HAL
open science

Embedded Perception & Decision-making for Safe Navigation in Uncertain, Dynamic and Human-populated Environments

Christian Laugier

▶ **To cite this version:**

Christian Laugier. Embedded Perception & Decision-making for Safe Navigation in Uncertain, Dynamic and Human-populated Environments. Coboteam Workshop on "Robot Navigation", May 2020, Grenoble & On-line event, France. hal-03147808

HAL Id: hal-03147808

https://inria.hal.science/hal-03147808

Submitted on 20 Feb 2021

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.

Embedded Perception & Decision-making for Safe Navigation in Uncertain, Dynamic and Human-populated Environments

Christian LAUGIER *, Research Director at Inria*
Inria Chroma team & IRT Nanoelec

Invited Talk – *Coboteam Workshop on "Robots Navigation"*
France, On-line event, May 28th 2020

© Inria & Laugier. All rights reserved

Technology status & Ongoing challenges for AVs

- **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)*
- **But Validation & Certification issues are still unclear … idem for Legal & Regulation issues**

=> Numerous experiments in real traffic conditions since 2010 (Disengagement reports => Insights on system maturity)

=> But still insufficient … Realistic Simulation & Formal methods are also under development (e.g. EU Enable-S3)

Millions of miles driven since 2010 (Google, Tesla, Waymo, Uber,)
Several benign & serious accidents in past few years
Safety is still not guaranteed !

Tesla Autopilot L2 with Radar & Mobileye/Intel
*Commercial ADAS product =>**Tested by customers** …*

Numerous EU projects in last 2 decades
Cybus, 3 months experiment, low speed
La Rochelle 2012 (France)

Dense 3D mapping & Numerous vehicles
10 years R&D, 8 millions km covered since 2010 & 25 000 km/day

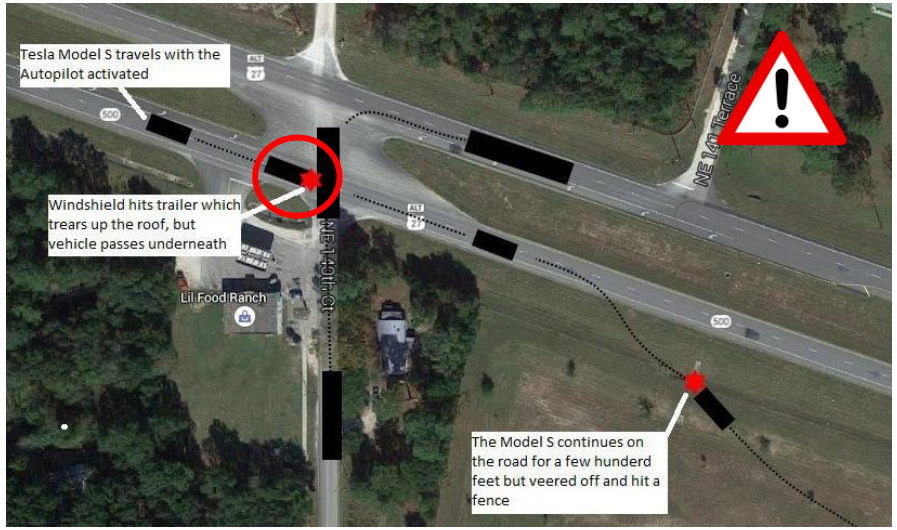
Drive Me trials (Volvo, 2017)
- *100 Test Vehicles in Göteborg, 80 km, 70km/h*
- *No pedestrians & Separations between lanes*

"Self-Driving Taxi Service L3" testing in US *(Uber, Waymo)* & Singapore *(nuTonomy)*
⇒ ***Autonomous Mobility Service**, Numerous Sensors + "Safety driver" during testing (take over in case*
⇒ ***Uber:** System testing since 2017, Disengagement every 0.7 miles in 2017 (improved now)*
⇒ ***Waymo:** 1st US Self Driving Taxi Service launched in Phoenix in Dec 2018*
⇒ ***Disengagement reports provide insights on the technology maturity***

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*
- *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 Bayesian Perception & Decision-making

Main Challenges & Required Technological Breakthrough

=> Robustness, Efficiency, Dynamic Human Environments (Safety is still not guaranteed)

=> Real-time integration of Perception & Motion planning & Control

=> Integration into Embedded Hardware & Software (future products)

