



# Detection of Unusual Behaviours for Context Awareness Estimation

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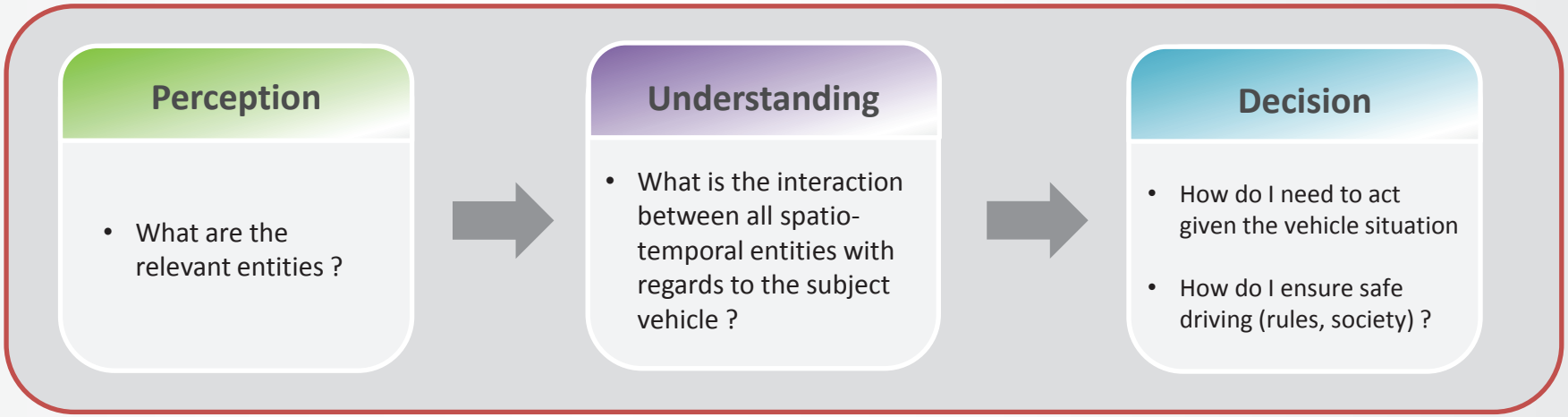
# Outline

- Background
- Context Awareness Problem
- Bayesian Network Based  Approach
- Experimental Evaluation : Use Case Driven
- Results and Analysis
- Conclusions

# Background

## Accidentology shows that :

- Most road accidents are due to human errors
- Poor situation understanding often leads to bad decisions which are at the origin of accidents



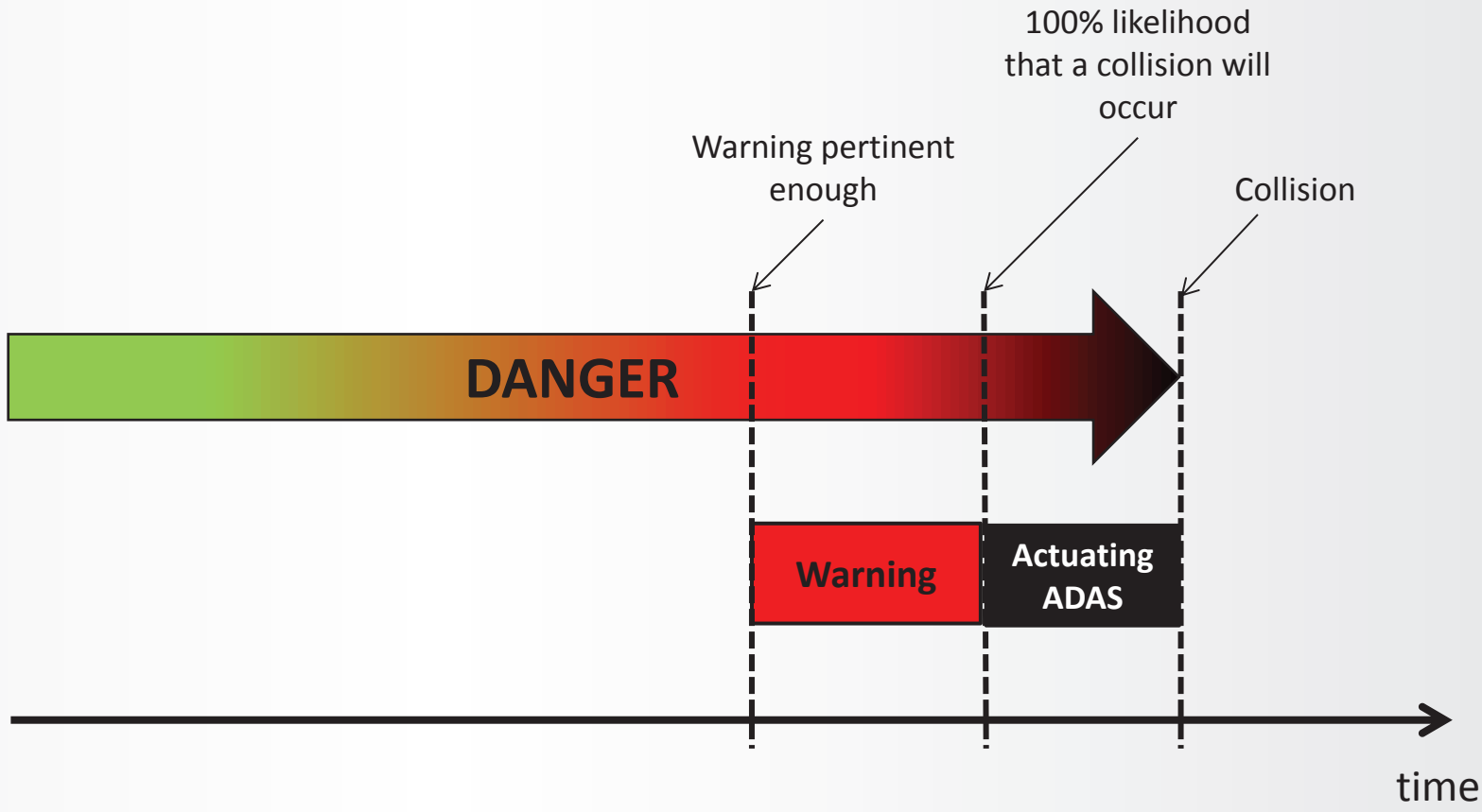
# Background

## Conventional ADAS Solutions

- Usually based on
  - Estimation of Collision Likelihood
  - Trajectory Prediction
  - Estimation of Driver Intention
- Can provide drivers  warnings and/or actuates on the vehicle when necessary
- Challenge : Predict with certainty the soonest that a collision may happen
- Problem : Pertinence and integrity of warning

