Robustness Certification of Deep Learning

09/06/2025

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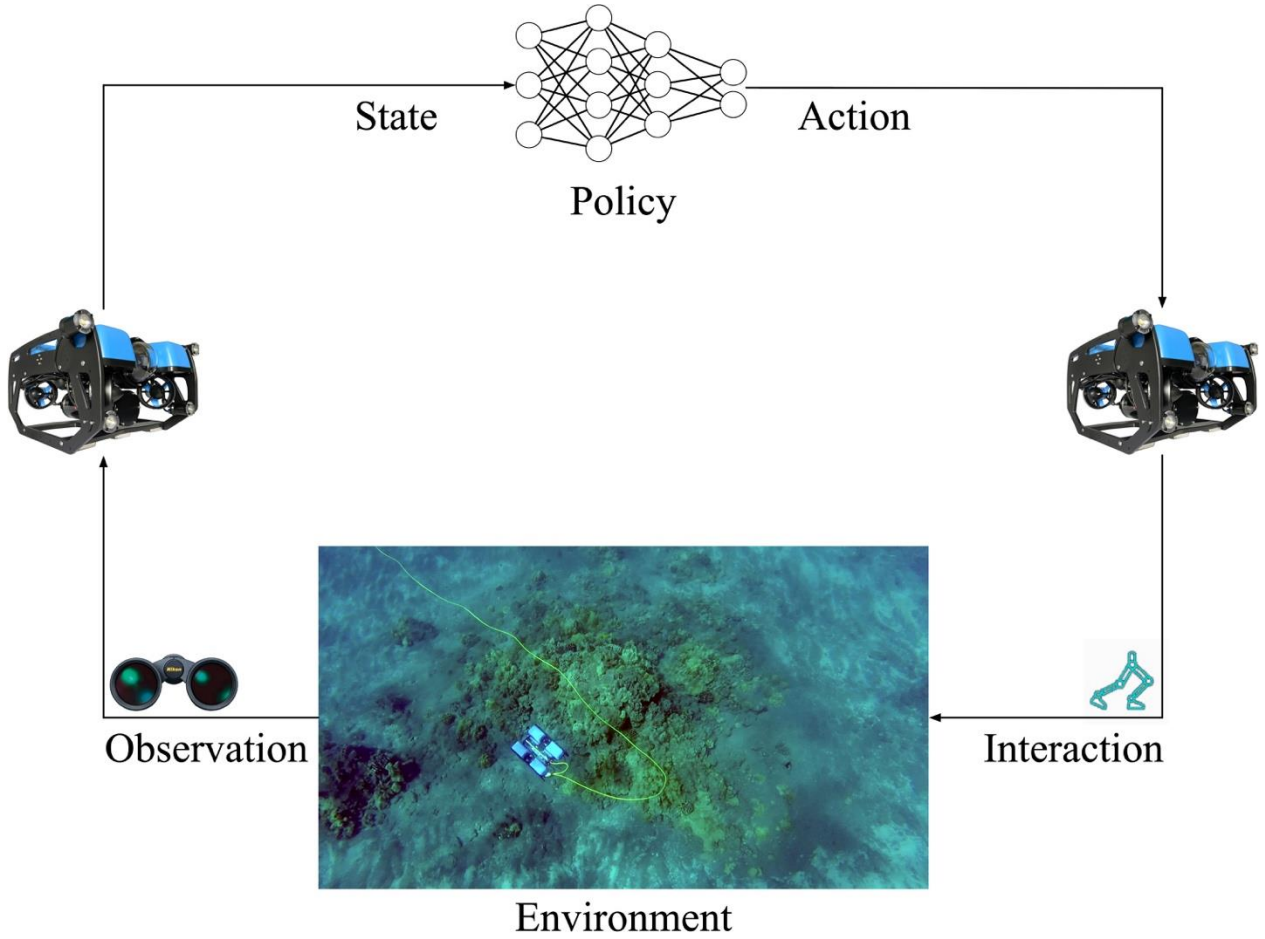
Outline

- Probabilistic Verification of Deep Reinforcement Learning
- Reachability Verification of Deep Reinforcement Learning
- Privacy-preserving Distributed Learning

Deep Reinforcement Learning



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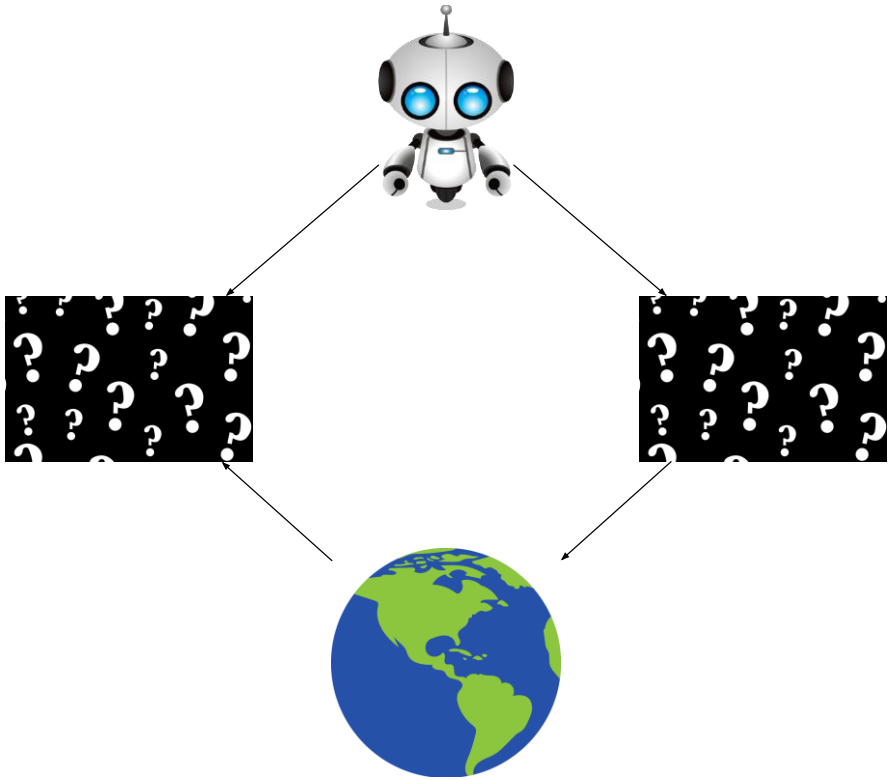
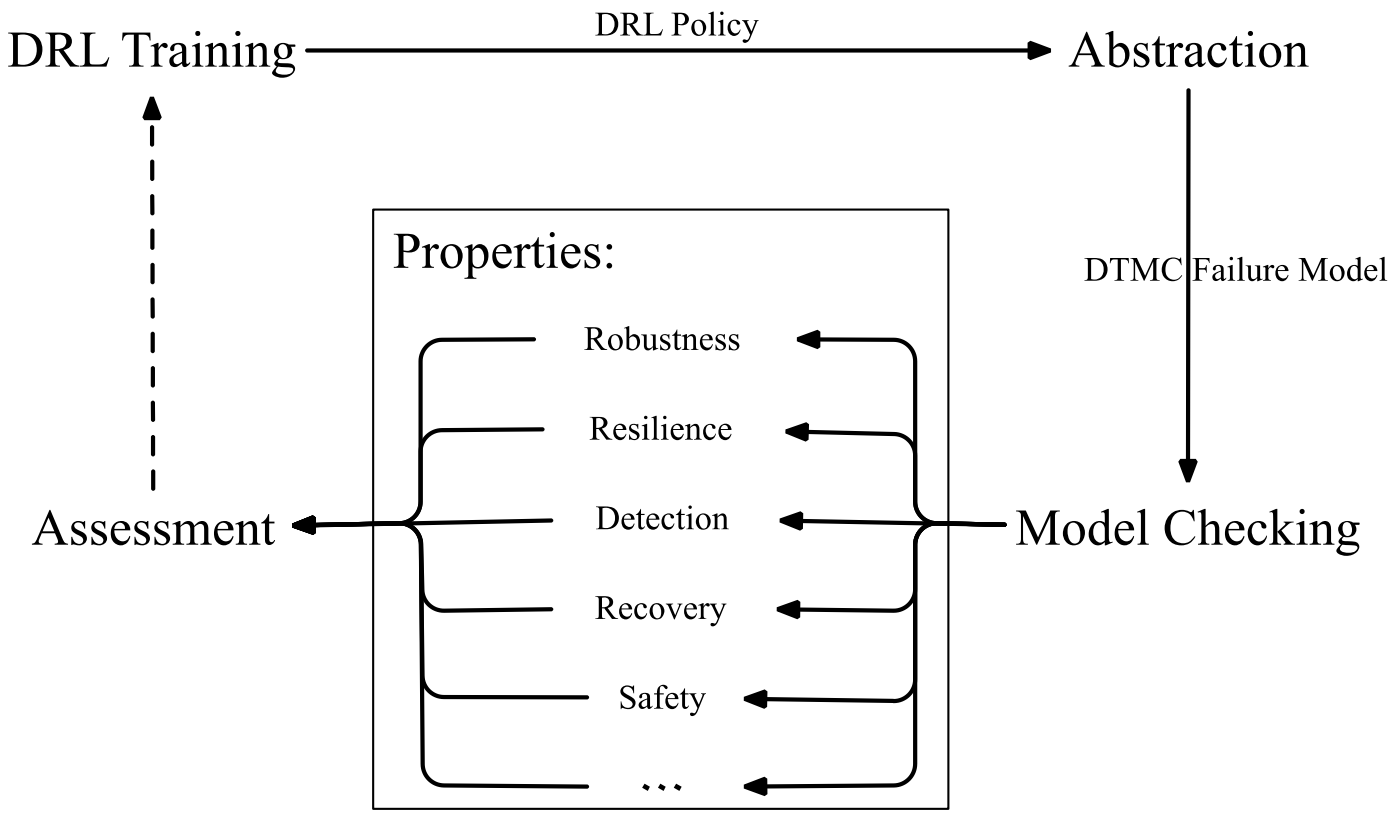
Case 1: Unknown Environment