=> Validation & Certification

ADAS & Autonomous Driving

Perception & Decision-making requirements for AVs

Dynamic Scene Understanding & Navigation Decisions

Situation Awareness & Decision-making

⇒ *Sensing + Prior knowledge + Interpretation*

⇒ *Selecting appropriate Navigation strategy (planning & control)*

Embedded Perception & Decision-making for Safe Intentional Navigation

Dealing with unexpected events

Anticipation & Risk Prediction technologies

for avoiding upcoming collisions with "something"

=> *High reactivity & reflexive actions*

=> *Focus of Attention & Sensing*

=> *Collision Risk estimation + Avoidance strategy*

Main features

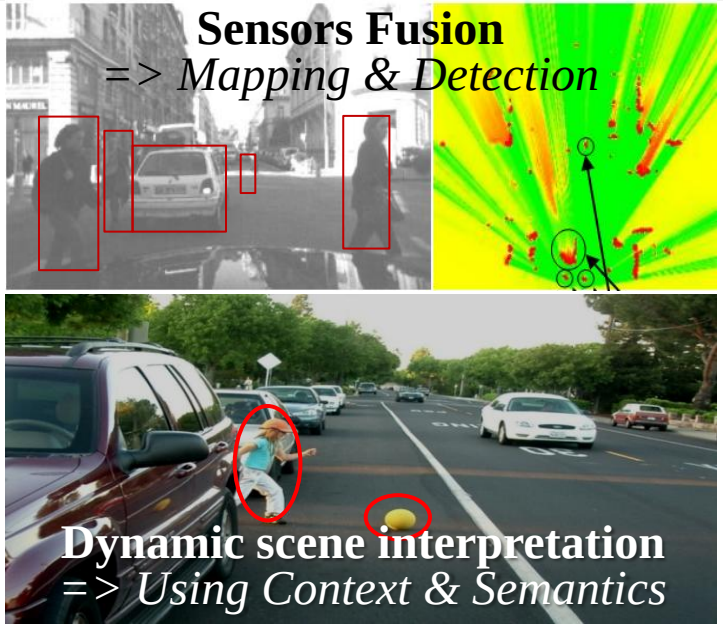
- ✓ Dynamic & Open Environments => *Real-time processing & Reactivity (several reasoning levels are required)*
- ✓ Incompleteness & Uncertainty => *Appropriate Model & Algorithms (probabilistic approaches)*
- ✓ Sensors limitations (no sensor is perfect) => *Multi-Sensors Fusion*
- ✓ Hardware / Software integration => *Satisfying Embedded constraints*
- ✓ Human in the loop (mixed traffic) => ***Human Aware Decision-making process (AI based technologies)***

  Taking into account Interactions + Behaviors + Social rules (including traffic rules)

1st Paradigm : Embedded Bayesian Perception

Embedded Multi-Sensors Perception

⇒ ***Continuous monitoring of the dynamic environment***



❑ Main challenges

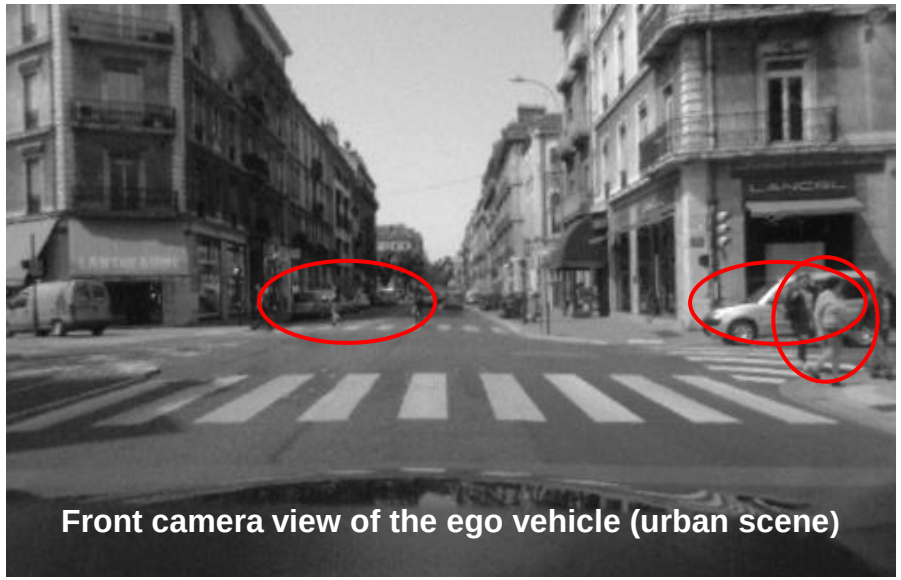
- ✓ *Noisy data, Incompleteness, Dynamicity, Discrete measurements*
- ✓ ***Strong Embedded & Real time constraints***

