Exchanging dynamic and imprecise information in V2V networks with belief functions

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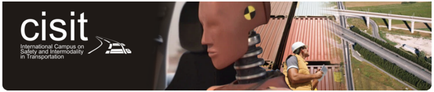
Introduction

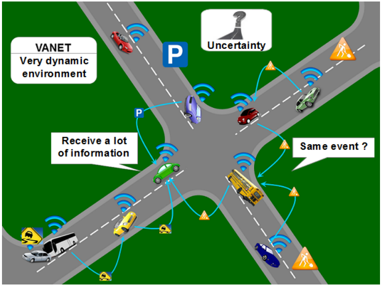
Context: Work is carried out under the french regional project CISIT.



Goal:

- Get for each vehicle an accurate knowledge of reality, especially that of neighboring events.
- Help vehicles to arrive as quickly as possible to destination.

➡ Share and manage imperfect information without infrastructure using belief functions.



First work: Cherfaoui et al. FUSION'2008, Bou Farah et al. IV'2011

Plan

1. Theory of belief functions
2. Proposed method
   - Exchanged messages
   - Management of exchanged messages
   - Give an overview of the situation to the driver
3. Experimental tests
   - Simulator
   - Scenario n°1 - non-spatial event
   - Scenario n°2 - spatial event
4. Conclusions and future work

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Theory of belief functions: summary

- **Information representation:** knowledge is represented by mass function $m : 2^{\Omega} \to [0,1]$ where:

$$\sum_{A \subseteq \Omega} m(A) = 1 \ .$$

  - A belief mass can be assigned to a singleton or to a subset.
  - The subsets A of Ω such that $m(A) > 0$ are called the *focal elements* of m.
  - Belief functions are a generalization of probability functions since the size of focal elements can be greater than 1.

- **Discounting:**

$$\begin{cases} {}^{\alpha}m(A) &= (1-\alpha)m(A) \ , \quad \forall A \subset \Omega \ , \\ {}^{\alpha}m(\Omega) &= (1-\alpha)m(\Omega) + \alpha \ , \end{cases}$$

where discounting rate $\alpha \in [0,1]$.

Theory of belief functions: summary

- **Information fusion:** conjunctive rule of combination

$$m_{1 \textcircled{\cap} 2}(A) = \sum_{B \cap C = A} m_1(B) \cdot m_2(C) \ , \forall A \subseteq \Omega$$

where m_1 and m_2 are obtained from distinct and reliable sources.

- **Decision making:** pignistic probability

$$BetP(\{\omega\}) = \sum_{\{A \subseteq \Omega, \omega \in A\}} \frac{m(A)}{|A| \ (1 - m(\emptyset))}, \quad \forall \omega \in \Omega \ .$$

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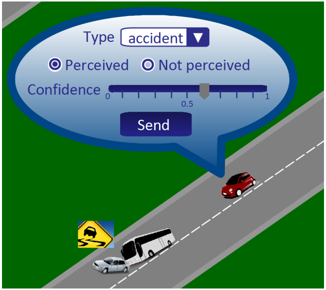
Exchanged messages

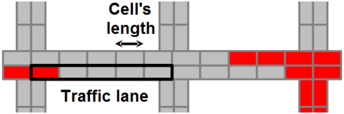
- A created or received message contains information about an event on the road.
- A source S having perceived an event of type t, at date d and at location ℓ, creates a message $M(S, t, d, \ell, m)$ to inform of its presence.
- The belief of the source S concerning the presence or the non-presence of an event is represented by the mass function m, where $\Omega = \{\exists, \nexists\}$.



- A vehicle can either broadcast a new message, or forward a received message. The fusion result is not disseminated.

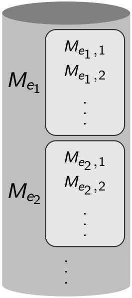
Management of exchanged messages

- Each vehicle has an internal database of created and received messages.
- Traffic lanes are divided into small rectangular areas named *cells*, whose width is equal to the traffic lane width, and length is fixed and depends on event type.



- An event e is a couple (t, c) where t is its type and c is the cell on whitch it is located.
- Created and received messages $M_{e,i}$ concerning the same event e are grouped into a table M_e in vehicle database.

Vehicle v



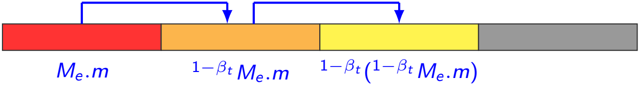
Give an overview of the situation to the driver

Main mechanism - fusion of received messages:

1. For each event: conjunctive combination of discounted belief functions ${}^{\alpha_{e,i}}M_{e,i}.m$, with $\alpha_{e,i} = \frac{\Delta(now, M_{e,i}.d)}{Del_t}$ (ageing).

