Institutionen för systemteknik
Department of Electrical Engineering

Examensarbete

Identification of Driver Unawareness based on User Interaction

Examensarbete utfört i Fordonssystem
vid Tekniska högskolan i Linköping
av

Pär Löfgren

LITH-ISY-EX--07/3910--SE

Linköping 2007

Linköpings universitet
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Detektering av förarouppmärksamhet baserad på förarinteraktion.

Identification of Driver Unawareness based on User Interaction

Författare
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Sammanfattning
Abstract

In new cars of today there are several electronically controlled systems that seek to aid the driver and make the journey as safe as possible. This include not only systems that directly control the vehicle such as ABS and ESP, but also systems that might make driving easier such as navigation systems, cruise control and even seat adjustments.

It is important that the effects on the driver from the use of such systems do not lead to an environment that diverts the attention of the driver from the main task, i.e. driving safely.

In this thesis a possible way of modeling the driver distractedness level due to the operation of these systems is discussed. This is done in Simulink with vehicle CAN data as inputs. An expert field test is done with 6 drivers over 18 trial runs with 31 secondary tasks on a highway. Two criteria are used to measure the distractedness, one objective based on the attributes of an element and one subjective, based on the use of the elements while driving during the trials. A lane monitoring system is evaluated and the offset from the lane center over time is used as an external criteria to the distractedness level. There is however no correlation between the external criteria and the subjective distractedness level.

The results of the subjective distractedness level are used in the model and possible future extensions to it are discussed.

Nyckelord
Keywords

Driver distractedness, In Vehicle Information Systems

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The results of the subjective distractedness level are used in the model and possible future extensions to it are discussed.

Preface

This thesis completes my studies at Linköping University for a Master of Science in Applied Physics and Electrical Engineering International. It has been performed at DaimlerChrysler in Untertürkheim in Stuttgart, Germany. The work has given me plenty of opportunities to practice what I learned during my studies. In addition it has also given me an insight in other fields, such as cognitive science, where things are not always as clear and concise as in mathematics and physics.

Outline

The introductory chapter contains a brief presentation of the method and the purpose of this thesis. Chapter two covers some of the current existing classifications of driving and driver awareness. In chapter 3 the available signals are explained and a description on about how the data was acquired is presented. Following this in chapter 3 is an explanation about the build up in the test vehicle and considerations on data acquisition. Chapter 5 explains how the solution was made and describes the different parts of the solution. The second last chapter describes the tests that were made and the last chapter contains discussion and suggestion on future work.

Acknowledgments

First of all I wish to thank my supervisor at DaimlerChrysler Dipl. Ing. Matthias Krebs for the interesting task, many discussions as well as a very good way of integrating me in the team. An appreciation also goes to the colleagues in the team of Dr Klaus Peter Kuhn as well, Dr Wolfgang Stolzmann, Herr Peter Bezitza, Herr Andreas Proettel, Herr Sigfried Rothe, and many others. You helped me not only by answering questions and performing trials, but also by creating a very good working environment.

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Pär Löfgren, Stockholm, 2007

Contents

Chapter 1

Introduction

Automobiles of today have several hierarchies of control systems. Most of them are somehow connected to each other via bus systems such as Controller area network (CAN), Local Interconnect Network (LIN) etc. Some of these control systems and bus hierarchies are unknown to the driver and operate in order to, for example use the engine in an optimal way or prepare the vehicle for an emergency situation. Other systems interact or at least share vital information with the driver. These systems are for example the instruments and the warning signs but also buttons which helps the driver change different aspects of the driving environment. These so called In Vehicle Information Systems (IVIS) which also includes the radio and navigation system, are designed to aid the driver but may also have reverse effect and overload the driver with too much information. This overload may lead to difficulties in keeping the concentration and ultimately to missed vital information.

Research show that a significant amount of fatal crashes are related to inattentiveness, in USA 2004, 6.3 percent of the fatal crashes of drivers and motorcyclists were due to inattentive drivers (drivers who were talking, eating, etc.) [1]. In the future we will probably see more and more IVIS introduced in vehicles, all with the purpose of aiding and entertaining the driver and passenger. It is important that the added IVIS are examined and that they do not lead to undesirable, safety diversion effects.

A few international projects are currently under way in order to somehow try and standardise the development and testing of IVIS. In Europe the German ADAM or Advanced Driver Information Metrics is a joint project between DaimlerChrysler and BMW. One of the main goals of ADAM is to develop easy methods for the measuring of driver distraction. This was one of the principles from the Alliance of Automobile Manufacturers (AAM) Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems, in which the both companies are taking part [8].

1.1 Objective

The object of this Thesis, is to examine the possibilities of creating a system which dynamically asserts the driver unawareness based on the CAN signals in the car and to create an example model showing how it could be solved. Specifically a Lane Monitoring System should also be examined. Furthermore it should be made in such a way as to make testing and evaluating easier in the future. This problem definition was further divided into the following tasks:

- Evaluate the signals that come from the lane sensor.
- Design and develop trials to test the driver distractedness when using different systems.
- Design scripts that evaluate differences between potentially easy tasks and potentially hard tasks.
- Produce a first model which delivers an distractedness level in accordance to the trial data.
- Discuss and propose a solution for further work.

