HAL
open science

The challenge of on-board Perception and Decision-making for Autonomous Driving in Mixed traffic conditions

Christian Laugier

To cite this version:

Christian Laugier. The challenge of on-board Perception and Decision-making for Autonomous Driving in Mixed traffic conditions. IROS 2021 - IEEE/RSJ International Conference on Intelligent Robots and Systems - Interactive session on "Future advances and research directions for autonomous robotics", Sep 2021, Prague, Czech Republic. hal-03518473

HAL Id: hal-03518473

https://inria.hal.science/hal-03518473v1

Submitted on 9 Jan 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

The challenge of on-board Perception & Decision-making for Autonomous Driving in Mixed traffic conditions

Christian LAUGIER, PhD & Dr Es Science
Research Director at Inria & Scientific Advisor for Probayes
Inria Chroma team & IRT Nanoelec – christian.laugier@inria.fr

Interactive session on "Future advances and research directions for autonomous robotics"
Workshop on "Perception & Navigation for Autonomous Robotics in Unstructured and Dynamic Environments"
IROS 2021, Prague, September 27th 2021

© Inria & Laugier. All rights reserved

Autonomous Driving: Where are we now ?

- **A Technological breakthrough & Numerous AV experimentations in real traffic conditions**

Commercial Autopilot L2 system
(tested by customers)

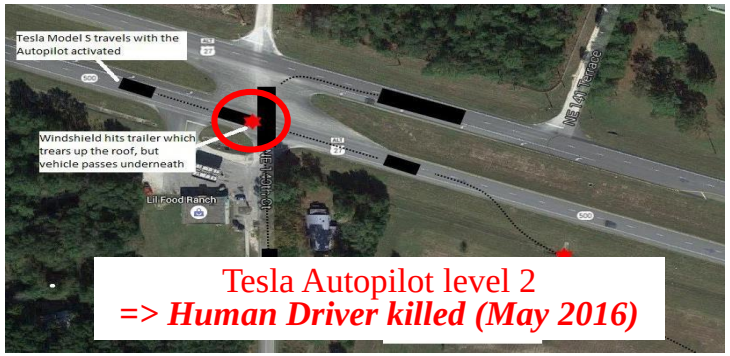
- Large fleet & 20 Million miles covered
- **Self-driving taxi service L3**
(1st in US, Phoenix, Dec 2018)

- Similar **Self-driving taxi service L3**
- Experimented in several cities

Increasing number of
Autonomous Shuttle service
experiments

- **Millions of miles driven last decade… but SAFETY is still not fully guaranteed !**

=> Several benign or fatal accidents involving AVs (Perception failure & Takeover difficult)



Tesla Autopilot level 2
=> Human Driver killed (May 2016)

Self-driving Uber L3
=> Pedestrian killed (March 2018)

- **Additional R&D work is still mandatory on 2 main research lines**

1- Improving "Perception & Decision-making" technologies *(in particular for Robustness & Scalability issues)*

2- Developing new "Validation & Certification" approaches for making future deployment feasible *(in addition to traditional testing approaches)*

Realistic Simulators & Augmented Reality & Formal methods ***(Inria & IRT Nano)***

Mixed traffic: AVs have to face two main challenges

1st Challenge: *The need for* ***Robust, Self-diagnosing & Explainable Embedded Perception***

Video Scenario *(Tesla Autopilot L2)*

- *The Tesla perception system failed to detect the barriers blocking the left side route.*
- *The human driver has to take over & steer the vehicle away from the blocked route (for avoiding the collision)*

Video source: AutoPilot Review @ youtube.com

2nd Challenge: *The need for* ***Understandable Driving Decisions*** *(share the road with human drivers !)*

Human drivers actions are determined by a complex set of interdependent factors difficult to model *(e.g. intentions, perception, emotions …)*

