The Importance of Open Simulators and AI in a Changing Mobility Landscape

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Eclipse SAAM Mobility 2021

Security | AI | Architecture | Modelling

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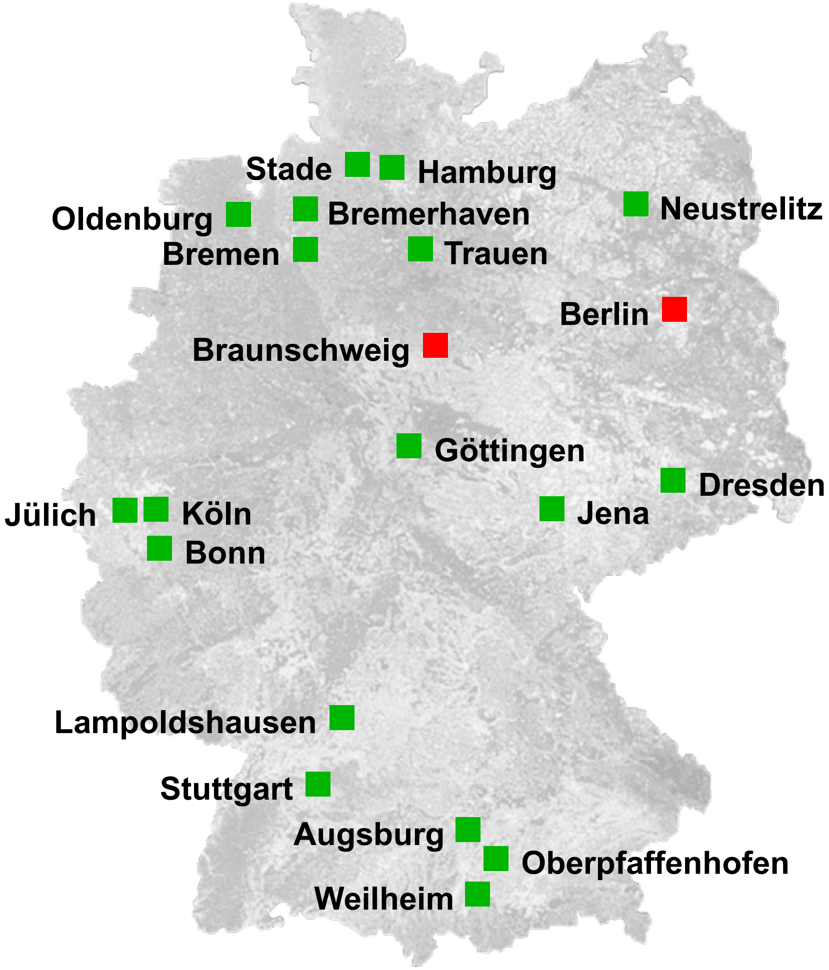
German Aerospace Center

- Research branches
  - Aeronautics / Space / Transport / Energy
  - Safety / Digitalization

- Around 9.000 employees working in 40 research institutes and facilities at 20 sites in Germany.

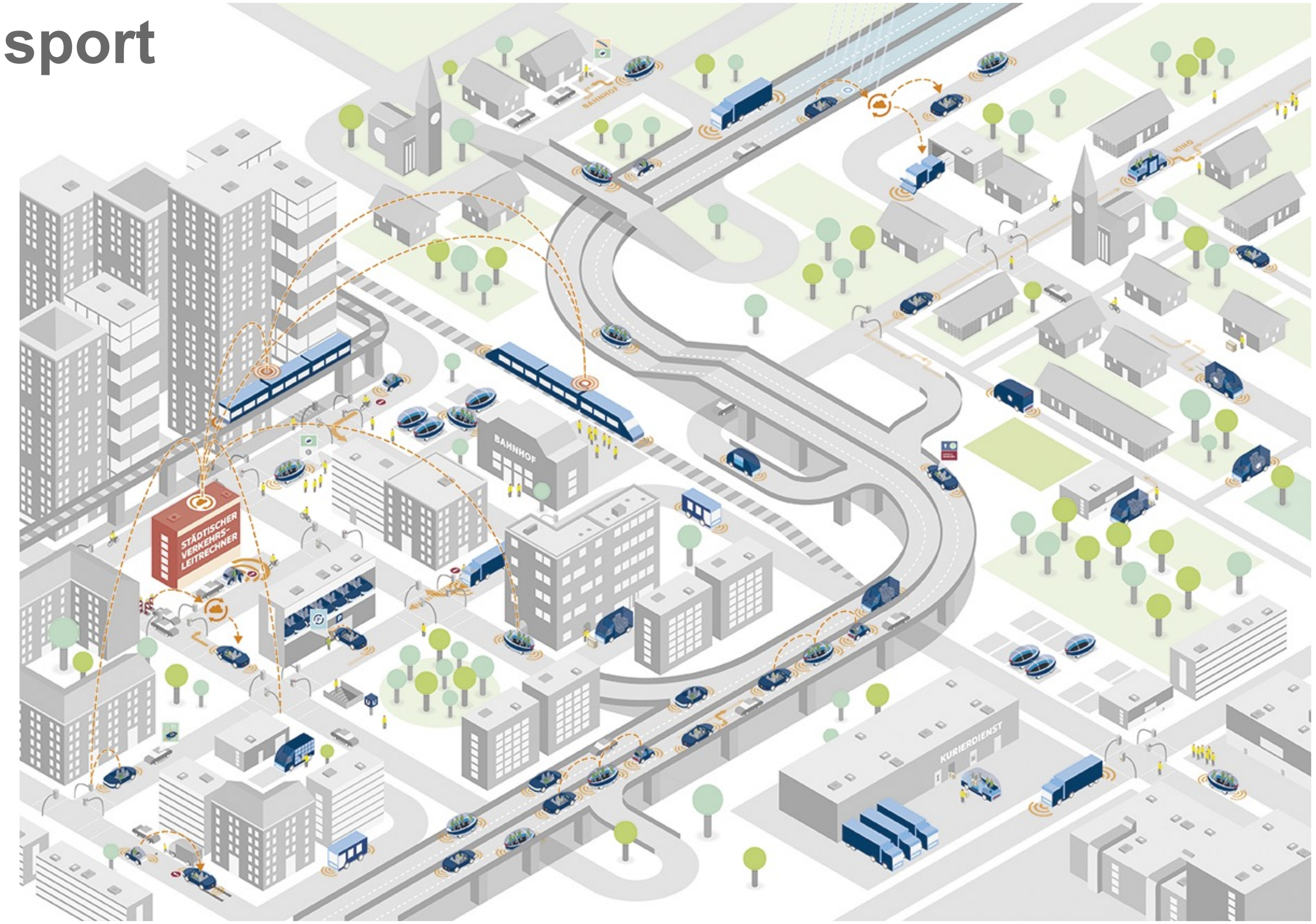
- Offices in Brussels, Paris, Washington, and Tokyo.



Research in Real World Mobility

German Aerospace Center – Transport

- **Green** → environment-oriented traffic management, …
- **Smart** → automated & connected driving, intelligent traffic infrastructure, intermodal transport chains, ...
- **User Friendly** → human-centered design, intuitive interaction, comfortable, affordable ...
- **Reliable** → safe, secure, highly available ...
- **Systemic Approach**
  land use ↔ city planning ↔ traffic planning & management ↔ technologies ↔ humans and society …



