UNR157-05-12

European Commission

Alternative assessment of ALKS performance

Response to OICA's comments
Assessment of additional scenarios
Criticality-based scenario classification

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Joint Research Centre

OICA's comments (UNR157-04-10) to EC proposed text (UNR157-03-06)

1. Possible adverse affect on the surrounding vehicles' traffic flow

- The proposed conditions don't take false reaction avoidance sufficiently into account
- When braking earlier, it is natural, that more collisions could be avoided, <u>but this could be detrimental to many other aspects of road safety, (e.g. rear end collision by a following vehicle)</u>
- When ALKS vehicles are forced to brake too strongly too early, this will likely disrupt traffic flow

- **<u>EC reply</u>**

1. The proposed approach is a **performance model** used only to define whether a certain scenario would be <u>preventable or not</u> for an **attentive human driver**. It does not introduce any operational requirement to the ALKS. It is based on tactical safety approach adopted by experienced drivers
2. The model assumes that driver is able to anticipate the risk by **mild decelerations before reaching a safety critical situation**. The comment on braking <u>too strong too soon does not seem to hold</u>.
3. Is industry suggesting that **ALKS vehicles will not be able to be at least as safe as a competent human driver**?

OICA’s comments (UNR157-04-10) to EC proposed text (UNR157-03-06)

2. Design constraints (not technology neutral)

- In order to meet the required performance, the underlying approach would likely need to be implemented into the system software when assessing the criticality of a situation
- So instead of setting a performance expectation, the approach is so detailed, that it would likely be a technical requirement on implementation

- **EC reply**

1. Is industry suggesting that ALKS vehicles will not be able to be as safe as a competent human driver without using an approximation of her/his driving logic?
2. Is it possible that a **shorter reaction time** and a continuous monitoring by the ALKS would not be sufficient to have in place something better than the **driver model proposed by the EC**?
3. The model is set to be a performance model and there is no requirement to implement such a high-level control logic. For this reason **also this comment does not seem to hold**

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OICA's comments (UNR157-04-10) to EC proposed text (UNR157-03-06)

3. Possible Intel patent conflicts

- The proposed approach could require the use (see 2.) of certain potentially protected IP, as some aspects of the RSS are protected by international patents (WO2018115963, WO2019180506, WO2020035728, WO2020245654)

- **EC reply**

1. Even in the case that the comment would hold true for the RSS, since the EC **is not suggesting to use the RSS** as performance model and the proposed approach is included in the legislation as a set of equations on which there cannot be protected IP, even in the case that an OEM would use the equation as part of the high-level vehicle controller there would be no issue. For this reason **also this comment does not seem to hold**

OICA's comments (UNR157-04-10) to EC proposed text (UNR157-03-06)

Industry considers the proposed concept **not mature enough to replace the recently introduced provisions** for ALKS. The discussion should **first be finalized within FRAV/VMAD**, then a **comparison between the new approach and what is established for ALKS** shall be made and if necessary the new approach can be **used to provide guidance within ALKS** on how to assess the performance of the system.

- **EC reply**

1. Since the model in the amendment proposal has the same scope as that used in the current R157 (define the performance of an **attentive and competent human driver**) we don't believe that the discussion should be necessarily finalized in FRAV
2. A thorough **assessment of the model has been performed** including **comparison** with the performance models used in R157 and other models (i.e. RSS).

Insights to the EC performance model proposal (FSM)

- Given the questions raised by Industry the following slides will:
  - **Compare the results** of the EC performance model with RSS and the two performance models currently in R157 for the **cut-in** scenario
  - Make the same comparison for **cut-out and car-following** scenarios
  - Show that by using the «membership» of the Fuzzy model it is possible to **classify scenarios on the basis of their criticality**
- At the end of the presentation additional background slides are provided with more information about the model

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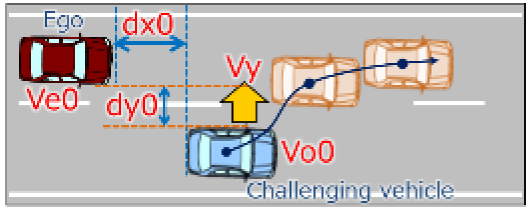
Unpreventable cut-in scenarios

Simulation framework proposed by Japan for the CC model



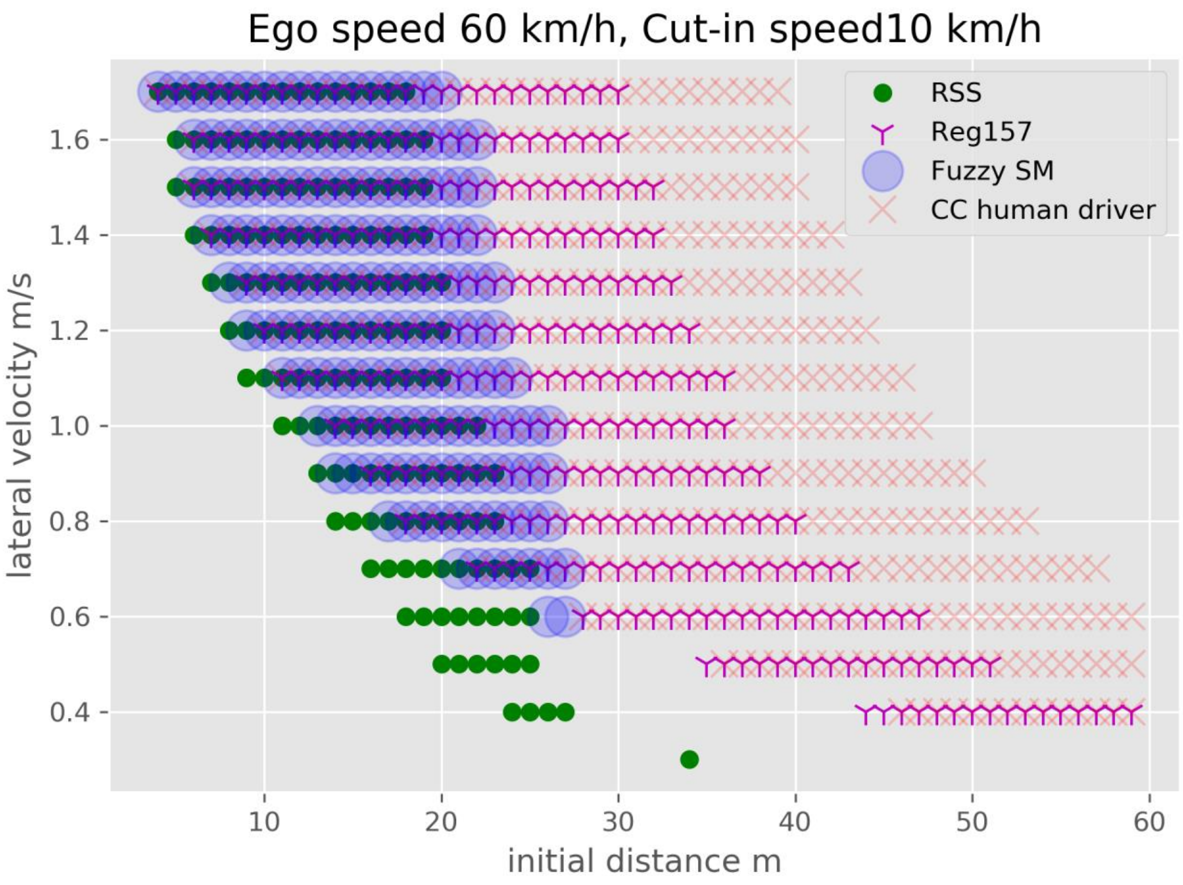
Initial condition	Initial velocity	[Ve0]	Ego vehicle velocity
		[Ve0-Vo0]	Relative velocity
	Initial distance	[dy0]	Latteral distance※
		[dx0]	Longitudinal distance
Vehicle motion	Lateral motion	[Vy]	Lateral velocity

※Latteral distance

ex) Lane width : 3.5[m]
Vehicle width:1.9[m]
Driving in the center of the lane
dy=1.6[m]

Same values for the common parameters of FSM, RSS and CC.

The Reg157 model uses its own parameters



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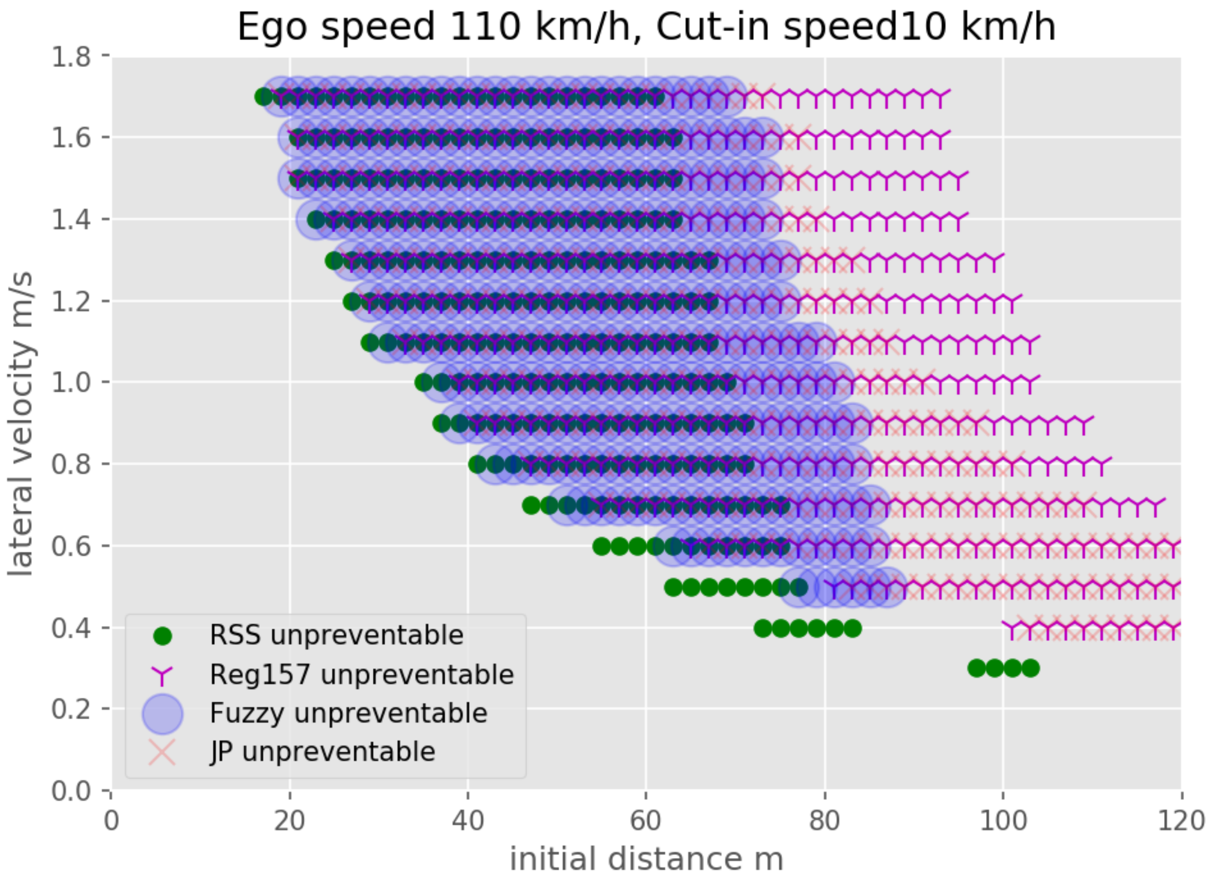
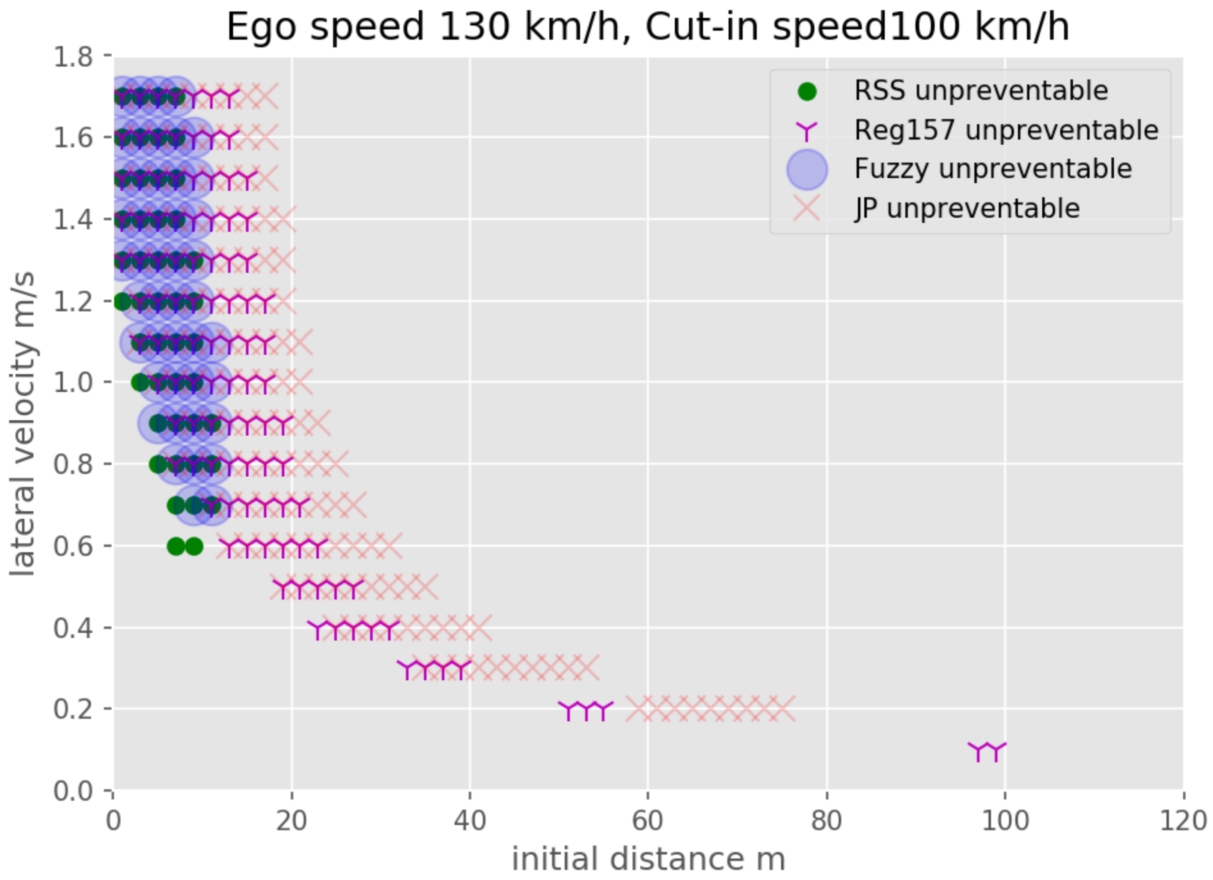
Unpreventable cut-in scenarios





