Smart Vehicles for a Smart City

Reinhard Klette
Auckland University of Technology, New Zealand

Thomas Braeunl
The University of Western Australia, Australia

A Keynote at IEEE Smart City 2015, Chengdu, China

Thanks for comments go to Garry Tee and Radu Nicolescu, Auckland

Beauty and Practicality of Safe and Pollution-Free Traffic

Source: `parisetech.com/wirelessbus.html`

1.24 Million People Killed in Traffic Accidents in 2013

On average, **2.4 people every minute**, thus more fatalities than all the wars or terroristic attacks together.

Even More Fatalities due to Combustion Emissions

Source: online reports about Beijing, 2015

The impact of combustion emissions on fatality rates is actually estimated to be even **more critical** than the number of peoples killed in road accidents.

Source: `pubs.acs.org/doi/abs/10.1021/es2040416`, a study on UK

Outline

“Smart City” Definition on Wikipedia

A **smart city** uses information and communication technologies

- to enhance quality, performance and interactivity of urban services,
- to reduce costs and resource consumption and
- to improve contact between citizens and government.

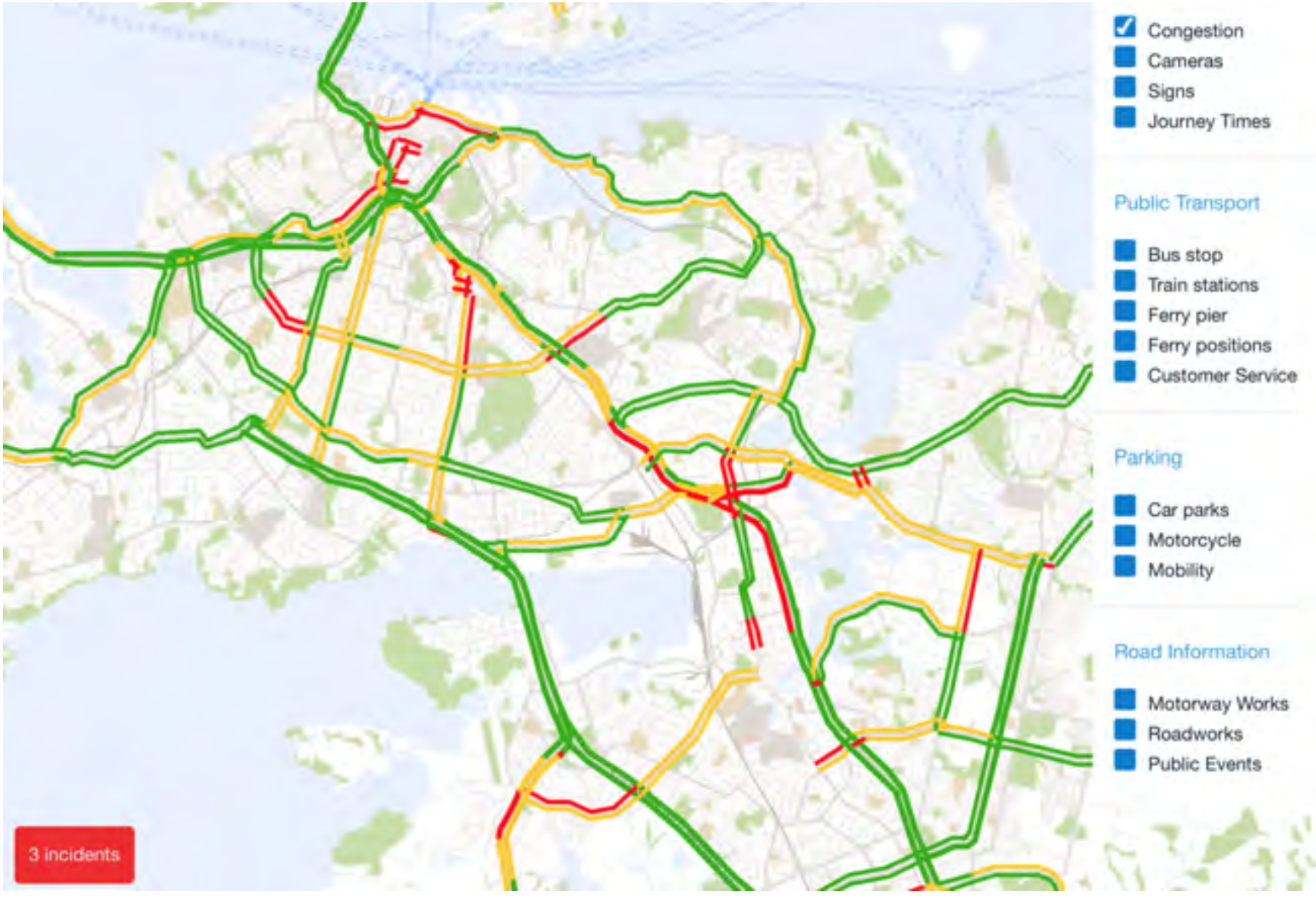
...

Other terms that have been used for similar concepts include ‘cyberville, ‘digital city’, ‘electronic communities’, ‘flexicity’, ‘information city’, ’intelligent city’, ‘knowledge-based city, ’MESH city’, ‘telecity, ‘teletopia’, ’Ubiquitous city’, ‘wired city’.

Source: Wikipedia, 10 December 2015

Live Traffic Congestion Map

an example for a smart city?



Smartness on Gartner (a leading IT Research and Advisory Company)

One of the predicted three main trends in 2016 on Gartner

"Smartness" is being applied across the entire fabric of the work environment.

"... When devices become smart enough to go beyond simple autonomous behavior, to behavior that is **less predictive**, we open the door to **unexpected** – and potentially unwanted – results..."

"... These are questions that, while not yet fully answered – and perhaps not fully answerable, are examined implicitly as part of our predictions on the future of smart machines."

Source: `www.gartner.com/doc/3142020?srcId=1-3132930041`

Founded in 1979, headquartered in Stamford, Connecticut, 7,600 associates including 1,600 research analysts, and clients in 90 countries

Our Expectation about a "Smart City"

A smart city is a place where people

- live in peace with sufficient space provided,
- in a healthy environment,
- able to do their duties and to follow their interests in their local communities,
- with minimized constraints defined by the community.

