Enhancing robot autonomy: Introducing safety strategies for immediate recovery

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Motivation and Research Goal

Functional safety is key to realizing the potential of AI-driven autonomous robots, as these robots work alongside humans in unpredictable environments [1]. However, current safety behaviors require the robot to stop or revert to a safe state. While generally effective in preventing immediate harm, these behaviors can disrupt operations and reduce the usability of autonomous robots, especially in dynamic environments. We propose to use a dual-purpose runtime safety monitoring system that maintains a safe operational state and also guides the high-level planner to recover from unsafe situations, thus balancing safety and continued operation.

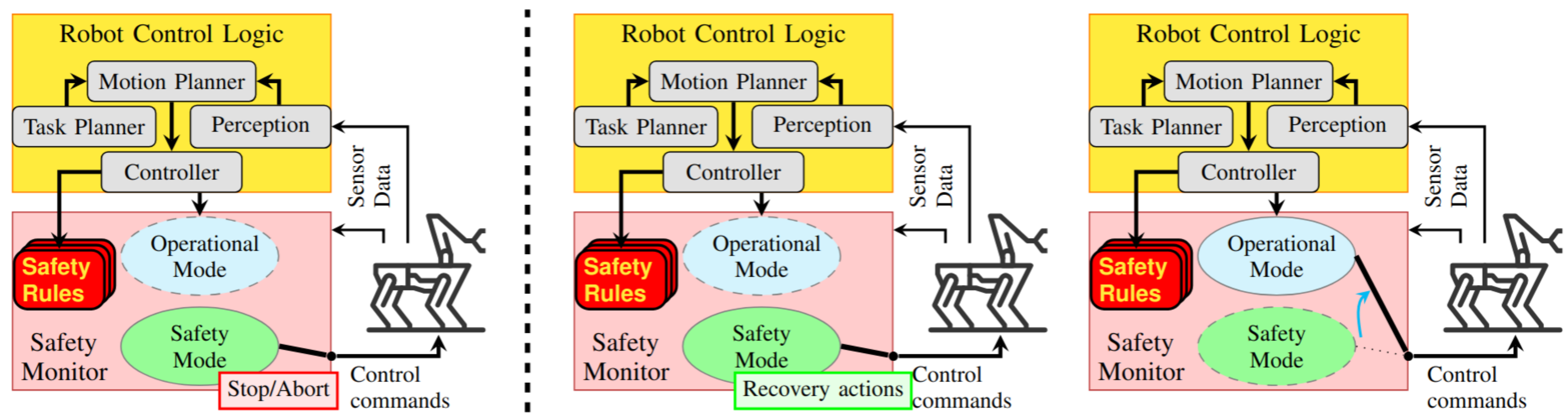


Fig. 2: A comparison between the runtime behavior of state-of-the-art Safety Monitoring approaches (left) and our proposed approach in safety mode (centre), and our approach reverting back to operational mode (right).

Safety Strategies

Adaptive	The robot temporarily modifies its behavior to manage a detected change or hazard. *Examples:* Speed reduction (possibly but not necessarily gradual), smaller detour around a human.
Self-Recovering	The robot performs specific operations in response to a hazard with the aim to resume or transform the robot control logic's original plan. *Examples:* Tracing back the most recent steps, calculating an alternative route, switching to another task that achieves the same goal.
Temporary	The robot temporarily enters a safe state but resumes when the trigger is removed. *Examples:* Full stop on LIDAR contact, until the hazard disappears again.
Terminal	The robot permanently enters a safe state. *Examples:* Stuck in a corridor with no way out, toppled, non-recoverable sensor malfunction.

Table 1: Categories of safety behaviors.