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Cut in scenario classification

- The FSM is a satisfactory compromise among the different approaches proposed so far to **identify unpreventable cut-in scenarios**.
- **What about the preventable ones?**
  - Is it possible to **classify them on the basis of their criticality** to allow their fair random selection?
- Two possible approaches:
  - TTC
  - FSM

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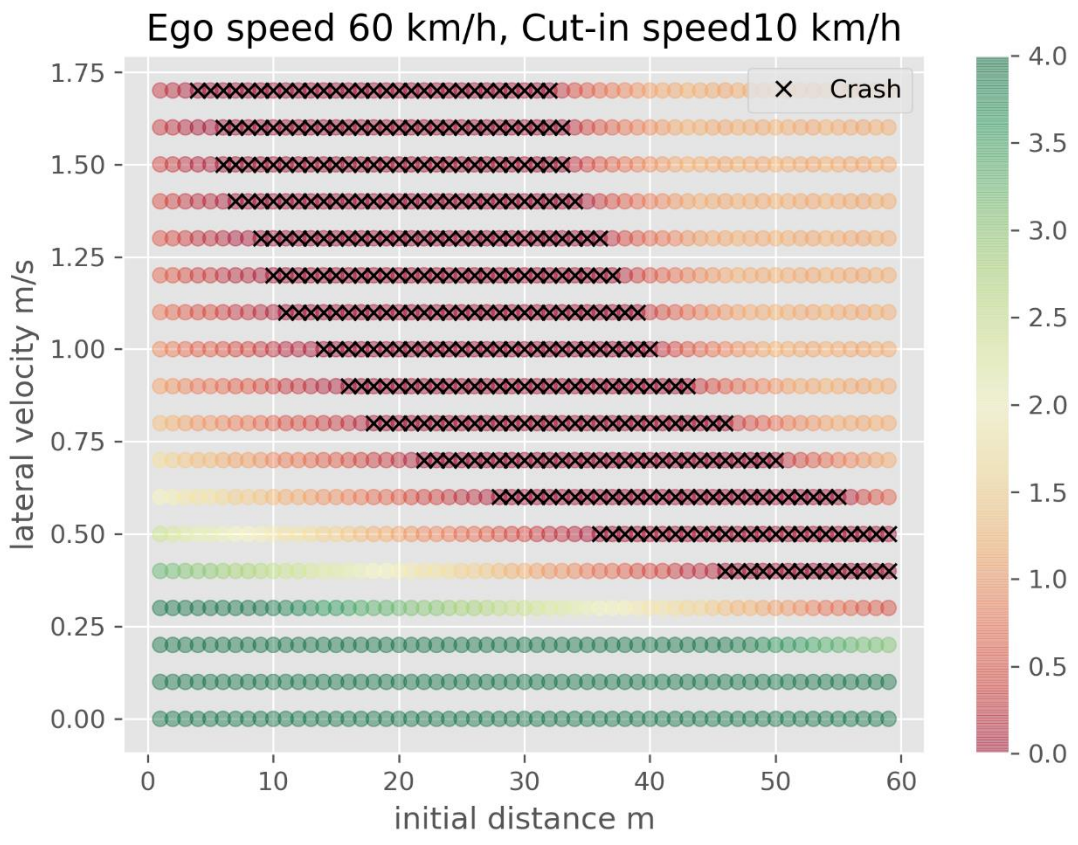
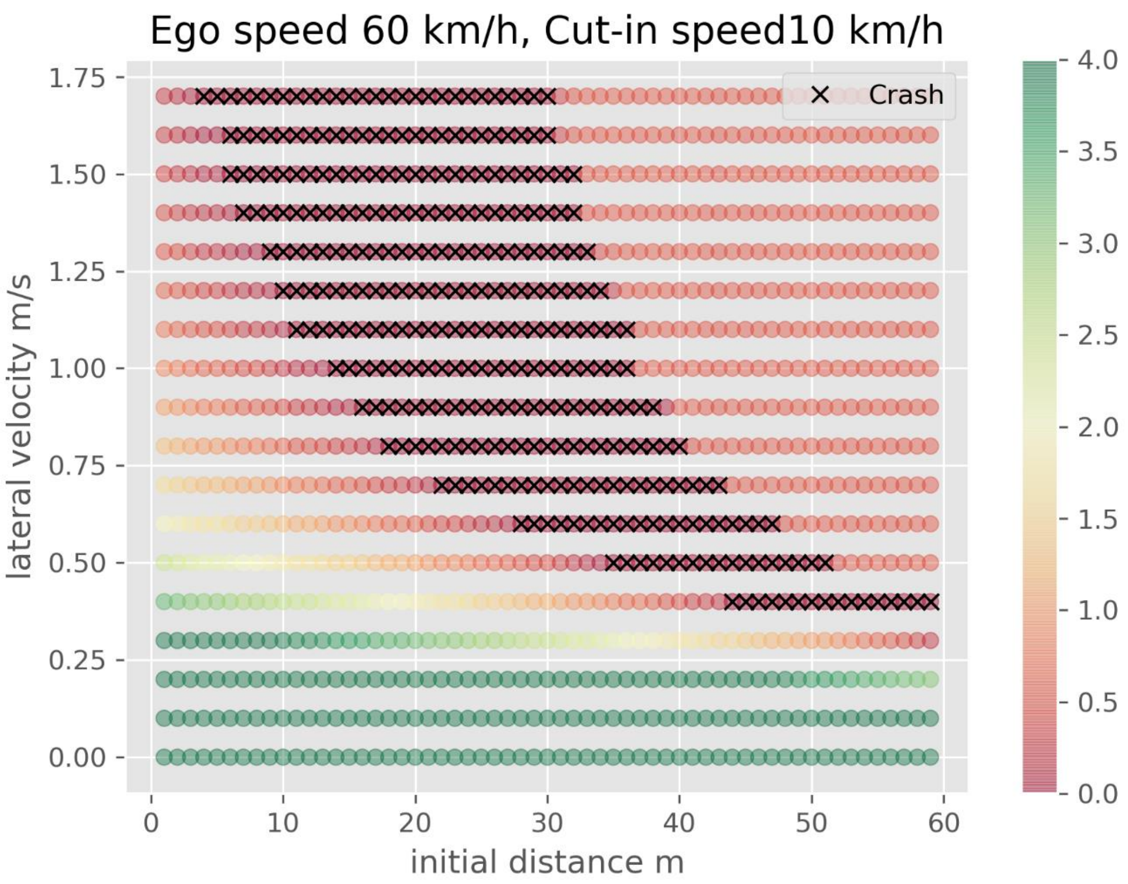
Cut in scenario, minimum TTC