1.2 Method

By using signal lists and performing small tests in the car the signals from buttons, switches and levers were examined to check their function. At the same time these elements were given an objective rating. Further on field trials were planned and carried out under real traffic conditions. During the field trials the test subjects completed secondary tasks and rated resulting inattentiveness level that they felt. This resulted in the subjective rating to each task. The data from the field trials, subjective rating and objective rating were evaluated with the help of Matlab scripts and Excel tables. A lane monitoring system was also evaluated and possible usage in distractedness modeling was discussed. A basic distractedness model was created in Matlab and Simulink and was designed to be able to run in the car. Due to external circumstances this model could not be tested in the car after the Modeling. Extensions and further work on a distractedness model is discussed and how the existing car CAN signals could be used.

1.3 Assumptions and limitations

- The experts for trials were given.
- All signals were assumed noise free and unbiased.

Chapter 2

Theory and definitions

Most people have surely on numerous occasions felt that they somehow missed something; from missing a sentence while talking to missing to turn in an intersection. People may then state that they were inattentive or distracted. Although attentiveness may seem easy to understand, it may be easier to discover the sources and differences of inattention if it is properly defined. In this chapter *one* definition of inattentiveness will be presented and explained in a way as to suit the following chapters of the master thesis.

2.1 The Concept of Attention

There are many views on how to look at attention and performance limitations. For the discussions and the work presented in this thesis, a profound knowledge of the different psychological descriptions is not needed. For a thorough investigation on the topics see [4]. The concept of attention can be described by the hierarchy in figure 2.1.

2.1.1 Focused Attention

The *Focused Attention* concerns itself about how effectively people select certain inputs rather than others and is studied by presenting people with two or more stimulus[1] at the same time, and instructing them to respond to only one. There is sometimes also one more topic added, the *Selective Attention*. By this is meant the ability to ignore distractors and select the one that is necessary and appropriate at the specific time. [9] and (Wickens, 1987) in [7].

2.1.2 Divided Attention

Divided Attention is also studied by presenting two or more stimulus at the same time, but with instructions that all stimulus must be attended to and responded

[1] audial, visual, haptic etc.

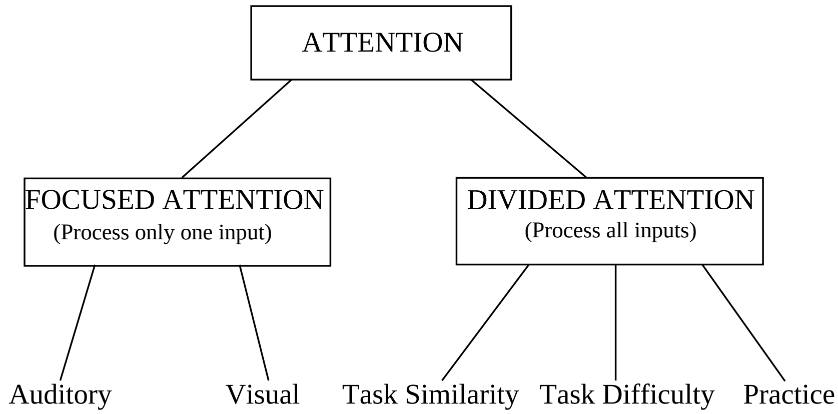


Figure 2.1. Hierarchy from [4] depicting two different topics of attention.

to. Studies of divided attention concerns itself with an individual's processing limitations and may tell us something about attentional mechanisms and their capacity [4].

One way of looking at the limitations of the divided attention is called Central Capacity Theories (CCT) . Basically CCT asserts that humans have a central processor, which may only process a limited amount of information, the Central Capacity (CC). The resources of this processor may be used for different tasks, and as long as the tasks added together do not use up all the resources, they can be processed simultaneously. Although the processor's capacity is limited, this limitation may differ. For example due to concentration, motivation, age etc.

As seen in the figure 2.1, Divided Attention may further be subdivided into three factors. These factors determine the so called dual-task performance (the ability to perform two tasks at the same time) and are in the literature described as follows:

- *Task similarity* It is clear that the similarity of the tasks play a big role in the study of dual-task performance. Two tasks that use the same sense modality[2] (visual or auditory) has been shown to interfere more than when the tasks were in different modalities (Treisman and Davies (1973) in [4].
- *Task difficulty* That the ability to perform two task together depends on how difficult the tasks are, is perhaps clear. It is however not only the respective task difficulties that matter. It may also arise new difficulties with co-ordination and avoidance of interference [4] and task similarity above.
- *Practice* A person who is confident with a task and has performed the task a lot of times, is more likely to cope with extra tasks without risking to become overexerted. Certain tasks that may be quite hard at first can after practice

[2] the 5 senses

be performed with quite little effort, such as riding a bike. The demands on other resources may also be reduced by practice [4].

