HUMAN-MACHINE COOPERATION IN HIGHLY AUTOMATED DRIVING

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Abstract: This paper presents a concept for a highly automated vehicle which allows for adaption to and cooperation with a human driver. This addresses the problem of vehicle automation level 3, as defined by the NHTSA, where a vehicle is capable of being driven automatically, but the human driver is still in charge from a legal point of view.

Keywords: Human-Machine Interaction, Automated Driving, Driver Modelling

INTRODUCTION

Today the development of highly automated driving is the research focus of many OEMs [2] and research institutes. A major need regarding automated vehicles is an increased usability. This encompasses cooperation and adaption of the machine agent to the human driver and other road users, with a human centered design process as the foundation of the system development [3]. The main challenges are the development of a fluent, yet transparent task allocation and transition between human and machine agent [4] and at the same time integrating the host vehicle into the flow of other road users, where a number of agents are acting in a shared space with shared resources. This aims at increasing the confidence of the human driver in a highly automated system, as described by vehicle automation level 3, which is defined by the NHTSA [1].

The novelty of the automated driving approach presented here is the advanced cooperation with a human driver and adaptation to his or her capabilities, needs and preferences, to other road users and the environmental conditions, as illustrated in Figure 1. It is characterized by a decentralized decision making between the artificial and the human intelligence.

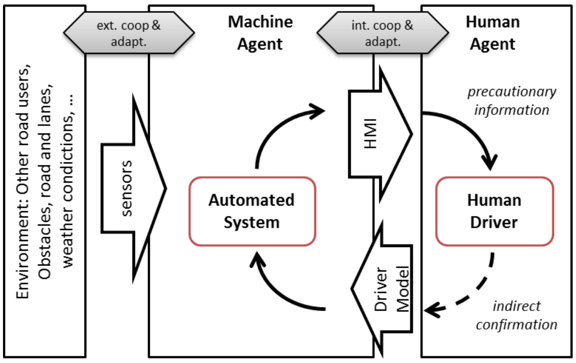
This research is carried out within the EU ARTEMIS JU project HoliDes, which addresses the development process and qualification of adaptive and cooperative Human-Machine Systems.

SYSTEM ARCHITECTURE AND AUTOMATED DRIVING APPROACH

For testing and evaluation purposes a demonstrator vehicle is currently under development, equipped with a number of cognitive sensors and a highly detailed digital road map for environmental perception. The information obtained by the system includes detection of other traffic participants and their motion, boundary objects, road markings, traffic signs as well as the field of view of the human driver (eye tracking system). These signals represent the input to the automated driving system.

The information from all cognitive sensors is synchronised and fused into a single environmental model. Additional features are extracted from this by the situation assessment module including, among others, vehicle to lane associations, object manoeuvre estimation, free space estimation representing driveable space as well as a motion map.

The main focus of this research is the design and development of an integrated approach for highly automated driving. The main task of this module is the calculation of trajectories and driving manoeuvers using configuration space techniques as well as methods motivated by swarm theories, taking into account the flow of other traffic participants. The innovation of this approach will be the adaptivity as well as the cooperation aspect between the automated system, the human driver and the environment including other road users.



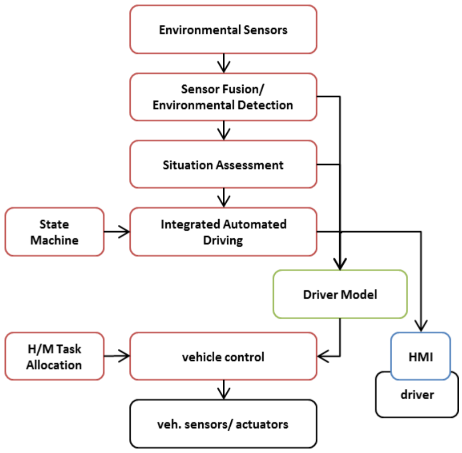


Figure 1 – Adaptation and Cooperation Aspect of the Automated System

Figure 2 – Structure of the Automated Driving System.

