Automated Driving Applications and Technologies for Intelligent Vehicles

Automation technologies

Where we are and where we are going

Dr. Angelos Amditis

Technical Workshop

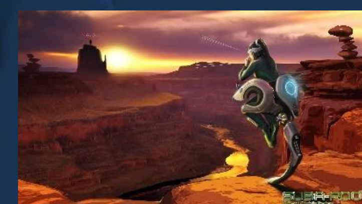
Athens, Greece
21-22 APRIL 2016

//Content

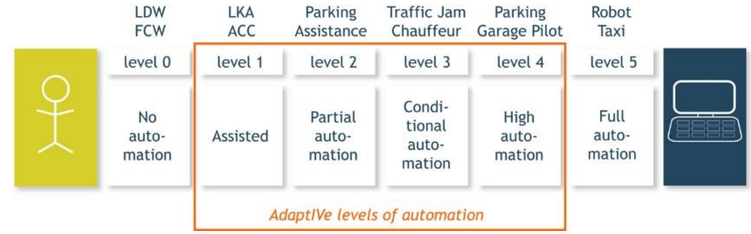
- Introduction (the slow vehicle transformation)
  - Key motivators
  - Response of the research community
- Advances in
  - Sensing and computation
  - Algorithms for perception
  - Algorithms for control
  - HMI design
  - Infrastructure
- Technological challenges
- Paradoxs: does one (fully)automated swallow makes a spring?
- Outlook
  - New directions: beyond vehicle automation (building the automated transport holistic paradigm)
  - Conclusions

Introduction – the slow vehicle's transformation

[...]



//Introduction
Key motivators



Road safety
- Colision avoidance
- Colision mitigation
- Assist driver in blind spots (lane change)/intersections
- Truck run-off road prevention

Social | Economic
- Driver's comfort/assisitance
  - Aging population, disabled
- Increased road network efficiency
- Reduced CO2 consumption

Ground exploration
- Planet area
- Underground
- Building
- Dessert

//Introduction

Response of the research community – **autonomous long distance drives**

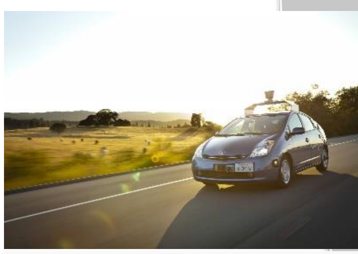
(x 2) DARPA GRAND CHALLENGE

212 km

Stanford University

- 2004,2005

Supervised/unsupervised



Google

.more than 1.5 million miles driving
.more than 30k miles in simulation

- 2008 …

13,000km test from *Parma*, Italy, to *Shanghai*

- 2010

- 2013

100km Mercedes B.Benz drive

“No lidar onboard”

