How can we use AI on Big Data in the Transport Sector

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AALBORG UNIVERSITET

DiCyPS

DiCyPS

CENTER FOR DATA-INTENSIVE CYBER-PHYSICAL SYSTEM

(2015–2021)

32.5, 74 MDKK

Innovationsfonden

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NYFORS

seluxit

ENERGI STYRELSEN

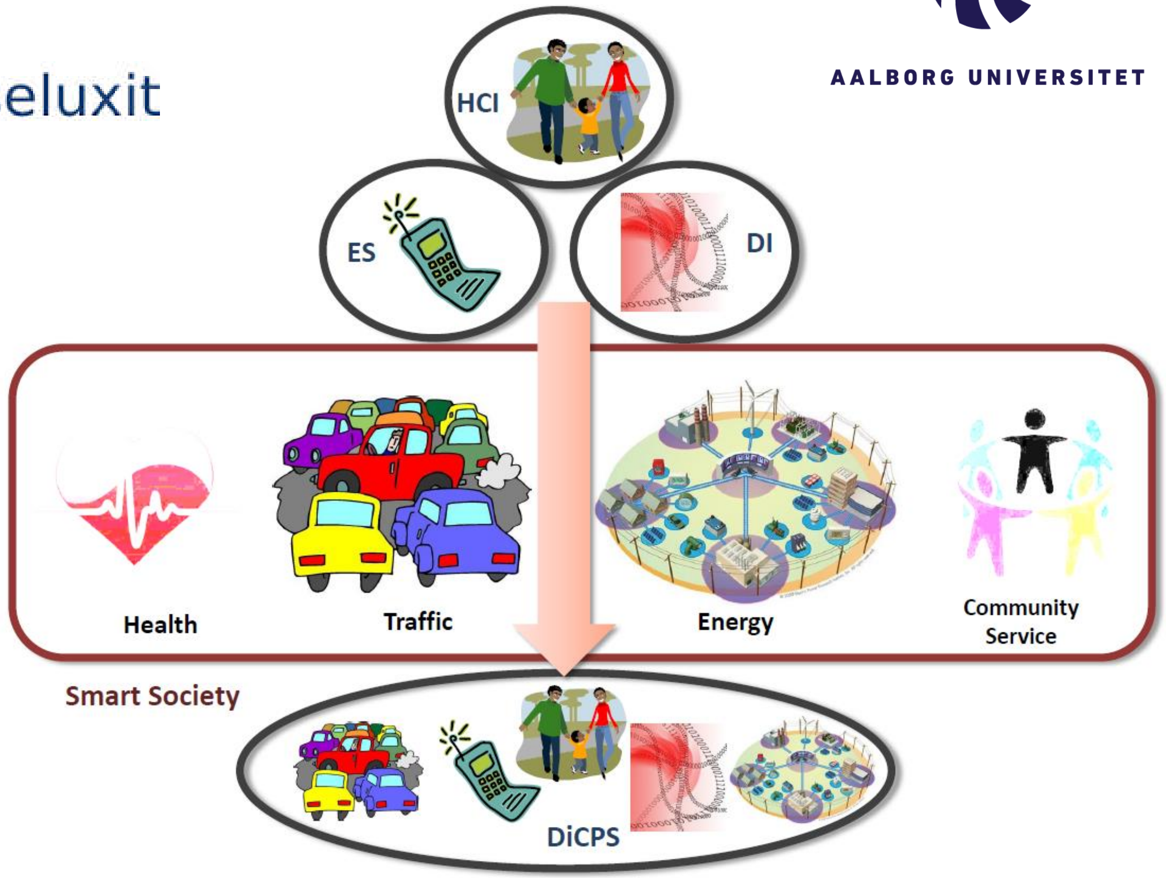
GRUNDFOS

Nilfisk

NEOGRID TECHNOLOGIES

Danfoss

SCADA international



TECHNISCHE UNIVERSITÄT DRESDEN

Inria

UCL

REGION NORDJYLLAND – i gode hænder

AALBORG KOMMUNE

REJSEKORT

RAMBØLL

BLIP systems

ERSTANDENS BRANDFORSIKRING

FLEXDANMARK

Smart Society – Vision

Challenges for ICT

- Big Data
- Communication
  Internet-of-Things
- AI and Machine Learning
- Cyber-Physical Systems
- Safety & Security
- Privacy & Ethics.