CC human driver model



Reg 157 model

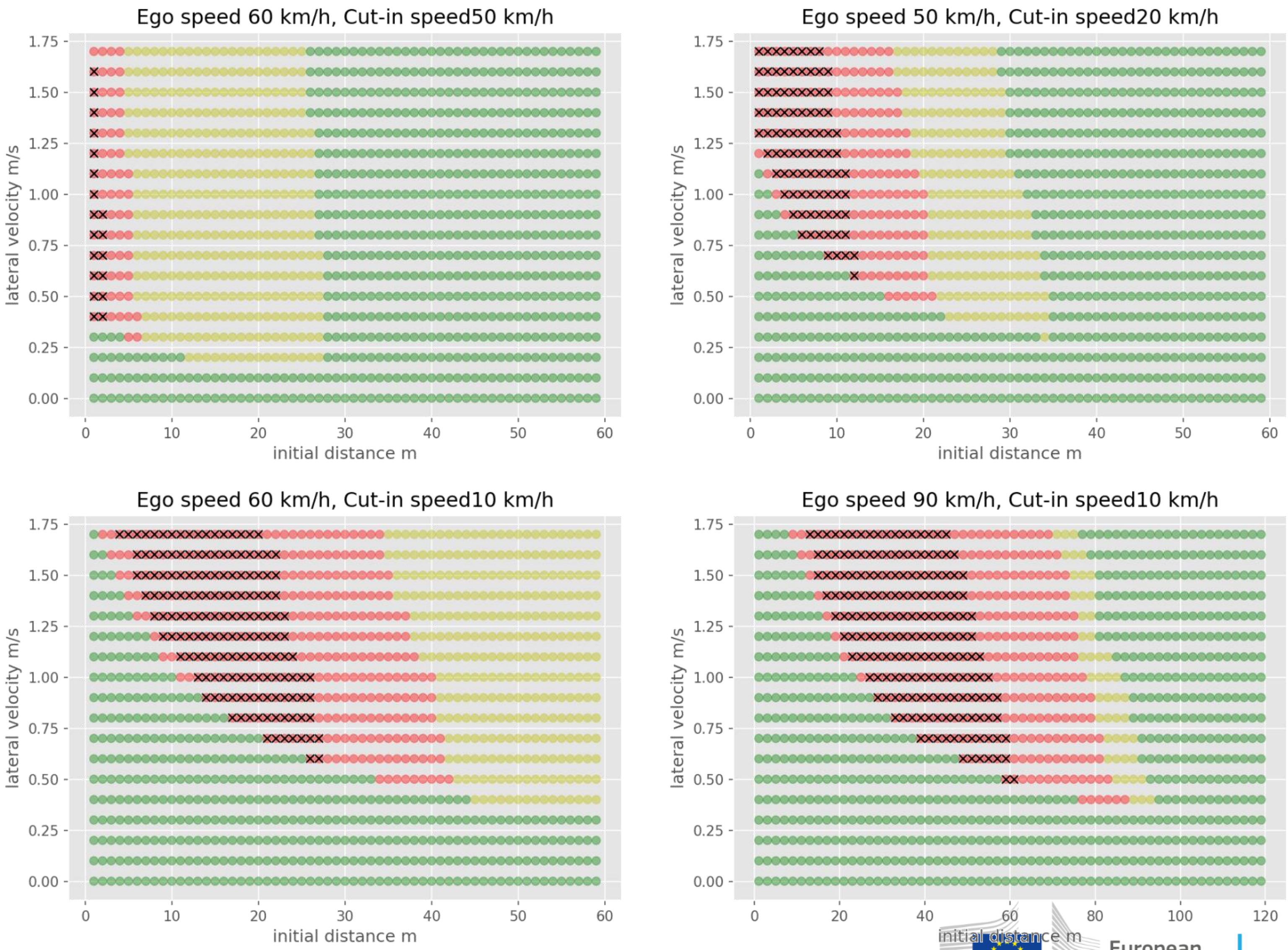


Cut in scenario, using Fuzzy SSMs examples

Green: Easy
Not a big challenge for the ADS

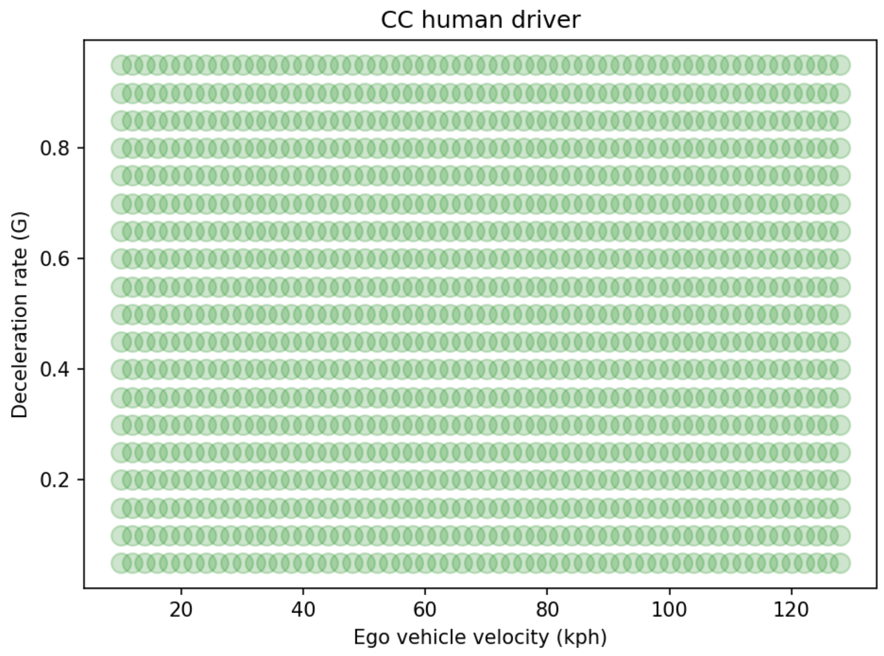
Yellow: Medium
More interesting than easy cases

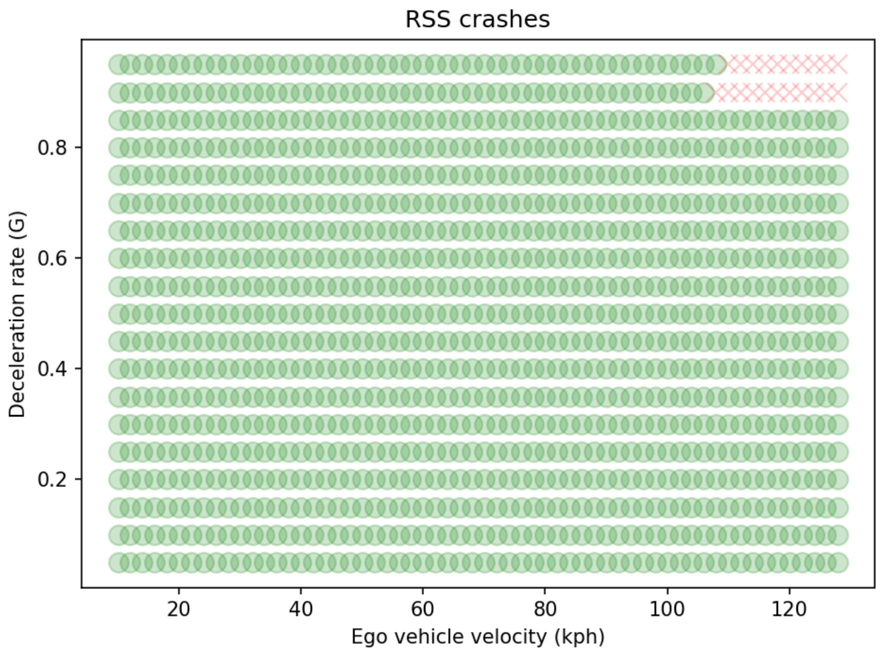
Red: Hard
Most of the scenarios in test track should be hard cases, as they represent the most important challenge to the control

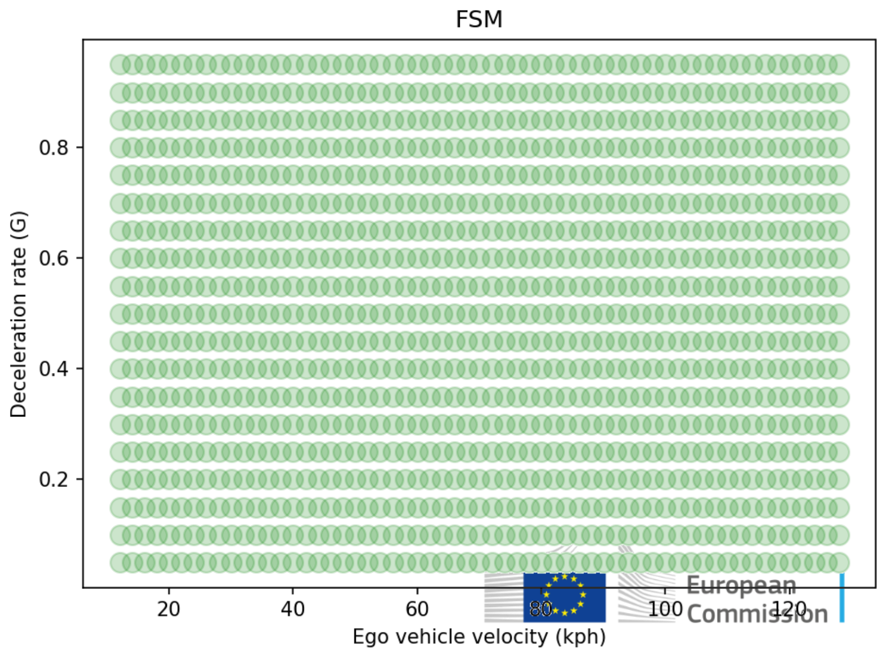


Car-following scenarios

- CC -> no collisions
- RSS -> collisions at high speed
- FSM -> no collisions



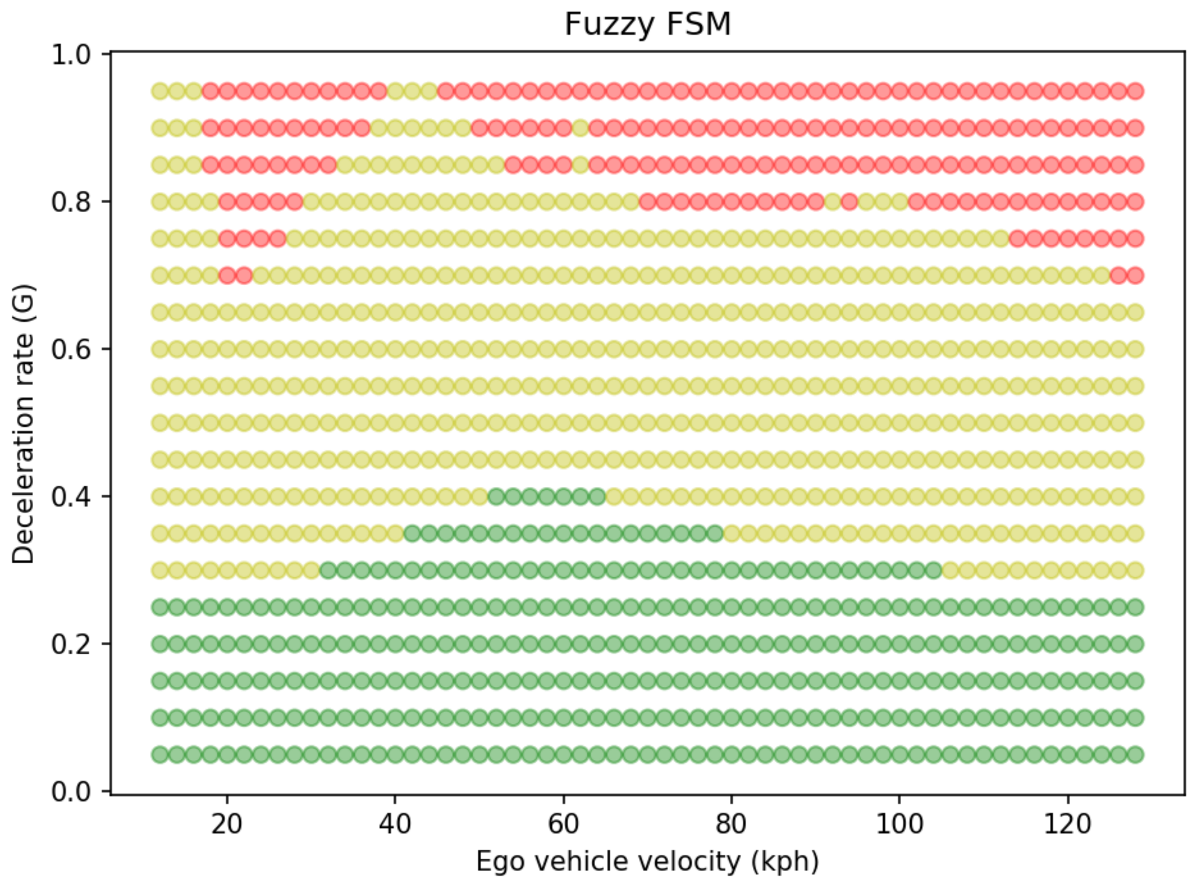




Classification of car-following scenarios

In this case the criticality of the scenario is affected by the steady state distance used for the driver

