Autonomous Vehicles: Learning and Simulation for Safe & Robust Behavior

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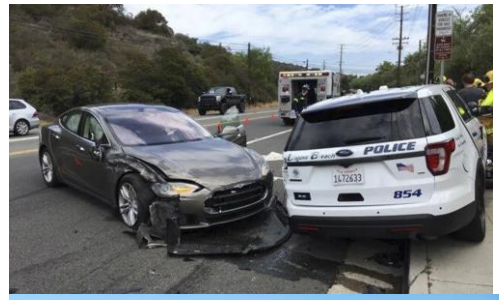
Autonomous Vehicles Edge-Cases: the risky reliance on real-world data

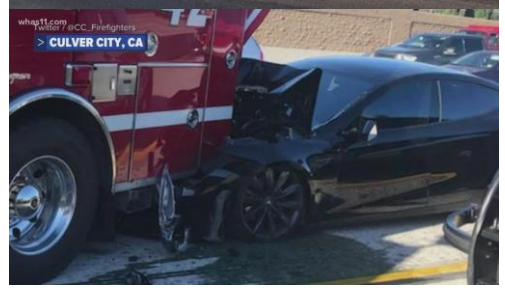
Cases

- Tesla hitting Police Cars 10 times in three years - Stationary objects and flashing lights seemed to trick the A.I.**[NY Times 2022]**
- US investigates Autopilot after 11 Teslas crashed into emergency vehicles **[ArsTech 2021].**
- Safety regulator says automakers reported nearly 400 crashes of cars with automatic driver-assist **[PBS 2022]**

However - Over-optimism: "My guess as to when we would think it is safe for somebody to essentially fall asleep and wake up at their destination: probably toward the end of next year," Elson Musk in 2019 **[Ark 2019]**

Current Mitigation: The Tesla engineers manually specified 221 triggers that are activated in their fleet **[Karpathy 2021].** The models run in a "shadow mode", which works as a digital twin of the real system that allows to deal with disagreements between the camera and Lidar.



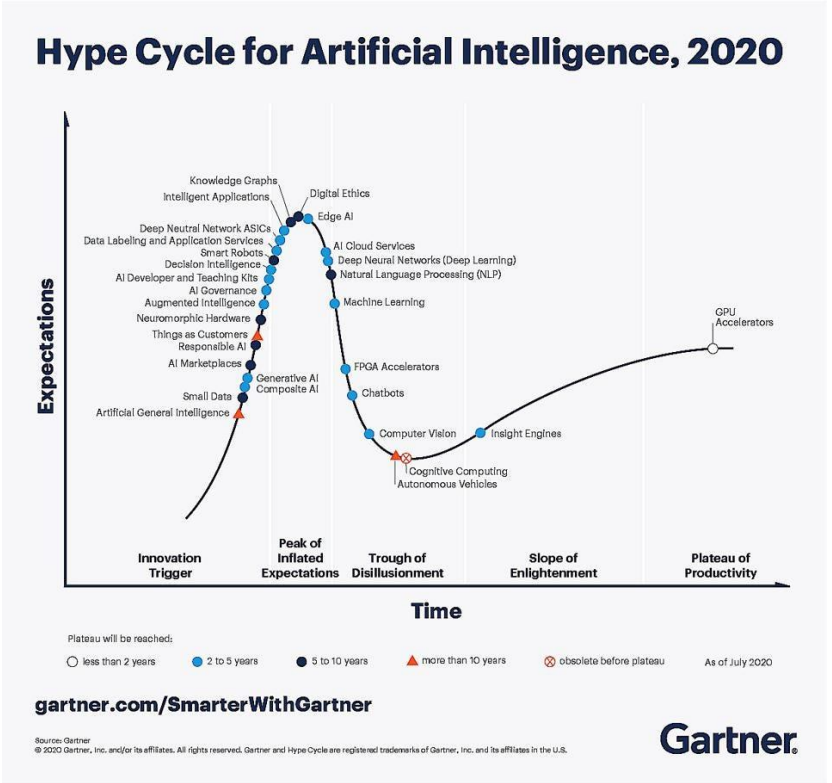


[NY Times 2022] Elon Musk's Appetite for Destruction - https://www.nytimes.com/2023/01/17/magazine/tesla-autopilot-self-driving-elon-musk.html
[ArsTech 2021] https://arstechnica.com/cars/2021/08/us-investigates-autopilot-after-11-teslas-crashed-into-emergency-vehicles/
[PBS 2022] https://www.pbs.org/newshour/nation/u-s-safety-regulator-says-automakers-reported-nearly-400-crashes-of-cars-with-automatic-driver-assist
[Ark 2019] On the Road to Full Autonomy With Elon Musk - https://ark-invest.com/podcast/on-the-road-to-full-autonomy-with-elon-musk/
[Karpathy 2021] Closed AI Loop at Tesla for Labeling data that Trigger Corner Cases, Keynote at CVPR'21