# Background

## Conventional ADAS Solutions



# Background

## Drivers

- Driver profiles depend on gender, age, experience, etc
- Drivers have different perception of danger
- Drivers have different way to react in similar contexts
- All drivers are different

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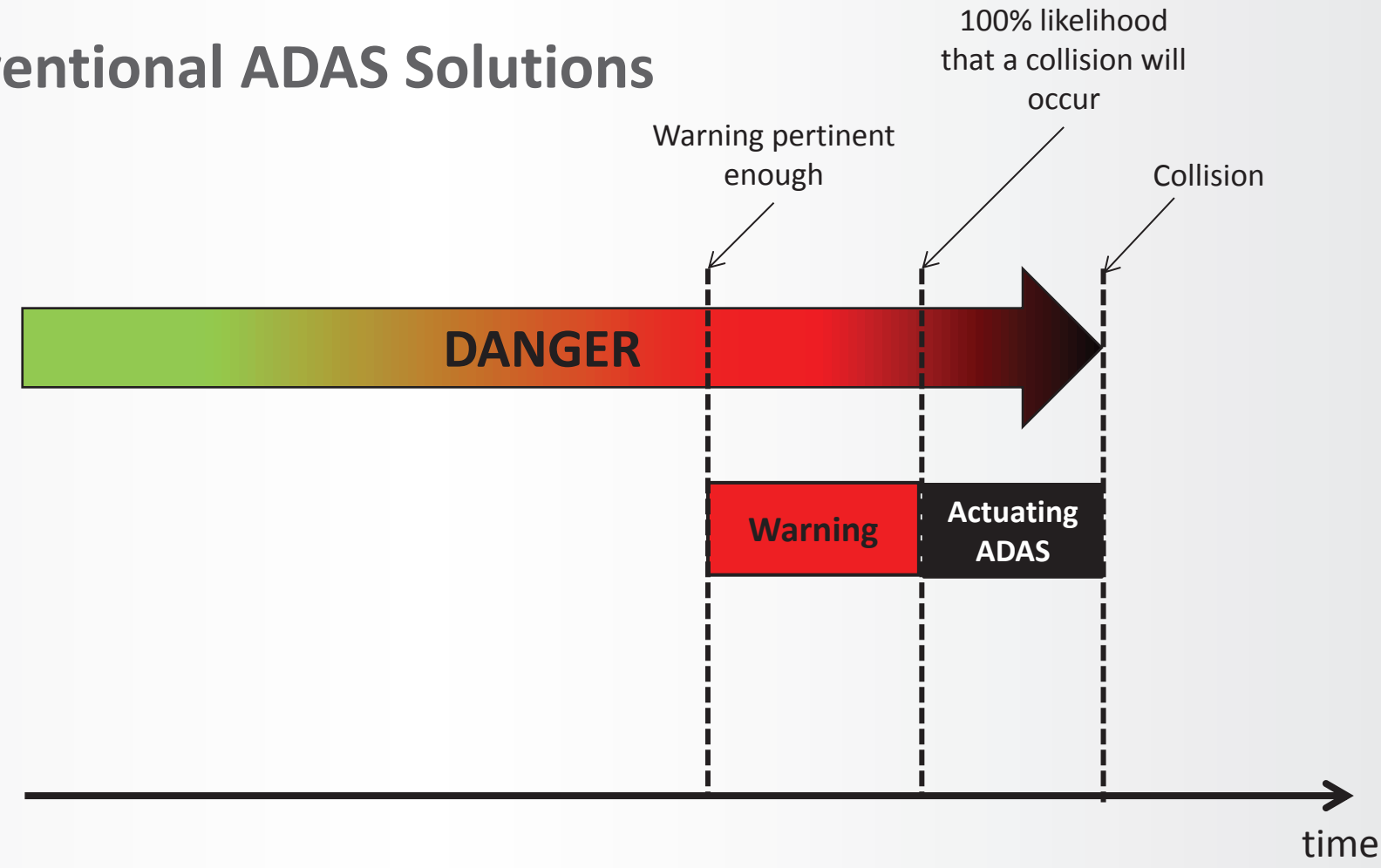
# Context Awareness Problem