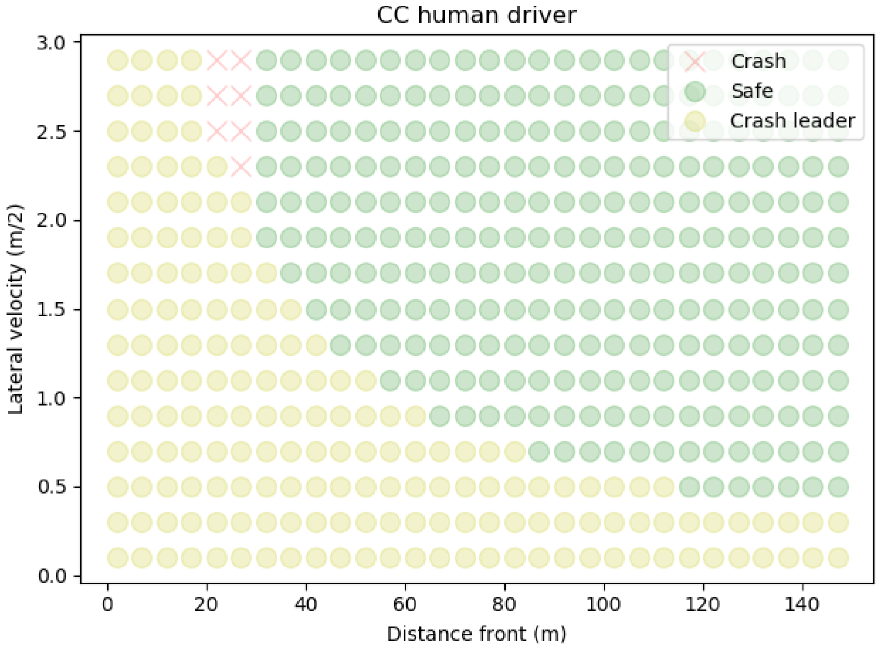
The initial distance is set to have PFS = 0 in the model.

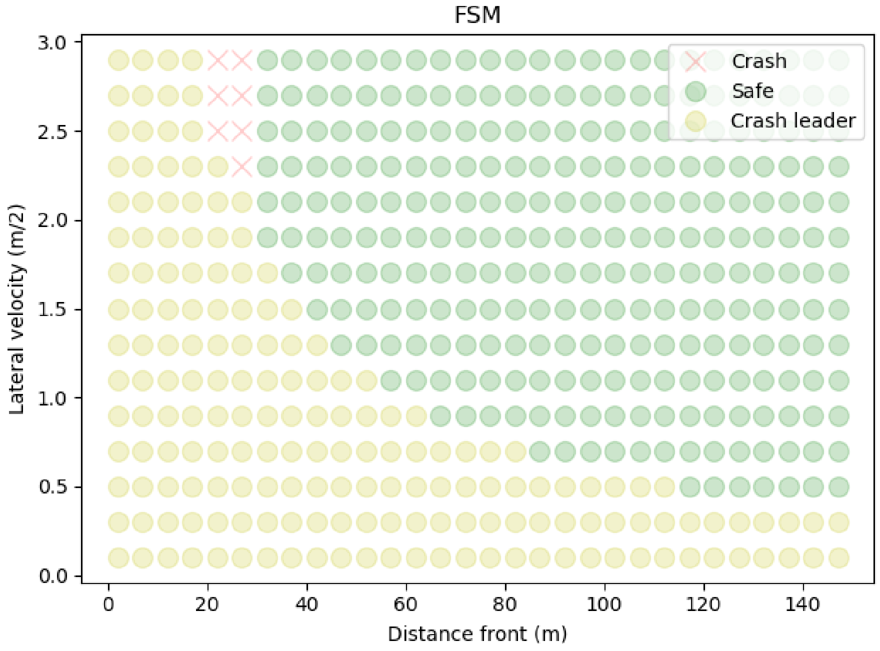


Cut-out scenarios results

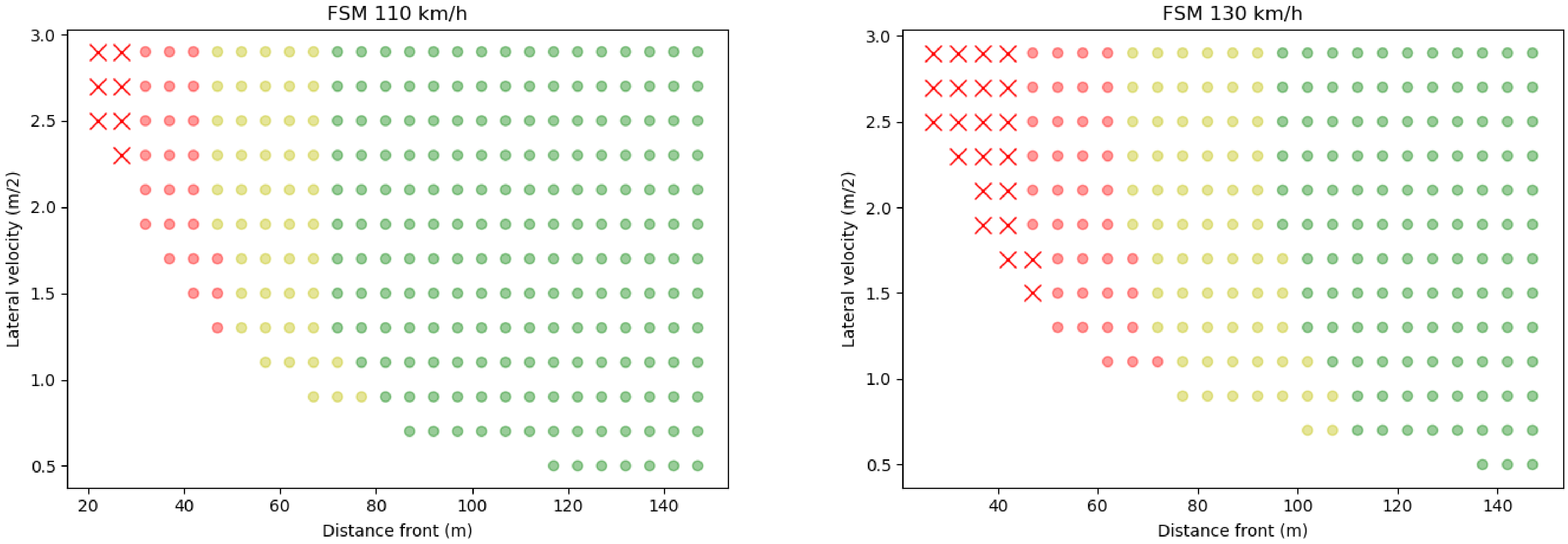
At higher speeds a few collisions for all models.

Pictures for ego vehicle speed of **110 km/h**





Classification for cut out scenarios



Conclusions

- Criticisms to the performance model proposed by the EC raised by industry **do not seem to hold**
- The proposed approach shows **better performances** than what included in current text and a **good compromise** wr other SoA models like the RSS
- The proposed model allows a **simple classification of the criticality of a prevetable scenario** that can help in the parameter selection for track-tests
- The proposed model shows similar results to the current models regarding **car-following** (no unpreventable cases) and **cut-out** (a few unpreventable cases for high-speed scenarios)

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Background information

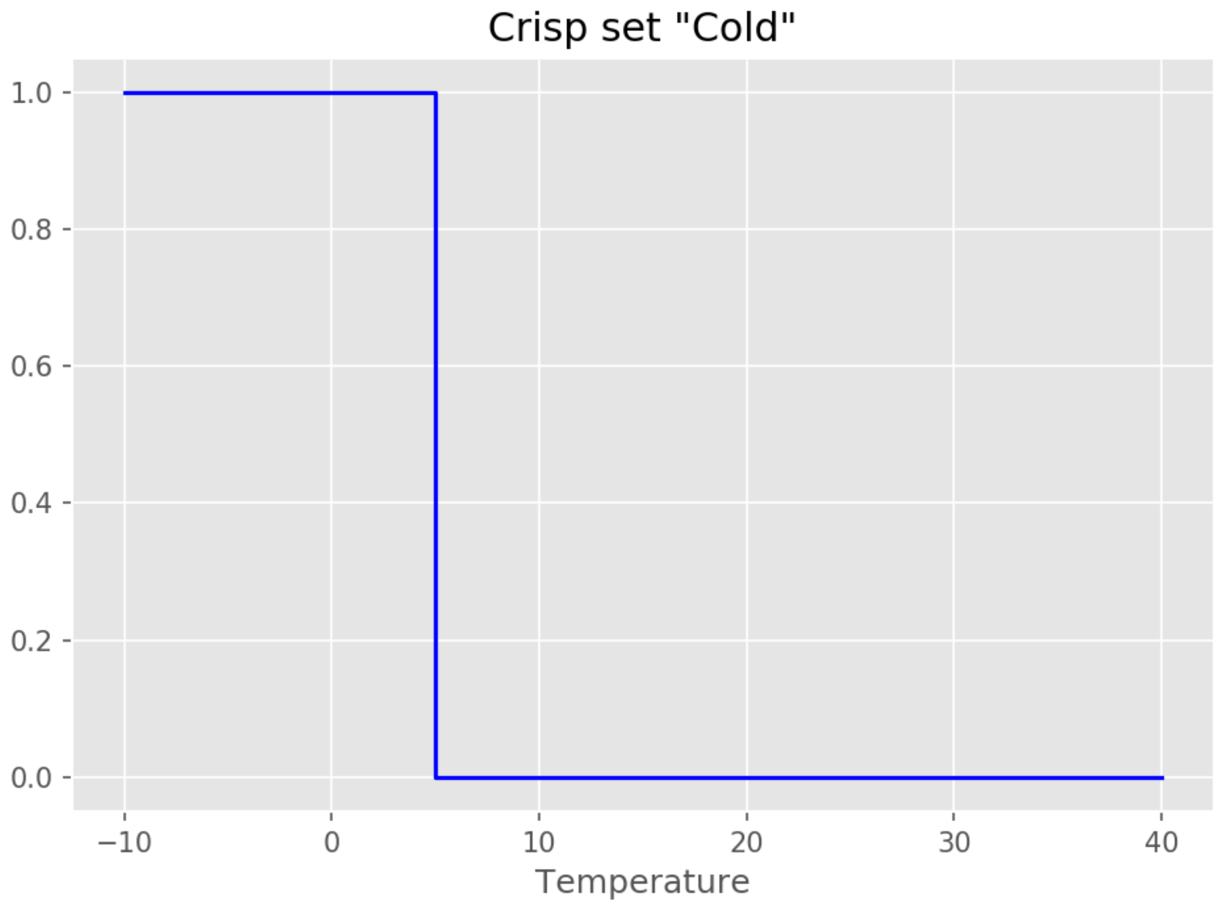
Section 1. The Fuzzy surrogate Model

What is Fuzzy Logic? Crisp sets

Classical set is a collection of distinct objects. Any element is either in a set or not.