Meanwhile,
AI systems are not being deployed

- **55%** of companies surveyed haven't deployed a machine learning model **[Algorithmia 2020]**
- **72%** that began AI pilots before 2019 haven’t deployed a single system yet **[Capgemini 2020]**

Why? Current models cannot **adapt** to more complex and evolving realities - adversarial environment

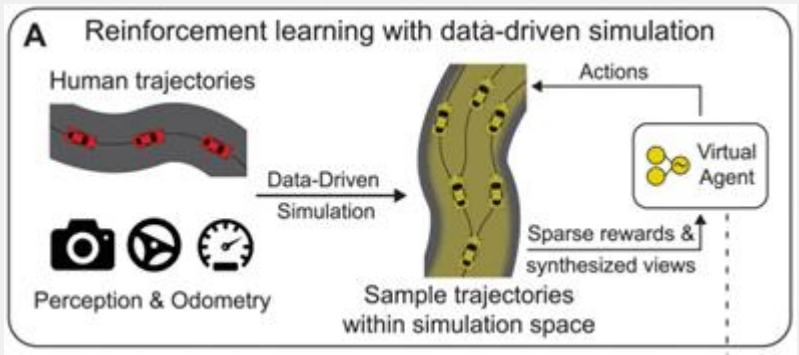


[Gartner 2020]

Problem? Lack of Robustness in AI Systems

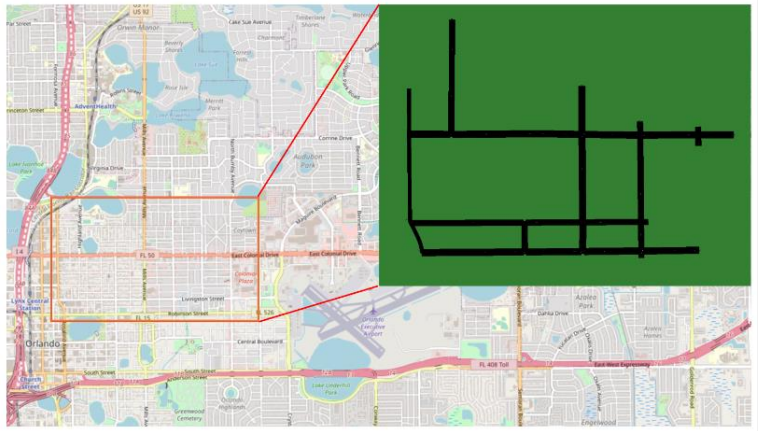
[Jordan 2019], [D’Amour et al. 2020]

Reinforcement Learning for Autonomous Vehicle with Model-Based and Data-Driven Simulators



Learned policies not only transfer directly to the real world (B), but also outperform state-of-the-art end-to-end methods trained using imitation learning.

VISTA - From a single human collected trajectory our data-driven simulator synthesizes a space of new possible trajectories for learning virtual agent control policies (A). Preserving photorealism of the real world allows the virtual agent to move beyond imitation learning and instead explore the space using reinforcement learning with only sparse rewards.