## Conventional ADAS Solutions

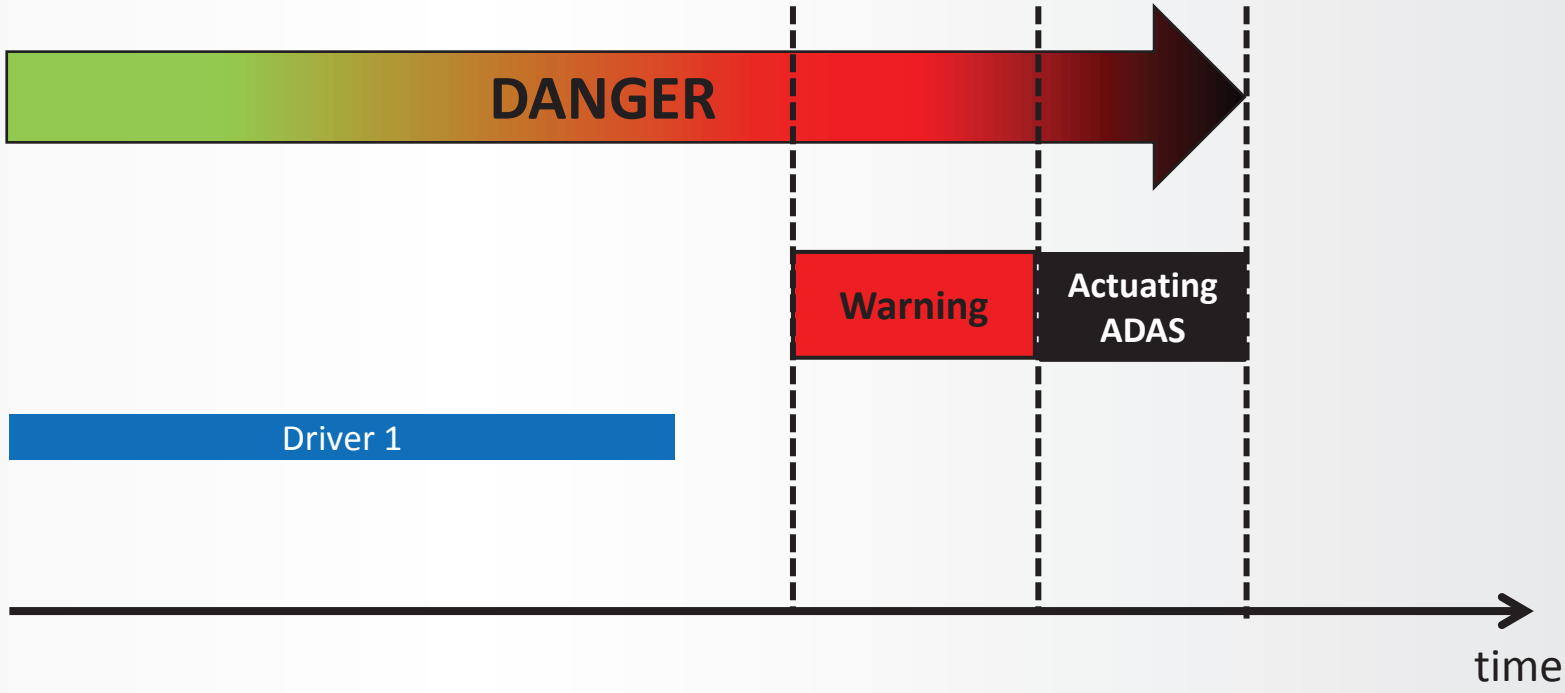


# Context Awareness Problem

## Concept

**Drivers do not behave the same manner**

- Some are very safe

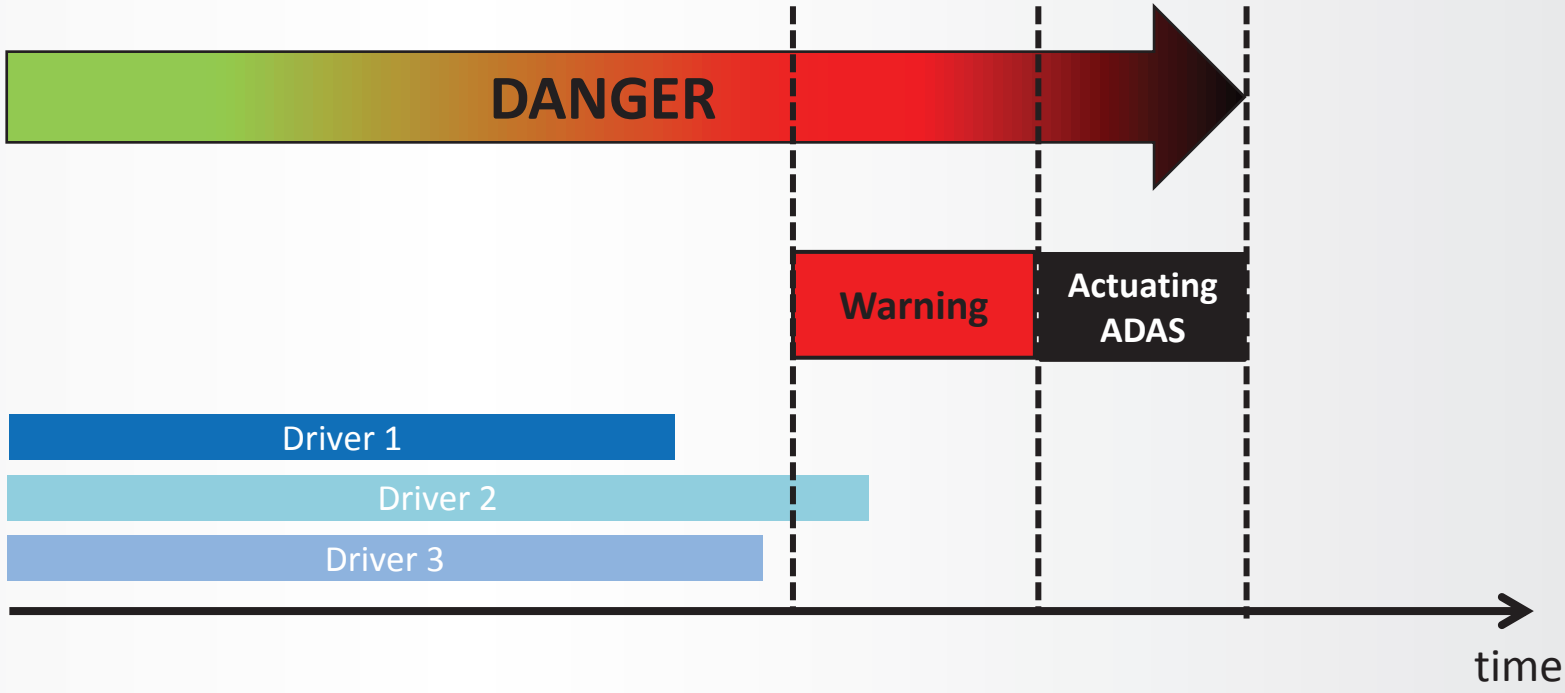


# Context Awareness Problem

## Concept

**Drivers do not behave the same manner**

- Some are very safe
- Others prefer sensations

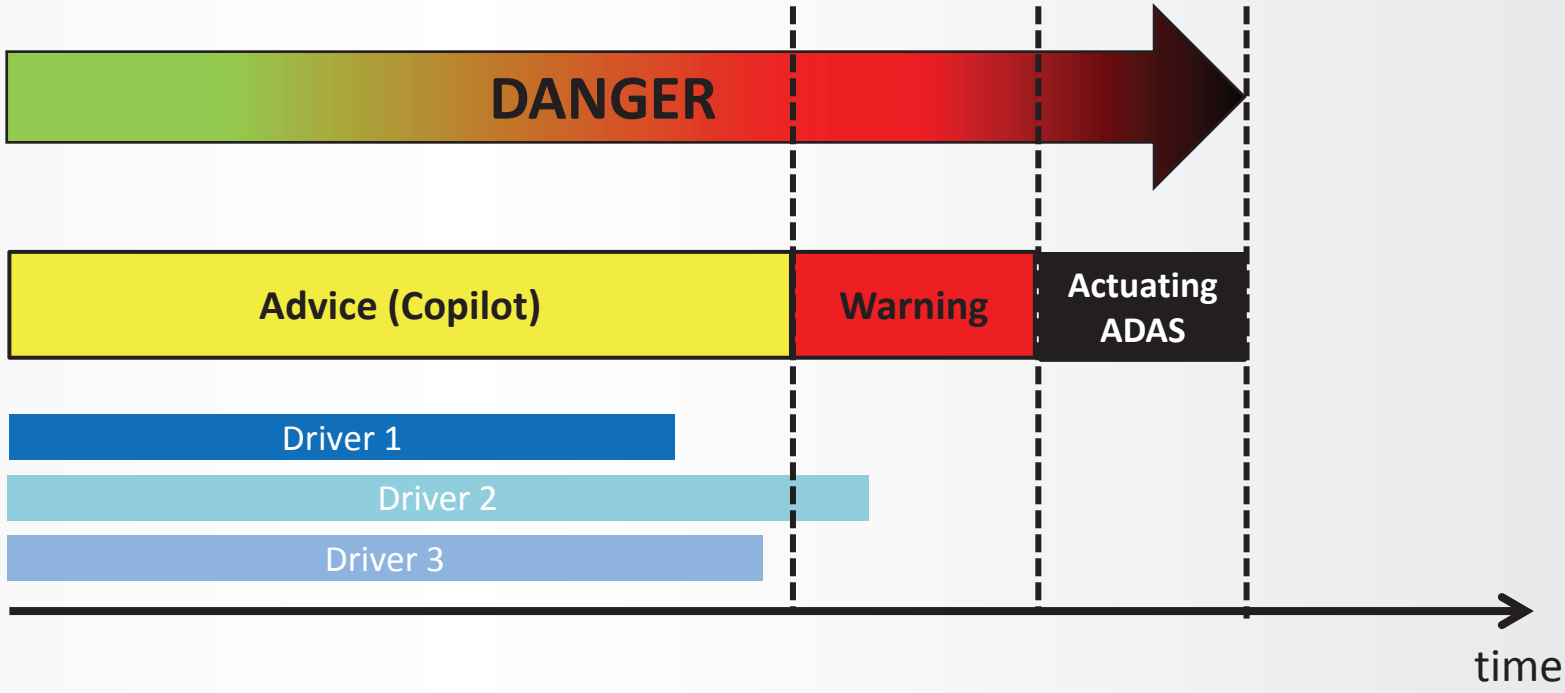