Better living for citizens

Increased QoS and improved decision making for local governments

Better utilization of resources

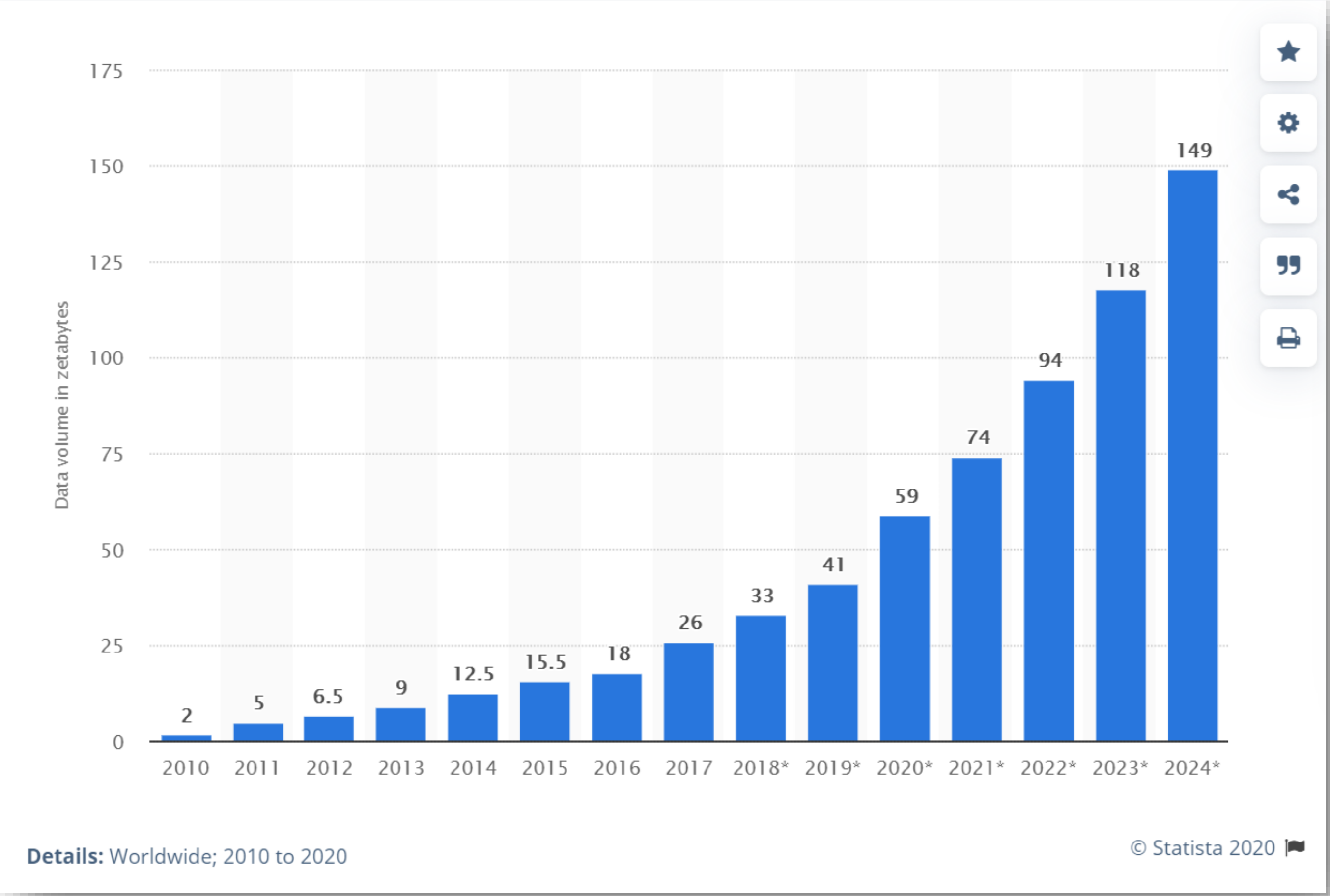
Growth potential for new businesses

Big Data

- Data is the new oil

  - Search Data (Web, Google, ..)
  - Social Network Data (Twitter, Facebook, ..)

627 petabytes moved over internet daily ..
1PB =1 000 000 000 000 000 bytes

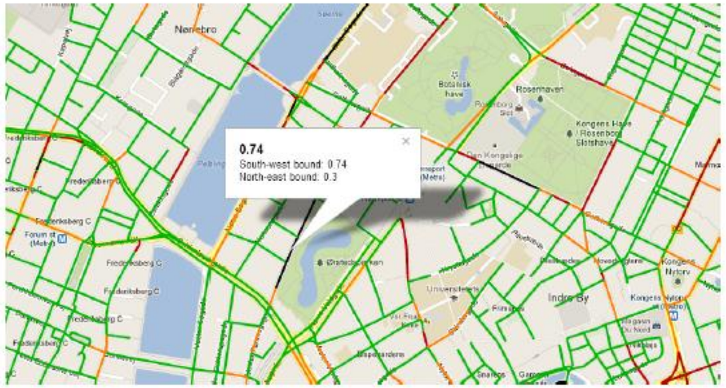


Big Data and AI in Transport

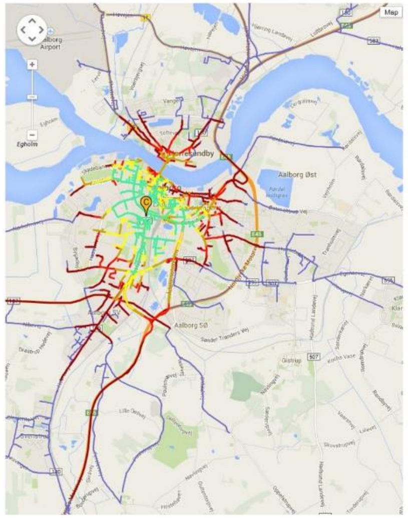
- Data is the new oil
  - Search Data (Web, Google, ..)
  - Social Network Data (Twitter, Facebook, ..)
  - Big Sensor Data (IoT, ..)
  - GPS, Radar, Canbus, Cameras
- Traffic analysis (historical)
- Traffic monitoring (on-line)
- Traffic prediction (future)
- Traffic control (on-line)
- Traffic design (future)

- **What to estimate/monitor/predict (machine learning)**
  - Road-signs
  - Obstacles
  - Delays
  - Congestion of traffic
  - CO2 emission
  - Traffic jams
  - Unexpected events
- **What to control (game theory)**
  - Car maneuvers
  - Traffic Lights, Dynamic Road Signs
  - Route suggestions
- **What to design (mechanism design)**
  - Effect of new road Infrastructure (physical, digital)
  - Placing of loading stations for electrical vehicles

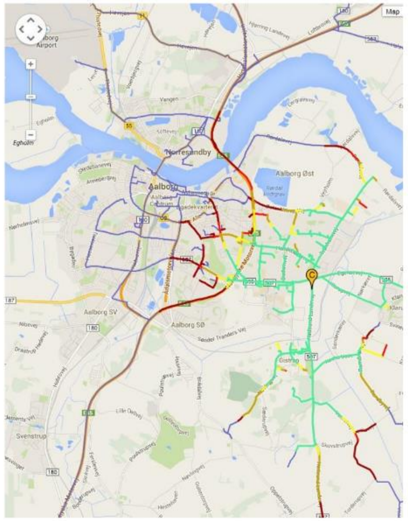
Traffic Congestion



Aim: *Reduce CO^2 emissions and congestion*



Existing



New

Making it to the hospital in 5 min

- Data
  - Some 100 billion GPS records, 70.000+ vehicles
  - 350+ million CAN Bus records
  - Conventional and electric vehicles, mini-buses, buses, taxis, trucks
  - ~20 data sources, ~1 billion records per week
  - Maps
  - Weather data
- Software and hardware
  - A complete software stack for handling traffic data, data cleansing, multiple map support, maps-based analytics
  - Modern servers (up to 2TB main memory)

Intelligent Routing

Personalized Routing DK

- Ca. 2 billion distributions for the 1.6 million edges
- There are 2.4 million cars.
- Each car (driver) has two contexts.
- Result: 10 million billions = 10 quadrillion distributions

- For each routing query, compute weights using a different set of trajectories.

- Result: Weights cannot be precomputed.
- A new on-the-fly paradigm is needed.

Traffic Accidents

Kristian Torp

Background, Questions, and Goals

- Background
  - Estimated that 50% of delay in traffic is due to "unplanned events"
  - Major issue for traffic planning, price goes up
- Questions
  - Can GPS data be used to **detect** the impact on traffic when there is an accident?
  - Can we quantify for **how long** an accident has an impact?
  - Can we determine the **area** in which an accident has an impact?
- Goals
  - Explain why late
  - Early warning for traffic planners