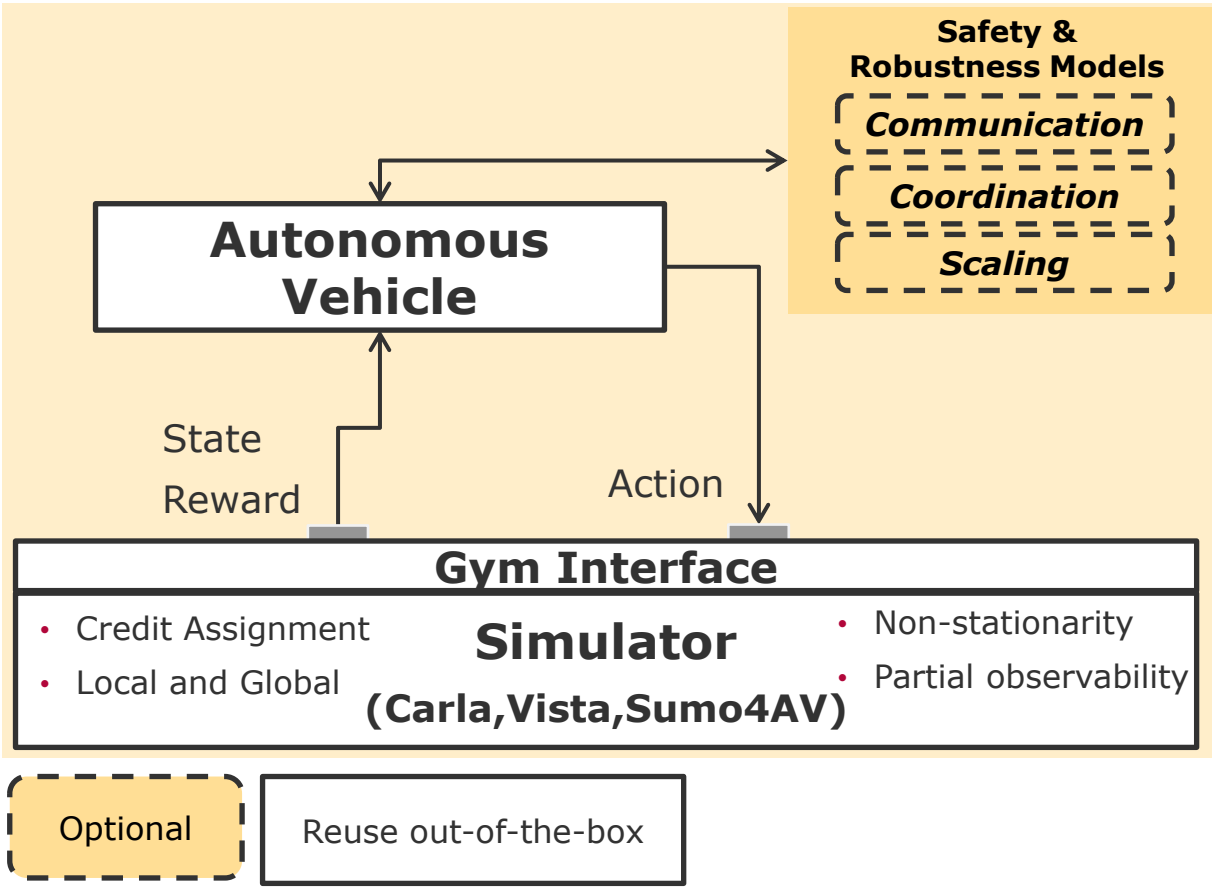


Gym is an open source Python library developed by OpenAI and originally designed for developing and testing reinforcement learning algorithms.

SUMO-Gym is a portable, user-friendly AV simulation platform. Users of SUMO-Gym can test their AV pipeline to generate actions compatible with the package based on generic observations from SUMO-Gym

CARLA has been developed from the ground up to support development, training, and validation of autonomous driving systems. In addition to open-source code and protocols, CARLA provides open digital assets (urban layouts, buildings, vehicles) that were created for this purpose and can be used freely. The platform supports flexible specification of sensor suites, environmental conditions, control of all static and dynamic actors, and maps generation

Possible Architecture and its Realization



Implementation Effort Expected

Safety & Robustness - Design and Implementation for coping with the chosen (few) traffic edge-cases

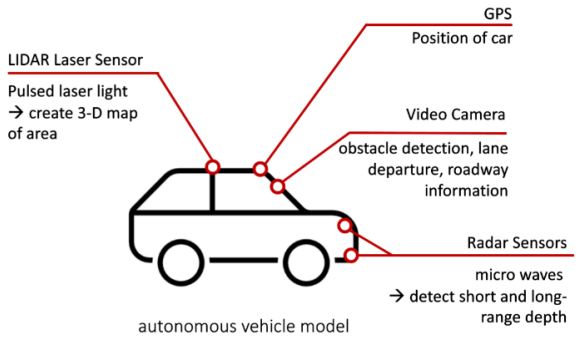
Agent's policy Learning – Reuse out-of-the-box Stable Baselines API – no coding expected