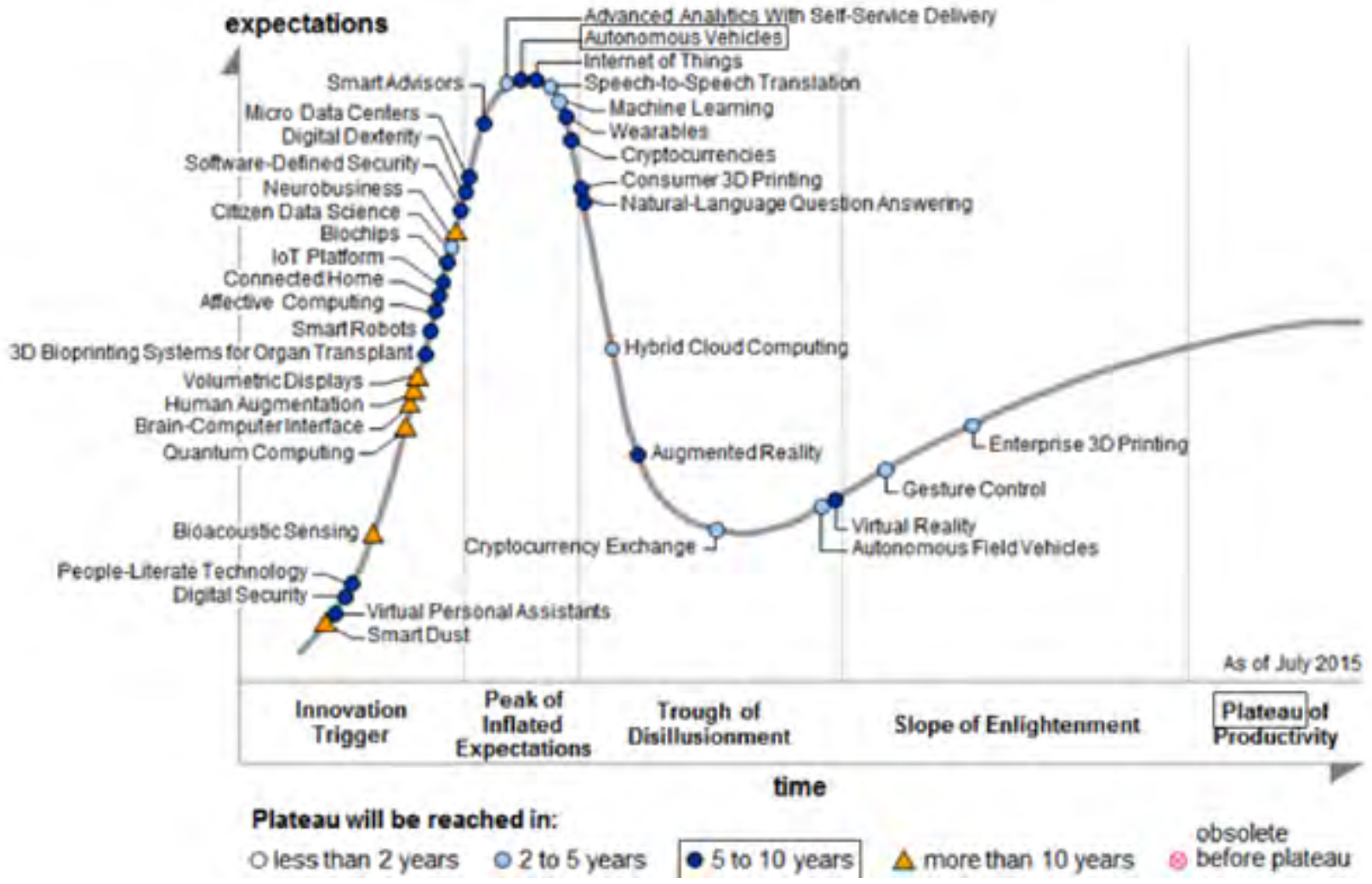
Road traffic is an essential part of this:

Commute safely and in reasonable time, with a good degree of personal freedom, minimized air and noise pollution, cost-efficient, and environmental friendly.

Outline

Peak of the Hype in July 2015 on Gartner

Current IT subjects on the (fixed) **curve of expectations**, which goes from innovation to hype and disillusionment, and then, possibly, to enlightenment and plateau of implementation



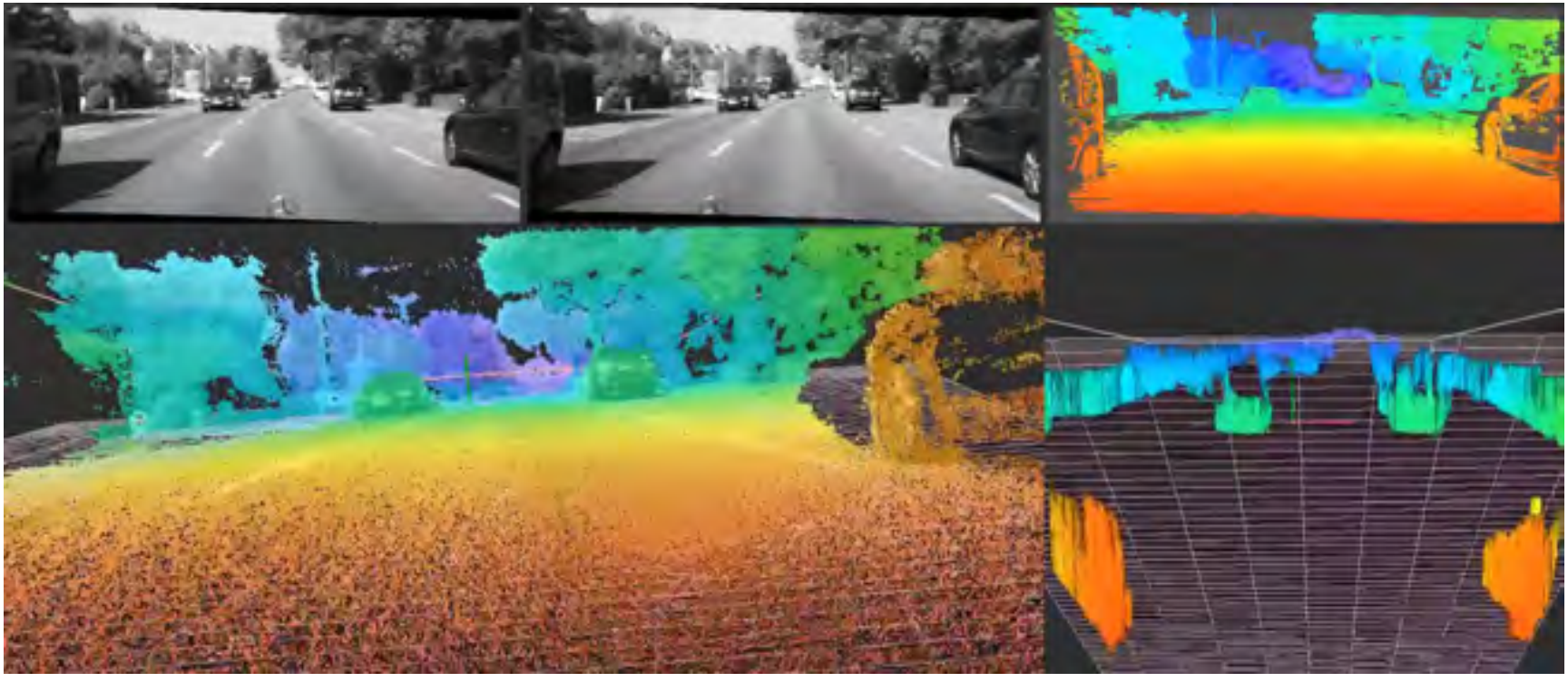
Autonomous Driving is on the Peak

of (inflated ?) expectations.