# Context Awareness Problem

## Concept

**For relaxed drivers, why should we wait for real danger ?**

- Could early advices be relevant ?



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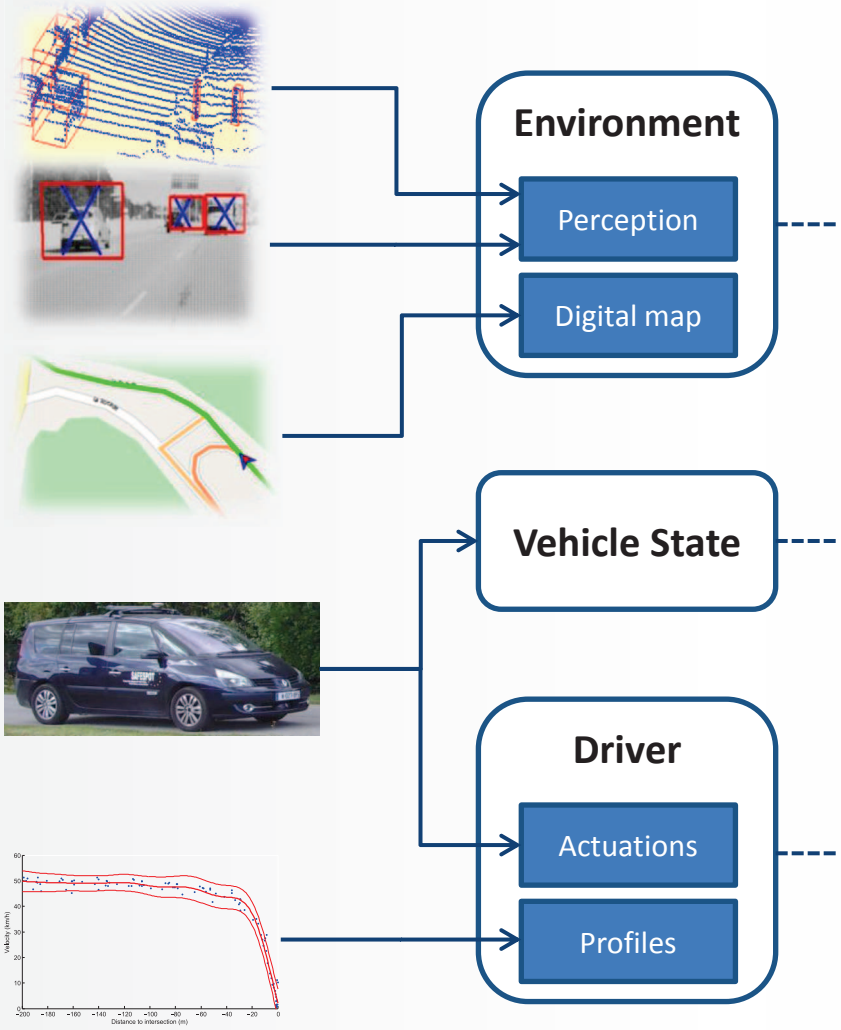
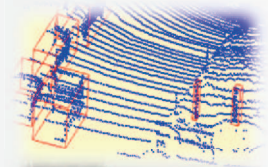
# Approach

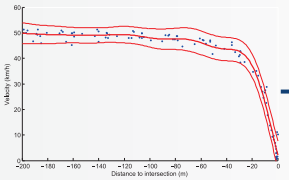
**Tenet :** In a similar context, the driver will behave the same manner