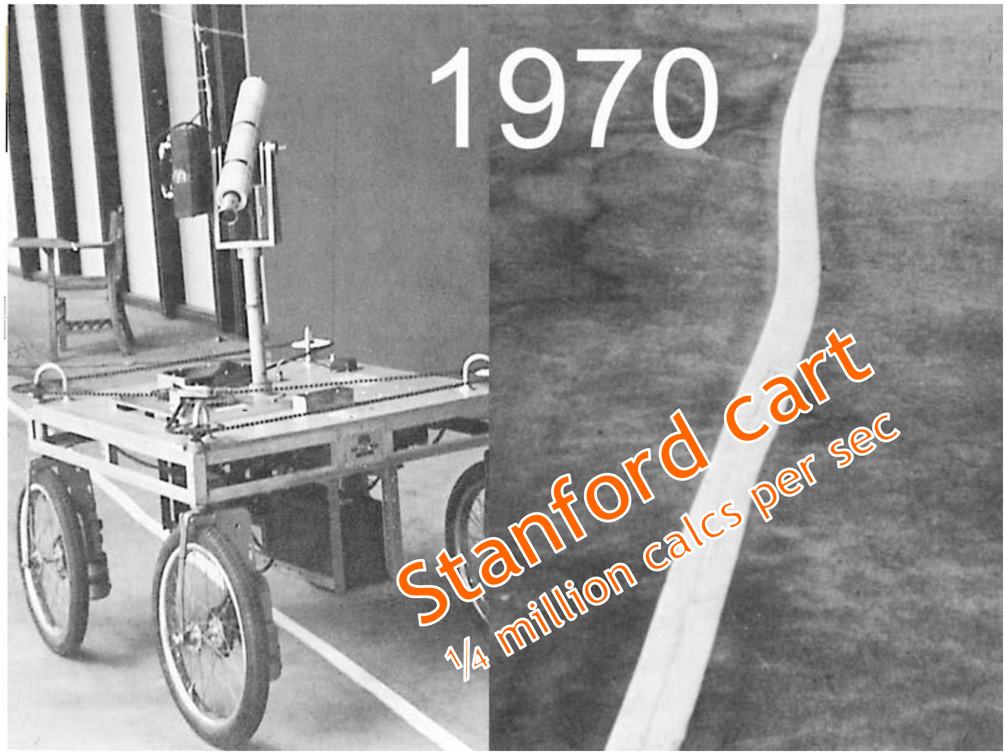
- 2015

3400 miles California Delphi drive

1500 miles Mexico road trip

//Introduction

Response of the research community(academic labs)



