Exchanging dynamic and imprecise information in V2V networks with belief functions

Mira Bou Farah, David Mercier, Eric Lefèvre et François Delmotte

Univ. Lille Nord de France, UArdois, LGI2A, Béthune, France

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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
1 Theory of belief functions

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Theory of belief functions: summary

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

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

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


Information fusion: conjunctive rule of combination

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

where \( m_1 \) and \( m_2 \) are obtained from distinct and reliable sources.

Decision making: pignistic probability

\[ BetP(\{\omega\}) = \sum_{\{A \subseteq \Omega, \omega \in A\}} \frac{m(A)}{|A| (1 - m(\emptyset))}, \forall \omega \in \Omega. \]
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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 $\ell$, 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 which 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.
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 $\alpha_{e,i} = \frac{\Delta(now,M_{e,i}.d)}{Delt}$ (ageing).

Secondary mechanism - consider neighboring cells influences:

2. For each occupied cell by a spatial event type: generate influences on its neighborings ($\beta_t$ 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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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 $\tau$. At each $\tau$, each vehicle:
  - Confirms the presence of detected events ($m(\{\exists\}) = \text{confidence}$ and $m(\Omega) = 1 - \text{confidence}$).
  - Denies non-perceived events which are present in its database ($m(\{\nexists\}) = \text{confidence}$ and $m(\Omega) = 1 - \text{confidence}$).
  - 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:

- Method cells per traffic lane:
  - 3
  - 4
  - 6
  - 8
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 ($Del_t$, $\beta_t$ 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.