Artificial Intelligence and Traffic Systems

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What is artificial intelligence?

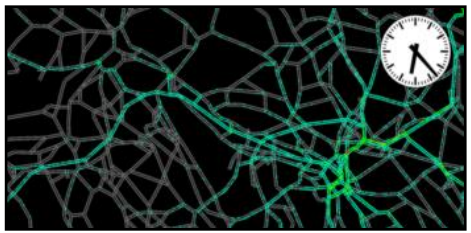
- Artificial narrow intelligence ('weak AI')
  - Very narrow, specific purpose
  - Big Data and complex algorithms (chess players, Facebook wall, …)
  - Will not pass Turing test

- Artificial general intelligence ('strong/true AI')
  - AI thinks as humans do (incl. intentionality)
  - Machines that are good at doing what comes easily for humans
  - Eventually learns and upgrades itself, on its own (~ 2035)

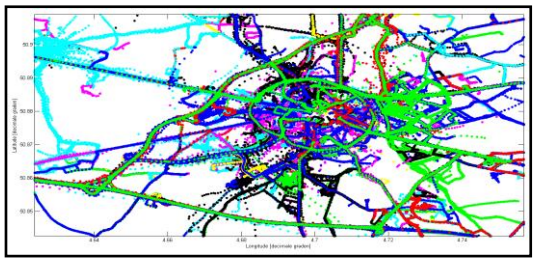
- Artificial superintelligence
  - Behold, the technological singularity! (~ 2040)
  - Cannot be easily 'turned off'

AI in a nutshell

- Background:
  - The study of 'intelligent agents' (**optimisation**)
  - Goal: mimic cognitive functions learning / problem solving



- Techniques:
  - Multi-objective/level optimisation
  - (Fuzzy) reasoning engines
  - Multi-agent systems (MAS)
  - Artificial Neural Networks (ANNs)
  - Reinforcement learning
  - Classification and regression



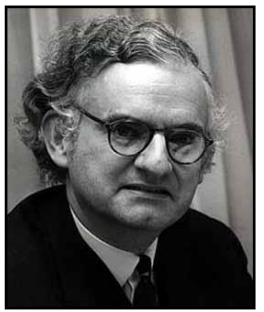
➔ **In general: machine learning through statistics**

What about the 'intelligence'?

- Some key ingredients:
  - Incremental problem solving (incl. learning)
  - Real-time adaptation to changing context/environment
  - Self-analysis (success ⇔ failure at tasks)
  - Memory (short- and long-term storage)
  - Cope with large volumes of data (cf. **V**ol/**V**ar/**V**el/**V**al/**V**er)

- AI's highs and lows
  - Expectation management
  - AI Winters ('70-'90) and Summers
  - Nowadays: deep learning

The Lighthill Report (1973)



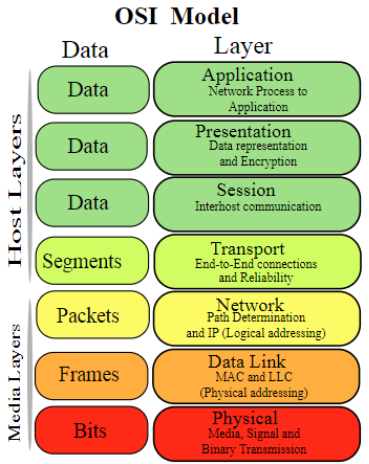
Classic traffic management

- Scope (for road traffic):
  - The focus lies heavily on urban traffic management (i.e., traffic lights)

- Techniques:
  - Classic algorithmic solutions, simple heuristics, expert systems, …
  - Ramp metering, speed harmonisation, route guidance, incident detection, …
  - Some fancier stuff: congestion prediction (MPC), fuzzy logic, …

- Tools:
  - Traffic Network Study Tool (TRANSYT)
  - Split Cycle Offset Optimisation Technique (SCOOT)
  - Urban Traffic Optimisation by Integrated Automation (UTOPIA)
  - OPAC / Rhodes / OMNIA / MOTION / SCATS / Optimax / Green Logic / MOVA / LHOVRA / COCON / …
  - LISA+ / VERA+ / ANNA+ / INES+ / SYLVIA+

