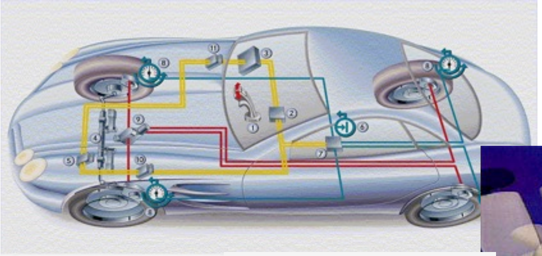
W1. Objectives, Challenges, State of the Art, Technologies

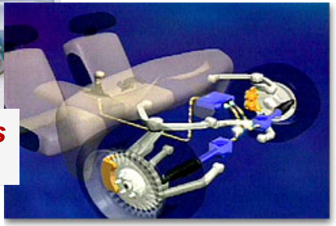
- Socio-economic context
- Technological evolution of Robotics & State of the Art
- New challenges for Robotics in Human Environments
- Decisional & Control Architecture for Autonomous Mobile Robots & IV
- Sensing technologies: Object Detection
- Sensing technologies: Robot Control & HRI
- Basic technologies for Navigation in Dynamic Human Environments
- Intelligent Vehicles: Context & State of the Art
- **Intelligent Vehicles: Technical Challenges & Driving Skills**

Car technology is almost ready for *Driving Assistance & Fully Autonomous Driving*

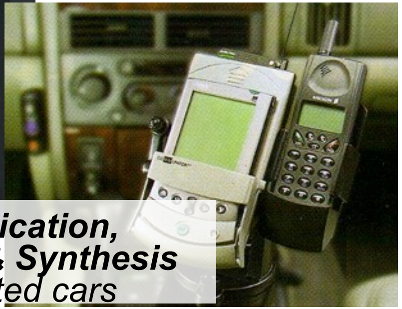


Electronics
Informatics

Micro-controllers
Sensors …



Modern Cars
➔ *Steering by wire*
Brake by wire
Shift by wire



Wireless Communication,
Speech Recognition & Synthesis
… Towards connected cars

Navigation systems, Multiple sensors,
Driving assistance *(speed, ABS, ESB …)*

Autonomous Driving capabilities
(e.g. Parking Assistant)

Car technology is almost ready for *Driving Assistance & Fully Autonomous Driving*

Cost decreasing & Efficiency increasing *(mass production, embedded systems…)*

…But a real **deployment of Advanced Technologies for ADAS & Autonomous Driving**, requires to still Address & Improve 3 main technical issues:

- ✓ ***Robust**, **Integrated**, and **Cheap** enough "**Embedded Perception Systems**"*
- ✓ ***Advanced Control & Decision Making technologies** … for **Realistic Traffic Situations***
- ✓ ***Friendly Human – Vehicle Interaction***

Autonomous Parking Assistant

Autonomous Vehicles – *Current Limitations*

Current Autonomous Vehicles are able to exhibit quite impressive skills…

*BUT they are **not fully adapted to Human Environments** & they are sometime **Unsafe** !*

➔ ***DARPA Grand Challenge 2004 & Urban Challenge 2007***

- ✓ *Significant step towards Motion Autonomy*
- ✓ ***But still some "Uncontrolled Behaviors & Collisions** (event at low speed)*


Cornell - MIT collision

➔ ***Google Cars & Others in the world have started projects for "Autonomous Driving"***

- ✓ *Impressive results in some realistic traffic conditions*
- ✓ ***But numerous costly Sensors are still required (including dense 3D mapping) & Human Factor is weakly addressed***

Autonomous Vehicles – *Current Limitations*

Some technologies are almost ready for use in some restricted or protected public area, **but**...

- ✓ *Fully **Open & Dynamic environments** are still beyond the state of the art*
- ✓ ***Safety** is still not guaranteed*
- ✓ *Many **costly onboard sensors** & **High computing power** are still required*

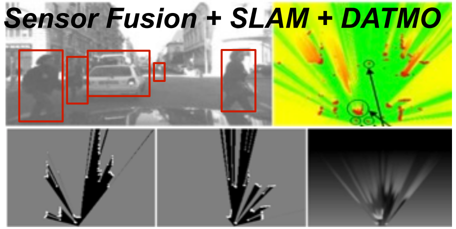
Google Cars 2011 & Other projects in the world

- ✓ *Impressive results & fully autonomous driving capabilities*
- ✓ ***But numerous costly Sensors***
  - \+ ***Dense 3D mapping required***
  - \+ ***Human Factor weakly addressed***

ADAS & Autonomous Driving –*Technical Bottlenecks*

- ***Robust Embedded Perception for Open & Dynamic Human Environment***

  ➔ *Bayesian Perception paradigm*
  (see week 4)



