OPEN SCENE GRAPHS
FOR OPEN-WORLD OBJECT GOAL NAVIGATION

Joel Loo* [joell@u.nus.edu], **Zhanxin Wu*** [zhanxinwu@u.nus.edu], **David Hsu** [dyhsu@comp.nus.edu.sg]

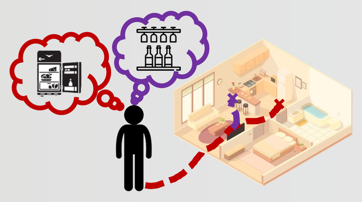
NUS National University of Singapore

Check out our website!

Open-World ObjectNav

Can we search novel scenes for an open-set object class, in *any* environment, with *any* embodiment?

- Requires semantic reasoning, common-sense priors

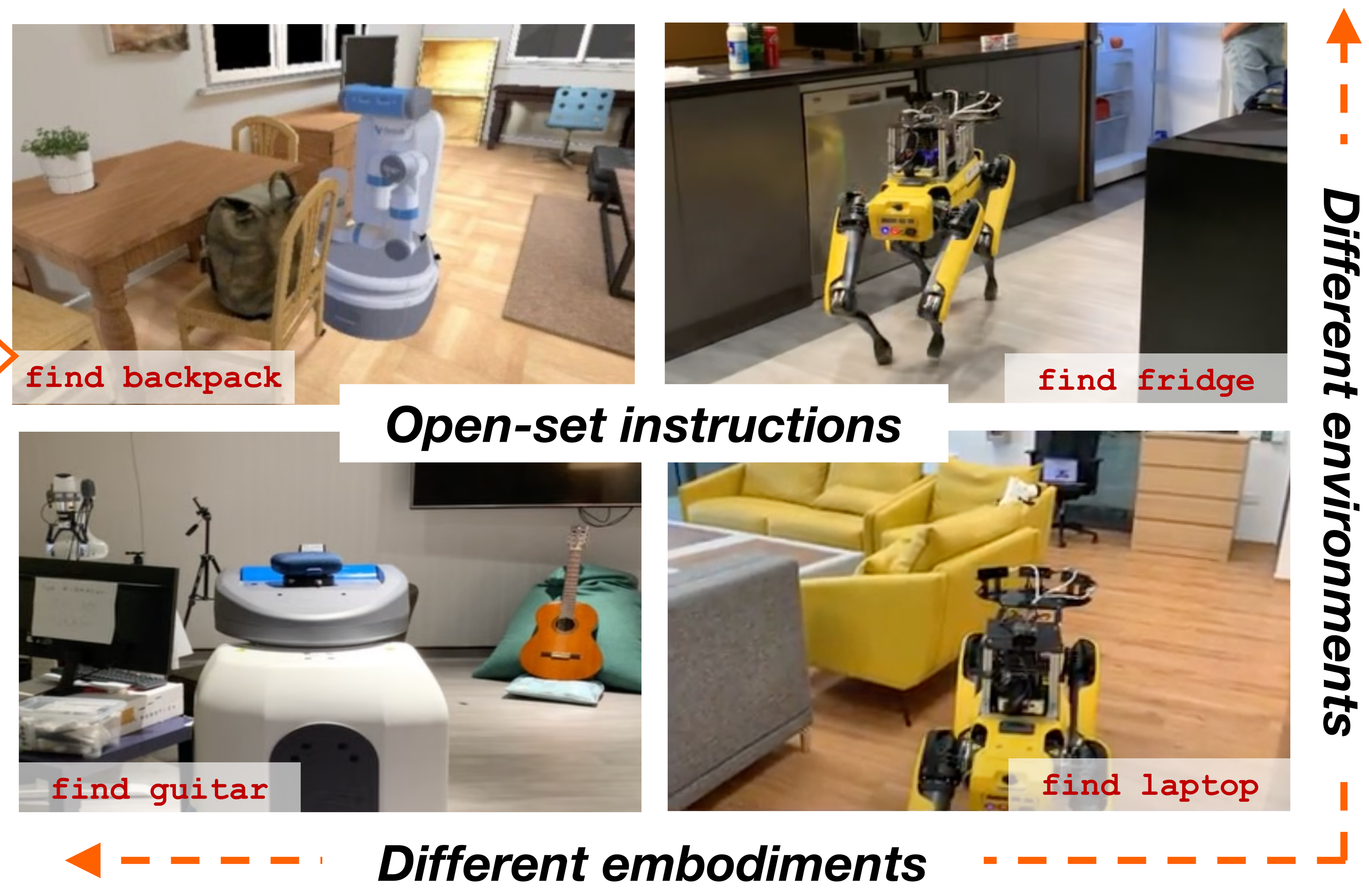


- Must handle diverse instructions, environments & embodiments

Approach: Compose an ObjectNav robot system purely built from Foundation Models (FMs)

Problem: Need a structured scene memory to retain information for FMs, that is also built with FMs

