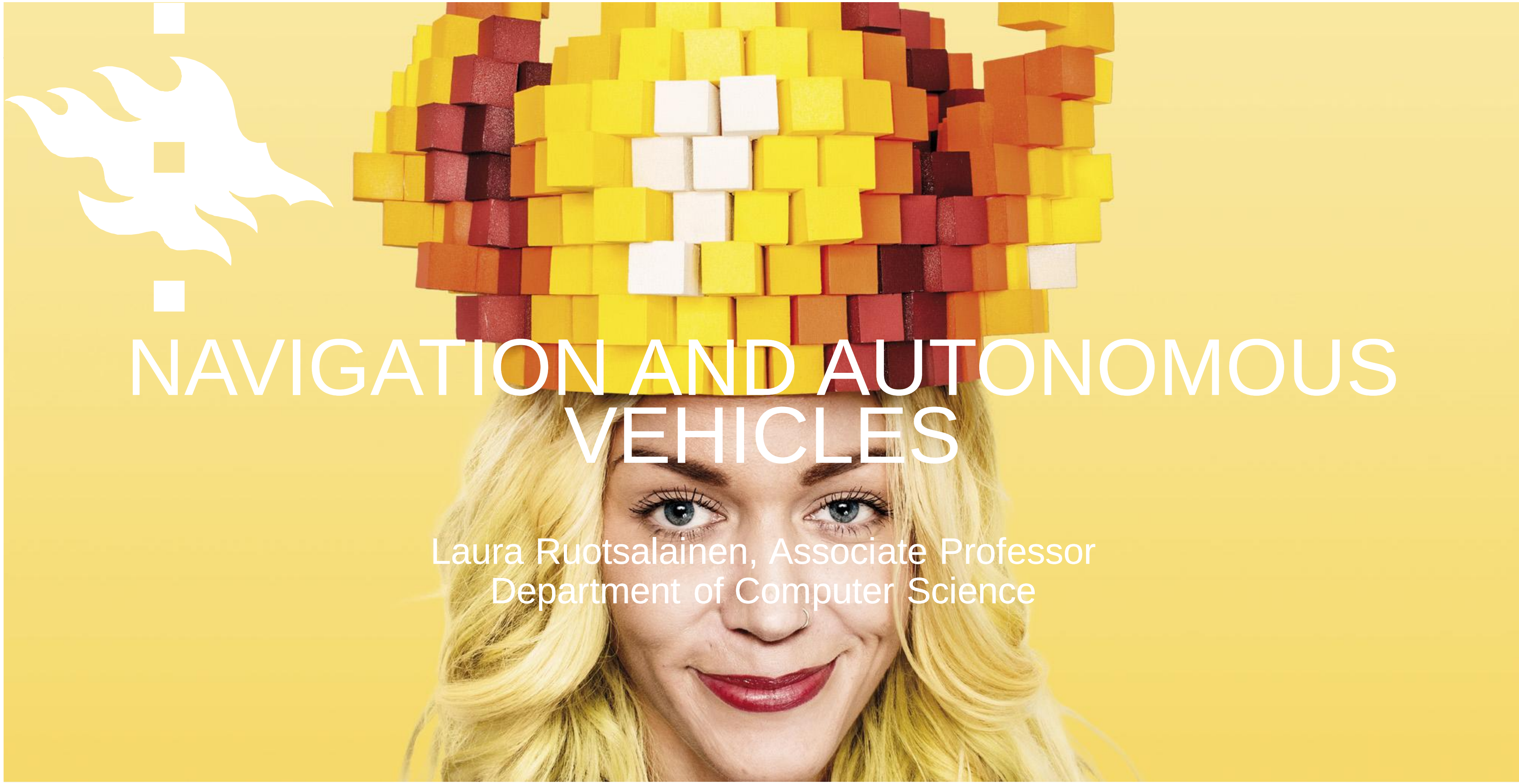


NAVIGATION AND AUTONOMOUS VEHICLES

Laura Ruotsalainen, Associate Professor
Department of Computer Science

SPATIOTEMPORAL DATA ANALYSIS FOR SUSTAINABILITY SCIENCE

HELSINKI CENTRE FOR DATA SCIENCE

HELSINKI INSTITUTE OF SUSTAINABILITY SCIENCE

LAND TRANSPORTATION AND SUSTAINABILITY

- Traffic deaths 1.35 M per year globally, 10 M injured or disabled
- 93 % of accidents caused by or contributed to by driver error
- 1st leading cause of death for 5-29 year olds
- More than half of global traffic deaths are among pedestrians, cyclists and motorcyclists
- Land transportation is one of the most significant sources of greenhouse gas emissions

WHO Global Status Report on Road Safety, report 2018

Box 3: Sustainable Development Goals for Road Safety (September 2015)

3 GOOD HEALTH AND WELL-BEING

By 2020, to halve the number of global deaths and injuries from road traffic crashes.

11 SUSTAINABLE CITIES AND COMMUNITIES

By 2030, to provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities, and older persons.