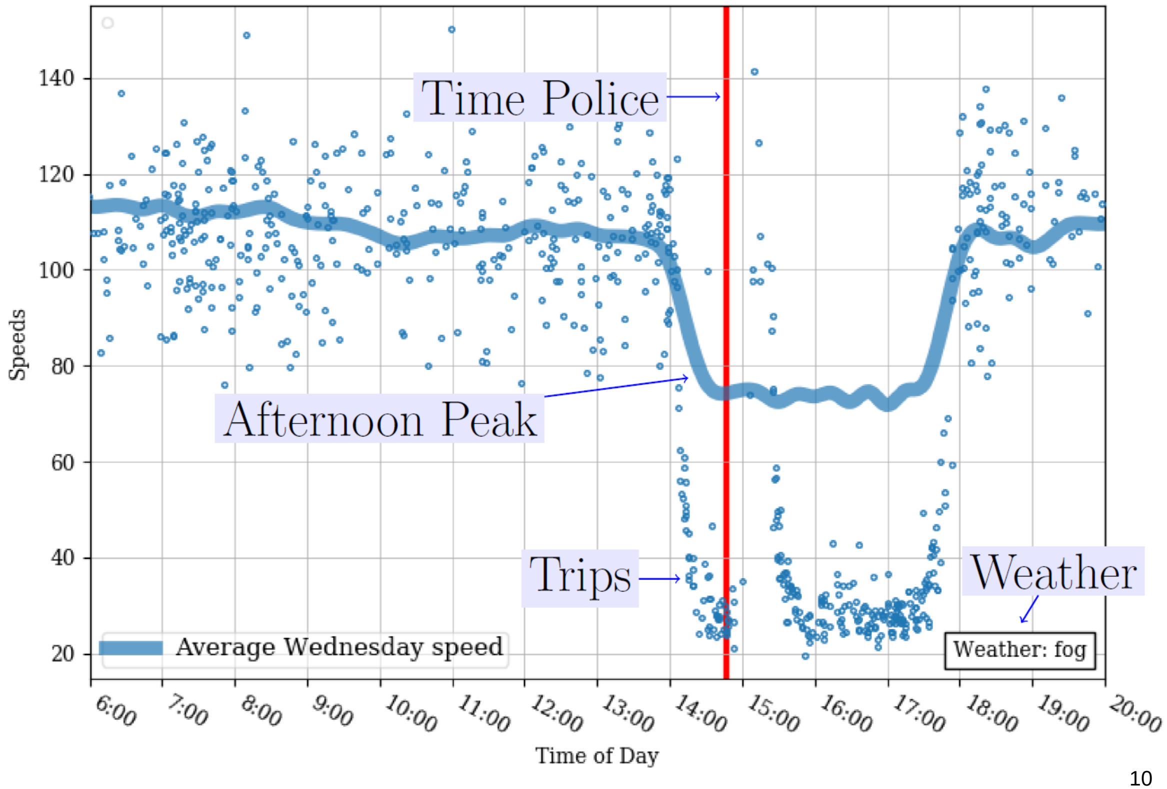
Traffic Accidents

Kristian Torp

Summary

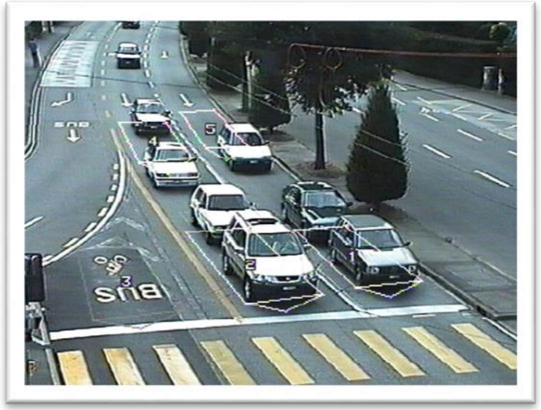
- *Can GPS data be used to detect the impact on traffic when there is an accident?*
  - Yes, but need a very large set of vehicles
  - Works best on the major road network
- *Can we quantify for how long an accident has an impact?*
  - Yes, quite clearly on main roads, less on smaller roads
- *Can we determine the area in which an accident has an impact?*
  - Maybe, very hard to determine accurately!
- Working on
  - Real-time assessment
  - Spatial/temporal impact assessment in a more generic fashion
    - Key Performance Indicators (KPIs)
  - Opening up to the world

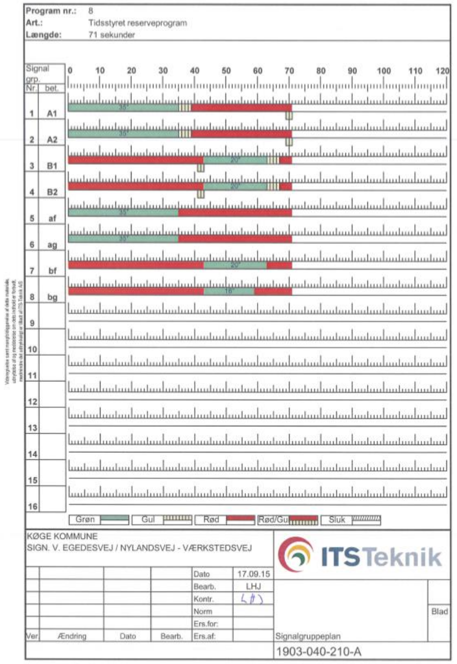
Motorway, Accident Wednesday

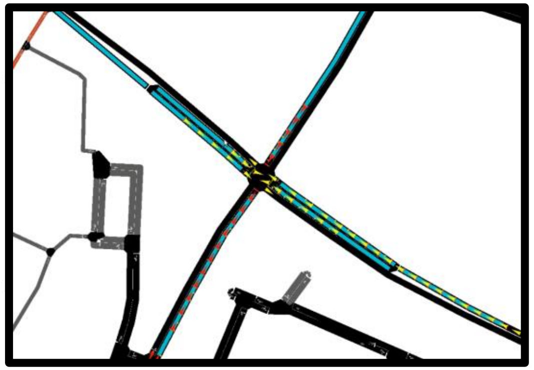


Intelligent Traffic Control

- Observation: Unnecessary waiting time
- Currently:
  - Time triggered
  - Induction loops
- Exploit new information from radars





