Heterogenous Robot Collaboration in Unstructured Environments with Grounded Generative Intelligence

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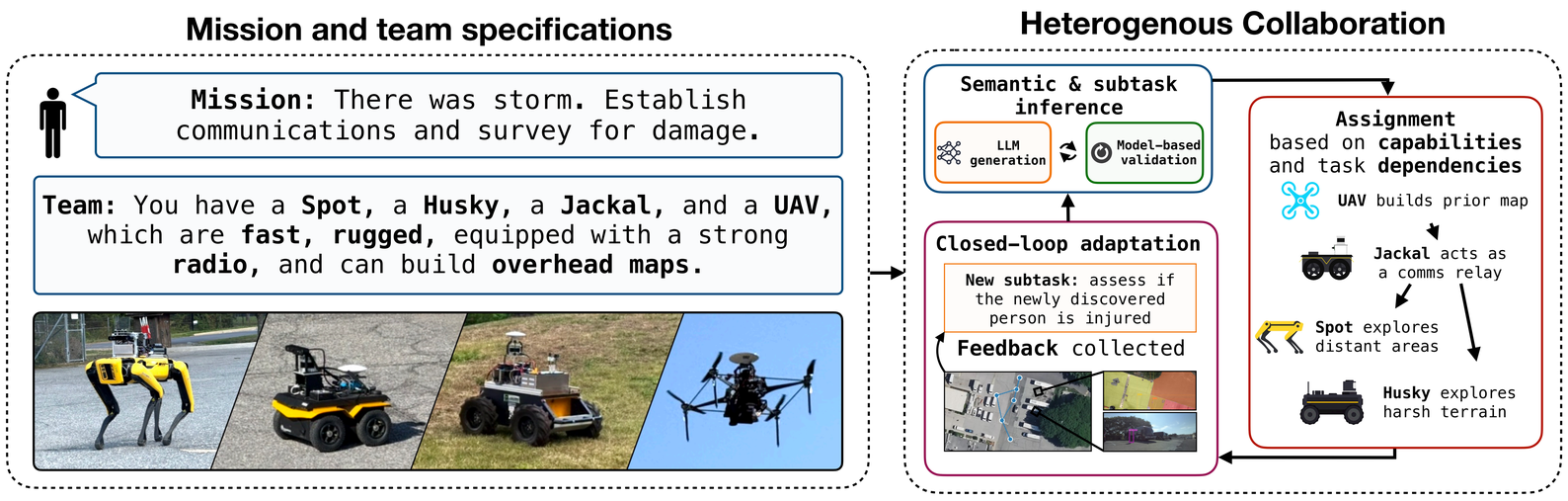
Illustration and experiments