We can describe a set by its characteristic function. It takes the value 1 for elements that are in the set and the value 0 for elements that are not in the set

The sets are ‘Crisp’

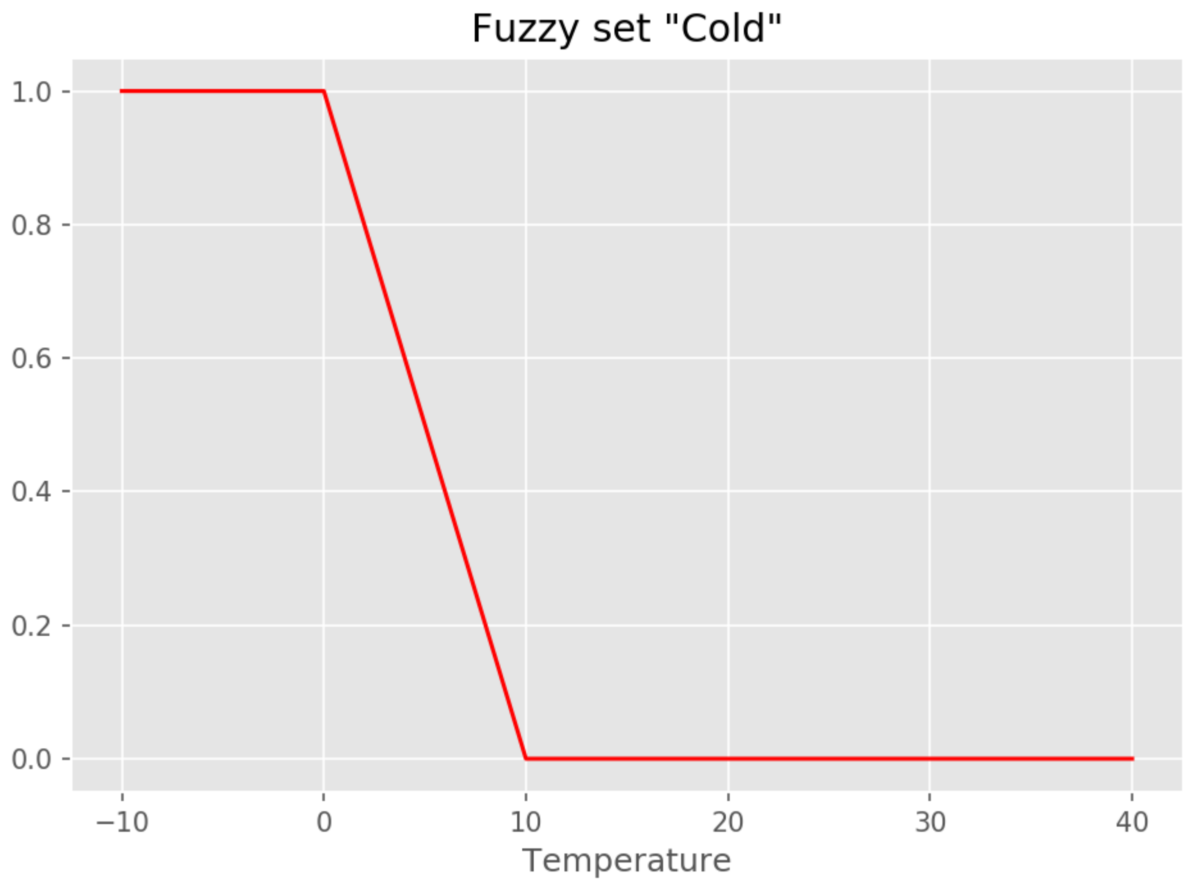


What is Fuzzy Logic? Fuzzy sets

Characteristic functions of Fuzzy sets can take all values from 0 to 1

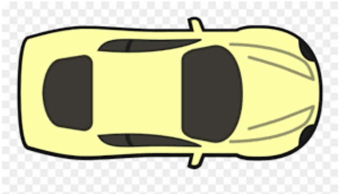
This can be helpful in many cases to better describe a situation

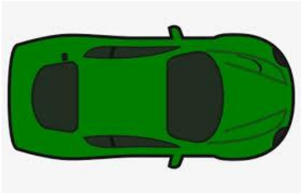
Based on those we can create fuzzy rules

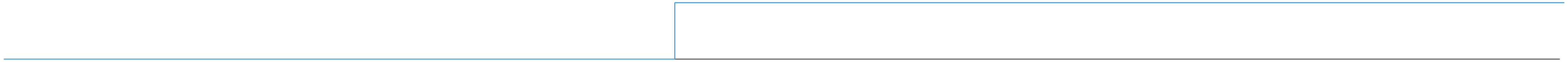


Why Fuzzy logic

Two vehicles with known speeds. What is a safe distance?





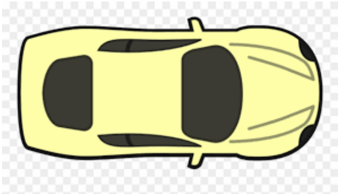


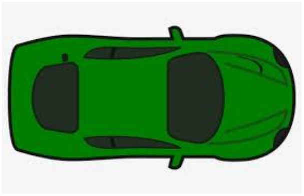
Safe

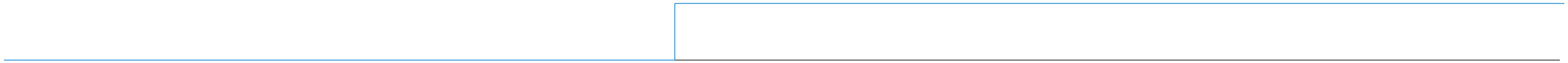
Unsafe

Why Fuzzy logic

Two vehicles with known speeds. What is a safe distance?





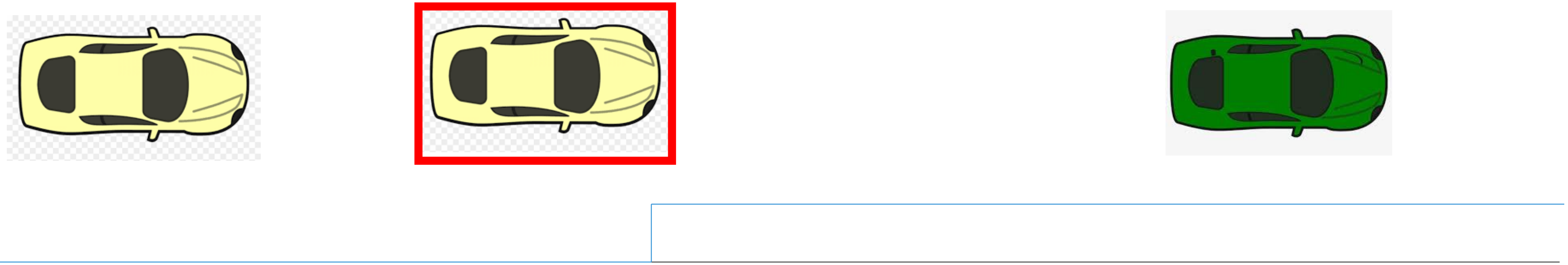


Safe
Do nothing

Unsafe
Decelerate hard

Why Fuzzy logic

Two vehicles with known speeds. What is a safe distance?



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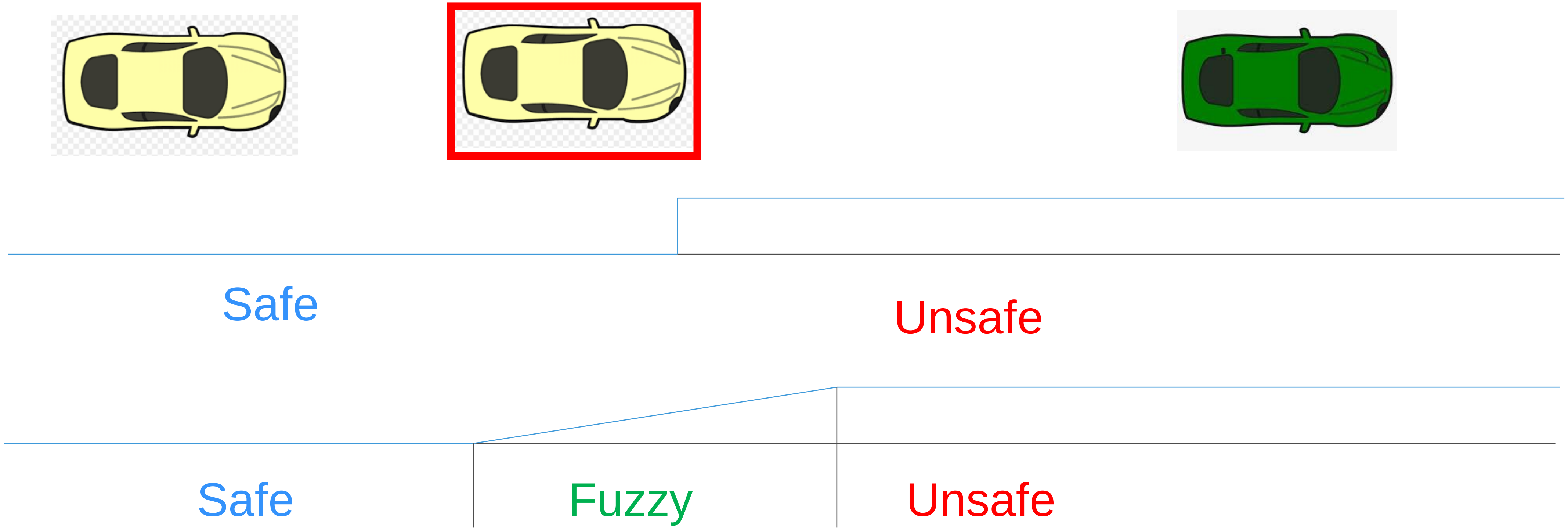
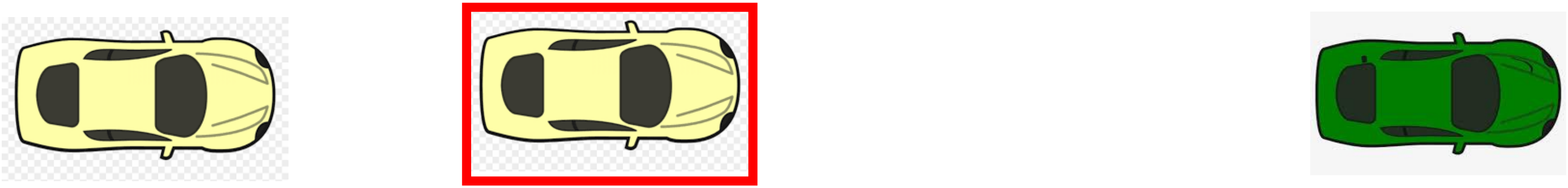
Why Fuzzy logic

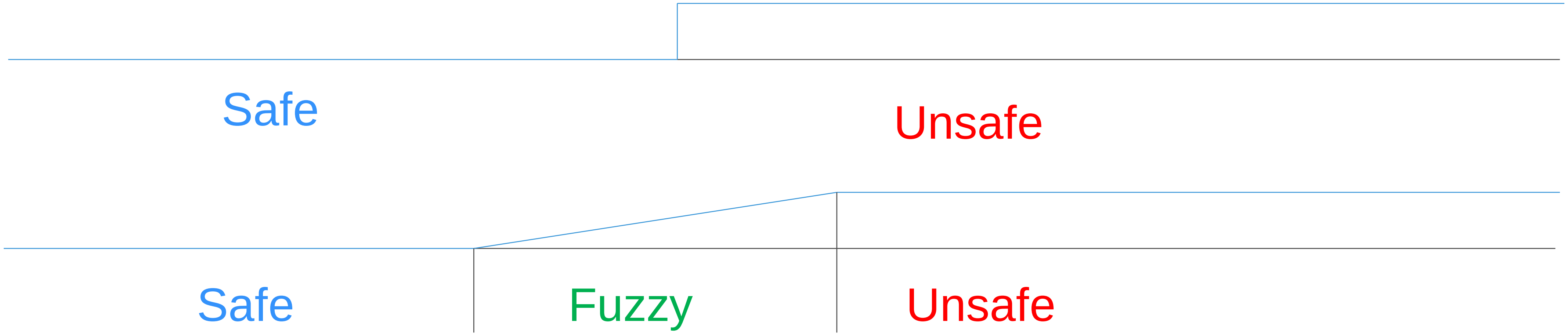
Two vehicles with known speeds. What is a safe distance?



