Taxonomy

How is a system heterogeneous?

We introduce a taxonomy to classify heterogeneous systems.

Robots can have differences:

- Physical differences $\mathcal{P}$
- Behavioral differences $\mathcal{B}$
  - Due to different objectives $\mathcal{B}_d$
  - Even with same objective $\mathcal{B}_s$

Each agent has:

- a stochastic policy $\pi_i(a_{t+1} | o_t)$
- a value function $V_i(o_{t+1})$

Heterogeneous systems

- Same objective ($B_s$)
- Different objective ($B_d$)

Model

How we learn heterogeneous policies

We introduce GPPO and HetGPPO, two actor-critic models for Multi-Agent Reinforcement Learning.

HetGPPO learns individual agent policies

- Uses neighborhood communication to overcome partial observability
- Allows decentralized training

Behavioral typing

How homogeneous robots emulate heterogeneous behavior

We find that homogeneous robots are able to infer behavioral roles through observations, emulating heterogeneous behaviors.

They encode multiple roles in the same policy, activating them based on the input observation.

Behavioral typing is disrupted by sim-to-real transfer

Tasks where heterogeneous robots achieve better performance and resilience

We perform evaluations of our heterogeneous (HetGPPO) and homogeneous (GPPO) models in multi-robot cooperative scenarios.

We demonstrate the benefits of heterogeneous behavior in terms of performance and resilience in tasks with a shared global objective ($B_s$).

Our results highlight the need for heterogeneity to achieve collective intelligence.

Heterogeneous behavior is vital for performance

Heterogeneous behavior achieves better resilience

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