Summary

This document describes the development, dissemination, and evaluation/utilization of several driver state monitors from within the HFauto project.

DSM 1: Eye Tracking of Distraction, Drowsiness, and Cognitive Load

A multi-state driver monitoring system has been developed and demonstrated at the IEEE International Conference on Systems, Man, and Cybernetics (SMC) (Cabrall et al., 2016). This system (DSM 1) was programmed with classification criteria from previous driving safety literature and studies as described per driver state sub-sections below. DSM 1 functions by simultaneously processing eye-behaviour data through three separate analyses to detect non-mutually exclusive sub-states of driver distraction, drowsiness, and/or cognitive overload. DSM 1 consequentially triggers and raises a general elevated detection of off-nominal driver eyes based on the presence of any of these compromised driver states.

Distraction/Inattention

Gaze positions on the screen of the simulation were first calculated with trigonometry from known screen dimensions and real-time eye-tracker measures of camera-to-eye distances before then being normalized around a 0,0 x/y coordinate origin in the middle of the screen (i.e., upper right corner = +1, +1; lower left corner = -1, -1). As vetted within the Master's thesis of Janssen (2016), 1.5 full seconds of consecutive off-screen gaze samples was used to assess and signal a state of distraction. This distraction state was reset by 4.5 full seconds of consecutive on-screen gaze samples.

Drowsiness/Fatigue

Size of eyelid opening was measured in real-time by the eye-tracker and was used in lieu of pupil coverage for the standardize measure of PERCLOS (i.e., percentage eye closure). This was calculated as the proportion of time in a moving window that the eyes were at least 80% closed (Wierwille et al., 1994). Across a moving time window of the last 60 seconds, if at least 80% (i.e., 48 seconds) of eyes in a cumulative manner were registered as at least 80% closed, then the drowsiness state was signalled and otherwise lifted.

Cognitive Overload/Mental Workload

Cognitive overload was assessed every sample update by computing the product of 1 standard deviation of horizontal gaze degrees and 1 standard deviation of vertical gaze degrees over the last 120 seconds of samples. While gaze variability is thuswise constricted below a threshold of 15 square degrees (cp. results Table 1 of Recarte & Nunes, 2003) the cognitive overload state of the driver is assessed and signalled and otherwise lifted.

Design Value of System Architecture

A depiction of the DSM 1 system architecture is provided in Figure 1. The implementation was designed to support multiple benefits. With a goal for quick/transparent adjustment of driver state classification threshold criteria, Mathworks Simulink model GUI interfaces are used to specify new values of constant variables or block field settings for common thresholds (i.e., amount of gaze variance, lengths of time for (in)attentive looking behaviour, and time period windows to sample prior to applying assessment). Additionally, "clickable" toggle switches were used so that various sub-states could be flexibly turned on/off as desired during run-time execution. The entire DSM 1 system was purposefully built external of any eye-tracker, simulated/veridical vehicle systems, to maximize flexibility in application and extension via standardized UDP communication channels. Lastly, an aim was to reduce the complexity of multiple possible states of inappropriate driver eye behaviour, by utilizing and showing parallel assessment streams and combining them together (with configurable logic controls) on a higher layer (general driver normality/aberrance). The motivation of such an aim was both to facilitate operator/end-user understanding (e.g., debugging) and minimize communication bandwidth burdens across an integrated systems network.

