GENESIS-RL: GEnerating Natural Edge-cases with Systematic Integration of Safety considerations and Reinforcement Learning

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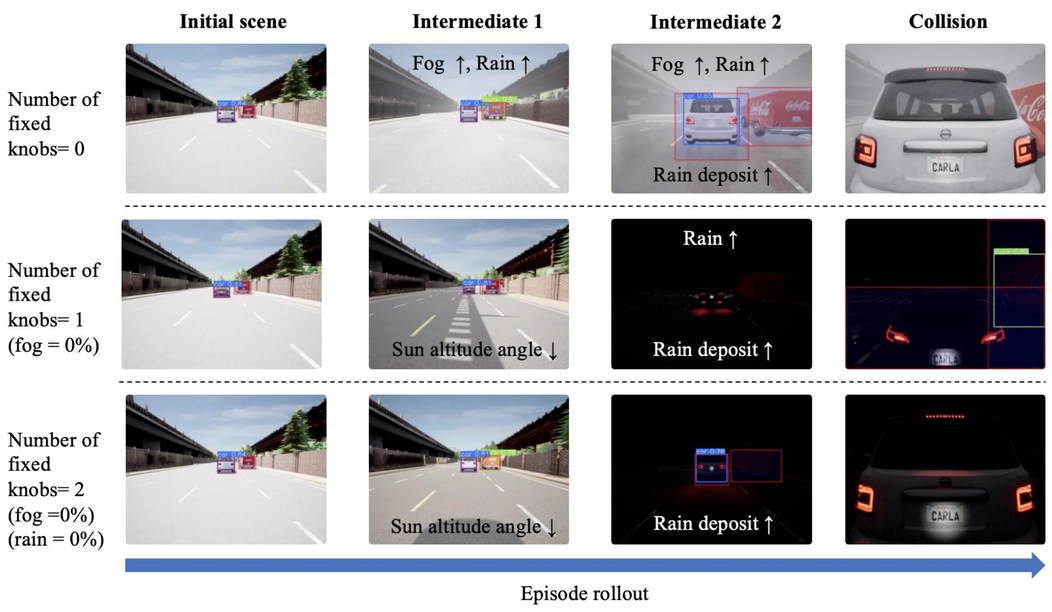
Highlights



- Synthetic edge case data generation framework focusing on system-level safety in autonomous systems
- RL algorithm identifies parametric settings in simulators to generate realistic edge cases
- Experimental validation using the CARLA simulator demonstrates the framework's effectiveness

Introduction

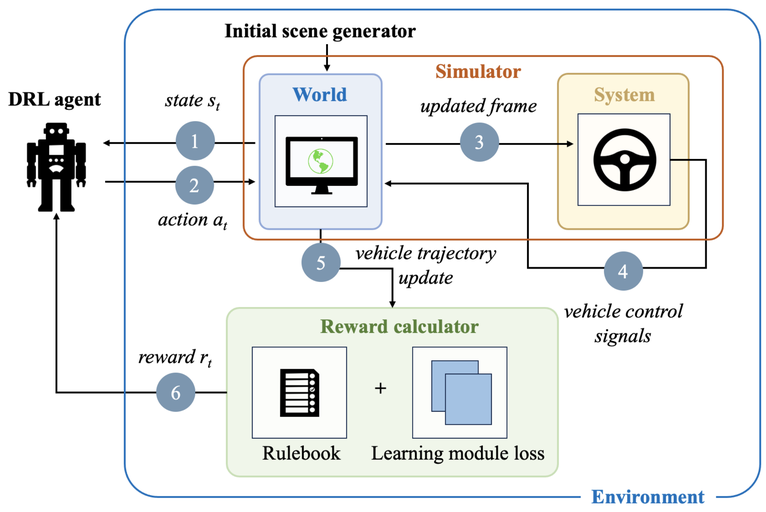
Challenges

- **Infeasibility of manual scenario creation:** Manual generation of each possible testing scenario is impractical due to the vast number of situations in dynamic environments
- **Unrealistic samples:** Traditional adversarial attacks and generative models often produce unrealistic samples
- **Narrow focus :** Traditional methods typically target component vulnerabilities instead of assessing overall system resilience