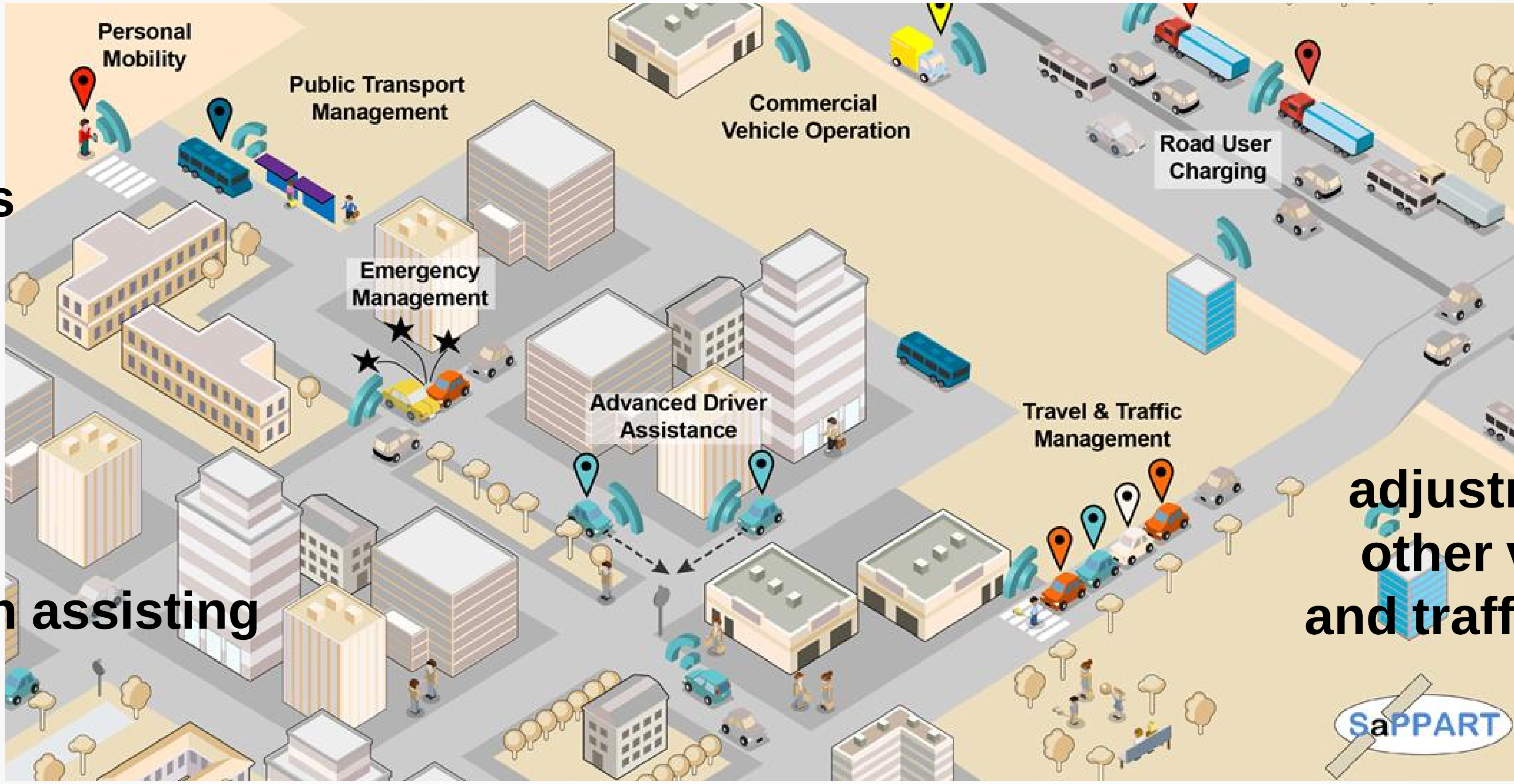
CAUSES OF CAR CRASHES

- 41% recognition errors: inattention, distraction
- 33% decision errors: speeding, illegal maneuvers
- 11% performance errors: overcompensation,...
- 7% driver falling asleep
- 8% other types of driver errors
- 2% vehicle problem: tire/wheel/brake related
- 2% driving environment
- 2% unknown

Source: NHTSA Crash Stats (Feb. 2015)