A Medicine Delivery Robot

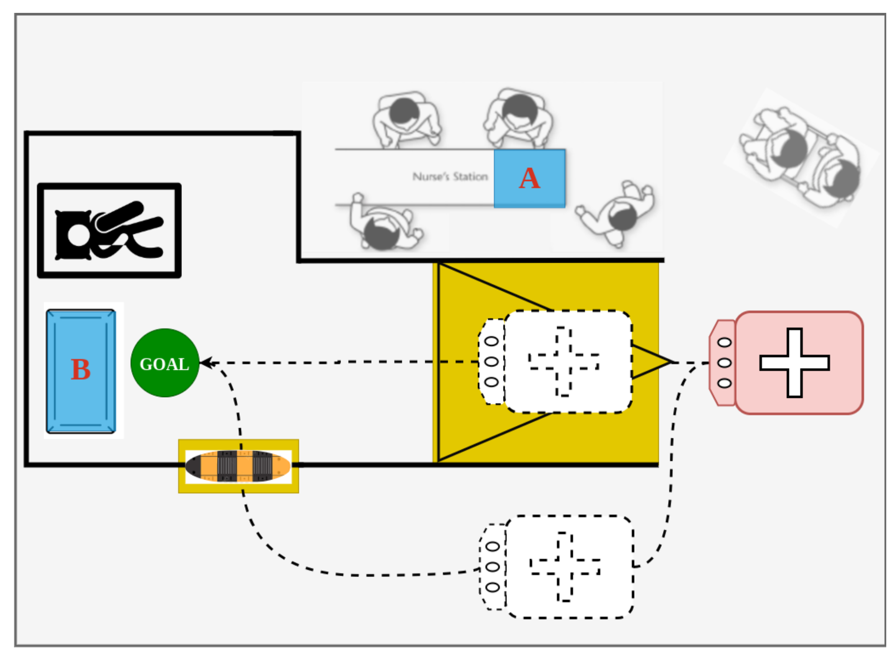
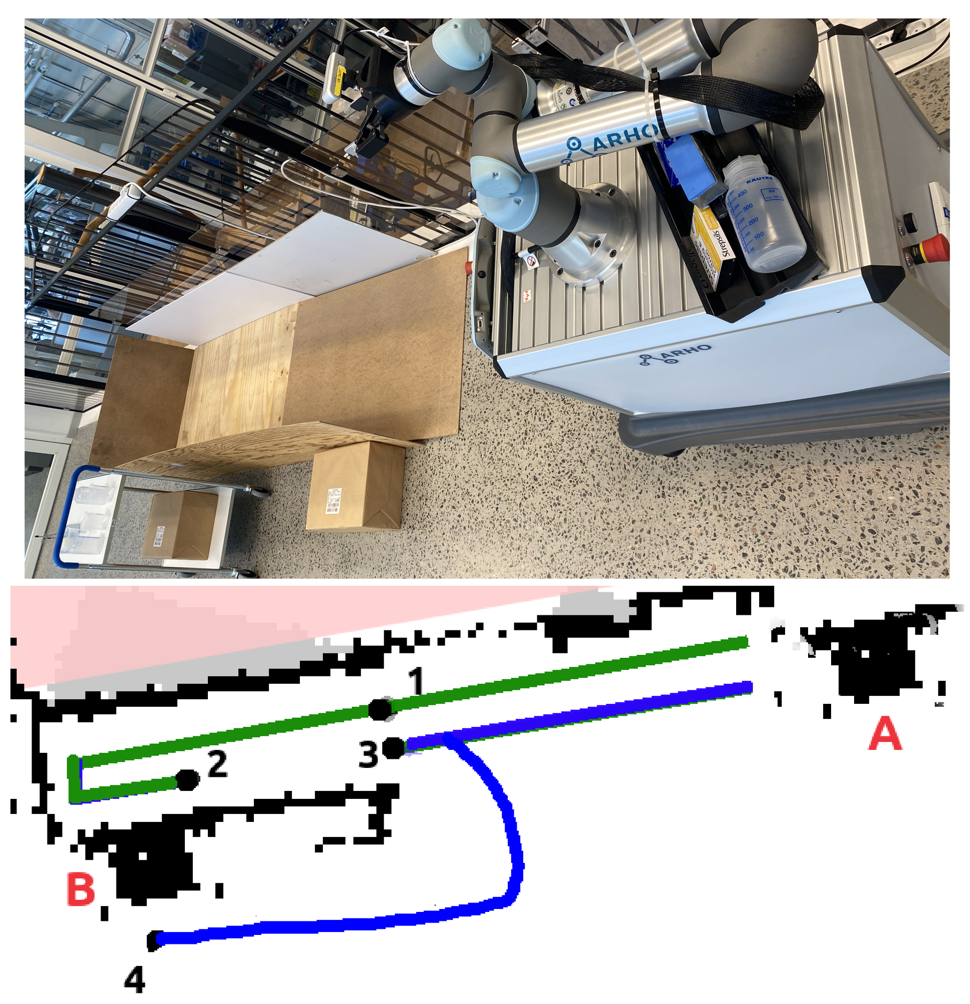


Fig 1: A robot that require quick, safe decision-making to protect human lives.

Experimental Evaluation and Results



Hazard Points	Safety Monitor			High-level Planning			Task Completion
	Actions	Response Time (sec)		Actions	Response Time (msec)		
1	Slow down	0.88	0.039	–	–	–	✓
2	Stop Go back	0.34 0.50	0.002 0.006	No alternative plan found	5.05	2.00	✗
3	Stop Go back	0.40 0.68	0.008 0.002	Take a longer route	6.43	1.76	✓
4	Retract Switch controller	0.49 0.41	0.002 0.325	–	–	–	✓

Key Insight: The actions executed by the safety monitor exhibit lower response time ensuring that it functions as a fast reflex system. While the response times of the high-level planner are longer due to the communication latency and the complexity of executing recovery behaviors.

References

[1] Rizwan, Momina, Christoph Reichenbach, and Volker Krueger. "ROSSMARie: A Domain-Specific Language To Express Dynamic Safety Rules and Recovery Strategies for Autonomous Robots." Second Workshop on Quality and Reliability Assessment of Robotic Software Architectures and Components. 2023.

Video Demonstration

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