- ***Situation Awareness & Risk Assessment for Decision Making***

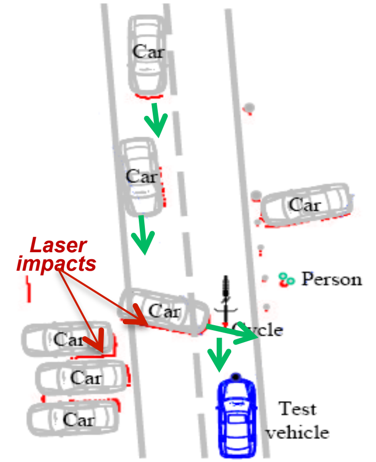
  ➔ *Bayesian Reasoning & Decision*
  (see week 4)

- ***Safe & Socially acceptable Navigation / Control***

  ➔ *Driving skills & Share control*
  (partly addressed in this course)

Challenge 1: Perception & Situation Awareness in Dynamic Human Environments

Traffic scene understanding

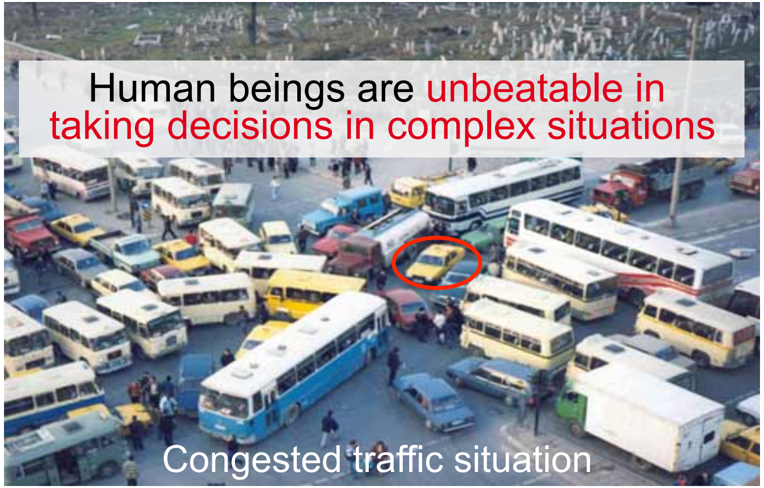


Detect, Localize, Track, Classify
Mobile scene components
(from sparse & noisy sensory data)

New Models & Algorithmic Tools are required

- Dynamicity & Uncertainty
  - ➔ *Space & Time + Probabilities*
- Interpretation ambiguities
  - ➔ *History, Context & Semantics, Prior knowledge + Sensor fusion*
- Prediction of future states & Evaluation of collision Risk
  - ➔ *Behaviors, prediction models*
- Embedded Perception under real-time constraints
  - ➔ *Miniaturization & Software / Hardware integration*

Challenge 2: Human Aware Decision Making for Navigation & Interaction



Human driver & IV have complementary capabilities

⇒ ***Share Control is mandatory***

⇒ ***Bayesian Reasoning is useful for Decision making under uncertainty***

➔ *Detailed in weeks 4*

Challenge 2: Human Aware Decision Making for Navigation & Interaction

Share control implies appropriate **HRI functionalities**

*…but **Driver inattention** is still a major cause of accident !*

Seat pressure

Steering actions

Pedal signals

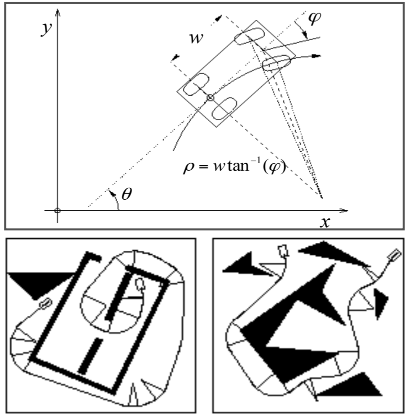
Head /Eye Visual analysis

Driver Monitoring (using on-board Perception)

+

Safe & Socially Acceptable **Human / Vehicle Interaction are necessary**

Challenge 3: Safe & Socially acceptable Navigation
Control Architectures & Driving Skills

