iHERO: Interactive Human-oriented Exploration and Supervision Under Scarce Communication

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Motivation

Multi-robot Exploration:

- **limited** communication
- crucial role of **human operator**

Human-robot Teaming:

- **supervise** exploration progress
- send **requests** to robot team
- operator may **move** in the environment

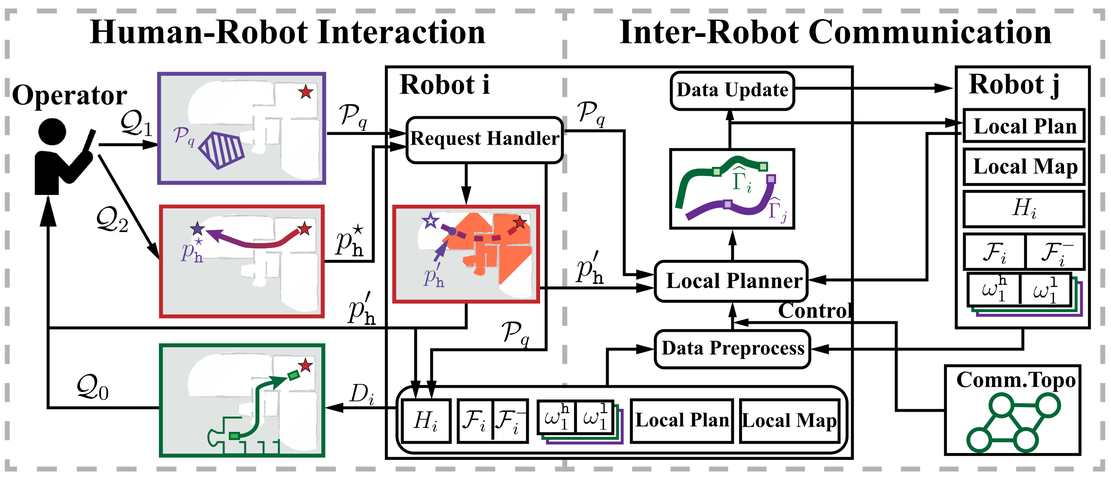
Problem Formulation

Human Requests:

- Q_0 :latencies should be smaller than bound
- Q_1 :prioritize the specfied region
- Q_2 :specify operator's desired next position

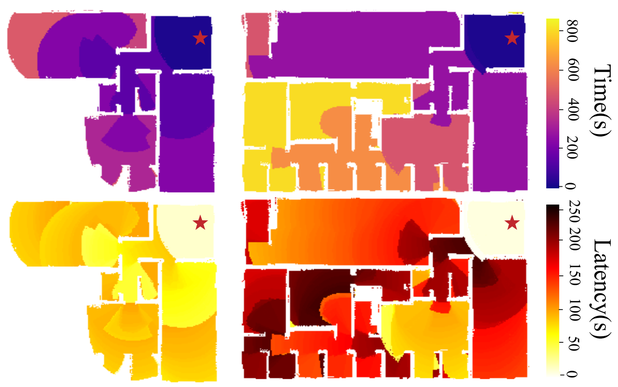
***Objective*:** **minimize** exlporation time subject to **human requests**

Overall Framework



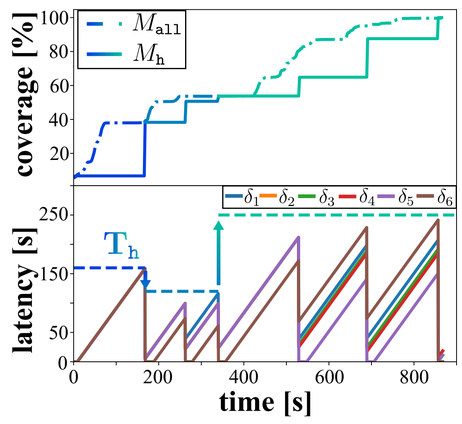
Experiments

Different constraints



- Latency constraint is satisfied at all time.
- Small bound: frequent update, but small coverage.
- Large bound:complete coverage, but larger latency

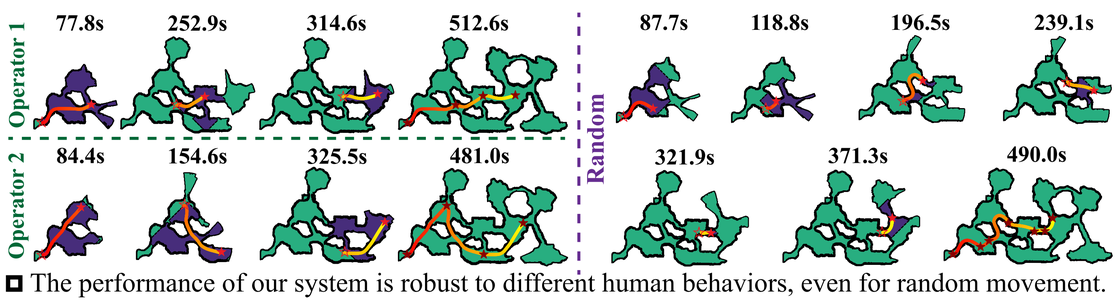
Dynamic constraint



- The operator can change latency bound through online interaction.
- Latency and efficiency change accordingly.

