hypothesis - Intelligence occurs when an agent interacts with an environment

- Virtual embodied agents taking action in virtual world similar to real world.

Example of a robot performing pick up task in a simulation [2]

Introduction to Embodied AI

Paradigm shift from the era of “internet AI” to “embodied AI”



Various embodied AI research tasks with increasing complexity [1]

Dataset → Simulator → Task → Benchmark

From internet image datasets to 3D simulators [4]

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Habitat

Standardizing the Embodied AI “software stack”

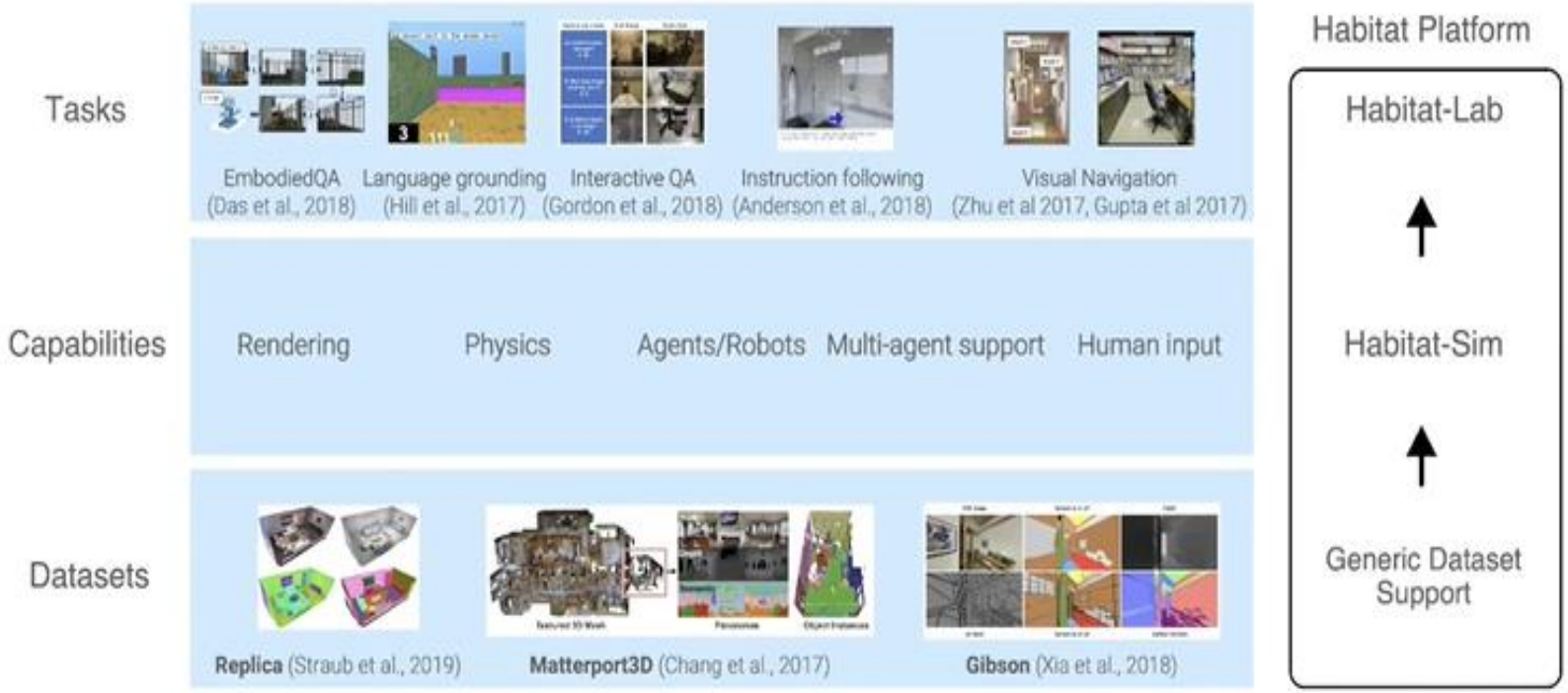

Image representing the software stack used by Habitat- predecessor of Habitat 2.0 [4]

