CAREER: Probabilistic Risk Evaluation for Safety-Critical Intelligent Autonomy

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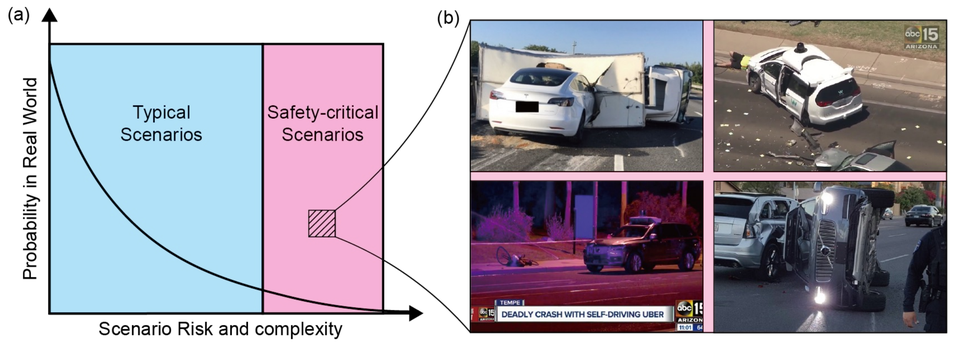
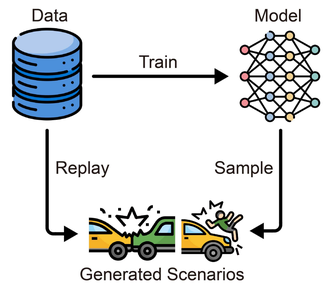
https://safeai-lab.github.io/digital-twin.html

1. Safety-critical Scenarios are extremely rare but important



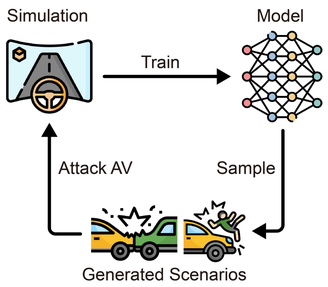
Method 1: Data-driven generation

- Directly sample from the dataset to reproduce the real-world log
- Use density estimation models to learn the distribution of scenarios



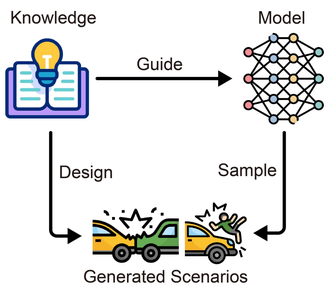
Method 2: Adversarial Generation

- Build a game between self-driving car and scenario generator.
- Actively creates risky scenarios by attacking the autonomous driving system.