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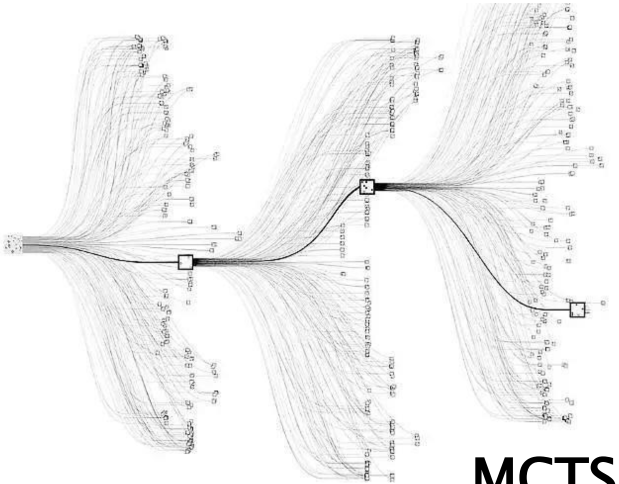
<phase duration="4" state="rryyyrryyy"/>
<phase duration="4" state="rrrrrrrrrr"/>
<phase duration="20" state="GGrrrGGrrr"/>
<phase duration="4" state="yyrrryyrrr"/>
<phase duration="4" state="rrrrrrrrrr"/>
</tlLogic>
```

Intelligent Traffic Control

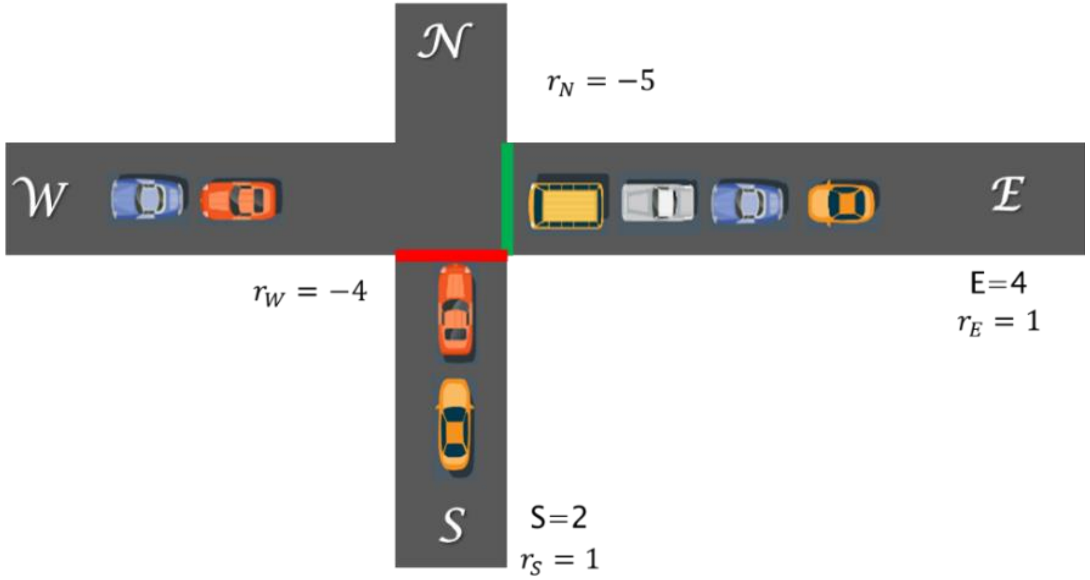
- Light control = a game between traffic and control.
- Hard timing constraints (minimum green time)
- Explicit optimization criteria.

- Strategy calculated on-line using Machine Learning
  - Monte Carlo Tree Search
  - Reinforcement Learning
  - Deep Neural Networks

GO



MCTS



Intelligent Traffic Control

- Light control =