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[1] Y. Dong, X. Zhao and X. Huang, "Dependability Analysis of Deep Reinforcement Learning based Robotics and Autonomous Systems through Probabilistic Model Checking," *2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*

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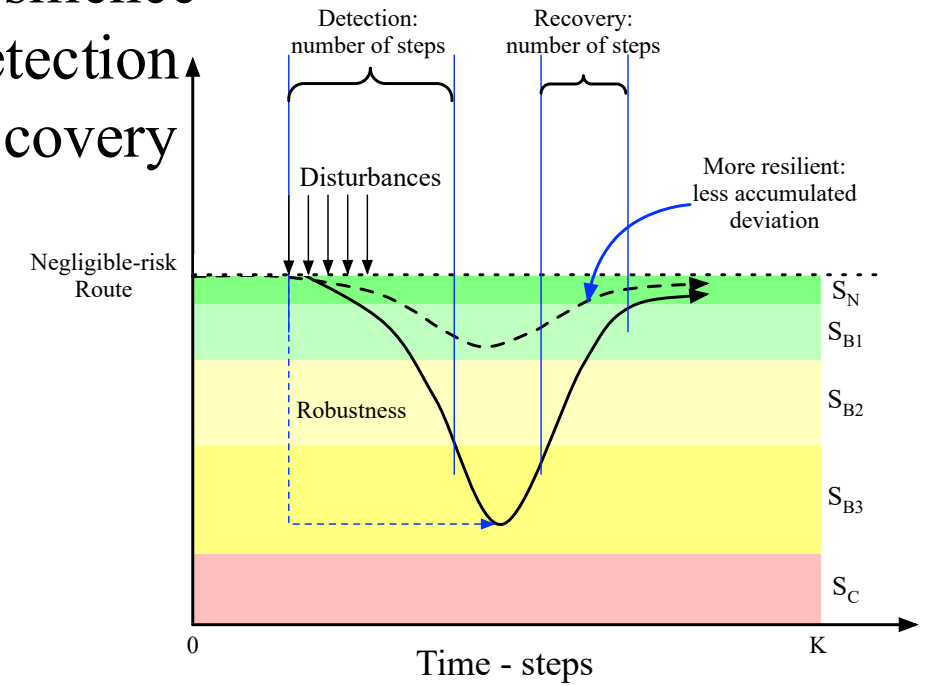
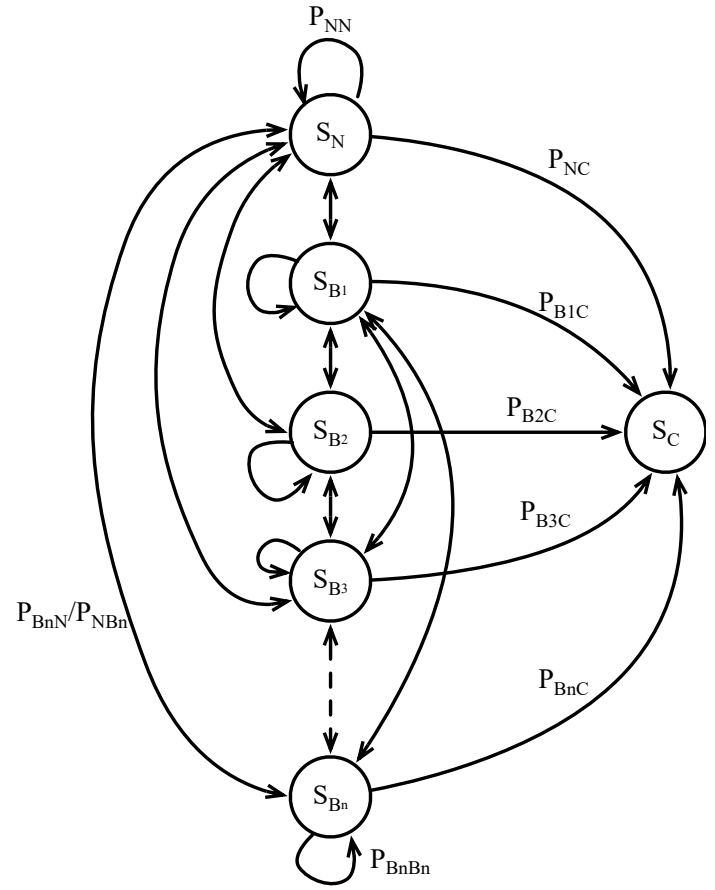
Our Solutions

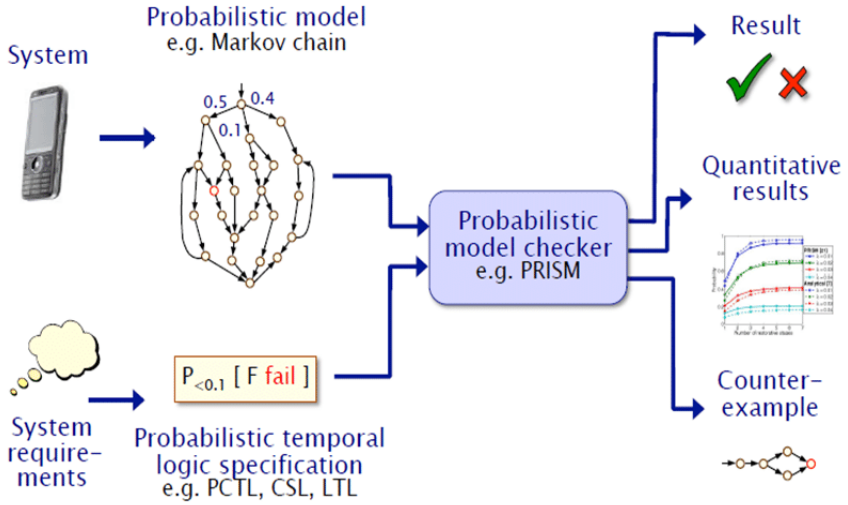
1. Safety Properties:
- Robustness
- Resilience
- Detection
- Recovery
- …