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ReplicaCAD

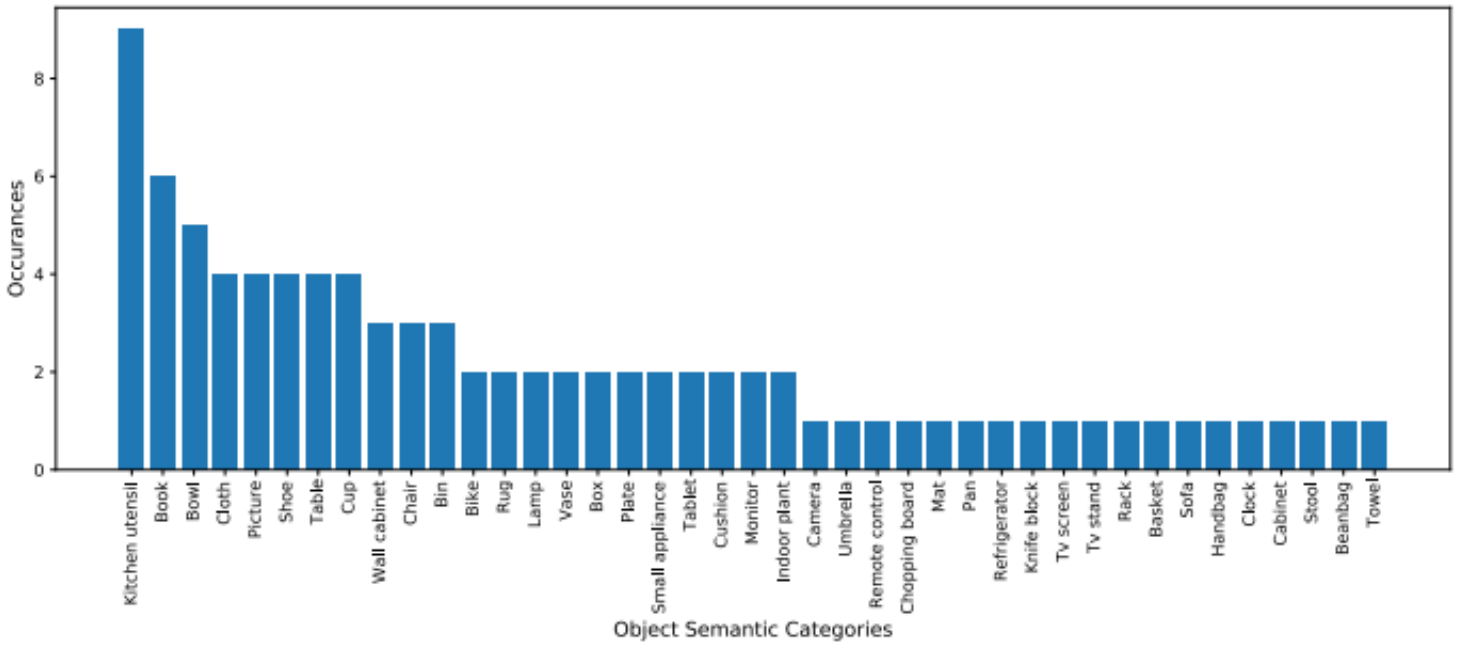
- Static 3D scans have been converted to individual 3D models
- Enable training of robots for movement and manipulation

The original Replica scene [2]

Recreation of scene objects in ReplicaCAD that are interactive [2]

ReplicaCAD

- Asset Creation
- Procedural Clutter Generation



Histogram of objects belonging to each semantic category [2]

ReplicaCAD

- Human layout generation
  - Macro variations
  - Micro variations

Macro variations of semantically plausible configurations of furniture [2]