  a game between **traffic** and **control**.
- Hard timing constraints (minimum green time)
- Explicit optimization criteria.

- Hobrovej
  - 2 km stretch
  - 6 signalized intersections
  - 20.000–30.000 vh/day
  - VISSEM (7.00–9.00)

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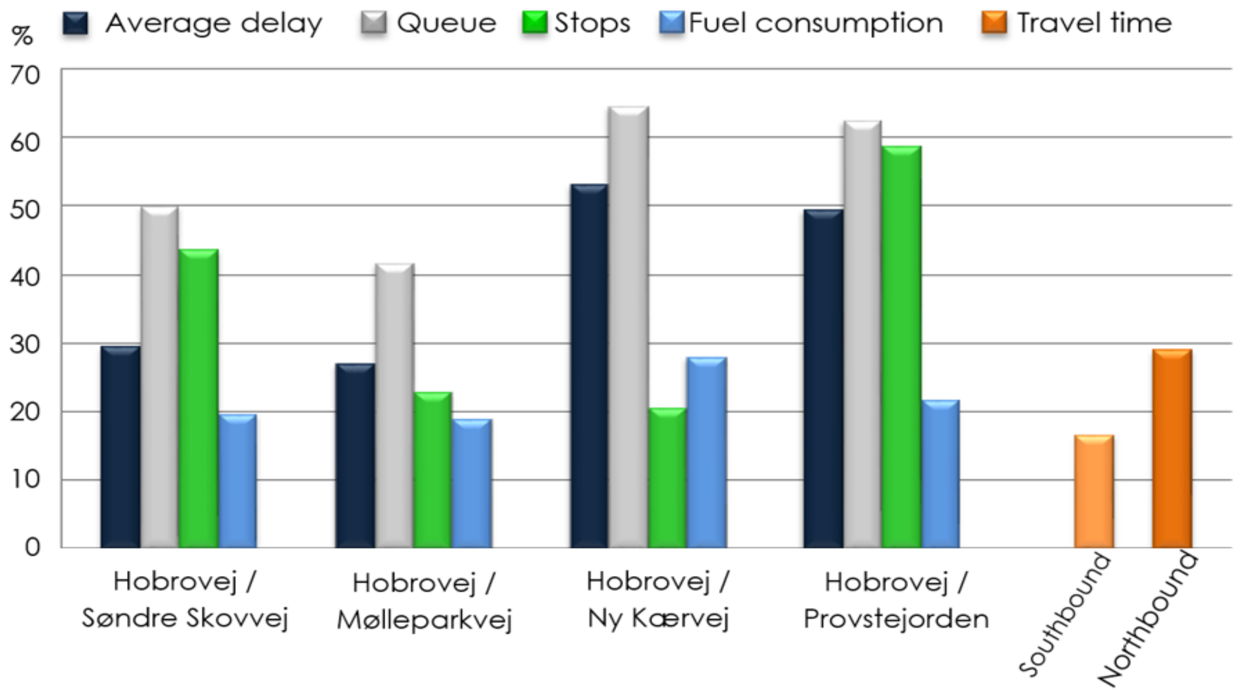
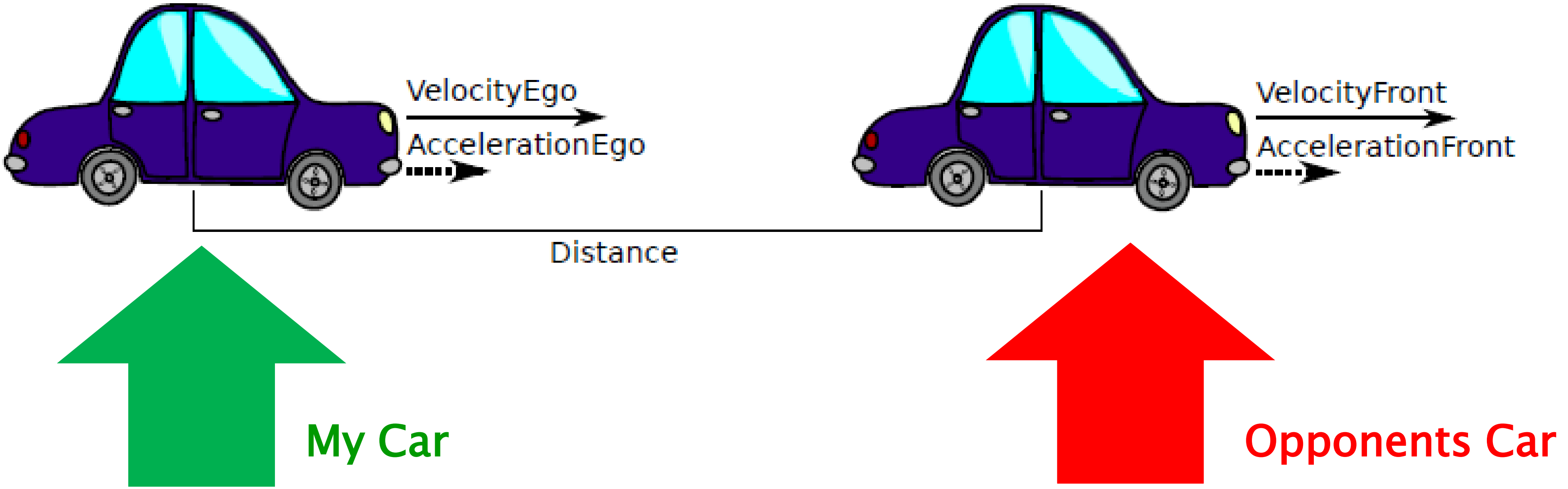
COWI AALBORG KOMMUNE AARHUS KOMMUNE swarco RAMBØLL



Autonomous Driving

Adaptive Cruise Control

Adaptive Cruise Control in UPPAAL

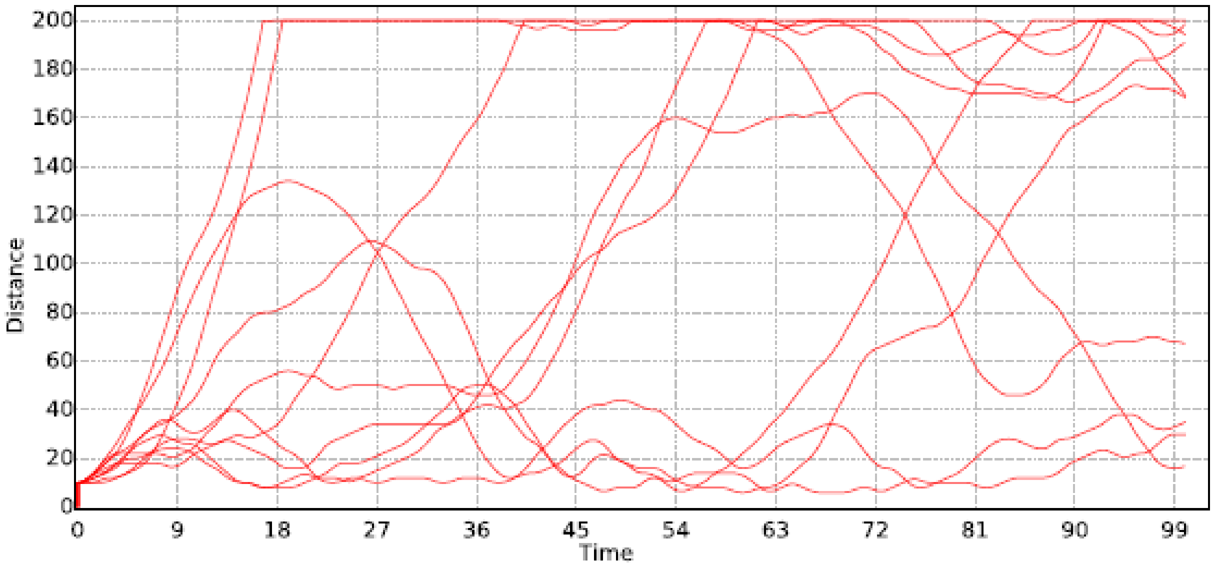


Objective: Control Acceleration of My Car so

1) Guaranteed No Crashes
2) As close as possible to Opponents Car

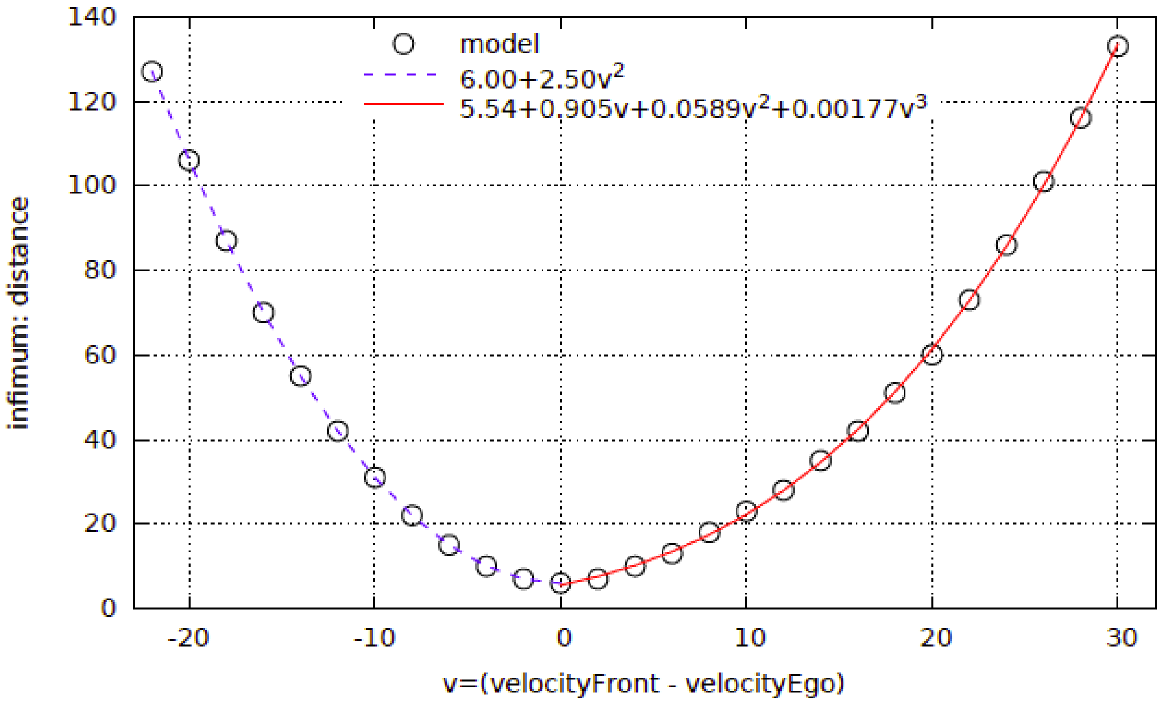
Safe Cruise