SMART CITY 2035

AUTOMATED AND AUTONOMOUS TRAFFIC

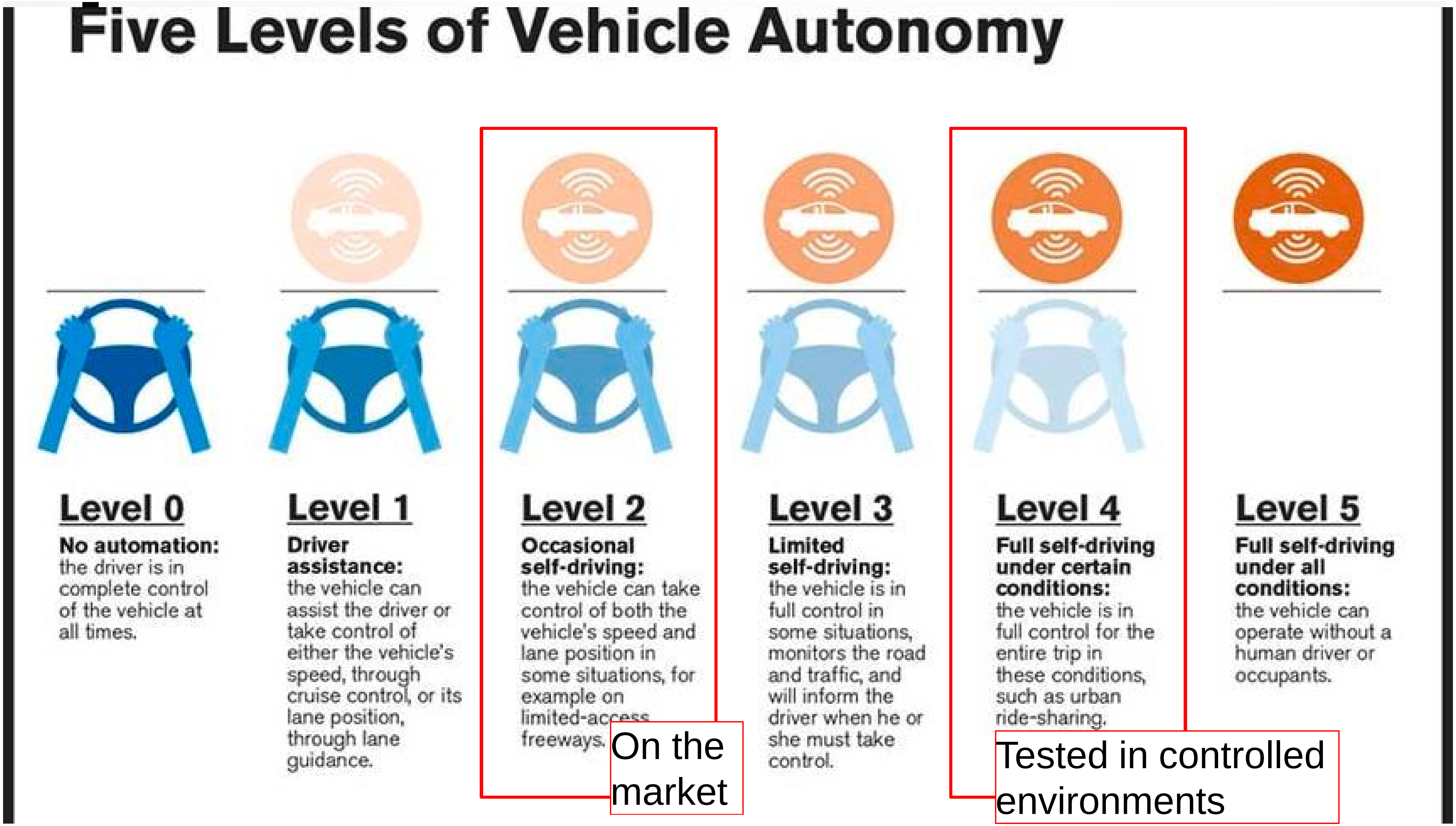


Monitoring pedestrians and bicycles

Intersection assisting

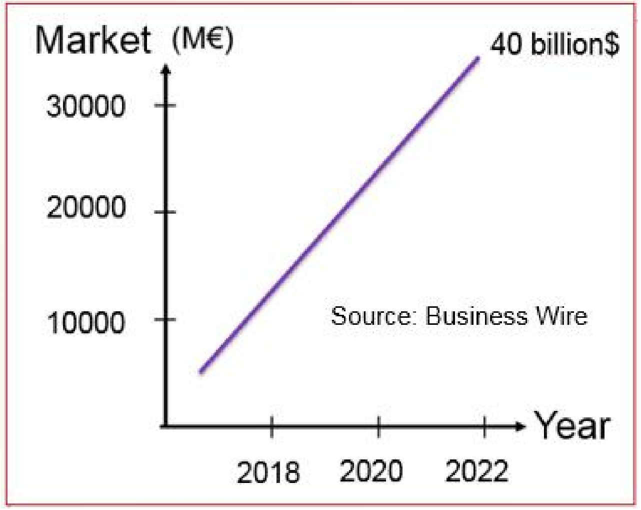
Speed adjustment for other vehicles and traffic lights

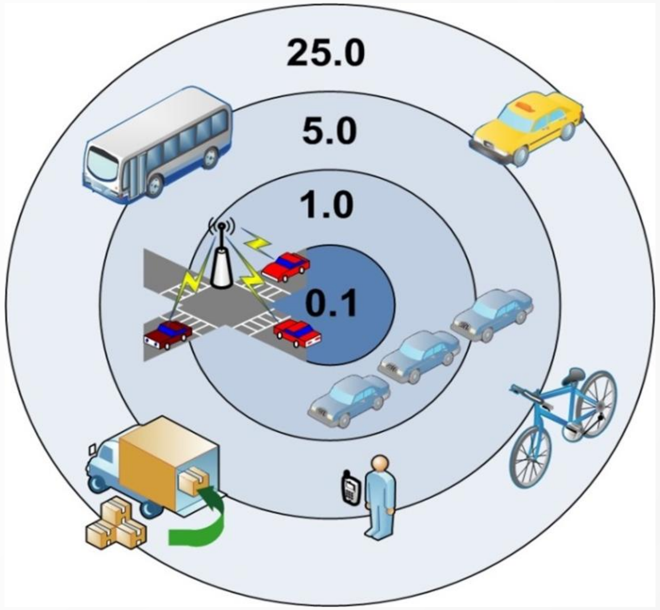
Comprehensive situational awareness


Five Levels of Vehicle Autonomy
Level 0
No automation: the driver is in complete control of the vehicle at all times.
Level 1
Driver assistance: the vehicle can assist the driver or take control of either the vehicle's speed, through cruise control, or its lane position, through lane guidance.
Level 2
Occasional self-driving: the vehicle can take control of both the vehicle's speed and lane position in some situations, for example on limited-access freeways.
Level 3
Limited self-driving: the vehicle is in full control in some situations, monitors the road and traffic, and will inform the driver when he or she must take control.
Level 4
Full self-driving under certain conditions: the vehicle is in full control for the entire trip in these conditions, such as urban ride-sharing.
Level 5
Full self-driving under all conditions: the vehicle can operate without a human driver or occupants.
On the market
Tested in controlled environments

NAVIGATION DATA - KEY ENABLER FOR AUTONOMOUS TRAFFIC

- From tracking individual actors into traffic ecosystem
- Can't afford any gaps in location computation
- Information has to be obtained everywhere
- Accuracy and reliability of data at new level



