Digital trust for Autonomous Vehicles

Christian Laugier

Confiance numérique & Véhicule Autonome

La voiture autonome séduit … mais inquiète aussi ! => Statut & Challenges ?

Dr. Christian LAUGIER

Research Director at Inria (christian.laugier@inria.fr)

Invited Talk & Public Debate
IRT Nanoelec Annual Meeting
Minalogic Amphitheater & Internet broadcast
Grenoble, September 8th 2020

Digital trust for Autonomous Vehicles

The autonomous car is attractive, but it also worries ! => Status & Challenges ?

C. Laugier, Research Director at Inria

- **Strong involvement of Car Industry & GAFA + Large media coverage + Increasing Governments supports**
- **An expected market of 515 B€ at horizon 2035** *(~17% world automobile market, Consulting agency AT Kearney, Dec 2017)*
- **Last decade: A technological breakthrough & Numerous AV experimentation in real traffic conditions**

Tesla Autopilot L2 (ADAS)

- *32 millions km covered since 2009*
- *1st US self-driving taxi service L3 (Phoenix, since Dec 2018)*

Drive Me trials, Volvo 2017
100 vehicles, 80km, 70km/h

Autonomous Shuttle service

"Self-Driving Taxi Service L3" ***(Waymo, Uber, nuTonomy …)***
=> Numerous sensors & Safety Driver during experimentations

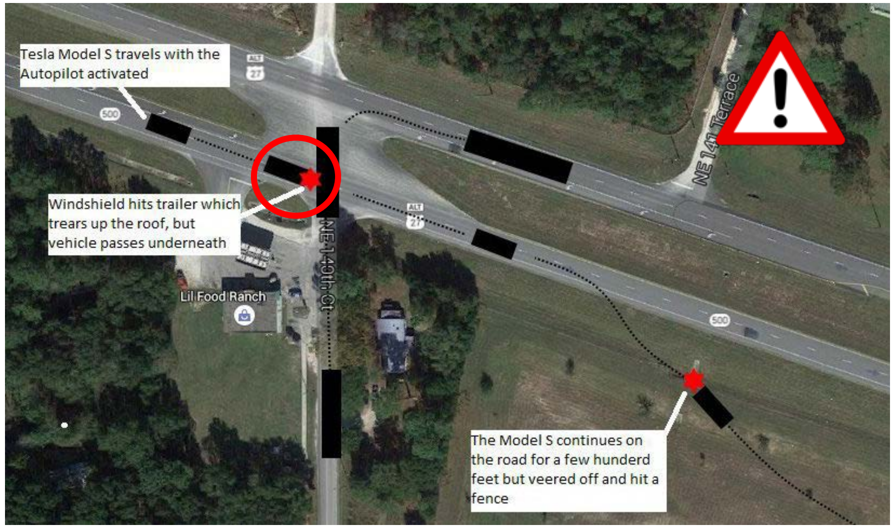
- **Millions of miles driven last decade… but SAFETY is still not guaranteed** *(Too many Benign & Serious accidents)*

=> Perception & Decision-making technologies have still to be improved !!!

Fatal accidents involving AVs – *Perception failure*

❑ Tesla driver killed in a crash with Autopilot "level 2" active *(ADAS mode) – May 2016*

- ✓ ***The Autopilot <u>failed to detect</u> a white moving truck, with a brightly lit sky*** *(Camera Mobileye + Radar)*
- ✓ ***The human driver was not vigilant & didn't took over***



❑ Self-driving Uber L3 vehicle killed a woman

=> First fatal crash involving a pedestrian

Temple, Arizona, March 2018

- ✓ ***Despite the presence of multiple sensors (lidars, cameras …), the <u>perception system failed to detect the pedestrian & didn't disengaged</u>***
- ✓ ***The Safety Driver reacted too lately*** *(1s before the crash)*

AVs have to face two main challenges

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

Video Scenario:

- *The Tesla perception system failed to detect the barriers blocking the left side route (no lidar !)*
- *The driver has to take over and steer the vehicle away from the blocked route (for avoiding the collision)*

Video source: AutoPilot Review @ youtube.com

Challenge 2: 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:

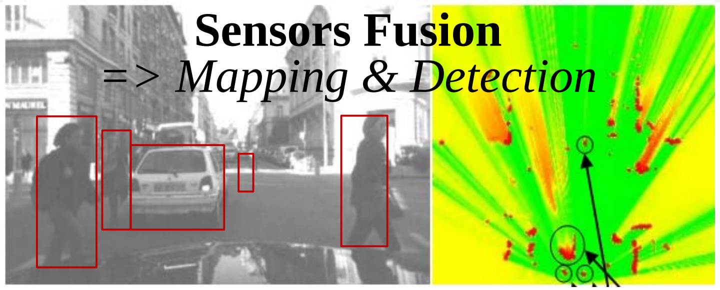
*Scene observed by the dash cam of a **bus** moving behind the Waymo AV*

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

Video source: The Telegraph

1st *Paradigm:* Embedded Bayesian Perception

Embedded Multi-Sensors Perception
⇒ ***Continuous monitoring of the dynamic environment***



❑ Main challenges

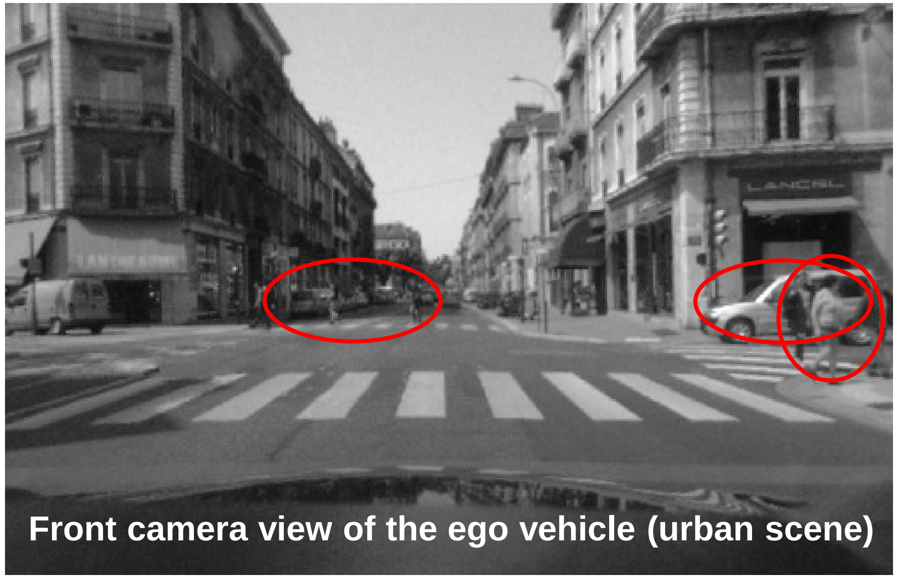
Noisy data, *Incompleteness*, ***Dynamicity***, *Discrete measurements +* ***Embedded & Real time*** *constraints*

❑ Embedded Bayesian Perception paradigm

- ✓ ***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 GPU, Multicore, Microcontrollers…*

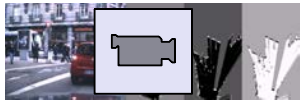
Embedded Bayesian Perception – *Illustration & Valorization*

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


Front camera view of the ego vehicle (urban scene)

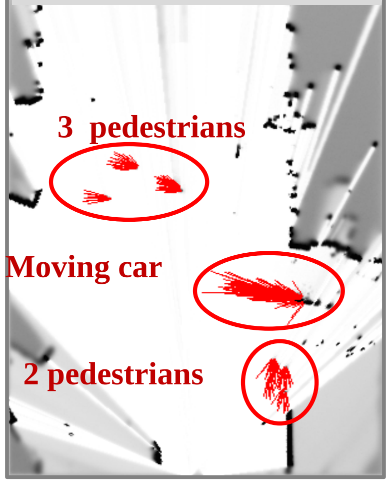
Sensors data fusion
+
Bayesian Filtering
+
Extracted Motion Fields

