Filtration analysis of pedestrian-vehicle interactions for autonomous vehicle control

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IAS-15 Workshop on Robot Perception of Humans
Baden-Baden June 11th 2018

Team

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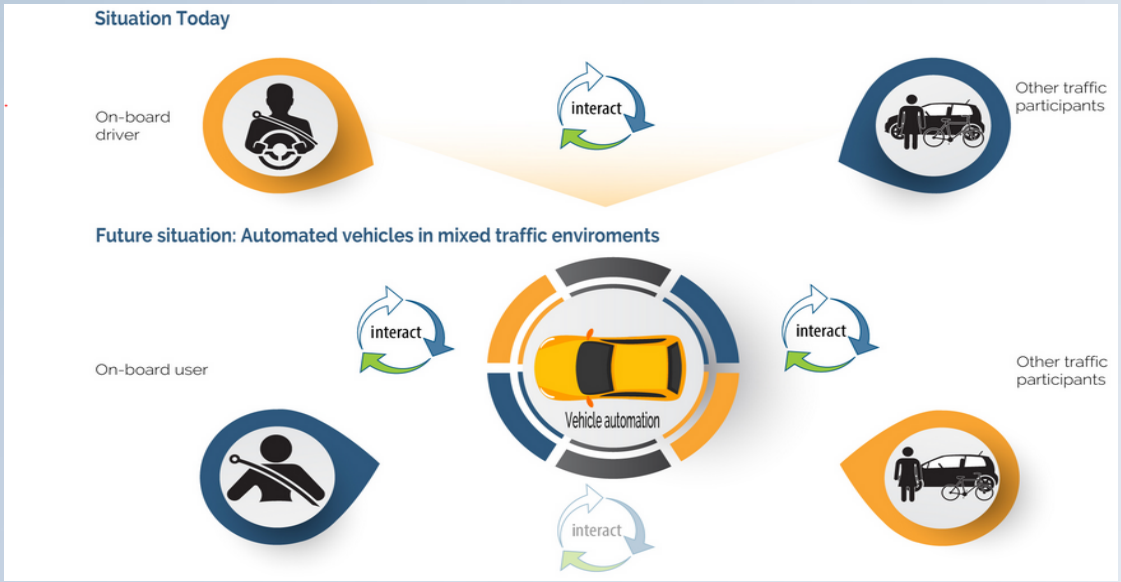
Motivations

EU City mobil 2 project

Trials of an AV:
La Rochelle (France) and Trikala (Greece)

Finding from Madigan et al.:
pedestrians intentionally step in front the AV once every 3 hours



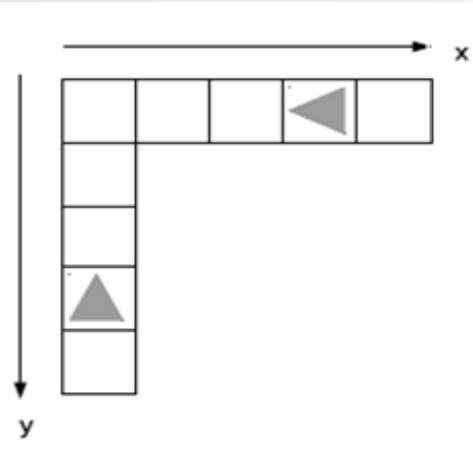
EU H2020 interACT project

Background

- Sequential Chicken Game: Game theory model for pedestrian-vehicle interactions
- Non-zero probability for a collision to occur
- Fit parameters U_crash and U_time to H-H interactions

Real world pedestrian-pedestrian interactions
Between Hollywood and Highland, Los Angeles

Fox et al. 2018



Camara et al. 2018

Data collection: Pedestrain-Vehicle interactions

Observers“ standing locations (X and Y)
Intersection near Woodhouse Lane, University of Leeds

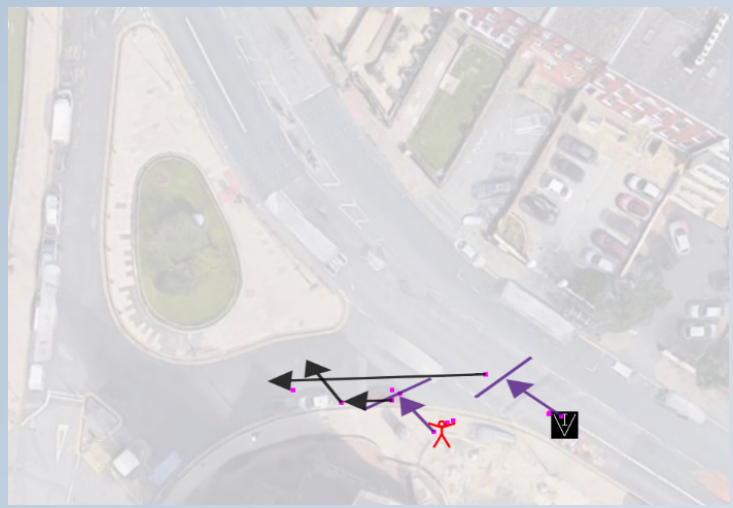
2 Observers standing next each other:
- one focusing on the pedestrian
- the other focusing on the vehicle