OpenSearch, a general system for Open-World ObjectNav



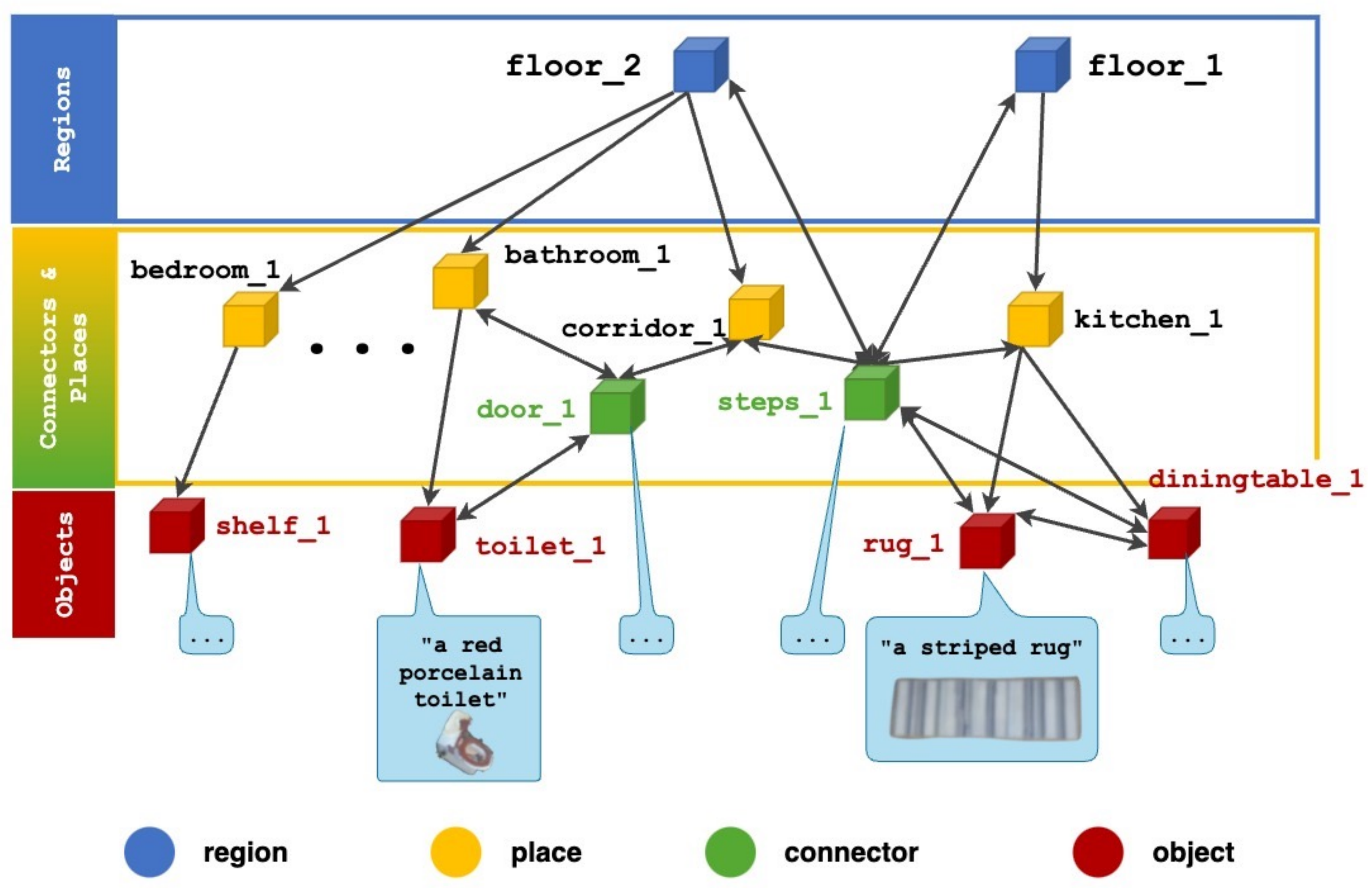
Open Scene Graphs

OSG Schema (*Environment types*, e.g. homes)

```
                    ⋮
"RegionAbstraction1_Layer": {
# [Optional] Semantically meaningful spatial abstractions
    "layer_type": "floor",
"Places_Layer": {
# [Required] Smallest semantically meaningful regions
    "layer_type": "room",
"Connectors_Layer": {