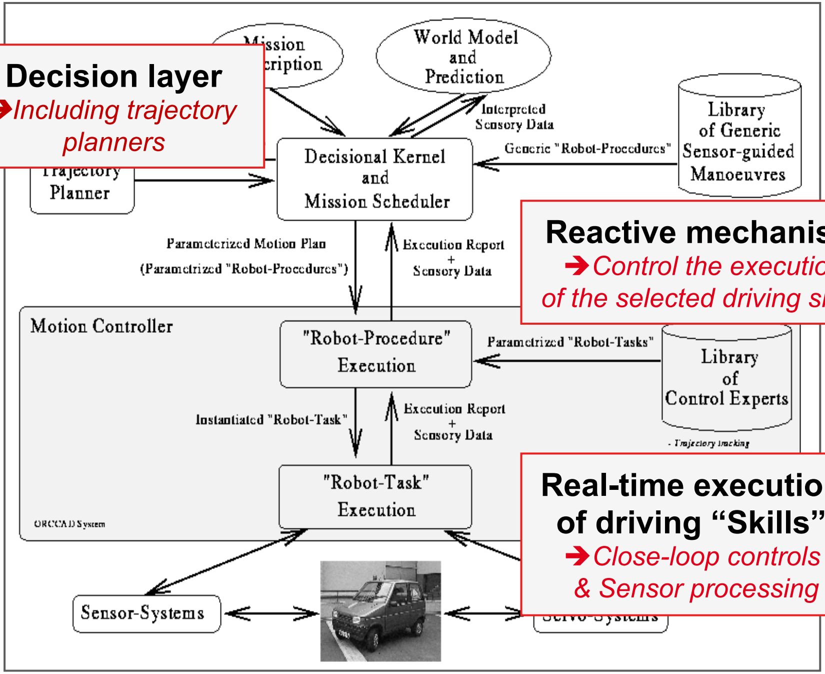


Safe paths & Kinematic constraints

=> *Non-Holonomic Motion Planning*

e.g. CC-Paths [Scheuer & Fraichard 98]

Continuous curvature profile + upper-bounded curvature & curvature derivative



Decision layer

➔ *Including trajectory planners*

Reactive mechanism

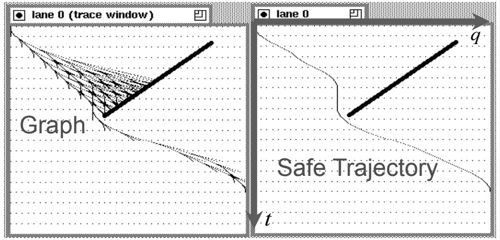
➔ *Control the execution of the selected driving skills*

Real-time execution of driving "Skills"

➔ *Close-loop controls & Sensor processing*

An example: The traditional 3-layered control architecture

$$\begin{cases} F_{min} \leq F \leq F_{max} & \text{(engine force limit)} \\ \sqrt{R_t^2 + R_n^2} \leq \mu R_b & \text{(no sliding constraint)} \\ 0 \leq \dot{s} \leq \dot{s}_{max} & \text{(speed limit)} \end{cases}$$



Safe trajectories & Dynamic constraints

e.g. Kinodynamic Motion Planning (State-Time Space) [Fraichard 92]

Driving Skills examples – *Platooning*

Approach: *Following a leader & **Controlling the motion** of the following vehicles using an **"Electronic Tow-bar"***

Platooning principle
[Parent & Daviet 96]

Infrared target

CCD Linear camera
(high rate & high resolution)

Driving Skills examples – *Platooning*

Approach: *Following a leader &* ***Controlling the motion*** *of the following vehicles using an* ***"Electronic Tow-bar"***

Driving Skills examples – *Automatic Parallel Parking*

Approach: *Real-time local world reconstruction & Incremental motion planning*

US Sensors
⇒ *Obstacle Detection*
⇒ *Environment reconstruction*
⇒ *Relative localization*

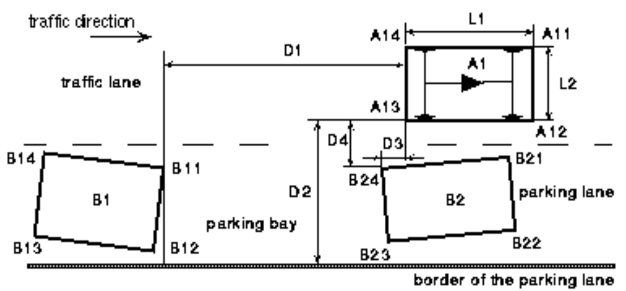
$$\begin{cases} \phi(t) = \phi_{\max}\, k_\phi\, A(t), & 0 \le t \le T \\ v(t) = v_{\max}\, k_v\, B(t), & 0 \le t \le T' \end{cases} \qquad \phi_{\max} > 0,\ v_{\max} > 0,\ k_\phi = \pm 1,\ k_v = \pm 1$$

$$A(t) = \begin{cases} 1, & 0 \le t < t' \\ \cos\dfrac{\pi(t - t')}{T^*}, & t' \le t \le T - t', \\ -1, & T - t' < t \le T \end{cases} \qquad t' = \frac{T - T^*}{2}, T^* < T$$

$$B(t) = 0.5\left(1 - \cos 4\pi t / T\right), \qquad 0 \le t \le T$$

On-line **Motion Decision & Control using**
sinusoidal controls $\Phi(t)$ and $v(t)$
➔ *search for control parameters T and Φ_{max}*

Start location characterization



[Paromtchik & Laugier ICRA 96]

Driving Skills examples – *Automatic Parallel Parking*

Approach: *Real-time local world reconstruction & Incremental motion planning*

[Paromtchik & Laugier 96]

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