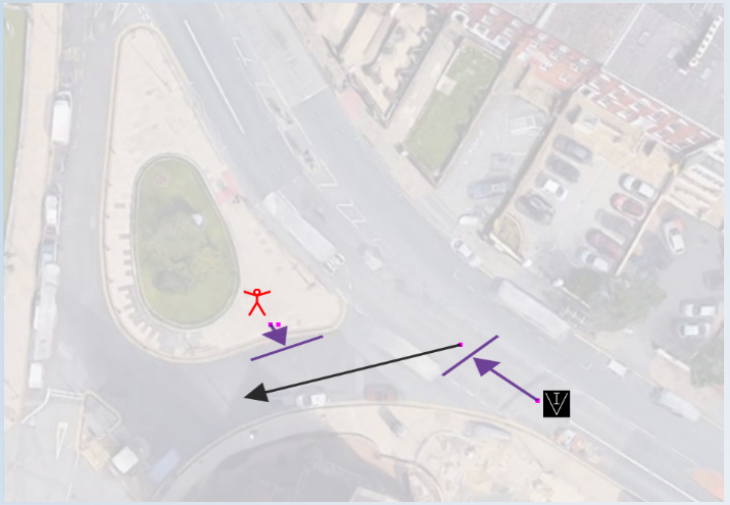
Descriptor Features:
gender, age, weather, number of pedestrian and vehicle, pedestrian“s distraction

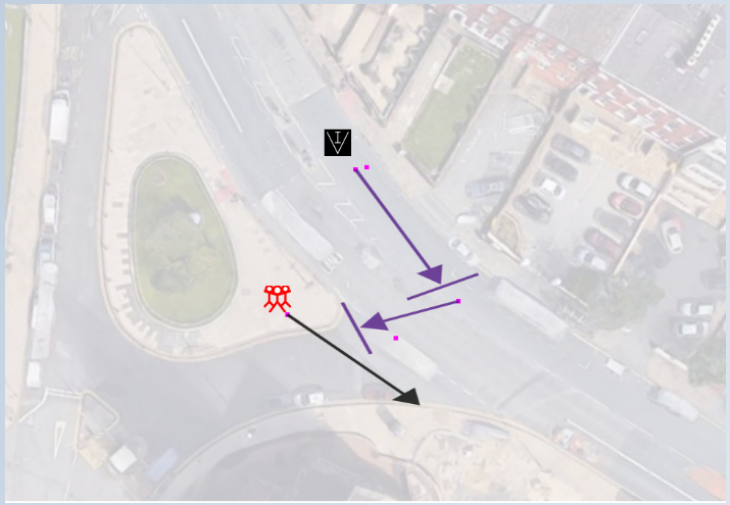
Event Features:
(what is the pedestrian/vehicle doing ?)

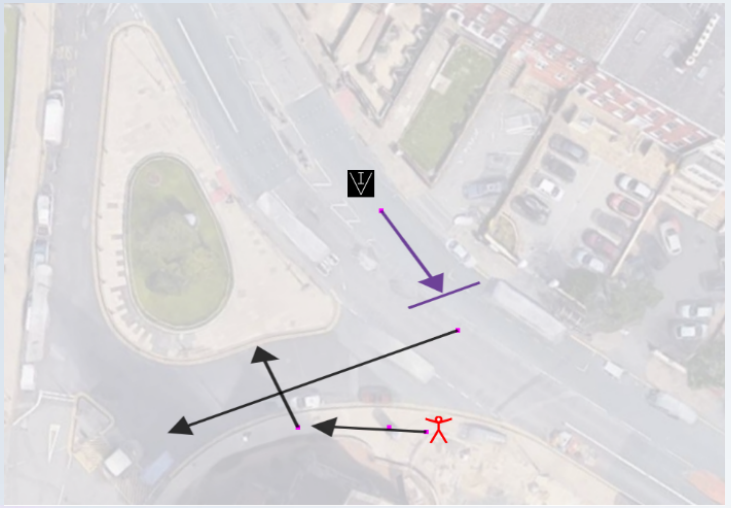
Approaching while keeping pace, stopped to due the traffic, turning the head to the right, using the turn indicator, looking at other road users, etc