Gym Interface as a wrapper of the Simulator API - a few lines of code expected

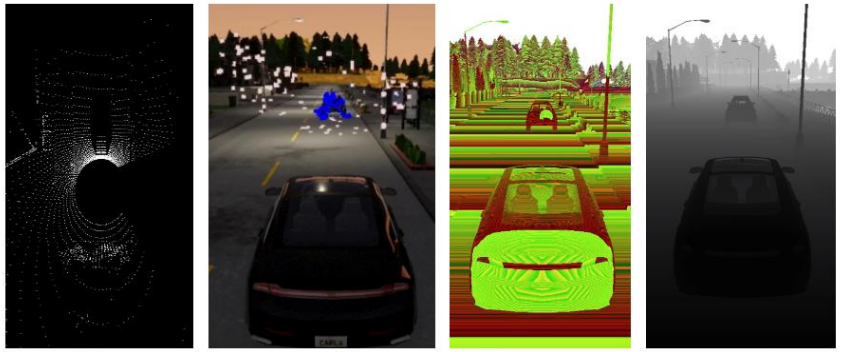
Simulator - Reused out-of-the-box, no coding expected

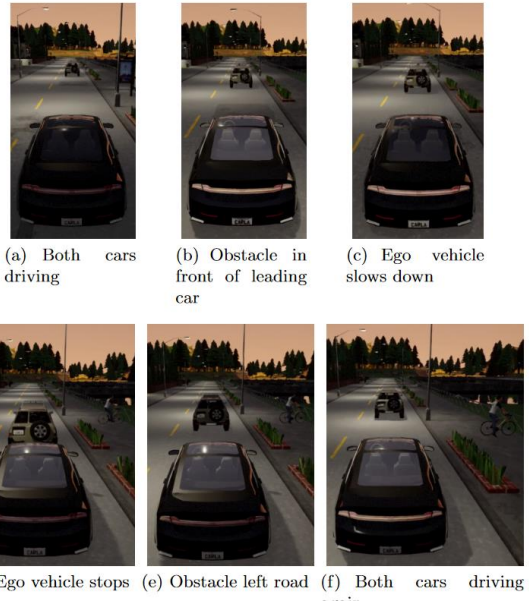
Nguyen, et al. (2020). Deep reinforcement learning for multiagent systems: A review of challenges, solutions, and applications
Leibo, et al. (2017) "Multi-agent Reinforcement Learning in Sequential Social Dilemmas."

Example with Carla - developed during a previous project seminar [Terboven & Andree 2020]

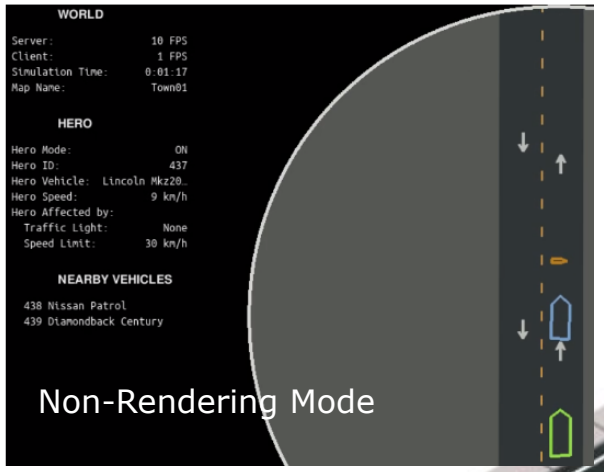


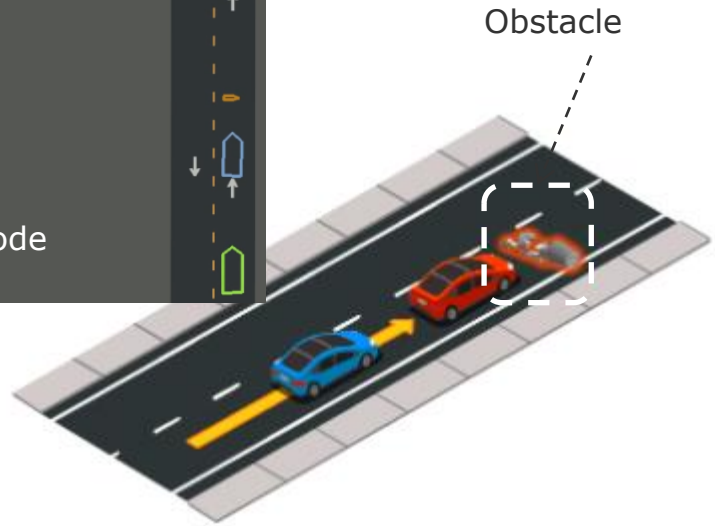
autonomous vehicle model


(a) LiDAR Sensor (b) Radar Sensor (c) Raw Camera Depth (d) Converted Logarithmic Depth


(a) Both cars driving (b) Obstacle in front of leading car (c) Ego vehicle slows down

(d) Ego vehicle stops (e) Obstacle left road (f) Both cars driving





Carla Terboven and Kerstin Andree, 2020, **Simulation of Autonomous Vehicles**, Project Seminar Simulation, Summer Term 2020, Hasso-Plattner Institute, Uni-Potsdam.