2. DTMC model:



3. Probabilistic Model Checker:



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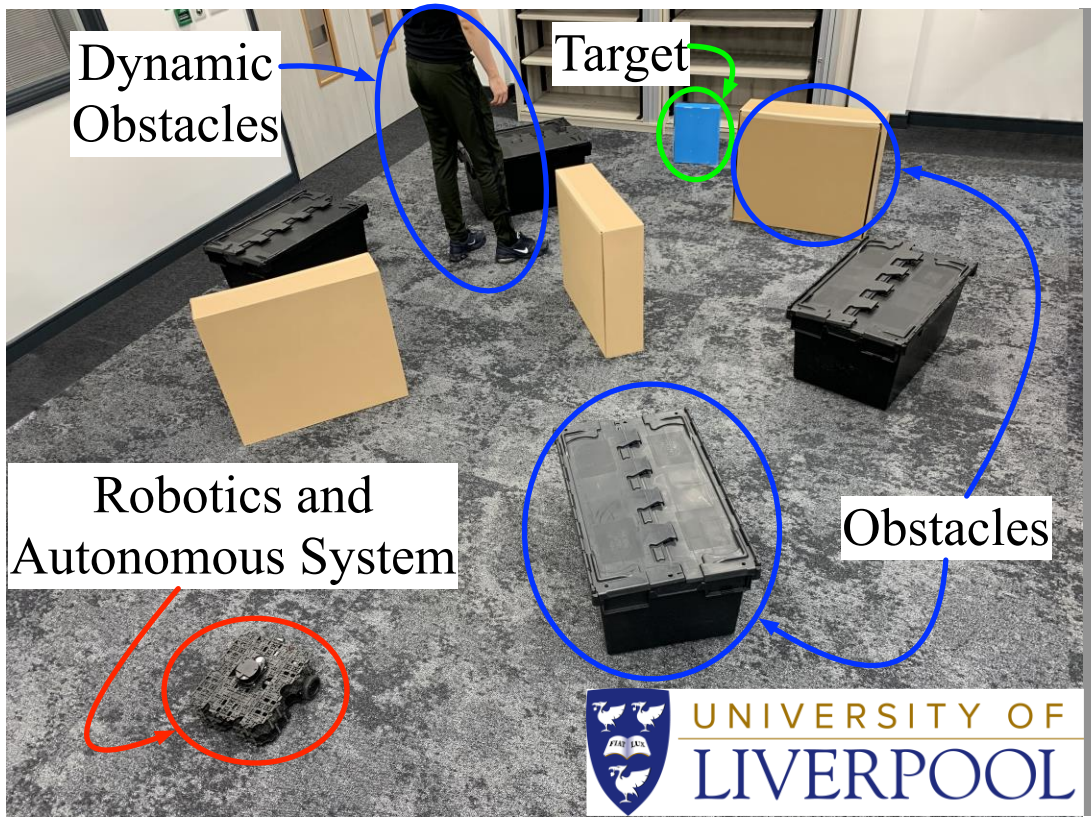
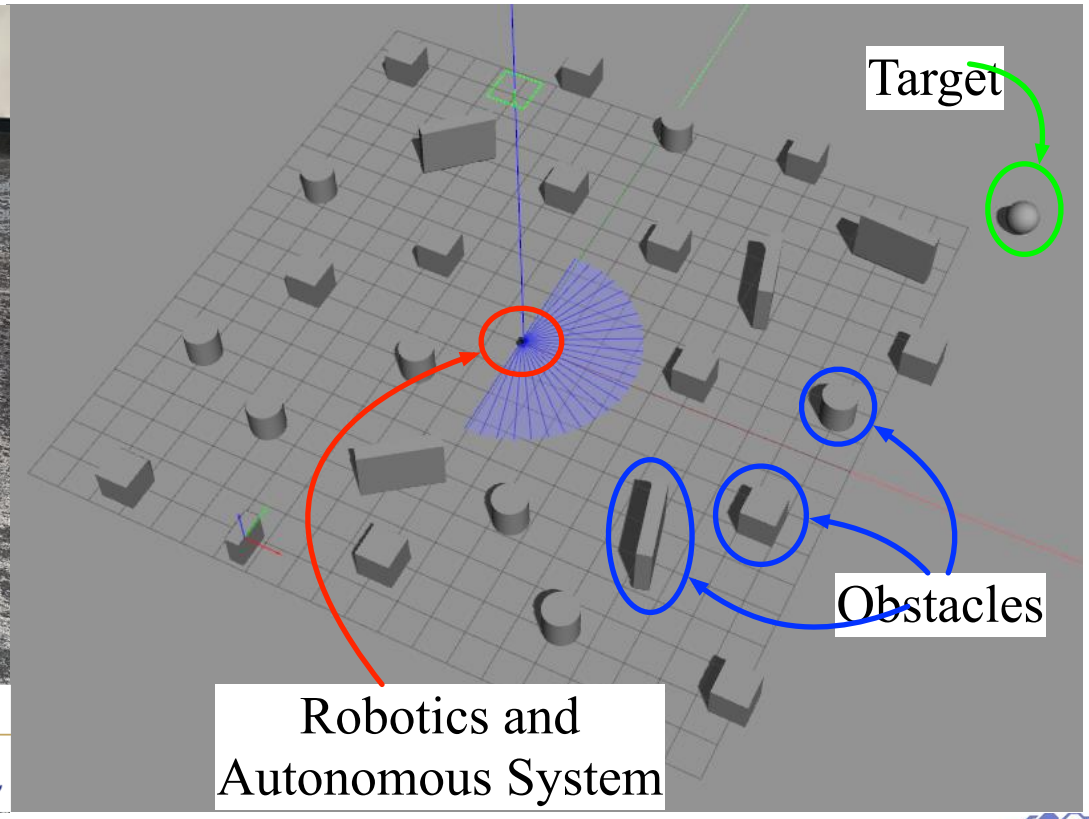
Experiments





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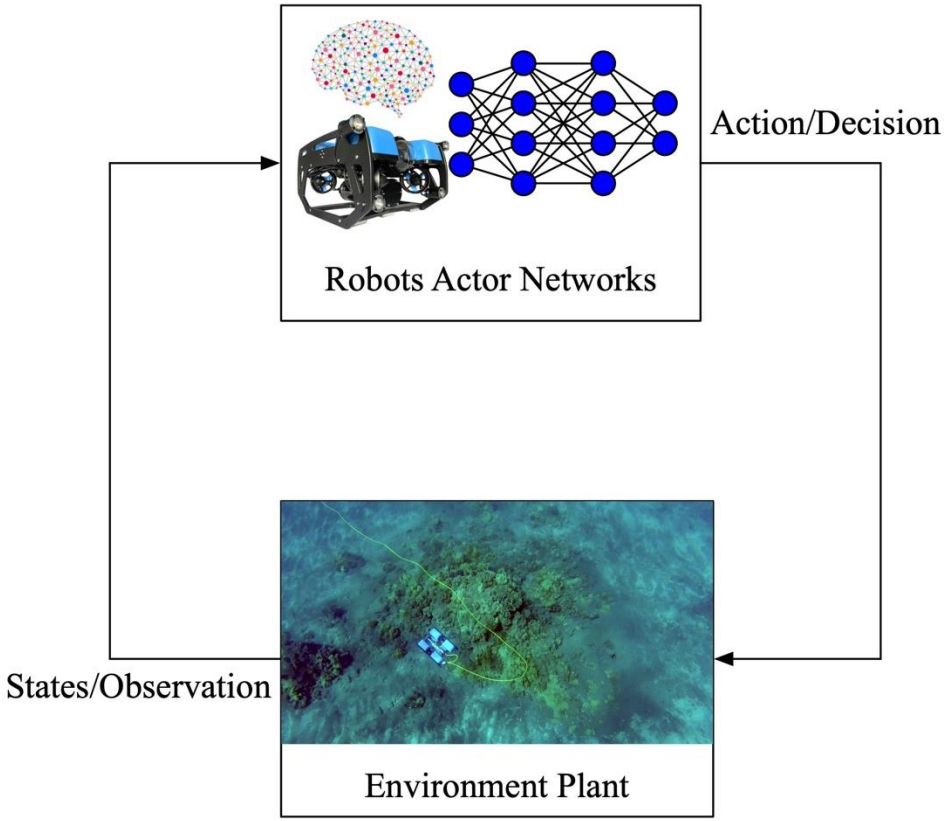
Case 2: White-box Verification

Target: Probability of crash per random initial-condition (*pci*)



Robot Actor Networks:

- Number of Layers
- Number of Neurons
- Weights and Bias

Environment Plant:

- Transition Probability
- Kinetic Model

[2] Y. Dong, X. Zhao, S. Wang and X. Huang, "Reachability Verification Based Reliability Assessment for Deep Reinforcement Learning Controlled Robotics and Autonomous Systems," in *IEEE Robotics and Automation Letters*, vol. 9, no. 4, pp. 3299-3306, April 2024