```
strategy safe = control: A[] distance > 5
```



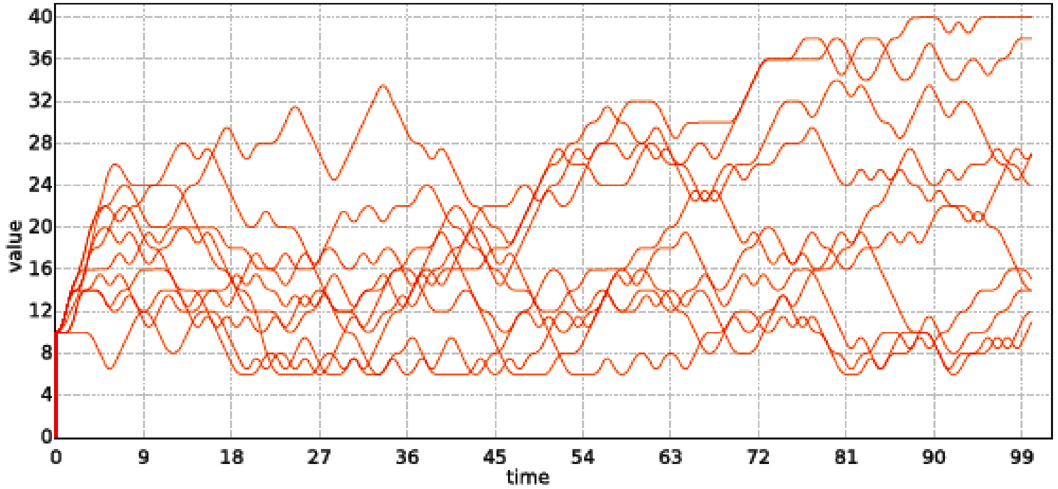
Runs of Safe Strategy

Safe Strategy

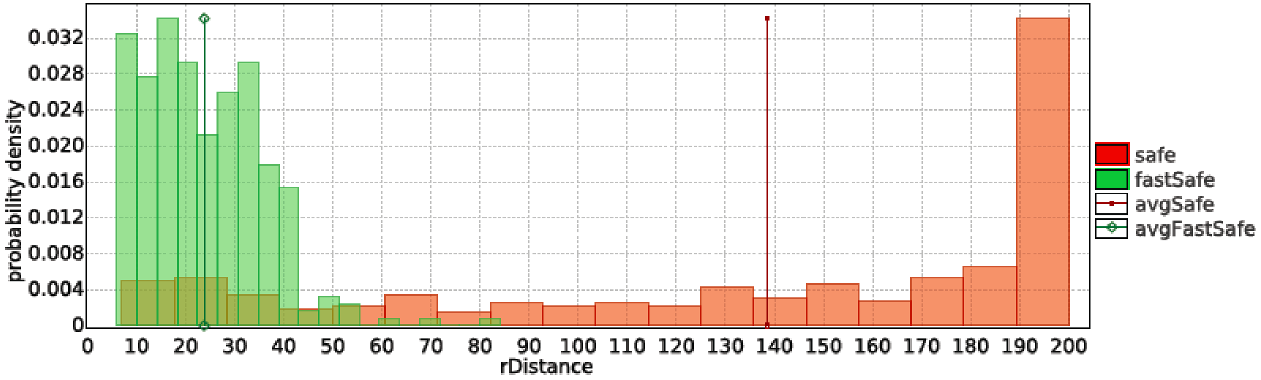


Optimal and Safe Cruise

