Predicting the Focus of Attention and Deficits in Situation Awareness with a Modular Hierarchical Bayesian Driver Model

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Introduction

Situation Awareness (SA) is defined as *the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*. Lacking SA or having inadequate SA has been identified as one of the primary factors in accidents attributed to human error. Here we present a probabilistic machine-learning-based approach for predicting the focus of attention and deficits of SA in real-time using a Bayesian driver model as a driving monitor. This Bayesian driving monitor generates expectations concerning the focus of attention and deficits in SA conditional on the actions of the driver which are treated as evidence in the Bayesian driver model.

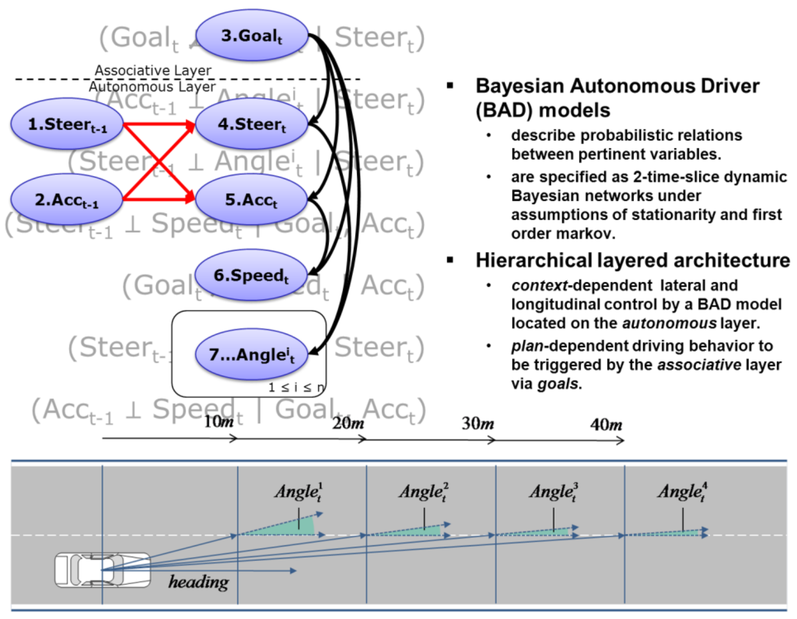


Fig.1. Reactive Bayesian Autonomous Driver (BAD) model based on a 2-time-sliced dynamic Bayesian network

Methods

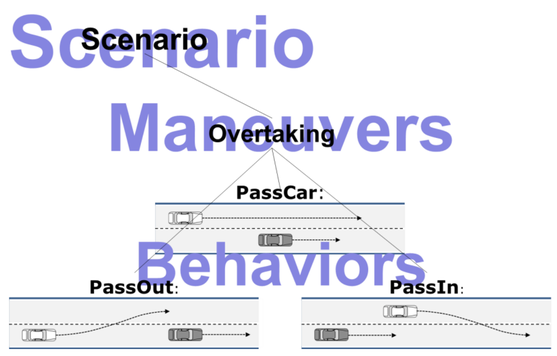


Fig.2. Skill hierarchy partitioning the overtaking *maneuver* into the *behaviors* PassOut, PassCar, and PassIn

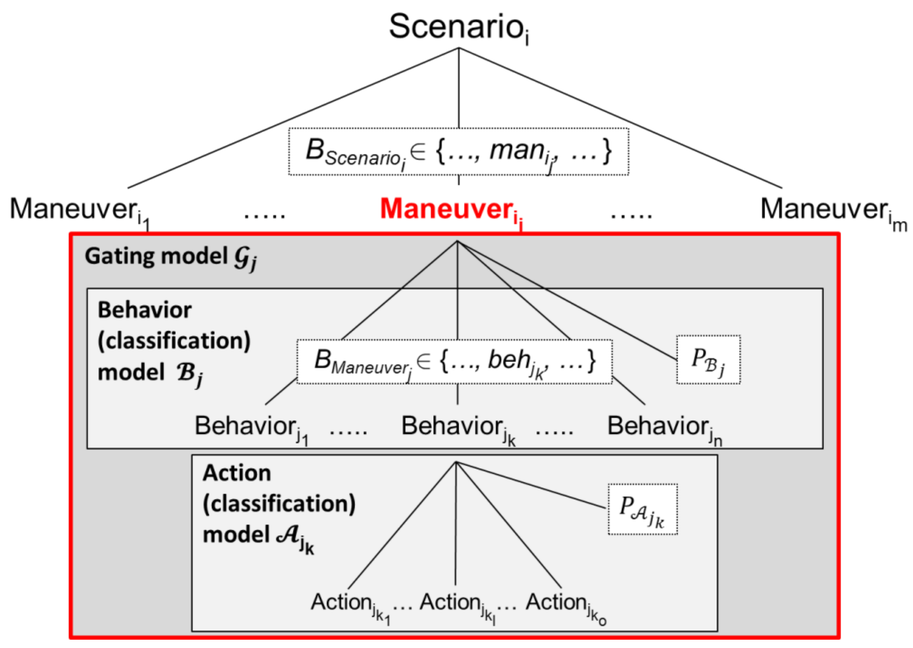
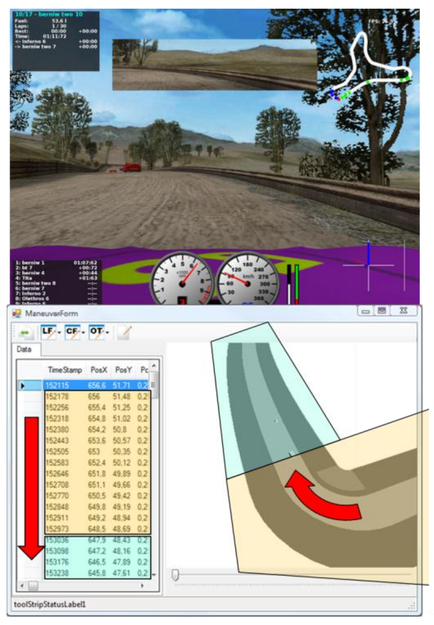