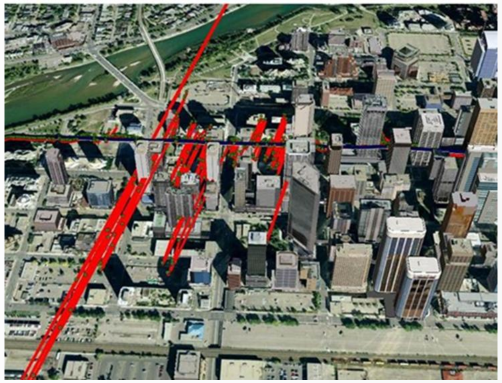


Indoor Navigation Market

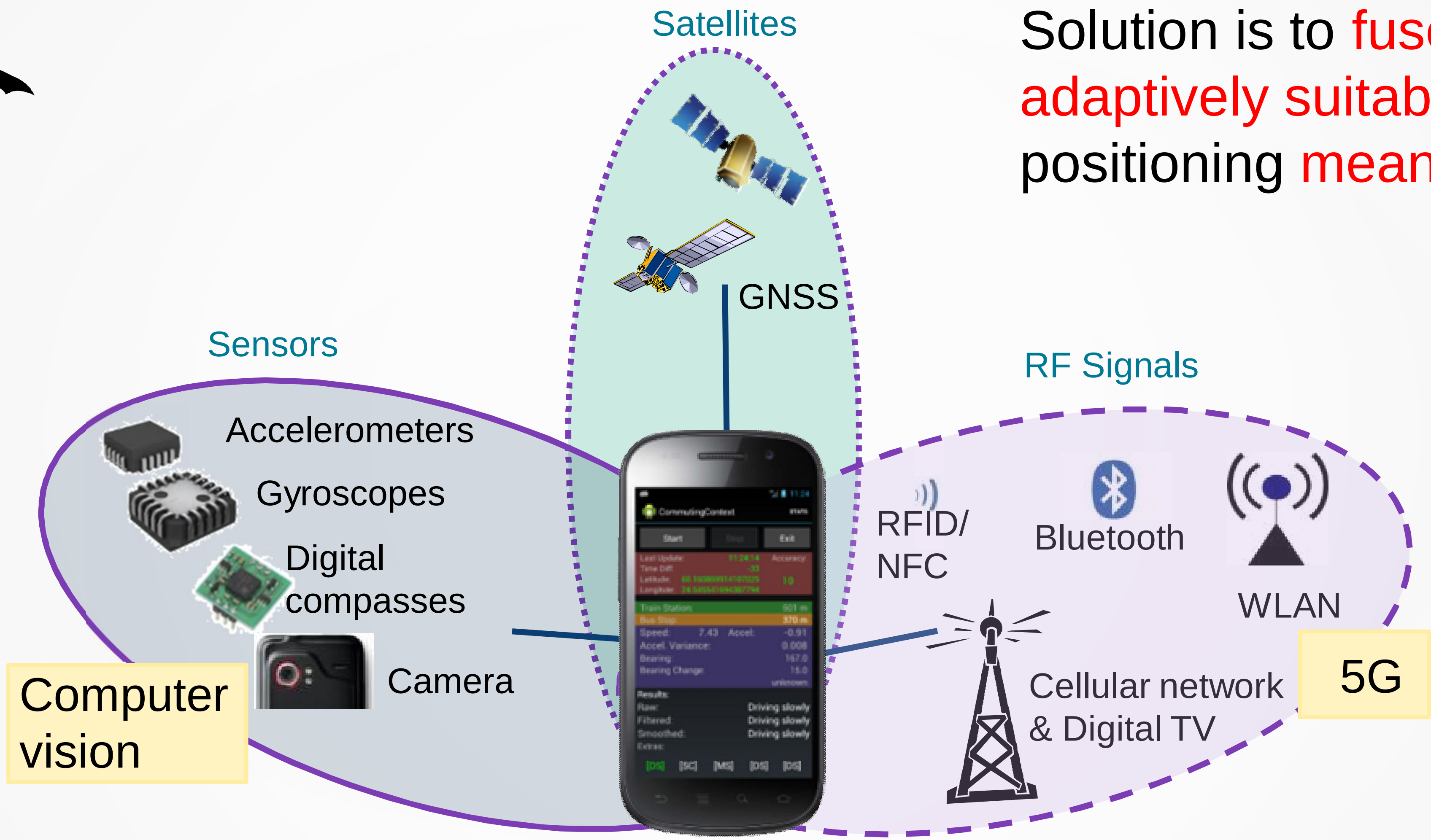
NAVIGATION CHALLENGES

- Satellite signals degraded in urban areas
- Satellite signals not usable indoors
- Autonomous vehicles in Arctic environment
- Intentional interference of satellite positioning

- Everything must work in one small , low-cost device with limited user interaction
- Position data is very personal, user privacy addressed in all research