```
strategy safeFast = minE (D) [<=100]: <> time >= 100 under safe
```

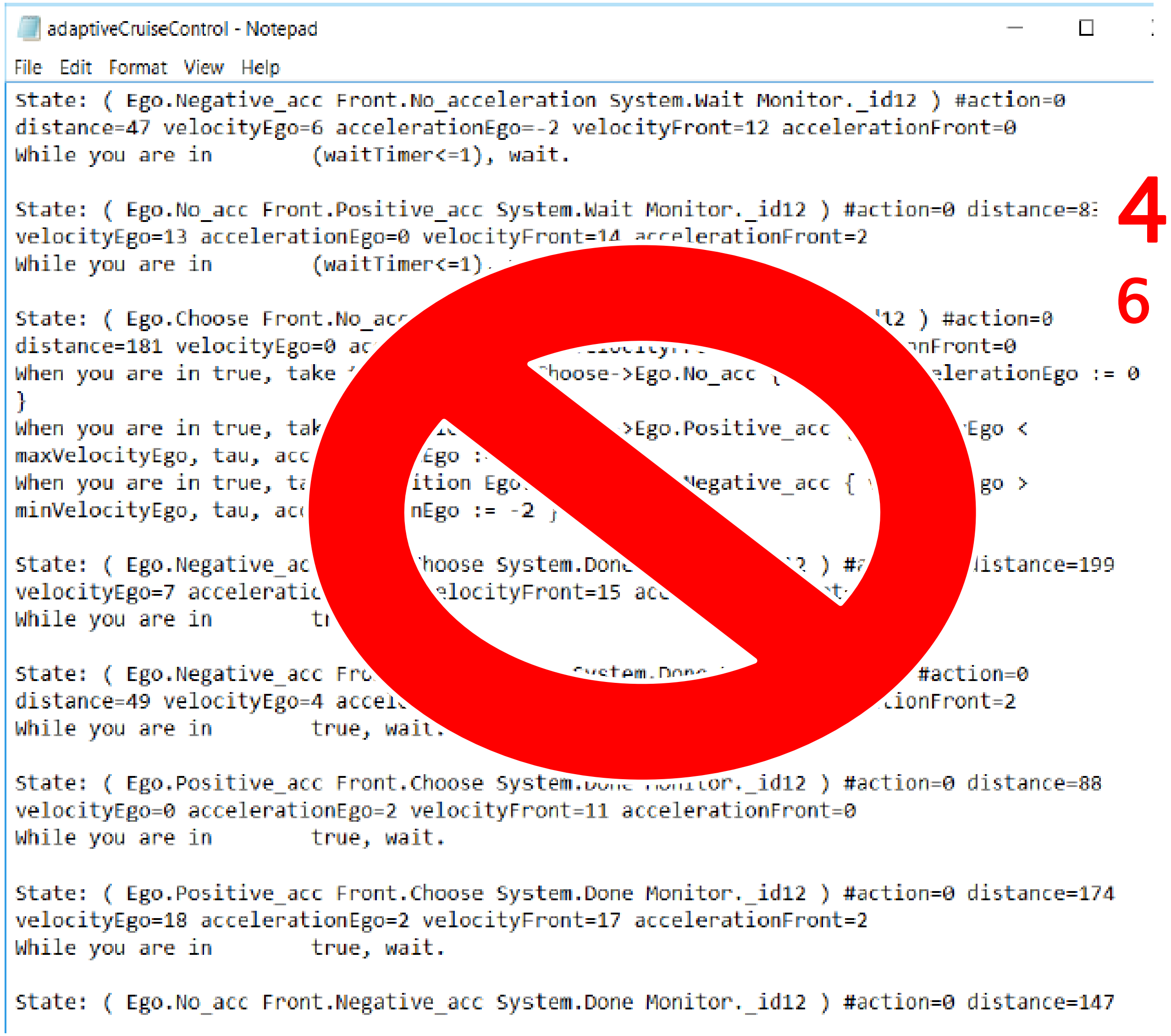


Runs of Safe & Optimal Strategy



Average Distance

Strategy – Explicit


adaptiveCruiseControl - Notepad
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State: (Ego.Negative_acc Front.No_acceleration System.Wait Monitor._id12) #action=0
distance=47 velocityEgo=6 accelerationEgo=-2 velocityFront=12 accelerationFront=0
While you are in (waitTimer<=1), wait.

State: (Ego.No_acc Front.Positive_acc System.Wait Monitor._id12) #action=0 distance=83
velocityEgo=13 accelerationEgo=0 velocityFront=14 accelerationFront=2
While you are in (waitTimer<=1)

State: (Ego.Choose Front.No_acc … 12) #action=0
distance=181 velocityEgo=0 ac… nFront=0
When you are in true, take … Choose->Ego.No_acc … elerationEgo := 0
}
When you are in true, tak… >Ego.Positive_acc … Ego <
maxVelocityEgo, tau, acc… Ego :…
When you are in true, ta… ition Ego… Negative_acc { … go >
minVelocityEgo, tau, acc… nEgo := -2 …

State: (Ego.Negative_ac… hoose System.Done…) #… distance=199
velocityEgo=7 acceleratio… elocityFront=15 acc…
While you are in tr…

State: (Ego.Negative_acc Fro… System.Done… #action=0
distance=49 velocityEgo=4 accel… ionFront=2
While you are in true, wait.

State: (Ego.Positive_acc Front.Choose System.Done Monitor._id12) #action=0 distance=88
velocityEgo=0 accelerationEgo=2 velocityFront=11 accelerationFront=0
While you are in true, wait.

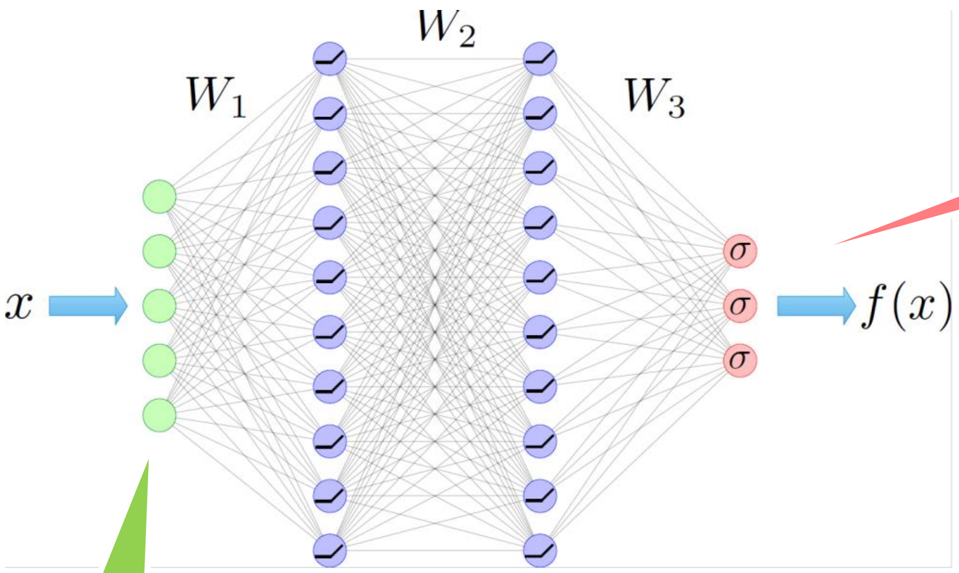
State: (Ego.Positive_acc Front.Choose System.Done Monitor._id12) #action=0 distance=174
velocityEgo=18 accelerationEgo=2 velocityFront=17 accelerationFront=2
While you are in true, wait.

State: (Ego.No_acc Front.Negative_acc System.Done Monitor._id12) #action=0 distance=147

4Mb

6 mio configurations

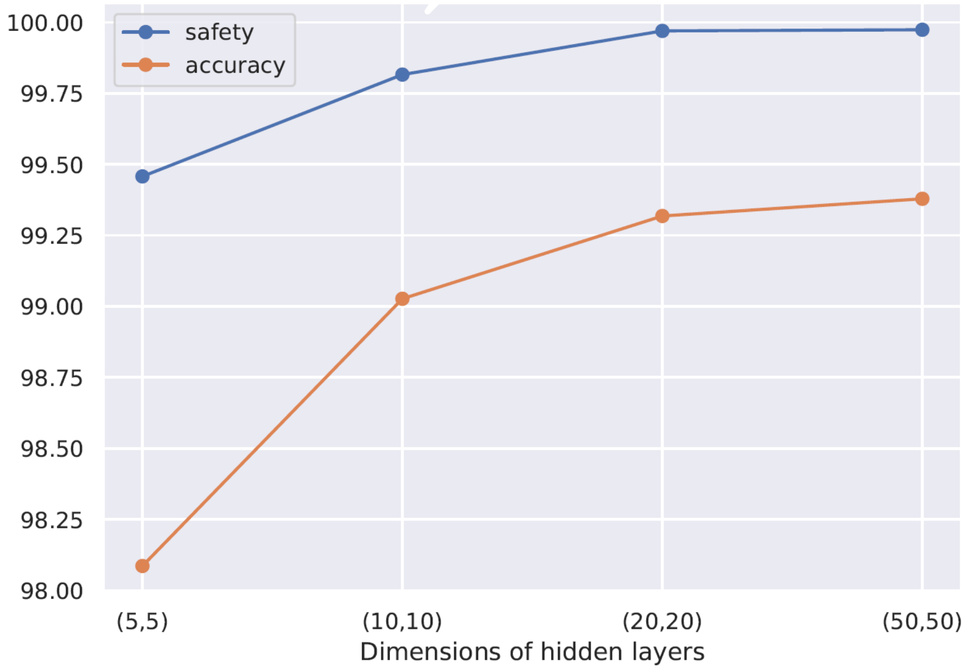
Strategy – Neural Network



- Accelleration

- velEgo
- velFront
- accEgo
- accFront
- distance

Safety ?



Strategy – Decision Tree