⇒ ***Predicting human driver behaviors is inherently uncertain***

⇒ ***AV have to reason about uncertain intentions of the surrounding vehicles***

Video scenario *(Collision: Waymo AV & Human Driven Bus)*

*Scene observed by the dash cam of a **bus** moving behind the Waymo AV*

- ***Waymo AV** is blocked by an obstacle and it decides to execute a left lane change*
- *The **bus driver misunderstood the AV intention**, and didn't yield*
- *The two vehicles collided !!!*

Video source: The Telegraph

Perception & Decision-making challenges

Dynamic scene analysis & Navigation Decisions
Traditional Formulation

⇒***Scene interpretation*** *using Sensing & Prior knowledge*
⇒***Safe Navigation decisions*** *(using semantics & context)*

Embedded Perception & Decision-making
for Safe Intentional Navigation

Detecting & Reacting in real-time to
Unexpected Events

Typical situation: A pedestrian suddenly comes out from behind a stopped bus

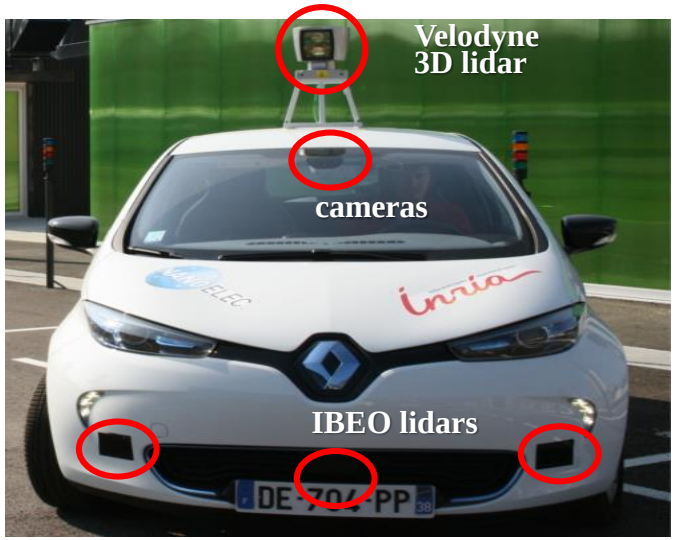
⇒***Detect & Predict*** *imminent collision with* ***"something"***
(unclassified unexpected event)
⇒*Activate appropriate* ***reflexive avoidance strategy***

Main difficulties & Open issues

- ❑ Dynamic & Open Environments, Incompleteness & Uncertainty, Sensors limitations, Real-time constraint
  ... but also ***Reactivity to Unexpected events*** *(e.g. imminent collision)* & ***Validation issue***

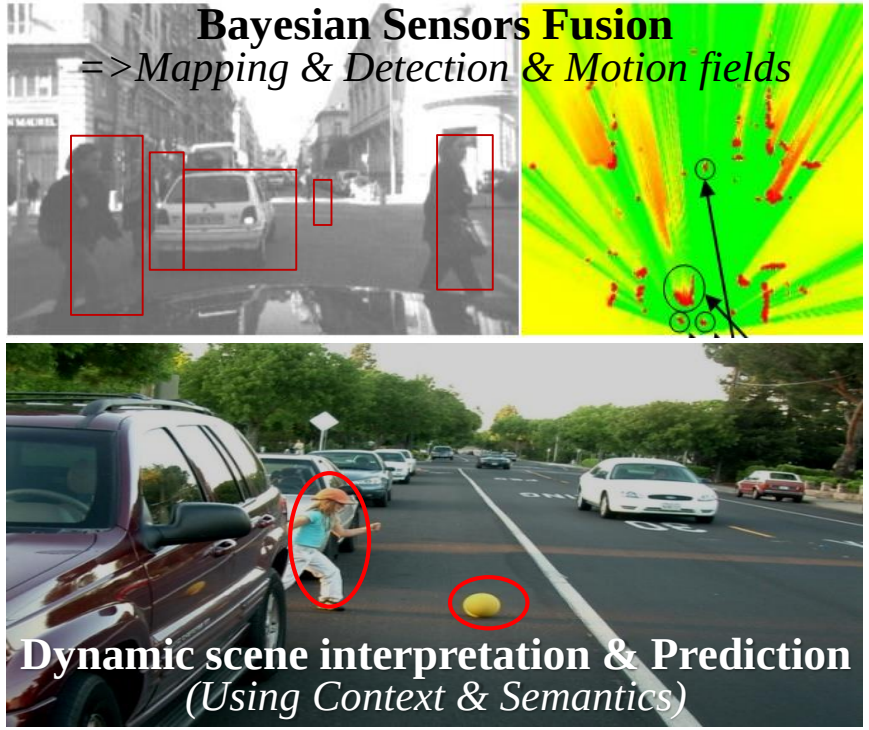
- ❑ Mixed traffic (Human in the loop) => ***Design a "Human-Aware Decision-making process"***
  Taking into account ***Interactions*** + ***Behaviors*** + ***Social & Traffic rules***

