W4. Perception & Situation Awareness & Decision making

- Robot Perception for Dynamic environments: Outline & DP-Grids concept
- Dynamic Probabilistic Grids – Bayesian Occupancy Filter concept
- Dynamic Probabilistic Grids – Implementation approaches
- Object level Perception functions (SLAM + DATMO)
- Detection and Tracking of Mobile Objects – Problem & Approaches
- Detection and Tracking of Mobile Objects – Model & Grid based approaches
- Embedded Bayesian Perception & Short-term collision risk (DP-Grid level)
- Situation Awareness – Problem statement & Motion / Prediction Models
- **Situation Awareness – Collision Risk Assessment & Decision (Object level)**

Collision Risk Assessment – *Outline*

- **Motion models** can be used to ***predict the evolution of the current traffic situation***. Then, the ***"Risk"*** of the current traffic situation can be estimated

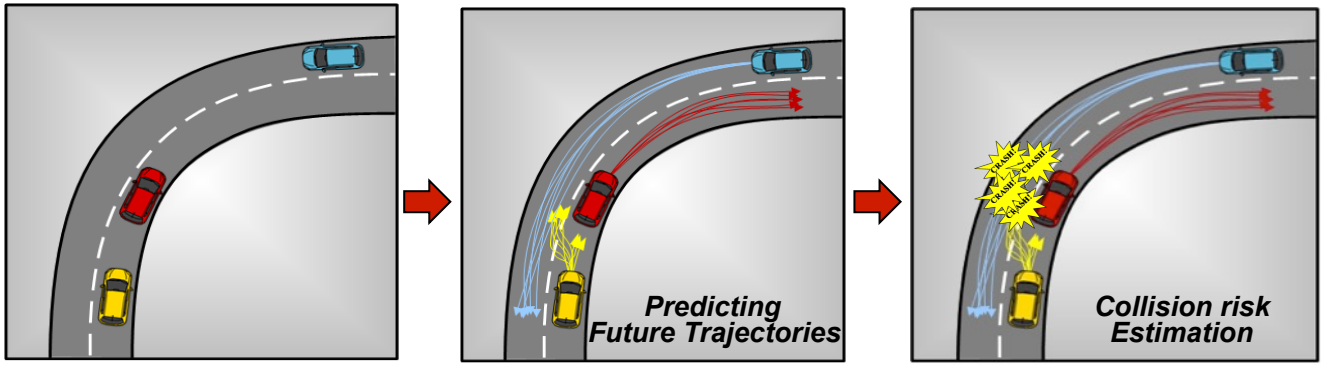
- **Risk is an ambiguous concept**
  In general it is associated with the idea that a *situation may be dangerous for the driver*, i.e. may result in harm or injury

  - **Collisions** are considered as the main source of Risk
    ➔ *Risk assessment is solely based on* ***"Collision Prediction"***

  - A **more general interpretation** of the notion of Risk consists in detecting **"Dangerous Situations"**
    ➔ ***"Dangerous Situations"*** *arise from drivers performing* ***unexpected maneuvers***

Approach 1: Risk based on collision prediction

- **Two complementary steps**
  1. **Predict** the potential future trajectories for all the moving entities *(see session 8)*
  2. **Detect collisions between each possible pair of trajectories**, and derive a ***Risk estimate*** *based on the overall chance of collision*



$$Collision\_risk = \sum_{(T_i,T_j)} P(T_i) \times P(T_j) \times P(collision|T_iT_j)$$

Risk based on collision prediction

Binary collision prediction

- A **vehicle** is typically approximated as a ***point***, ***ellipse***, *or* ***polygon***

- Detecting **collisions between pairs of trajectories**:
  - ⇒ *Analytical solution (case of linear motion models)*
  - ⇒ *Discretized trajectories* & *Checking for collision points iteratively*

Risk based on collision prediction

Probabilistic collision prediction

- Takes into account the **uncertainty on the future motion** of the vehicles in the scene
- **Main idea:** **Integrate** over the possible future trajectories & **Detect collisions** between each possible pair
- **Several ways to compute the probabilistic collision risk:**
  - Sum over both the *Maneuvers & their Physical Executions*
  - Select the *most likely Maneuver & Sum on the possible Physical Executions*
  - Compute the *Risk of colliding with a specific vehicle*
  - Sum over all the vehicles to obtain a *Global collision risk*