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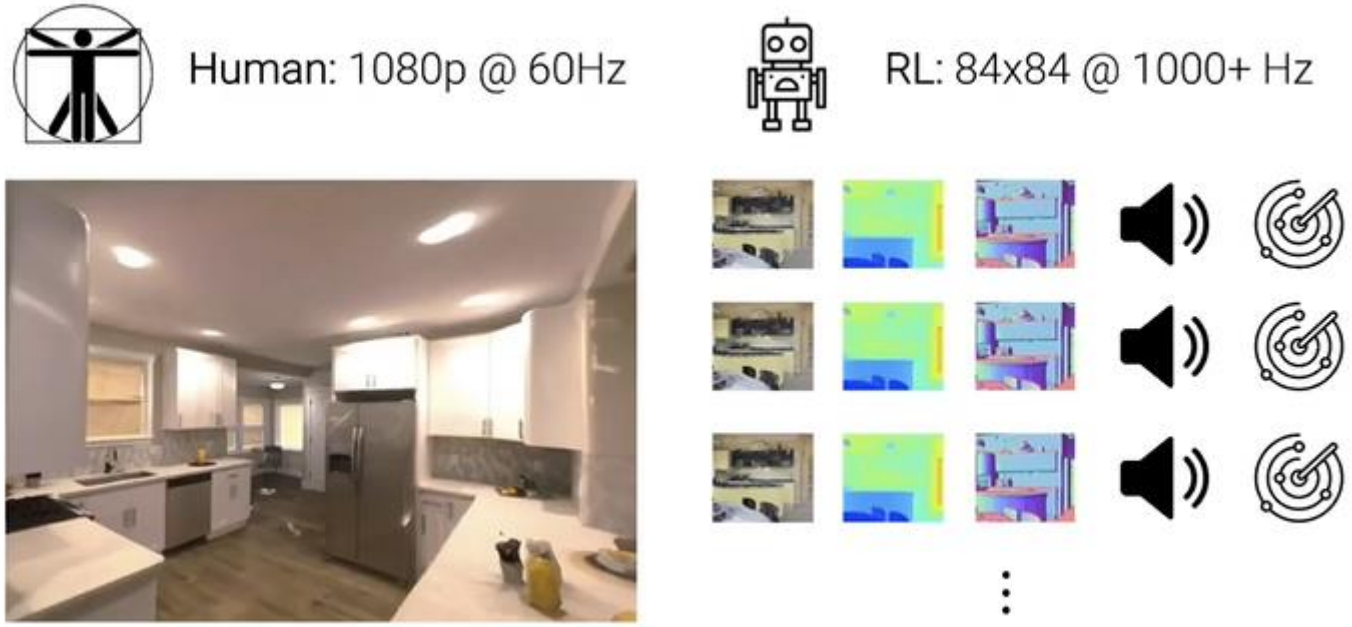
Habitat 2.0 - A Lazy Simulator

- Problem with existing simulators



Comparison of simulators required for gaming(perceived by humans) and robots for learning [4]

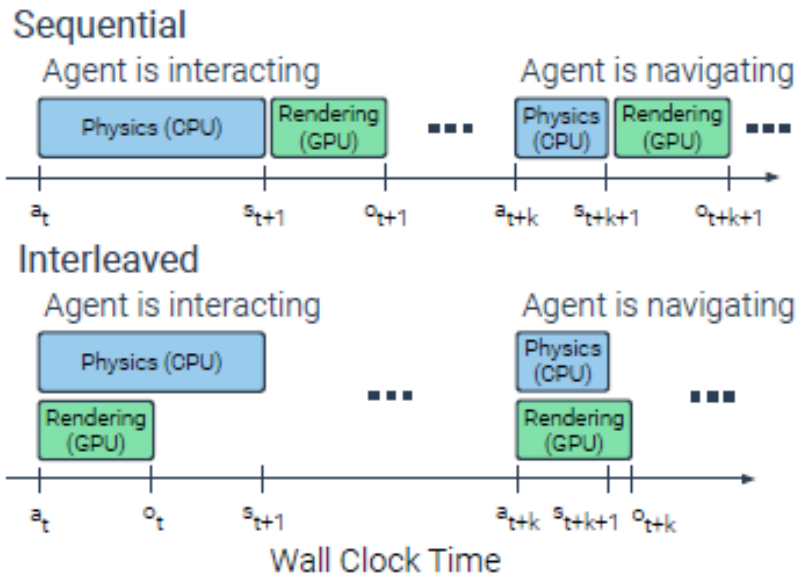
Habitat 2.0 - A Lazy Simulator

- Localized physics and rendering

Example navigation by trained agents [5]

Habitat 2.0 - A Lazy Simulator

- Interleaved rendering
  - Sequential dependency $\mathcal{T} : (s_t, a_t) \rightarrow s_{t+1} \quad \pi : o_t \rightarrow a_t, \quad \mathcal{O} : s_t \rightarrow o_t.$
  - Break this sequential dependency by changing the agent policy to be $\pi(a_t \mid o_{t-1})$ instead of $\pi(a_t \mid o_t)$



Interleaved physics and rendering used in H2.0 [2]

Habitat 2.0 - A Lazy Simulator

- Simplify and Reuse
  - GPU texture compression to 3D assets.
  - Pre-fetching object assets and caching them in memory.
  - Use convex decompositions of the objects and separate these simplified collision meshes from the high-quality visual assets.