❑ Our Approach: Embedded Bayesian Perception

- ✓ *Reasoning about* ***Uncertainty & Time window*** *(Past & Future events)*
- ✓ ***Improving robustness*** *using* ***Bayesian Sensors Fusion***
- ✓ ***Interpreting the dynamic scene*** *using* ***Contextual & Semantic*** *information*
- ✓ ***Software & Hardware integration*** *using GPU, Multicore, Microcontrollers…*

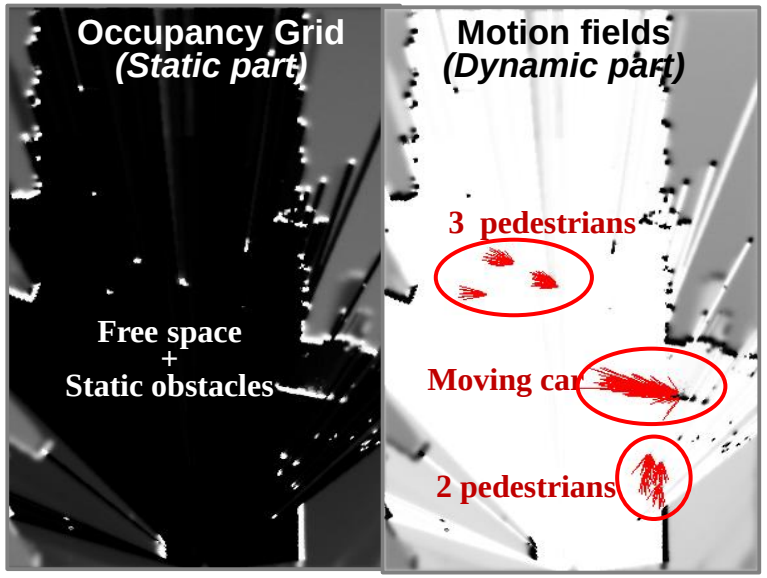
Dynamic Probabilistic Grid & Bayesian Filtering – *Main Features*

Exploiting the dynamic information for a better understanding of the scene

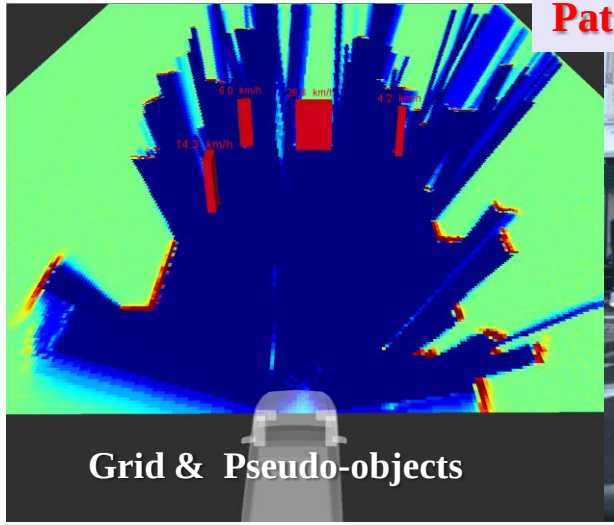


Sensors data fusion
+
Bayesian Filtering
+
Extracted Motion Fields

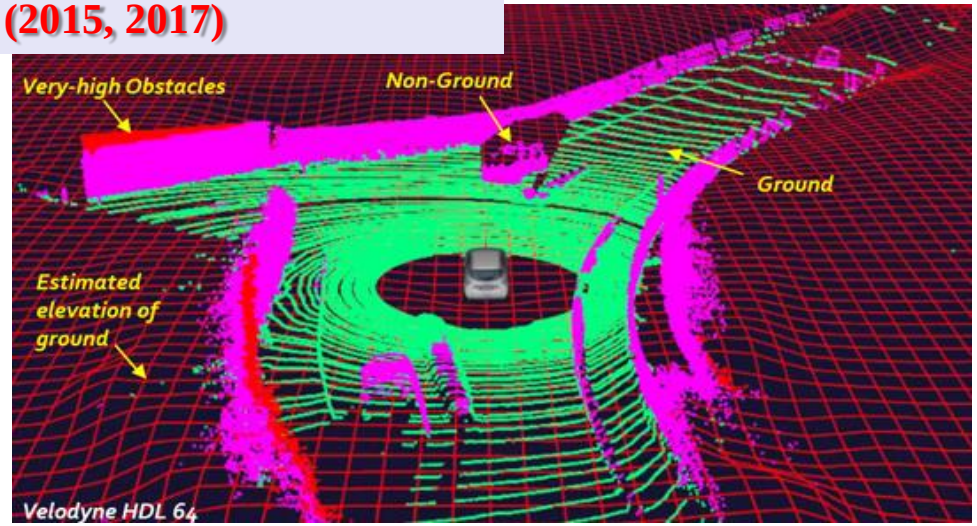
1st Embedded & Optimized version
(HSBOF, patent 2014)