  …

Risk based on collision prediction

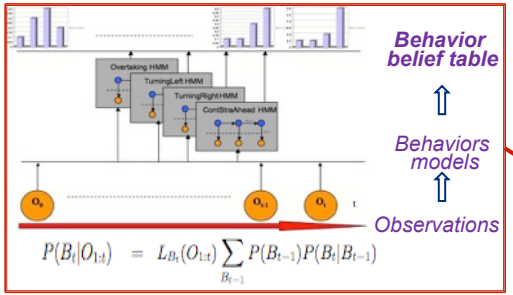
Other risk indicators

- **By analyzing further the Predicted Trajectories & their Intersecting Points**, it is possible to **derive some indicators** *(giving more information about the potential collision)*
  - *Velocity of the vehicles when the collision occurs*
  - *Configuration of the collision*
  - *Time-To-X indicators*
    - ✓ *Time-To-Collision (TTC): time remaining before the collision occurs*
    - ✓ *Time-To-React (TTR): time available for the driver to react before the collision becomes inevitable*

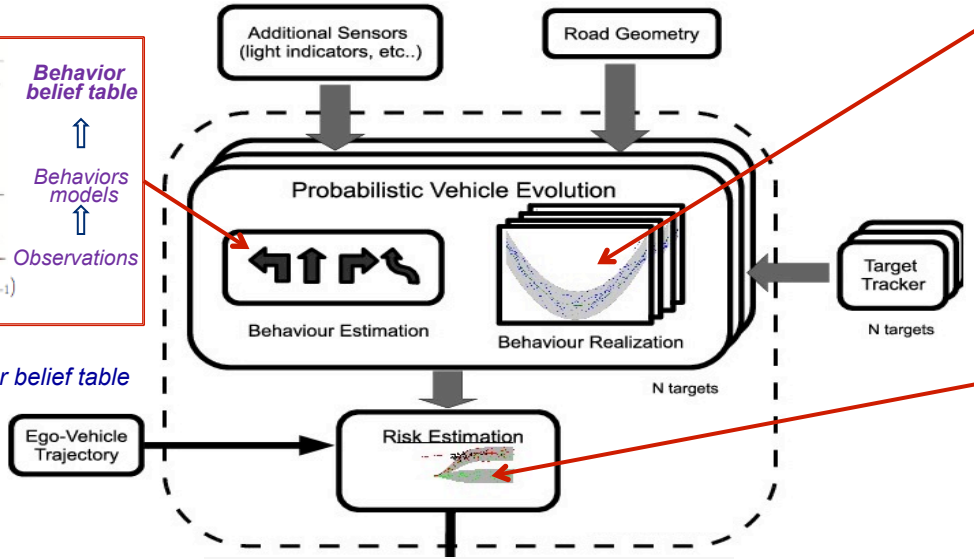
- **These other risk indicators** can be used to determine the best way to **mitigate** or to **avoid** the potential collision

Risk based on collision prediction

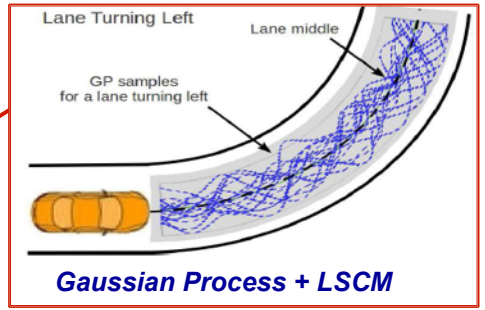
A practical architecture (Patented Inria / Toyota / Probayes)