Habitat 2.0 - A Lazy Simulator

- Benchmark data
  - Idle-1 X RGB - D
  - Idle-RGB with two RGB-D cameras
  - Interact
- H2.0 single-process with all optimizations turned off is 240% faster than iGibson

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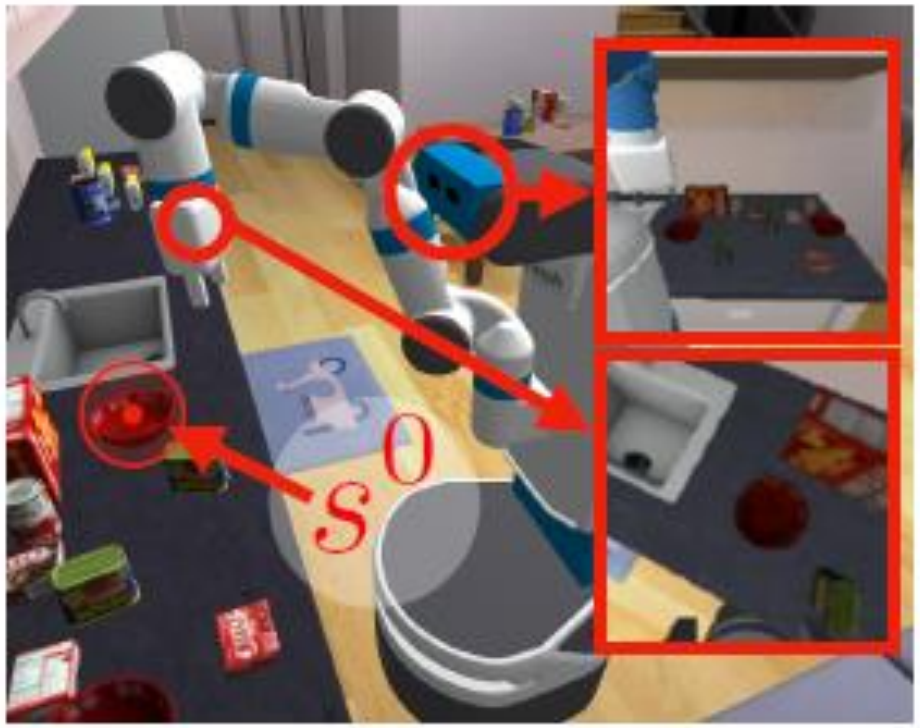
Pick Task - A base case of rearrangement