video

Source: Advertisement clip, Daimler A.G., March 2013

3D Data Available from **ONE** Stereo Frame



video

recorded at 30 fps. Result by Simon Hermann in 2012, PhD student at that time in Auckland, on Daimler test data

5 May 2015: First Self-Driving Truck on a Highway

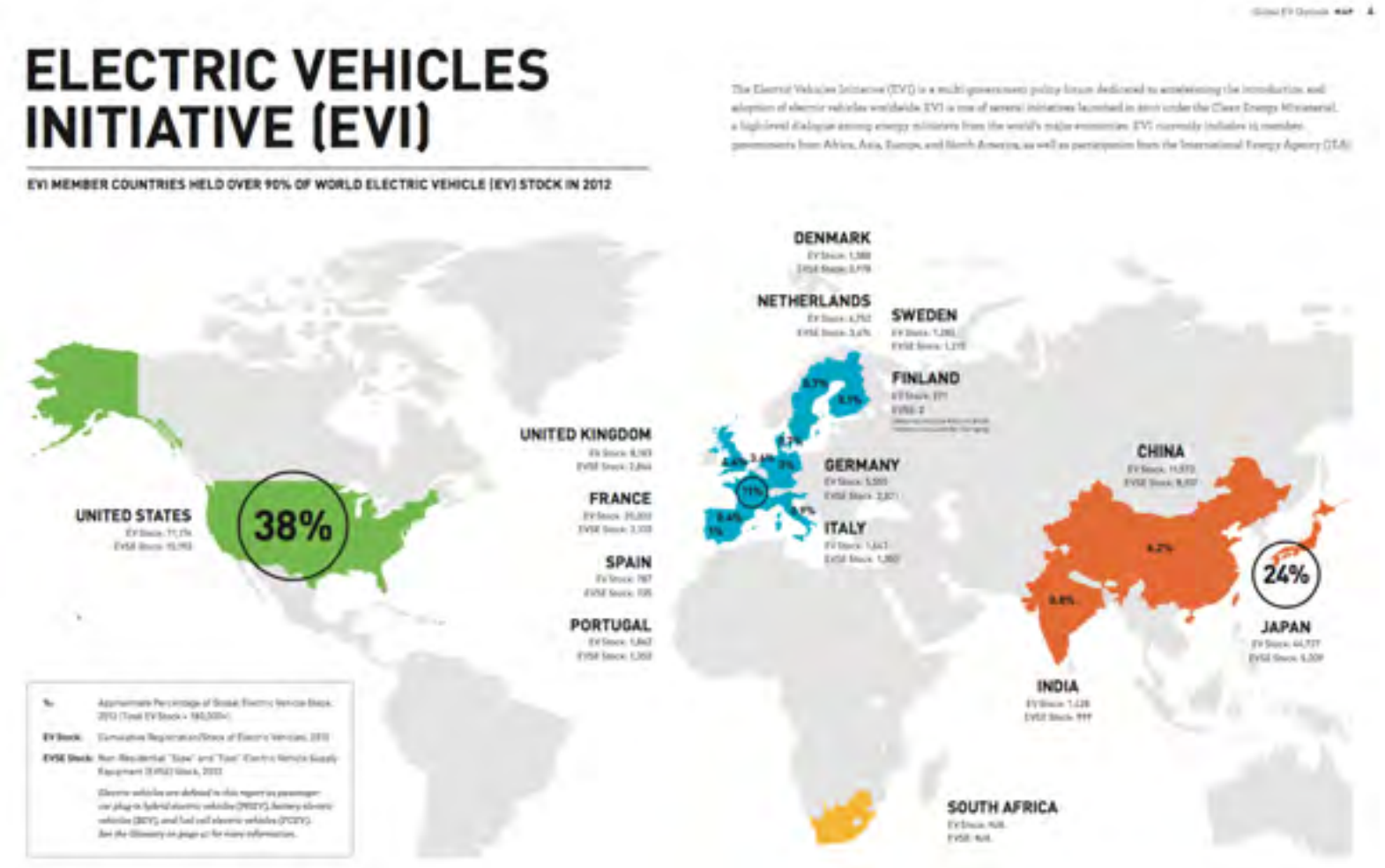
near Las Vegas

Daimler "says that drivers will remain 'the boss in their vehicle' because the technology of the Freightliner Inspiration still requires the presence of a qualified truck driver with valid commercial driver's license in the cab and on the gauges."

Source: `www.rt.com/news/255981-self-driving-truck-nevada/`

But: What about the Electric Vehicles?

Will they again disappear, as did the hydrogen fuel cell cars?
This was the EV distribution in 15 EVI countries in 2012:



From the Electric Vehicles Initiative (EVI) Report 2012

Electric Vehicles: Slow Increase in Market Shares

Electric vehicles exist since end of 19th century.

> *Auckland in the 1940s: Milk was delivered at night to homes by milkmen, who walked and controlled a battery-powered trolley carrying milk in large containers (a few hundred litres)*

2012: "The electrification of the global vehicle fleet is undoubtedly a long-term ambition. EV market shares are still below 1% in most major markets ..."

> Source: Electric Vehicles Initiative Report 2012

2016: Increase in market shares expected due to, for example,

- investments of automakers into EVs (e.g. Ford invests US$4.5 billion in EV solutions by 2020)
- newcomers to the automotive industry (e.g. Tesla cars)

Newcomers to the Automotive Industry

They take EVs and autonomous driving as a **combined** initiative

(1) Google: `www.theguardian.com/technology/2014/may/28/google-reveals-driverless-car-prototype`

(2) BYD (Build Your Dreams) in China

(3) 14 Dec 2015: **Baidu** announces their autonomous vehicles, see `v.qq.com/cover/7/7p80wtr28sywarq.html?vid=k00194eacot`

(4) Chinese billionaire Jia Yueting plans that his company **Faraday Future** (based in USA) sells its first e-car model in 2017 including autonomous driving

See: `www.faradayfuture.com/about.html`

Kodak failed due to missing out on digital camera technology; which traditional automaker will miss out on EV technology?