2.2 Driving Tasks and Demands

Driving a car is a complex task with multiple sub tasks that have to be done simultaneously. How a person drives differs as well as this persons driving skills. Certain things needs however to be done in order to drive safely. In order to be able to describe certain parts of the task of driving, it is important to use a common ground. In this section a 3-level-model of the task of driving a car will be described from [7]. All of the possible sub tasks on these three levels must be processed simultaneously in order for the task to be performed satisfactorily. This section also explains the difference between driver distraction and driver inattention. Finally aspects of a secondary task while driving is explained.

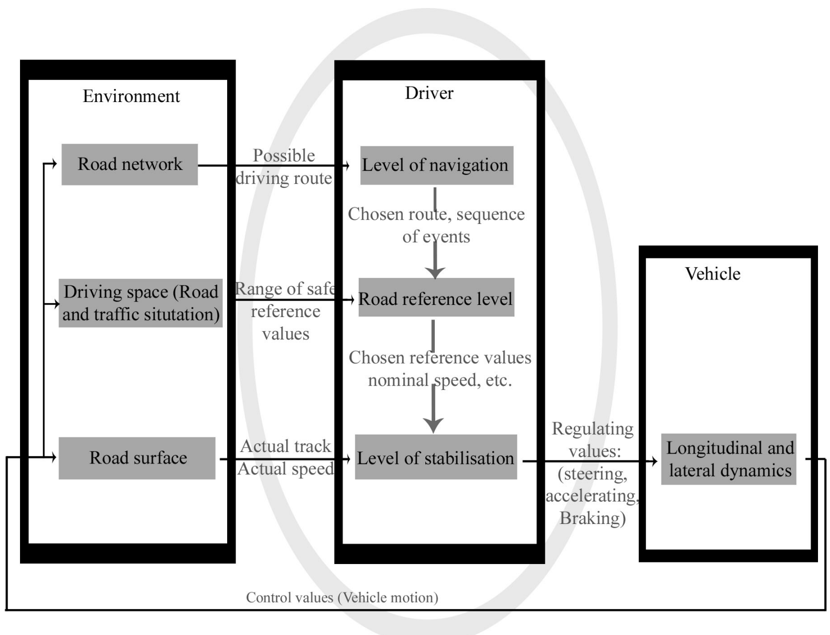


Figure 2.2. Hierarchical 3-Level structure showing the task of driving a car (from Donges, 1982 in [7]). Highlighted is the part which applies to the driver perspective.

2.2.1 3-Level model

- The 1:st level is the *navigational level* and incorporates the task of choosing a route and on this route trying to get to a selected goal.

- In a more narrow space the actual maneuvers need to be planned according to the over-lying navigational task. For example: the driver decides to take the next turn to the left. This level is called *Road reference level*.

- The bottom-Level is called *Level of stabilisation* and is described as the choice of correct control values to the vehicle such as for example steering wheel angle and the use of the pedals.

These three levels posses different time horizons and have different priorities concerning the information processing that needs to take place in order to solve the task of driving the car. Problems on one level may in some cases divert to another level. For example driving under a pressed time table may lead to an increased number of overtaking maneuvers, this leads to an increased demand on the level of stabilization. In the other direction a bad road with a lot of traffic may influence the choice of the route [7].

2.2.2 Primary and secondary tasks

The primary task is the task of driving the car as described above in the three level model in section 2.2.1. If this task is not performed satisfactorily problems might occur such as badly kept safety distances or even worse, lead to crashes. Secondary tasks will here be tasks that are not necessary to be performed and therefore compete with the primary task over the total Central Capacity. Examples are: changing radio station, talking on the phone, spraying the windscreen and changing the positions of the mirrors. Even though it for safety reasons can be essential to change the mirrors or to spray the windscreen while driving it is possible and recommended to do before starting the car.

2.2.3 Driver Distraction/Driver Inattention

As written earlier in this Thesis a considerable amount of people die every year due to being inattentive. Inattentiveness is however not precisely what will be examined in this thesis. While driving the driver might be preoccupied by deep thoughts, tired, drowsy or in another sense inattentive. Most of these effects will be measured even though the actual test or trial tries to seek driver distractedness. Therefore as in [10] driver distraction will be defined as follows: *Driver distraction occurs when:*

- A driver is delayed in the recognition of information necessary to safely maintain the lateral and longitudinal control of the vehicle (the driving task)

- Due to some event, activity, object or person, within or outside the vehicle that compels or tends to induce the driver's shifting attention away from fundamental driving tasks

- By compromising the driver's auditory, biomechanical, cognitive or visual faculties, or combinations thereof.

Basically Distraction can be external or internal in view of the car. External distraction is typically weather, odd behaviour by pedestrians etc and internal is distraction due to IVIS or other sources. Internal Distraction can be initiated by the driver (placing a call) or spontaneous (unpredictable actions by a passenger)[10].

- Further on in the thesis it is assumed that by stating *distraction* it is specifically meant internal driver initiated distraction.