1st Embedded & Optimized version
=> Patent HSBOF 2014, Inria-IRT



Static part
=> Occupancy Grid

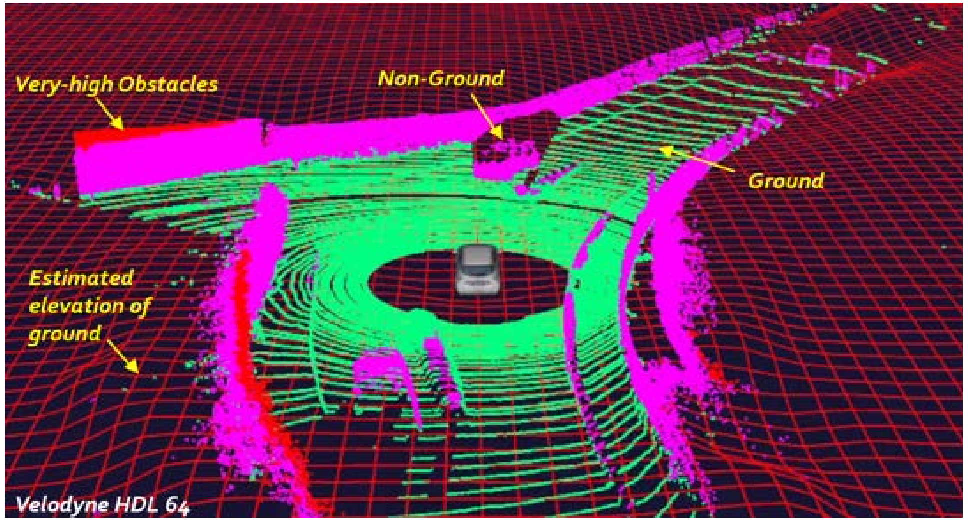
Dynamic part
=> Motion fields



Classification *(using Deep Learning)*

Detection & Tracking & Classification of Moving Objects
=> CMCDOT 2015 (including a "Dense Occupancy Tracker")

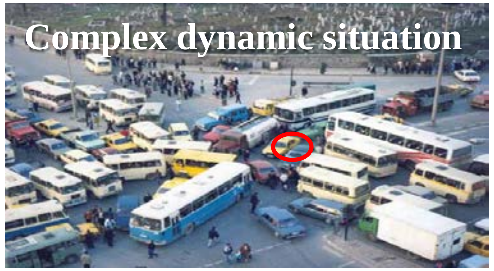
Patented & Registered Improvements
- ⇒ *Inria-IRT, 2015 & 2017*
- ⇒ *New patent filed 2020*
- ⇒ *Industrial Licenses 2018 (Toyota, Easymile)*

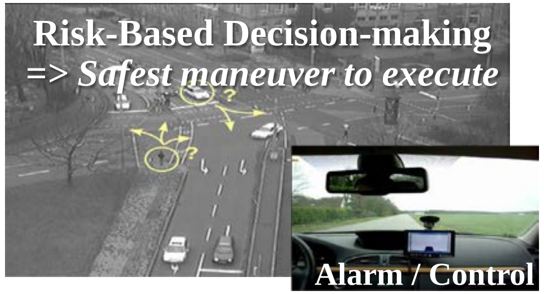


Ground Estimation & Point Cloud Classification (patent 2017)