1st Paradigm: Embedded Bayesian Perception



Embedded Multi-Sensors Perception

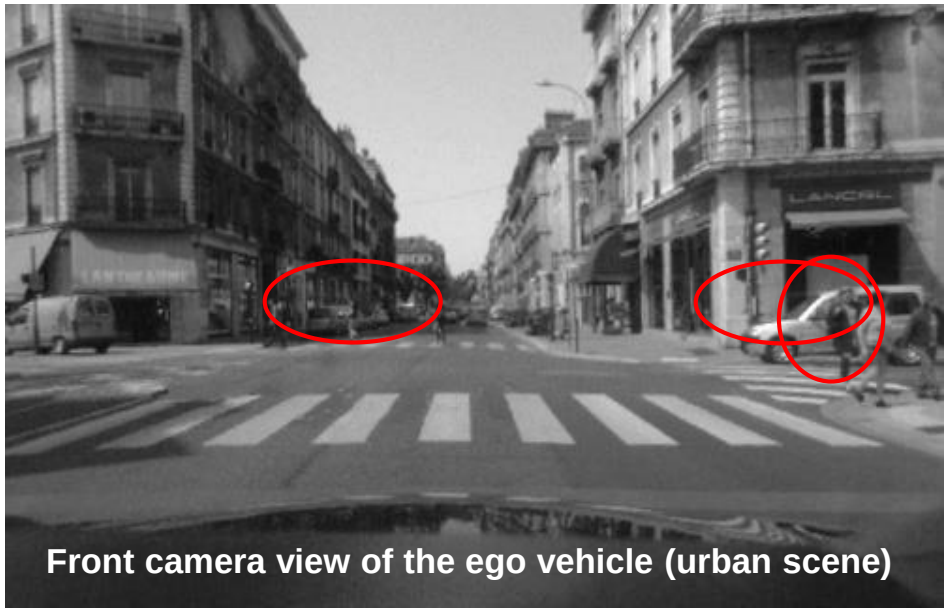
⇒ *Continuous monitoring of the surrounding dynamic environment*



- ✓ ***Exploiting the Dynamic information*** *for a better understanding of the scene !!!!*
- ✓ *Reasoning about* ***Uncertainty & Time window*** *=> Past & Future predicted events*
- ✓ *Bayesian* ***Sensors Fusion*** *+ Scene interpretation using* ***Contextual & Semantic*** *information*
- ✓ ***Software / Hardware integration*** *using hardware accelerators (GPU, Multicore, Micro-controllers ..)*

Embedded Bayesian Perception – *Illustration*

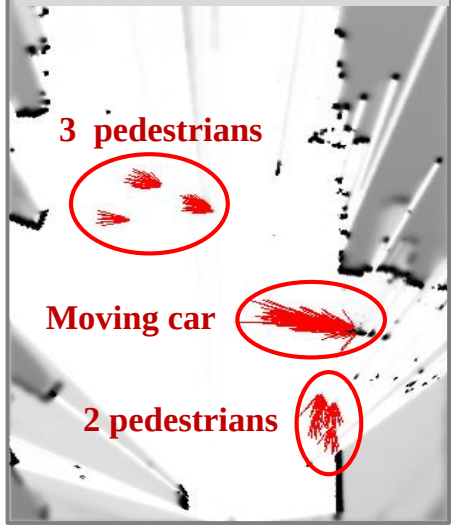
=> Exploiting the dynamic information for a better understanding of the scene