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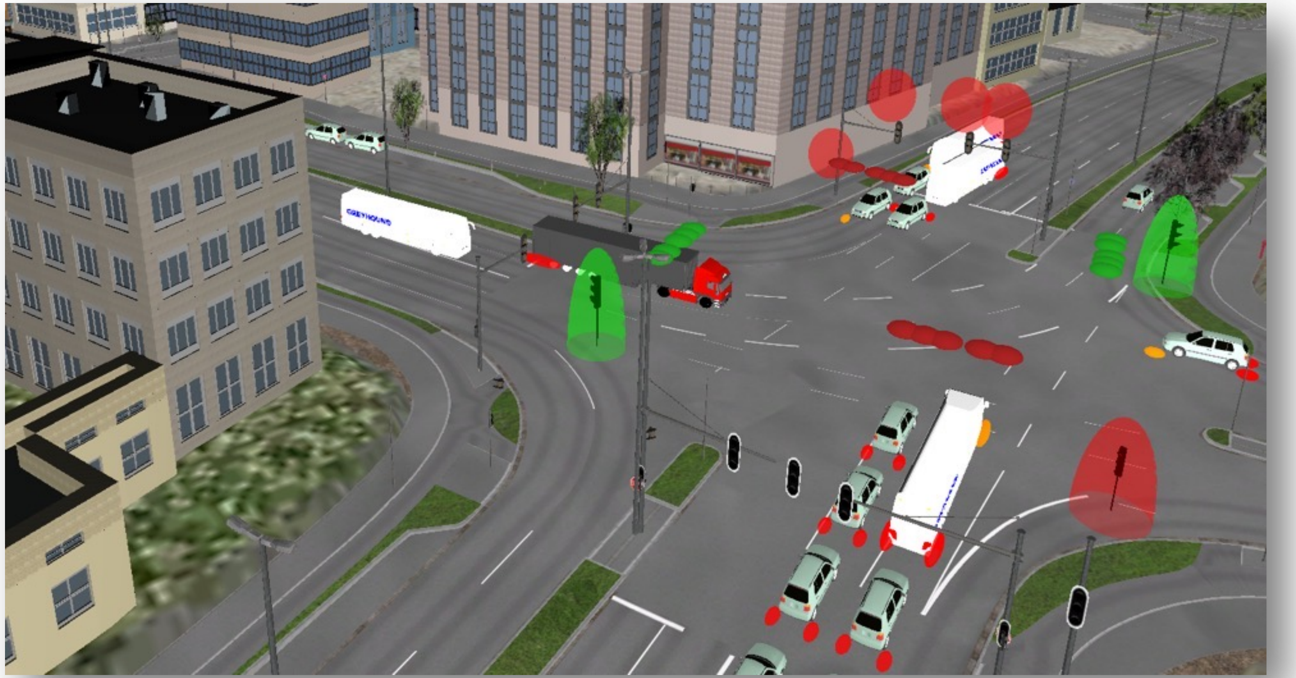
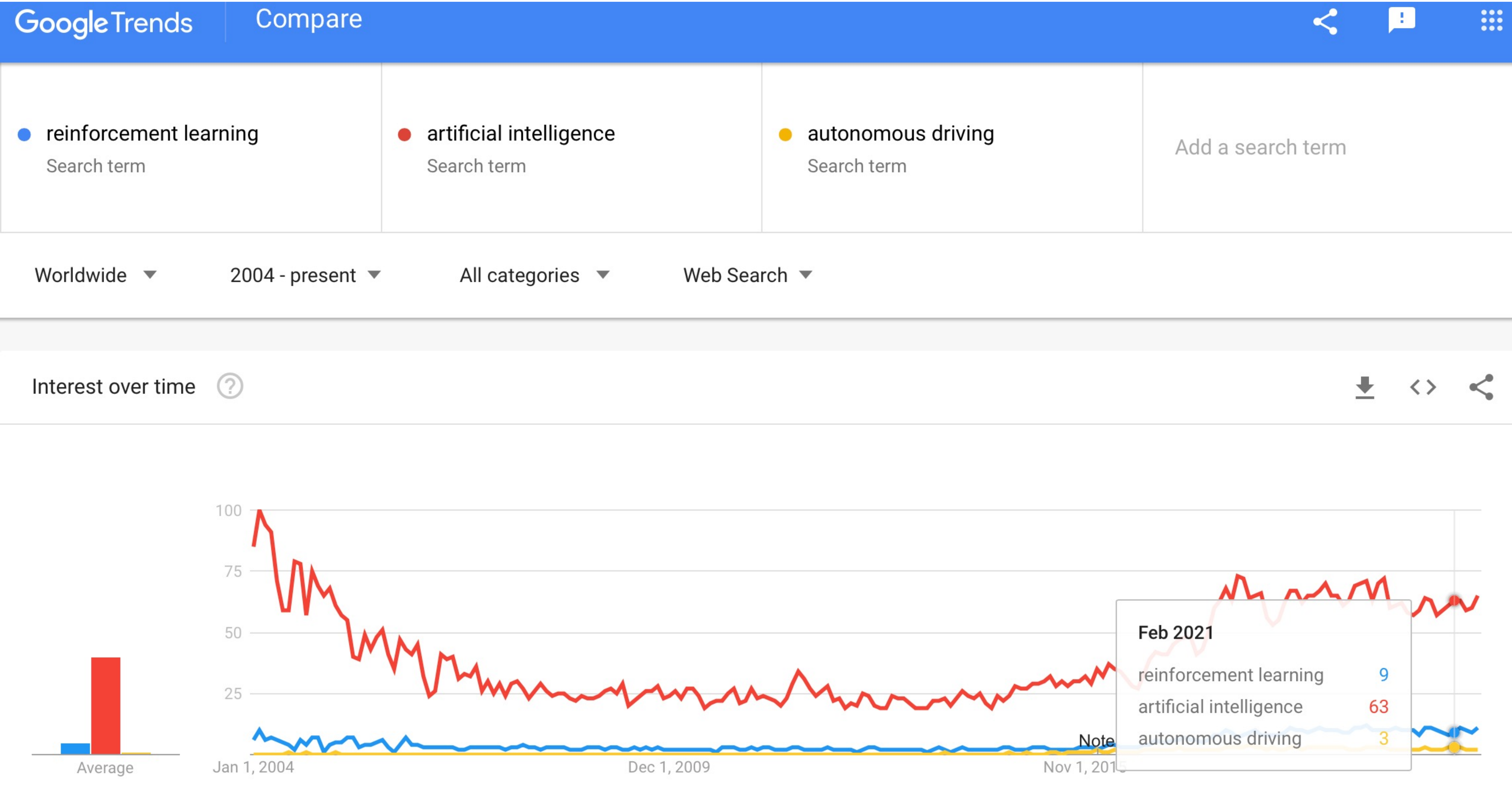
Simulation of Urban Mobility (SUMO) – Our “Real World Traffic Simulator”



… the most popular open source software project of the German Aerospace Center (DLR)
www.eclipse.org/sumo