#[Optional] Connective structures between regions
    "layer_type": ["stairs", "doors"]
"Objects_Layer": {
# [Required] Task-relevant semantic features
                    ⋮
```

specifies structure of

OSG (*Scenes, e.g.* a specific house)



OSG Mapper: Builds OSGs online, following OSG spec

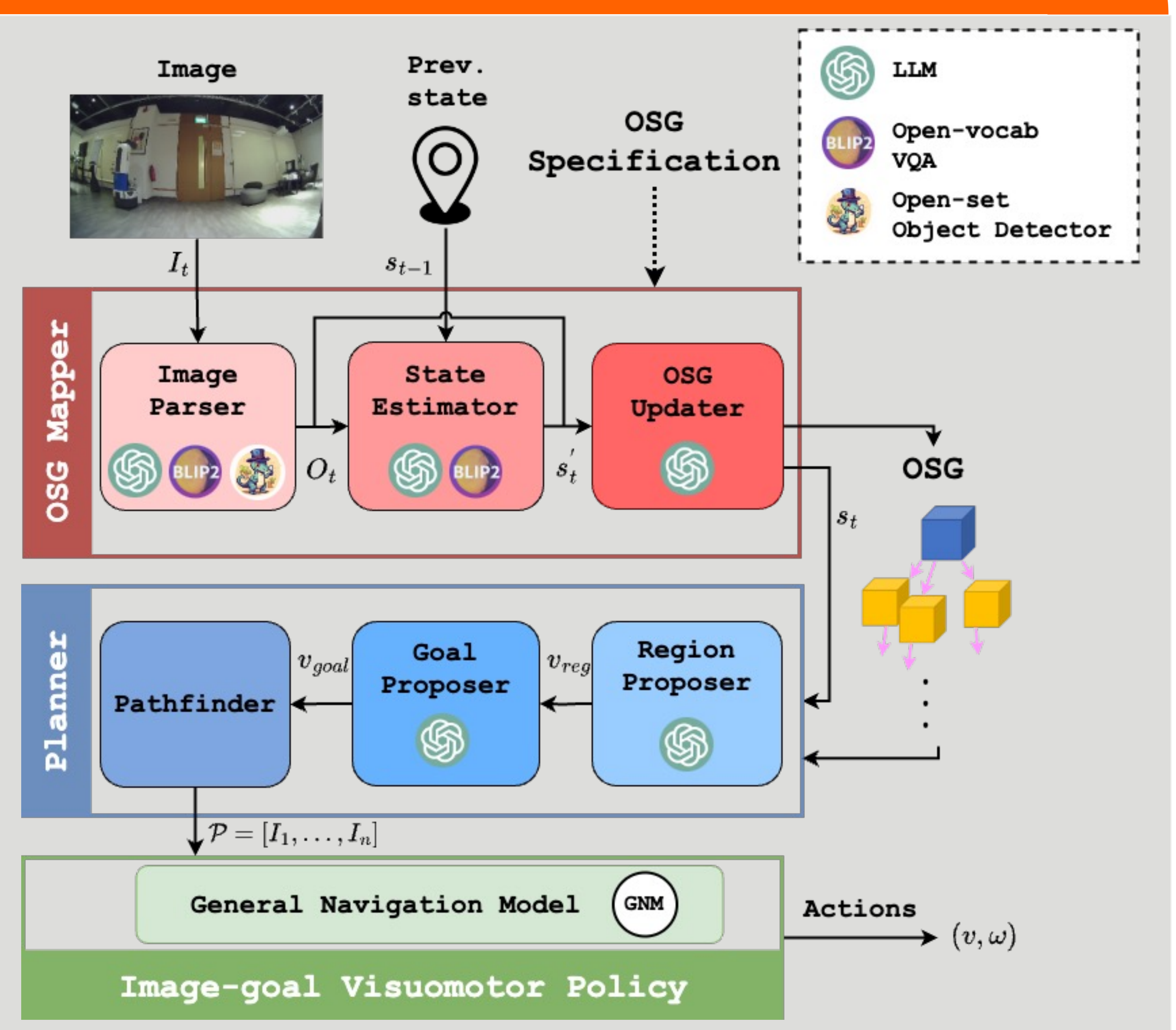
- Uses only ***FMs***: *i.e.*, LLM, open-vocab VQA, open-set Object Detector
- Uses ***objects as features*** for data association

