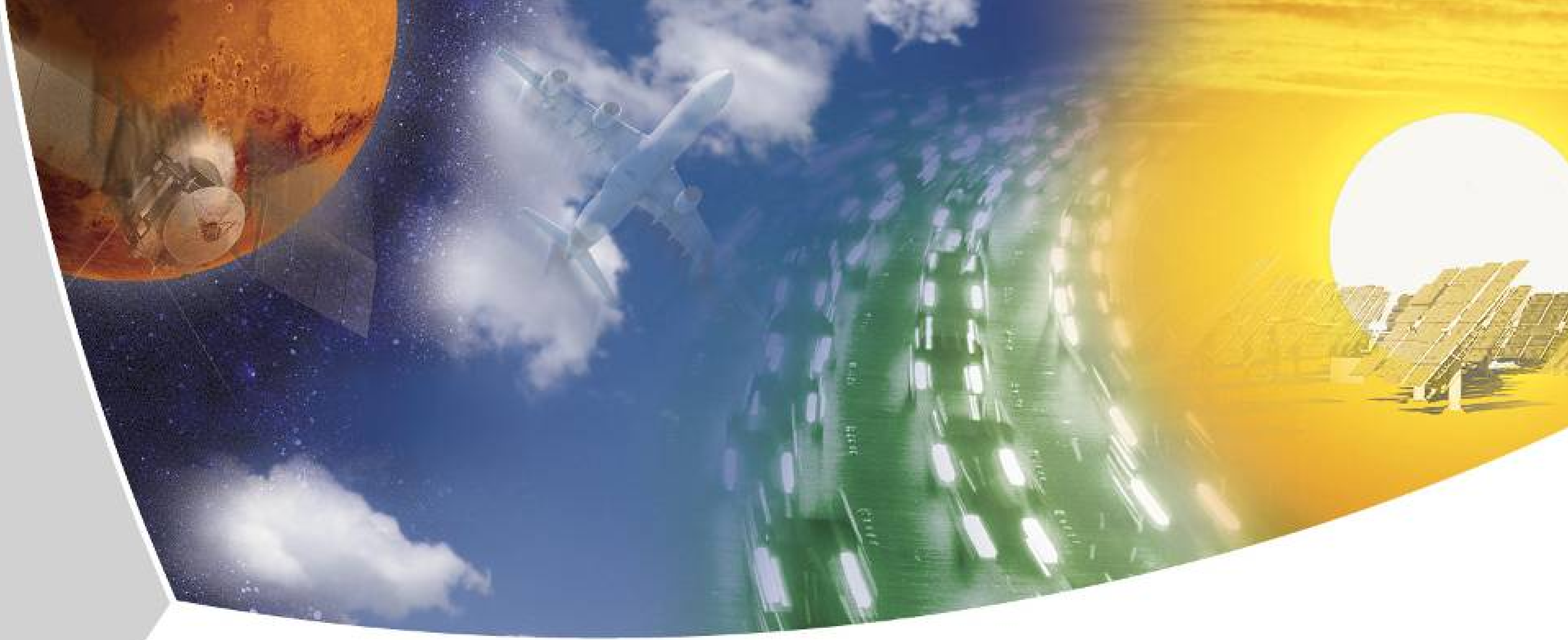

Intelligent Information Dissemination in Collaborative, Context-Aware Environments

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in der Helmholtz-Gemeinschaft

Outline

- The Need for Intelligent Information Dissemination
- Plugging Different Inference Modules with Bayeslets
- Utility Determination
  - Determination of the Net Expected Utility
  - A Probability Based Utility Function
  - A Decision Based Utility Function
- Application for Cooperative Adaptive Cruise Control
  - Position Dissemination Frequency (Probability Based Utility)
  - Acceleration or Deceleration (Decision Based Utility)
- Conclusion

