Chapter 23
Prototyping Smart Assistance with Bayesian Autonomous Driver Models

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ABSTRACT

The Human or Cognitive Centered Design (HCD) of intelligent transport systems requires digital Models of Human Behavior and Cognition (MHBC) enabling Ambient Intelligence e.g. in a smart car. Currently MBHC are developed and used as driver models in traffic scenario simulations, in proving safety assertions and in supporting risk-based design. Furthermore, it is tempting to prototype assistance systems (AS) on the basis of a human driver model cloning an expert driver. To that end we propose the Bayesian estimation of MHBCs from human behavior traces generated in new kind of learning experiments: Bayesian model learning under driver control. The models learnt are called Bayesian Autonomous Driver (BAD) models. For the purpose of smart assistance in simulated or real world scenarios the obtained BAD models can be used as Bayesian Assistance Systems (BAS). The critical question is, whether the driving competence of the BAD model is the same as the driving competence of the human driver when generating the training data for the BAD model. We believe that our approach is superior to the proposal to model the strategic and tactical skills of an AS with a Markov Decision Process (MDP). The usage of the BAD model or BAS as a prototype for a smart Partial Autonomous Driving Assistant System (PADAS) is demonstrated within a racing game simulation.

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1 INTRODUCTION

The Human or Cognitive Centered Design (HCD) (Norman, 2007; Sarter et al., 2000) of intelligent transport systems requires digital Models of Human Behavior and Cognition (MHBC) enabling Ambient Intelligence (AMI) e.g. in a smart car. The AMI paradigm is characterized by systems and technologies that are embedded, context aware, personalized, adaptive, and anticipatory (Zelkha et al., 1998). Models and prototypes we propose here are of that type.

Currently MBHC are developed and used as driver models in traffic scenario simulations (Cacciabue et al., 2007, 2011), in proving safety assertions and in supporting risk-based design. In all cases it is assumed that the conceptualization and development of MHBCs and ambient intelligent assistance systems are parallel and independent activities (Flemisch et al., 2008; Löper et al., 2008). In the near future with the need for smarter and more intelligent assistance the problem of transferring human skills (Yangsheng et al., 2005) into the envisioned technical systems becomes more and more apparent especially when there is no sound skill theory at hand.

The conventional approach to develop smart assistance is to develop control-theoretic or artificial-intelligence-based prototypes (Caccibue et al., 2007, 2011) first and then to evaluate their learnability, usability, and human likeness ex post. This makes revision-evaluation cycles necessary which further delay time-to-market and introduce extra costs. An alternative approach would be the handcrafting of MHBC (Baumann et al., 2009; Gluck et al., 2005; Jürgensohn, 2007; Möbus et al., 2007; Salvucci, 2004, 2007; Weir et al., 2007) on the basis of human behavior traces and their modification to prototypes for smart assistance. An ex post evaluation of their human likeness or empirical validity and revision-evaluation cycles remains obligatory, too.

We propose a third machine-learning alternative. It is tempting to prototype assistance systems on the basis of a human driver model cloning an expert driver. To that end we propose the Bayesian estimation of MHBCs from human behavior traces generated in new kind of learning experiments: Bayesian model learning under driver control. The models learnt are called Bayesian Autonomous Driver (BAD) models.

Dynamic probabilistic models are appropriate for this challenge, especially when they are learnt online in Bayesian model learning under driver control. For the purpose of smart assistance in simulated or real world scenarios the obtained BAD models can be used as prototypical Bayesian Assistance Systems (BAS). The critical question is, whether the driving competence of the BAD model is the same as the driving competence of the human driver when generating the training data for the BAD model.

We believe that our approach is superior to a proposal to model the strategic skills of a PADAS with a Markov Decision Process (MDP) (Tango et al., 2011). A MDP needs a reward function. This function has to be derived deductively solving the inverse reinforcement learning problem (Abbeel et al., 2004). The deductive derivation of reward function often results in strange nonhuman overall behaviors. The inductive mining of the reward function from car trajectories or behavior traces seems to be a detour and more challenging than our approach.

The two new concepts Bayesian learning of agent models under human control and the usage of a BAD models as BAS or PADAS are demonstrated when constructing a prototypical smart assistance system for driving stabilization within the racing game simulation TORCS (TORCS, 2011).

BAD models (Eilers et al., 2010a,b, 2011; Möbus et al., 2008, 2009a,b,c, 2010, 2011) are developed in the tradition of Bayesian expert systems (Jensen et al., 2007; Neapolitan, 2004; Pearl, 1988, 2009; Russell et al., 2010), probabilistic robotics (Forbes et al., 1995; Thrun et al., 2005), and Bayesian (robot) programming (BP) (Bessiere, 2003, 2008; Lebeltel et al., 2004; Le Huy
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