Why Fuzzy logic

Two vehicles with known speeds. What is a safe distance?





The more unsafe, the harder the vehicle must decelerate

Car following scenarios

Three models are compared

- Regulation Appendix 3 model
- RSS model
- Fuzzy logic model

Longitudinal safe distance according to Fuzzy SSMs

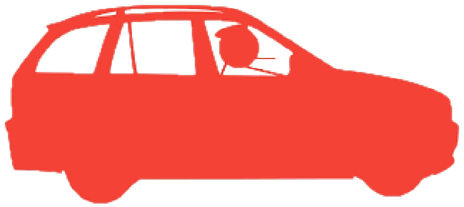
Two different definitions of unsafe:

- If the leader vehicle decelerates, the follower vehicle cannot avoid an accident (Vienna Convention on Road Traffic)
- If nothing changes, there will be a collision in x sec (TTC)

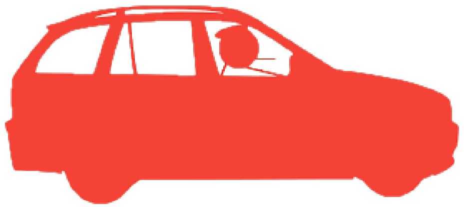
We calculated the Proactive Fuzzy SSM (PFS) and the Critical Fuzzy SSM (CFS)

Longitudinal safe distance according to Fuzzy SSMs

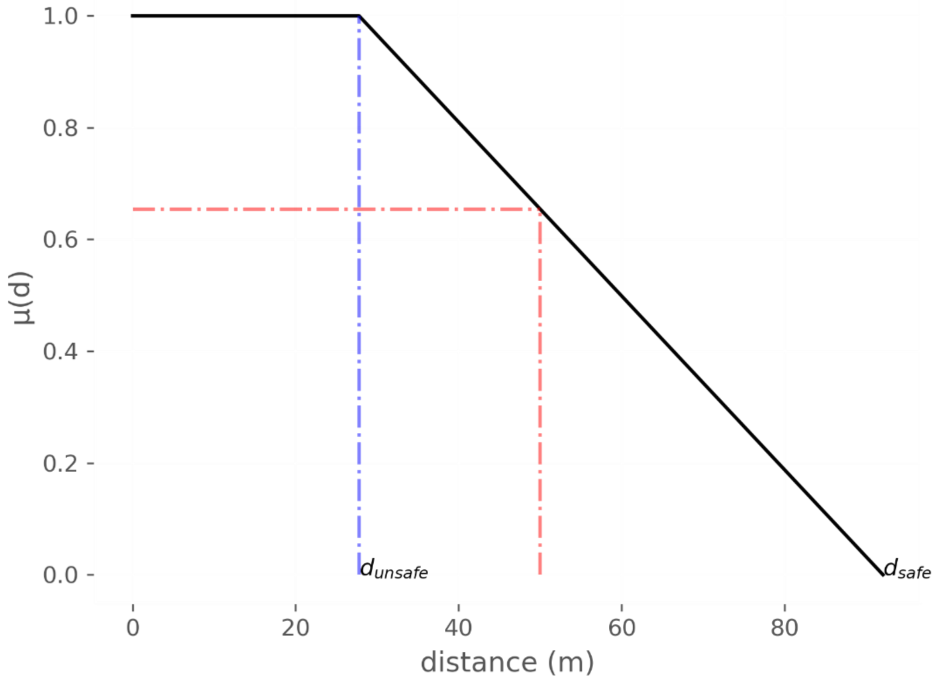
Maximum
Unsafe
distance



Minimum
Safe
distance



$$\mu_A(d) = \begin{cases} 1 & , \quad 0 < d < d_{unsafe} \\ 0 & , \quad d > d_{safe} \\ \dfrac{d - d_{safe}}{d_{unsafe} - d_{safe}} & , \quad d_{unsafe} < d < d_{safe} \end{cases}$$

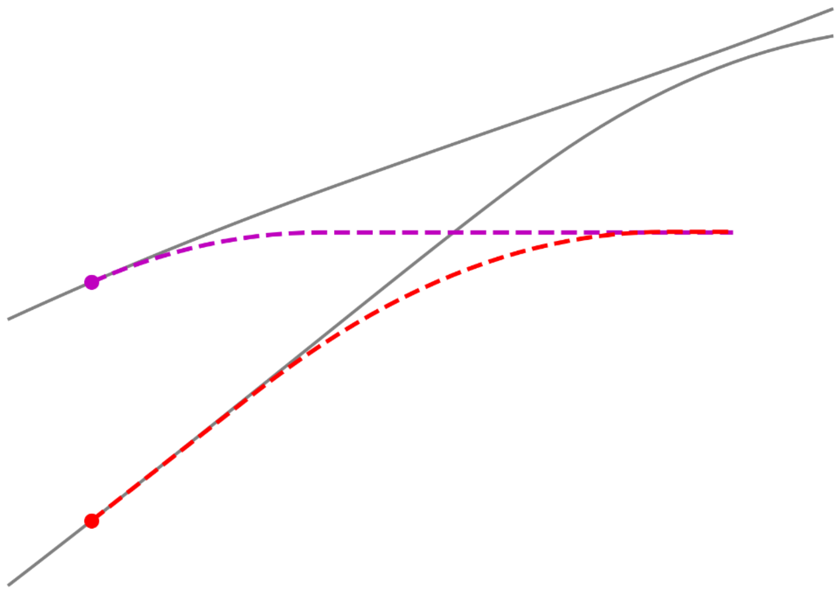


Longitudinal safe distance according to Fuzzy SSMs

PFS: If the leader vehicle decelerates, the follower vehicle cannot avoid an accident

$$d_{safe}(t) = u_2(t)\tau + \frac{u_2^2(t)}{2b_{2comf}} - \frac{u_1^2(t)}{2b_{1max}}$$

$$d_{unsafe}(t) = u_2(t)\tau + \frac{u_2^2(t)}{2b_{2max}} - \frac{u_1^2(t)}{2b_{1max}}$$



Longitudinal safe distance according to Fuzzy SSMs

CFS: If nothing changes, there will be a collision

$$a_2'(t) = \max(\, a_2(t), -b_{2comf})$$

$$u_2(t+\tau) = u_2 + a_2' t$$

If $u_2(t+\tau) \leq u_1(t)$:

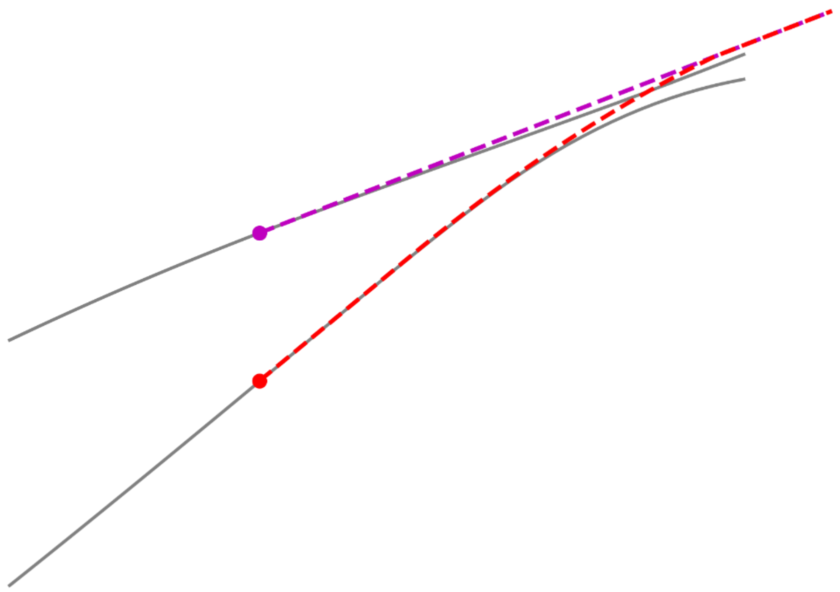
$$d_{safe}(t) = d_{unsafe}(t) = \frac{(u_2(t) - u_1(t))^2}{-2a_2'(t)}$$

Else if $u_2(t+\tau) > u_1(t)$:

$$d_{new} = \left(\frac{(u_2(t)+u_2(t+\tau))}{2} - u_1(t)\right)\tau$$

$$d_{safe}(t) = d_{new} + \frac{\left(u_2(t)+a_2'(t)\tau - u_1(t)\right)^2}{2b_{2comf}}$$

$$d_{unsafe}(t) = d_{new} + \frac{\left(u_2(t)+a_2'(t)\tau - u_1(t)\right)^2}{2b_{2max}}$$



Capacity for calm proactive reaction

The deceleration is relative to the values of PFS and CFS

PFS value of 1 induces full comfortable deceleration (e.g. 3 m/s^2)

CFS value of 1 induces full deceleration (e.g. 6 m/s^2)

PFS value of 0.2 induces 20% of comfortable deceleration (e.g. 0.6 m/s^2)

- The suggested model has the ability to apply a calm deceleration proactively, to avoid getting into a more serious (and possibly unavoidable) conflict

Background information

Section 2. Cut-in scenario: additional results

Range of concrete scenario assessed

Ego vehicle longitudinal speed 10 – 130 kph

Cutting-in vehicle longitudinal speed 10 – 120 kph

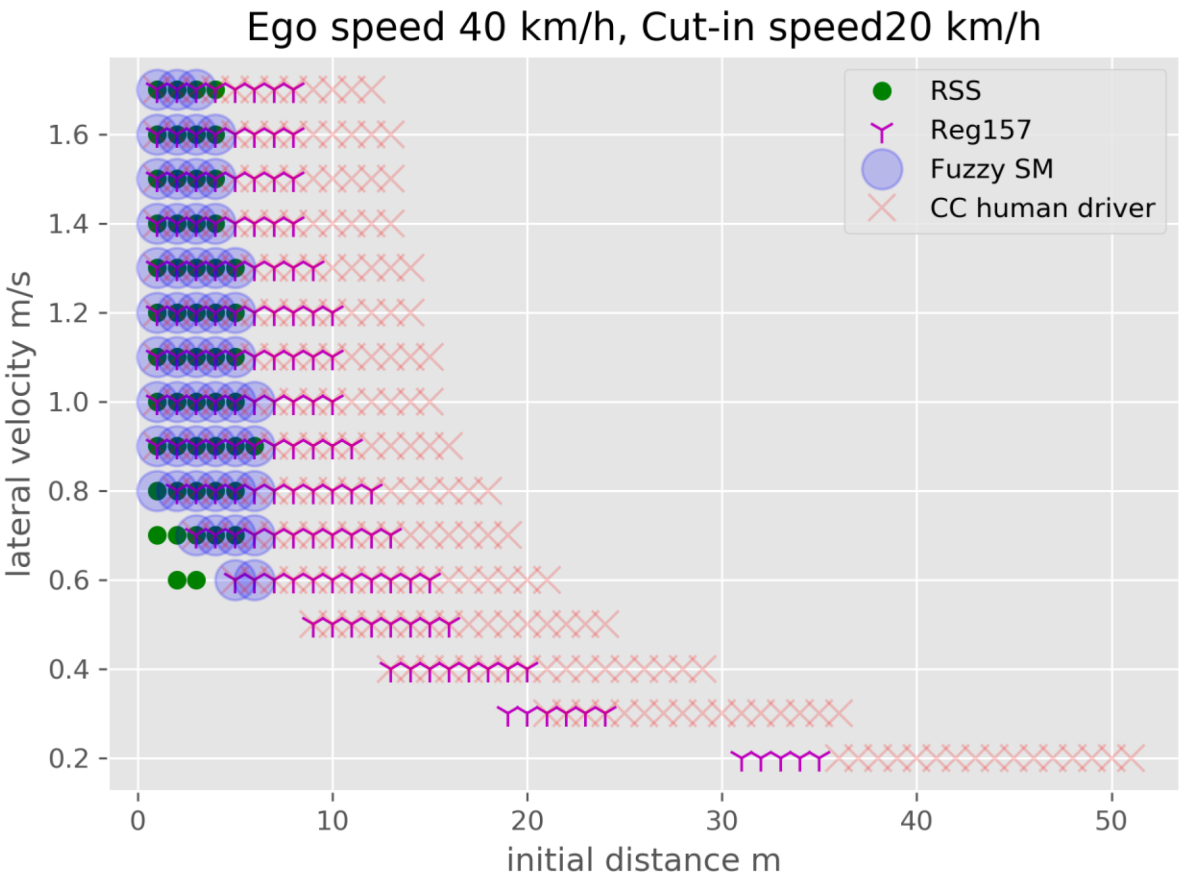
Cutting-in vehicle lateral speed 10 – 120 kph