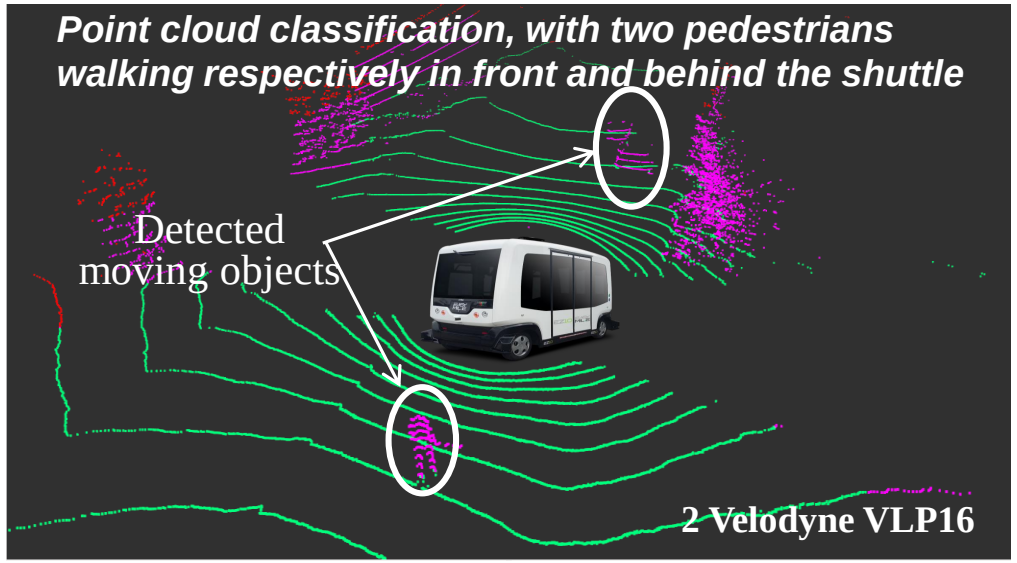


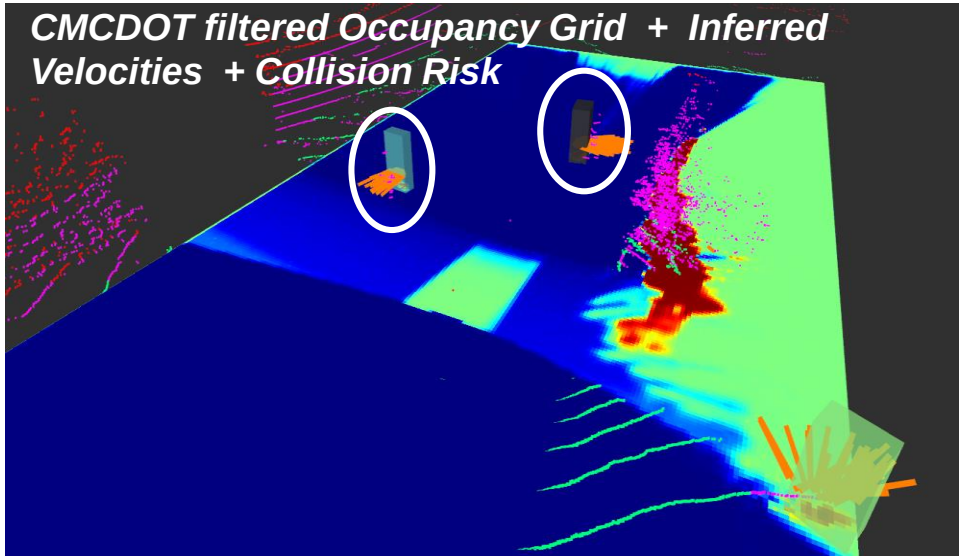
Sensors data fusion
+
Bayesian Filtering
+
Extracted Motion Fields