Solution is to fuse adaptively suitable positioning means



SOLUTIONS FROM DATA SCIENCE

Machine Learning

Recognizing environment
Recognizing motion

Route prediction

Improving measurements
- visual
- radio signal

Statistical error modelling

Recursive Bayesian Estimation

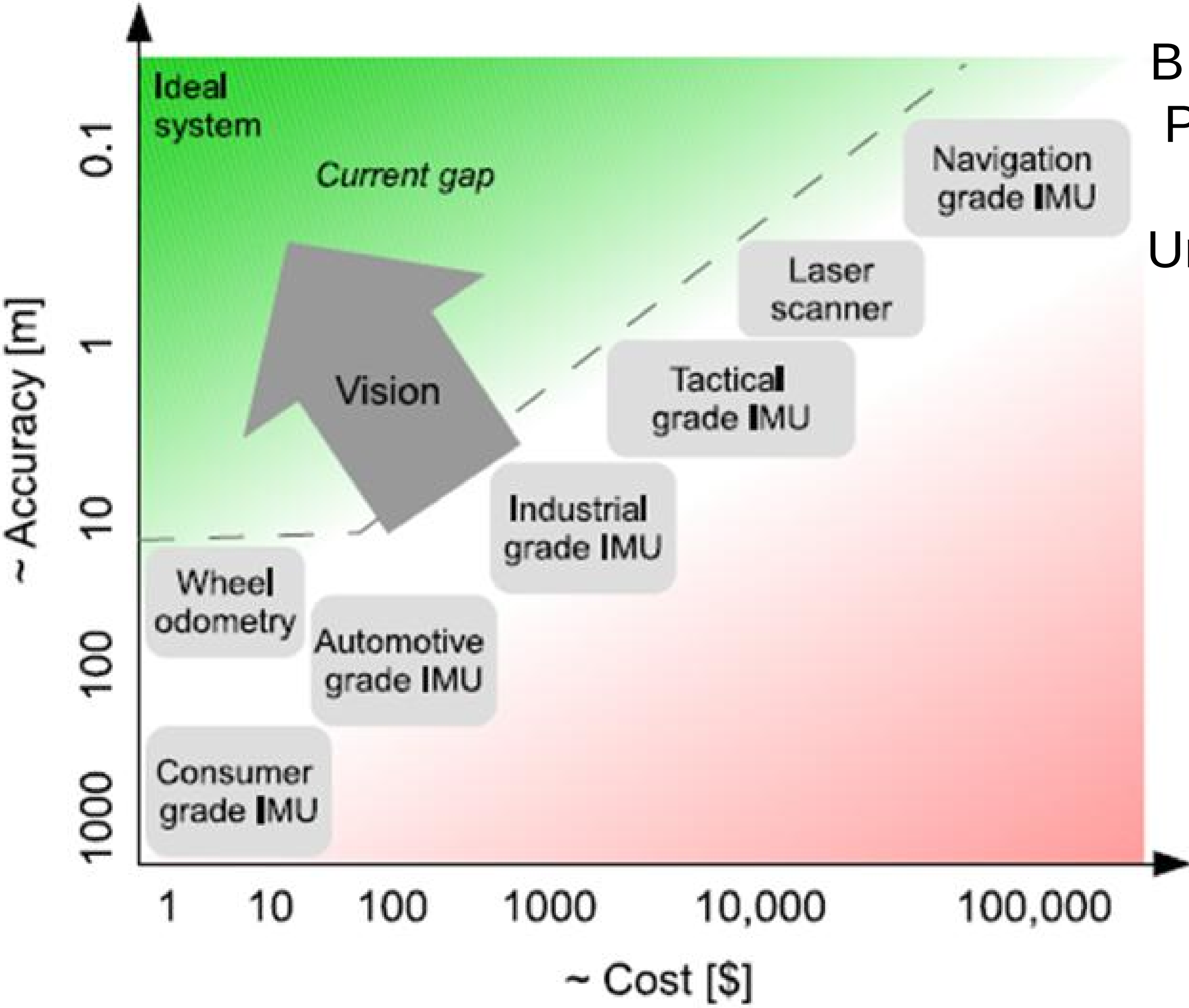
Kalman filtering
Particle filtering

Cooperative positioning

NAVIGATION TECHNOLOGIES IN AUTONOMOUS VEHICLES

- Precise satellite positioning
- Inertial sensors
- Mapping
- Lidars, Radars
- Vision systems
- Realtime networks

SENSORS IN AUTONOMOUS VEHICLES



B. Aumayer, PhD thesis 2016, University of Calgary

VISION IN AUTONOMOUS VEHICLES

Camera x 4 | Tri objective camera = stereo + monocular | camera

Navigation information

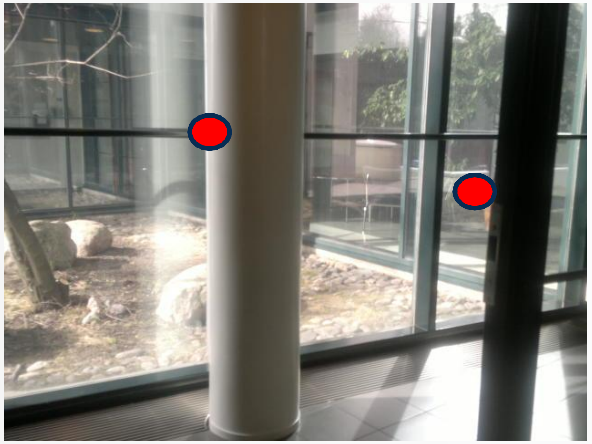
Detecting objects (obstacles, human)

Lane marks, traffic signs

https://www.volvocars.com/intl/buy/explore/intellisafe/autonomous-driving

MOTION INFORMATION FROM IMAGES

- Motion of the features representing the same real world object in consecutive images implies the motion of the camera, and thus the user when correctly mechanized



x

x'

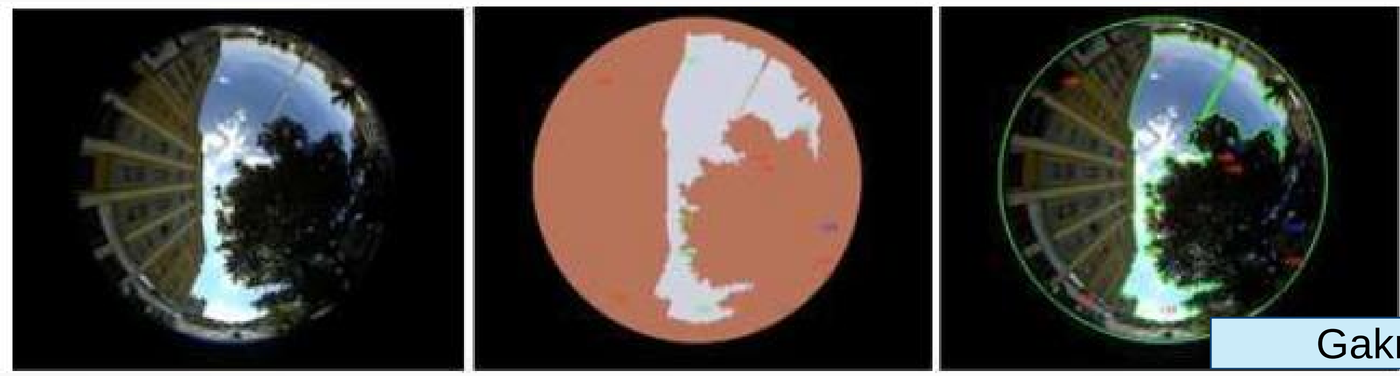
$$\mathbf{x}' = \mathbf{K}'\mathbf{R}\mathbf{K}^{-1}\mathbf{x} + \mathbf{K}'\mathbf{t}/Z$$