# Approach

**Tenet :** In a similar context, the driver will behave the same manner





**Environment**

Perception

Digital map

**Vehicle State**

**Driver**

Actuations

Profiles

1. Context understanding - What context element to monitor ?

2. Is the driver behaving as usual ? - Does he seem aware of the context ?

3. Would an advice be relevant ?

# Approach

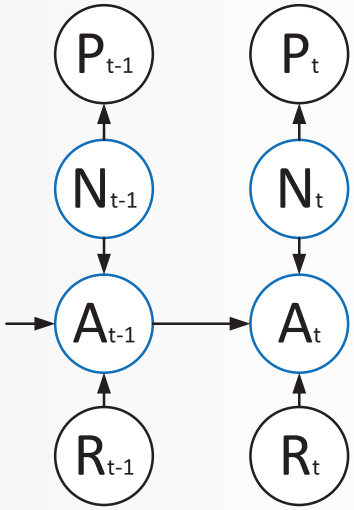
**Estimation of awareness regarding a contextual object**

- Based on learnt driver patterns, parameter to monitor : **$P_t$**
- Estimates the “normality “ of the driver’s behaviour : **$N_t$**
- Checks any reaction of the driver : **$R_t$**
- Estimates awareness : **$A_t$**

➢ **Modelled within a Bayesian Network**

# Approach

## Bayesian Network




Parameter to monitor (observable) $\boldsymbol{P_t} \in \mathbb{R}$

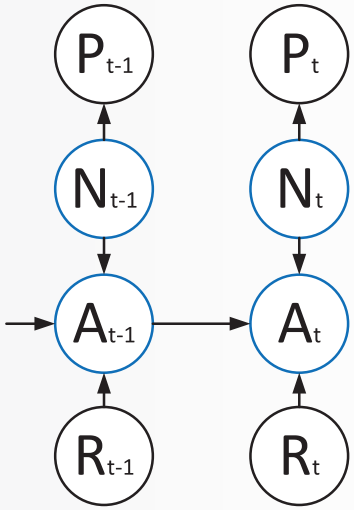
Reaction of the driver (observable) $\boldsymbol{R_t} \in [\mathbf{0}, \mathbf{1}]$

Normality of the behaviour (hidden) $\boldsymbol{N_t} \in [\mathbf{0}, \mathbf{1}]$

Awareness of the context (hidden) $\boldsymbol{A_t} \in [\mathbf{0}, \mathbf{1}]$

# Approach

## Bayesian Network




Parameter to monitor (observable) $\boldsymbol{P_t} \in \mathbb{R}$

| $N_t$ | $P_t$ |
|---|---|
| 0 | $\mathcal{N}(p_{Abnormal}, \sigma_{Abnormal})$ |
| 1 | $\mathcal{N}(p_{Normal}, \sigma_{Normal})$ |

Reaction of the driver (observable) $\boldsymbol{R_t} \in [\mathbf{0}, \mathbf{1}]$

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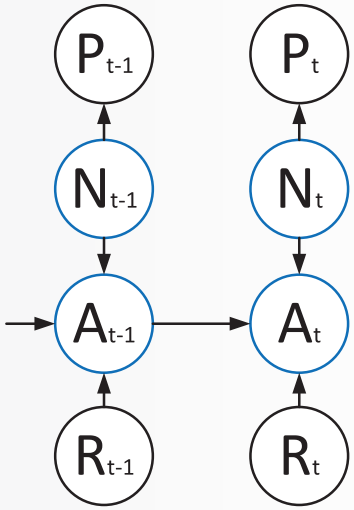
# Approach

## Bayesian Network




Parameter to monitor (observable) $P_t \in \mathbb{R}$

Reaction of the driver (observable) $R_t \in [0, 1]$

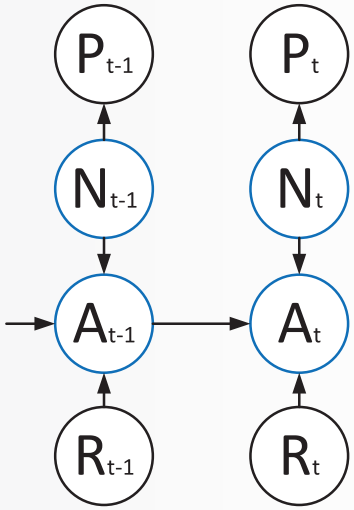
$P(R_t = 1) = 0.5$

Normality of the behaviour (hidden) $N_t \in [0, 1]$

Awareness of the context (hidden) $A_t \in [0, 1]$

# Approach

## Bayesian Network




Parameter to monitor (observable) $\boldsymbol{P_t} \in \mathbb{R}$

Reaction of the driver (observable) $\boldsymbol{R_t} \in [\mathbf{0}, \mathbf{1}]$

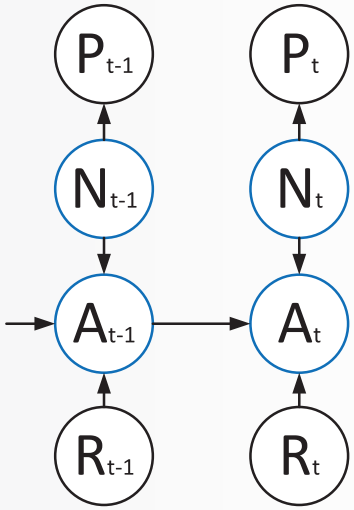
Normality of the behaviour (hidden) $\boldsymbol{N_t} \in [\mathbf{0}, \mathbf{1}]$

$\boldsymbol{P(N_t = 0) = \gamma}$

Awareness of the context (hidden) $\boldsymbol{A_t} \in [\mathbf{0}, \mathbf{1}]$

# Approach

## Bayesian Network

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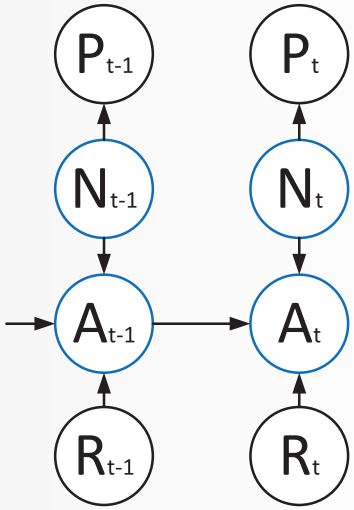
Awareness of the context (hidden) $\boldsymbol{A_t} \in [\mathbf{0}, \mathbf{1}]$

| Conditions | | | Probability |
|---|---|---|---|
| $N_t$ | $A_{t-1}$ | $R_t$ | $P(A_t = 1 \mid N_t, A_{t-1}, R_t)$ |
| 0 | 0 | 0 | $\alpha$ |
| 1 | 0 | 0 | |
| 0 | 1 | 0 | |
| 1 | 1 | 0 | $\beta$ |
| x | x | 1 | |