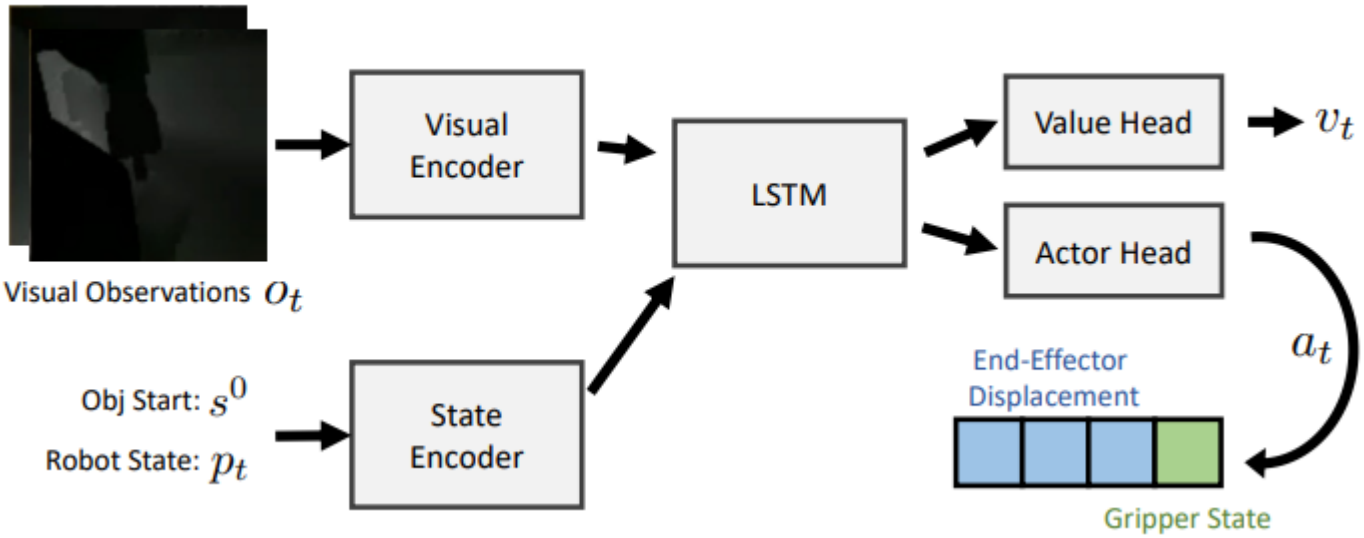
- Picking up one object from a cluttered receptacle
- Task Definition: **Pick** (s0)
- Action space: gross motor control
- Abstracted grasping
- Evaluation



Pickup task executed by the Fetch robot [2]

Pick Task – A base case of rearrangement

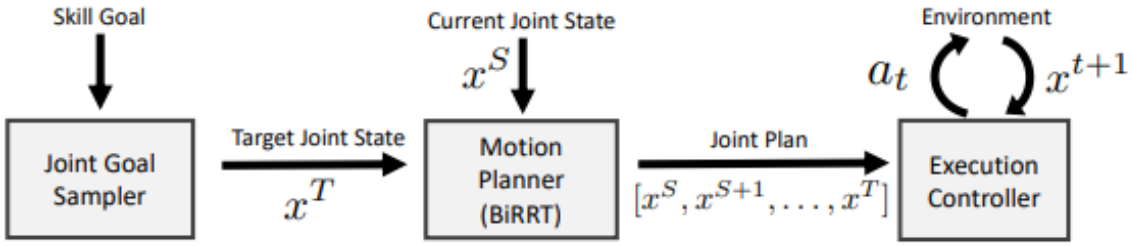
Monolithic RL



Monolithic reinforcement learning architecture used to train the robot [2]

Pick Task – A base case of rearrangement

SensePlanAct(SPA) - traditional non-learning based robotics pipeline



Three stages of robotics pipeline for SPA-Priv and SPA [2]

Comparison

Method	Seen	Unseen		
		Layouts	Objects	Receptacles
MonolithicRL	91.7 ±1.1	86.3 ±1.4	74.7 ±1.8	52.7 ±2.0
SPA	70.2 ±1.9	72.7 ±1.8	72.7 ±1.8	60.3 ±2.0
SPA-Priv	77.0 ±1.7	80.0 ±1.6	79.2 ±1.7	60.7 ±2.0

Analysis: Success rates of different methods [2]

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Home Assistive Benchmarks (HAB)

(a) TidyHouse

(b) PrepareGroceries

(c) SetTable

Task definition [2]

Home Assistive Benchmarks (HAB)

- Monolithic RL
  - Same as base case arrangement, but accepts list of start and end goal coordinates
- Task Planning + Skills RL
- Task Planning + SensePlanAct

$$\overbrace{\texttt{Navigate}(b^0), \texttt{Open drawer}(b^0)}^{\text{Open Drawer}}, \overbrace{\texttt{Pick}(b^0), \texttt{Navigate}(b^*), \texttt{Place}(b^*)}^{\text{Transport Bowl}}, \overbrace{\texttt{Navigate}(b^0), \texttt{Close drawer}(b^0)}^{\text{Close Drawer}},$$

