Towards Realizing Autonomous Driving Based on Distributed Decision Making for Complex Urban Environments

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Intelligent vehicle is good ...

But

Intelligent environment is better ...
Digital Mobility – Our vision

Make the road talk to vehicles

- Equip the roads with different sensors
- Enable the vehicles to communicate with each other
- Computation resources for decision making

- Vehicles equipped with different sensors
- Decision logics for assistance system
- Communication mechanisms

DIGINET PS is Open & Urban
DigiNet-PS Aims at Achieving ...

- Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment
Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment
Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment

- Digitized Environment
- Intelligent Vehicle
  - Stereo Kamera
  - Kamer für 360° Vision
  - LIDAR
  - RADAR
  - Application Unit
  - Communication Unit
  - Vehicle Device Provider

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Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment
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Open & Distributed Intelligent Solutions for Autonomous Driving in Urban Environment

- Digitized Environment
- Intelligent Vehicle
- Intelligent Infrastructure
- Intelligent Cloud & Datacenter
- Intelligent Communication

sensors

- P
- Parking
- Speed
- 5G

Map showing urban infrastructure and vehicle sensors.
DigiNet-PS Impacts on Vehicle Manufacturers

Can we test the impacts of our envisioned evolution path?

Create use cases for the testing?

Many others ...

Driving in a Digitized City

**DigiNet-PS Impacts on Vehicle Manufacturers**

**Can we test the impacts of our envisioned evolution path?**

**Create use cases for the testing?**

**Many others ...**

**Driver Assistance**
Vehicle can assist the driver or take control of either vehicle’s speed, its lane position.

**Limited self-driving**
Automation that takes over all safety-critical functions under certain traffic conditions. Driver is available for occasional control.

**Full self-driving under all conditions**
Vehicle can operate without human driver.

**No Automation**
Driver is in complete and sole control of brakes, steering, throttle, and motive power at all times.

**Occasional self-driving**
Vehicle can take control of both vehicle’s speed and lane position in some situation.

**Full self-driving in some conditions**
Vehicle is in full control for the entire trip in these conditions such as urban ride sharing.

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Driving in a Digitized City

DigiNet-PS Impacts on Government and Citizens

- Study the impact of autonomous driving on citizens
- Predict major changes to urban landscape
- Study citizens’ perception by realizing various use case scenarios

Government

Citizens

Faced with

Analog cities / Traditional cities

Digital cities / Smart cities

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DigiNet-PS Impacts on entrepreneurs and startups

- Ecosystem
- Business models for future transportation

- Study and inputs for the business model shifts
- Enable the entrance of new entrants in the market

Many others ...
DigiNet-PS Impacts on existing markets

- Study the co-existence models
- Study the new business models

License holder intelligent car

New Markets

Car Sharing

Taxi services
Driving in a Digitized City

DigiNet-PS Route Overview

Complex Roundabouts

3.65 km, three-lane each direction, with road markings
Driving in a Digitized City

DigiNet-PS Route Overview

- Complex parking situations,
- marked and non-marked,
- parallel and slanted parking (about 1000 parking spaces),
- center island parking (about 600 parking spaces),
- separate parking areas

3.65 km, three-lane each direction, with road markings
• 15 traffic control systems with group control for vehicles, bicycles, pedestrians and handicapped, each having a different topology
• Complex traffic situations, rush hour traffic, governmental convoys

3.65 km, three-lane each direction, with road markings

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Driving in a Digitized City

DigiNet-PS Vehicle Solution Suite

Intelligent Decision Making Platform
- Machine learning
- Proactive / Reactive
- Local decisions

Additional functions & sensors
- New sensors
- New functions

Test Vehicles
- Q5
- ...