Secondary mechanism - consider neighboring cells influences:

2. For each occupied cell by a spatial event type: generate influences on its neighborings (β_t is the influence rate).



3. For each cell: conjunctive combination of obtained masses.

Overview:

4. Pignistic probability of each event (event type, cell).

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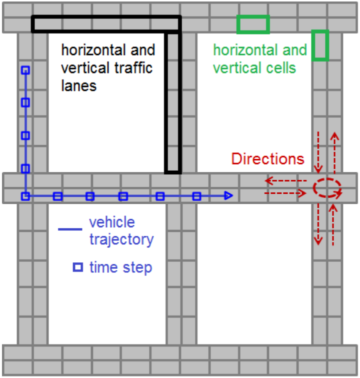
Simulator

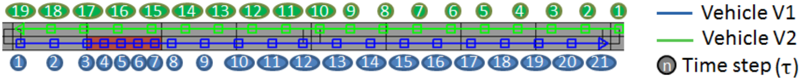
- A simulator has been developed in Matlab™.

- A map is composed of horizontal and vertical two-way streets.
- Traffic lanes are divided into cells.
- The scenarios are discretized in time steps τ. At each τ, each vehicle:
  - Confirms the presence of detected events ($m(\{\exists\}) = \mathit{confidence}$ and $m(\Omega) = 1 - \mathit{confidence}$).
  - Denies non-perceived events whitch are present in its database ($m(\{\nexists\}) = \mathit{confidence}$ et $m(\Omega) = 1 - \mathit{confidence}$).
  - Communicates its messages to neighboring vehicles.



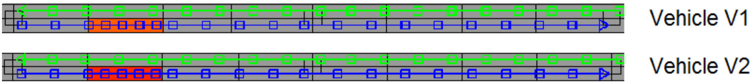
Scenario n°1 - non-spatial event

- **Reality:** An accident is present on a simulator cell of a traffic lane.



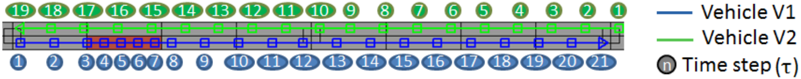
  - $\tau = 3$: V_1 creates a message M_1 concerning the accident;
  - $\tau = 9$: V_2 receives M_1 (V_1 and V_2 become in the same network);
  - $\tau = 15$: V_2 creates a message M_2 concerning the accident.

- **Result in the databases of vehicles at the end of the simulation:**
  - V_1 database contains M_1, and V_2 database contains M_1 and M_2.

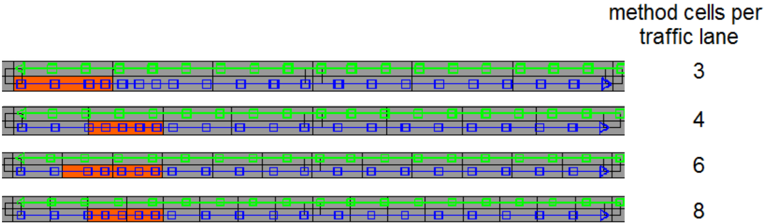


Scenario n°1 - non-spatial event

- Important: The method does not know the real size of the cells given by the simulator.
- **Reality:** Accident present on a simulator cell of a traffic lane.

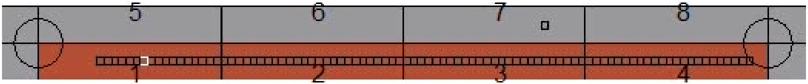


- **Results in V_1 database when varying simulator cells length:**

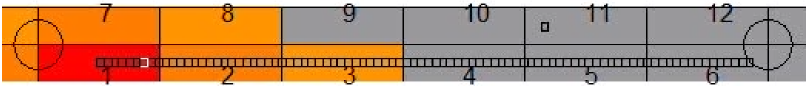


Scenario n°2 - spatial event

- **Reality:** Traffic jam present on all simulator cells of a traffic lane.



- **Result in white vehicle database:**
  - In this scenario, only the white vehicle creates messages, $\beta_t = 0.2$.
  - It creates messages concerning method cells 1, 3 and 6.
  - It turns around, and denies events on cells 5, 3 and 1 (not present in the reality).



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Conclusions and future work

- The proposed method allows exchanging and managing information about non-spatial and spatial events using belief functions.
- The parameters (Del_t, β_t and method cells sizes) are set based on empirical knowledge. This can be improved by implementing automatic learning methods.
- Consider in future work:
  - irregular areas and other types of spatial events such as flog blanket;
  - links between different types of event;
  - vehicles reactions.

Thank you for your attention.

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