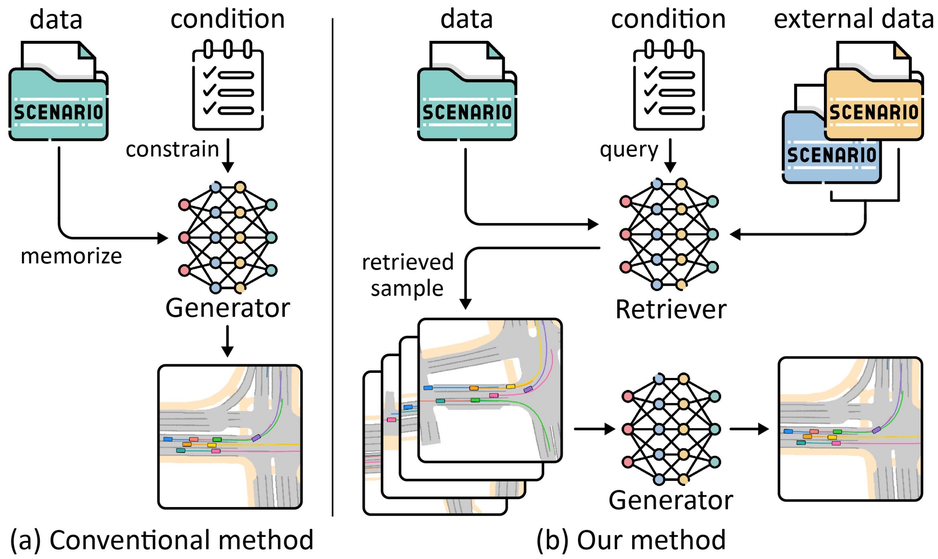


Method 3: Knowledge-based Generation

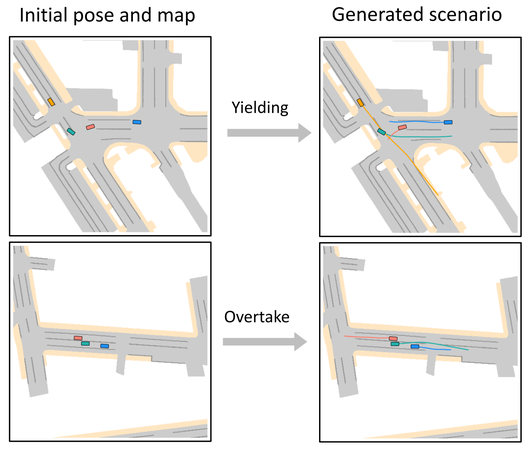
- Use human expert knowledge to make scenario realistic
- Inject traffic rules and physical laws.



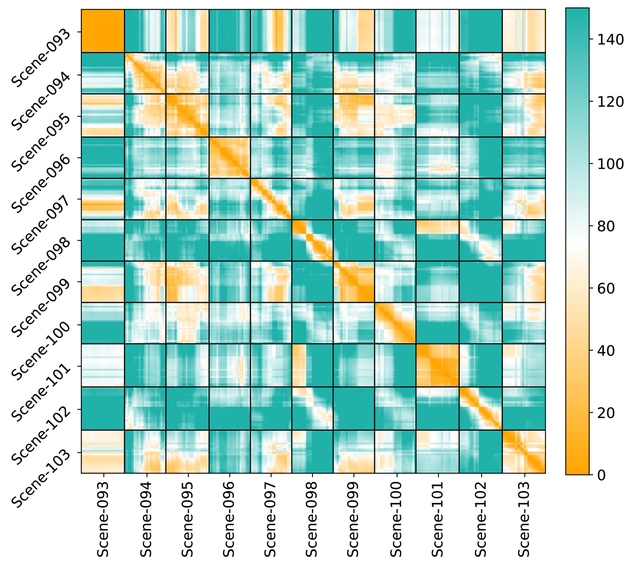
2. Retrieval Augmented Generation (RAG)



Qualitative results of generation



4. Quantitively results of generation



Distance matrix: similar scenarios have low distance score while different scenarios have high distance score.

RealGen achieves better realism than other retrieval-based baselines.

Method	mADE	mFDE	Speed	Heading	Collision Rate	Off-Road Rate
AE	**0.18±0.03**	0.41±0.06	**0.04±0.01**	0.10±0.01	**0.02±0.00**	**0.02±0.00**
Masked AE	0.16±0.01	**0.39±0.01**	**0.04±0.01**	**0.09±0.01**	0.03±0.00	**0.02±0.00**
Contrastive AE	0.92±0.02	1.47±0.04	0.12±0.00	0.36±0.02	0.04±0.00	0.04±0.00
RealGen-AE	0.31±0.01	0.53±0.01	0.08±0.00	0.15±0.01	0.03±0.00	**0.02±0.00**
AE-KNN	14.3±0.03	16.4±0.05	0.57±0.01	0.59±0.02	0.15±0.01	0.15±0.01
LCTGen	4.76±0.09	6.24±0.08	0.52±0.06	0.57±0.03	0.07±0.01	0.07±0.01
LCTGen (w/o z)	14.2±0.07	16.7±0.09	2.04±0.04	1.42±0.00	0.16±0.02	0.13±0.04
RealGen-AE-KNN	13.1±0.06	14.1±0.03	0.46±0.01	0.44±0.00	0.12±0.01	0.11±0.00
RealGen	**1.54±0.04**	**1.21±0.03**	**0.21±0.03**	**0.21±0.01**	**0.05±0.00**	**0.04±0.00**

References

[1] Ding, W., Cao, Y., Zhao, D., Xiao, C., & Pavone, M. (2023). RealGen: Retrieval Augmented Generation for Controllable Traffic Scenarios. arXiv:2312.13303.
[2] Ding, W., Lin, H., Li, B., Eun, K. J., & Zhao, D. (2021). Semantically adversarial driving scenario generation with explicit knowledge integration. arXiv:2106.04066.
[3] Ding, W., Xu, C., Arief, M., Lin, H., Li, B., & Zhao, D. (2023). A survey on safety-critical driving scenario generation—A methodological perspective. IEEE Transactions on Intelligent Transportation Systems.

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