Outline

However ...

in general, people still seem

to ignore electric vehicles

which now need more political support so that they can expand soon (as they will some day anyway).

As a positive item, the already large, and steadily growing fleet of **electric scooters** in China is a very valuable experience and development.

Why Electric Vehicles?

Pros

- Zero emissions if charged from renewables
- Silent at low speed
- Significantly cheaper running cost compared to petrol
- Significantly cheaper servicing cost compared to petrol
- No (immediate) infrastructure required

Cons

- Limited range (≈150km) in combination with longer recharge time (≈20min at DC charger)
  - This is sufficient for ≈90% of drives: daily avg. 39 km in Perth
  - Petrol range extenders available (plug-in hybrid)
- Currently higher purchase price, but lower operating costs

Creating a Fleet of EVs

Mid 2015: 260,000 EVs in use in the US, 95,000 in Japan

China: In Jan-Oct 2015 a 290% surge in EV sales compared to same period in 2014: **171,000** EVs, due to government's favourable policies

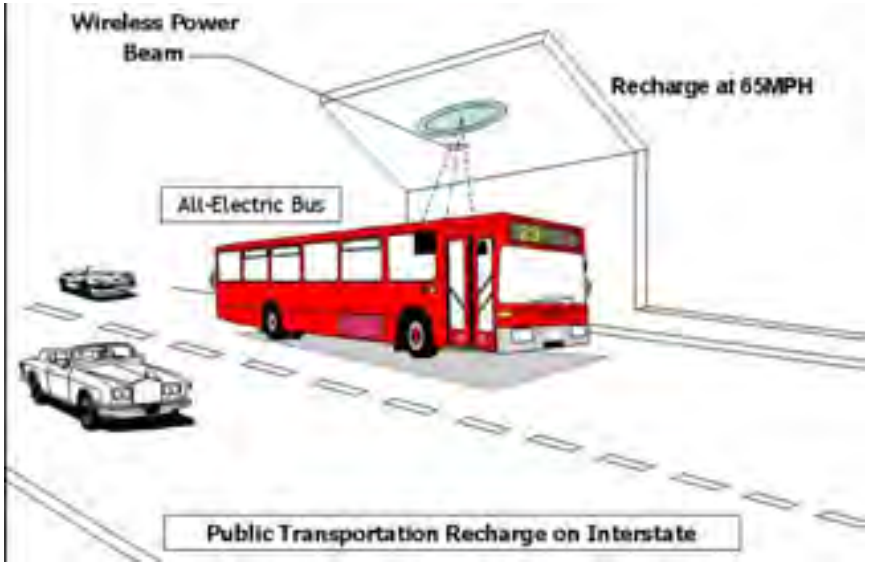
South-Korea: From 2015, EVs have to make up 25% of fleet purchases **by all public offices**, including state run universities. The country builds a network of 5,580 charging stations.

Source: `www.just-auto.com/news/government-wants-to-expand-ev-infrastructure_id156535.aspx`

If other national governments and larger company fleets do the same, we will have a large number of reasonably priced EVs for everyone

The Future: Wireless Electric Car Charging

while driving or at a temporary stop



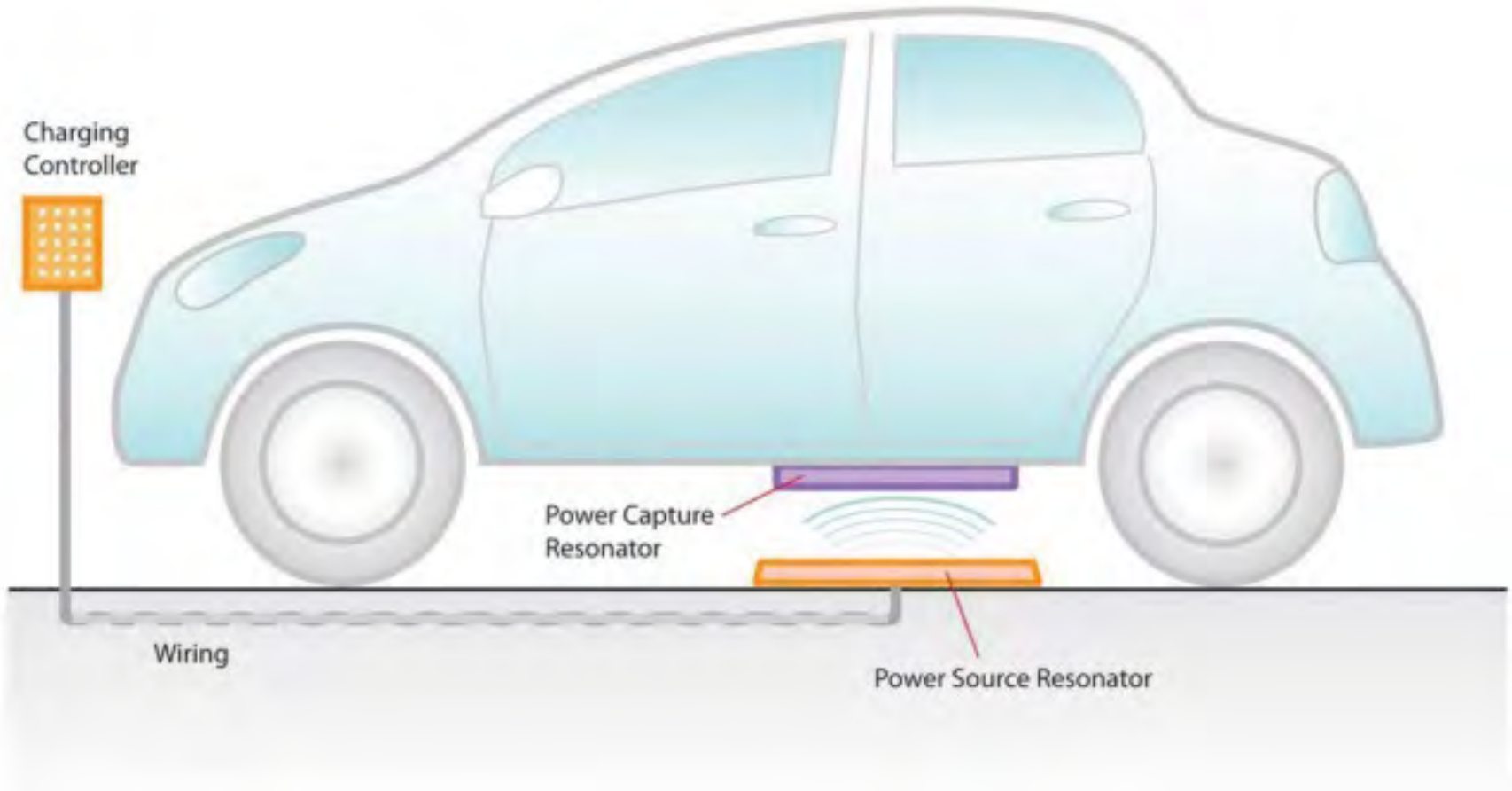
Sources:

Left: 2011, `www.greencarreports.com/news/1059122_toyota-joins-wireless-electric-car-charging-revolution`

Right: 2014, `parisetech.com/wirelessbus.html`

The Future: Wireless Electric Car Charging

... or being parked, using wireless power transmission



Source: 2012, `www.greencarreports.com/news/1081262_wireless-electric-car-charging-steady-growth-through-2020`

Solar Roadways - Dream or Reality?