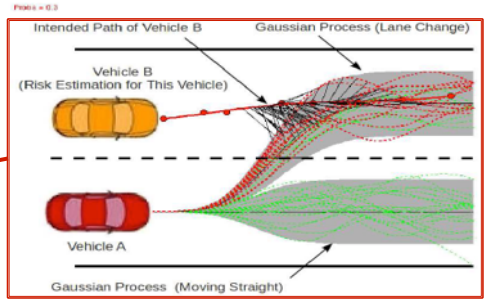


*Modeled using **Layered HMM***
=> Learned Behaviors + Behavior belief table



Probabilistic Collision Risk
Calculated for a few seconds ahead

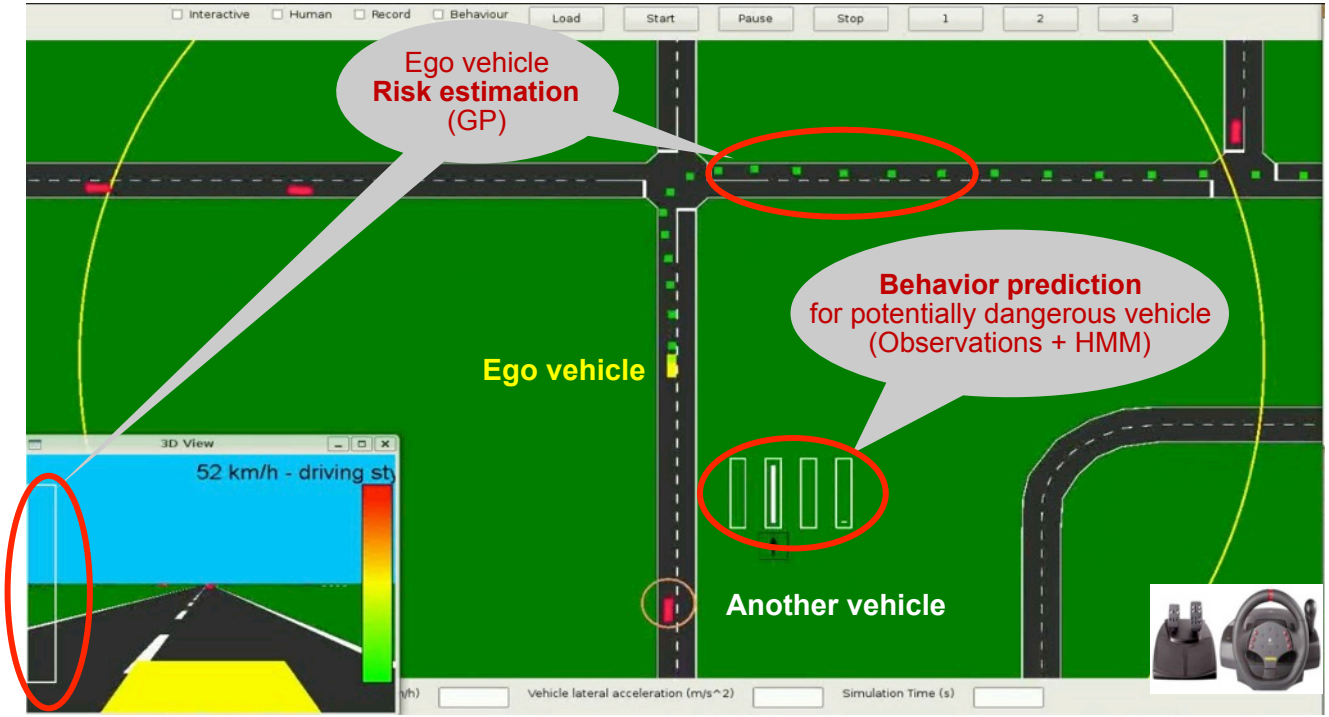




For more details see [Tay 09] [Handbook of IV 2012 (chap. 54)]