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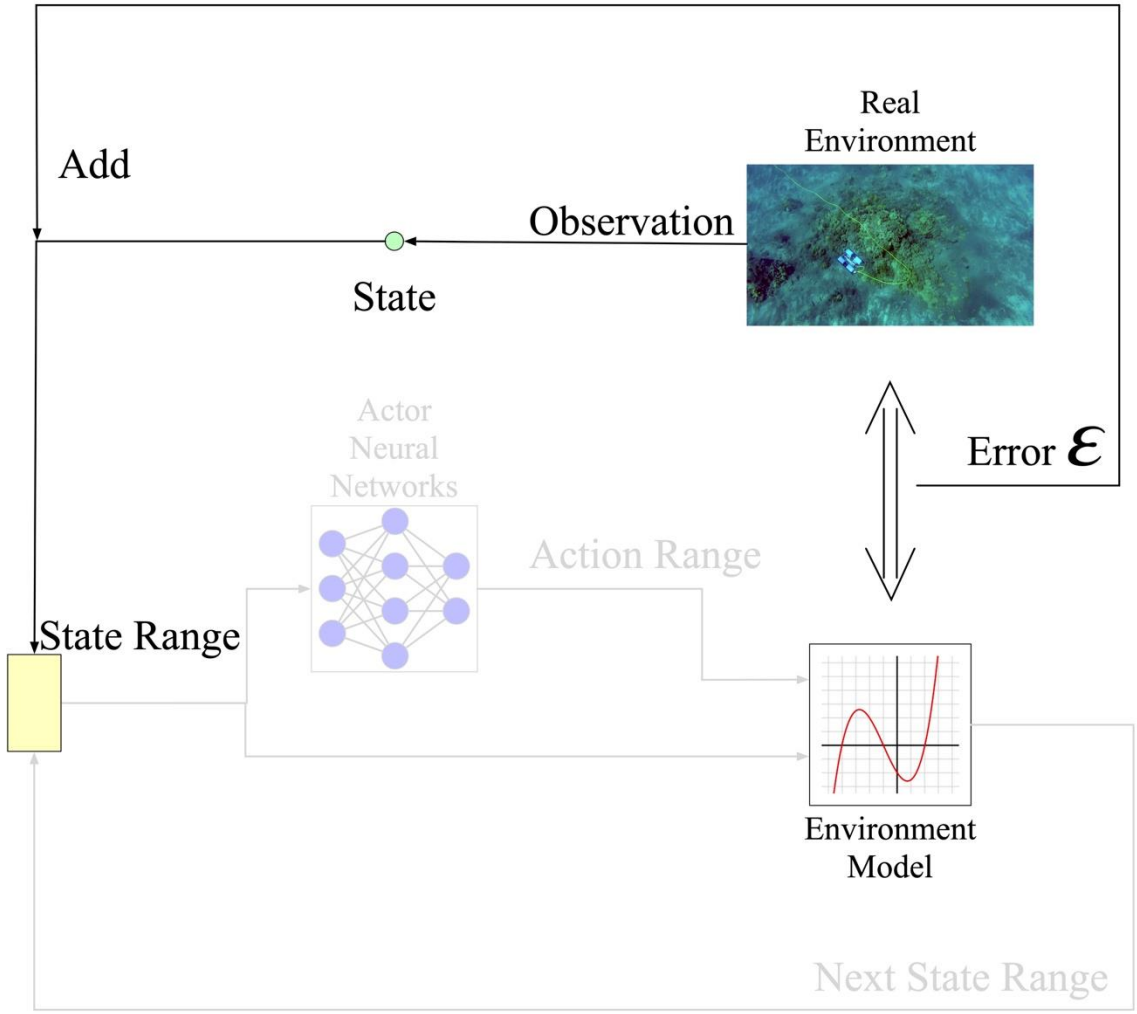
Reachability Verification



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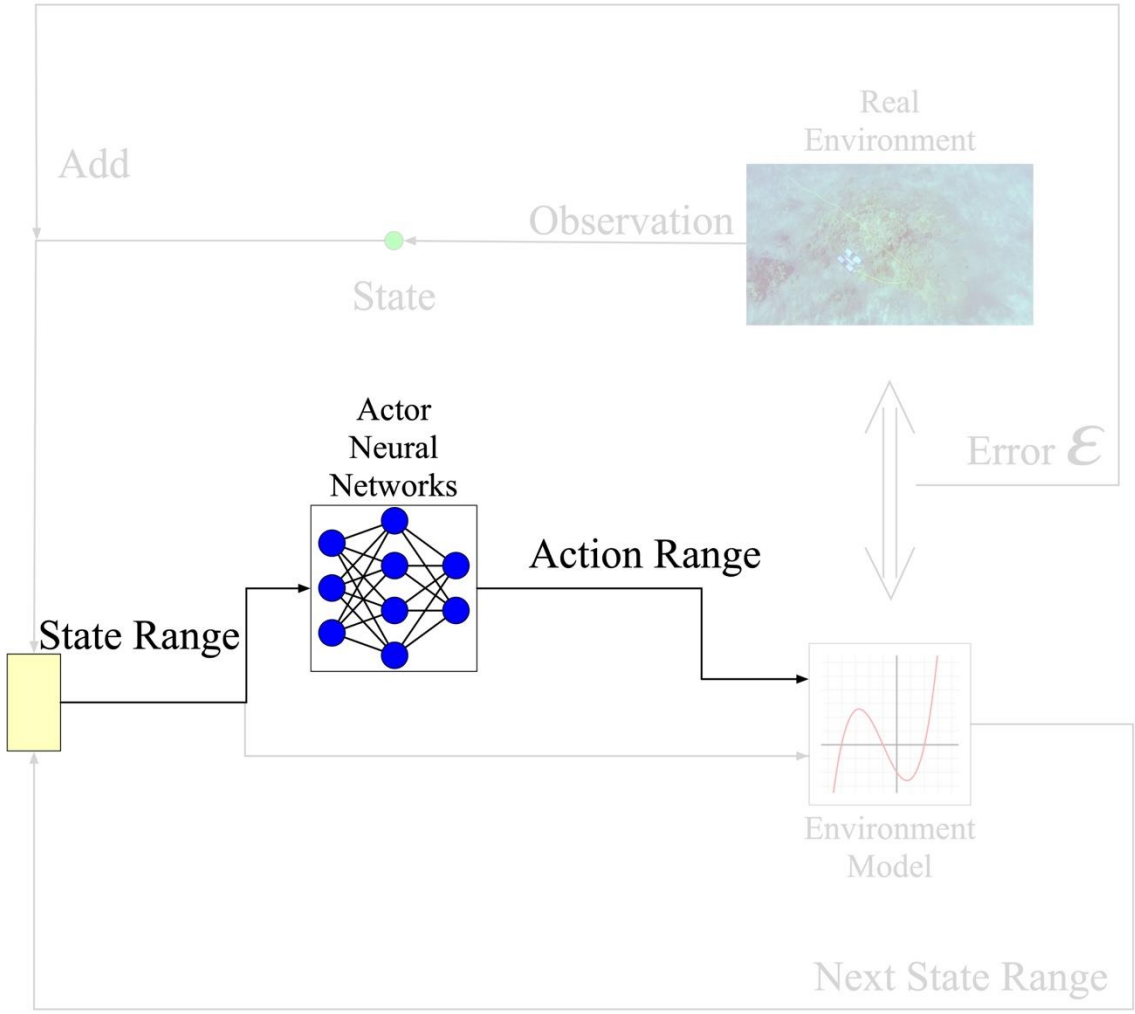
Reachability Verification