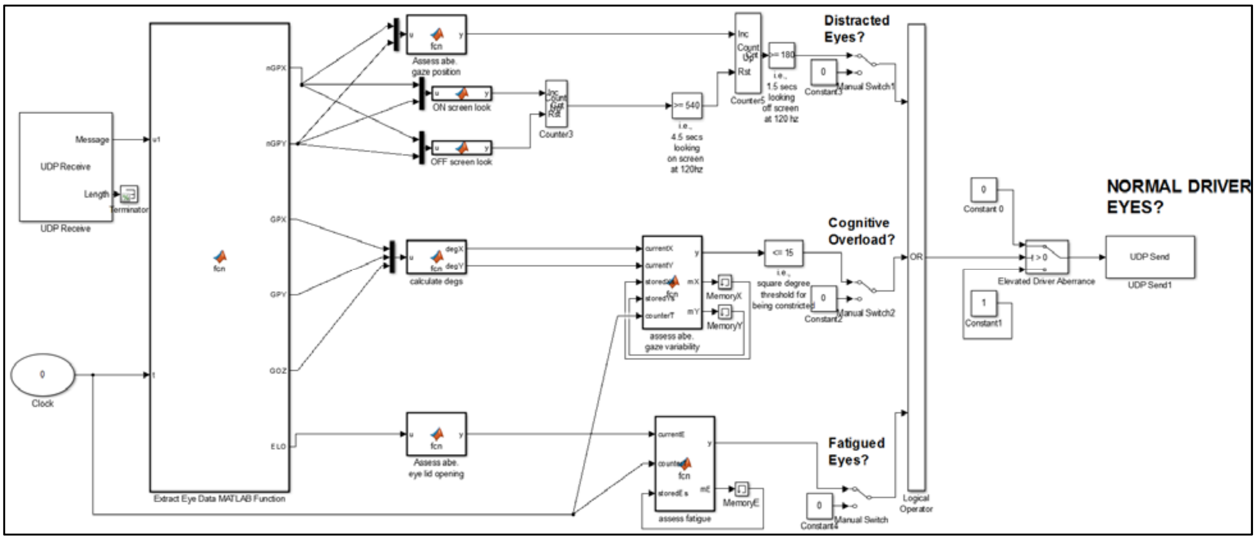

Figure 1. Overall flow of information proceeds from left to the right. Data from an eye-tracker is received on the left in a UDP package, unpacked and formatted via a MATLAB script before feeding three parallel streams of driver aberrance state detection (distraction, cognitive overload, and fatigue from top to bottom) each operating over different thresholds and time period windows. An “or” logic gate passes forward an elevated overall assessment of a nominal or aberrant state of driver eye behaviour based on if any of the preceding (included) sub states are exhibited. The system continuously broadcasts that resultant binary signal via UDP.

DSM 1 was additionally enhanced with real-time feedback as shown in Figure 2. The aim of the feedback was to provide an overview of the current classified aberrant driver states along with the specific thresholds and time windows unique to each. Real-time feedback was added to DSM 1 via color-coded and spatially ordered display fields. Blue boxes presented the current binary value of each sub state of classified driver eye behaviour (i.e., distracted, overloaded, and/or fatigued). Red boxes presented the current continuous value used as principle criteria in classification decision threshold logic. A green box displayed the value specific to the number of seconds counted as contributing towards obtaining a classification of “attentive”. The spatial grouping order followed consistently from that depicted in the overall architecture (Figure 1). This real-time feedback was purposively placed in blown up detail just beyond (to the right) of the driver sub-state “or” gate and before the resultant broadcast message to provide greater insight as to the analytical working principles currently at play and how various eye behaviour interacted in real time over time to result in state classification and communication.