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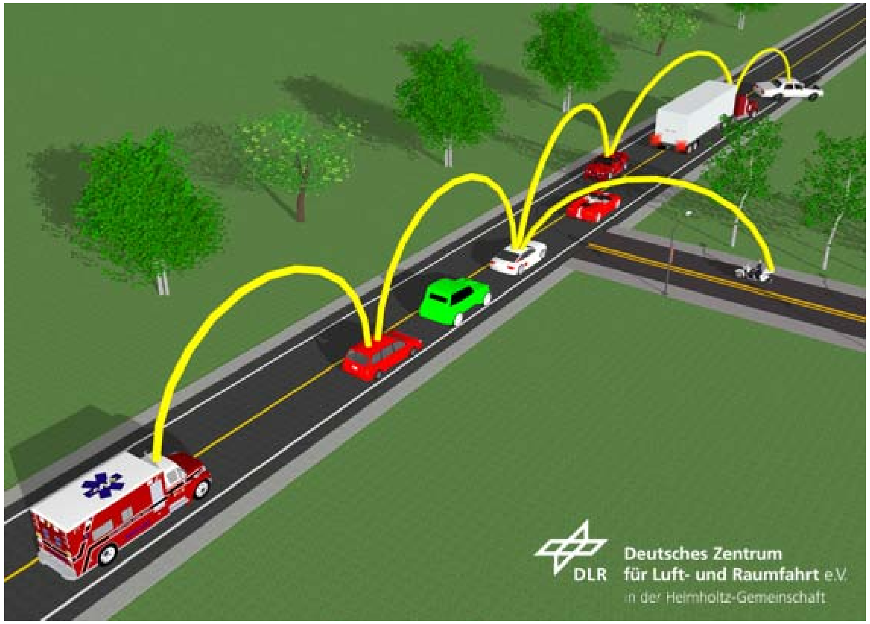
The Need for Intelligent Information Dissemination
Motivation

- Assistance systems have to recognise the current situation. E.g.:
  - Stress situations at work
  - Hazardous situations in traffic
- Only when situations are known, countermeasures can be taken



The Need for Intelligent Information Dissemination
Motivation

- Such situations have to be inferred as they cannot be sensed directly
- In ubiquitous systems, all information could in theory be shared – from millions and billions of sensors
  - every new car has hundreds of sensors, more than 50 CPUs
  - Innumerable stress factors, often caused by others and their situation
- Information however always connected to cost for:
  - Transmission
  - Processing
- Resources in ubiquitous systems however are limited
  - Network Bandwidth
  - Computing power and memory in mobile smart devices

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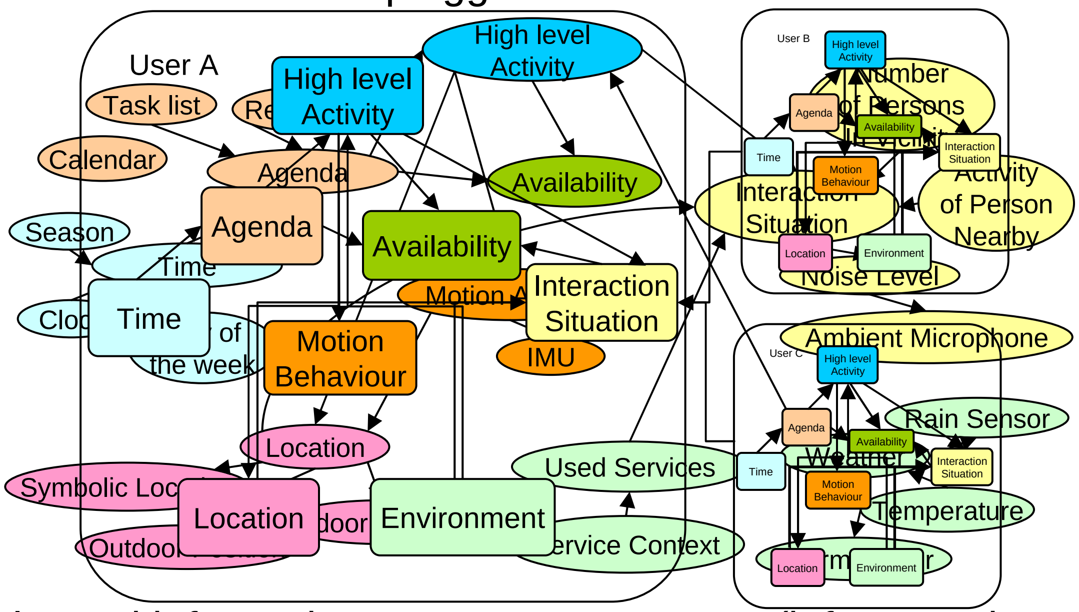
Plugging Different Inference Modules with Bayeslets

Application Background

- Bayesian Networks are a powerful means for context and situation inference
- To cope with frequently changing availability of information sources, the concept of “Bayeslets” makes them pluggable