2.2.4 Aspects of a secondary task while driving

Total task time (TTT)

The total task length is defined as the time from when the hand leaves the steering wheel until the last control actuation is received [6]. The total task time is important because it is indirectly a measure of the crash frequency. The crash frequency is well correlated with the total-eyes-off-the-road time[3] which is further well correlated with the total task time [6]. There is a suggestion for a possible standard when designing IVIS which states that the TTT should not be longer than 15s. In the evaluation in chapter 6.2 the total task time will be further subdivided into *search*, *usage* and *return*. This is done because the user interaction which is directly indicated in the CAN signals only states the time of the usage of the element. The search and return times is assumed dependent on other properties such as for example placement of the element, ambiguity and physical form of the element.

Task difficulty

As described in section 2.1 the task difficulty is critical in determining dual task performance. While driving the primary task difficulty is naturally varying depending on traffic density, weather, familiarity with the road etc. How difficult a secondary task is while driving can be seen as how much it competes with the important modalities used in the driving task (as in section 2.1.2). In the tests in chapter 4 the secondary tasks that are tested are chosen according to what is *considered* (according to a number of parameters) being hard and easy tasks. Some of the tasks are also used in the ADAM project trials (see the introduction section 1).

2.3 Measuring Distraction

There are numerous things in a car that may distract the driver. But to what extent can one measure it? There are a lot of ways described in literature, perhaps the most common one nowadays being the Peripheral Detection Task (PDT). Normally one or a couple of test runs are done with each test person, where they are allowed to drive without any secondary tasks. These runs are called Baseline

[3]The time in which the driver does not look at the road.

runs [9]. The difference between certain parameters are then examined between the baseline test run and the test runs where secondary tasks were introduced. Below in 2.3.1 two ways of measuring distraction are examined. One thing can be said about most of the measurements or tests of distraction. They are probably not viable for series production and more constructed for tests on how much distraction the use of specific elements induces. These are done in order to compare different button designs and layouts to each other.

2.3.1 Peripheral Detection Task and Tactile Detection Task

The Peripheral Detection Task (PDT) is normally performed in simulators, where subjects are required to respond to small red dots presented on the simulator screen. The PDT test involves driving on a 80km/h road and on a motorway and to respond by pressing a micro switch placed on the dominant finger or sometimes on the steering wheel. Reaction time is measured and the dots are placed in such a fashion, as not to require any movement of the head (they require little attention to notice). If the driver does not respond to the dots or respond too late, the stimuli is noted as missed. The PDT has proved to be sensitive to variations in (primary) driving task demand or distraction of in-vehicle messages [11]. The PDT is a way of measuring how much the driver is able to respond to while driving and is thus a measure on the driver cognitive workload. The Tactile Detection Task (TDT) functions much like the PDT. The difference between both of them is that TDT signals to the driver via tactile vibrators placed on the wrists of the drivers [3].

2.3.2 Lane Change Test (LCT)

The lane change test is done in order to measure the effect of driving performance due to distraction induced by IVIS. The task involves driving in a simulator on a straight three lane motorway and to do lane changes at certain positions signaled by signs on the side of the road. Between the baseline test and the secondary task tests, reaction time, lateral control, missed signs and way of lane change[4] evaluated.

2.4 Operating Elements (OE)

The test car has numerous buttons and levers that are placed in such a fashion as to be as intuitive and easy to find as possible. The actual buttons within the drivers reach will from now on in this thesis be referred to as Operating Elements (OE). This definition is done because of the distinction between the pulling of a lever or pressing of a switch and the actual data that is sent from that lever or switch. The OE signal is the result of an interpretation of one or more signals concerned with the specific button or lever. More on this will be seen in section 5.4.1.

[4] The trial persons are instructed to perform fast lane changes

In order to exemplify the modeling and solution of the problems two signals will be used as examples throughout the following chapters. Figure 2.3 show where these are located in the car and figure 2.4 shows what the specific OE look like.

The number pad can be used to dial and place calls and is also used to type in codes. There are several other more easy ways of placing a call. The CAN signals representing these OE are however not intuitive and the number pad was therefore chosen. The COMAND controller is a combined joy stick and force feedback wheel which is used to navigate the IVIS system on the COMAND display (number 7 in figure 2.3). Generally a menu level is entered by pressing and left by pushing the controller to the left. In lists with for example radio stations, available letters for searching names and menu items the force feedback is used to give a haptic feedback on that the end or beginning of the list has been reached.