Static part
=> Occupancy Grid

Dynamic part
=> Motion fields



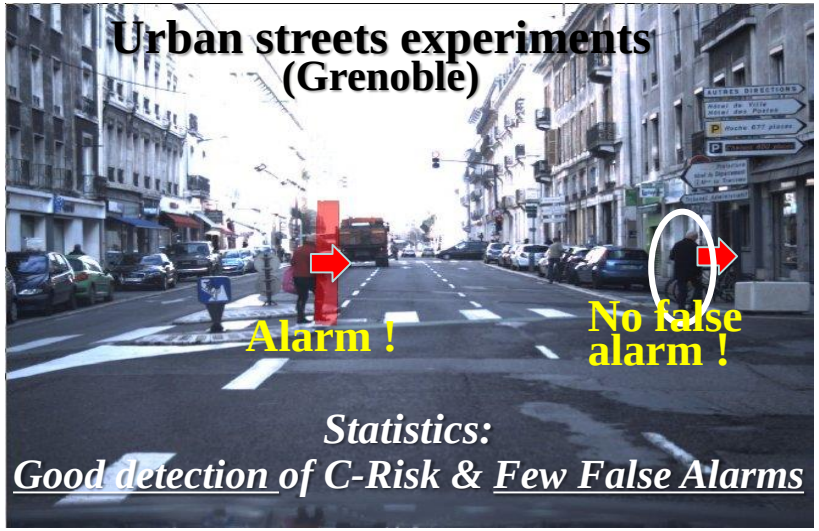


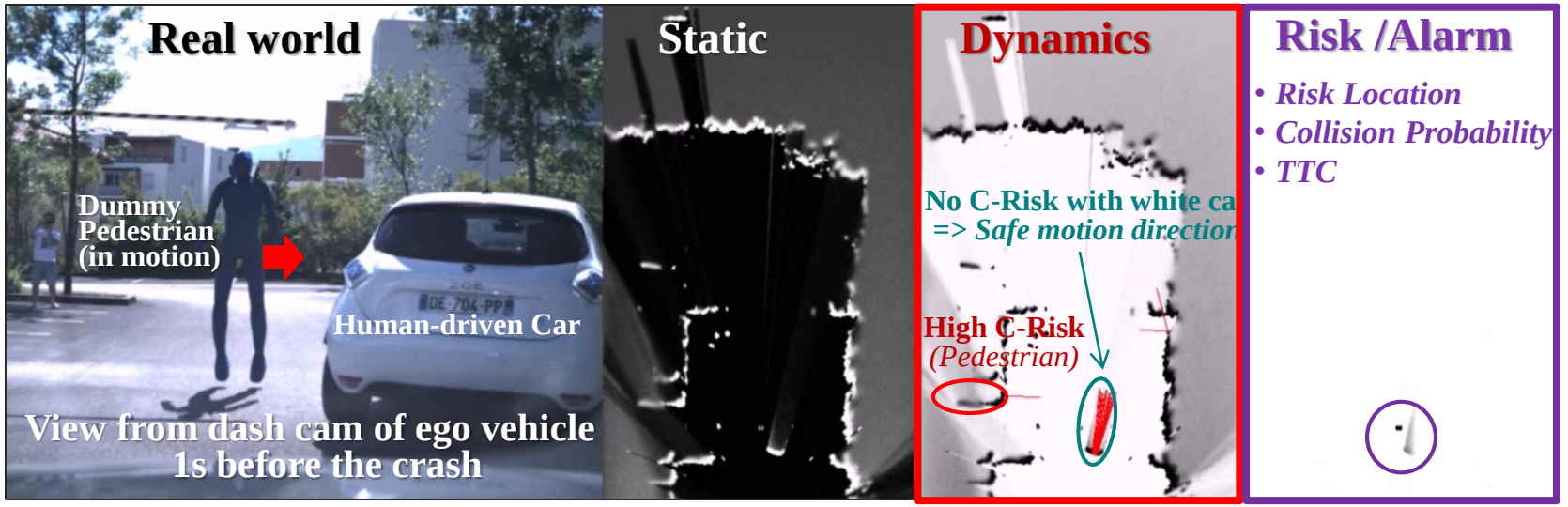


2nd Paradigm: Collision Risk Assessment

How to Avoid both Pending & Future Collisions ?