2nd *Paradigm:* Collision Risk Assessment & Decision-making

=> Decision-making for avoiding Pending & Future Collisions





- **Main challenges**

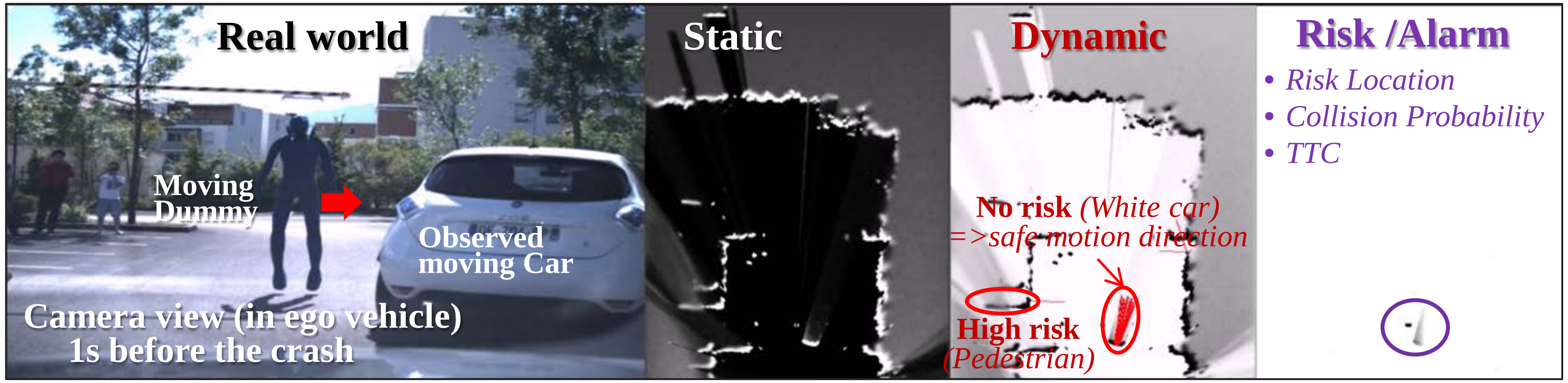
  *Uncertainty, Real-time … + **Continuous World changes & Unexpected events**, **Human in the loop***

- **Approach: Real-time Prediction + Risk Assessment + Bayesian Decision-making**

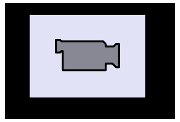
  ✓ ***Prediction:*** *Reason about **Uncertainty & Contextual Knowledge** (using **History** & **Prediction**)*

  ✓ *Estimate **Probabilistic Collision Risk** at a given **time horizon t+δ** (δ = a few seconds ahead)*

  ✓ *Make **Driving Decisions** by taking into account the **Predicted behavior** of all surrounding traffic participants (cars, cycles, pedestrians …) & **Social / Traffic rules** (interactions with traffic participants)*

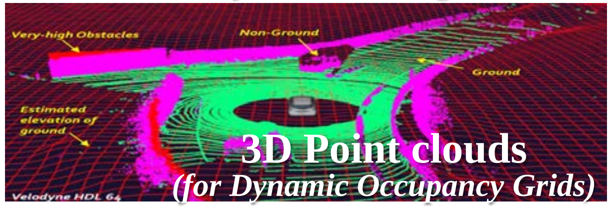


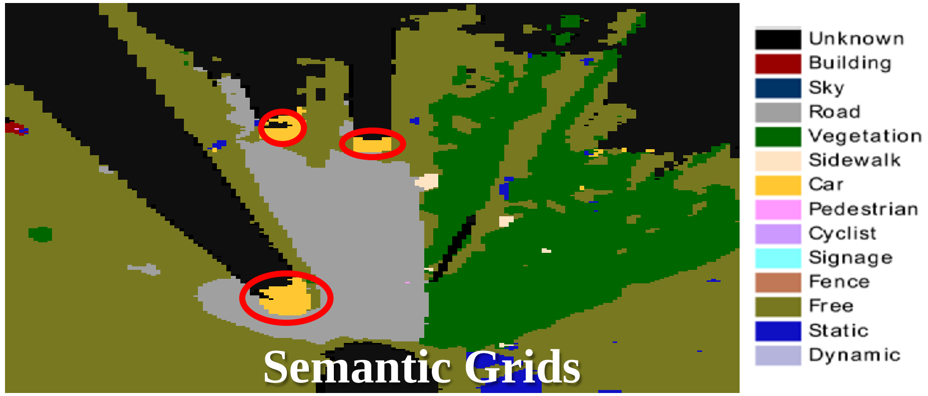
Video: Collision Risk Assessment
- Yellow => *time to collision: 3s*
- Orange => *time to collision: 2s*
- Red => *time to collision: 1s*