Examples of interactions





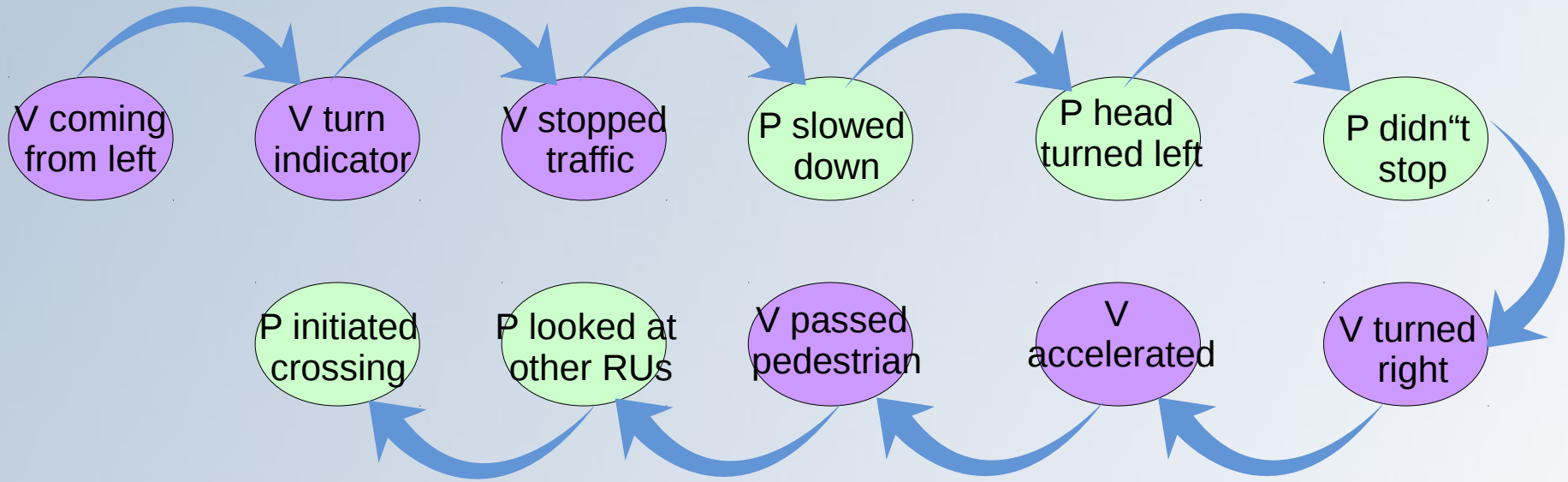




Interactions

- 204 interactions → 204 sequences of actions

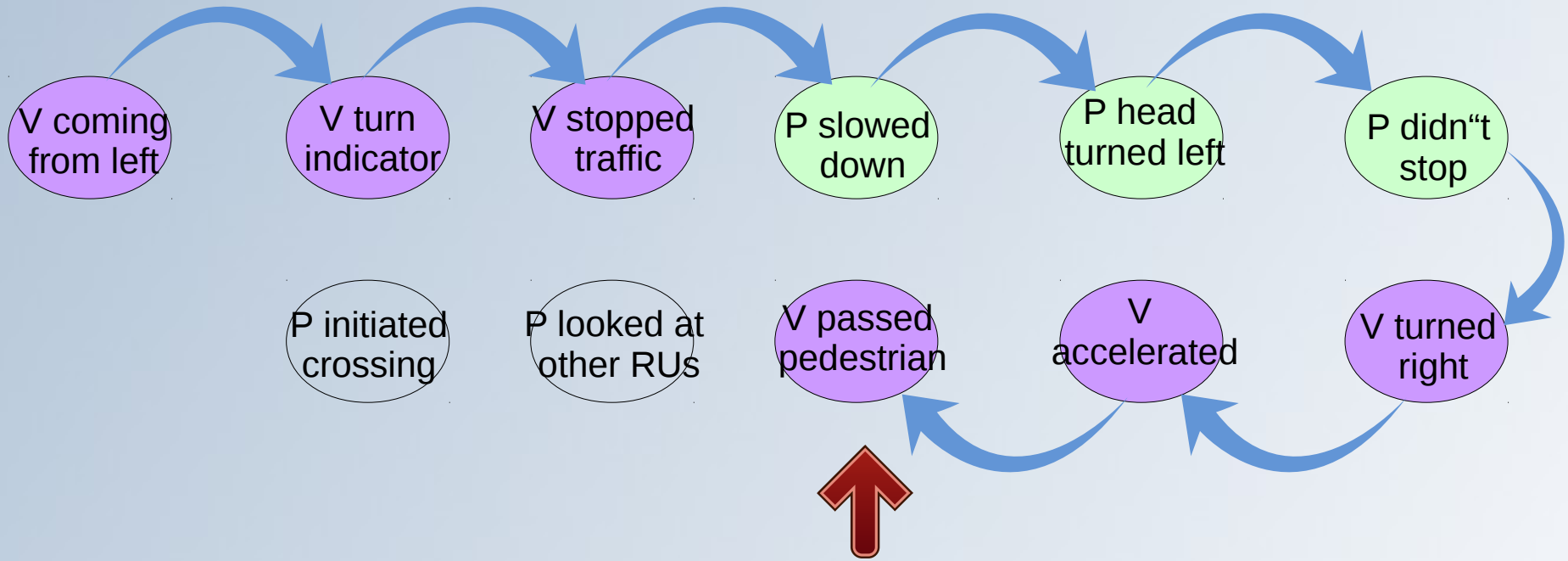
- Example: a sequence of an interaction



P: Pedestrian
V: Vehicle

Interactions into games

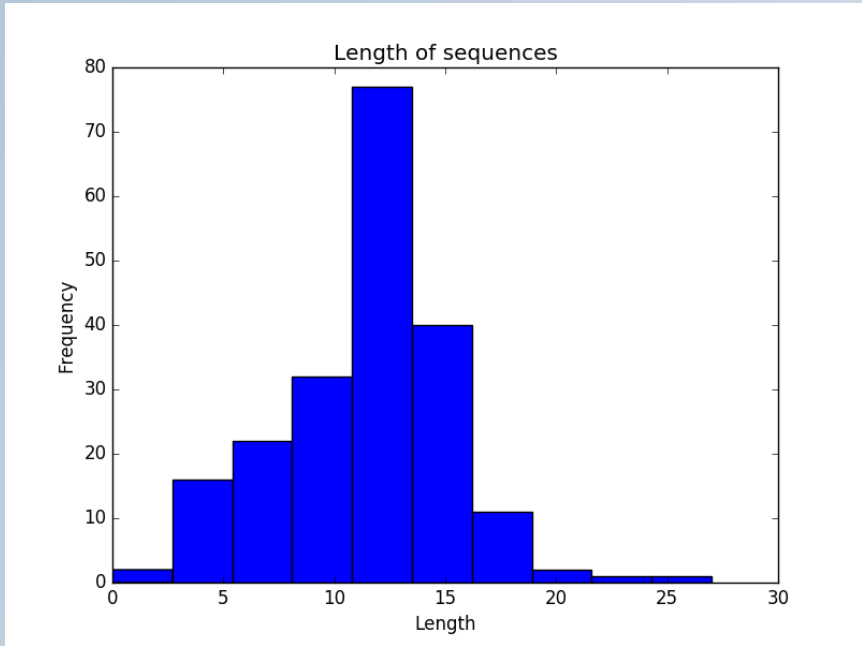
- Game: Vehicle or Pedestrian winner ?