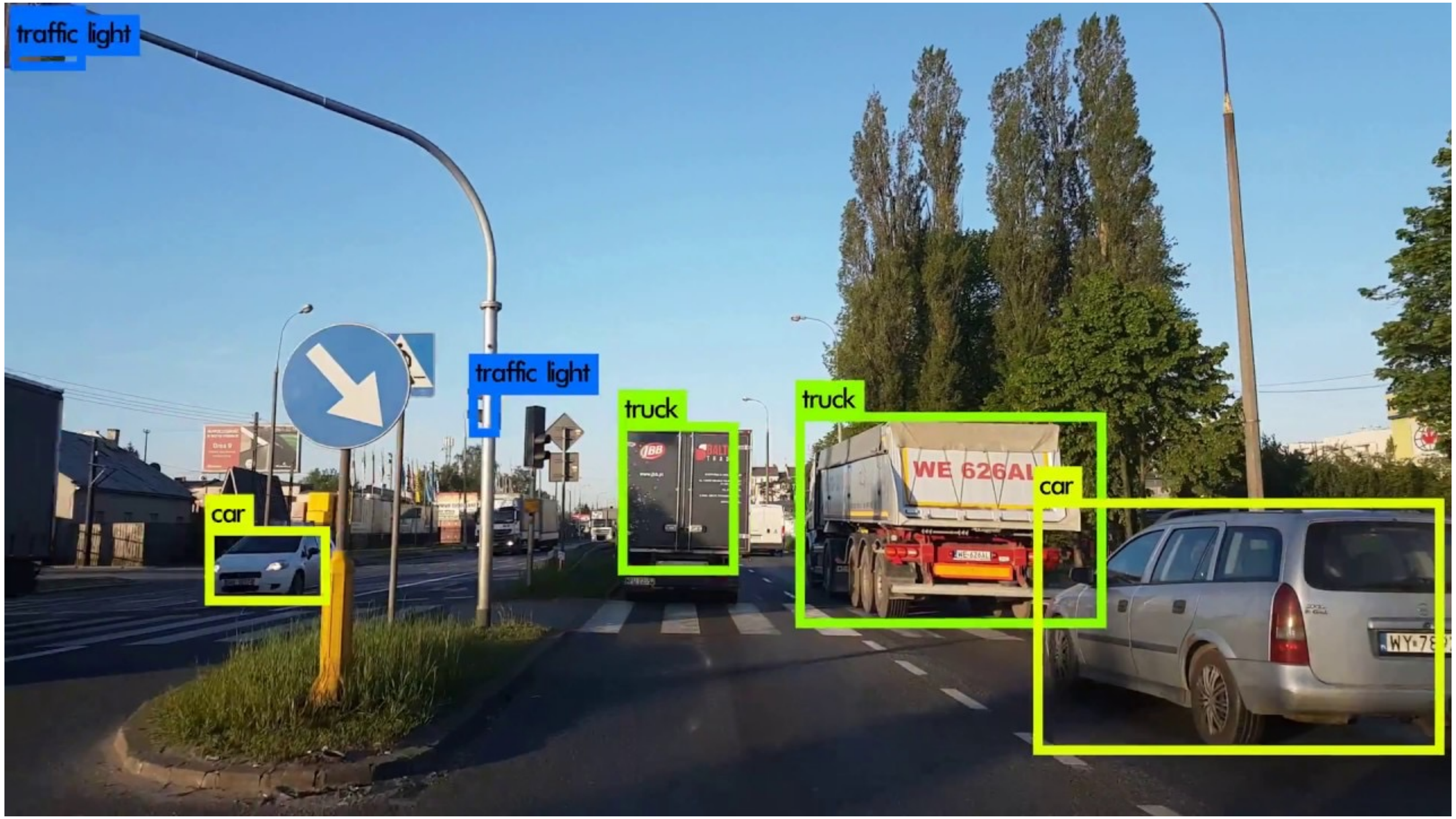
Google Trends, 8.6.2021



Success Stories
for AI in Mobility Systems

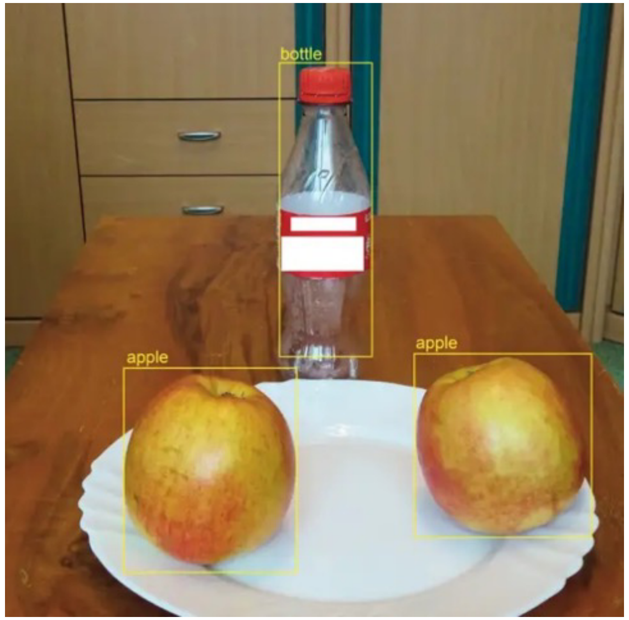
Example 1: AI for Image Recognition and Classification

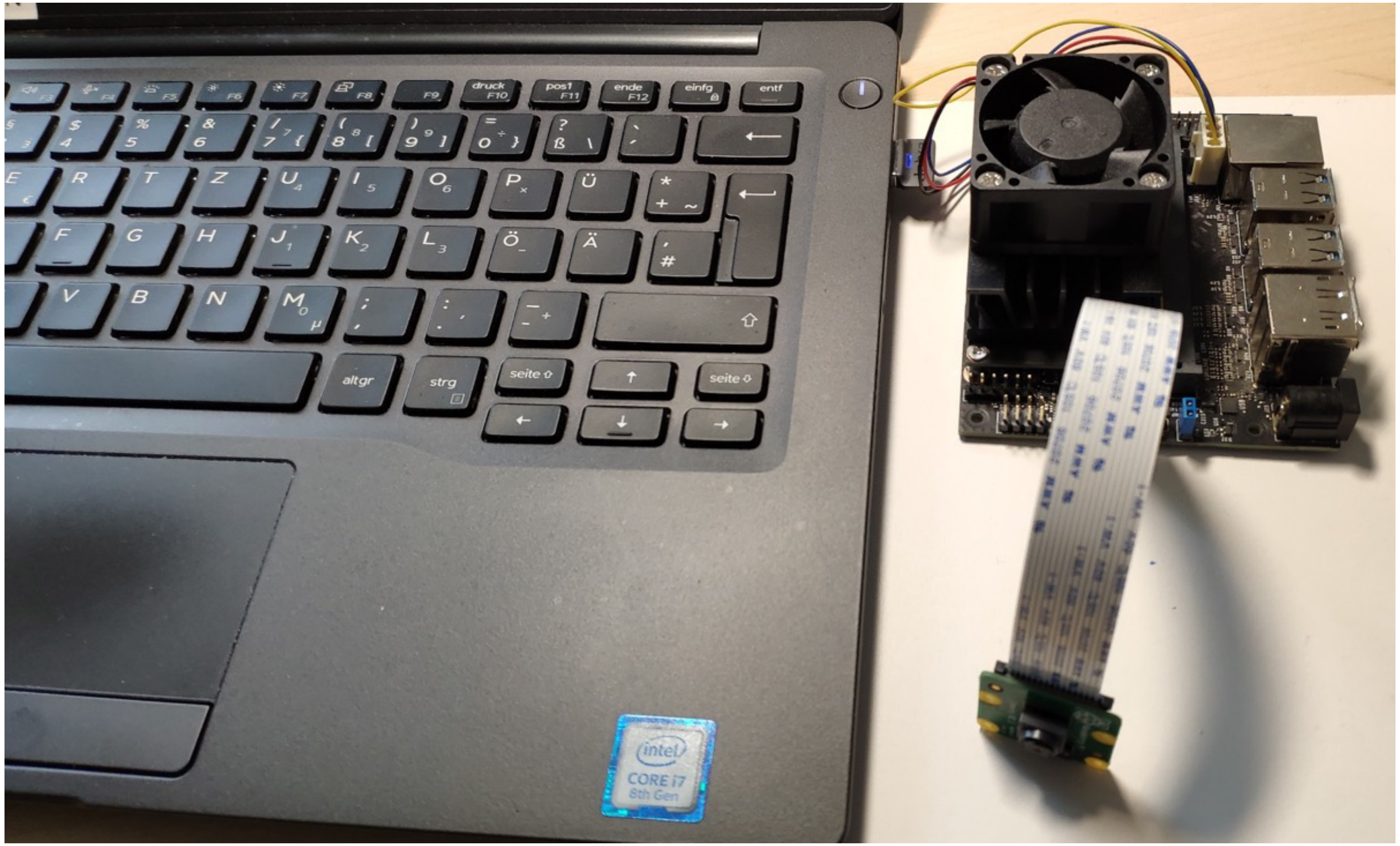
- Image recognition and vehicle classification works well
- AI may have exceeded human capabilities (“super human”)



https://lazyprogrammer.me/new-deep-learning-course-advanced-computer-vision/

Example 2: Image Recognition & Classification – Do it yourself!





https://www.heise.de/select/make/2019/3/1561278575740040

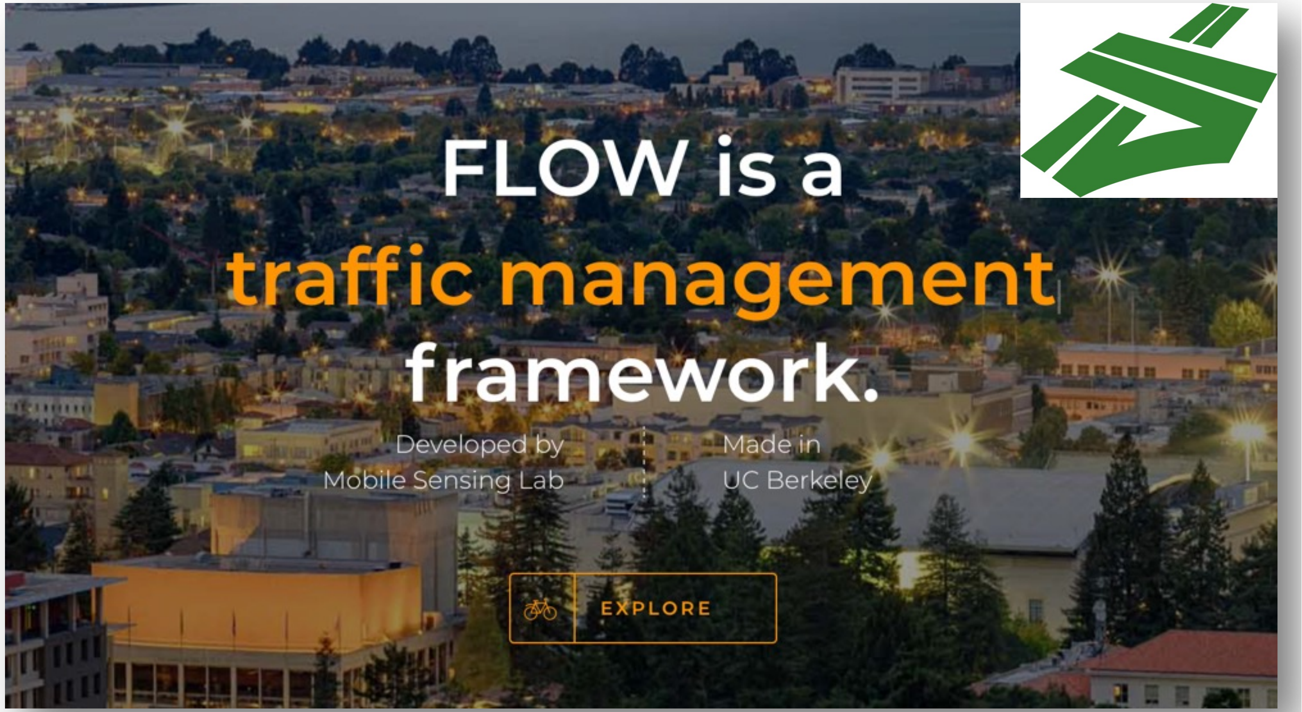
Example 2: AI for Automated Driving and Traffic Management