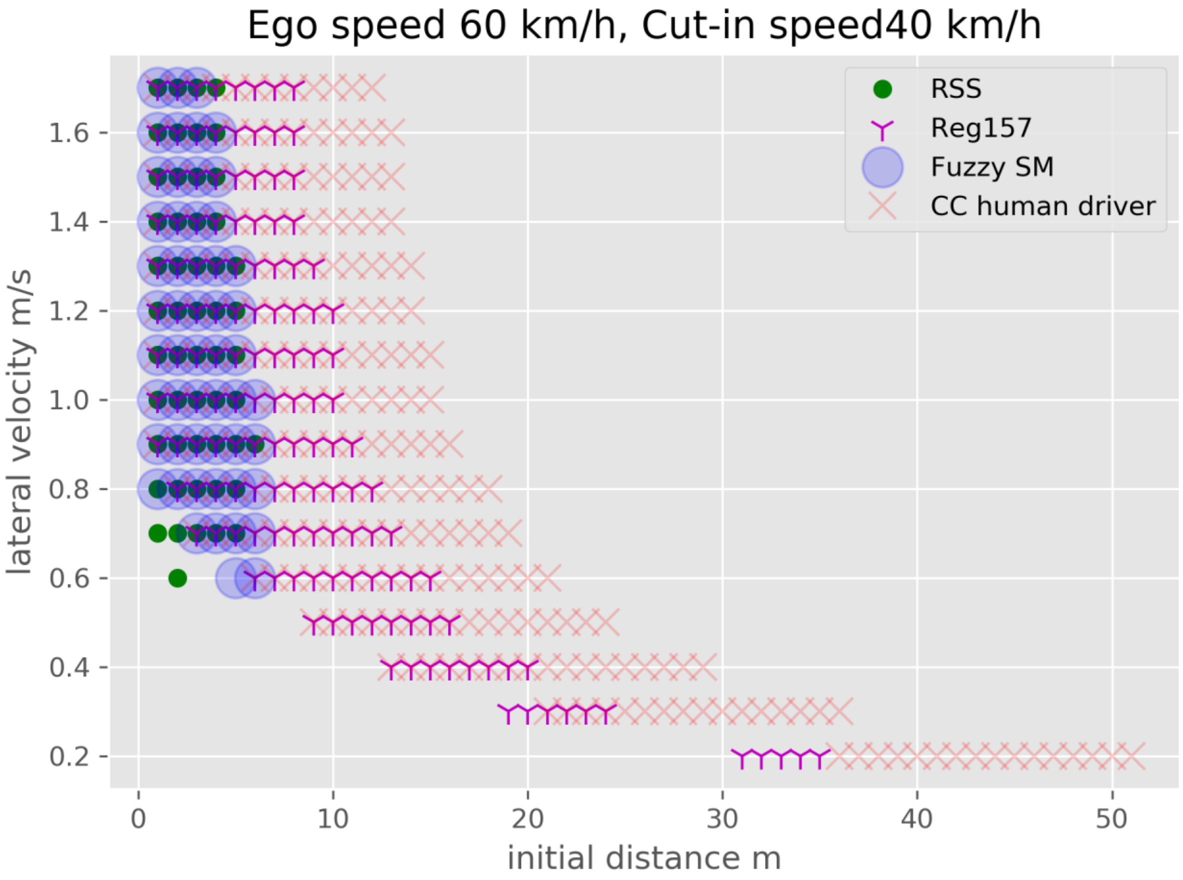
Initial longitudinal distance 1 – 60 m (1 – 120 for high speeds)

Parameters used in the simulations

- **Reaction time:**
  - Reg157 -> 0.35 sec
  - CC human driver, FSM, RSS -> 0.75 sec
- **Maximum deceleration (ego-vehicle)**
  - CC human driver, RSS -> 0.774 G
  - Reg157, FSM -> 6 m/s^2
- **Maximum jerk (ego-vehicle, absolute)**
  - CC human driver, RSS, FSM -> 12.65 m/s^3

Cut in Unpreventable





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Background information

Section 3. Criticality based classification of preventable scenarios

Criticality-based classification using Fuzzy SMs

In each simulation, PFS and CFS (see background information) are calculated for each simulation step. They take values for 0 to 1, with:

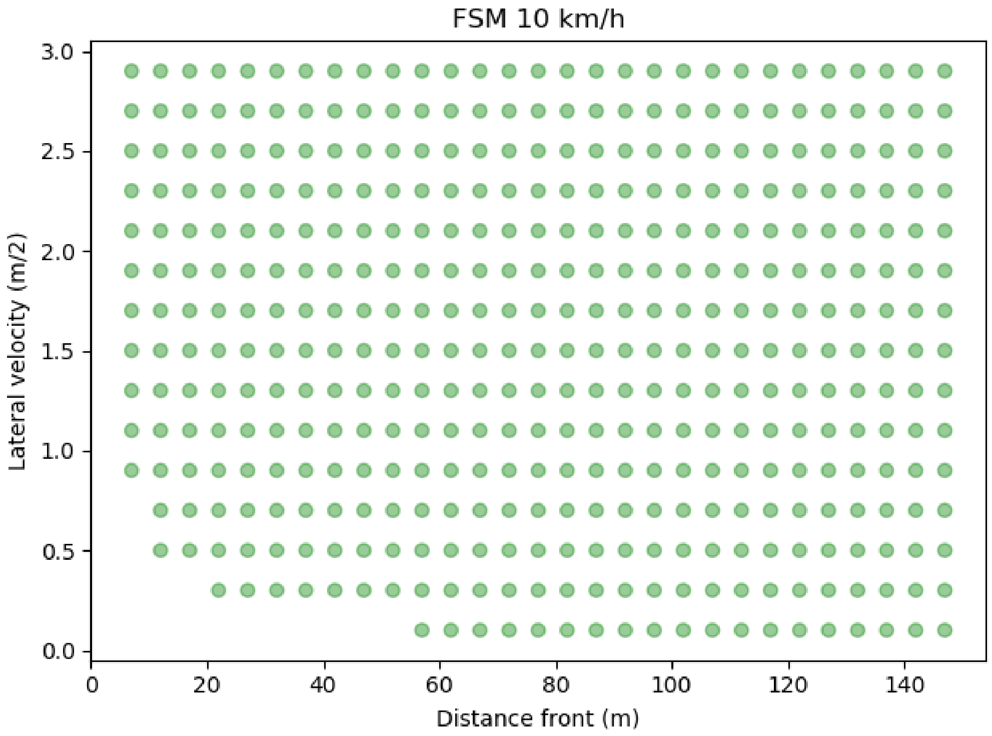
PFS = 1, the situation is “proactively unsafe”, the ego vehicle would not avoid an accident in case of a hard deceleration of the preceding vehicle

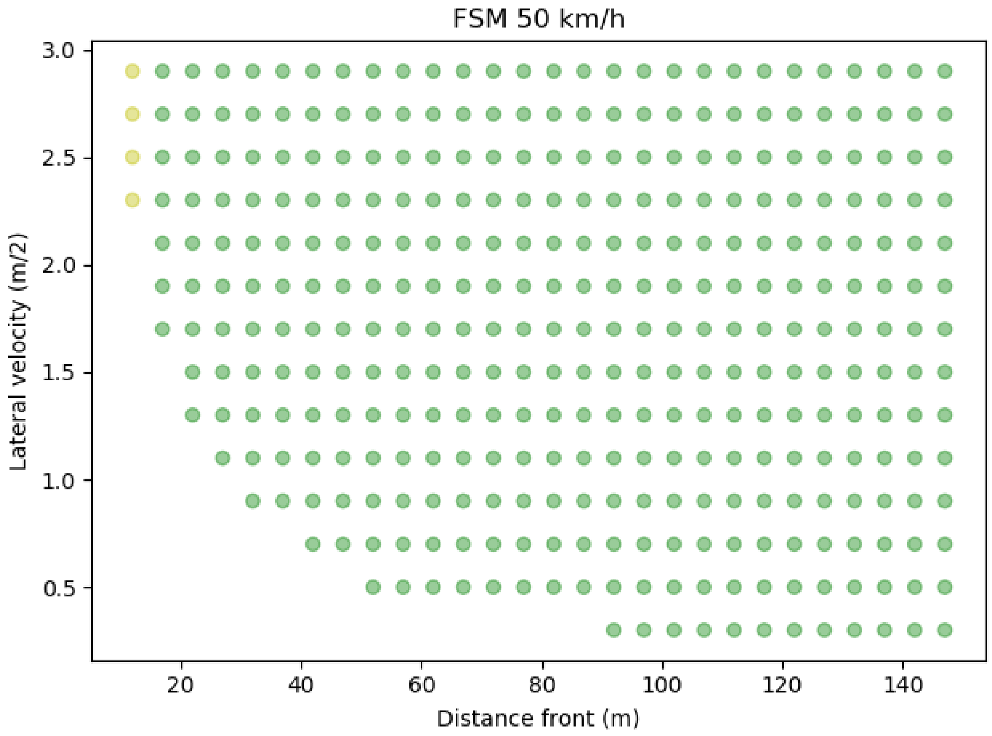
CFS = 1, the situation is “critically unsafe”, there is a severe conflict, and a very hard deceleration is required

By the maximum value of each scenario we classify in:

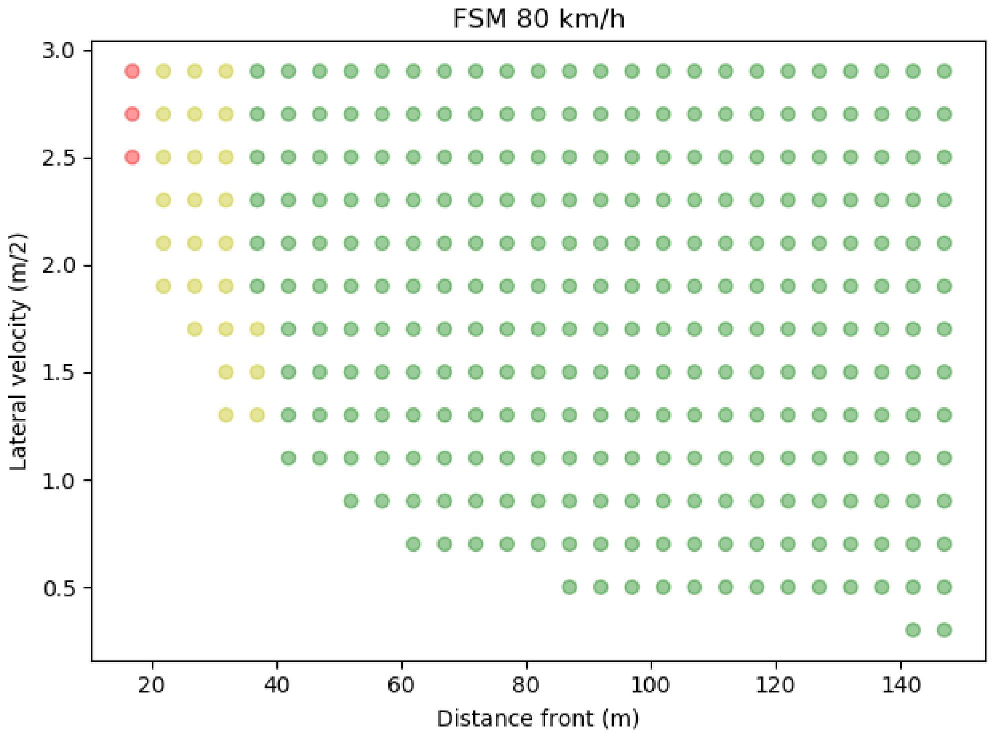
Easy: PFS <=0.85, Medium: PFS>0.85 and CFS <0.9, Hard: CFS=>0.9