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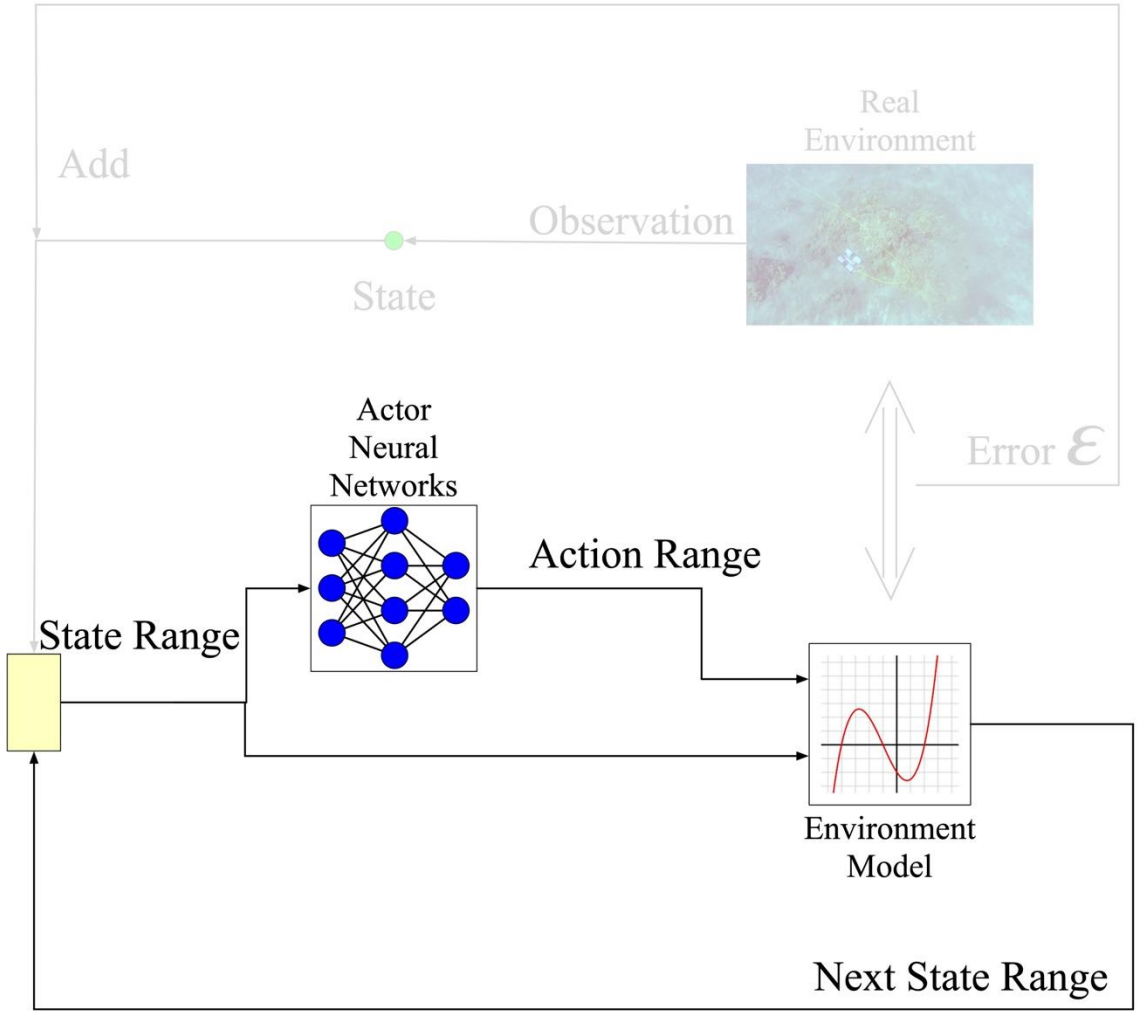
Reachability Verification



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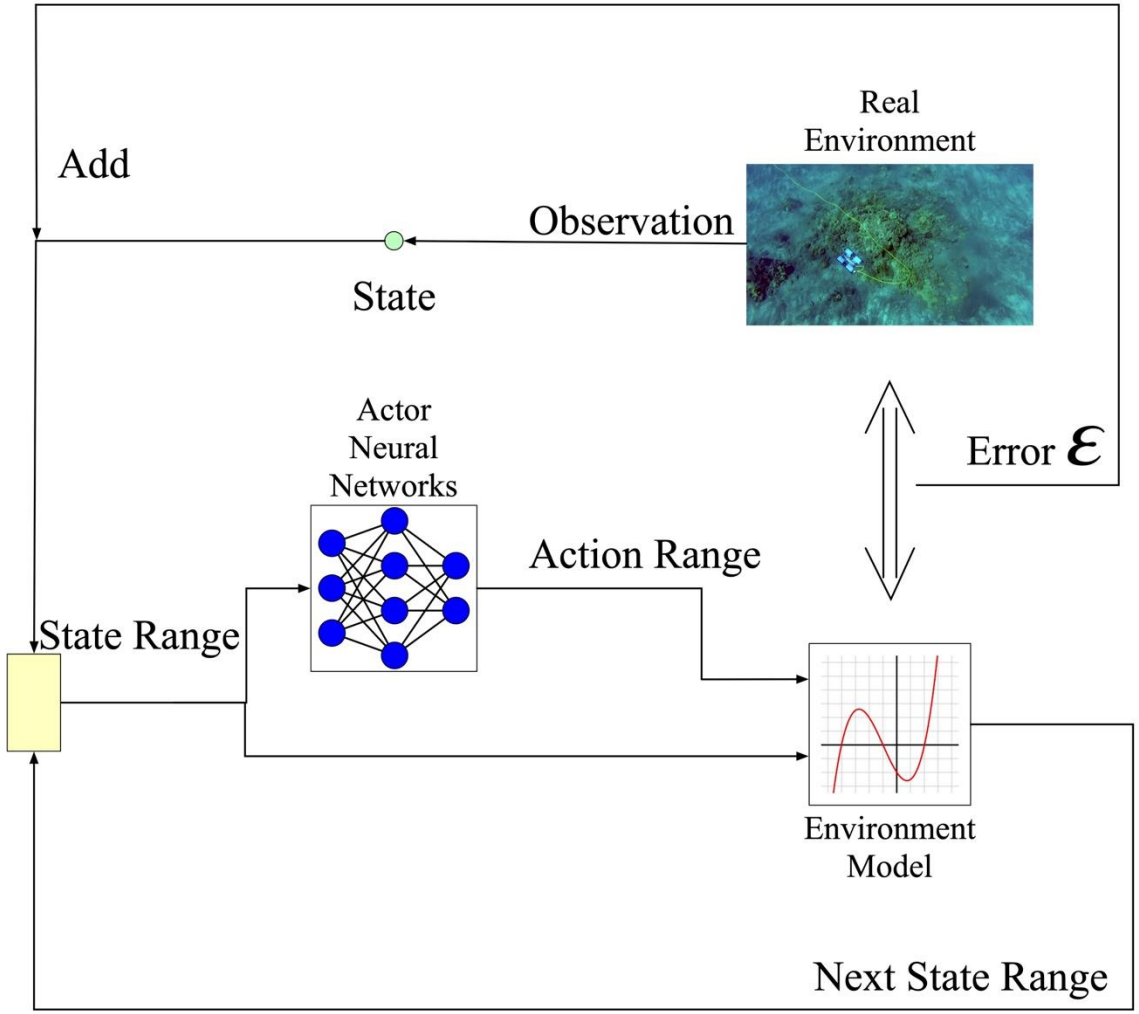
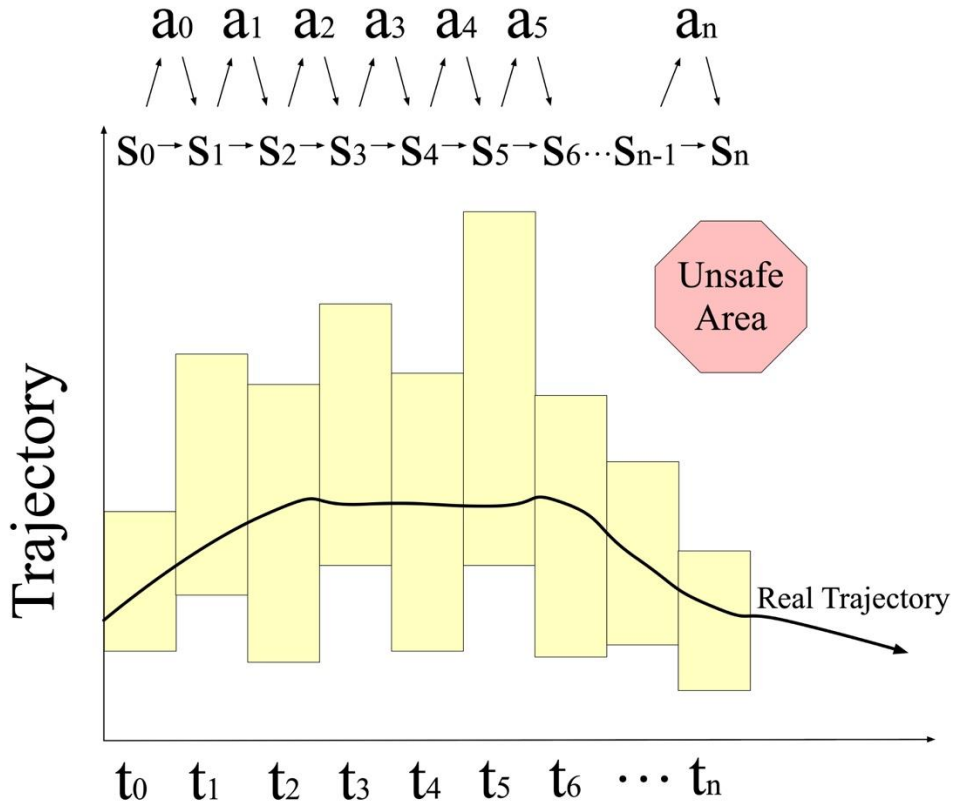
Reachability Verification