# Approach

## Bayesian Network

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Normality of the behaviour (hidden) $\boldsymbol{N_t} \in [\mathbf{0}, \mathbf{1}]$

Awareness of the context (hidden) $\boldsymbol{A_t} \in [\mathbf{0}, \mathbf{1}]$

Probability that the driver is not behaving as usual and not aware of the contextual object

$$P([N_t = 0], [A_t = 0] | P_t, R_t, A_{t-1})$$

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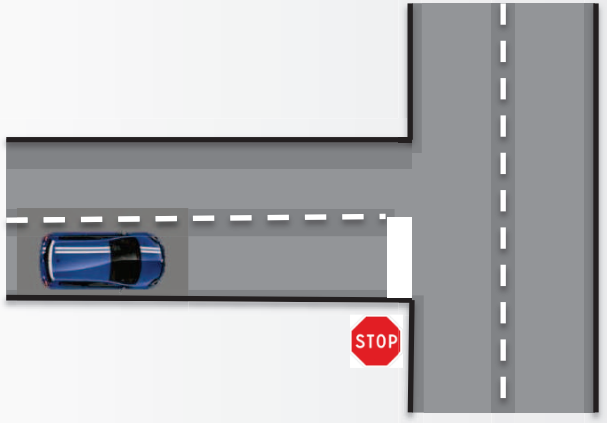
# Evaluation

## Use Case

- Approach to a stop intersection



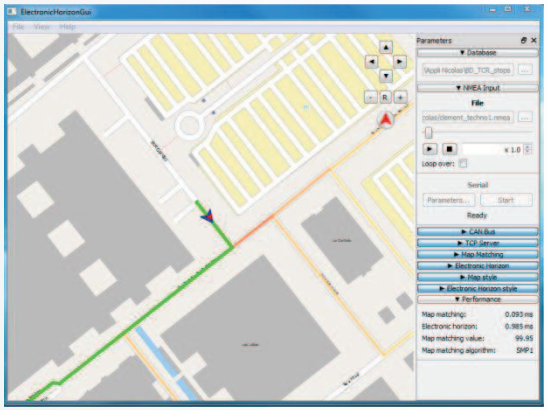

### Adaptation of the Bayesian Network

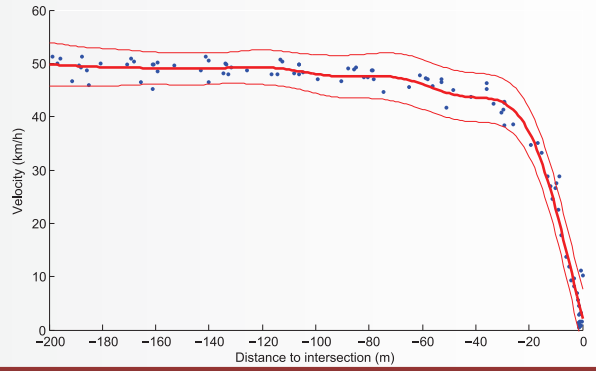
- **Parameter** : Vehicle velocity
- Customized velocity profiles were initially learnt
- **Reaction** : State of the brake pedal

# Evaluation

## Experimental protocol

- Real data recorded on open roads was used



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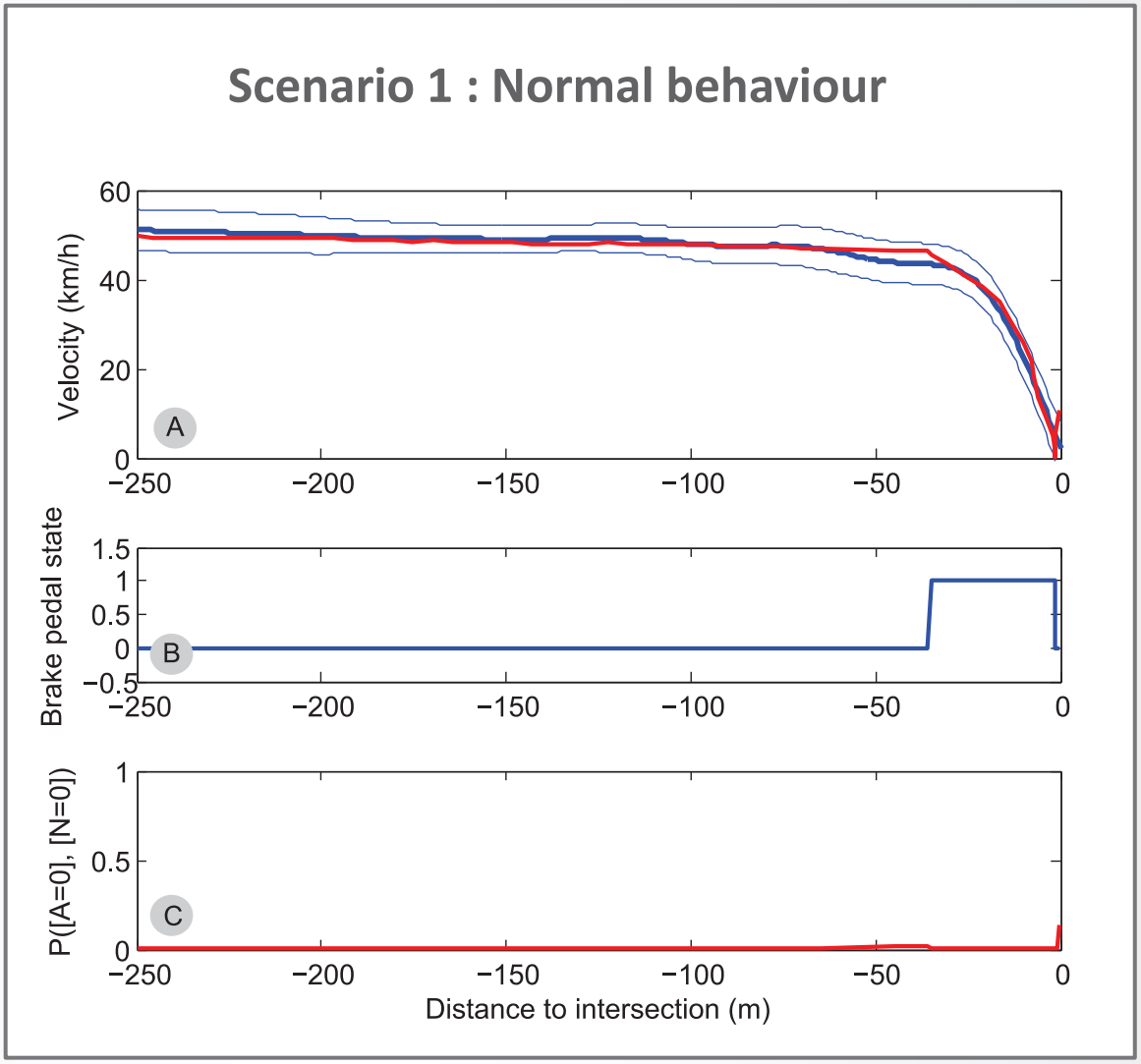
# Results