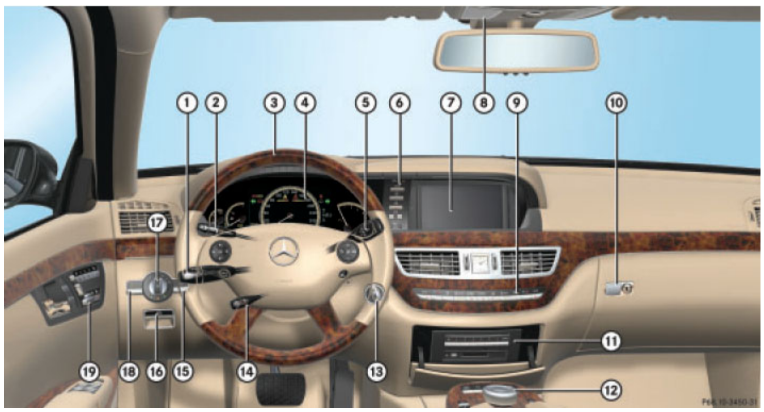
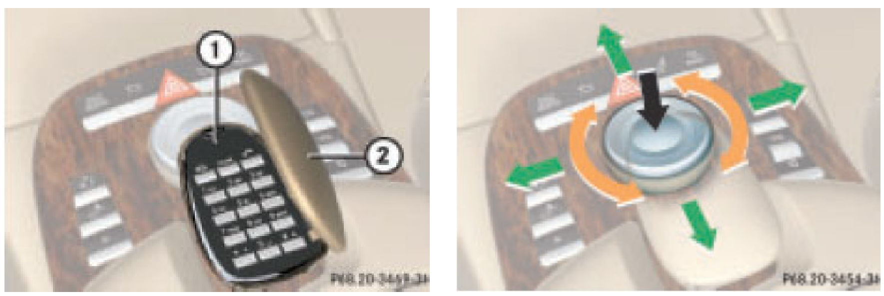


Figure 2.3. Operating elements in the driving seat. Number 12 points at the area where the COMAND controller and the number pad is situated. Number 7 points at the Comand display. ©DaimlerChrysler



(a) NumberPad (b) COMAND Controller

Figure 2.4. Two OE that will be used as examples in the thesis a) shows the number pad for typing in telephone numbers and b) shows the function of the COMAND controller, a joy stick with force feedback function when turned ©DaimlerChrysler

Chapter 3

Signals

In this chapter, a description about the method of collecting the data is presented and the different parts of the on board computers are briefly explained. Following that, the added measurement devices such as the lane monitoring camera and the driver and street observation cameras are described.

3.1 Build up in the Car

The test car computer system consisted of one PowerPC computer, one PC and one Laptop PC computer installed in the boot of the car. The PowerPC was connected to the on board CAN busses via an interface which also had CAN connections to other parts of the added equipment, see figure 3.1. From the car CAN, parameters are sent from the various sensors of the car to the respective actuators. By tapping in to the CAN Bus these parameters were read and saved for the evaluation later.

Added to the PowerPC CAN's was also a control-box with buttons marked 1 to 6 that were used in order to signal the start and end of an secondary task test (see section 4.3). A lane monitoring camera was also installed and connected to the CAN. This is further described below in 3.1.2.

The CAN signals were saved on the hard drive of the PowerPC with a frequency of 50Hz. This produced a data rate of approximately 880 bytes per sample or $43kB/s$. A normal trial run as will be described in chapter 4 gave a data file of about 214MB for a trial of 1h 25min.

In order to keep the system in hard real time the Unix real time operating system LYNX was used. The models from SIMULINK were compiled and linked with the Real Time Workshop[1] and run in LYNX. The communication to the model was done via a terminal window on the PC computer and the PC screen was placed on a mount in the back seat of the test car. All saved CAN Data could be viewed in real time on the screen via the terminal program.

[1] A subsystem of Matlab and Simulink

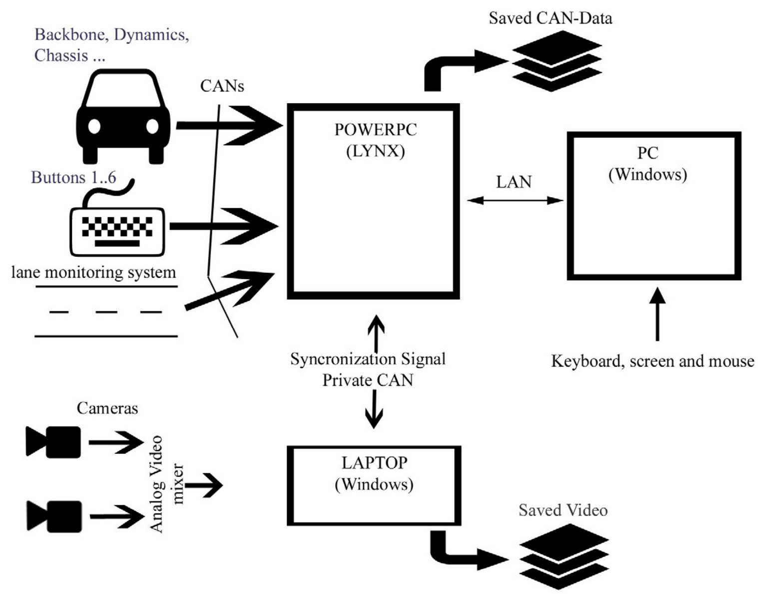


Figure 3.1. The buildup in the car

3.1.1 Driver cameras

Two cameras were mounted in the car, one directed toward the driver and one directed out on to the street in front of the vehicle (see figure 3.2). These two cameras made it possible to examine the road conditions, the traffic and the way the driver used the OE during the trials.