Surface: Thick hardened glass has proved able to handle trucks weighing several times the legal limit. Heated roads or footpaths can melt the snow.

Source: `www.takepart.com/article/2014/05/18/solar-roadways`

Discontinued: Battery Swapping

1899 Battery swapping, France – **1970** Electric van, Germany

2010 "A Better Place", Israel, now bankrupt

Will not work because of cost & vehicle design reasons

Battery Charging 2014

Level 1 (2.4kW)
Slow charging
at home

10 hours

Level 2 (7.7-21kW)
Medium-fast charging
in parking lots and
shopping centres

3 hours

Fast-DC (50-120kW)
Fast charging
at service stations

30 min

Differences in Battery Charging Standards

Alternating Current (AC) Charging

US and Japan: IEC 62196-2 Type 1 (SAE J1772), Single Phase, 120-240V, max 70A, 16.8kW

Europe: IEC 62196-2 Type 2 ("Mennekes"), Three Phase, 230/690V, max 63A, 43kW

China: Earlier version of IEC Type 2, Three Phase





Direct Current (DC) Charging

Japan: ChaDeMo

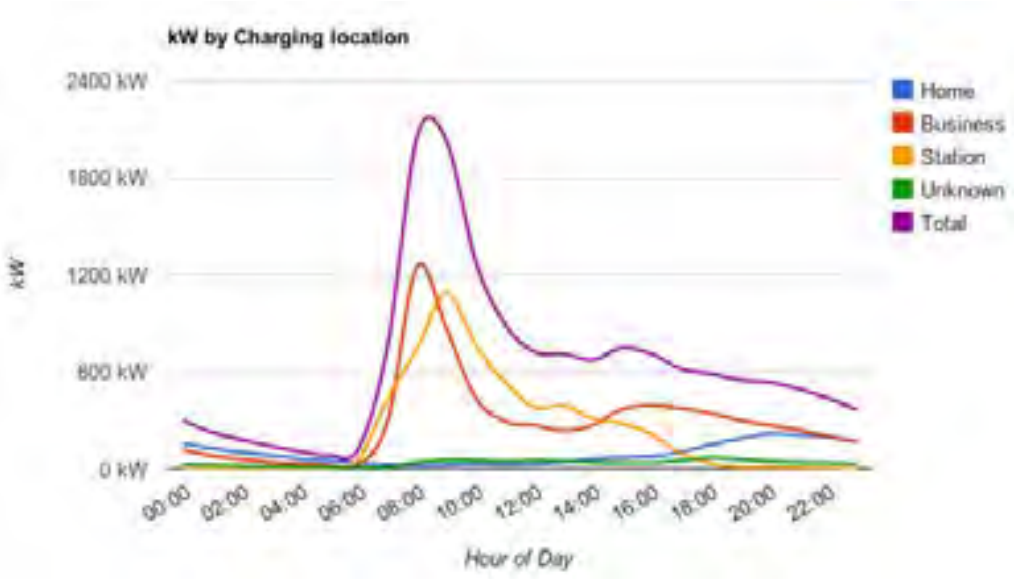
Europe: Combo Type 2

US: Combo Type 1, Tesla Mennekes

Project on EV Driver and Charging Behaviour

of the Australian Research Council (ARC)

Renewable Energy Vehicle (REV) **Project**
at the University of Western Australia, see: `therevproject.com`



Charging network, Perth 2015: 23 level-2 charging bays, 1 fast-DC station

How much infrastructure will be required in future? Where do EVs charge? When do EVs charge? How to shift load?

About 100 participating EVs.

EV Trial in WA has Shown

- EV charging hours **coincide with solar photovoltaics** (PV) curve, so can be ideally offset by solar and be 100% environmentally friendly
- Level-2 charging station (4-5 hours charging for complete load) do not work effectively for public access, as cars have to stay too long, blocking the station all day
- Fast-DC charging should be pushed for public charging stations

EVs will be the largest revolution in Automotive History

Automotive Industry

- Heavily relies on dealerships with regular service income
- EVs will significantly reduce service income
- Will cause a major shake-up in this industry, smaller dealerships will disappear

Federal Income

- Cars are cash cows: For example, fuel excise was worth $15 Billion in Australia in 2010
- There will be a major budget gap without fuel excise income
- Not easy to create EV electricity surcharge, as home owners can create their own using photovoltaics (PV) or wind turbines

Oil Industry

- Substantial losses

Outline

Used Sensors and Tasks

Driverless vehicles use sensors such as

GPS, radar, ultra-sound, stereo cameras, or LIDAR

to detect and analyze

other vehicles, traffic signs, lane borders, pedestrians, other obstacles, weather and road conditions, and so forth.

The vehicle's computer system optimizes with respect to

1. **safety** and
2. driver comfort;

it controls acceleration, steering, and braking.

Driverless vehicles will communicate with each other to allow as many cars as possible to fit on the roads.