Proposed Solutions

- **Automated scenario generation with RL:** Using RL to dynamically create diverse and complex scenarios, eliminating the need for manual setup
- **Incorporate high fidelity simulation:** Uses high-fidelity simulators and the RL formulation to ensure the naturalness of the generated scenarios
- **Exposing system vulnerabilities:** Generating scenarios where systems fail to meet standards, exposing critical systemic failures

Framework



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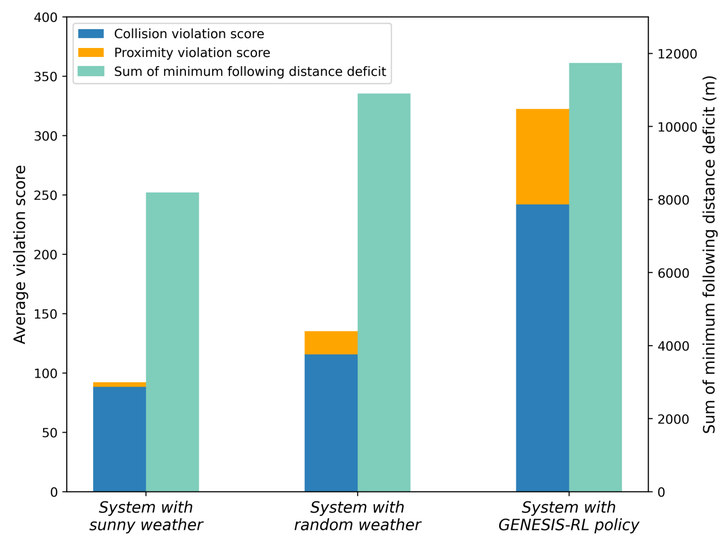
Experiments

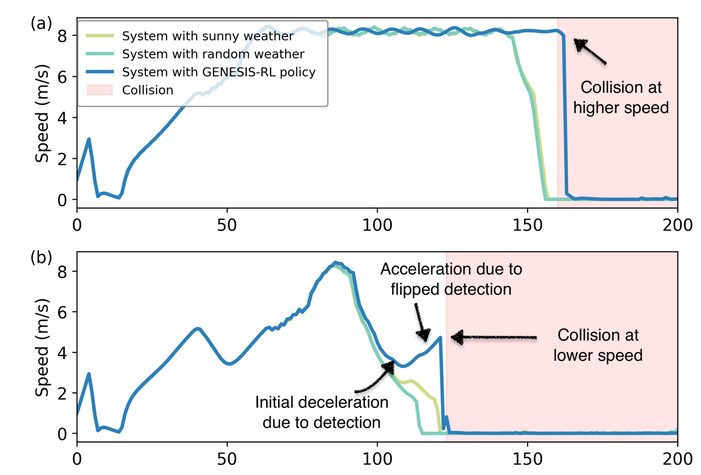
- **DRL Agent**
  - **State space:** A 640 x 480 three channel array from the RGB camera attached to the ego vehicle
  - **Action space:** A tuple representing the delta in value for each parametric knob, the weather parameters
- **Simulator:** CARLA simulator
- **Initial scene generator:** A selection of initial scenes generated using Scenic, the scenes are randomly sampled during training and testing
- **System:** An ego vehicle navigating itself within the simulated world with RGB and depth cameras onboard, equipped with a perception-based controller
- **Reward calculator:** The reward r_t is calculated by the weighted sum of the learning module loss r_m and the violation score r_v :

$$r_t = r_m + r_v = e^{-iou} + ln(1 + w_c\alpha_c + w_p\alpha_p)$$

where $w_c = 500$, $w_p = 100$ and α_c, α_p violation scores from collision and proximity rules, respectively

Results





Conclusion

- **Demonstrated capabilities:** Our proposed framework successfully demonstrated its capability to generate complex and challenging edge cases for autonomous systems
- **Robustness without dominating factors:** GENESIS-RL proved capable of producing edge cases that lead to system failure even without relying on dominating environmental factors

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