https://flow-project.github.io

Flow is …

- a **deep reinforcement learning framework** for mixed **autonomy** traffic

- a traffic control benchmarking framework with
  - a suite of **traffic control scenarios**,
  - tools for designing custom traffic scenarios,
  - integration with **deep reinforcement learning** and traffic microsimulation libs



Recommended video: https://youtu.be/P7xx9uH2i7w (2min) - **autonomous vehicles preventing traffic congestions**

Example 3: Real-time Crash Prediction on Urban Expressways

Idea:
- Estimate probability for accidents **live** – based on current traffic and past accident data

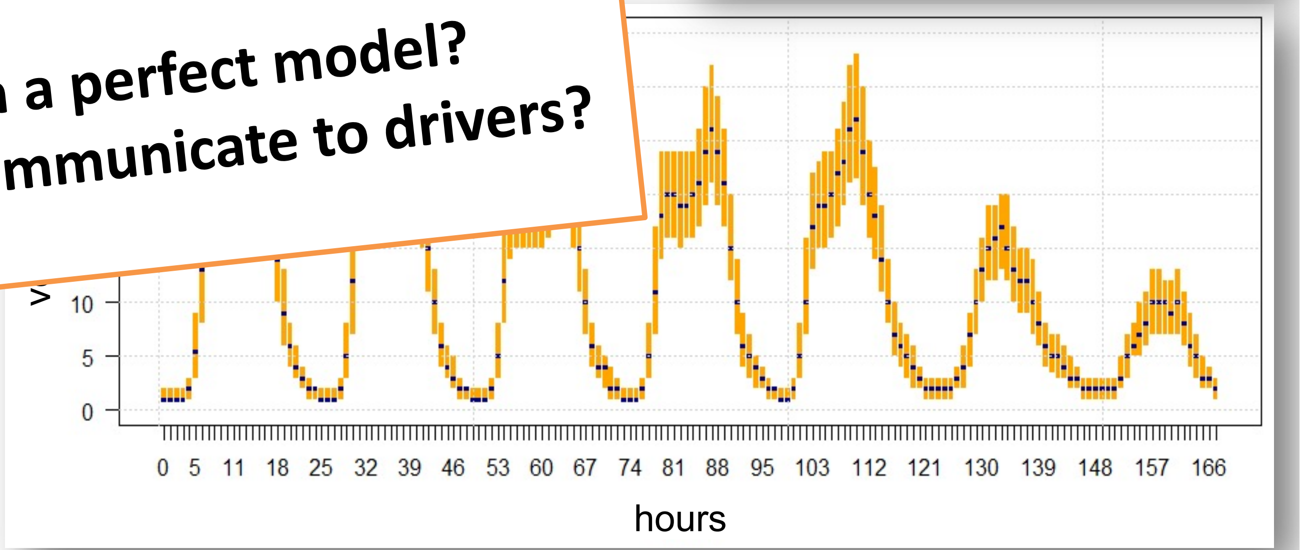
Data:
- Chinese highway, 236km
- Traffic data (flow, speed, counts)
- Accidents counts from April 2014

Approach:
- Split April
accident /

Result:
- 63%-65% c

Problem
- Accidents are rare – **imbalance** in the model
- Deep Neural Network learns “no accident”

What would you do with a perfect model?
What message would you communicate to drivers?

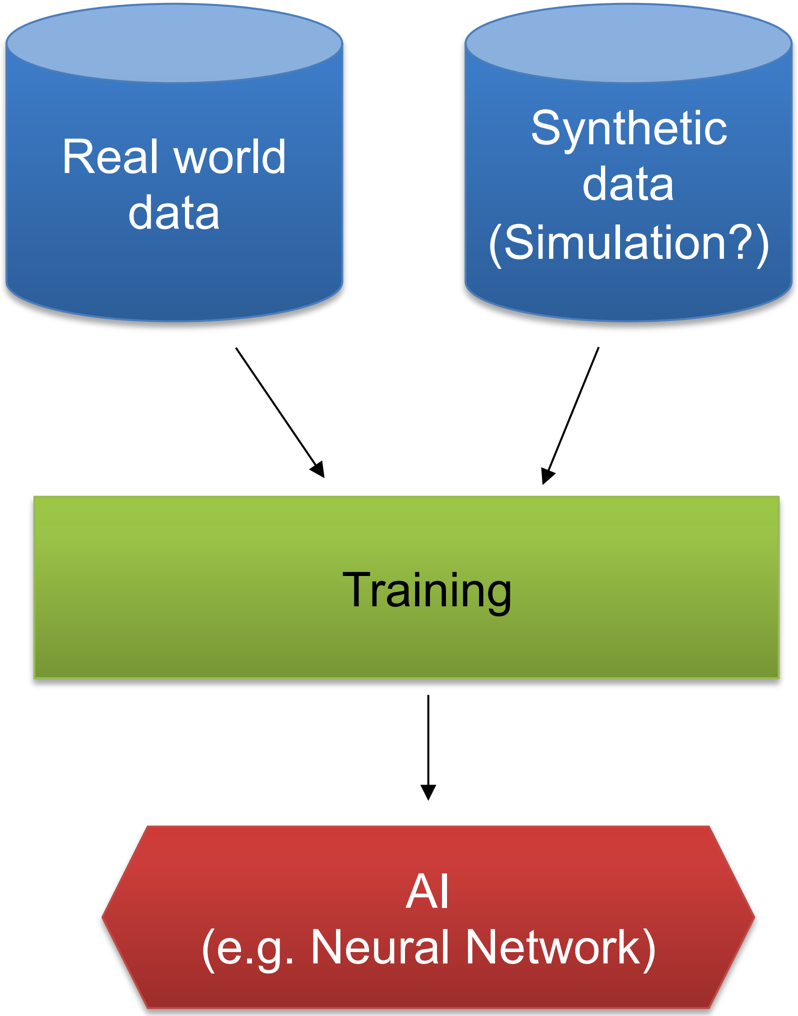


https://trid.trb.org/view/1496427

Challenges
for AI in Mobility Systems

Challenge: AI Training and "Learning"

- Requires a LOT of data
  - Quality of data set? Hidden bias?
    - https://www.propublica.org/article/machine-bias-risk-assessments-in-criminal-sentencing
- Data captures **past** events and object encounters
- Get synthetic data from simulators
  - Reality vs. simulation – do you trust the simulator?
- Energy and Carbon Footprint of Machine Learning
  - Computations required for deep learning research have been doubling every few months, resulting in an estimated 300,000x increase from 2012 to 2018
    https://cacm.acm.org/magazines/2020/12/248800-green-ai/fulltext
- Optimization function is tricky to get right (and complete!)