MIT School of Engineering

Carnegie Mellon THE ROBOTICS INSTITUTE

UNIVERSITY OF MICHIGAN

Imperial College London

Stanford University

CIS The Center for Internet and Society

TECHNISCHE UNIVERSITÄT MÜNCHEN

CVL Computer Vision Lab ETH zürich

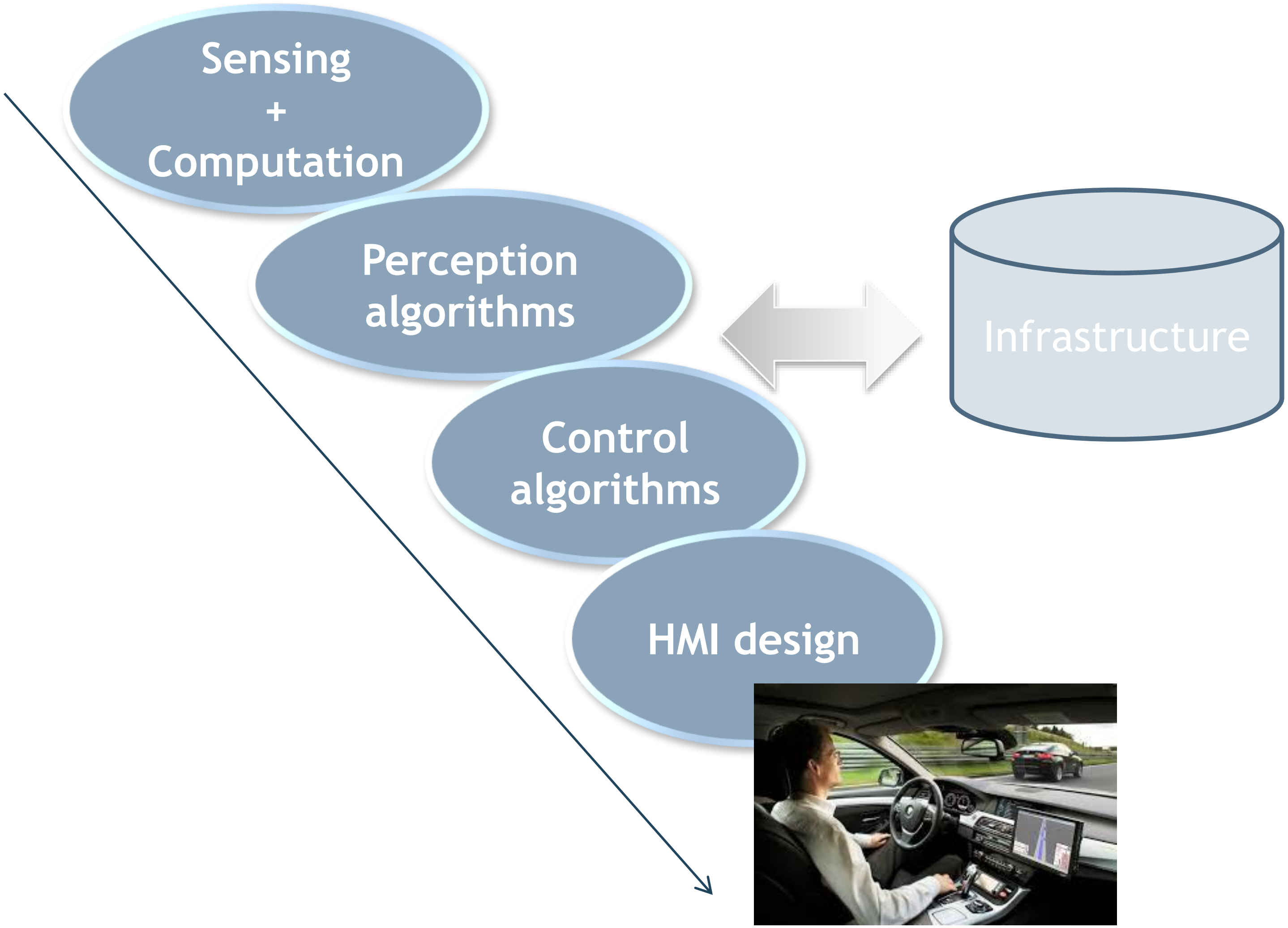
ICCS

Robotics Lab

//Introduction

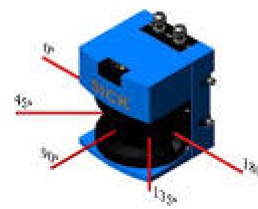
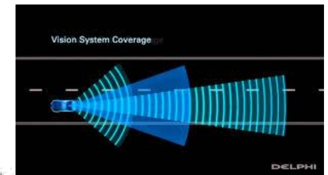
Response of the research community (EU fund + others)

// Advances in


Sensing
+
Computation
Perception algorithms
Control algorithms
HMI design
Infrastructure

//Advances in sensing and computation

- 2D 3D scanning Lidars (good with both objects & surfaces /problems if road potholes)
- Mid-short-long range Radars
- Ultrasonics (firsts to be used –low data volume- now auxiliary)

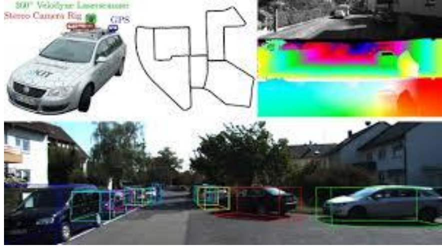



- Stereo vision (2 cameras
  HINT: 3D but computationally heavy)

- Single Camera (HINT: GPU processing enables dense representation >=2Gb GPU memory)
  - RGBD Camera (KinektFusion Api)

- GNSS antennas (RTK corrections, cm accuracy)
- IMU (gyro, accel)

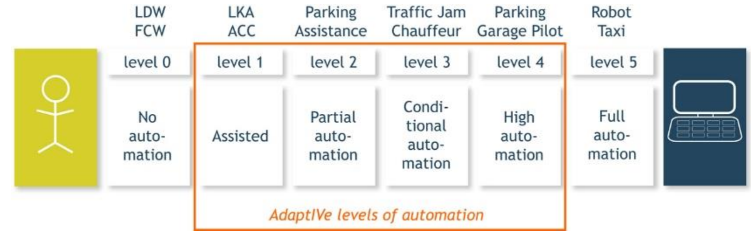
//Advances in perception



- Sensor Fusion and Object detection and tracking
  – Multiple heterogeneous sensors
  – Data clustering
  – Data association
- Machine learning:
  – From feature descriptors to (embedded) deep learning (20 years of computer vision research)
  – Probabilistic inference

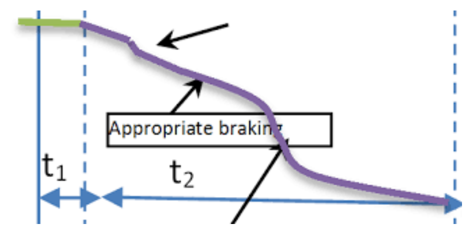
- SLAM : reaching accuracies of 5 cm! (lateral localization)
  - + IMU
  - Lidar-based odometry
  - Vision odometry