fn ImageParser(I_t):
- // *Extract Place, Objects, Connectors from observations*
- P_t = LabelPlace_VLM_VQA(I_t)
- D_t = DetectObjectsConnectors_VLM_OD(I_t)
- O_t, C_t = ClassifyObjectsAndConnectors_LLM(D_t)
- **for** o *in* $O_t \cup C_t$ **do**
  - $o.attr$ = LabelWithTextualAttribs_VLM_VQA(o)
- **return** P_t, O_t, C_t

fn StateEstimator(P_t, O_t, C_t):
- // *Estimate robot's current location (Place)*
- P^{OSG} = SortByDistance(*all Place nodes in OSG*)
- **for** p *in* P^{OSG} **do**
  - **if** IsPlaceMatchedWithObs_LLM($p, O_t \cup C_t$)
    - **return** p
- **return** None

fn OSGUpdater($\hat{p}, O_t, C_t$):
- // *Update OSG with observed Place, Objects, Connectors*
- **if** $\hat{p}$ *is* None
  - p_t = AddPlaceNode($\hat{p}$)
  - AddObjectConnectorLeafNodes(O_t, C_t)
  - AddEdges(s_t, O_t, C_t)
  - InferRegionAbstractions_LLM(p_t)
- **else**
  - $p_t = \hat{p}$
  - **for** o *in* $O_t \cup C_t$ **do**
    - $\mathcal{V}_{leaf}$ = GetObjectConnectorLeafNodes(p_t)
    - v_{match} = FindMatchedLeafNode_LLM($o, \mathcal{V}_{leaf}$)
    - **if** v_{match} is None
      - AddNewLeafNode(o)
    - **else**
      - UpdateLeafNode(o)
    - UpdateEdges(o)
- **return** p_t

OSG Navigator



Experiments: Simulation

Comparison With LLM-based ObjectNav Methods On HM3D

Method	Success (↑)	SPL (↑)	DTG (m) (↓)
Greedy LLM (based on [11])	0.275	0.080	5.078
LFG [39]	0.675	**0.389**	2.411
Explorer-FMM-GT	**0.775**	0.380	**1.702**
Explorer-FMM	0.693	0.283	2.338

Comparison With ObjectNav Methods On Gibson

Method	Success (↑)	SPL (↑)	DTG (↓)	TF	NM
SemExp [5]	0.657	0.339	1.474	✗	✗
PONI [31]	**0.736**	**0.410**	**1.250**	✗	✗
FBE [50]	0.641	0.283	1.780	✓	✗
SemUtil [8]	0.693	**0.405**	**1.488**	✓	✗
Explorer-FMM	**0.734**	0.386	1.722	✓	✓

(**TF: training free. NM: Non-metric**)

- LLM reasoning with ***Open Scene Graphs*** lets ***OpenSearch*** strongly outperform ***LLM-based methods***
- LLMs' rich semantic priors lets the ***zero-shot OpenSearch*** perform on par with ***task-specific learned methods***