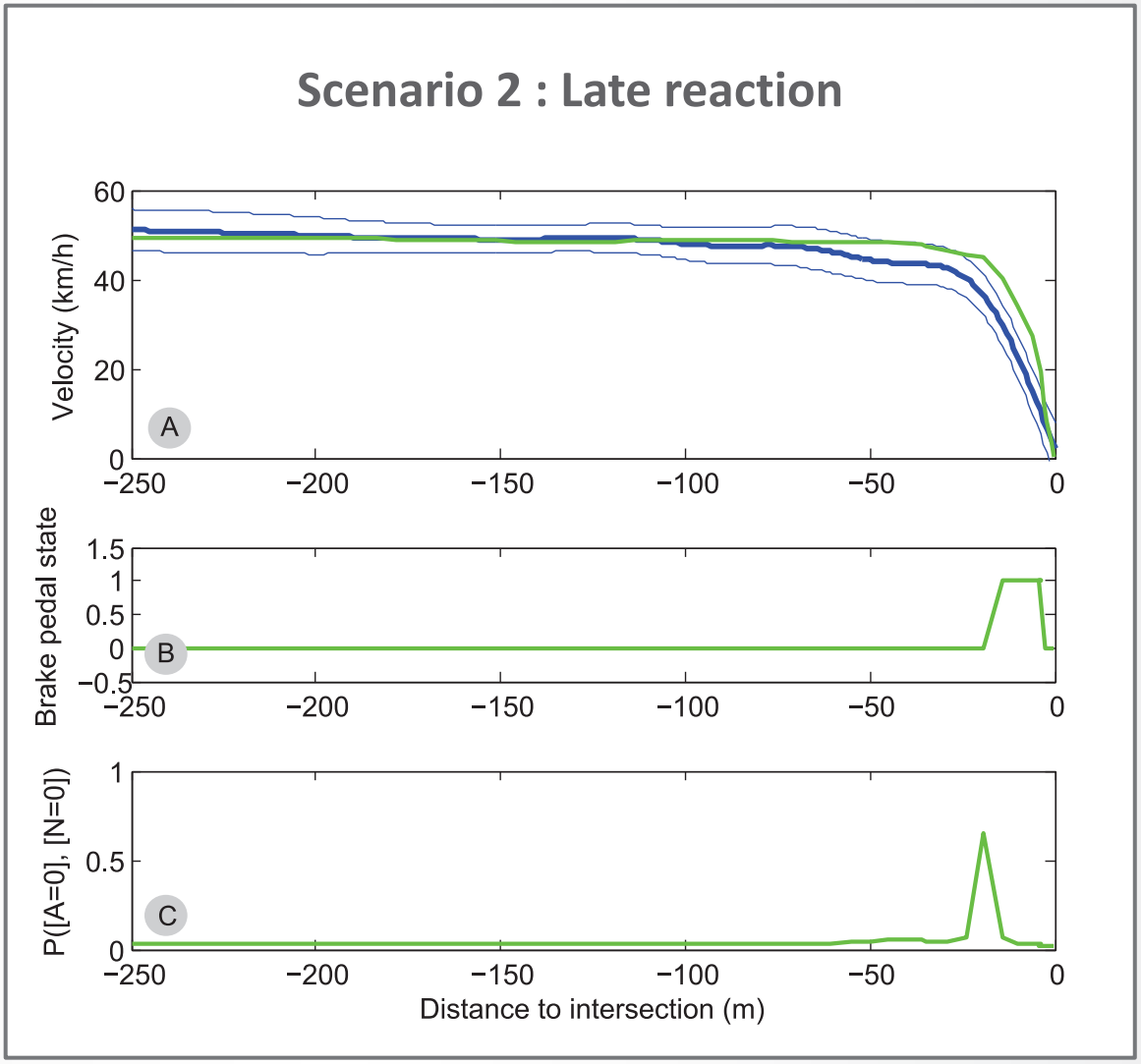
**Preliminary Evaluation was done for 3 scenarios**

- **Scenario 1 :** Driver aware of the intersection, normal behaviour.
- **Scenario 2 :** Driver aware of the intersection, but late reaction.
- **Scenario 3 :** Driver not aware of the intersection, no reaction, abnormal behaviour.