//Advances in control

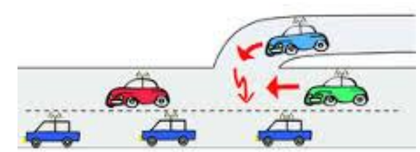


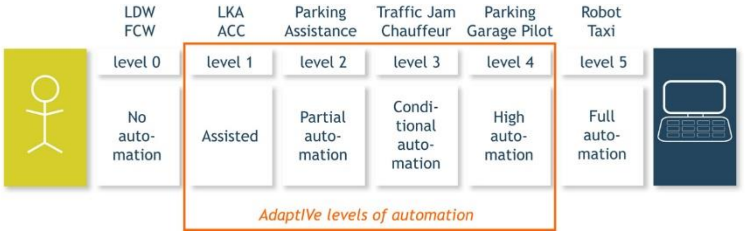
- 3D object kinematics (*6DOF* or 9DOF IMU sensors to compensate for vehicle pitch/tilt)

- Robust control: concepts of Redundancy + Minimum risk maneuver



- Formal logic to learn rules with hierarchical priorities to machine
  > it works for big but finite set of considerations but not programmed to make ethical decisions in case of two conflicting rules (run over a child or an elderly?)



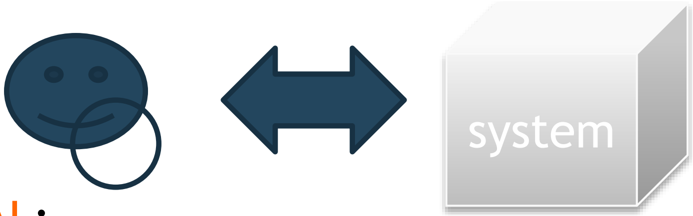


//Advances in HMI design

interactIVe
Accident avoidance by active intervention for Intelligent Vehicles

AdaptIVe Automated Driving

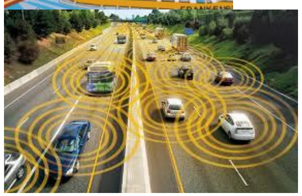
- Study of control transitions between driver and the system
- New devices (visual displays, haptic pedals, vibrating steering wheel)



- GOAL:
  - Smooth and easily perceived (intuitive) control transitions
  - adaptive support based on the driving task demand
  - “take over requests” based on system and driver state

AdaptIVe

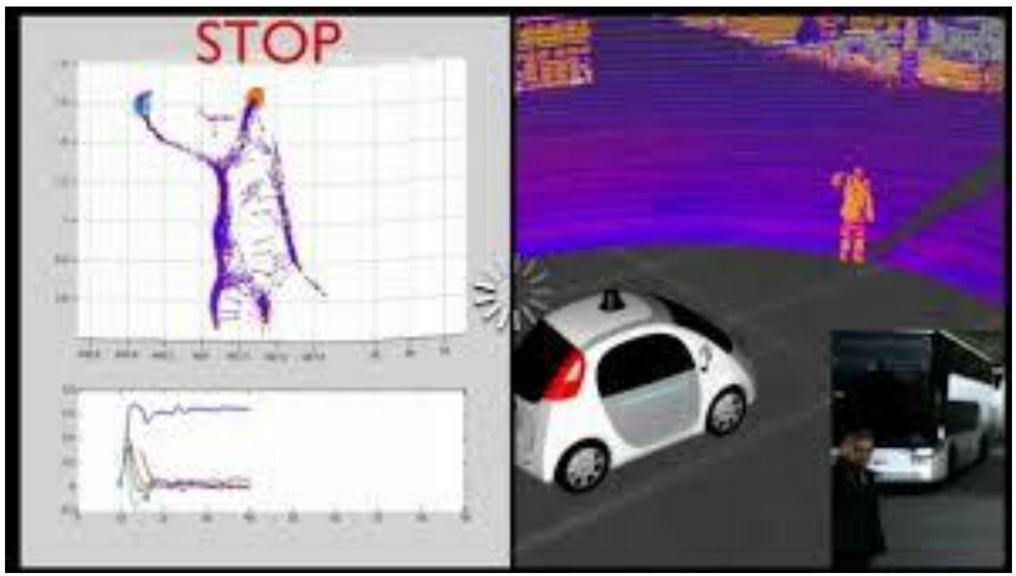
//Advances in infrastructure technologies