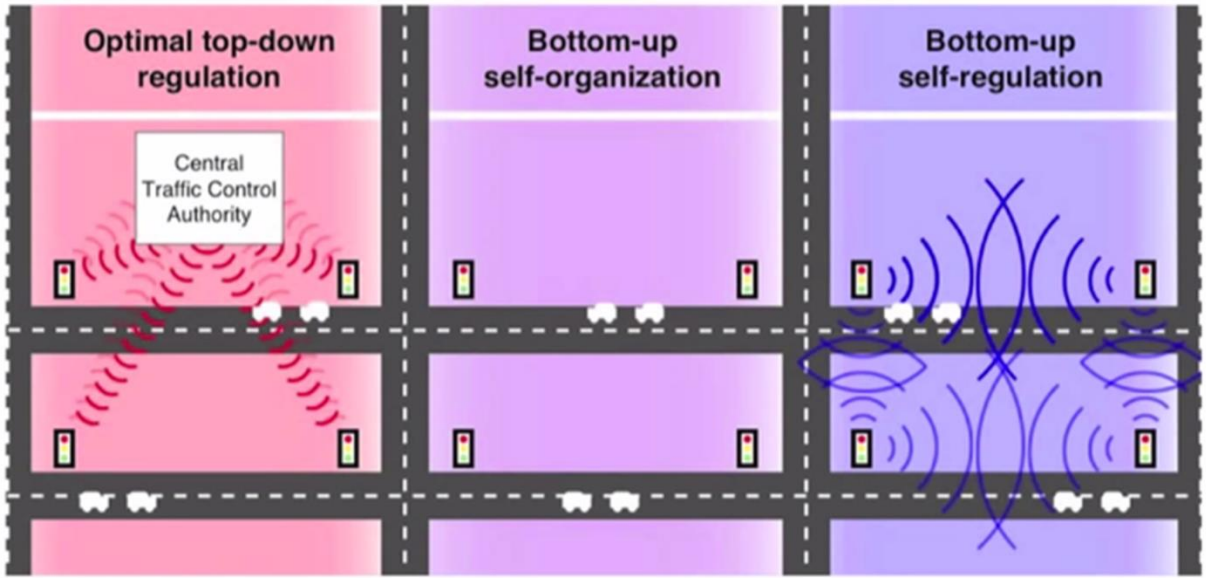
Hierarchical control



- Similar to the Open Systems Interconnection (OSI)
  - PATH framework (US) / Dolphin framework (Japan)
  - Auto21 Collaborative Driving System (CDS) framework
  - Cooperative Vehicle-Infrastructure Systems (CVIS) (EU)
  - SafeSpot (EU FP6) / PReVENT (EU) / …
- Possible layers:
  - Handheld ⇔ in-vehicle ⇔ roadside systems
  - Physical ⇔ regulation ⇔ coordination ⇔ planning ⇔ link ⇔ network
- Scope of the layers:
  - Controlling vehicle dynamics, manoeuvring, HMI, V2X, …
  - Path/network/congestion control (platoon sizes, route assignments), …
  - Global ⇔ locally distributed controllers

Organising complex systems

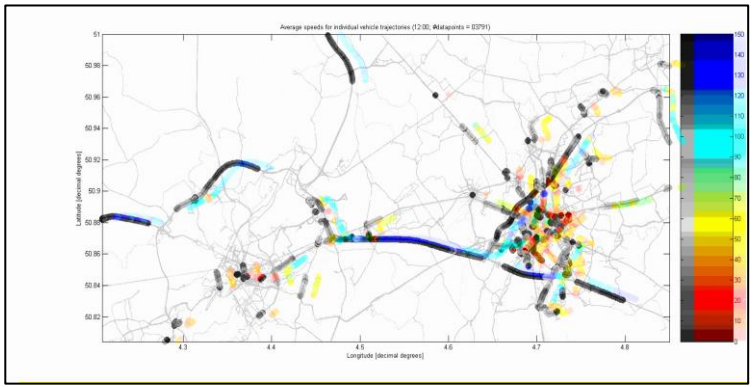
- Cf. Helbing's classification:



Including 'social' aspects

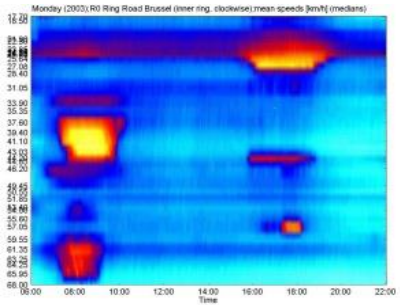
- Shifting perspective towards the individual (informing)

- Input data for personalised services:
  - Twitter feeds / WhatsApp / Facebook traffic-related content
  - On-demand ride matching
  - Waze / Google Maps probes
  - Various floating vehicle data
  - C-ITS



- Social traffic management:
  - Leverage the power of the community
  - Accomplish large-scale behavioural changes

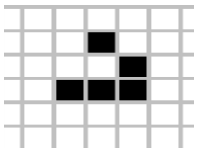
Current AI and traffic cases



- Traffic light control:
  - Congestion / queue length predictions
- In the automotive sector:
  - Traffic sign / context recognition, ACC, ISA, route guidance, …
- The Theory-Practice Gap (*experimental* ⇔ *mainstream*)
  - Only limited advancements are exploited in the field
  - Currently AI is mostly used as a building block
  - Dealing with long platoons
  - Scalability (from a single freeway to network-wide coordination)

AI and traffic lights

- Intersection control has non-linearities and NP-hard
- Techniques:
  - Vehicles and intersections as intelligent agents
  - Self-organisation through ant-based optimisation
    - Information exchange (pheromones and evaporation)
    - 'Antiquette' (moving aside)
    - **Ants speed up with density**
  - Examples of decentralised control:
    - Pittsburgh: I2I(V) (+ unknown AI algorithms)
    - Toronto/Burlington (MARLIN): game theory + learning
    - Dresden: multimodal + model-based predictions

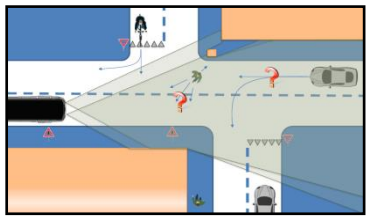


- Benefits: 25%↓ TTs, 40%↓ idling time, 20%↓ braking, …

AI adoption and AVs

cooperative connected automated mobility (CCAM)

- AVs require a model of the world around them
  - Lots of sensor inputs (camera's, LIDAR, wheel encoder, GPS, …)
  - Goal: remove the (absolute) need for pre-programmed maps



- AV levels:
  - Level 3 → feasible
  - Level 4 → promised 2025 (Honda)
  - Level 5 → 

(SAE, 2014)

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability (*Driving Modes*)
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

- The AV revolution will enable/require traffic management on a higher and broader level (+ infrastructure modifications)