AI for Traffic Lights (1) – Research from Texas A&M Uni. / Uni. of Edinburgh

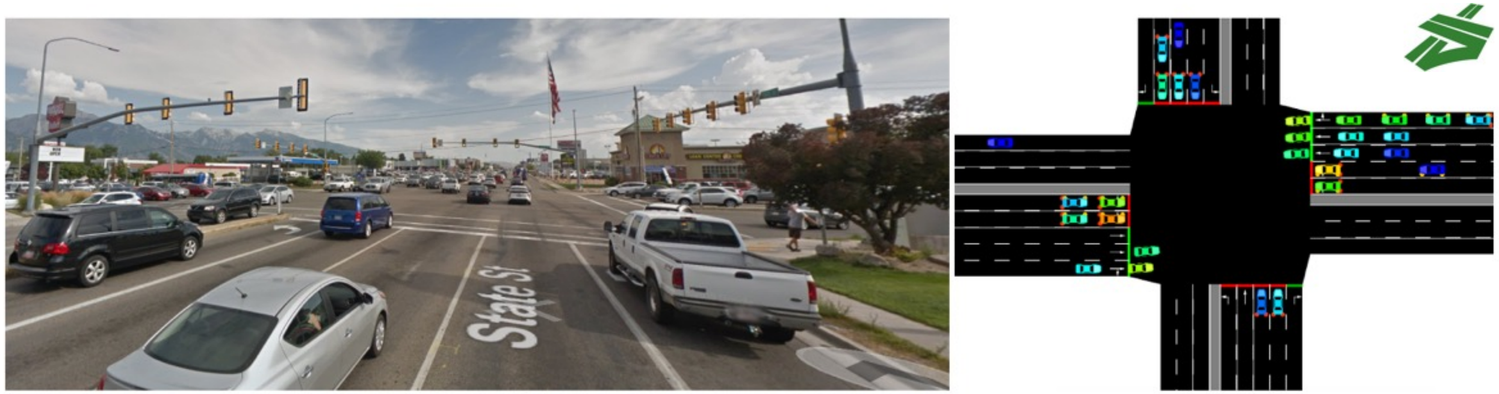
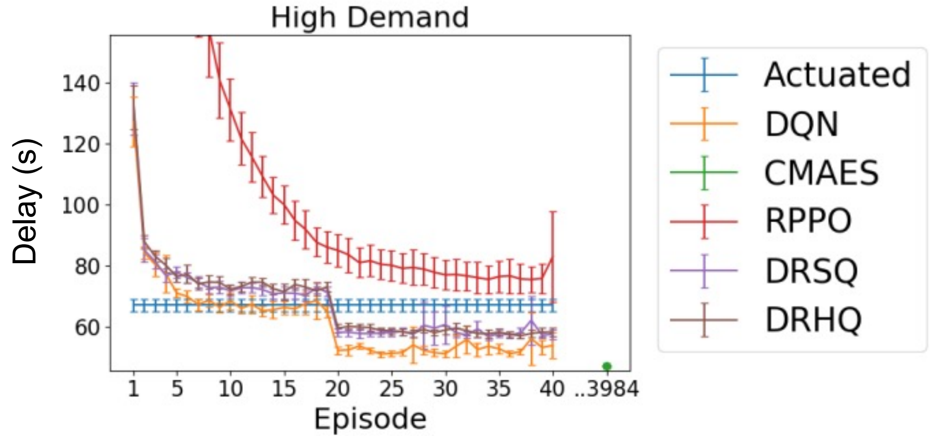


Figure 3: A signalized intersection at State St & E 4500 S, Murray, Utah (left), (picture credit: Google Maps), and an equivalent intersection modeled in SUMO (right).



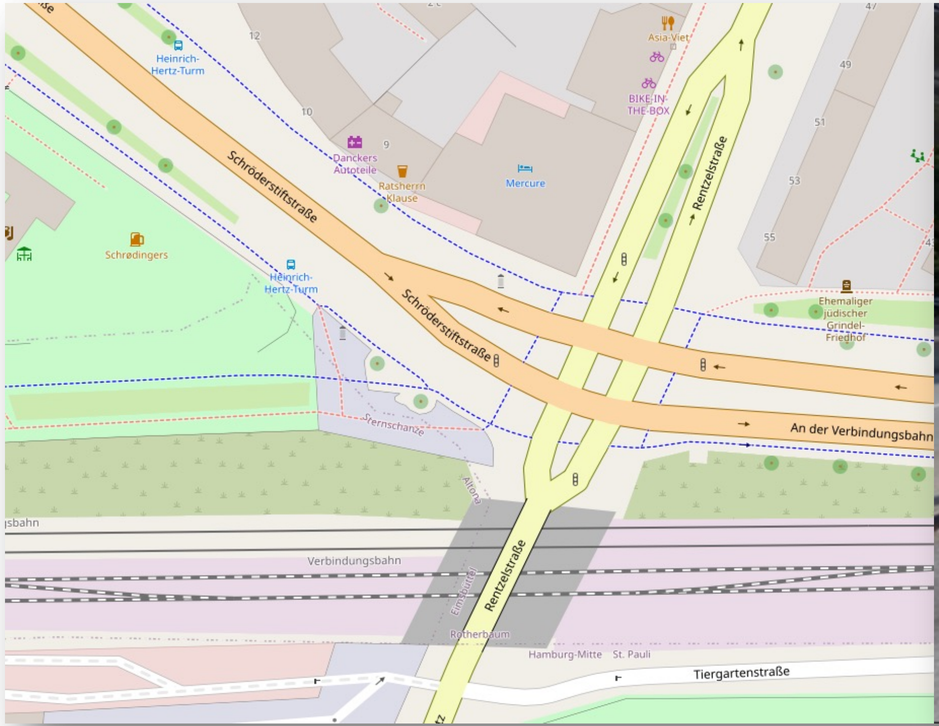
(full days of traffic for training)

- Evaluation of different Deep Q-learning algorithms
- J. Ault, J.P. Hanna, G. Sharon, "Learning an Interpretable Traffic Signal Control Policy" (2020) https://arxiv.org/abs/1912.11023v2
- See the code here: https://github.com/jault/StateStreetSumo

- Own experiments:
  - after about **1 day of computing (training):** results are about as good as current actuated control strategy

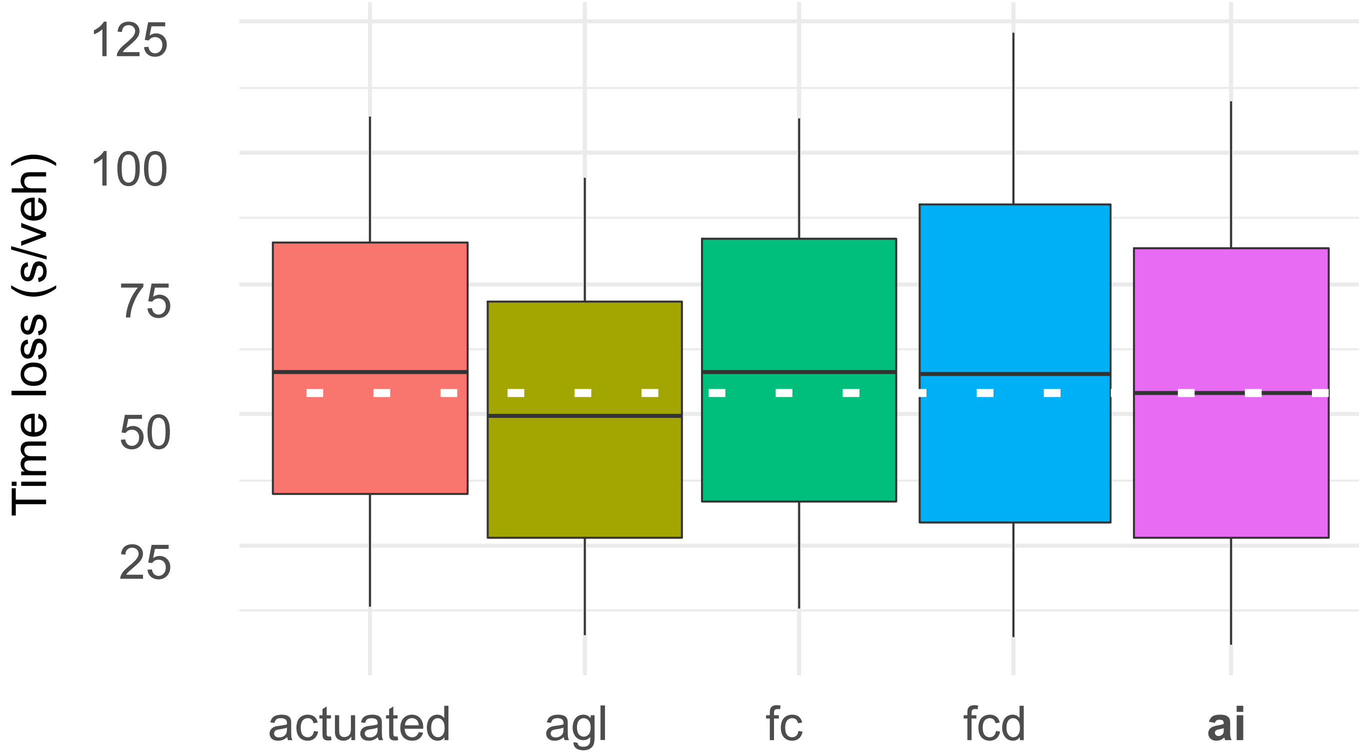
AI for Traffic Lights (2) – DLR Customer Project