Vision

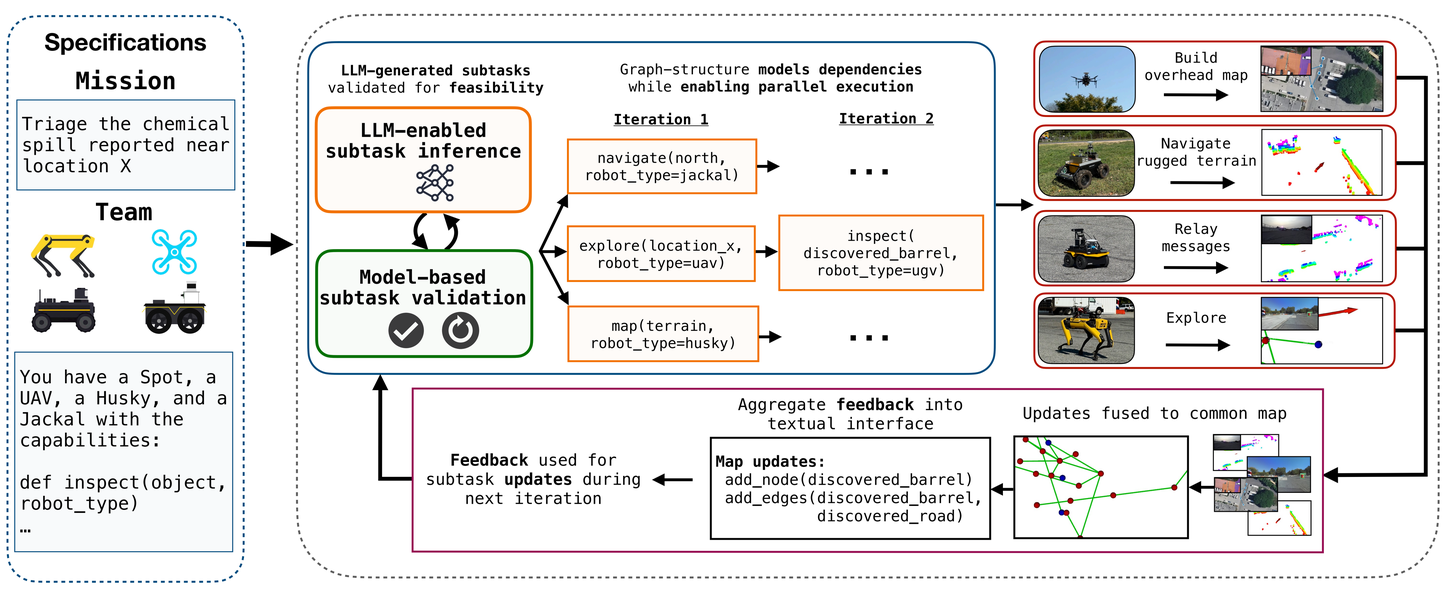


> First system for natural language tasking of heterogeneous teams in unstructured environments.

> Planner infers subtasks and semantics based on task dependencies and robot capabilities. Adapts given information inquired.

> Previous work requires fixed semantics and designed specifically for air-ground teams [1,2].

SPINE-HT Framework



> Mission specifications and team description provided in natural language.

> LLM generates infers semantics and subtasks given. Subtasks are validated for physical realizability.

> Subtasks allocated to team.

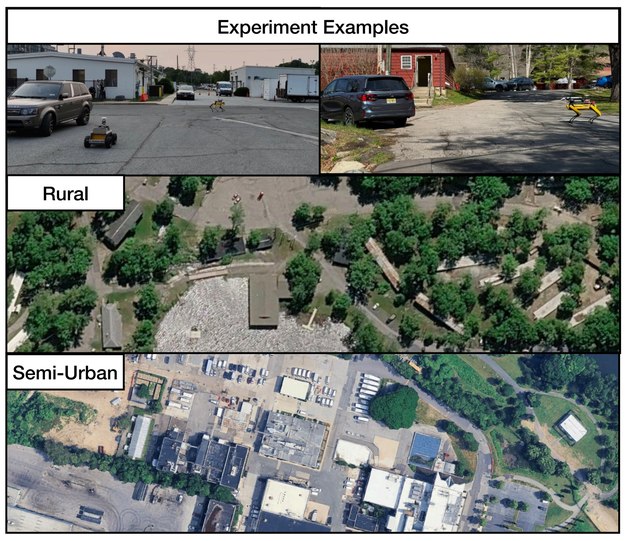
> Feedback collected to common semantic map representation and used for plan adaptation.

Deployment and Experiments

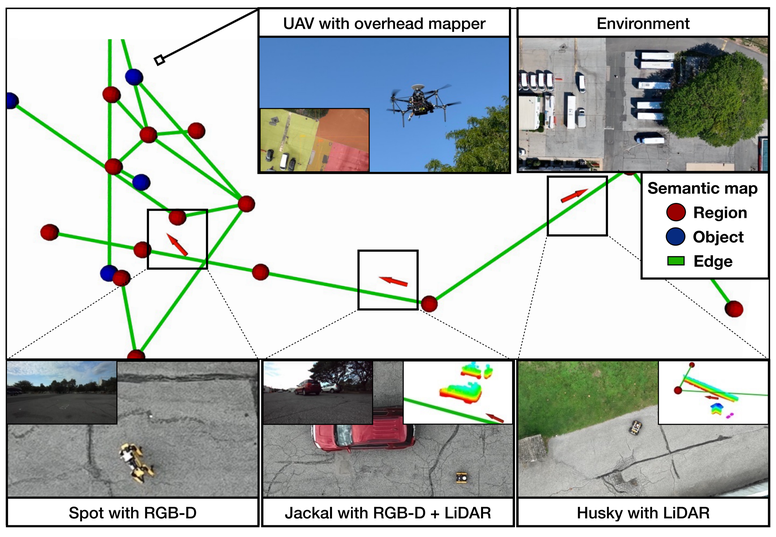
> 21 real-world and 24 simulated missions.