Patented Improvements & Implementations (2015, 2017)



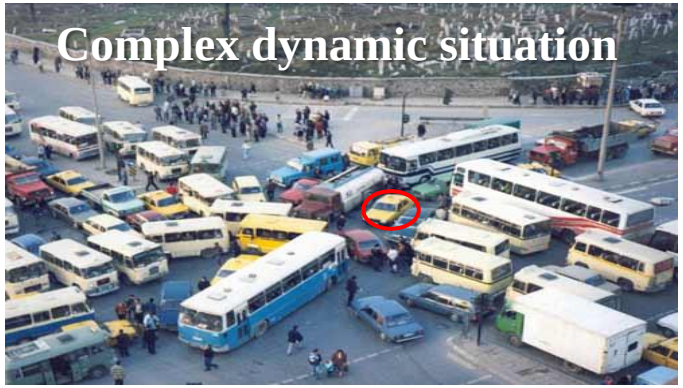
Detection & Tracking + Moving Objects Classification
=> CMCDOT 2015 (including a "Dense Occupancy Tracker")



Ground Estimation & Point Cloud Classification
(patent 2017)

2nd Paradigm: Collision Risk Assessment & Decision-making

Decision-making for avoiding Pending & Future Collisions



❑ Main challenges

Uncertainty, Partial Knowledge, World changes, Real time

Human in the loop + Unexpected events + Navigation Decision based on <u>Perception & Prior Knowledge</u>

❑ Approach: *Prediction + Risk Assessment + Bayesian Decision-making*

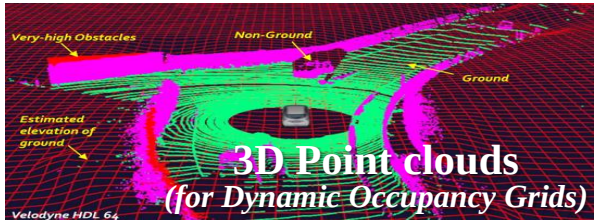
- ✓ *Reason about **Uncertainty & Contextual Knowledge** (using **History** & **Prediction**)*
- ✓ *Estimate **<u>Probabilistic Collision Risk</u>** at a given **time horizon t+δ** (δ = a few seconds)*
- ✓ *Make **<u>Driving Decisions</u>** by taking into account the **Predicted behavior** of <u>all the observed surrounding traffic participants</u> (cars, cycles, pedestrians ...) & **Social / Traffic rules***

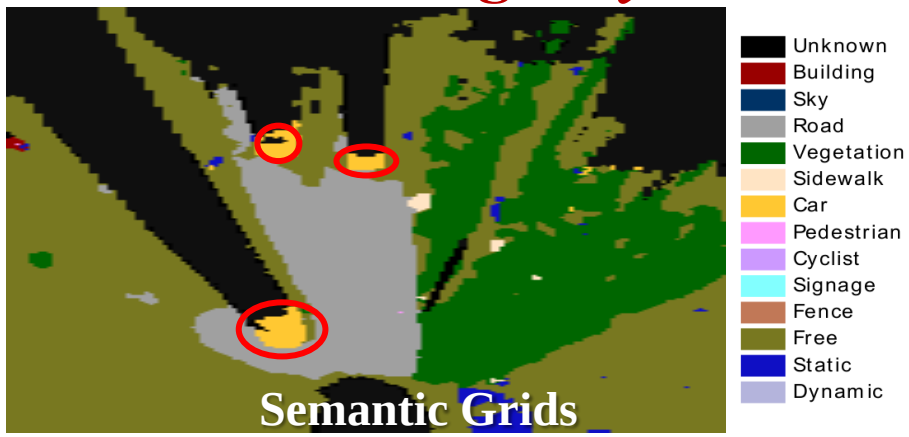
❑ Decision-making: *Two types of "collision risk" have to be considered*

- ✓ ***Short-term collision risk** => Imminent collisions with "<u>something</u>" (unclassified), time horizon <3s, conservative hypotheses*
- ✓ ***Long-term collision risk** => Future potential collisions, horizon >3s, Context + Semantics, Behavior models*