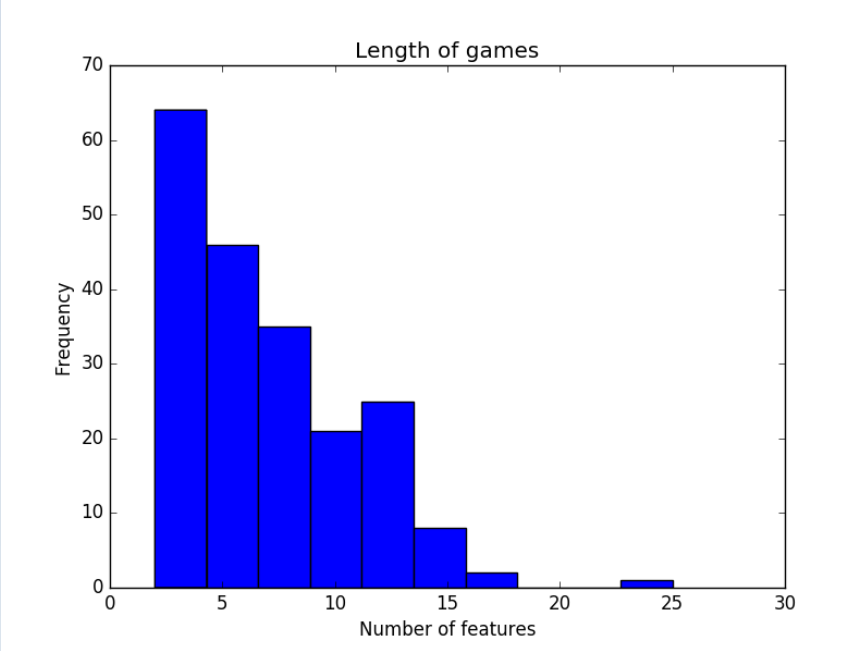
End of game event: vehicle winner of the interaction

P: Pedestrian
V: Vehicle

Interactions vs Games



Interactions



Games

Filtration

- Concept to incorporate events over time, used in optimal stopping problems
  e.g: Mariage problem, Biology (sequence analysis), Finance