> One to four heterogenous platforms: Clearpath Husky, Clearpath Jackal, Boston Dynamics Spot, Falcon 4 UAV.

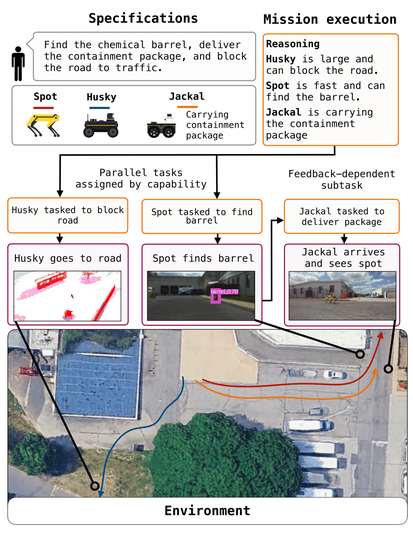
> Real-world semi-urban office park, rural environment, and simulations.



Example environment and experiments

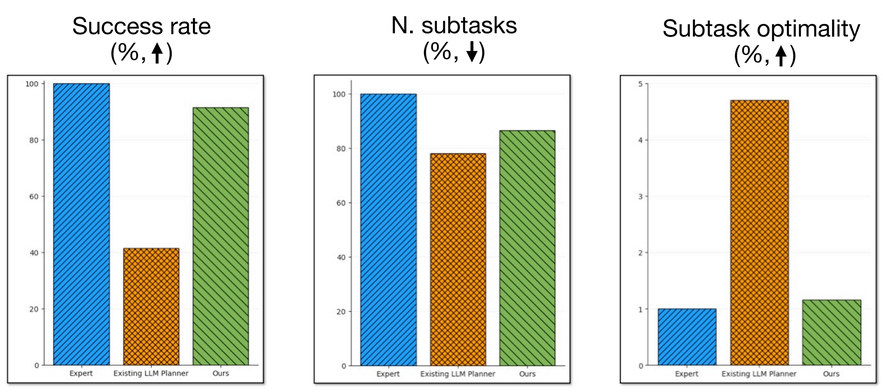


Shared semantic map built during mission

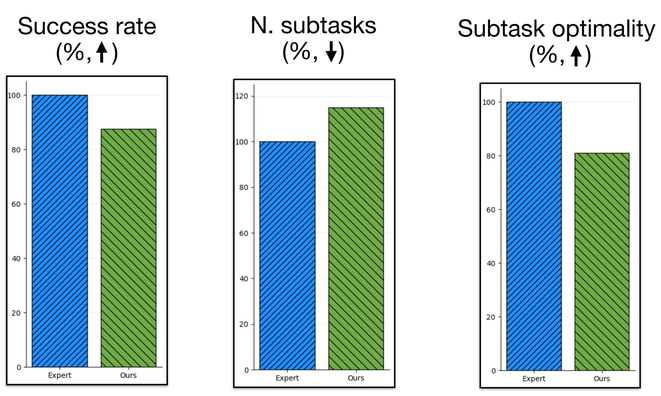


Mission with inter-robot dependencies

Empirical Results



Compared to Expert Planner and LLM baseline in simulation



Compared to Expert Planner in real-world experiments.

Measuring success rate, number of required subtasks, and subtask optimality normalized against expert planner and compared to LLM-enabled baseline [3]

References

[1] Cladera et al. *Air-ground collaboration for language-specified missions in unknown environments.* TF-R 2025.

[2] Miller et al. *Air-ground collaboration with SPOMP: Semantic panoramic online mapping and planning*. TF-R 2024

[3] Liu et al. Coherent: Collaboration of heterogeneous multi-robot system with large language models. ICRA 2025