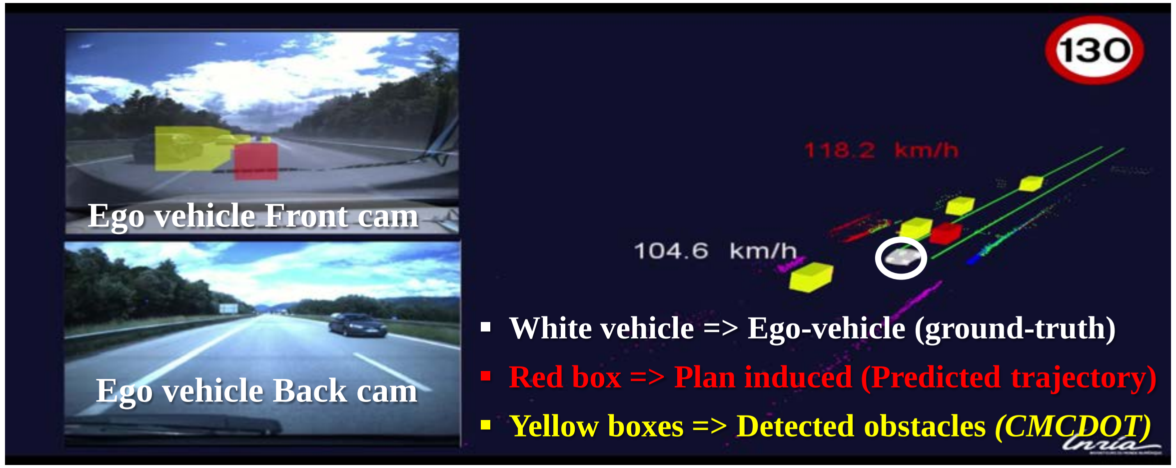
3rd *Paradigm:* Models improvements using Machine Learning

- **Perception level:** ***Construct "Semantic Grids" using Bayesian Perception & DL***





- **Prediction & Decision-making level:** ***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*

- **Open questions:** *Training step (Available Datasets limited), Real-time processing (difficult), Classification Errors (often not explainable), Domain adaptation (e.g. changing weather conditions)*

Concluding remarks & Discussion

- Increasing impact of AI + Real-time data processing capacity + Increased sensor performance + New Models & Embedded algorithms + Multiplication of tests in real conditions
  => The unmanned car is gradually becoming a technological reality

- Safety is not yet fully guaranteed !
  - *Current* ***Perception & Scene Understanding*** *algorithms are* ***not robust enough*** *for complex & highly dynamic environments*
  - *Need to take better account of* ***Interactions with other road users*** *(using also AI approaches)*
  - *Need to develop* ***Validation & Certification Tools and Methodologies*** *=> Realistic simulators, Real-world testing protocols, Formal methods (e.g. Enable-S3 EU project & future French project Prissma)*

- User confidence & Acceptance by the human society will be decisive to allow a real deployment (e.g. “cohabitation” with other users such as pedestrians, bicycles, scooters …)
  - *Autonomous vehicles* ***a priori safer*** *than cars driven by humans (inattention)…. but* ***0 tolerance in the event of a fatal accident involving an autonomous vehicle !***
  - ***Ethics & Responsibility issues*** *must also be taking into account before any deployment*