- Digital cartography (hint: covers mainly urban areas)
- V2V: extended CAM message transmitting information of tracked objects around (source: Autonet2030, AdaptIVe)
- V2X
  - closing the loop (where the sensors cannot see due to occlusions)
  - enables remote inteligence (e.g. Smart intersections controlled in the cloud)

- Embedded vs. Cloud-based (hint: cloud-based cannot be trusted for time- critical applications)

Are we there?



Google

AdaptIVe

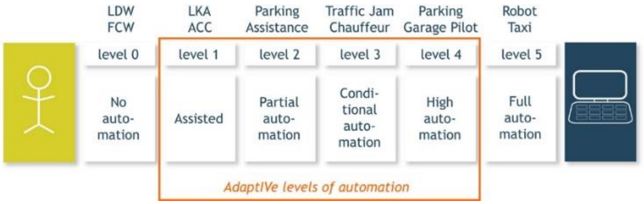
//Technological challenges
Function validation

- Tools (hint: simulation cannot represent allreal life conditions)
- Grountruth data (hint: data gathering and annotation is laborious)
- Standard methodology (hint: promotes comparability of results)
- Logic Model Checking for Formal Software Verification (hint: lines of sw code in boeing 787: 6.5 millions ; in average luxury auto: 100 millions!!!)

- The Mcity test facility

//Technological challenges

Understand and control the unpredictable



- Real world poses limitations to sensing

(Level 3 plus: Collision avoidance is mandatory: obstacles, pedestrians but depends on weather, traffic, road very challenging!!)

IEEE spectrum

Illustration: J.D. King

- Learning from training data cannot cover the novel situations (+environment is changing)

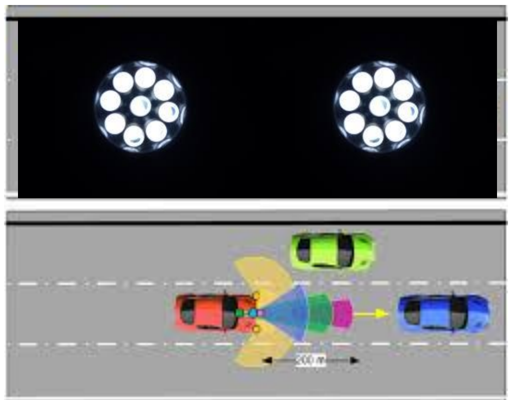
- Desision making by machines respecting ethics is yet a non existing field and it's needed

  [Stanford law researcher: would you buy a car that it is programmed to kill you?]

- Milion lines of code, difficult to be fail-proof

AdaptIVe

//Technological challenges
Prevent perception sensor spoofing



[source: 2016, UTWENTE paper, Lepetit]

- Lidar and camera can be spoofed (no license required)
  - Camera by led flash light (very cheap)
  - Lidars by second pulse generator that creates delays to the signal and this is interpreted as phantom objects

  (hint: solution undertaken by lidar manufacturer already: lidar with random pulse generator)

- **What would happen if you could attack flammable cargo?**

[Canadian Post] Driverless truck corridor from Mexico to Manitoba proposed. Corridor would follow Route 83 from Mexico through U.S., up to Manitoba