3.1.2 The lane monitoring system

The Lane Monitoring System from Continental Temic was mounted on the inside of the wind screen and connected to the CAN interface of the PowerPC. The two signals used were the lateral position of the vehicle and the lane width. In figure 3.3 and 3.4, two examples of normal signal progression are shown. The lateral offset is the offset between the center of the the car and the center of the lane.

3.1.3 CAN Signals

The saved CAN signals were numerous and will not be described here each one separately. They range from GPS coordinates and the speed of the driver in front of the car, to signals concerning angular velocity of each wheel and vehicle slip. In order to help the building of models connected to the system a model block in Simulink was given. The block separated the signals and set names which were equivalent to a list of the signals. For more explanation of this see section 5.4.1.

(a) driver camera (b) street camera

Figure 3.2. Camera positions in the test car

3.2 Signal Types

There are basically two types of signals coming from the OE. These will be named *State Signals* and *Duration Signals*. State Signals are signals generated for example by turning a knob, pulling a lever or flipping a switch. These signals change state when operated and it is therefore not possible to directly find out the exact length of the actual total operation time (see section 2.2.4). For an example of a state signal, see figure 5.6 on page 28 where the evaluation of the CAN signals is explained.

The Duration Signals are signals where start and end are registered. Such signals come from OE which spring back such as normal push buttons and certain levers that spring back (for example the head lamp flasher). In order to make these signals represent a total task time one would have to add the search of the button as well as the return to the normal state.

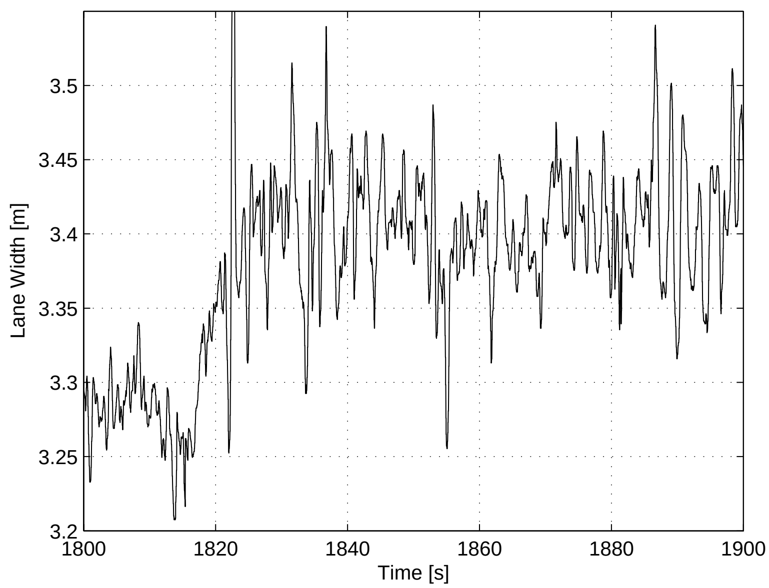


Figure 3.3. Lane width signal from the lane monitoring system.

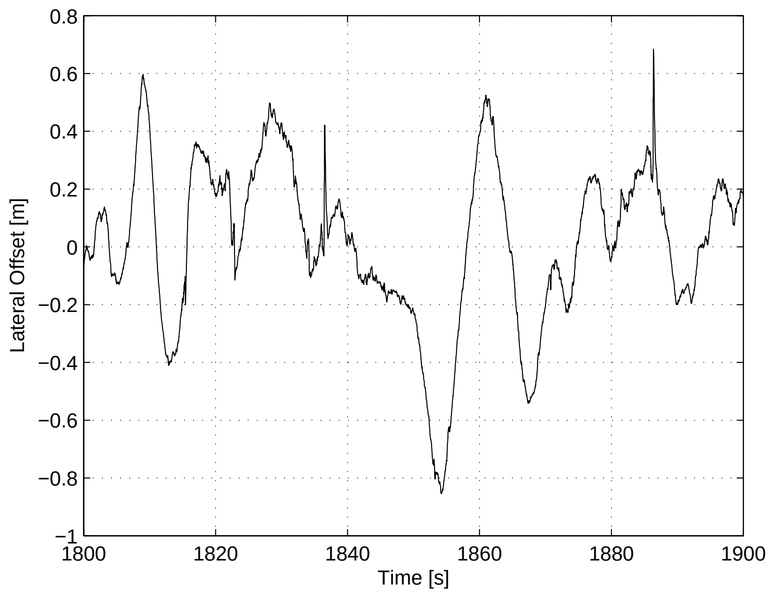


Figure 3.4. The lateral offset signal from the lane monitoring system

Chapter 4

Trials

In this chapter the method of the secondary task trials are described. Examples of secondary tasks are shown in order to get an understanding of the process. A complete list of the trial descriptions can be seen in appendix A. In total 6 Drivers did 18 trial runs altogether, each one with 31 secondary tasks tests. A trial leader supervised and assisted all trial runs from the back seat of the car.