Fig. 3. Implementation of the skill *Maneuver$_j$* by the assemblage of a *Bayesian Gating Model G$_j$* and *submodels B$_j$* and *A$_{jk}$* with BIC-relevant *peephole* percepts *P*



- **TORCS racing simulation**
- **Multivariate time series of human behavior traces**
  - Approx. 15000 samples
  - Sample rate: 50ms => 12 min 30 sec
  - Racing courses „Aalborg" and „Street1"
    - 2 laps each, covering 4 overtaking maneuvers
    - 6 additional overtaking maneuvers
- **2 action-variables**
  - Steering wheel angles
  - Acceleration and braking pedal positions
- **205 percept-variables**
  - Angles between heading and reference points on the road in various fixed (e.g. FLA_{5m}) and speed-dependent distances (e.g.) SLA_{9s}, $SCA_{0.2s}$
  - Angle of the back of the nearest car (*NCA*)
  - Distance to nearest other car (*NCD*)
  - Longitudinal speed (*LS*)
- **No state-variables**
- **Manual segmentation of traces according to the skill hierarchy**

Fig. 4. Experimental setup with TORCS course, variables of interest, and data classification

Results

The Bayesian Autonomous Driver Mixture-of-Behavior (BAD MoB) model could be used as a monitor of the driver's behavior. First, it could be used to compute the likelihood of the actual driving behavior under the assumption of a correct selected action model. Second, it could be used to predict the focus of attention on the basis of driver actions by answering the questions P(Percepts | Actions). Third, it could be used to predict deficits in SA. Behavior and actions which seem to be unlikely in the view of the scenario-relevant valid action model are indicators of reduced SA. At the same time the abducted BIC-*relevant* percepts should be checked whether they could be observed in the driving situation. If not then this gives a hint that the driving behavior is inadequate for the situation. Furthermore the abducted *nonrelevant* percepts give hints where hazards could intrude the local vicinity of the vehicle unnoticed from the situational attention system of the driver.

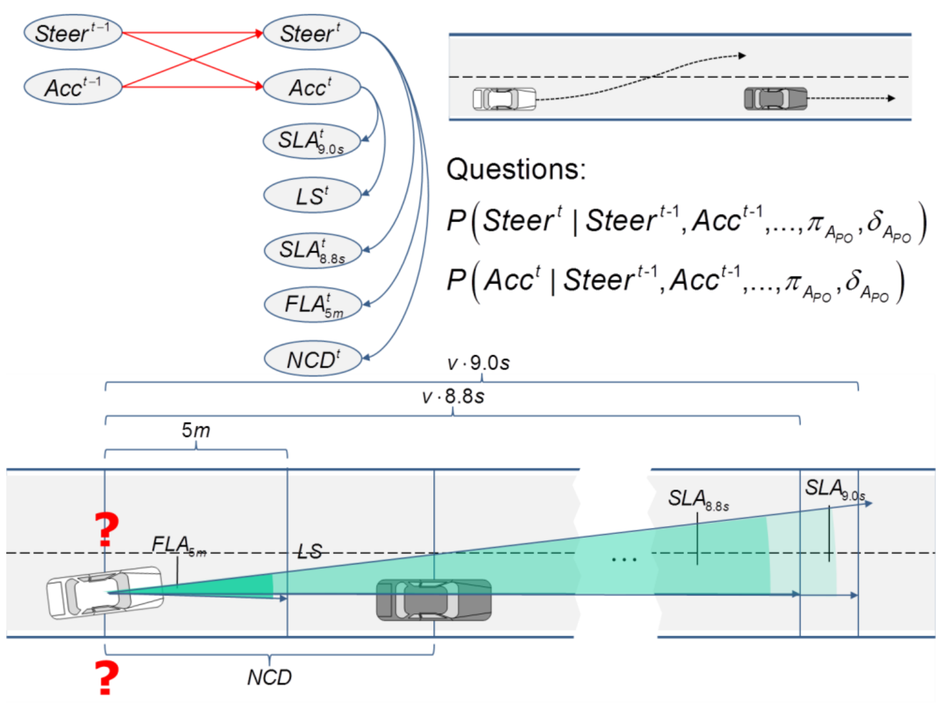


Fig. 5. *Action*-model *PassOut* (one speed-, two distance-, and time-based peephole percepts)