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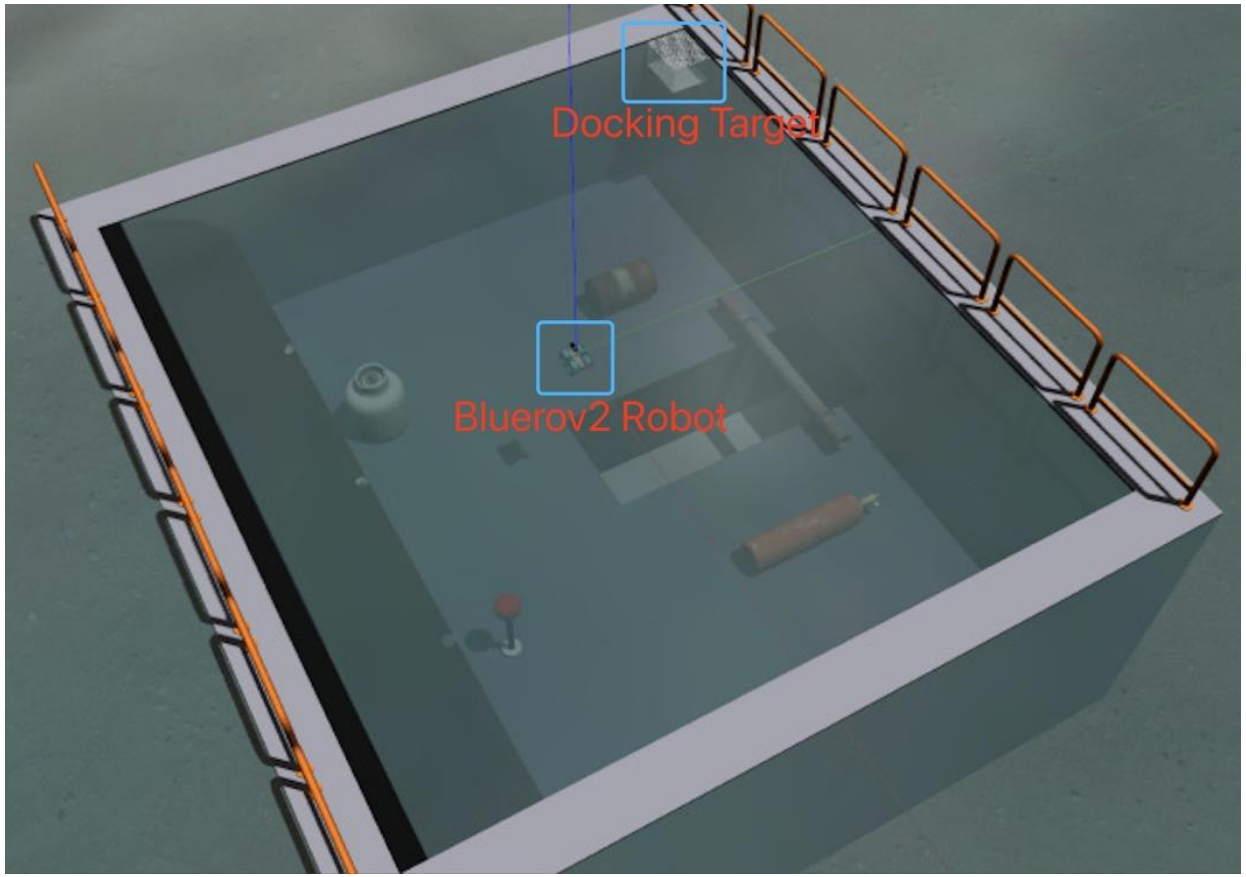
Environment Setup



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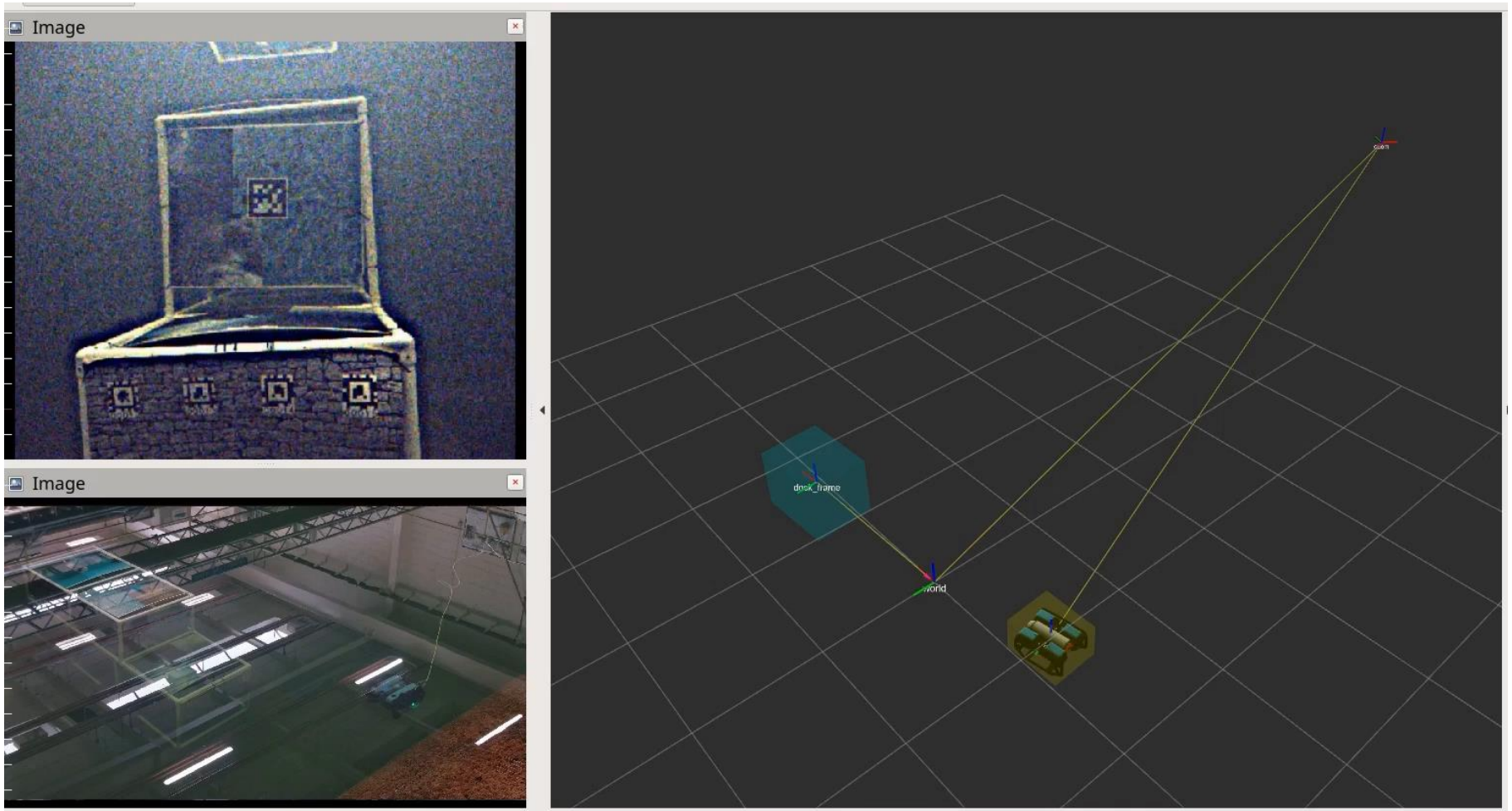
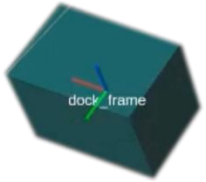
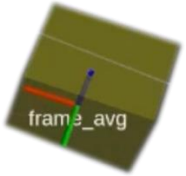
Demo a Safe Route



- Docking Cage



- Reachable Range of UUV



- World Frame (Static)