Stereo Vision: Challenges Still Remain

video

The winner of the 2012 “Robust Vision Challenge” at the European Conference on Computer Vision: Simon Hermann and Reinhard Klette, Auckland

Driverless Vehicles Need More Preparation

They require

- progress in sensor and analysis technology (e.g. "understanding" even challenging traffic situations)
- legal and practical issues (who is responsible in the case of an accident)
- ethical regulations (e.g. safety of the car's occupants first, or the least amount of harm to anyone possibly affected?)
- urban planning (e.g. road design for autonomous driving, not for human drivers)
- the security of car computer systems (e.g. no hacking into the car computer)

Challenging Road Scenarios

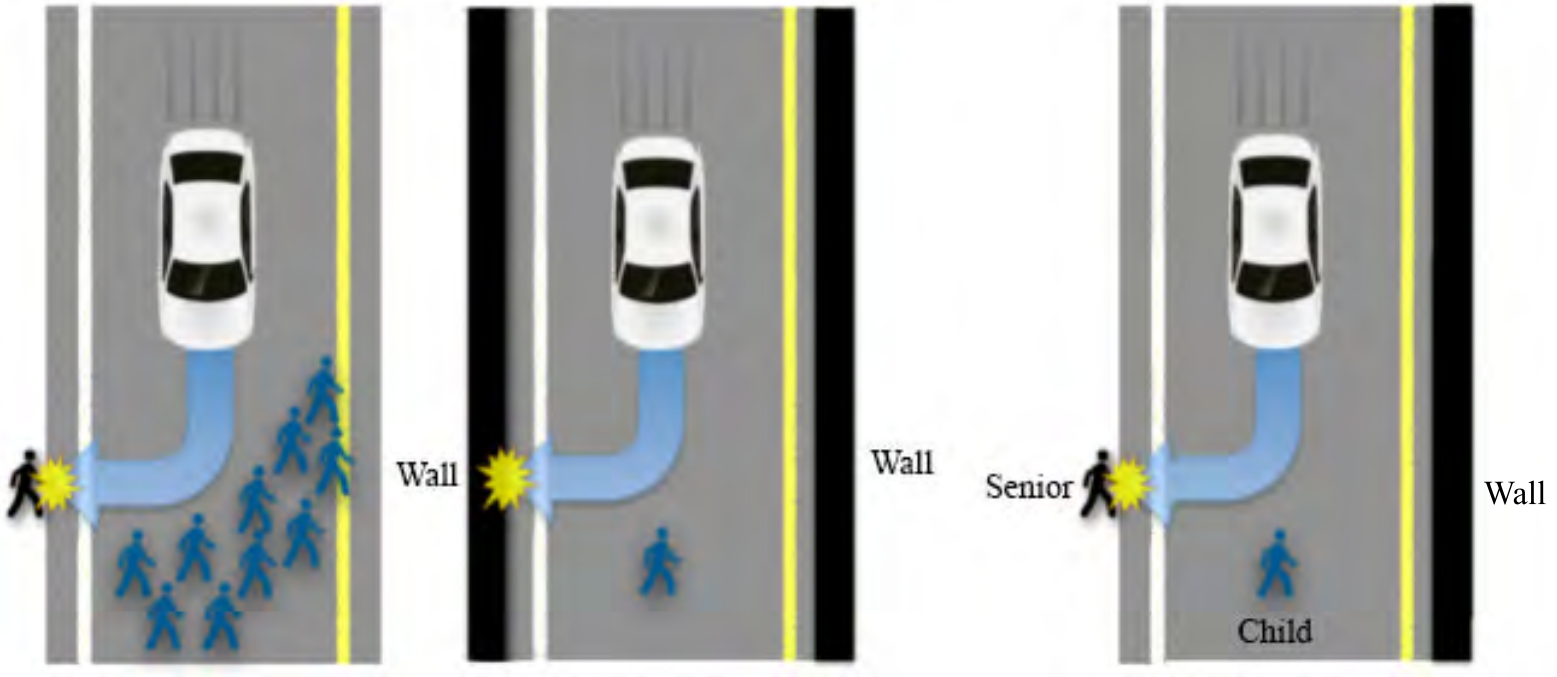
video

Different lighting on left and right camera, rain, snow, dense traffic, sun stroke, tunnels, unpaved roads - you name it

Ethics of Autonomous Cars

It is **not enough** for a driverless car to pass a human driving test!

May be: An **ethics review board** needs to evaluate programmed behaviour in a set of test scenarios? Who defines the rules?



Modified image from `www.technologyreview.com/view/542626/why-self-driving-cars-must-be-programmed-to-kill/`

From Horses to Horseless Carriages

This has been a change in freedom and thrill

Horse riding has always been associated with freedom, but traveling in horseless carriages created a new thrill of moving

1886 Daimler Motorized Carriage

Regarding Improved Safety ...

(1) Estimate of equestrian injury rate: one injury per 1,000 riding hours

This rate suggests that horse riding is **more dangerous than** motorcycle riding or **automobile racing** ...

Source: `www.nisu.flinders.edu.au/pubs/bulletin24/bulletin24.pdf`

(2) Over 100 deaths are registered a year in US due to equestrian related activities.

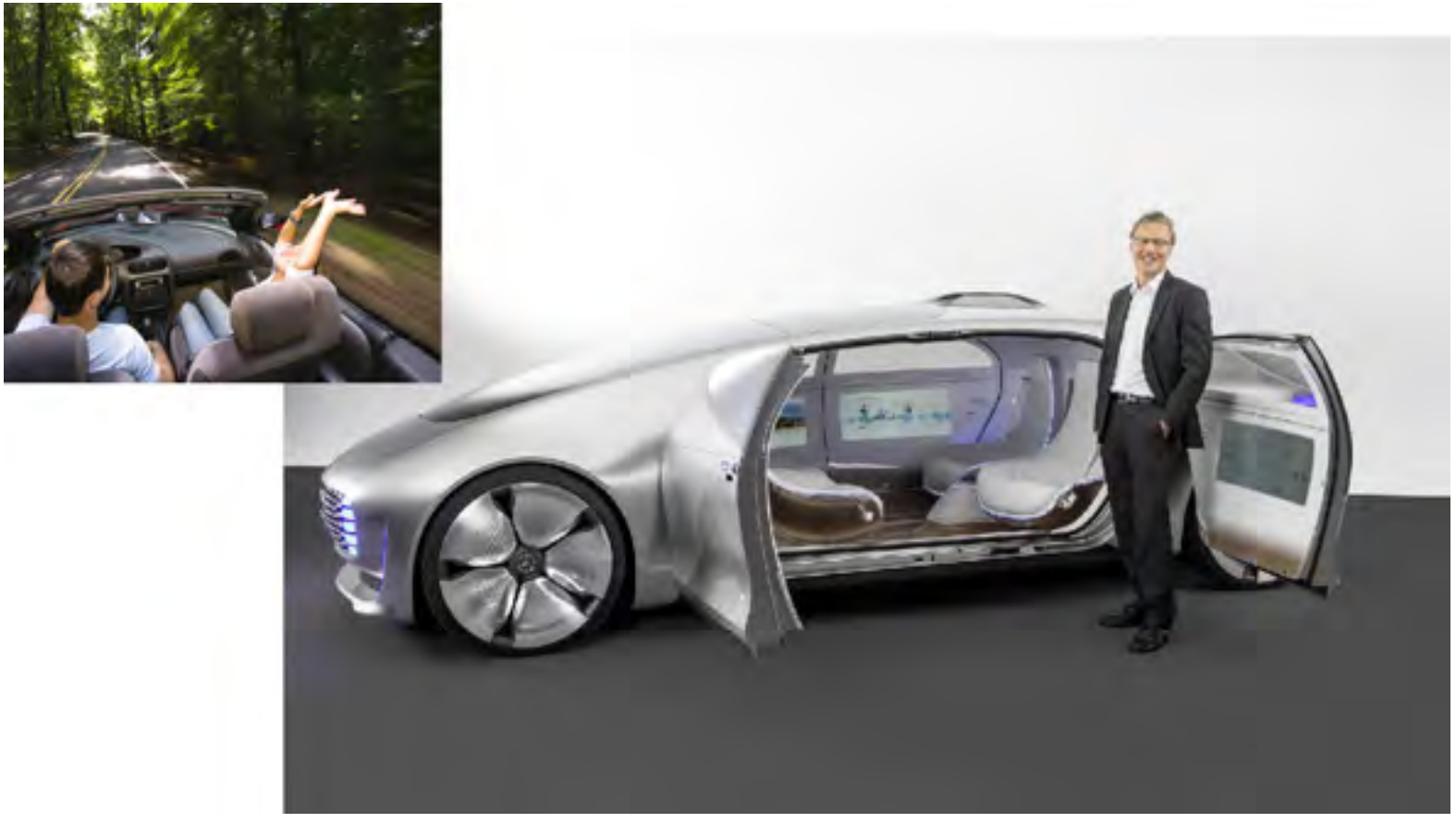
Source: `www.riders4helmets.com/2011/02/equestrian-sport-statistics-facts-what-you-should-know/`