4.1 Trial planning

4.1.1 The track

The trial track was a Bundesstrasse[1] with a speed limit of $120km/h$. The choice of this road was among other things due to the accessibility to the company and to the fact that the test drivers were familiar with the road. If one or a couple of drivers would have been less familiar, it might have meant that they would have had to pay more attention to signs and thus would have gotten a lessened dual task performance (see section 2.1). The track produced a variety of different road types and junctions. Unfortunately it was subject to some traffic jams during some of the trials due to a building site which moved from day to day. The building site however only occurred on the start, turn around and end parts of each trial, which meant that the tests were not interrupted very much more than the ones without traffic jams. The building site removed the road markings which meant that the lane camera was not able to measure the lane width properly. Fortunately the constructors painted new ones as soon as they moved on. The track had good road markings on the other parts. Traffic was dynamic, as well as naturally also the weather. The length of the track was about 90km.

4.1.2 Subjects

The 6 test subjects were a part of a so called Expertengruppe (expert group), which means that they had driven the car and that they were confident with using

[1] highway with separate lanes

the different OE.

4.1.3 Tasks

The trial subjects were given tasks which they had to perform as a secondary task while driving. Some of these tasks were selected from the ADAM trials whereas others were made up in order to fit new operations in the car. A total of 31 tasks were tested in the trials. A list in German of the different tasks can be seen in appendix A.

Rating	Description for trial subject	Description for trial conductor
1	I have no problem keeping the track or the distance.	The driver has no problems keeping the track or the distance.
2	I'm noticing small track deviations or deviations in the distance that I wish to keep.	The driver shows signs of small track deviations or distance deviations.
3	I'm noticing some deviations from the track or the distance that I wish to keep.	The driver shows a few signs of not being able to keep the track or the distance.
4	I'm noticing big deviations from the track or the distance that I wish to keep (within the track borders)	The driver shows big signs of not being able to keep the distance or the track.
5	I'm noticing extreme deviations from the track or the distance that I wish to keep ($<$ 0.5s or overridden road markings)	The driver has extreme troubles keeping the track or the distance and might need to be alerted.

Table 4.1. Distractedness rating of trial subject. The trial subjects' own assessment to the left and the assessment of the trial conductor to the right.

4.2 Trial preparation

For every test the data collection was prepared by connecting an empty USB stick to the PowerPC in order for the CAN data to be saved. The video capturing software and the cameras were also started and the picture was tested. The driving environment was then preset to the same position for all drivers. The only aspect which later was allowed to be changed before driving away was the seat position and the position of the mirrors. The temperature, radio, navigation, lights and telephone systems were all preset.

In order to alleviate some of the practice-, or learning effects (see section 2.1.2) between different tests with the same driver, the test persons were allowed to practice the tasks before starting. Before each trial, the subjects received the trial-sheet with precise descriptions of the secondary tasks. They also received rules about how to answer to the questions which were asked after each secondary task test. These rules are stated in table 4.1.

4.3 Trial runs

The test subjects were commanded to drive in the predefined direction. Upon reaching the open road the secondary task tests were commenced. A typical secondary task test normally proceeded as follows:

- *Task 2, involves typing a 12 digit telephone number on the number pad. I will give you a note with a telephone number. Please type the number on the number pad and confirm when you are ready. Do you understand the task?*
- *Yes*
- *Start!* `Button pressed for Start registration`
- Confirmation of test subject: *I have finished the task*
- `Button pressed for End Registration`

The buttons were pressed in the order $1 \rightarrow 2$ for the first task, $3 \rightarrow 4$ for the second and $5 \rightarrow 6$ for the third task in order to be able to distinguish them in the data later. The tasks were performed in the same order for all test subjects. After each secondary task the test subject had to state how distracted he was during the test (while doing the test). This was done according to table 4.1.The trial leader also stated how he perceived the distractedness level of the test person. This was however not done in the cases where the trial leader did not see or missed to check the distractedness. This rating as well as the pressed buttons for the start and end of each task was noted on a test sheet. On the sheet extra notes such as weather conditions and restarted secondary tests were also written down. A small piece of a test sheet can be seen in figure 4.1.

Nr.	Beschreibung Nebenaufgabe	Marker Beginn	Marker Ende	Unaufmerksamkeit Bewertung d. Fahrer	Unaufmerksamkeit Bewertung d. VL	Beschreibung
1	COMAND anschalten, Display Richtung schwenken, Helligkeit COMAND/MFD anpassen	1	2	3	3	
2	Eingabe einer 12 stelligen Telefonnummer (A) (Command)	3	4	4	4	1
3	Eingabe einer 12 stelligen Telefonnummer (A) (Ziffertastatur)	5	6	5	5	
4	Anpassen der Lautstärke über Lenkradtasten (A)	1	2	1	2	
5	Anpassen der Lautstärke über Rändelrad	3	4	1	2	[illegible]
6	Klang einstellen über ZBE/COMAND (A)	5	6	3	3	
7	Zieleingabe (Ort, Straße, Hausnummer) über Speller über ZBE/COMAND (A)	1	[illegible]	[illegible]	[illegible]	[illegible]

Figure 4.1. Test sheet for the registration of the distractedness ratings and button registrations.