```
Ego.Choose <= 0: 3 (1481817.0)
Ego.Choose > 0
|   velocityEgo <= -10: 0 (39705.0/18380.0)
|   velocityEgo > -10
|   |   distance <= 200
|   |   |   velocityEgo <= 18
|   |   |   |   velocityEgo <= 12
|   |   |   |   |   distance <= 184
|   |   |   |   |   |   velocityEgo <= 0: 2 (331464.0/208577.0)
|   |   |   |   |   |   velocityEgo > 0
|   |   |   |   |   |   |   distance <= 122
|   |   |   |   |   |   |   |   distance <= 102: 2 (132918.0/80433.0)
|   |   |   |   |   |   |   |   distance > 102
|   |   |   |   |   |   |   |   |   velocityEgo <= 2
|   |   |   |   |   |   |   |   |   |   velocityFront <= 12: 1 (6255.0/4155.0)
|   |   |   |   |   |   |   |   |   |   velocityFront > 12
|   |   |   |   |   |   |   |   |   |   |   velocityFront <= 13: 2 (162.0)
|   |   |   |   |   |   |   |   |   |   |   velocityFront > 13
|   |   |   |   |   |   |   |   |   |   |   |   distance <= 110: 2 (870.0/363.0)
|   |   |   |   |   |   |   |   |   |   |   |   distance > 110
|   |   |   |   |   |   |   |   |   |   |   |   |   velocityFront <= 15
|   |   |   |   |   |   |   |   |   |   |   |   |   |   velocityFront <= 14: 1 (207.0/99.0)
|   |   |   |   |   |   |   |   |   |   |   |   |   |   velocityFront > 14: 2 (63.0)
|   |   |   |   |   |   |   |   |   |   |   |   |   velocityFront > 15
|   |   |   |   |   |   |   |   |   |   |   |   |   |   distance <= 116
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   velocityFront <= 17: 2 (126.0/54.0)
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   velocityFront > 17: 1 (129.0/39.0)
|   |   |   |   |   |   |   |   |   |   |   |   |   |   distance > 116: 1 (108.0)
|   |   |   |   |   |   |   |   |   velocityEgo > 2
|   |   |   |   |   |   |   |   |   |   velocityEgo <= 4: 1 (7689.0/4929.0)
|   |   |   |   |   |   |   |   |   |   velocityEgo > 4: 2 (27426.0/17115.0)
```

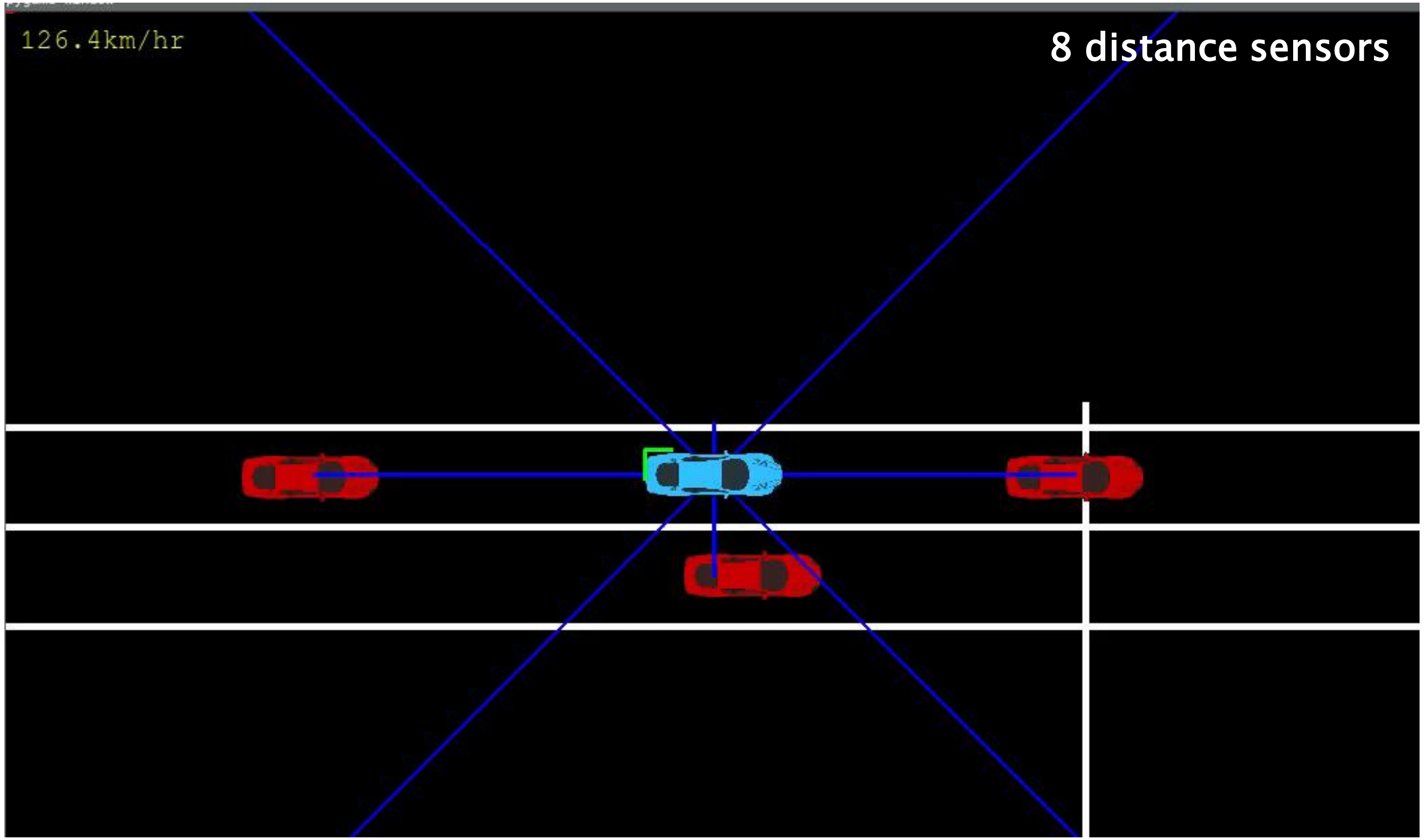
Learning Algorithms for Decision Tree (ID3, D4.5, CART)

→ 65 lines

(Jan Kretisnsky, Pranav Ashkot, TUM)

Safe

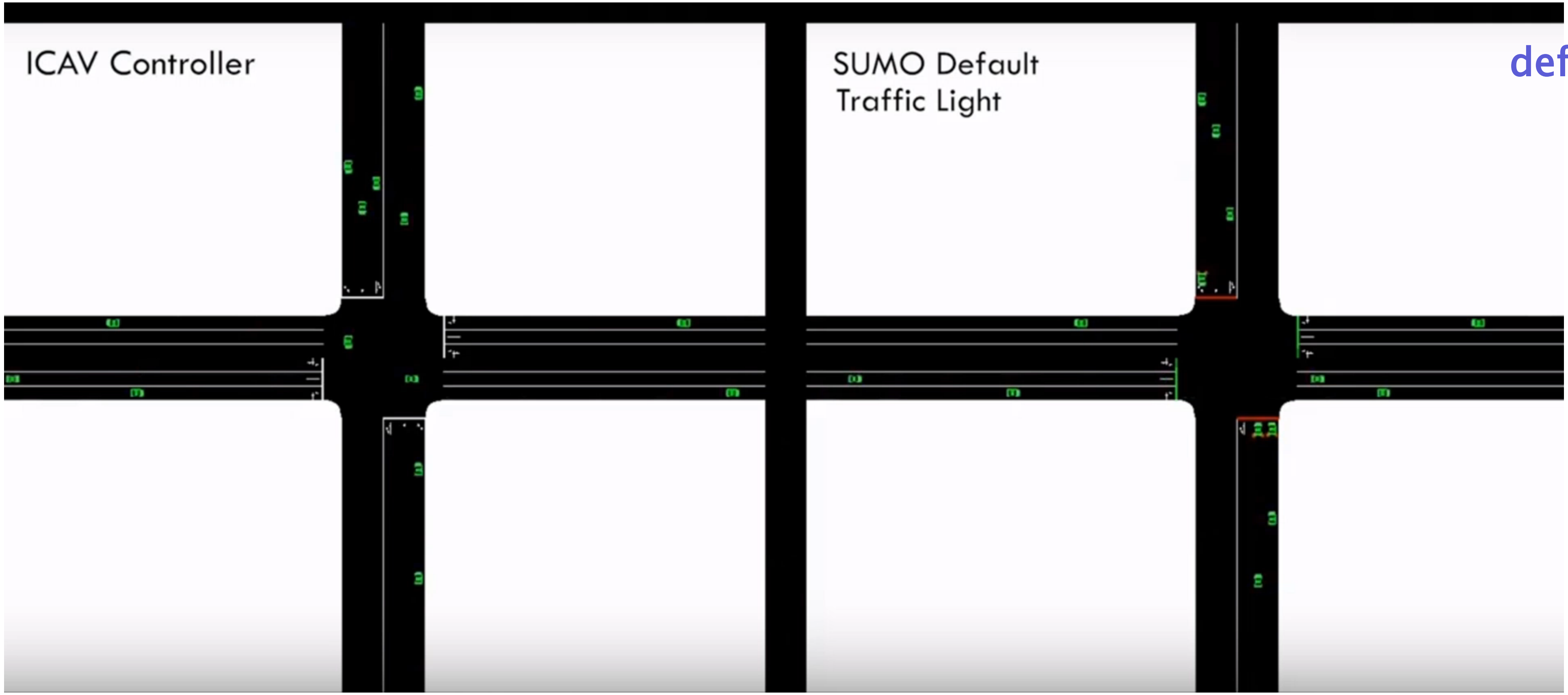
UPPAAL Adaptive Cruise Control



“Optimal” Strategy

Safe and “Optimal” Strategy

ICAV Playing Games with Speed of Cars in Intersections



Improvements to default SUMO traffic light
Avr Delay 68%
Avr Crossing Time 20%
Avr CO2 Emission 13%

Alexandre Bilgram,
Emil Ernstsen
Marco Muniz
Peter Taankvist
Morten Timmermann

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