

# HeRo: A State Machine-based, Fault-tolerant Framework for Heterogeneous Multi-Robot Collaboration

唐瑞杰, 吴国全, 汪涛, 陈伟, 魏峻

ICRA 2025

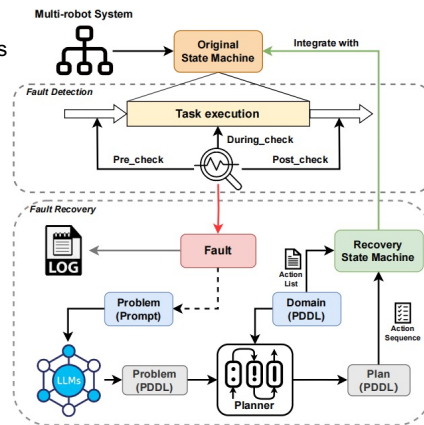
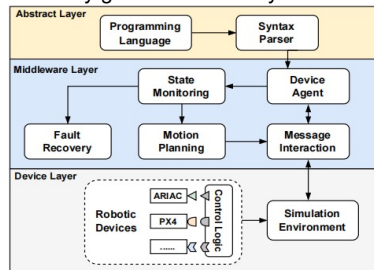
联系方式: 吴国全, 13811652932, gqwu@otcaix.iscas.ac.cn

## Motivation

- **Background:** Heterogeneous robots can work together to accomplish a variety of complex tasks and have shown great potential in many fields. The design, implementation, and runtime verification of heterogeneous multi-robot collaboration systems still require further improvement.
- **Challenges:**
  - Lack of unified programming abstractions for heterogeneous robots.
  - Limited reusability and portability of robot control logic.
  - Unstable communication and untimely response between different robots.
  - Lack the ability to automatically detect and recover from faults during runtime.

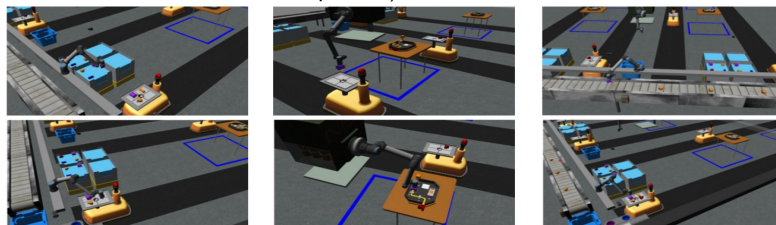
## Methodology (HeRo)

- **State Machine-Based Programming Language:**
  - Model heterogeneous robots and collaborative tasks in a unified and modular manner
  - Template-based behavior modeling to improve reusability, consistency, and scalability
- **State Synchronization Mechanism:**
  - Distributed shared memory
  - Fixed synchronization cycles to coordinate states
  - Mutual exclusion and timestamped concurrency
- **Fault Detection and Recovery:**
  - Introduce tree types of monitors to detect faults
  - Use Large Language Model (LLM) and PDDL to automatically generate recovery code



## Experiments

- HeRo can effectively model and execute tasks with different difficulty levels in ARIAC (Agile Robotics for Industrial Automation Competition)



- HeRo can identify runtime faults timely and generate corresponding recovery strategies efficiently
  - Recovery logic generation time  $\approx$  5% total time
- Performance overhead of the framework is low  $\approx$  2% CPU and 0.5GB memory
- Scalability: Scaling the number of robots does not increase the time complexity of system execution