Calibration matrix | Rotation | Translation | Depth

Hartley, Zisserman, 2003

SATELLITE AND VISUAL NAVIGATION IN URBAN AREAS

- Position solution is very errorneous when computed using Non-Line-Of-Sight signals
- Estimating satellite visibility by classifying an image into sky and non-sky areas
- Camera on the roof of a vehicle



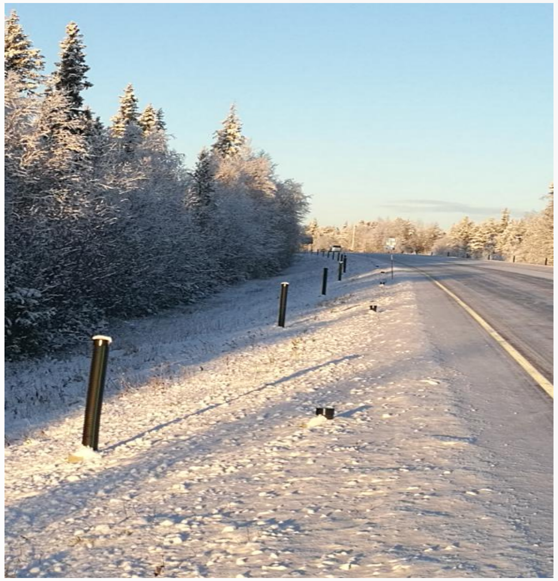
Gakne, 2018

Marais and Meurie, 2013

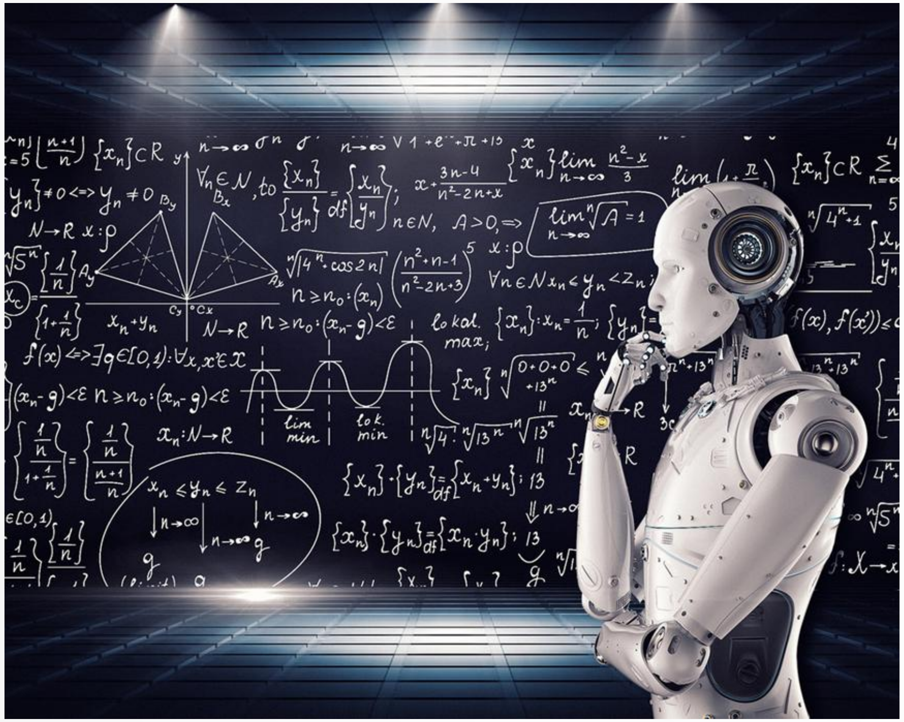
ARCTIC NAVIGATION

- Arctic areas are challenging for vision
  - Snow, ice
  - Darkness
- Also LiDAR suffers from reflections from snow

Ruotsalainen et al. 2018, submitted to IEEE ITS Magazine



MACHINE LEARNING IS ESSENTIAL IN SAFETY CRITICAL COMPUTER VISION



- Feature detection
- Image segmentation
- Object / obstacle recognition
- Tracking