Risk based on collision prediction

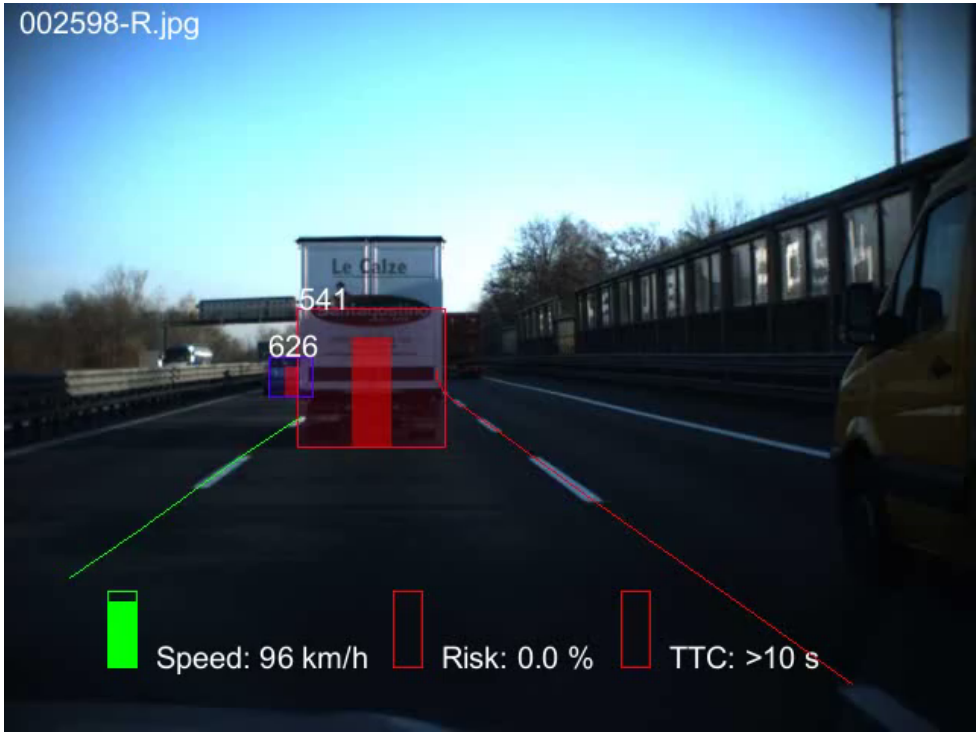
Validation using simulator *(Toyota simulator + Driving device)*



- Large road network & large number of simulation
- Ego vehicle driven manually
- Behaviors previously learned
  => using driving devices
- Behavior prediction for potentially dangerous surrounding vehicles
  => displayed on the simulator screen
- Risk estimation for ego vehicle
  => displayed the simulator screen

Risk based on collision prediction

Experimental results on highway *(Inria + Probayes +Toyota)*



Traffic participants behavior prediction & Collision risk estimation

(Courtesy Probayes)

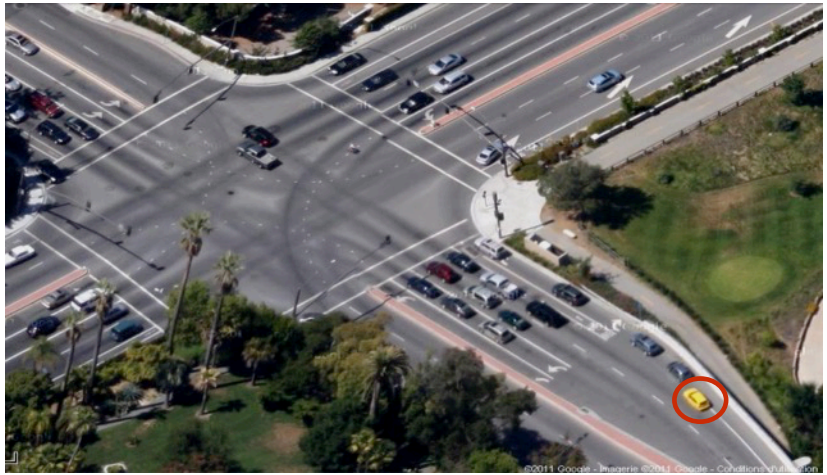
Approach 2: Risk based on unexpected behavior

- **Main idea**
  Instead of predicting future trajectories of vehicles: detect behaviors which deviate from the nominal behavior expected on the road

- **How to detect unexpected behavior?**
  - **Expected behavior =**
    - ✓ Behavior which complies with traffic laws
    - ✓ What human drivers usually do
    - ✓ **Combination of the two definitions above** when the traffic laws are vague, e.g. at **road intersections**

Risk based on unexpected behavior

Cooperative safety at road intersections



Road intersection

- *Complex Geometry & Traffic context*
- *Large number of Vehicles & Possible Maneuvers*
- *Vehicle behaviors are **Interdependent***
- ***Human Drivers are in the loop!***
- *90% of accidents are caused by **Drivers Errors***

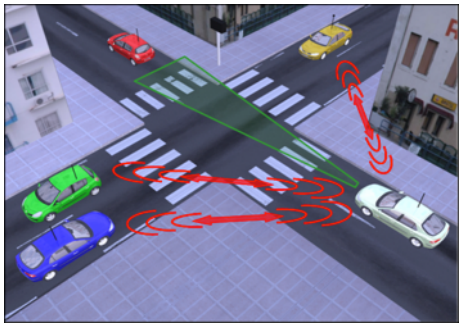
  => Detect Drivers Errors instead of colliding trajectories