Roadmap and Deliverables

- Equalize Team's knowledge (seminars provided by our chair) — ~ 1 week
  - Learning Methods: Reinforcement Learning, Multi-Agent Models, Sim-2-Real
  - Evaluation Methods: Experimental Design, Robustness, Sensitivity Analysis
- Proof of Concept of Simulator (Deploy, Generate Scenarios & Edge Cases) — ~ 2 weeks
- Ideate — ~ 1 week
  - Inception of Minimal Viable Product
  - Plan Iterations
- Iterate — ~ 12 weeks

Deliverables

- Technical Blog (lessons learned, how-to's)
- Presentation (seminar at our chair open to colleagues)
- Technical report (publishable by HPI or submitted to conference/workshop)

Communication Plan & Organization

- Coaching team – Chris, He, Prof. Giese
  - Weekly meetings – decision making, prioritization, brainstorming solutions
  - Monthly meetings - progress update

Motive	Content	Medium
Artifacts	Code, Data Documentation	Github
Papers	Intelectual property	Zotero
Messaging ad hoc	Questions, Suggestions, Sharing	Slack
Official	Schedule, Orientations, Administrative issues	christian.adriano@hpi.de
Meetings	Lectures, Status, Work meetings	B-2.2 or Zoom
Emergency	Call, SMS, messaging	Chris mobile (check Slack profile)

References-Papers

[Algorithmia 2020] The State of Enterprise ML, https://info.algorithmia.com/hubfs/2019/Whitepapers/The-State-of-Enterprise-ML-2020/Algorithmia_2020_State_of_Enterprise_ML.pdf

[Capgemini 2020] The AI-Powered Enterprise, https://www.capgemini.com/gb-en/research/the-ai-powered-enterprise/

[Chen et al. 2021] Decision Transformer: Reinforcement Learning via Sequence Modeling, *arXiv:2106.01345*

[D'Amour et al. 2020] Underspecification presents challenges for credibility in modern machine learning, *arXiv:2011.03395*

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[Janer et al. 2021] Janer, M., et al., Reinforcement learning as one big sequence modeling problem, *arXiv:2106.02039*

[Jordan 2019] Jordan, M., Artificial Intelligence, The Revolution Hasn't Happened Ye, MIT Press

[Nguyen, et al. 2020] Deep reinforcement learning for multiagent systems: A review of challenges, solutions, and applications. *IEEE transactions on cybernetics*, *50*(9), 3826-3839.

[Suton & Barto 2018] Reinforcement Learning, An Introduction, MIT Press

References - Simulators

SUMO-Gym - Kusari, Arpan, et al. "Enhancing SUMO simulator for simulation-based testing and validation of autonomous vehicles." *2022 IEEE Intelligent Vehicles Symposium (IV)*. IEEE, 2022. - https://arxiv.org/pdf/2109.11620.pdf

- Car following model - provide real-world like behavior of the background vehicles (BVs)
- Intelligent Driver Model (IDM) - captures/estimates the driving patterns of individual driver
- "SafetyPilot Model Deployment (SPMD) was a project undertaken by the U.S. Department of Transportation (USDOT) to evaluate the effectiveness of vehicle-to-vehicle communication technology (V2V) in safety applications"
- **Alternative**: **SUMO4AV** - An Environment to Simulate Scenarios for Shared Autonomous Vehicle Fleets with SUMO - https://www.youtube.com/watch?v=YUcfahIY2iU

CARLA - Open-source simulator for autonomous driving research - https://carla.org/

- Autonomous Driving sensor suite: users can configure diverse sensor suites including LIDARs, multiple cameras, depth sensors and GPS
- Fast simulation for planning and control: this mode disables rendering to offer a fast execution of traffic simulation and road behaviors for which graphics are not required.
- Maps generation: users can easily create their own maps following the OpenDrive standard via tools like RoadRunner.
- Traffic scenarios simulation: our engine ScenarioRunner allows users to define and execute different traffic situations based on modular behaviors.

MIT VISTA 2.0 - Data-driven Simulation for Resilient and Sustainable Mobility - https://vista.csail.mit.edu/

- Photo realistic simulation
- Various types of weather and geographic conditions
- Perception suites