Ø Deep learning: Convolutional Neural Networks

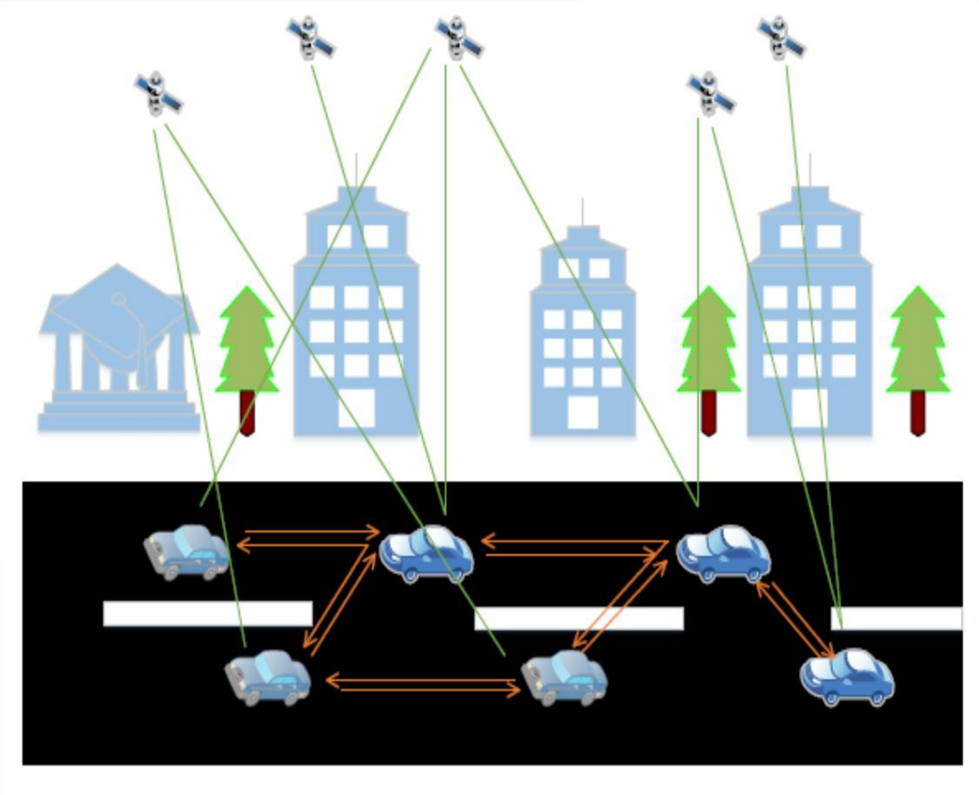
PEDESTRIAN NAVIGATION IN TRAFFIC IS EVEN MORE CHALLENGING

- Free motion
- Camera not fixed
- Small and very cheap equipment (smartphones in practice)

Ruotsalainen et al. 2018, Sensors

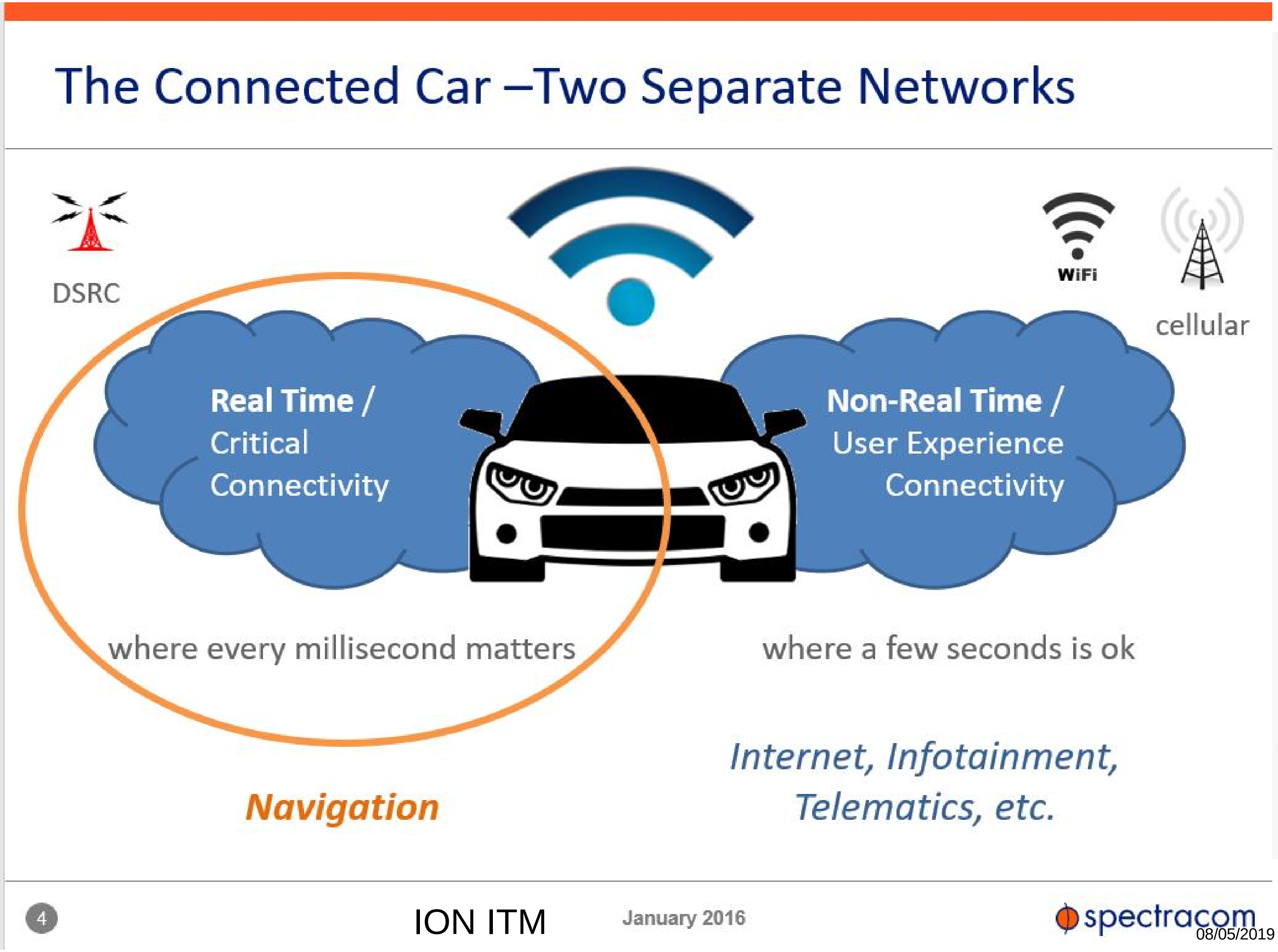
Rantanen, Ruotsalainen, Mäkelä, Kirkko-Jaakkola 2018, IEEE TIM