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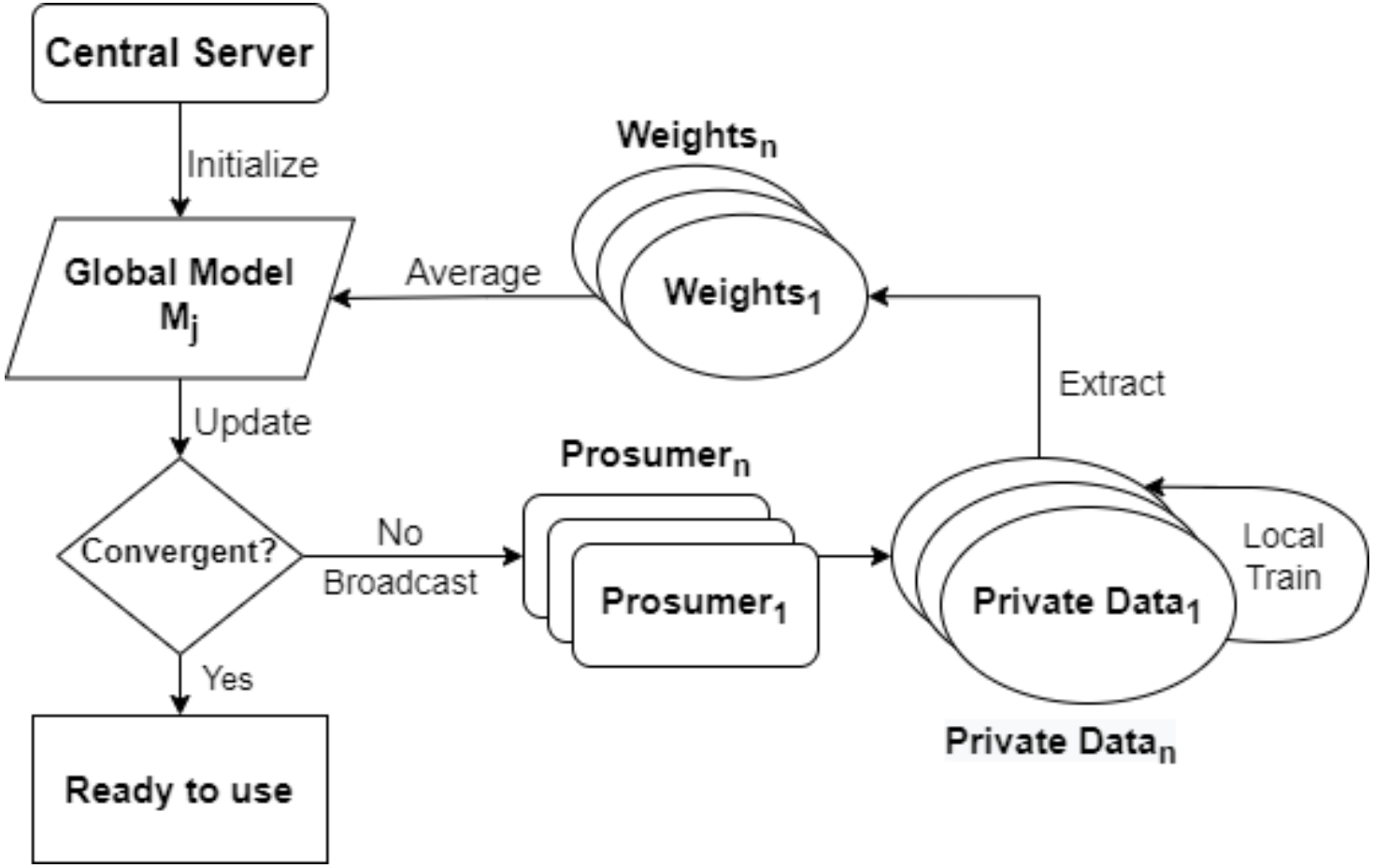
Case 3: Privacy-preserving Distributed Learning



Research Challenges:

- Scalability
- Accuracy
- Robustness
- Privacy

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[3] Y. Dong, Y. Wang, M. Gama, M. A. Mustafa, G. Deconinck and X. Huang, "Privacy-Preserving Distributed Learning for Residential Short-Term Load Forecasting," in *IEEE Internet of Things Journal*, vol. 11, no. 9, pp. 16817-16828, 1 May1, 2024

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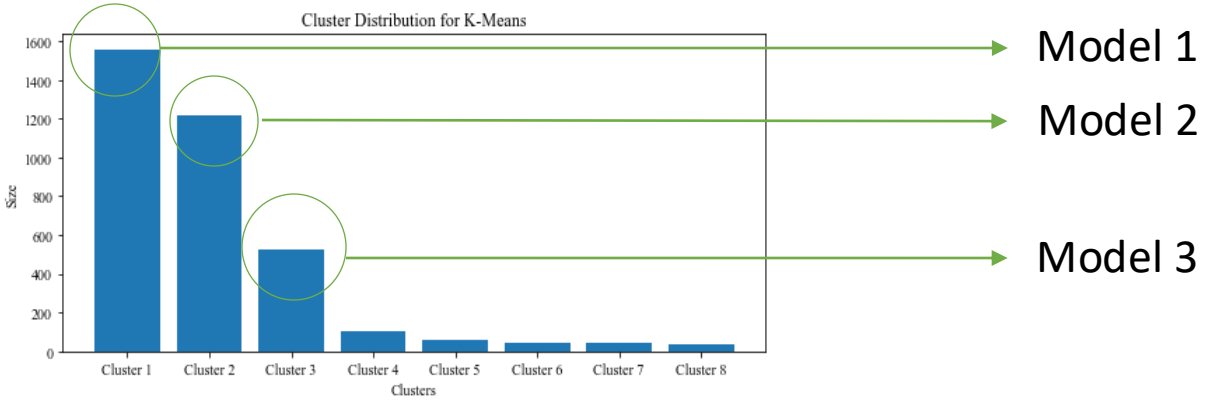
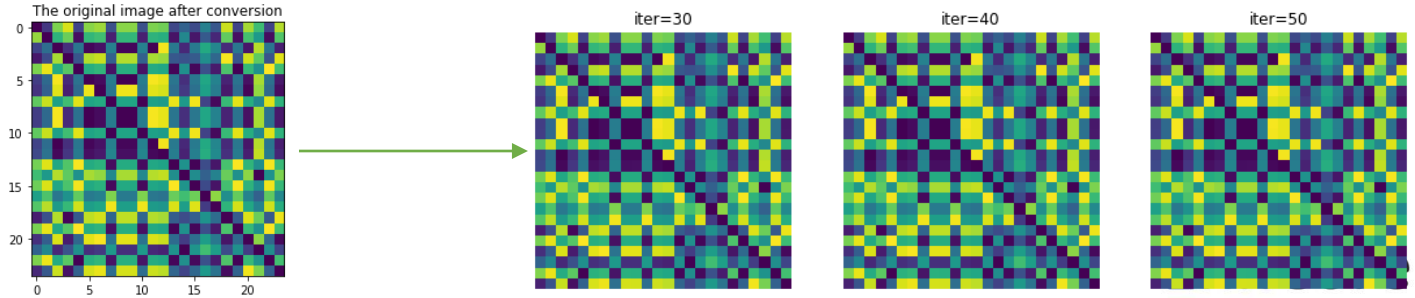
Our Solution



- Scalability: K-means clustering to handle the non-IID dataset.
- Accuracy: 4 types of NN models (DNN, LSTM, CNN, WaveNet)
- Robustness: Damaged training data.
- Privacy: Deep Leakage from Gradients.