- Compute likelihood for each descriptor/event features

$$\lambda(W|f_i) = \frac{freq(W|f_i)}{freq(W|f_i) + freq(\neg W|f_i)}$$

- Fuse likelihoods over time

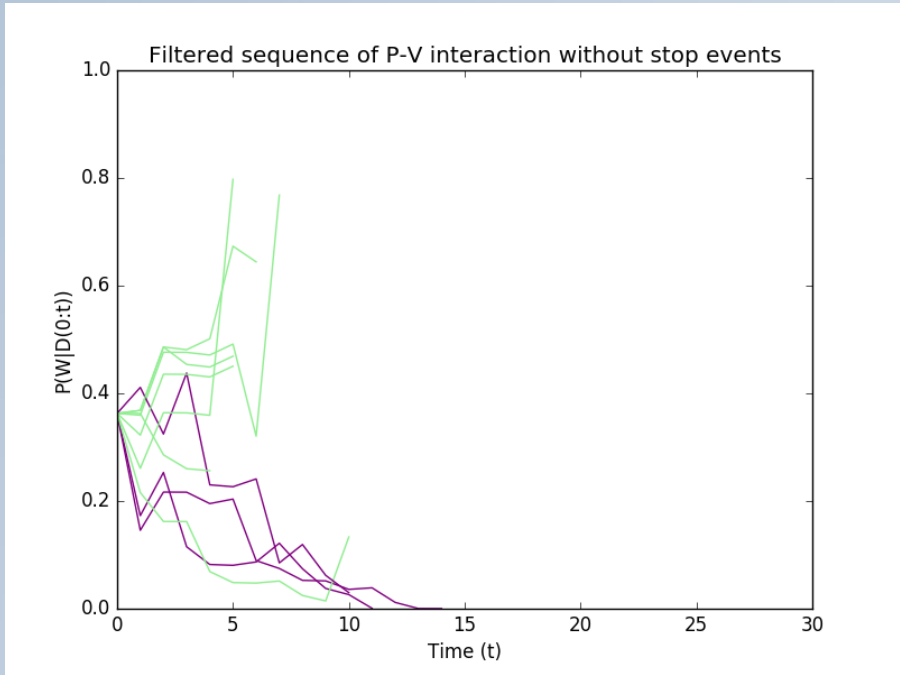
$$P(W|f_1, f_2, f_n) = P(W|0) \otimes \lambda(W|f_1) \otimes \lambda(W|f_2) \otimes \ldots \otimes \lambda(W|F_n)$$

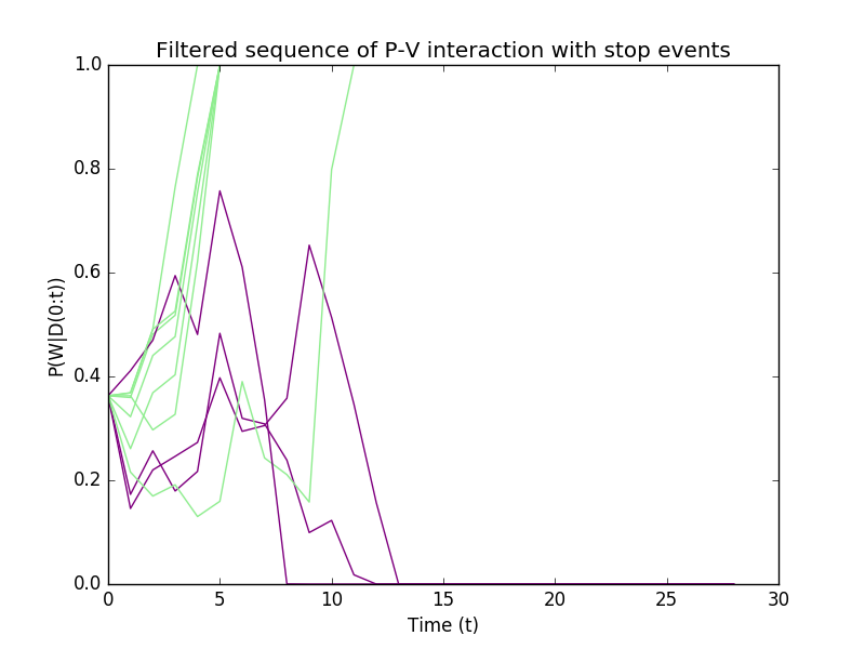
where $p \otimes q = \frac{pq}{pq + (1-p)(1-q)}$

- t=0 : prior P(W|0) (36%: 74 out of 204)
- t=1 : all descriptors are observed and incorporated
  …
- t=n : all features have been observed