(3) Definition of road traffic rules had been a totally new task

From Drivers to Driverless Vehicles

This will be another change in freedom and thrill

Car driving has always been associated with freedom, but traveling in driverless carriages will provide a new meaning for freedom



2015 Mercedes-Benz Driverless F-015

Maybe, just Two Steps

1. Get used to the experience that you don't have to pay attention to the road
2. Use the available time to communicate with others, to read, ...

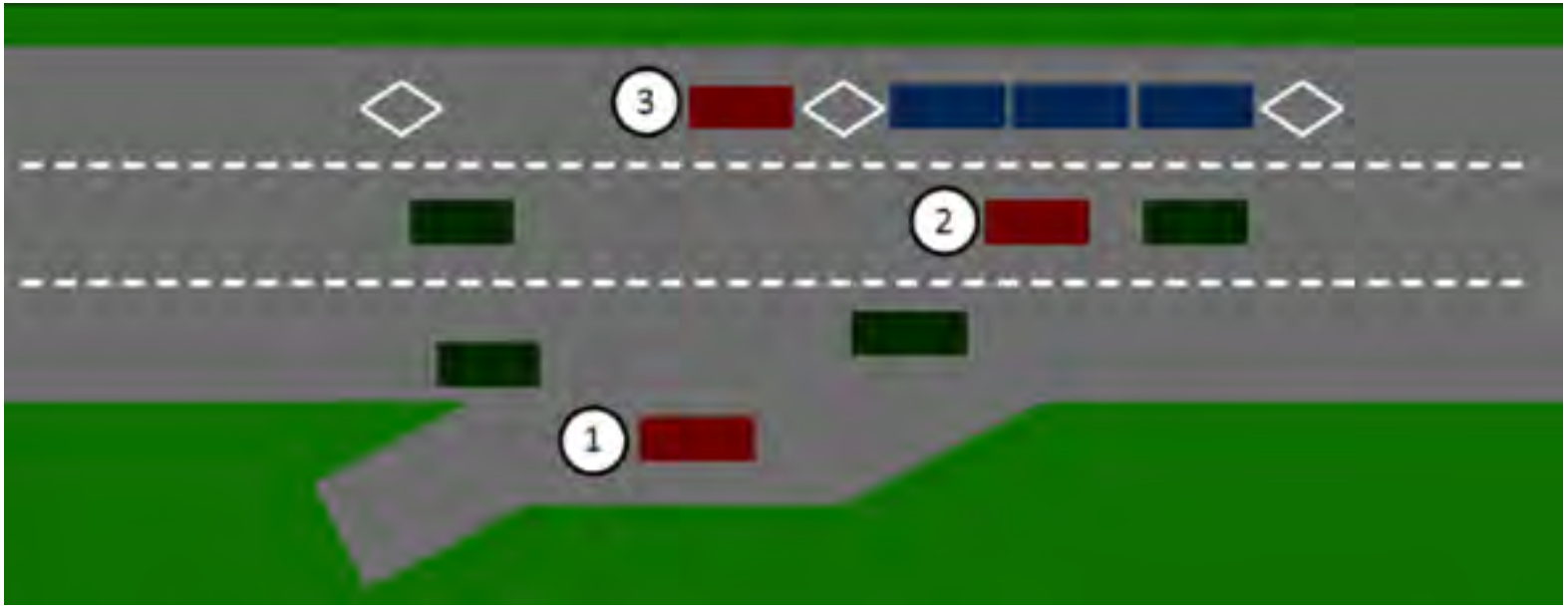
If long travel time then the driverless vehicle may turn into a *temporary home*?

And: You still can ride a horse!

Vehicles need to be **dual**, for driverless use (say, for the long travel patches), but also for being driven as today.

Note: This is a new meaning of "duality".

Example: Dedicated Lanes for Vehicle Platooning



1. Highway merging protocol into mixed traffic streams
2. Autonomous vehicle in mixed traffic stream
3. Autonomous vehicles only, also forming platoons

An example where inter-vehicle communication is required

Source: 2011 REA Project Proposal to US Government

Control Transfer Between Driver and Automated System

Automated system would normally be operating under conditions that exceed drivers' capabilities.

Control transfer normally at the check-in and check-out locations when entering and leaving the automated highway lane.