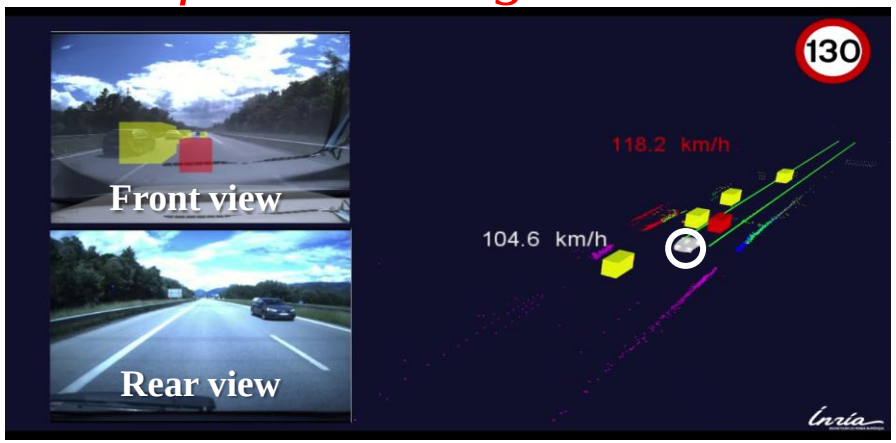
3rd Paradigm: Models improvements using Machine Learning

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





- **Decision-making level:** ***Learn driving skills for Autonomous Driving***
  - *1st Step:* ***Modeling Driver Behavior*** *using Inverse Reinforcement Learning (IRL)*
  - *2nd Step:* ***Predict motions*** *of surrounding vehicles &* ***Make Driving Decisions*** *for Ego Vehicle*



4th *Paradigm:* Combining Motion Planning & Safe navigation

Global planner – Hybrid-State E*

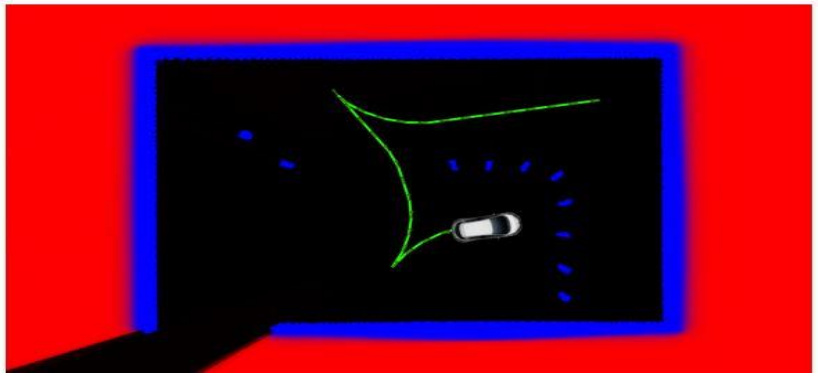
Pros & cons

+ Considers occupancy uncertainty
+ Continuous path even at low resolution
+ Allows complex maneuvers
+ Favors simple maneuvers
- Discrete space representation
- No obstacle motion

Future work

- Use exact vehicle shape
- Online replanning

Example of a computed path



Local planner – DWA

Accuracy

- Accurate trajectory prediction
- Accurate ego vehicle shape

Computing efficiency

- Massively parallel computations over ego vehicle positions and trajectories

Simplicity

- Only simple trajectories
- Short term prediction (5-10s)

Command sampling illustration

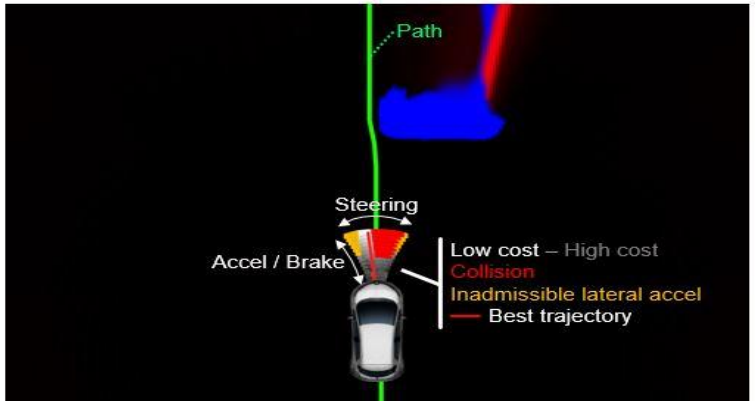


Illustration: Video demos IROS 2018 (Madrid)