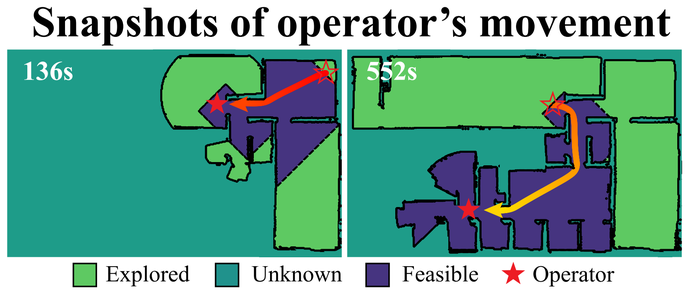
Generalization

Different Human Behaviors

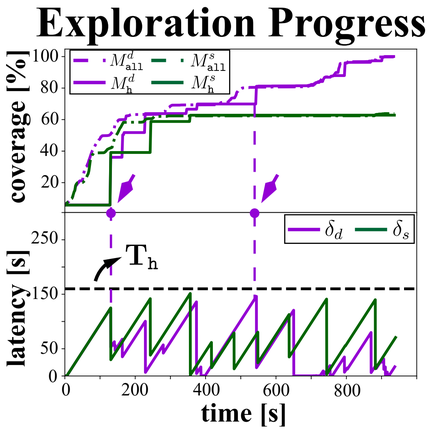


- The performance of our system is robust to different human behaviors, even for random movement.

Snapshots of operator's movement

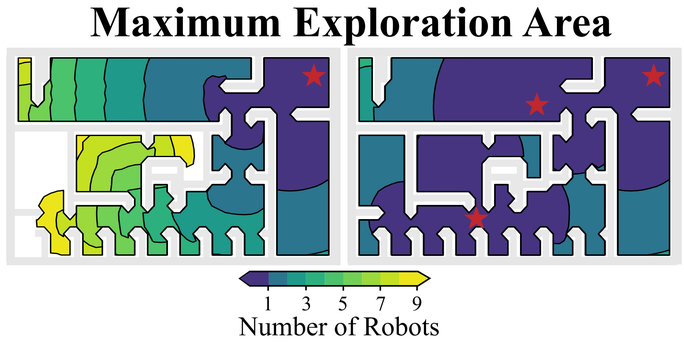


Exploration Progress

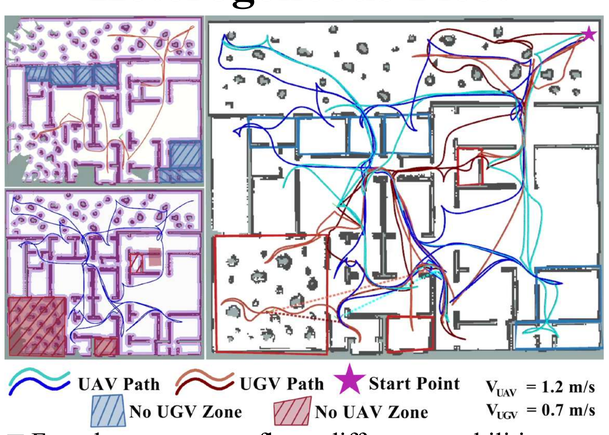


- Due to latency constraint, operator can only move in **feasible region**.
- The maximum area is bounded if operator stays static, and dynamic movement **extends this boundry**.
- Movement yields **larger efficiency**.