- DLR Project in Hamburg (Schröderstift- /Rentzelstrasse)
- Goal: Development of a custom AI-based traffic light control strategy



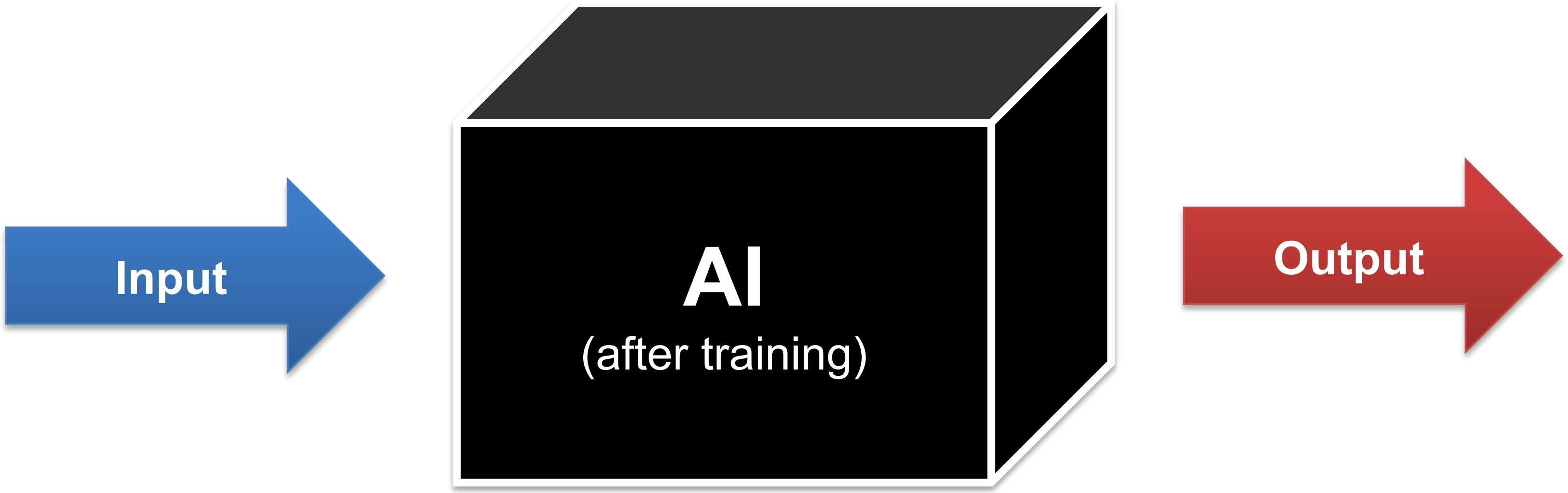
AI for Traffic Lights (2) – DLR Customer Project

- Reinforcement learning based on a SUMO simulation
- Optimization function: minimize the time loss for all vehicles
- Unfortunately: generated cycle time for traffic light was too long → optimization function was incomplete(!)



Best	49.8 s (-14% from avg)
Worst	58.2 s
AI	54.2 s (-7% from avg)

Challenge: Explicit vs. Implicit Knowledge



„We can either figure out how to […] allow humans to understand these things, or we can surrender entire modalities […] to be the sole domain of computers.“

http://colah.github.io/posts/2015-01-Visualizing-Representations/

Explicit vs. Implicit Knowledge: Safety-critical Systems

- Verification/Validation Approach based on (complete) **system observation**
- Eclipse openGENESIS Working Group
- New DLR Institute for AI Safety and Security
  - "**Safety and security by design**" is a central aspect in this context, since it directly supports future requirements of safety-critical applications that are based on AI or integrate AI-based components.
  - https://www.dlr.de/ki/en/

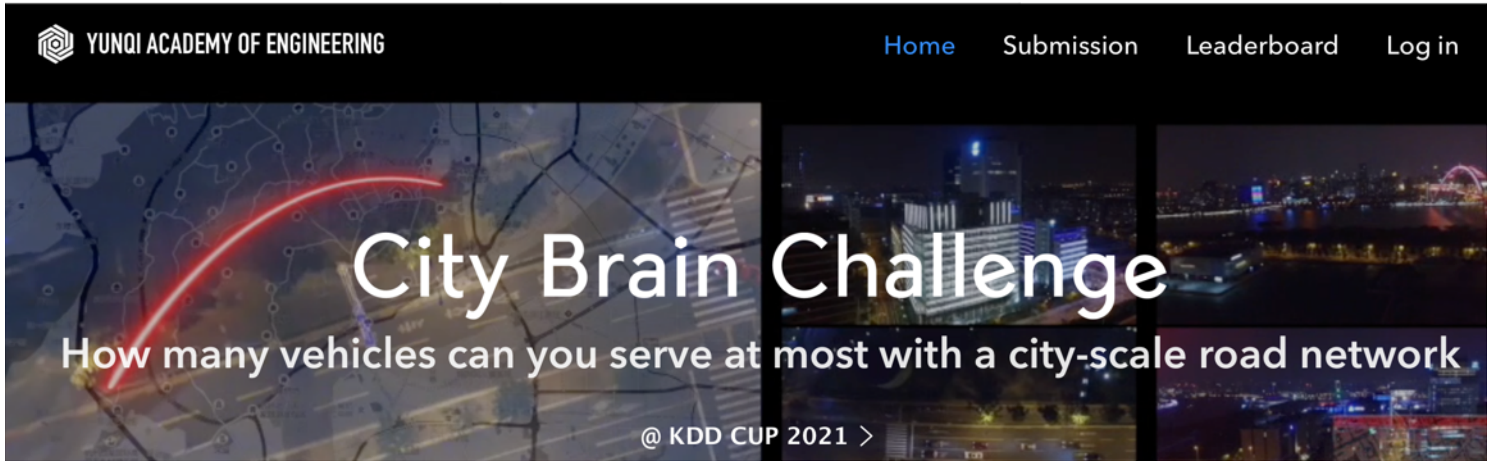
Credit: Dimi TVP(CC BY-SA 4.0)

openGENESIS

https://wiki.eclipse.org/OpenGENESIS_WG

Explicit vs. Implicit Knowledge: Benchmarking

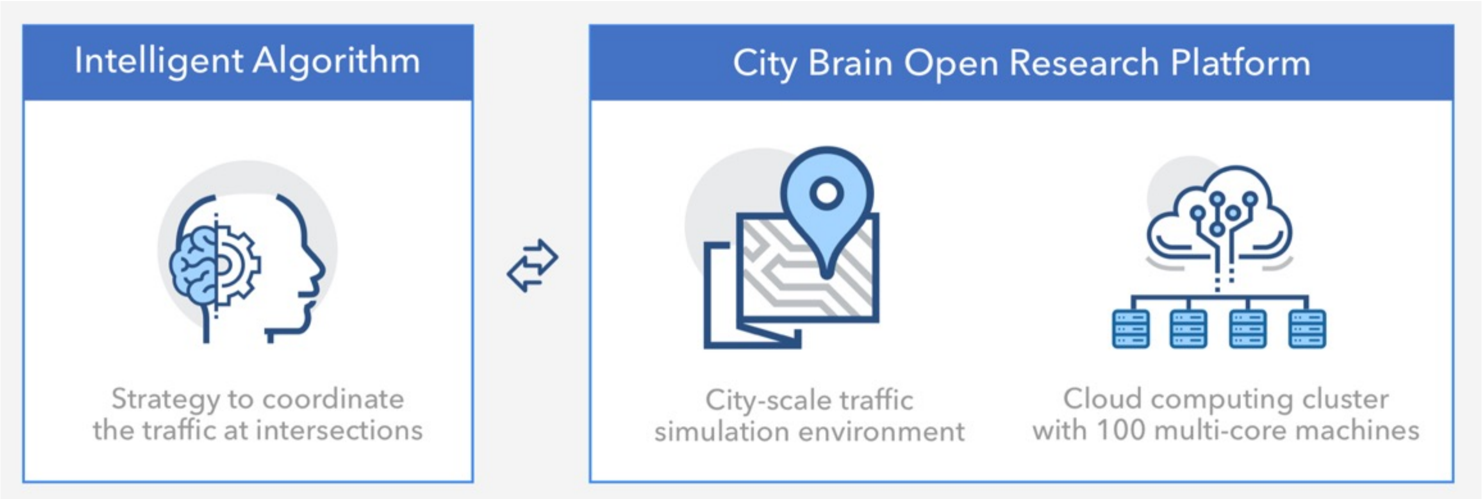
- Annual ACM SIG Knowledge Discovery und Data Mining (KDD) Cup
- “*You will be in charge of coordinating the traffic signals to maximize number of vehicles served while maintaining an acceptable delay.*“