Digital Mobility – Our vision

DigiNet
Roadside Unit Solution Suite

Sensors
- Parking
- Road condition
- Traffic Analysis
- Weather
- Environmental
- Traffic
- Light

Roadside Units
- Router
- DSCRC
- WiFi/5G
- Microwave

Intelligent Decision Making Platform
- Machine learning
- Proactive / Reactive
- Edge Computing

National Schaufenster for Autonomous Driving
DigiNet-PS Cloud Solution Suite

National Schaufenster for Autonomous Driving

Digital Mobility – Our vision

DigiNet - PS Cloud Solution Suite

Intelligent Decision Making Platform
- Machine learning
- Reactive
- Prediction Engine

Control & Visualization Center
- Facilitates in implementation of use cases
- Visualization of KPIs

Cloud infrastructure
- Hyperflex
- GPUs
- Transport Network
- Aggregation Network

Intelligent Core Network
- SDN, NFV, SON, etc.

Transport Network

Aggregation Network

Intelligent Decision Making Platform

Control & Visualization Center

Cloud infrastructure

Intelligent Core Network

Transport Network

Aggregation Network
- Machine learning
- Proactive decisions
- Integrating stakeholders & huge heterogeneous sensory data

- Edge computing
- Time critical decisions

Digital Mobility

- Plan
- Execute
- Sense

Global View & Control

Local Decision Making

Vehicle DM

Cloud Solution

Wide-range Backhaul

Cellular Communication (LTE)

Short Range Communication

DigiNet-PS Decisions Hierarchy

- Stereo Kamera
- Kameras für 360° Vision
- LIDAR
- RADAR
- Application Unit
- Communication Unit
- Vehicle Device Provider

National Schaufenster for Autonomous Driving

National Schaufenster for Autonomous Driving

DigiNet-PS Decisions Hierarchy
**DigiNet-PS Key Outcomes**

**Sustainability**
- Reduce fuel consumption and pollution
  - Avoiding search for parking spaces
  - Avoiding congested routes
  - Avoiding stop & go by choosing suitable speed and lane (green wave)

**Safety**
- Reduce accidents

**Efficiency**
- Reduced travel time
Driving in a Digitized City

Infrastructure for Street Digitization
## Infrastructure for Street Digitization

### Parking Sensors
- Visualizes motion and dwelling time
- Objective measurement of hot spots
- Compiles statistical evaluations
- Adjustable duration and intervals of evaluation

### Activity Analyzer

### Traffic Analyzer
- Automatic counting of vehicles (passenger cars, trucks, motorbikes)
- Classification into two-wheel, passenger car and bus/truck
- Up to four lanes
- Output in minutes, hours, days, weeks and months

### Queue Detection
- Alarm if a defined queue length is reached
- Crowd analysis & crowd density estimation
- Analyzing the speed of the flow
- Estimation of the average waiting time
Driving in a Digitized City

Infrastructure for Street Digitization

Parking Sensors

Traffic Analysis Sensors
Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors

- Temperature,
- Relative humidity,
- Precipitation intensity,
- Precipitation type,
- Precipitation quantity,
- Air pressure,
- Wind direction,
- Wind speed
Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors

Road Condition Sensors

- Layer thickness of water, snow and ice,
- Surface conditions (dry, damp, wet, snow, ice),
- Friction,
- Road surface temperature
Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
- Road condition Sensors
Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
- Road condition Sensors
- Environmental Sensors

- NO,
- No2
- O3,
- PM1,
- PM2.5,
- PM10
Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
- Road condition Sensors
- Environmental Sensors
Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
- Road condition Sensors
- Environmental Sensors
- Intelligent light sensors

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Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
- Traffic Analysis Sensors
- Weather Sensors
- Road condition Sensors
- Environmental Sensors
- Intelligent Light Sensors
Driving in a Digitized City

Infrastructure for Street Digitization

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Driving in a Digitized City

Infrastructure for Street Digitization

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- Traffic Light Sensors
Driving in a Digitized City

Infrastructure for Street Digitization

- Parking Sensors
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- Road condition Sensors
- Environmental Sensors
- Intelligent Light Sensors
- Traffic Light Sensors

Intelligent Communication Infrastructure

1. Access Network Node
2. Backhaul Network Node
3. Transport Network Node

- Connectivity of RSUs
- Backbone design
Driving in a Digitized City

Unique Standpoint of DigiNet-PS

DigiNet-PS will help achieve

- Intelligent Vehicle with human driver like perception
- New Eco-systems & Business Opportunities
- Digital Urban Environment
- Improved Quality of Life

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