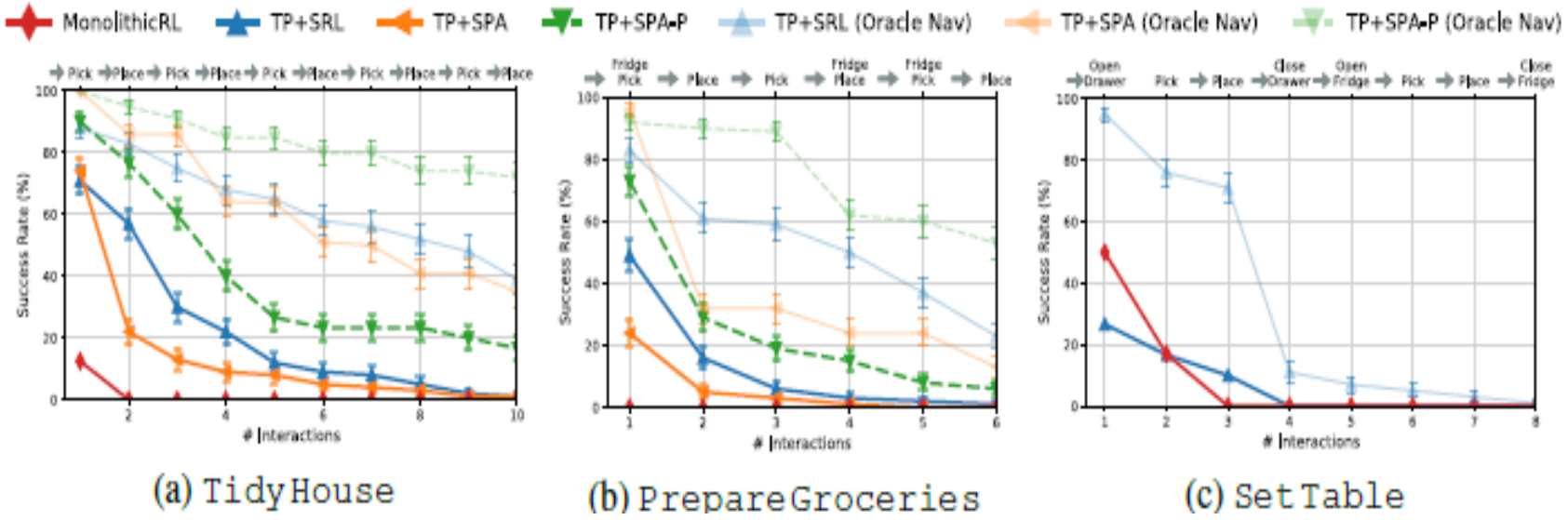
$$\underbrace{\texttt{Navigate}(a^0), \texttt{Open fridge door}(a^0)}_{\text{Open Fridge}}, \underbrace{\texttt{Navigate}(a^*), \texttt{Place}(a^*)}_{\text{Transport Apple}}, \underbrace{\texttt{Navigate}(a^0), \texttt{Close fridge door}(a^0)}_{\text{Close Fridge}}.$$

STRIPS Task planner listing the sequence of tasks to be performed [2]

Home Assistive Benchmarks (HAB)

Results

- Monolithic RL does not perform well.
- Learning a navigation policy to chain together skills is challenging.



Comparison of performance of different methods using HAB [2]

Home Assistive Benchmarks (HAB)

Results (ctd…)

- Compounding errors hurt performance of task planning methods.
- SPA variants scale poorly to increasing task complexity.

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Improvements

- More varied training that takes into account cultural- and region-specific layouts.

Conclusion

- Habitat2.0 along with ReplicaCAD datasets provides a platform for efficient experimentation involving embodied AI agents for different methods.

References

1. A Survey of Embodied AI: From Simulators to Research Tasks Jiafei Duan, Samson Yu, Hui Li Tan, Hongyuan Zhu, Cheston Tan [https://doi.org/10.48550/arXiv.2103.04918]
2. Habitat 2.0: Training Home Assistants to Rearrange their Habitat ,Andrew Szot et al. [https://arxiv.org/abs/2106.14405]
3. Supplemental notes of [2] [https://proceedings.neurips.cc/paper/2021/file/021bbc7ee20b71134d53e20206bd6feb-Supplemental.pdf]
4. Introduction to AI Habitat – (https://www.youtube.com/watch?v=L9GuINYhmZI&list=PLGywud_-HlCORC0c4uj97oppQrGiB6JNy&index=1&ab_channel=A-STAR)
5. Video from (https://aihabitat.org/)