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Digital trust for Autonomous Vehicles

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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

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**



“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 !!!**

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

- ✓ *The Autopilot failed to detect 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 perception system failed to detect the pedestrian & didn't disengaged*
- ✓ *The Safety Driver reacted too lately (1s before the crash)*



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



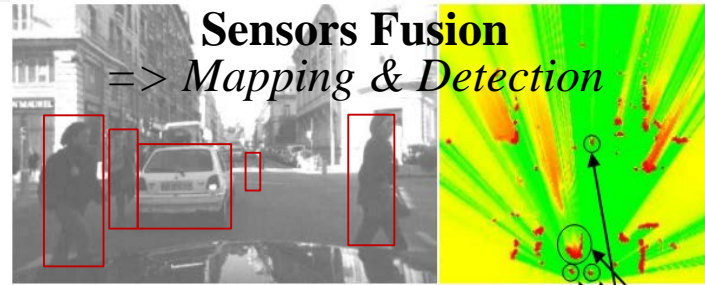
Video scenario:

- 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](#)



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



❑ Main challenges

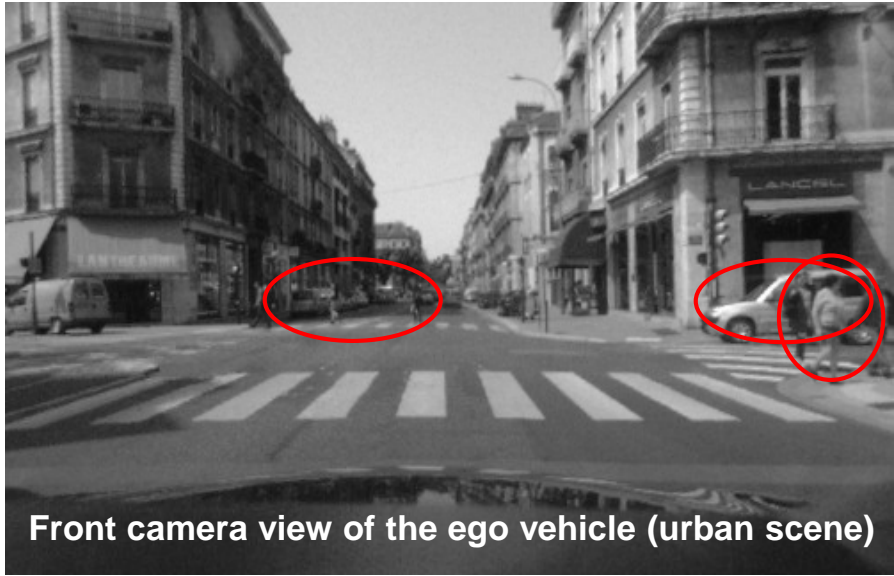
Noisy data, Incompleteness, Dynamicity, Discrete measurements + Embedded & Real time constraints

❑ 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



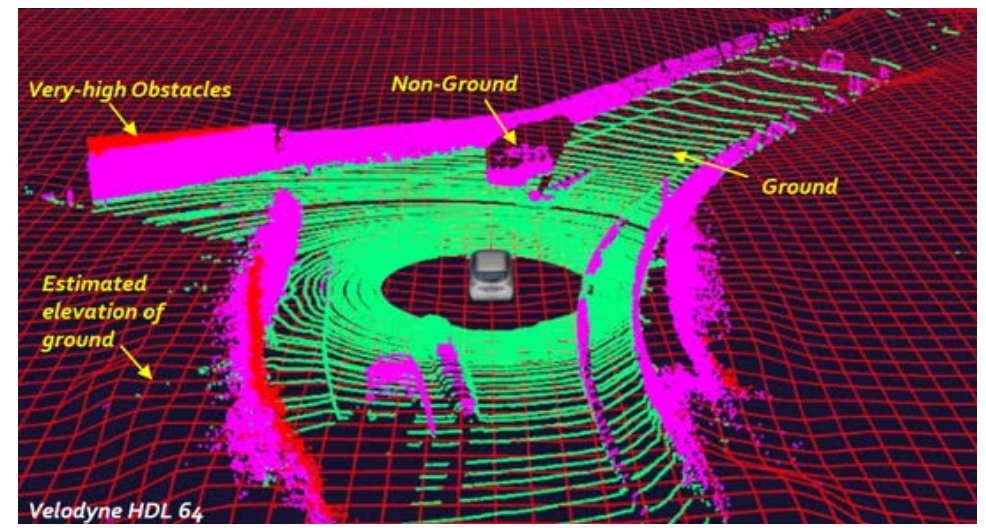
Sensors data fusion
+
Bayesian Filtering
+
Extracted Motion Fields