Maximum Exploration Area

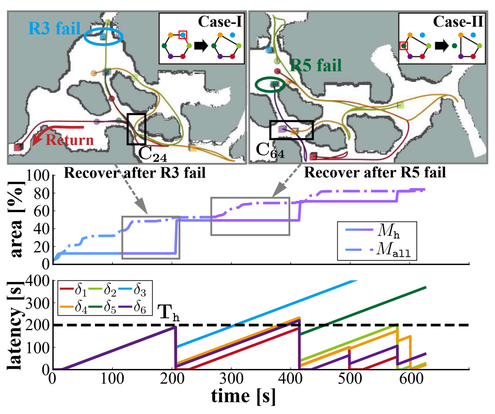


Heterogeneous Fleet



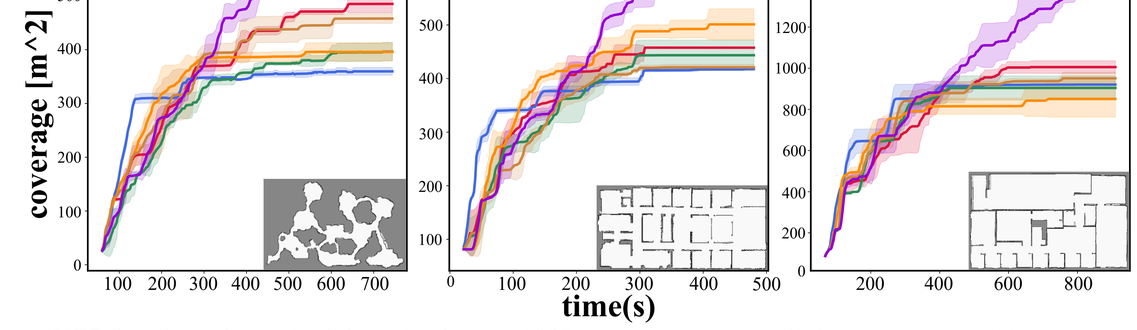
- For a heterogeneous fleet, different capabilities of robots are fully utilized during exploration.

Robot Failure



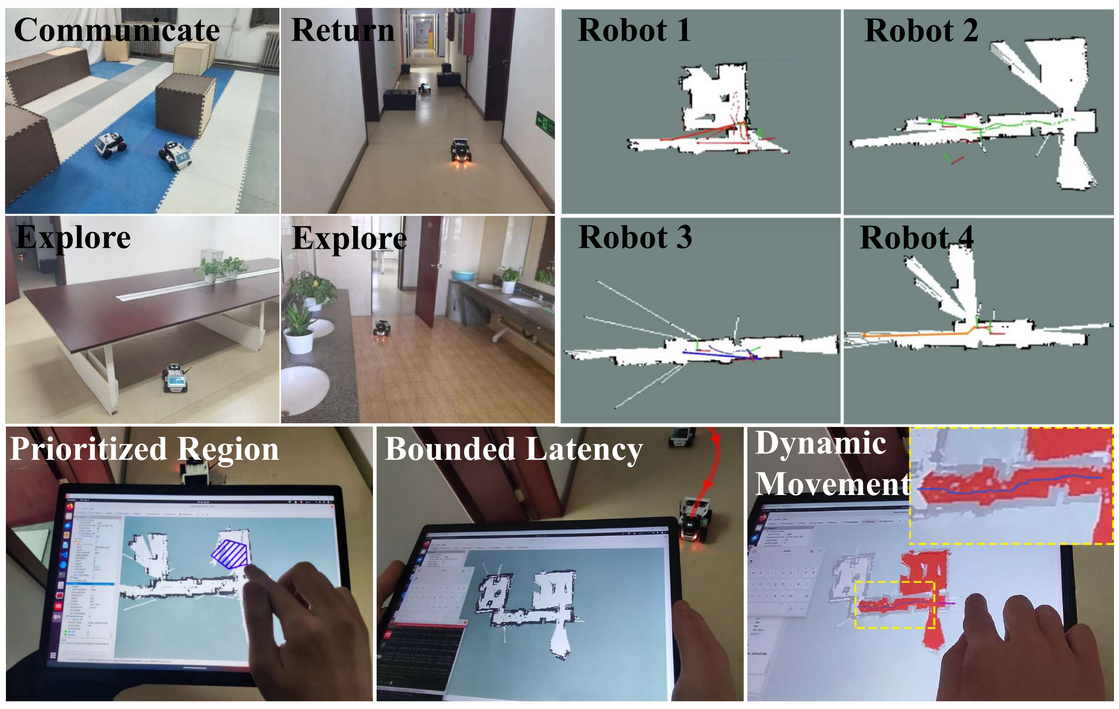
- Our framework can deal with robot failure through online coordination.

Comparison of Baselines



- iHERO is the only method that (i) achieves **100% coverage** across all three scenarios; (ii) requires the **least** number of return events than all baselines; (iii) has the **highest efficiency** over all baselines across all scenarios; (iv) supports **online interactions** such as Q0, Q1, Q2 requests.

Hardware Demonstration



Conclusion

- Intermittent communication protocol to ensure timely update to operator.
- Two explicit human requests:
  Specify prioritized region &
  Dynamically move in the environment.
- Various generalizations.