- “The safety distance car-following and lane-changing models used in CBEngine are similar to SUMO”

- Optimization function to minimize: average of $\mathbf{t}_{\mathbf{travel}}$ / $\mathbf{t}_{\mathbf{free\text{-}flow}}$ for all vehicles

  https://kddcup2021-citybrainchallenge.readthedocs.io/en/latest/city-brain-challenge.html



http://www.yunqiacademy.org/poster

KDD Cup 2021

Rank	Team Name	Total Served Vehicle	Delay	Submission Time
1	BOE_IOT_AIBD	126572	1.4849440797957865	2021-06-09 06:26:09
2	4PQC_team	126572	1.485730405526422	2021-06-07 08:00:01
3	IntelligentLight	126572	1.4862501081986428	2021-06-07 14:34:56
4	SupperNYU	126572	1.4873431719870123	2021-06-06 12:48:39
5	GoodGoodStudy	126572	1.4926704014134926	2021-06-05 15:41:07
6	SmartLight	126572	1.4955463604655208	2021-05-26 13:16:10
7	polixir	126572	1.4995456913064775	2021-06-07 08:52:43
8	SUMO	126572	1.5019871362799826	2021-06-09 08:27:27
9	two_slices_of_bread_with_cheese	126572	1.5065601070238663	2021-06-07 10:35:42
10	docomo_dev	126572	1.5189627245170698	2021-06-08 18:14:36

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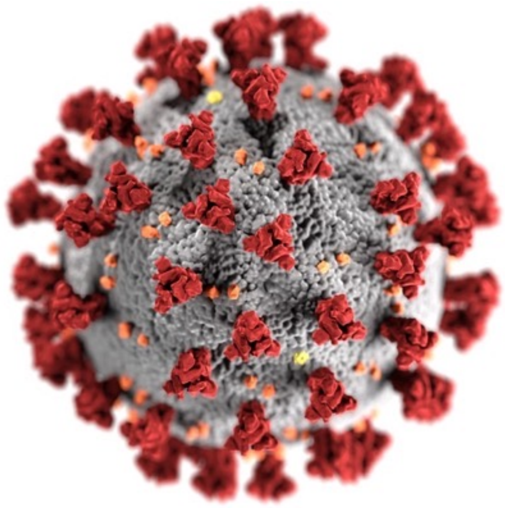
Qualification Round

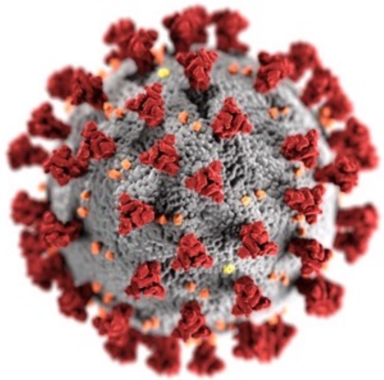
http://www.yunqiacademy.org/home/leaderboard
09.06.2021

Competitors: 1408 Teams: 1156 Submissions: 2633



Changes
in the Mobility System

Effects of CoVID-19: More Homeoffice – Less Traffic



- General German Automobile Club (ADAC):
  - Traffic jams: 513 500 **(-28%)**
  - Total length: 679 000 km **(-52%)**
  - Total hours: 256 000 h **(-51%)**

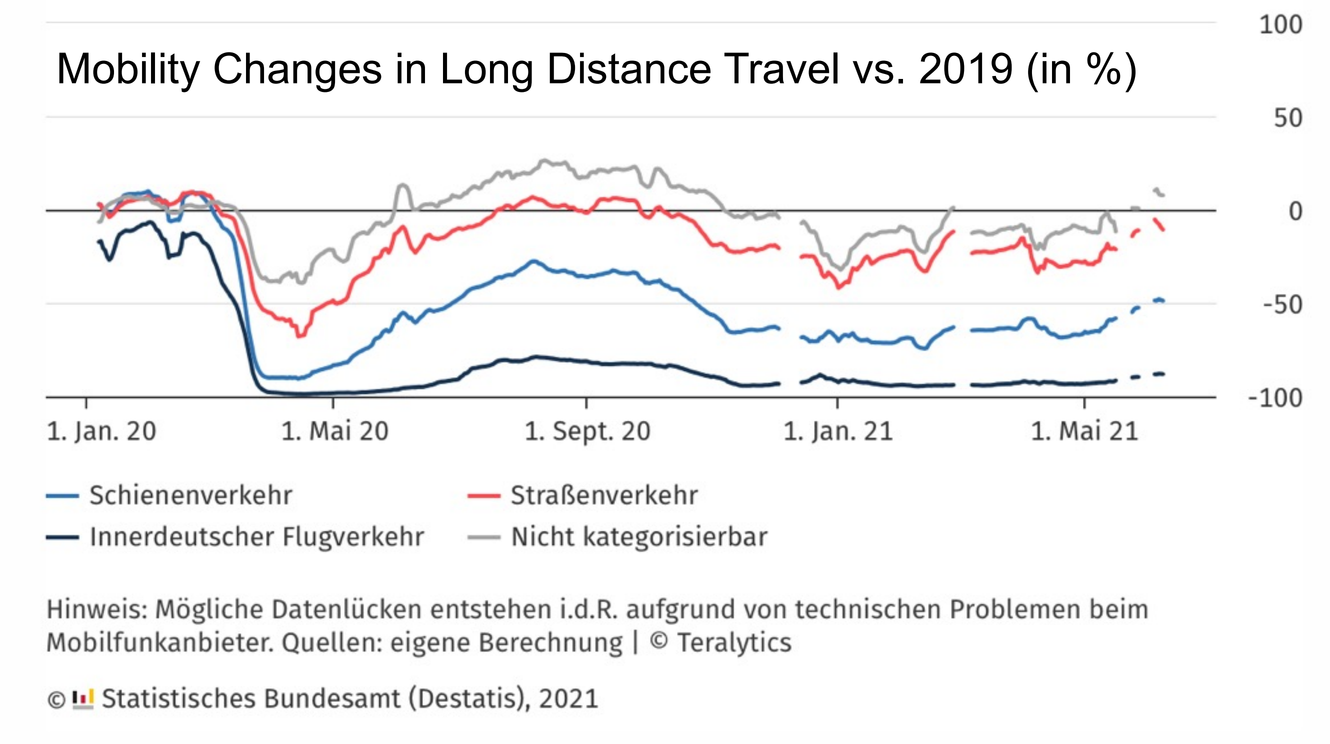
  https://www.adac.de/verkehr/verkehrsinformationen/staubilanz/

- German Federal Statistical Office (DESTATIS):
  - Mobility March 20 vs. March 19: **-40%**
  - Railway trips April 20 vs. April 19: **-88%**

  https://www.destatis.de/DE/Service/EXDAT/Datensaetze/mobilitaetsindikatoren-mobilfunkdaten.html

- Potential long-term effect: move to suburbs?

- How to predict these effects with historical data?



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Effects of New Technology

- Properties of mobility systems are affected by new technologies:
  - Smart traffic lights
  - V2X communication / Cloud-connected vehicles
  - Electric mobility
  - Autonomous vehicles (for public transport)
  - …

- Affected properties
  - Cost, capacity and travel times
  - Predictability and passenger comfort
  - Traffic demand and mode choice
  - …

- Mid/Long term changes
  - Germany: 48.3 Mio passenger cars - “Peak Car” reached?
    (https://de.statista.com/statistik/daten/studie/12131/umfrage/pkw-bestand-in-deutschland/)
  - Heterogeneous mix of “active mobility” / “micro mobility”

https://tavf.hamburg

https://github.com/DLR-TS/sumo-scenarios/TAVF-Hamburg

Using AI is tricky.