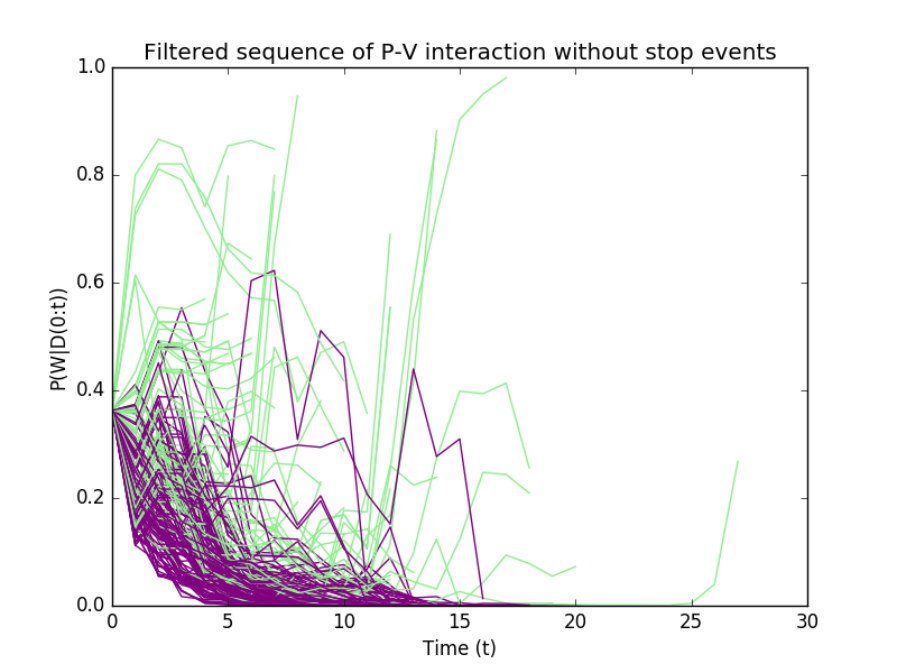
Event Features e_i	$\lambda(W\|e_i)$
'Crossing Phase: Pedestrian Speeded up'	0.95471
'Crossing Phase: Driver/Vehicle Decelerated for observed pedestrian'	0.84051
'Crossing Phase: Driver/Vehicle Used signals Turn Indicator'	0.77844
'Approaching Phase: Driver/Vehicle Waved hand'	0.77844
'Approaching Phase: Driver/Vehicle Head Movements Other (elaborate in notes)'	0.7784
'Crossing Phase: Driver/Vehicle Movement Other (elaborate in notes)'	0.77844
'Crossing Phase: Pedestrian Raised hand in front'	0.77844
'Crossing Phase: Driver/Vehicle Raised hand in front'	0.7784
'Crossing Phase: Driver/Vehicle Head Turned in the direction of pedestrian'	0.7784
'Crossing Phase: Driver/Vehicle Stopped for observed pedestrian'	0.7784
'Crossing Phase: Pedestrian Looked at driver'	0.7784
'Approaching Phase: Driver/Vehicle Stopped due to other pedestrian'	0.7784
'Crossing Phase: Pedestrian Movements Other (elaborate in notes)'	0.77844
'Crossing Phase: Pedestrian Initiated crossing movement'	0.7712
'Approaching Phase: Driver/Vehicle Head Turned in the direction of pedestrian'	0.74541
'Crossing Phase: Pedestrian Head Movements Turned left'	0.7454
'Approaching Phase: Driver/Vehicle Interacting vehicle Bus / Truck'	0.72490
'Approaching Phase: Vehicle Stopped for observed pedestrian'	0.7008
'Crossing Phase: Pedestrian Looking at other pedestrians entering the road	0.6372
'Crossing Phase: Pedestrian Waved Hand'	0.63725
'Approaching Phase: Driver/Vehicle Head Turned left'	0.6372
'Approaching Phase: Driver/Vehicle Movement Other (elaborate in notes)'	0.6372
'Approaching Phase: Pedestria Hand Movements Other (elaborate in notes)'	0.6372
'Crossing Phase: Driver/Vehicle Turned left'	0.6372
'Crossing Phase: Vehicle Waved hand'	0.63725
'Crossing Phase: Driver/Vehicle Accelerated'	0.63725
'Crossing Phase: Driver/Vehicle Turned right'	0.6372
'Approaching Phase: Pedestrian Looking at other pedestrians entering the road'	0.6372
'Approaching Phase: Pedestrian Looking at other RUs Others (elaborate in notes)'	0.6372
'Approaching Phase: Driver/Vehicle Used signals Flashed Lights'	0.6372
'Approaching Phase: Pedestrian Movements Kept pace'	0.6231
'Approaching Phase: Vehicle Used signals Turn Indicator'	0.559
'Crossing Phase: Driver/Vehicle Passed the pedestrian'	0.5394
'Approaching Phase: Pedestrian Movements Did not Stop'	0.5365
'Approaching Phase: Pedestrian Head Movements Turned right'	0.53485
'Approaching Phase:Driver/Vehicle approached From left'	0.5292
'Approaching Phase: Driver/Vehicle Decelerated due to other pedestrians'	0.5131
'Approaching Phase: Driver/Vehicle Stopped due to traffic'	0.51315
'Approaching Phase: Driver/Vehicle approached from Multiple'	0.5009
'Approaching Phase: Driver/Vehicle Decelerated for observed pedestrian'	0.4875
'Approaching Phase: Pedestrian Speeded up'	0.46762
'Crossing Phase: Pedestrian Raised hand sidewards'	0.4676
'Approaching Phase: Driver/Vehicle Interacting vehicle Other (elaborate in Notes)'	0.4676
'Crossing Phase: Pedestrian Stepped back on pavement'	0.4676
'Approaching Phase: Driver/Vehicle Turned left'	0.45419
'Approaching Phase: Pedestrian Stopped at the edge of the pavement'	0.43844
'Approaching Phase: Pedestrian Stepped on road and stopped'	0.42951
'Approaching Phase: Pedestrian Head Movements Turned left'	0.42951
'Approaching Phase: Pedestrian Movements Slowed down'	0.4260
'Crossing Phase: Pedestrian Looking at Looked at vehicle'	0.41269
'Approaching Phase: Driver/Vehicle Decelerated due to traffic'	0.3874
'Crossing Phase: Pedestrian Hand Movements Other (elaborate in notes)'	0.36931
'Approaching Phase: Driver Head Turned right'	0.36931
'Approaching Phase: Driver/Vehicle Interacting vehicle Van'	0.3693
'Approaching Phase: Driver/Vehicle Kept pace'	0.36931
'Approaching Phase: Driver/Vehicle Turned right'	0.3598
'Crossing Phase: Pedestrian Head Movements Turned right'	0.3341
'Approaching Phase: Pedestrian Looked at approaching vehicle'	0.3129
'Crossing Phase: Pedestrian Looking at other RUs (elaborate in comments)'	0.26
'Crossing Phase: Pedestrian Slowed down / stopped	0.26
'Approaching Phase: Driver/Vehicle Accelerated'	0.163316
'Approaching Phase: Driver/Vehicle Passed the pedestrian'	0.11514