COOPERATIVE NAVIGATION



- Resolving range and direction to other users (UWB, 5G)
- Sharing position or position related information between users
- Provides position to areas where it can’t be computed
- Improves position solution

Mäkelä, Rantanen, Kirkko-Jaakkola, Ruotsalainen 2018, Fusion

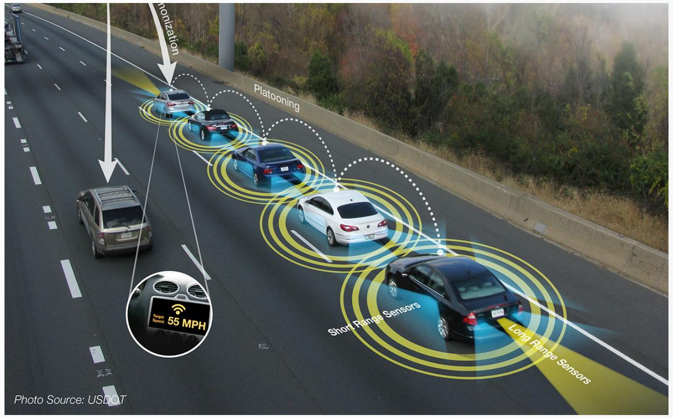

The Connected Car –Two Separate Networks
DSRC
WiFi
cellular
Real Time /
Critical
Connectivity
Non-Real Time /
User Experience
Connectivity
where every millisecond matters
where a few seconds is ok
Navigation
Internet, Infotainment,
Telematics, etc.
4
ION ITM
January 2016
spectracom

5G ENABLING AUTONOMOUS NAVIGATION

- 10 ms latency
- 10 cm ranging accuracy
- Satellite position solution few centimeters, requires real-time information
  - Precise Point Positioning (PPP) => requires correction information
  - Real Time Kinematics (RTK) => requires continuous connection to a reference station nearby

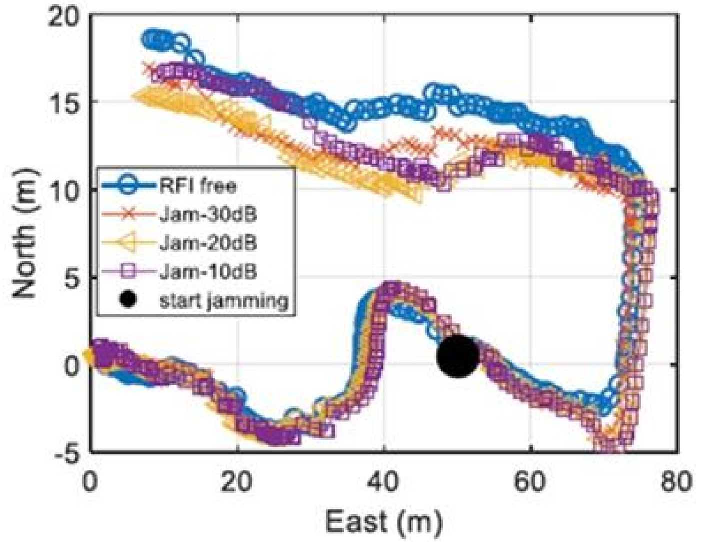
5GIVE PROJECT FOR AUTONOMOUS DRIVING

- 5G-assisted Ground-based Galileo-GPS receiver Group with Inertial and Visual Enhancement
  - Project funded by European Space Agency (ESA) 1.4.2019 – 31.3.2020
- Using 5G signals for
  - transmitting data for PPP, RTK with low latency
  - computing ranges between users for cooperative positioning



INTENTIONAL INTERFERENCE OF SATELLITE POSITIONING

- Society dependent on satellite positioning, but also timing
    - Intentional interference an increasing threat
- **Jamming**: signals at GNSS frequencies
    - Deteriorates or denies GNSS position
- **Spoofing**: fake GNSS signals
    - Deludes the receiver to be in wrong position



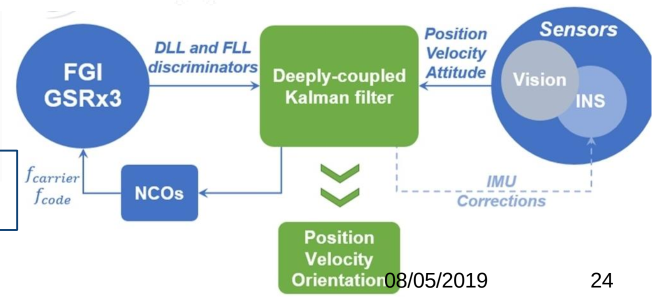

Asiantuntija: GPS-häirintä on harmittavan helppoa, signaalin voi peittää roskalla – "Netistä voi tilata laitteen muutamalla kympillä"

MTV.fi
22.11.2018

Yle aamu-TV 13.11.2018

Ruotsalainen et al, 2014, ION GNSS

Cristodaro, Ruotsalainen, Dovis 2018, Sensors



MAJOR CHALLENGES IN AUTONOMOUS TRAFFIC

- Who is responsible for the whole system working?
  - Sensors
  - Ownership of vehicles
  - Hacking of the networks
- Ethical questions in decision making

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- A national and international network of top experts
- Inclusive support for autonomous systems testbed development

TIMELINE AND RESEARCH AREAS

2019–2021

- Navigation reliability in difficult cases
- New open source initiatives, as SW requires huge investments

Motto: Reliable navigation capabilities for selected operational design domains (ODD)

2022–2025

First L4 field tests on public roads and new legal drafts

- Good performance with low-cost sensors
- AI methods for predicting road user behaviour

Motto: Mature SA including all users

2026–2030

Legal & ethical aspects, first L4 products

- New sensor tech, e.g. atom interferometry
- 5G communication

Motto: Safe and connected transport


60˚ 10 1.2 N, 24˚ 57 18 E