//Paradoxs

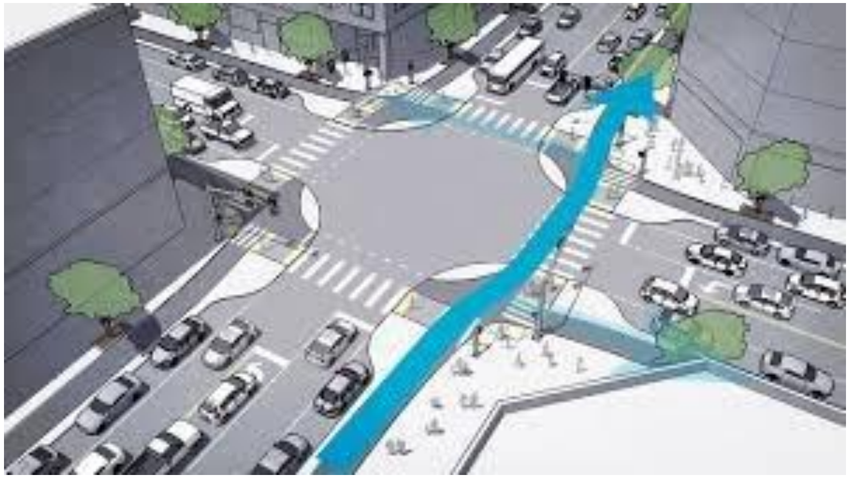
- Dont worry dad, this is a car for children too..!

(will we create competent machines that drive as human and in the same time prevent human from driving…? if the driver no longer drives, his experience behind the wheel deteriorates and he will be worse driver in the future; “Driver should be virtually engaged all the time” suggests prof J. Leonard (MIT) …

- AV: Where am I supposed to go?

Low penetration rate can create awkard situations (adverse affects in traffic/ puzzling the machine AI)

Outlook: vehicle automation and beyond

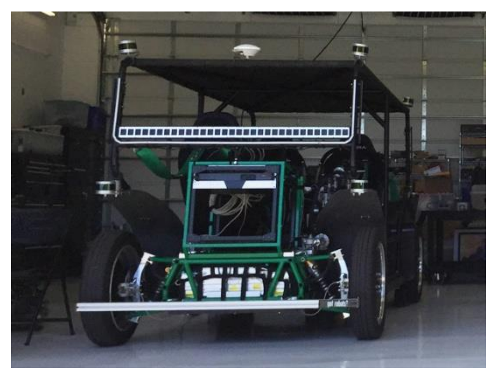


//New directions: full autonomy use cases to exist

- Taxi service pilot study singapore
  [Frazoli, MIT team, 2016]

- Roborace Formula E series
  [Nvidia, 2017]

- Zoox startup - robocab
  [2020]



IEEE spectrum

//New directions: multi-actor driving

- Combining action with perception
  - Idea: Make the vehicle turn a bit in order to be able to see occluded object (e.g. in a parking scenario)