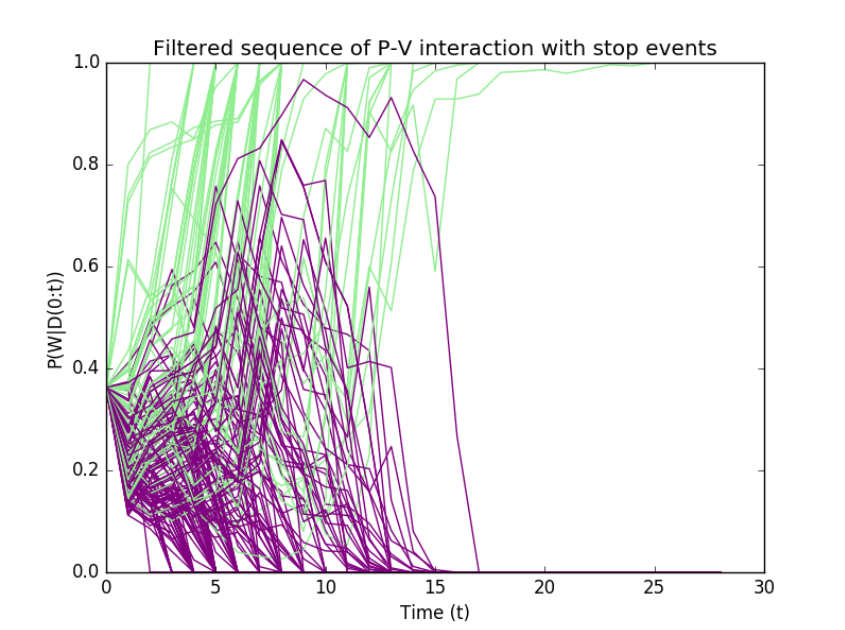
Filtration results for 10 interactions





Filtration results: all interactions

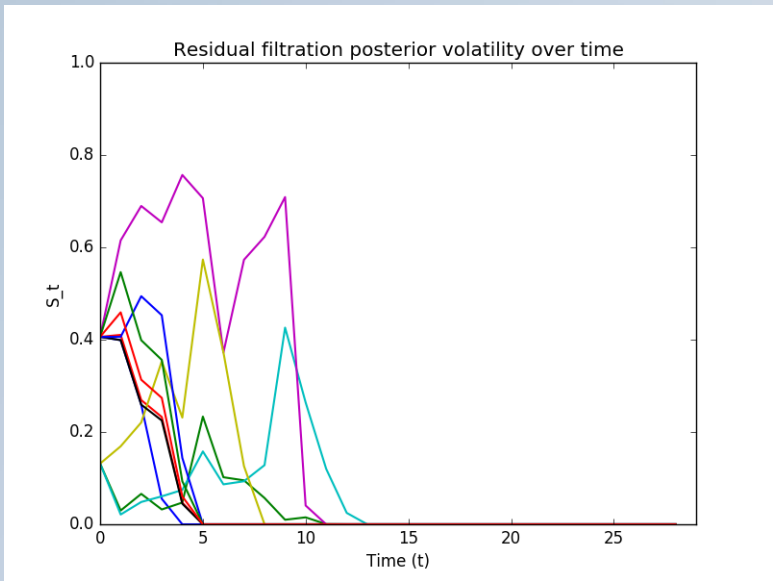


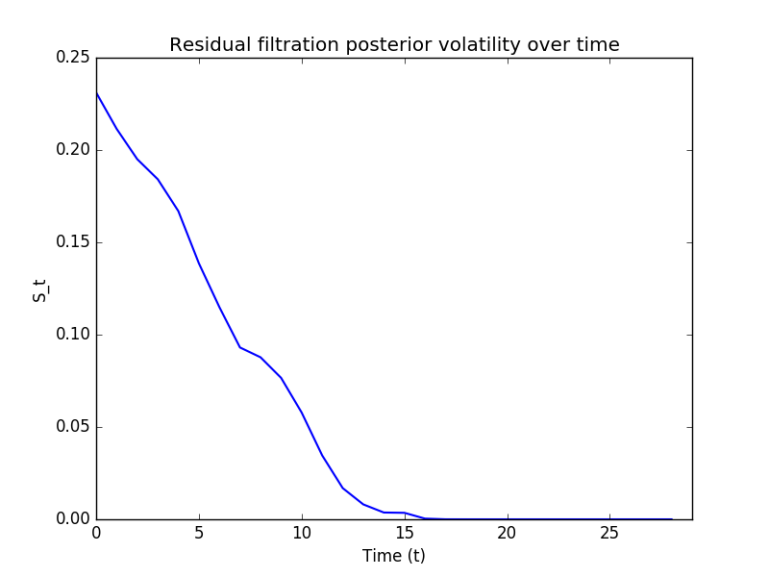


Residual filtration posterior volatility

- A series of statistics to inform about the standard deviation over the filtration