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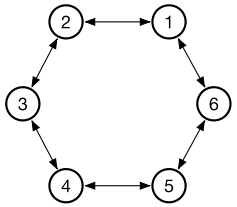
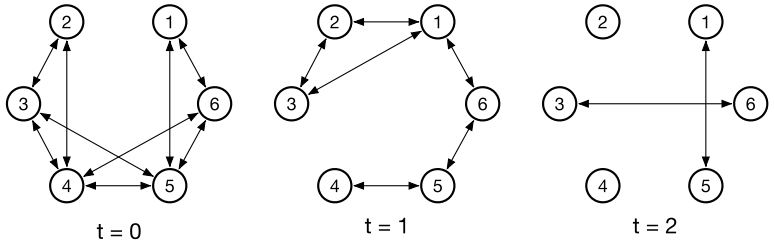
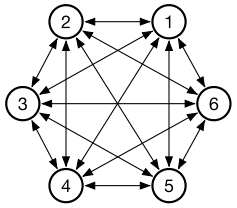
Our Solution



Ring Topology

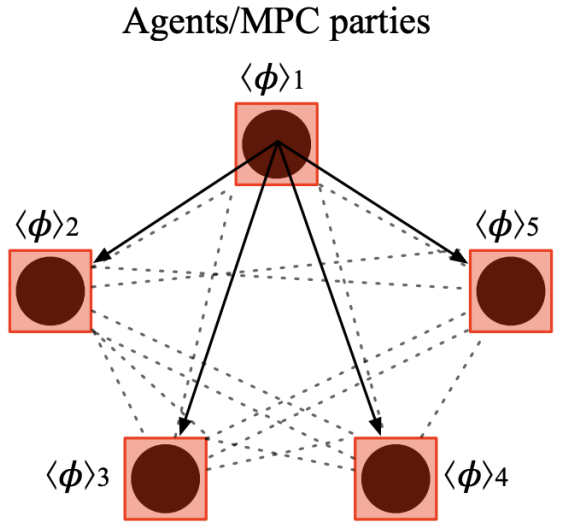




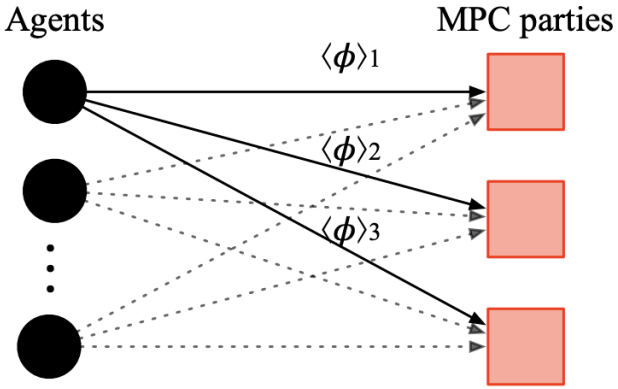
Fully Connected Topology

Markovian Switching Topologies

Distributed Frameworks



(a) MPC parties played by the agents.



(b) MPC parties played by external servers.

Agent secret sharing a gradient ϕ with the MPC parties.

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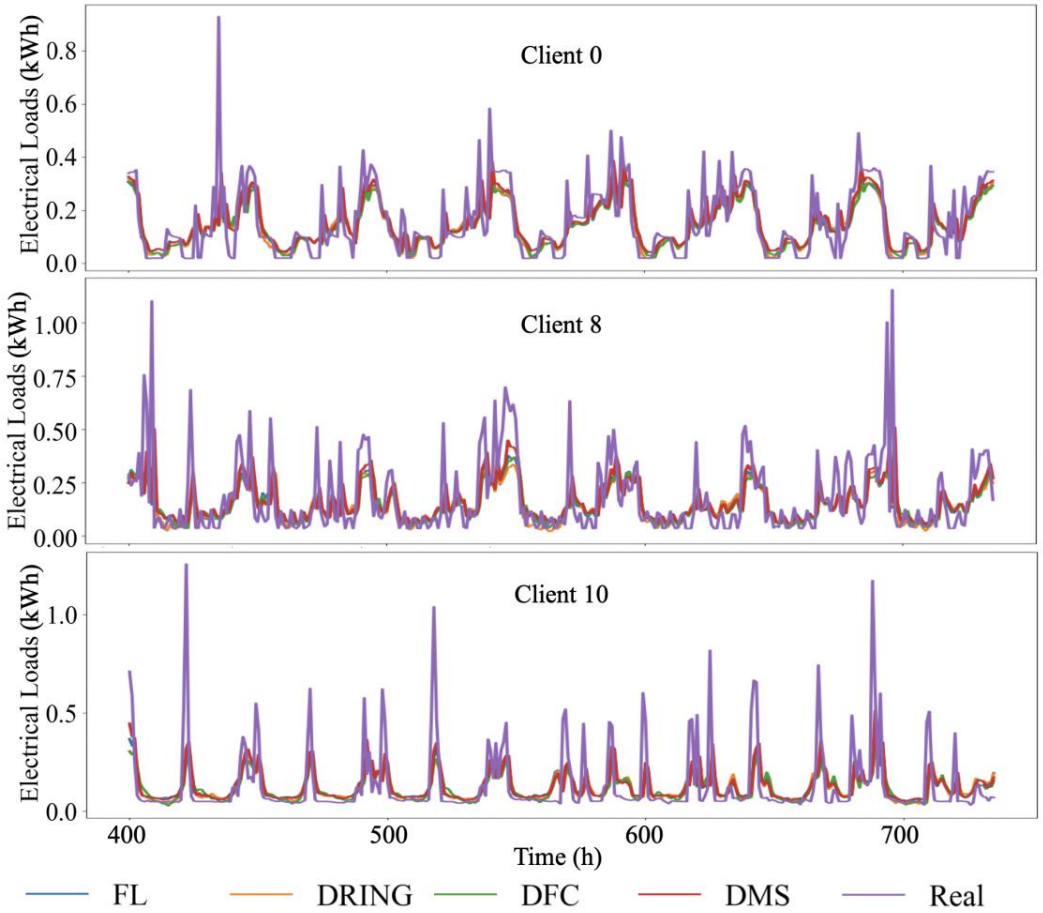
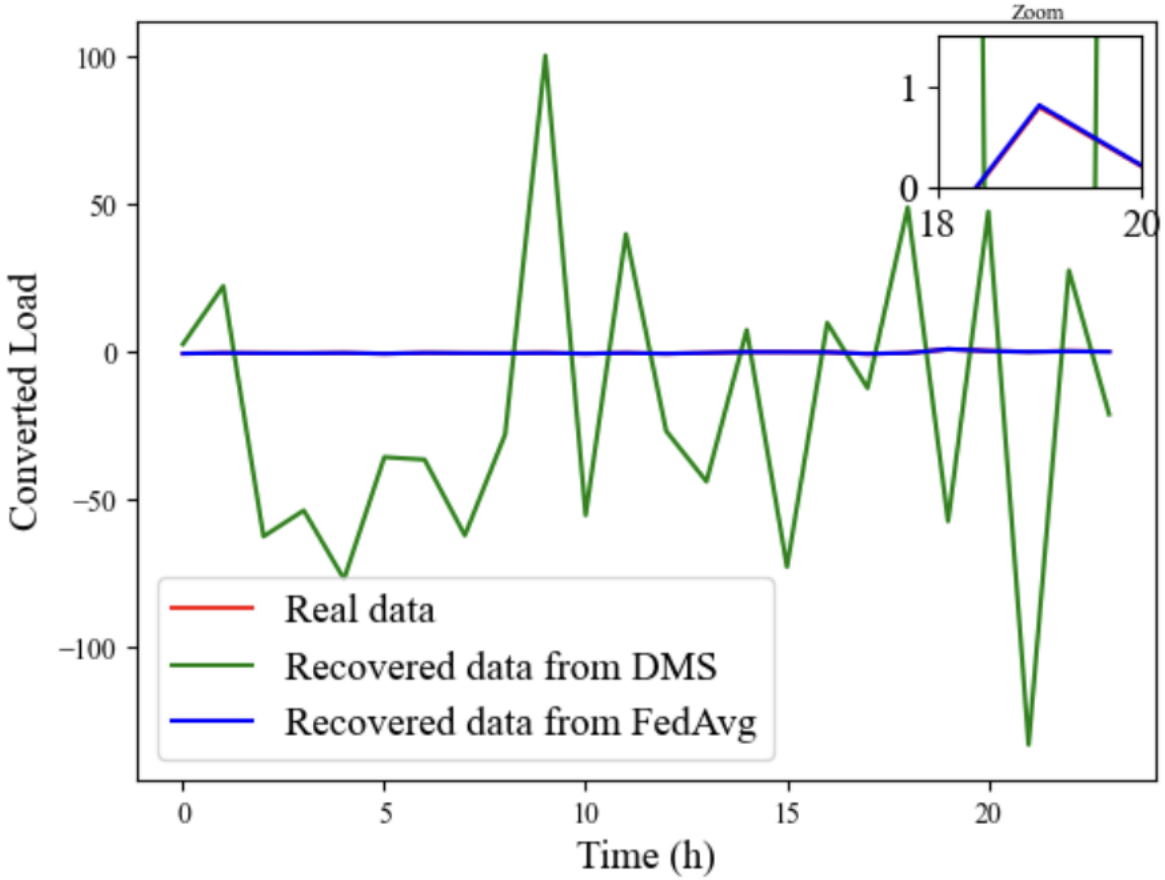
Experiment Results





Recovered data from DLG attack.

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Thank You

- Please refer to our EnnCore project website for more details:
- https://enncore.github.io/
- yi.dong@liverpool.ac.uk

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