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



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

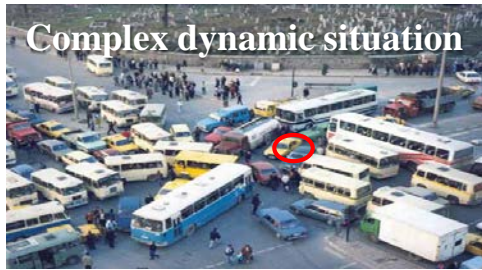


Detection & Tracking & Classification of Moving Objects
=> CMCDOT 2015 (including a "Dense Occupancy Tracker")

Ground Estimation & Point Cloud Classification
(patent 2017)

2nd Paradigm: Collision Risk Assessment & Decision-making

=> *Decision-making for avoiding Pending & Future Collisions*



□ Main challenges

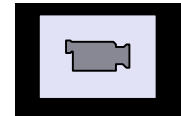
Uncertainty, Real-time ... + Continuous World changes & Unexpected events, Human in the loop

□ 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 $t+\delta$** ($\delta =$ 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)

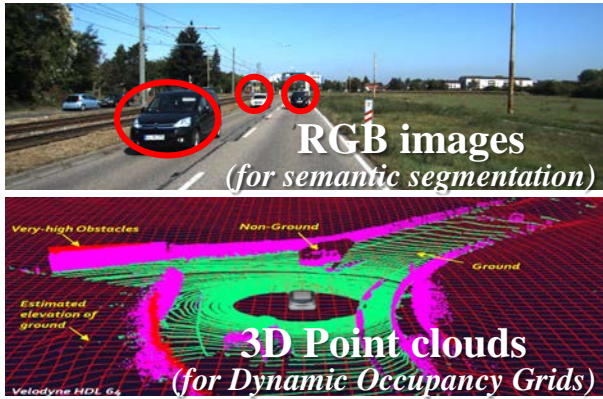


- Video: Collision Risk Assessment**
- Yellow => time to collision: 3s
 - Orange => time to collision: 2s
 - Red => time to collision: 1s

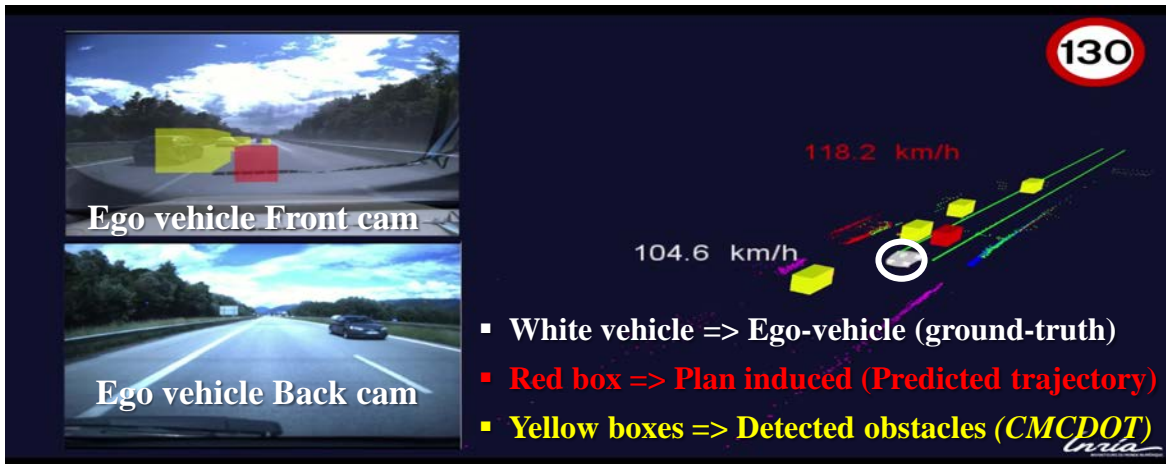


3rd Paradigm: Models improvements using Machine Learning

□ 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*