$$s_t = \langle std\{P(W|\mathcal{F}(\tau))\}_{\tau=t:T} \rangle$$





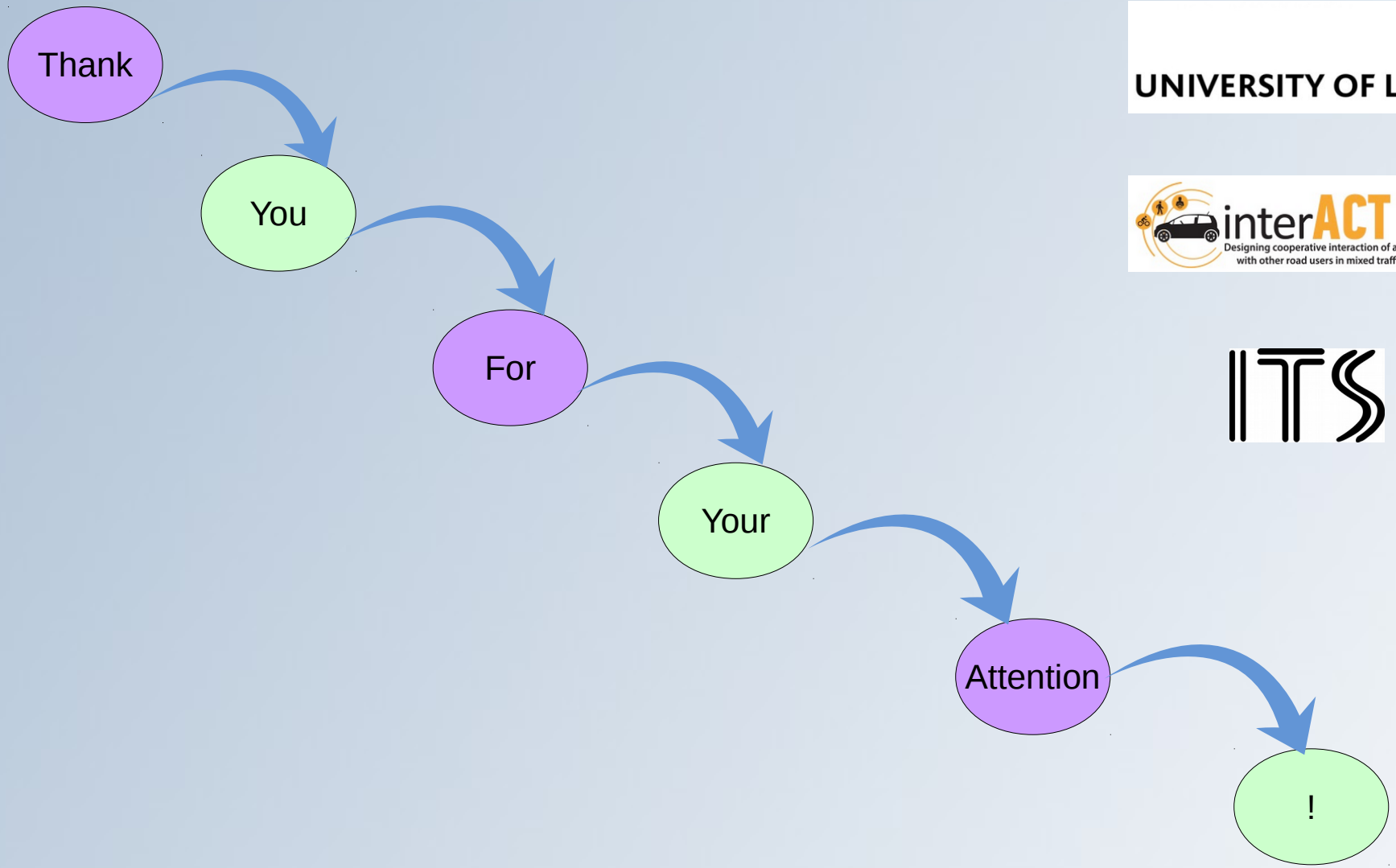
- The descriptor fetaures and the first event features are important but not the later ones

Conclusion

- Large scale observation of real world pedestrian-vehicle interactions
- Filtration on the sequences of interaction
- The residual shows that an Av should wait and observe the initial features before acting

Future work

- Features are assumed to be independent => new way to model that
- Infer pedestrian and driver assertiveness: U_crash and U_time
- Take into account observation of non-features



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interACT
Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

ITS

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