A group of safely drivable trajectories is analysed by a driver model, which is explained in more detail in the following section. A single trajectory is selected according to the driving behaviour of the human operator, which is passed into the low level vehicle control module. The output of the automated driving system is given by appropriate driving commands to the vehicle internal actuators, which are operated in cooperation with the human driver. The module H/M Task Allocation handles switching between manual and automatic driving.

DRIVER MODEL

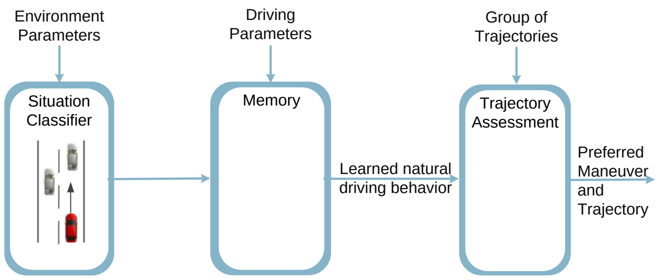


Figure 3 – Structure of the driver model

The general goal of the driver model is to learn the natural driving behaviour of the human operator situation based. Therefore the driver model is structured in three parts as illustrated in figure 3. Moreover the driver model combines a multivariate time series analysis with a pattern recognition approach to memorize the natural driving behavior. This approach is explained more detailed in [5]. In context of the HoliDes project the knowledge of the natural driving behaviour is used to assess the given trajectories by the machine agent.

HMI

The system will include an innovative HMI which addresses vehicle automation phase 3 [1]. It informs the driver in a precautionary instead of a reactive way, meaning that it provides information about how a certain traffic situation was interpreted. This aims at increasing confidence of the human driver in the automated system by providing system transparency. The key innovation is that information is presented in an integrated way rather than specific to individual subfunctionalities, such as ACC, LDW, BSD etc.

One main characteristic of the automation level 3 by NHTSA is the legal responsibility of the human driver. Hence, a manual intervention of the driver cannot be surpressed by the system, even if this action is considered to be hazardous. Nevertheless, the system will provide appropriate warnings to warn the driver of inapropriate manual interactions.

USE CASE / TARGET SCENARIO

The target scenario and the main use case are given by a lane change manoeuvre on a highway with two lanes, as illustrated in Figure 1. The host vehicle is travelling in the right lane, approaching a slower vehicle (obj 1). Other vehicles (obj 2 and 3) are travelling in the overtaking lane at a higher speed. The host vehicle aims at changing lane in order to overtake the preceding vehicle (obj 2) and changing back into the right lane in front of this vehicle.

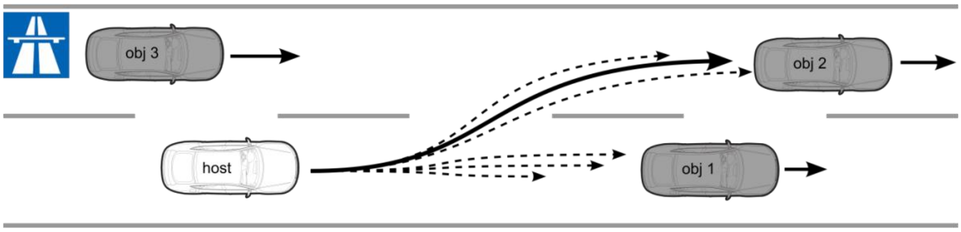


Figure 4 – Automated driving provides a group of trajectories, the driver model selects a single trajectory according to the driver's needs.

This use case is fulfilled when the lane change manoeuvre maneuver can be driven with varying degrees of automation, in a safe way that is close to the driving behaviour of the human driver regarding safety, efficiency and comfort. A number of measures and performance indicators will be defined that represent the quality of the driver maneuvres.

SUMMARY

In this work a concept for a highly automated vehicle is presented which acts in cooperation with a human driver and also adapts to the driver's characteristics, the current traffic situation, other road users and environmental conditions. The research on the presented subjects is ongoing.

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