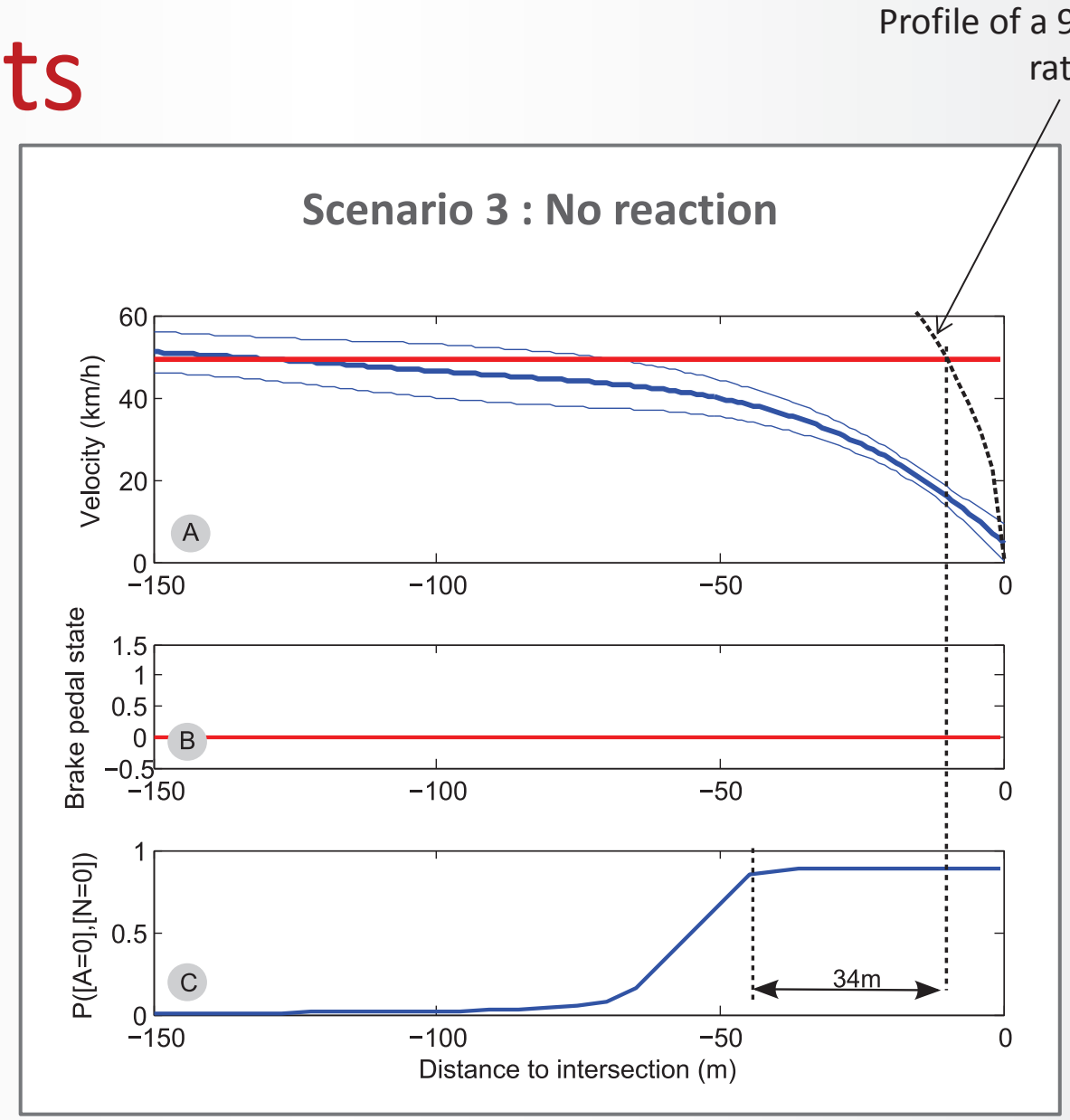
# Results


Scenario 1 : Normal behaviour
Velocity (km/h)
60
40
20
0
A
−250
−200
−150
−100
−50
0
Brake pedal state
1.5
1
0.5
0
−0.5
B
P([A=0], [N=0])
1
0.5
0
C
Distance to intersection (m)

# Results


Scenario 2 : Late reaction
Velocity (km/h)
60
40
20
0
A
−250
−200
−150
−100
−50
0
Brake pedal state
1.5
1
0.5
0
−0.5
B
P([A=0], [N=0])
1
0.5
0
C
Distance to intersection (m)

# Results


Profile of a 9m/s² decel rate
Scenario 3 : No reaction
Velocity (km/h)
60
40
20
0
A
−150
−100
−50
0
Brake pedal state
1.5
1
0.5
0
−0.5
B
P([A=0],[N=0])
1
0.5
0
C
34m
Distance to intersection (m)

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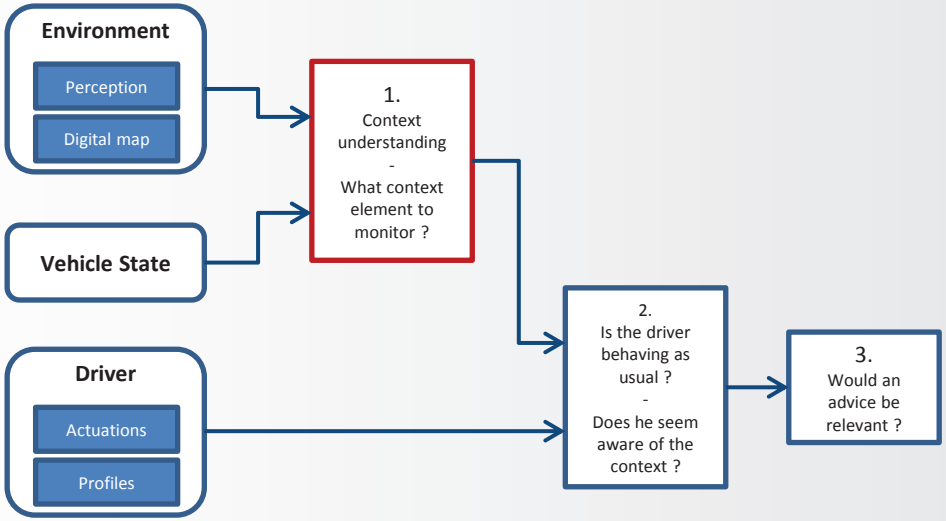
# Conclusion

- **Drivers adapt their behaviour to their understanding of context**
- **All drivers are different**
- **By knowing how a driver usually behaves, it is possible to estimate if he is aware of given contextual entities**
  - A Bayesian Network has been presented
  - Takes driver usual behaviours into consideration
  - For some drivers, it can provide early information while the situation is not dangerous yet

# Future work

- **The framework will be applied in other more complex road contexts**
  - Other driver patterns will have to be learnt

- **Need to be able to estimate when time is sufficient to provide advices before warnings**
- **Need to be able to automatically understand and interpret the context like a driver would do**
  - Choice of the main contextual object(s) and parameter(s) to monitor



# Thank you