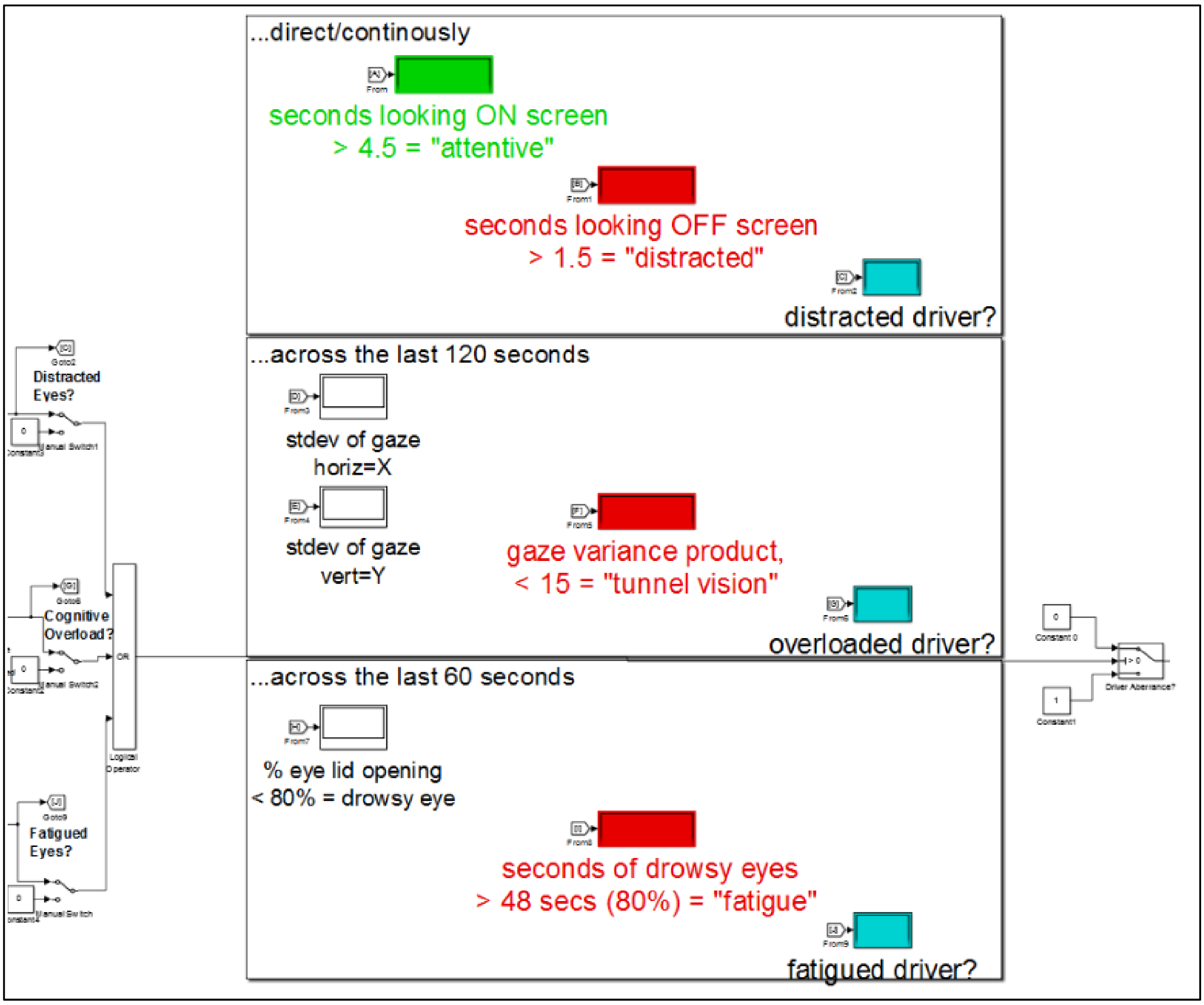

Figure 2. Additional feedback provided for an overview of the current classified aberrant driver states along with the specific thresholds and time windows unique to each.

Evaluation/Utilization in Human Factors of Automated Driving Research

DSM 1 was successfully deployed and utilized in a driving simulator study with 91 participants to compare various design implementations of adaptive automation (i.e., back-up vs. on-demand; implicit vs. explicit; situated vs. isolated) (Cabrall & de Winter, in preparation). The investigation required real-time eye tracking classification input to its adaptive control logic for triggering multiple transitions of control between manual and automated driving within a single journey. DSM 1 reliably provided the required driver state monitoring information of aberrant/nominal driver eye behaviour as a continuous binary value broadcasted exclusively over standardized UDP communication channels. In addition to the real-time driver state monitoring functionality, DSM 1 also provided a convenient single value distraction state classification output enabling a direct comparison between the investigated concept conditions. As can be seen in Figure 3, on average participants apparently showed higher percentages of visual distraction in the two hand on-demand human supervisory control conditions (EXP1, 76%; EXP2, 74%) compared to the manual control condition (EXP4C, 53%). In contrast, similar levels of visual distraction levels were found between the adaptive backup conditions (ranging between 47% and 58%) compared to the manual control condition.

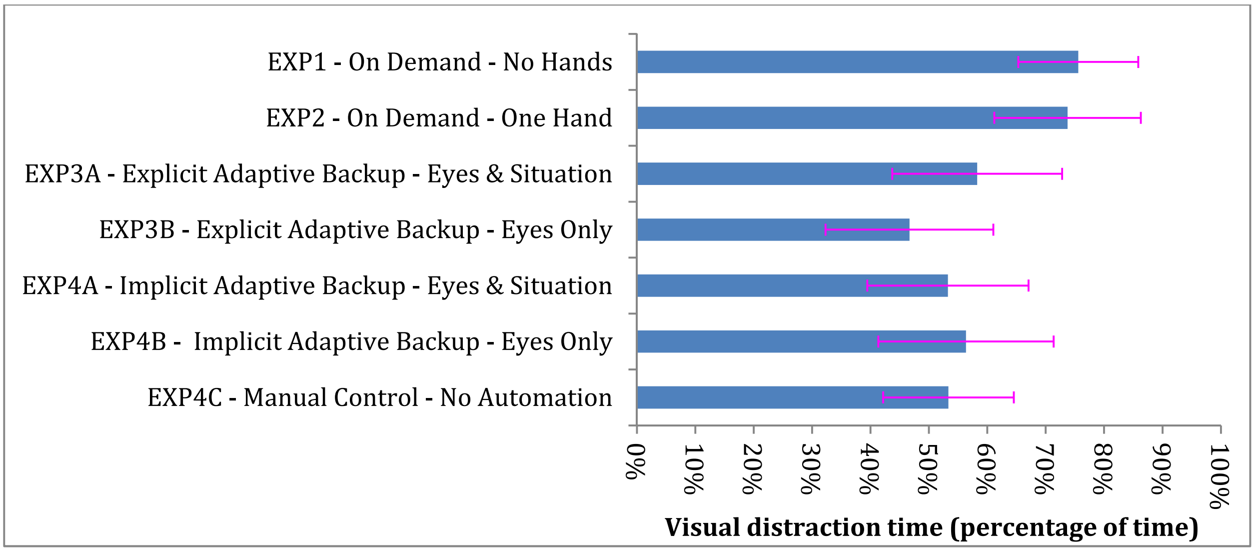

Figure 3. Average visual distraction time per condition (data provided by DSM 1).

DSM 2: Title/Summative Description

Additional text

References

Cabrall, C.D.D., Janssen, N., Goncalves, J., Morando, A., Sassman, M., & De Winter, J.C.F. (2016). Eye-based driver state monitor of distraction, drowsiness, and cognitive load for transitions of control in automated driving. *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics*. Budapest, Hungary. Demo Paper no. 1548.

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