Challenging issues: Abnormal control transfers when an overriding system decides under which conditions the driver takes control from the automated system

Driver Awareness Test

1. Driver in appropriate pose?
2. Determine driver level of awareness (e.g. tactile sensors in steering wheel)
3. Analyze driver's sobriety to check surround environment

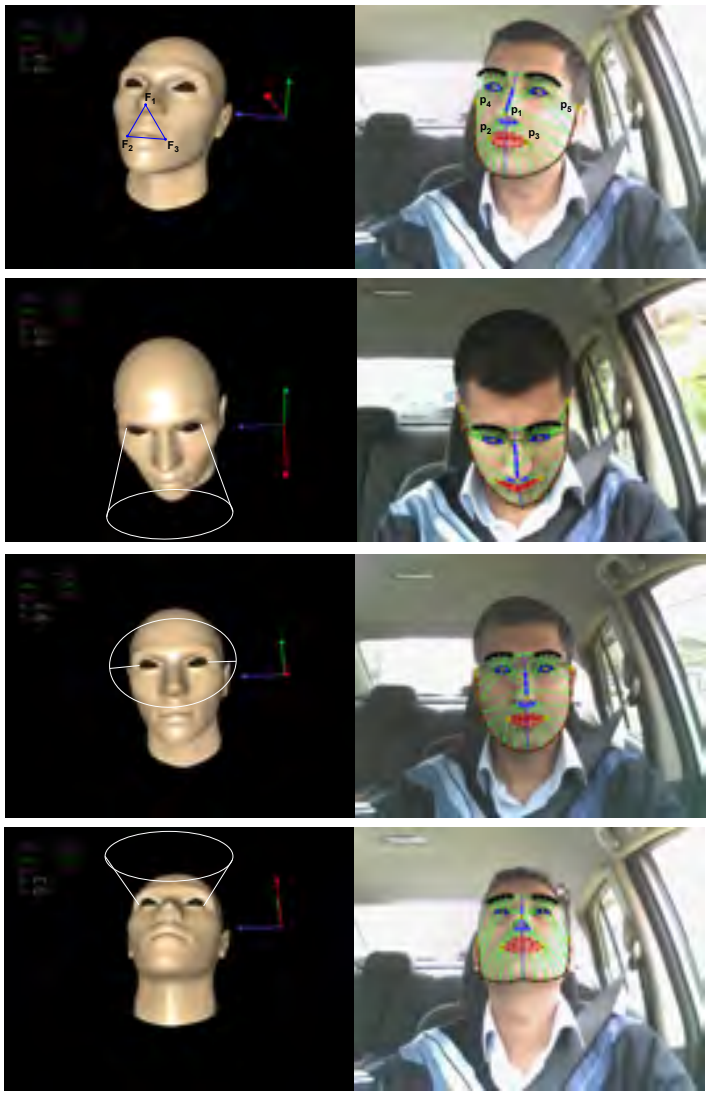
A "fail" requires an automated solution.

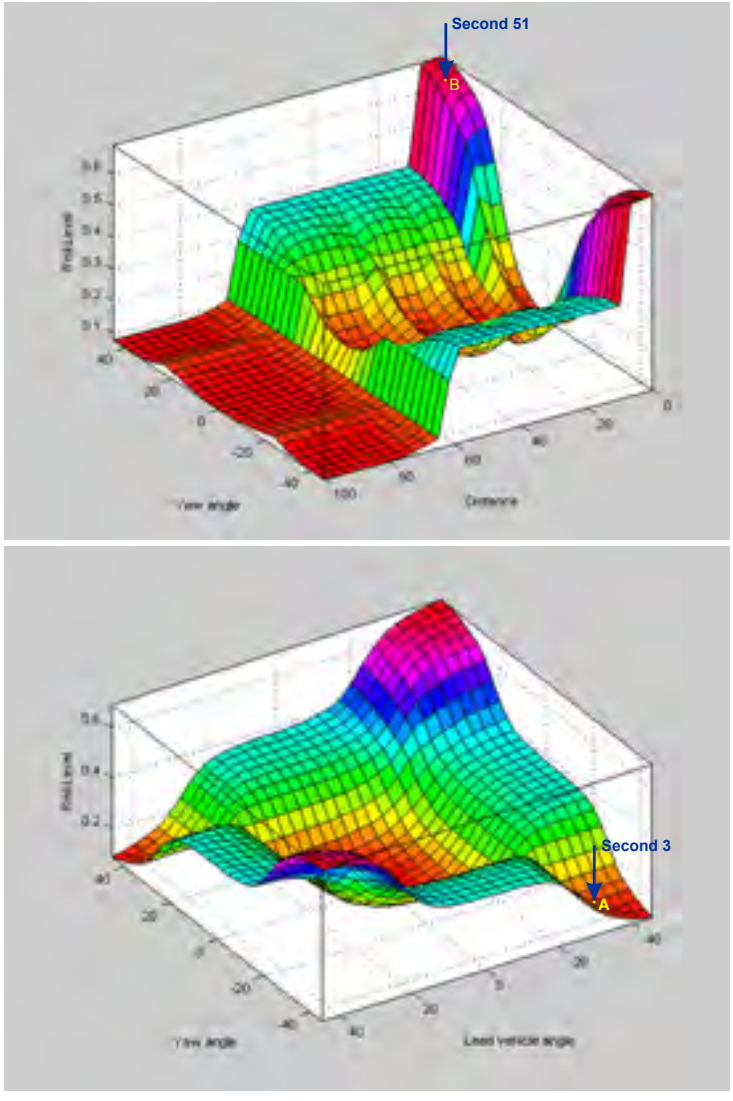
Driver Monitoring (In the shown example under ideal lighting conditions)

video

Does the driver pay proper attention to events happening around the car? (A novel subject, raised e.g. in [Mahdi Rezaei and Reinhard Klette, CVPR 2014])

Multidimensional Space for Reasoning





Eye gaze, head pose, distance to closest vehicle (in which lane?), ...
[Mahdi Rezaei and Reinhard Klette, CVPR 2014]

Outline

Subway, Bicycles, Lightrail, Electric Scooters, Escalators ...

Subway in Dalian, bicycles in Groningen, lightrail in Houston, electric scooters in Zhengzhou

A Failed Proposal in 2011

Roadmap to Roadway Electrification and Automation (REA)

Submitted by an international consortium to the US Government

Motivations: Reduce oil dependence, fossil fuel use, CO_2 emissions, congestions, crashes, injuries and fatalities, wasted time

Detailed Specifications of electrified roadways, wireless charging of vehicles (while driving, with consequences for vehicle design), autonomous driving (e.g. for platooning), vehicles entering or exiting roadway or platoon, design of entrance/exit bays, control transfers between driver and automated system, test highways in a selected city, standards, ...

Result in 2011: No funding provided by US Government

Proposal could be revised today based on progress since 2011, and submitted somewhere else: Which country is able to proceed with both pending revolutions properly combined? Which city is first?

Conclusion

Electric and driverless vehicles come with challenges. Driverless vehicles are **on the peak of the hype**; they will develop via **driver-assistance features** in the next 10 years. EVs still face a **strong opposition** (e.g. oil companies, federal income, service industry), and require more political support. China has proved already that it is able to make changes of the required magnitude.

Left: Linfen, Shanxi province, 2010, most polluted city on Earth
Right: 'floral city' Linfen, 2015, risen like a phoenix from the ashes