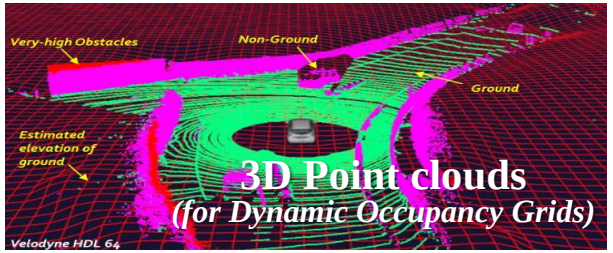
- ✓ ***Predict* environment changes** *on a given "time horizon t+δ"* => *Using* ***History*** *&* ***Motion models***
- ✓ *Estimate the* ***Probabilistic Risk of Collision*** *at t+δ (δ = a few seconds ahead)*
- ✓ *Distinguish* ***Short-term C-Risk*** *(Grid level & Conservative) &* ***Mid-term C-Risk*** *(Object level & Behaviors)*
- ✓ *Make* ***Driving Decisions*** *by taking into account the* ***Predicted behavior*** *of all surrounding traffic participants (cars, cycles, pedestrians…) &* ***Social / Traffic rules*** *(traffic participants interactions)*

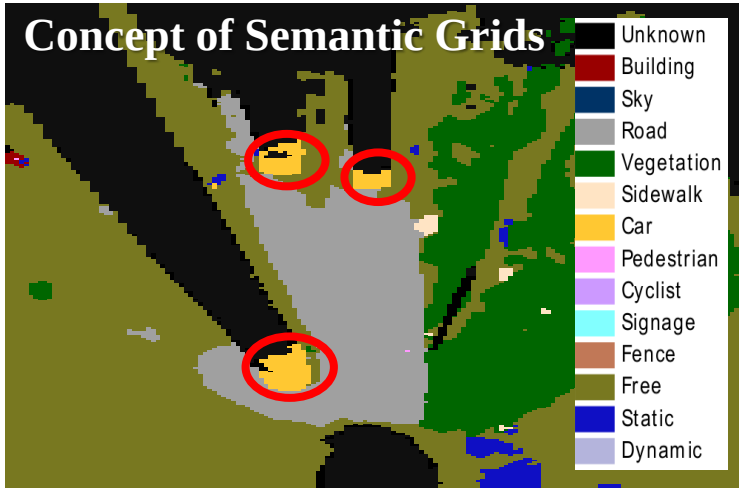


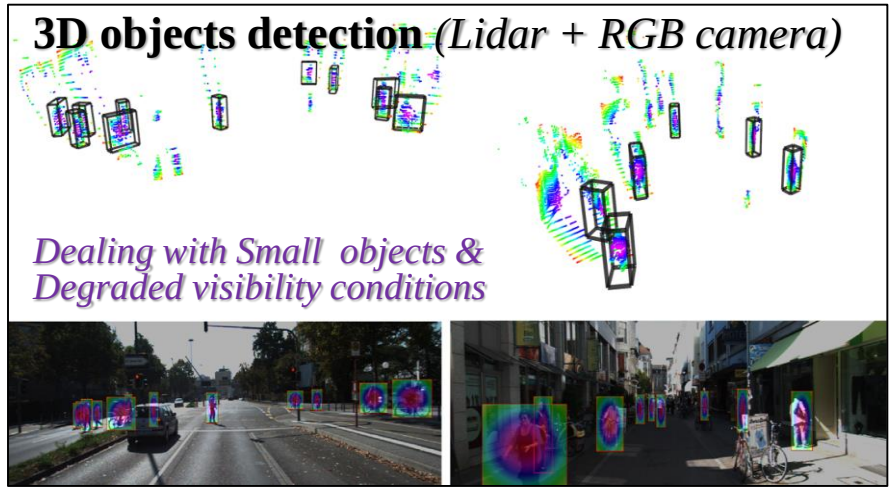


3rd *Paradigm:* Models improvements using Machine Learning

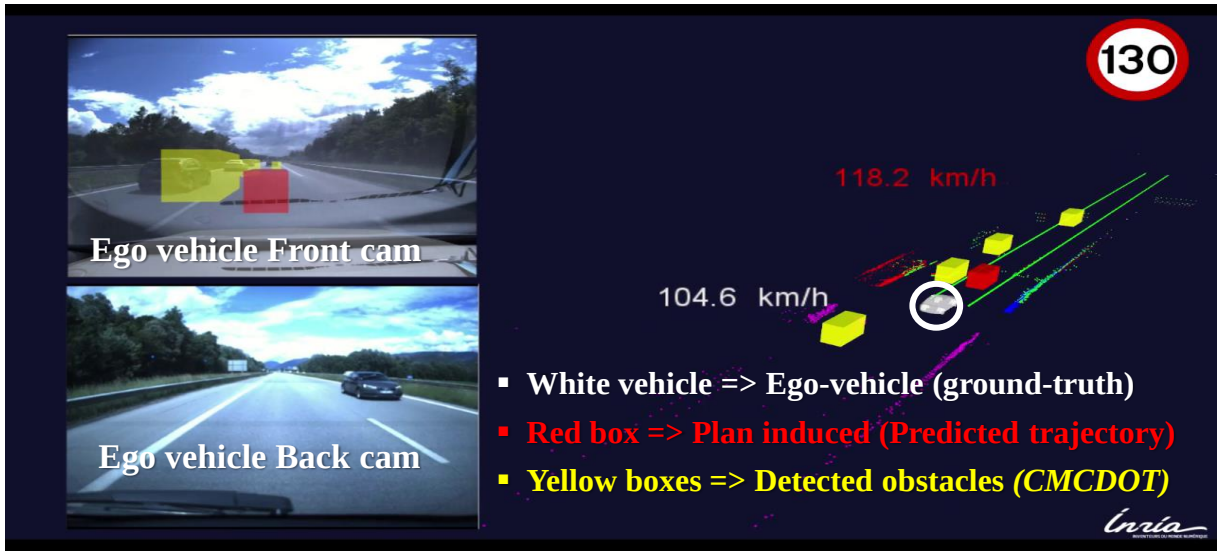
❑ Perception: *Hybrid sensor fusion (DOGMap & Semantically Segmented RGB images)*







❑ Prediction & Decision-making (Mixed Traffic): *Learn driving skills for Autonomous Driving*



- ***1st Step:*** *Modeling Driver Behaviors using IRL*
- ***2nd Step:***
  - *Predict behaviors of surrounding vehicles (using Perception & learned Behavior models)*
  - *Make "safe & consistent" Driving Decisions for Ego Vehicle (using Learnt models & Dynamic evidences)*

Open questions: *Robustness, Scalability, Validation*

- **Perception & Scene understanding:** *Fusing Bayesian & AI approaches should help … but still some open questions (even if CV community has already reached a quite good level of maturity)*
  - ✓ ***Training step*** *(Available Datasets insufficient) &* ***Classification Errors*** *(Hard to process)*
  - ✓ ***Degraded perception conditions*** *(Domain adaptation still an open question)*
  - ✓ ***Large-scaled scenes*** *(Combine different sensors modalities … but room for improvements)*

- **Decision-making in Mixed traffic:** *How to better take into account* ***Interactions with other road users*** *(human-driven cars, pedestrians, cyclists, etc.) ?*

  *=> "****Human-like models****" taking into account Social & Traffic rules* **…** *Still an open question !*

- **Validation & Certification approaches have to be developed**

  => Realistic simulators, Augmented Reality approaches, Formal Methods, and also Real-world testing protocols (e.g. EU Enable-S3 project & French project Prissma)