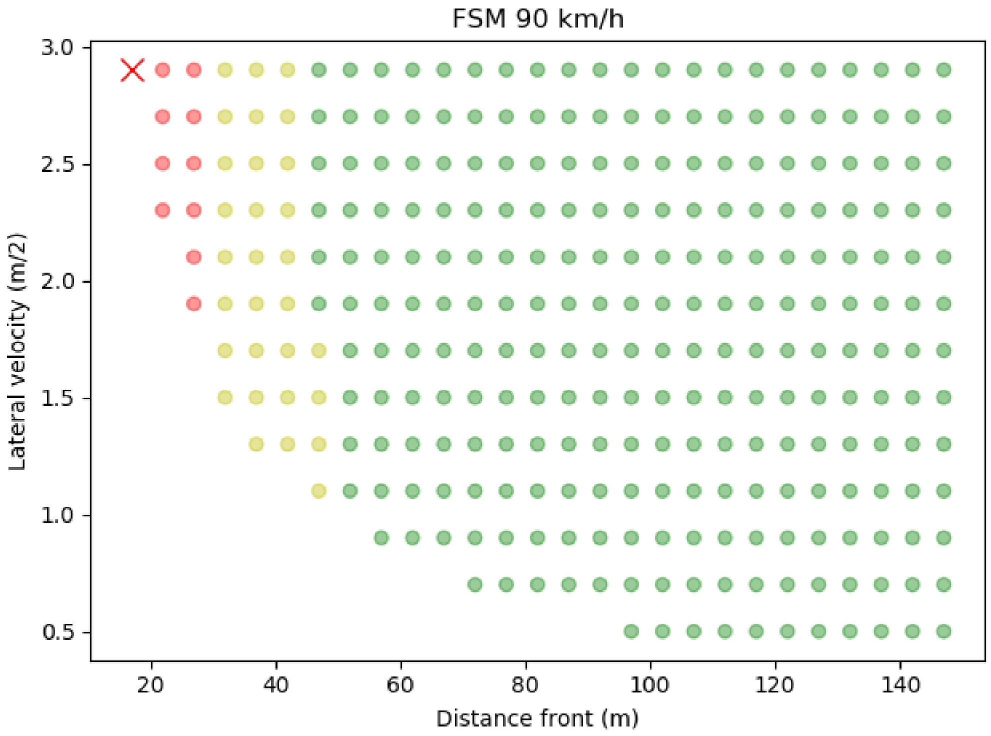
Classification for cut out scenarios





Classification for cut out scenarios





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Section 4. Car-following and cut-out

Car following scenarios

Steady state speed 2 – 130 kph

Leader's deceleration rate 0.05 – 1 G

Initial distance:

- CC human driver model → 2 sec THW
- RSS model → For time equal to τ, do not enter in d_{unsafe} if the leader vehicle decelerates
- Fuzzy logic model → PFS and CFS = 0

Car following scenarios simulated

Reaction time starts when:

- CC human driver model → Leader vehicles deceleration harder than 5 m/s^2
- RSS model → Ego vehicle enters d_{unsafe} (could be avoided with calm deceleration)
- Fuzzy logic model → PFS or CFS > 0

Parameters used in the simulations

- **Reaction time:**
  - CC human driver, FSM, RSS -> 0.75 sec
- **Maximum deceleration (ego-vehicle)**
  - CC human driver, RSS -> 0.774 G
  - FSM -> 6 m/s^2
- **Maximum jerk (ego-vehicle, absolute)**
  - CC human driver, RSS, FSM -> 12.65 m/s^3

Cut out scenarios

Three models are compared

- CC human driver model
- RSS model
- Fuzzy logic model

Cut out scenarios simulated

Steady state speed 10 – 130 kph

Distance in front 5 – 130 m

Initial distance:

- CC human driver model → 2 sec THW
- RSS model → For time equal to τ, do not enter in d_{unsafe} if the leader vehicle decelerates
- Fuzzy logic model → PFS and CFS = 0

Cut out scenarios simulated

Reaction time starts when:

Leader vehicle has moved more than 0.375 m (wondering zone) or has crashed **and**

- RSS model → Ego vehicle enters d_{unsafe} (could be avoided with calm deceleration)
- Fuzzy logic model → PFS or CFS > 0

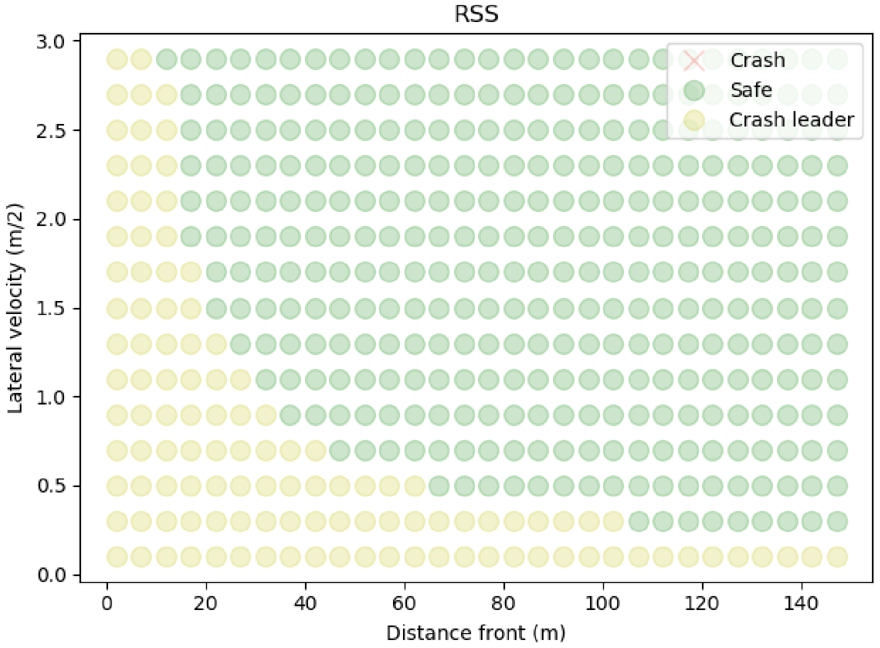
Parameters used in the simulations

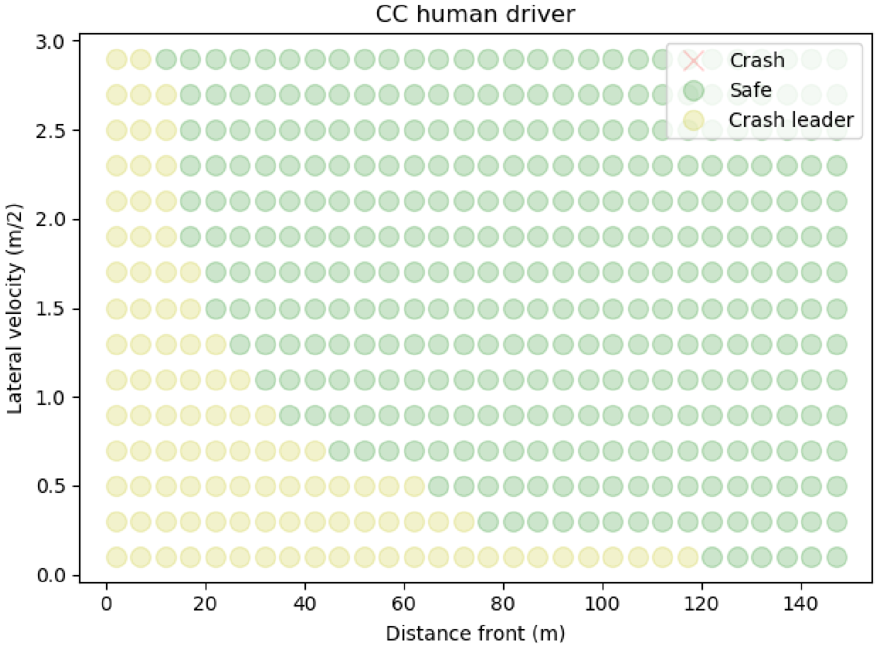
- **Reaction time:**
  - CC human driver, FSM, RSS -> 0.75 sec
- **Maximum deceleration (ego-vehicle)**
  - CC human driver, RSS -> 0.774 G
  - FSM -> 6 m/s^2
- **Maximum jerk (ego-vehicle, absolute)**
  - CC human driver, RSS, FSM -> 12.65 m/s^3

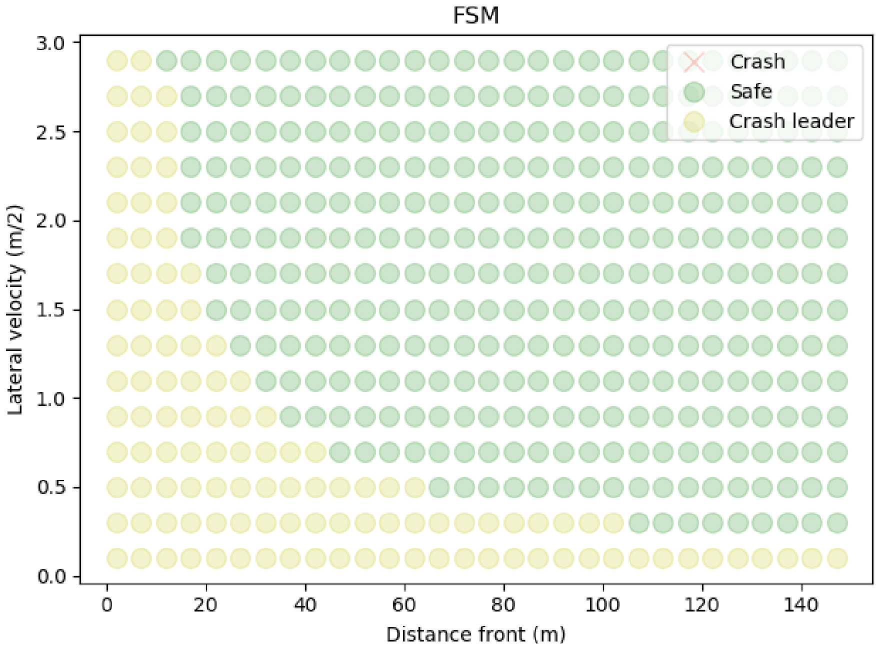
Cut-out scenarios results

For low speeds the ego vehicle avoids the collision with the stopped vehicle for any model

Pictures for ego vehicle speed of **60 km/h**







Thank you

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