Risk based on unexpected behavior

Road intersections: A human-like reasoning process

The Intention & Expectation approach *(Patent Inria / Renault)*

- *Exchanging vehicle states information (V2V communication and/or Perception)*
- *Estimating **"Drivers Intentions"***
- *Inferring **"Behaviors Expectations"***
- ***Risk** = Comparing Maneuvers **Intention & Expectation***



[Lefevre & Laugier IV'12]

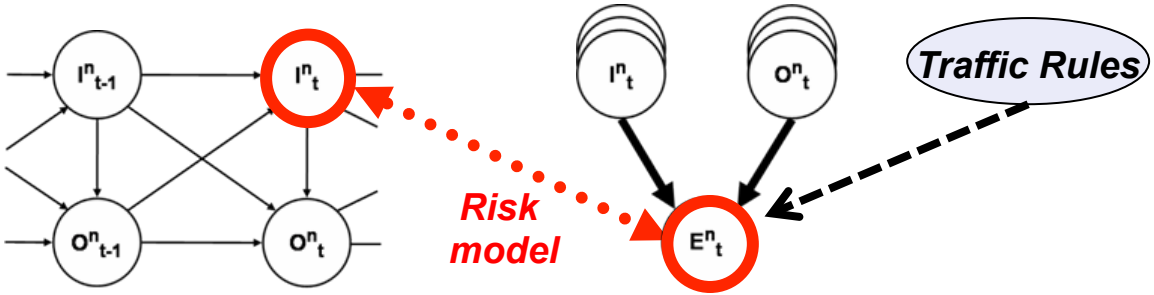
Risk based on unexpected behavior

Road intersections: A human-like reasoning process

Implemented process:

- **Intention** I_t^n: *Estimated from the* ***successive states observations*** O_t *=(X, Y, θ, S, Turn signal)*
- **Expectation** E_t^n: *Estimated from* ***Drivers Intentions & Traffic rules***
- **Risk**: *Based on* $P([I_t^n = 0][E_t^n = 1]|O_{0:t})$

Dynamic Bayesian Network



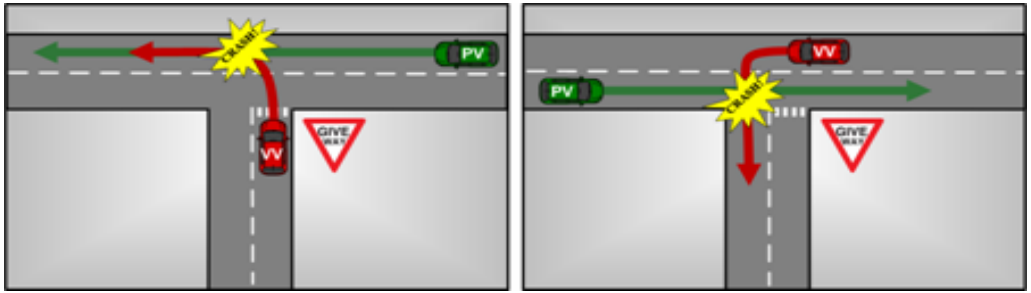
Intention model I_t^n **Expectation model** E_t^n

Risk based on unexpected behavior

Road intersections: Experimental results

- **Two Renault passenger vehicles**
  - *Equipped with off-the-shelf V2V modems*
  - *Sharing position, heading, speed, turn signal information at 10 Hz*

- **Collision scenarios:** *Blind rural intersection near Paris*



- **90 instances, 9 Drivers** *(No accident)*

Risk based on unexpected behavior

Road intersections: Experimental results

Conclusion

- **Risk estimation based on collision prediction**
  - Needs **trajectory prediction** for all the entities in the scene
  - Many metrics can be derived to **quantify the severity of the collision**
  - **Popular approach**, but often computationally demanding
- **Risk estimation based on unexpected behavior**
  - Assumes that risk is caused by **vehicles behaving differently from the nominal behavior**
  - **Conflicts are detected at the maneuver intention level**
  - Complementary to trajectory prediction

MOBILE ROBOTS AND AUTONOMOUS VEHICLES

1. Objectives, Challenges, State of the Art, Technologies
2. Bayes & Kalman Filters
3. Extended Kalman Filter, Observability properties
4. Perception & Situation Awareness & Decision Making
5. Behavior Modeling & Learning

Christian Laugier

Inria informatiques mathématiques