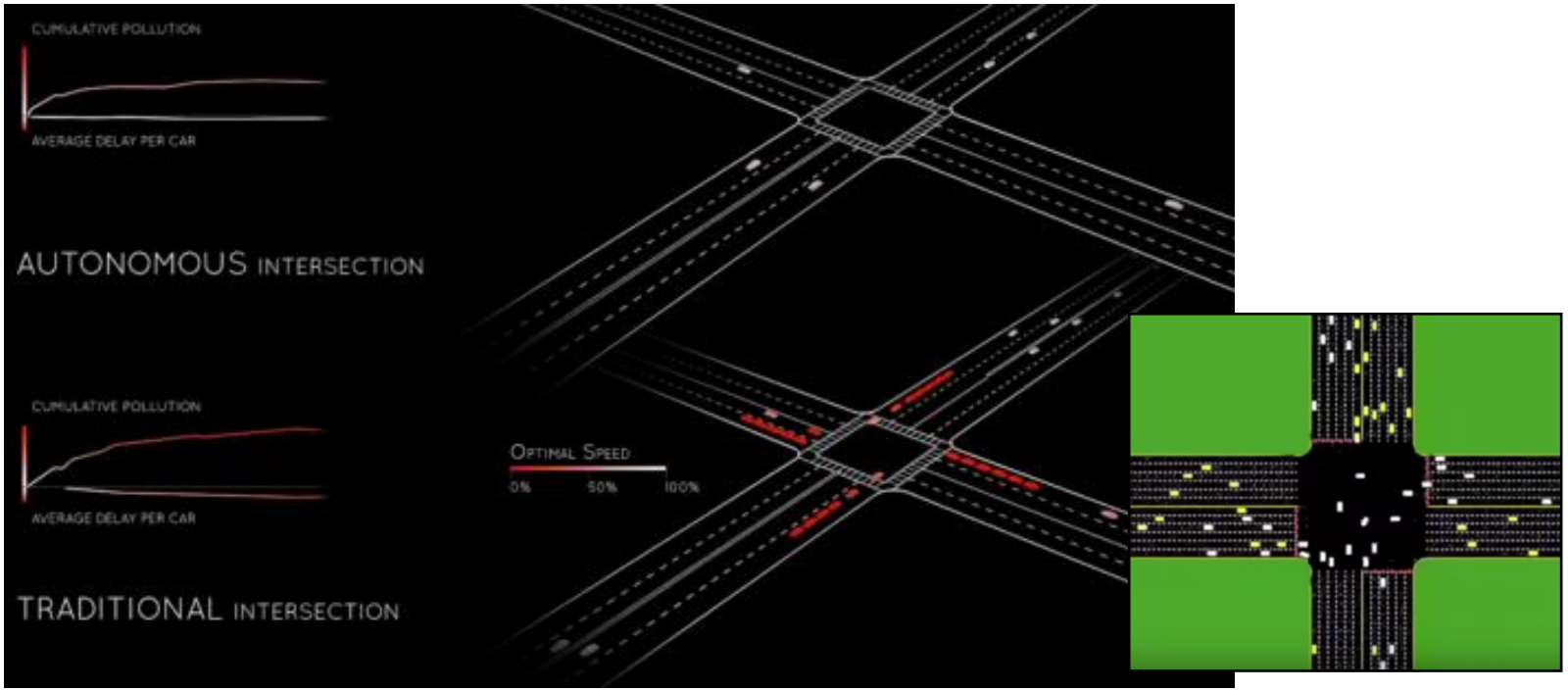
No more traffic lights?

- "*Traffic lights are no solution, they cause people to speed like hell and brake like idiots*"
- It's not about structurally changing into a roundabout
- Experiments with traffic lights switched off (UK)
- But mostly operating very locally and with low volumes (+ at the cost of pedestrians' waiting times)

AVs negotiating intersections

- Slot-based (platoons ⇔ individual vehicles)

1 human can screw up the system



Network-wide management

- Currently: ATMS ⇔ ATIS interactions + manual work
- Go beyond 'multiple intersections' (automatically!)
- Singapore:
  - Intelligent route finding algorithms
  - Minimise probability of traffic breakdown
  - Crucial element: non-linearity of congestion (10% connected)
- Traffic Management 2.0 (www.tm20.org)
  - Collaborations between road operators and service providers
  - Common interfaces, principles, and business models

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Further issues

- Dealing with transition areas (e.g., road works)
  - (Early) warning systems
  - Pro-active (mandatory) control of approaching vehicles
- To what degree can we automate the processes?
  - Discovering seeds of congestion (different patterns)
  - Finetuning ramp metering, VMS, …
  - Where to put the emphasis (i.e., what goal to optimise)?
- Various other issues:
  - Responsabilities and ethics (cf. AV debates)
  - Standards (EC ⇔ OEM ⇔ global consortia)

A note on the future of AI

- The evolution of the human race will go much quicker than that of the AI (cf. 2035-2040 time horizon)
  - Changes in mobility patterns
  - Changes in travel behaviour
  - Changes in infrastructure, vehicles, and communication
- Good ⇔ Bad AI (= human concepts)
  (abstract away)

More information?

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