- Every plugged information source causes costs (inference time, network bandwidth)

➔ Need for an intelligent way to decide if an available information source is needed

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Utility Determination
Determination of the Net Expected Utility

- Decision for connection based on the *utility* of the additional information
- Utility U of an additional piece of evidence y:
  $U(X:y) = U(X \mid y) - U(X)$
- X is subject to uncertainty ➔ calculation of the *Expected Utility* (EU) gain by summing over all states weighted by their probability of occurrence
  $$EU(X:y) = EU(X \mid y) - EU(X) = \sum_{x \in X} U(x \mid y) P(x \mid y) - \sum_{x \in X} U(x) P(x)$$
- Considering that Y is unknown before transmission and existing knowledge c:
  $$EU(X:Y) = EU(X \mid Y) - EU(X) = \sum_{x \in X} \sum_{y \in Y} U(x \mid y) P(x \mid y) P(y) - \sum_{x \in X} U(x) P(x) \qquad (1)$$
  $$EU(X:Y \mid c) = \sum_{x \in X} \sum_{y \in Y} U(x \mid y, c) P(x \mid y, c) P(y, c) - \sum_{x \in X} U(x \mid c) P(x \mid c) \qquad (2)$$
- Considering the costs of new information with the *Net Expected Utility ($NetEU$)*:
  $$NetEU(X:Y \mid c) = EU(X:Y \mid c) - C(Y) \qquad (3)$$

➔ **Decision on usage of information Y**, where threshold t is a constant:

$$\boxed{NetEU(X:Y \mid c) > t}$$

Utility Determination
A Probability Based Utility Function

- Utility of a random variable increases with certainty about it
- Increase can be modelled with any monotonous increasing function

- Shannon used the binary logarithm for the *Mutual Information* $I(X:Y)$
  - ➔ $U(x|y) = \log_2 P(x|y) \Rightarrow EU(X:Y) = I(X:Y)$

- Calculation based on the (conditional) *Entropy* $H(X)$, $H(X|Y)$, where $E_X(f)$ is the expectation function of function f over X

$$I(X:Y) = \sum_{x\in X}\sum_{y\in Y} \log_2 P(x|y) P(x|y) P(y) - \sum_{x\in X} \log_2 P(x) P(x) =$$

$$= E_{X,Y}(\log_2 P(X|Y)) - E_X(\log_2 P(X)) = -H(X|Y) + H(X)$$

Utility Determination

A Decision Based Utility Function

- Uncertainty reduction is not an end in itself, aim is the optimum outcome!
- Definition:

  An *action* a is a function attaching a consequence to each state of the world.

- An instance of the expected utility is the *Maximum Expected Utility (MEU)*

$$MEU(X \mid Y) = \max_{a \in A} EU(X \mid Y, a) = \max_{a \in A} \sum_{x \in X} U(x) P(x \mid a, Y)$$

- If used in equ. (1), $EU(X : Y)$ is equivalent to the *Value of Information (VoI):*

$$EU(X : Y) = MEU(X \mid Y) - MEU(X) = VoI(X, Y)$$

- An extension of Bayesian Networks models Utility functions and Decisions:

Decision Node

Values of this node are all possible actions

Utility Node

Relates costs of decisions with parent random variables

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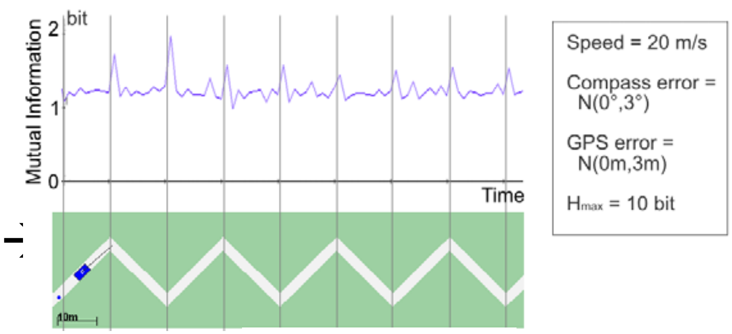
Application for Cooperative Adaptive Cruise Control

Position Dissemination Frequency (Probability Based Utility)

Experiment 1:

- a car drives along a road
- constant speed
- 3 sensors (GNSS, odometer, compass) → 3 Bayeslets
- Sensors are erroneous, update rate $10\ Hz$