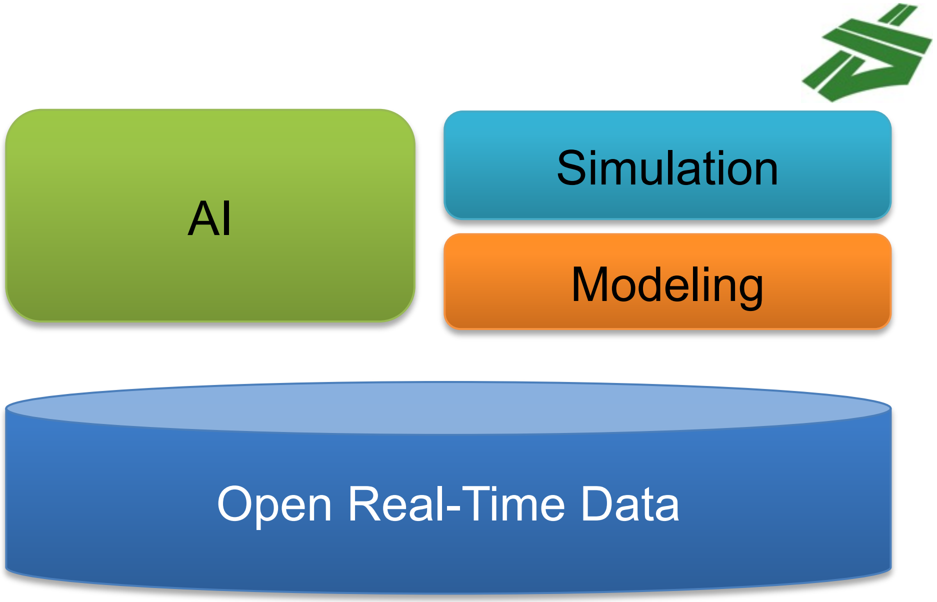
What can you do?

Combine AI with Open Simulators and Open Real-Time Data

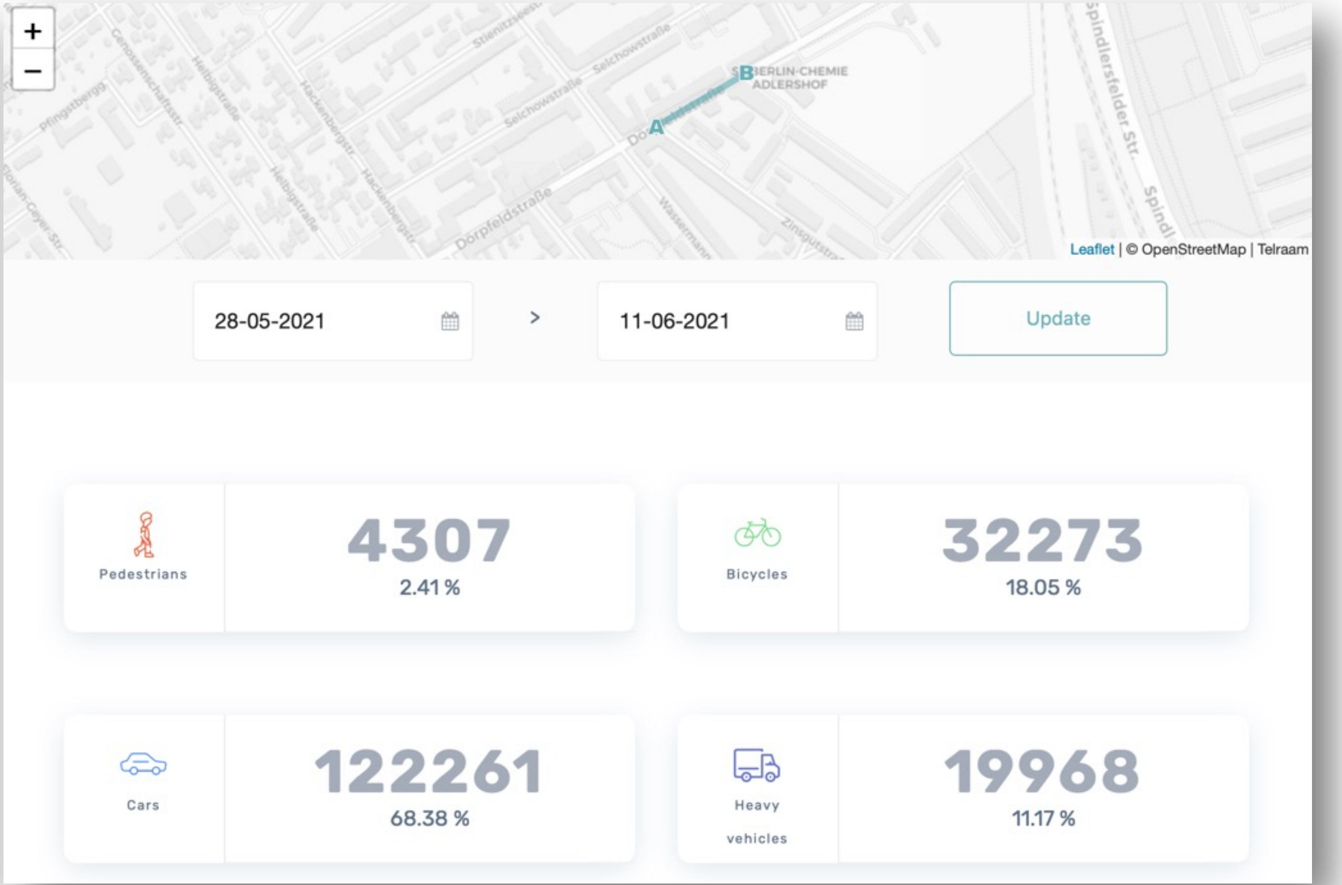
- Use Open Data to facilitate collaborative data management
  - Multiple stakeholders benefit from joint data maintenance
  - Example: OpenStreetMap

- Use real-time data to detect changes in real-time
  - Example: → next slide

- Enhance your system with modeling and mobility simulators
  - to improve your understanding („white box“)
  - to improve predictability
  - to work with a changing reality
  - to train the AI with synthetic data
  - to validate your AI results in a „Digital Twin“



Open Real-Time Data?



https://www.telraam.net
https://telraam-api.net

Some Things to Take Away

- Reality of mobility systems is complex and (very) dynamic
- Apply AI wisely
  - do not overestimate its power
  - do not underestimate the resources needed for its training
  - pay attention to the optimization function
- Modeling and Simulation may be „old school“ – but still tremendously valuable and powerful
- Mobility domain affects many stakeholders – openness is key for collaboration

IEEE SPECTRUM Topics Reports Blogs Multimedia Magazine

Article | The Institute | IEEE Member News

31 Mar 2021 | 17:00 GMT

Stop Calling Everything AI, Machine-Learning Pioneer Says

Michael I. Jordan explains why today's artificial-intelligence systems aren't actually intelligent

By **Kathy Pretz**

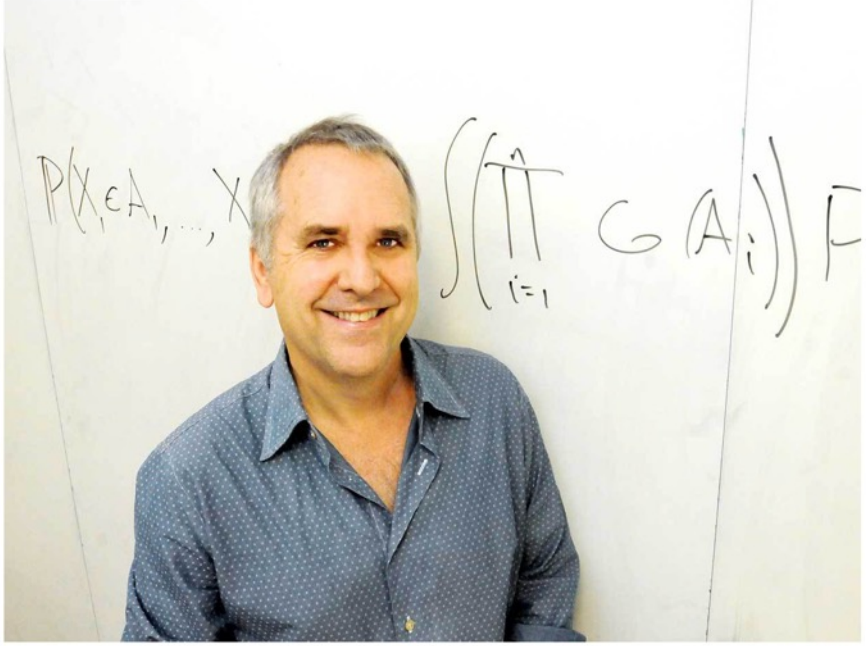


Photo: Peg Skorpinski

https://spectrum.ieee.org/the-institute/ieee-member-news/stop-calling-everything-ai-machinelearning-pioneer-says

Q & A

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