- **Identification of appropriate mixture of behaviors in a given situation**
  - Represent behaviors (*PassOut*, *PassCar*, *PassIn*) by *Behavior*-variable
- **Default structure for efficiency**
  - 2-time-slice Bayesian networks assuming stationary and first order Markov property
  - (Dynamic) *naïve Bayesian classifier*
- **Learning of minimal important (*peephole*-) percept-variables from human behaviour traces by methods of machine learning**
  - Heuristic search in the space of all possible combinations of percept-variables
  - Score combinations with *Bayesian Information Criterion*
- **Question to identify appropriate behavior:**

$$P\left(B^t_{OT} \mid NCA^t, SCA^t_{0.2s}, \pi_{B_{OT}}, \delta_{B_{OT}}\right)$$

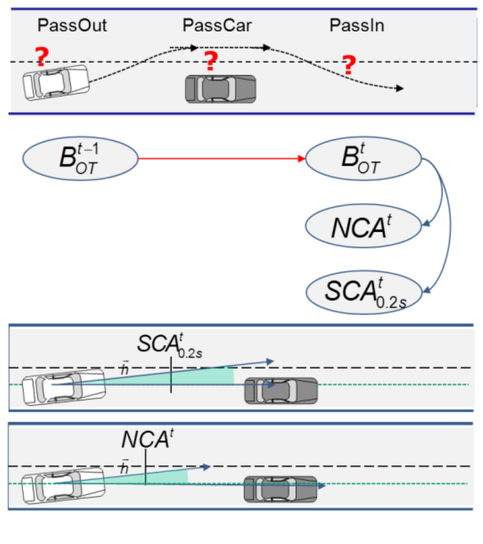


Fig. 6. *Behavior-Classification*-model *Overtaking* with one distance-based and one time-based peephole percept

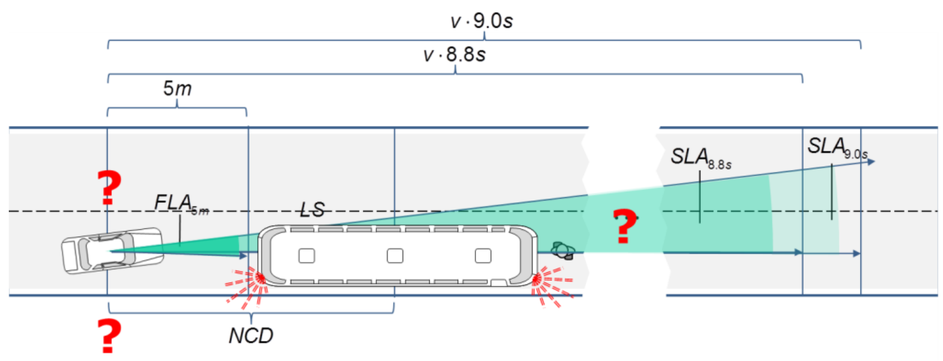


Fig. 7. Inadequate percept-action mapping behavior according *PassOut-Action* model

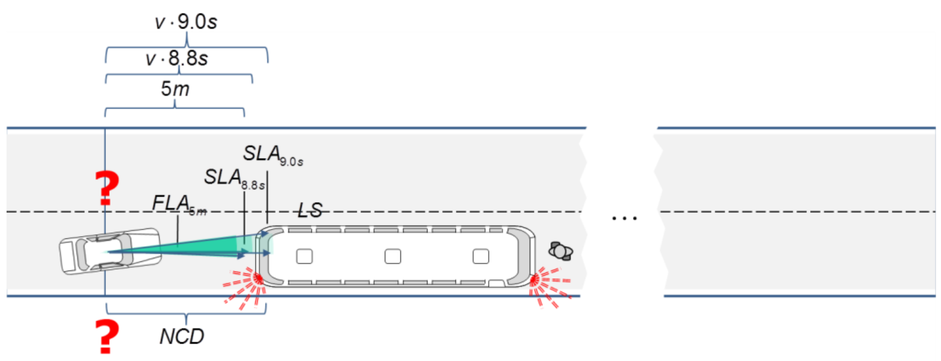


Fig. 8. Adequate percept-action mapping behavior according *PassOut-Action* model

References

Eilers, M. & Möbus, C.: Learning of a Bayesian Autonomous Driver Mixture-of-Behaviors (BAD-MoB) Model, In: Vincent G. Duffy (ed), Advances in Applied Digital Human Modeling, 436-445, CRC Press, Taylor & Francis Group, Boca Raton, ISBN 978-1-4398-3511-1 (2010)
Eilers, M. & Möbus, C.: Learning the Relevant Percepts for Modular Hierarchical Bayesian Driver Models using the Bayesian Information Criterion, HCII (2011, in press)