Case 1

- Case 1: “zig-zag” road:
  - ➔ $I = EU$ increases after bends
- Case 2: straight road
  - GNSS updates with only $0.4\ Hz$
  - ➔ $I = EU$ increases when new measurements are available

Case 2

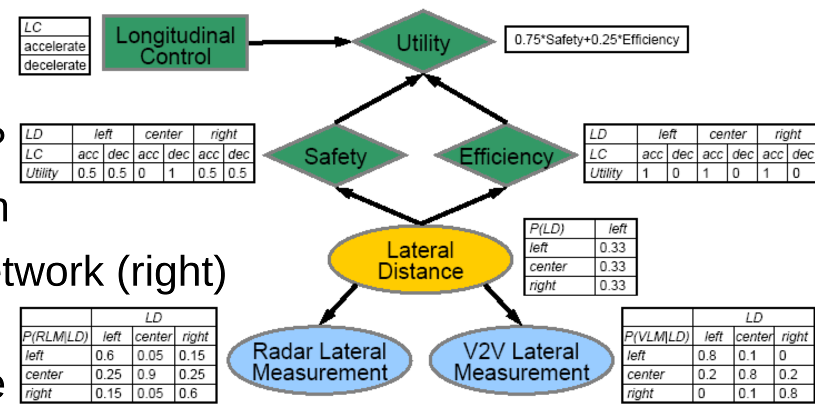
Application for Cooperative Adaptive Cruise Control

Acceleration or Deceleration (Decision Based Utility)

Experiment 2:

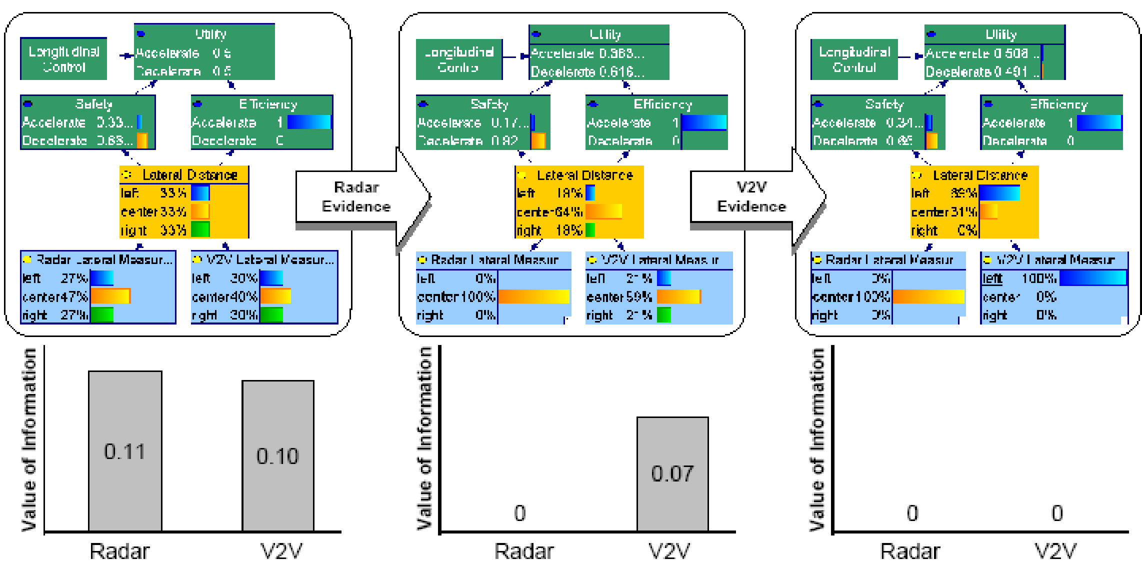
- radar sensor: is preceding car on same lane?
- Same info available from V2V communication
- Dependencies are modelled in a Decision Network (right)

- Given no information, Radar is more valuable
- Given Radar = center
  → V2V still adds value



Attention:

- depending on actual value:
  Radar=left → *VoI (V2V) = 0*
- Transmission costs are
  still neglected here!



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Conclusion

- Sound theory on intelligent, content based information dissemination
- Both approaches are applicable to real world problems
- Saving bandwidth and inference time
- Preference for one or the other method depends on
  - Available information about utility and costs to be modelled: more complex, but also flexible in decision based approach
  - Problem statement: decision between different options Y_1 and Y_2 in probability based approach only possible after normalisation
- Next step: testing of both approaches in practical experience