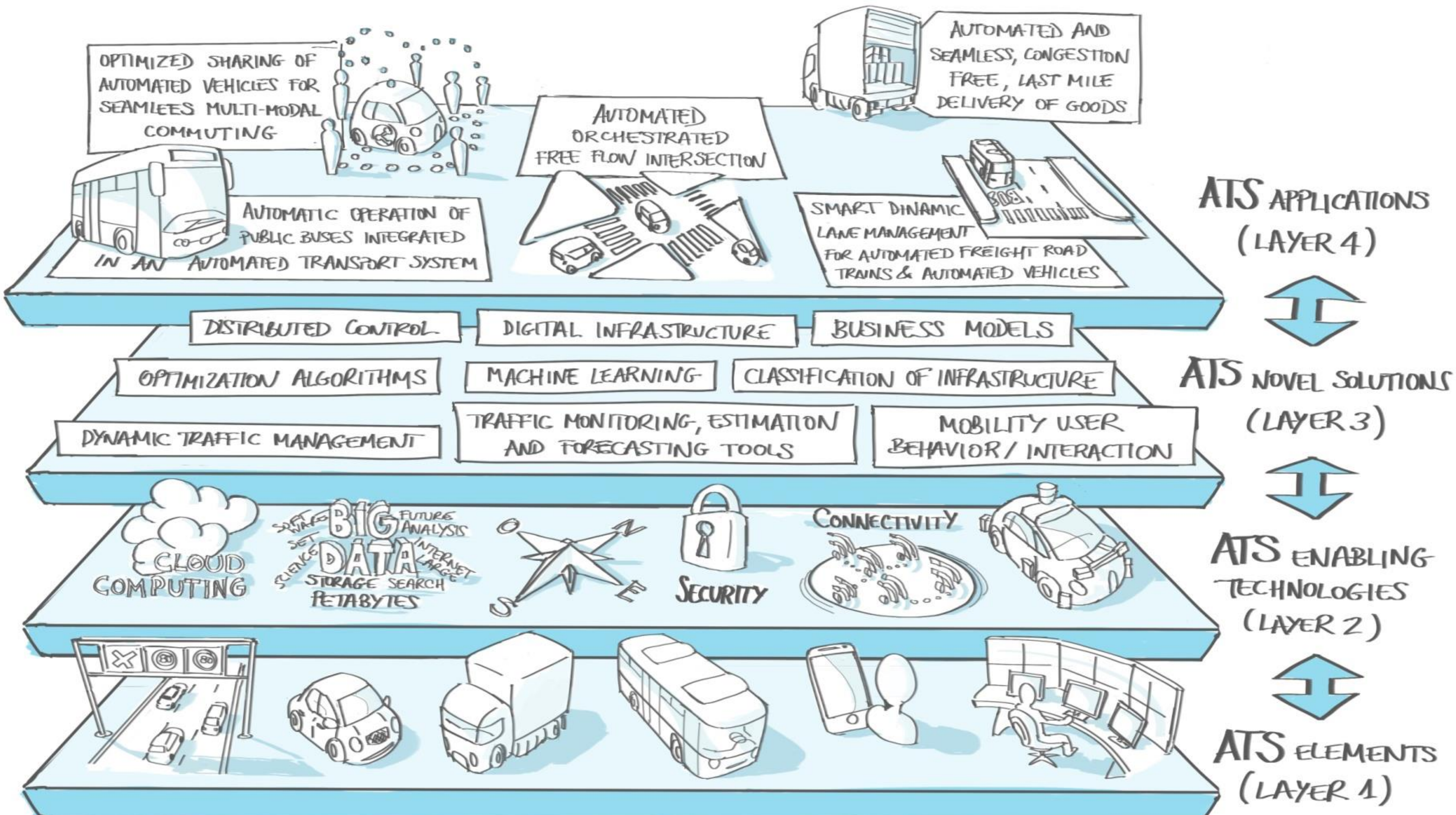
- Multi-actor sharing of information (V2V, V2X; e.g. share information on potholes' position so that vehicles behind are aware)

- Idea: take advantage of storing + processing in the cloud

- Combine actors of smart traffic:
  the Automated
  Transport
  System concept …

//New directions: multi-actor driving

ATS Layered architecture



AdaptIVe

//Automated Transport Systems

Definition

- From isolated automated elements

towards…

Automated Transport Systems

- An Automated Transport System (ATS) is an innovative holistic mobility concept, where all its different elements (i.e. vehicle, travellers, public transport, infrastructure, operations and control) are capable of self-organizing and operating at an “automated” manner, addressing in real time the needs of all and each participant of a specific traffic scenario, applying different levels of automation and supporting all transport modes for both passenger and freight

//Conclusions

- Don't overhype automated driving: “computers still have a perception issue” (prof. J.Leonard(MIT)) ☺
- Better sensors coupled with better learning and prediction are the future

- Human-like driving is not the objective (humans make mistakes)
  - Mixed traffic with automated/non automated vehicles will create unexpected situations
  - New driving/traffic rules may be needed to integrate autonomous vehicles (dedicated zones)
  - human and machine training to know what to expect

- Ethical decision engineering for machines is missing
- Holistic traffic/transport consideration: a multi actor cooperative game

Co-funded by
the European Union

AdaptIVe

Automated Driving Applications and Technologies for Intelligent Vehicles

Thank you.

Dr. Angelos Amditis

Research Director, ICCS
a.amditis@iccs.gr
+30 210 772 2398

I-SENSE GROUP

Technical Workshop

Athens, Greece
21-22 APRIL 2016