In some cases the driver was not able to finish the secondary task according to the plan. This meaning for example that the task had to be interrupted because of a tunnel, extreme traffic conditions or usage of the wrong OE for the specific secondary task that was tested. In these cases the trial leader interrupted the task and allowed the test person to redo the test. The most important task was always the primary task, i.e. driving the car withing regulations and keeping safety margins. This was also stated in the rules that the test persons received prior to the start. Secondary task interruptions were also done when the driver felt anxious due to upcoming traffic situations.

Chapter 5

Solution and Modeling

In this chapter, first a structure of the different parts of the solution is shown. Secondly the procedure of selecting and subdividing the OE is explained and the model for filtering out the Used Element Signal is described. After that the calculation of the Overridden Area (OA) as well as the method of detecting lane changes and drop outs is stated. The chapter is divided in the following way:

- Description about the subjective and objective rating of the distractedness level from tests and expert group.
- Evaluation of the signals from the lane sensor and description about the calculation of the Overridden Area.
- Description of the different parts of the Simulink model.
- Description about how the first distractedness model was made.

5.1 Objective assessment

The objective assessment was done in order to get a rating of the distractedness each button or OE induced, separate from the actual field trials. The different areas of button, switches and knobs were first divided into groups in respect to their locations (steering wheel, door, roof etc.). The elements in the groups were then examined and each element was given a number to state the level of distraction the operation of the element theoretically would induce (see table 5.1. This was done with the help of rules which were assembled in accordance with the guidelines of the ADAM project [8]. These can be seen in table 5.1. As an example an element which is found not only by sight, but also by haptic means is considered less distractive than an element which can only be found by the sense of touch. This can also be referred back to chapter 2 to the idea of dual task performance since the primary task is sight dependent. In order to get as good ratings as possible, the assessment was done in an expert group with persons who had been working with the development of the systems.

Level	description
1	Hardly distracting
2	Somewhat distracting
3	Distracting
4	Quite distracting
5	Very distracting

Table 5.1. Levels of distraction for each OE

Number	Criteria	Allowed values
1	Search Modus	0: Haptic, 1: Visual
2	Placement of OE	0: On Steering wheel, 1: Away from Steering wheel, 2: Far away from Steering wheel (requires movement of the upper body)
3	Support	0: Guided, 1: Unguided
4	Response	0: Haptic, 1: Acoustic, 2: Visual (close), 3: Visual (Far)
5	Locating possibility	0: Clear, 2: Ambigous

Table 5.2. Criteria for deciding the level of distraction each OE induces.

The ratings from the experts were then combined and discussed further, finally resulting in a list containing the ratings for the elements (table 5.1). For the example OE, i.e. the number pad, this evaluation resulted in the following points: The search modus is mainly visual since the buttons are small and most people do not use the markings for the blind on a keypad[1]. The placement of the OE was given a number 2 since it is considered placed far away from the steering wheel. The support is unguided since it is considered that the number pad is not adjacent to a common element. The response is visual (far) since the result of the pressed button appear on the screen which is far away from both the buttons and the steering wheel. The locating possibility is clear, since there is only one number pad, and that the way it is used should be clear to all drivers. The resulting objective assessment level for this element was 5.

5.2 Subjective assessment

The subjective assessment is done by the driver during the trials. The trials were described in chapter 4. The same rating scale is used in the subjective assessment as in the objective assessment described in table 5.1.

5.3 Overridden Area (OA)

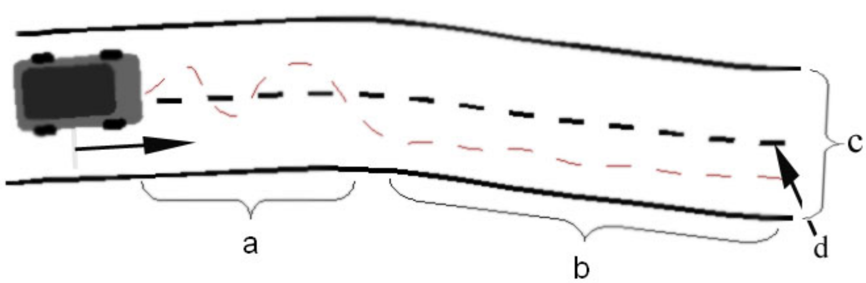


Figure 5.1. Description of the Overridden Area as seen from above the car. c is the lane width and d is the lane center

The track which the car follows may differ from a track always following the center of the lane. This might be due to the start of an overtake or simply due to that the particular driver prefers to drive slightly off the center of the lane, perhaps in order to get a better view of the traffic in front of him. The Overridden Area (OA) is in this master's thesis meant the area which the driver produces when he diverts from his *driving trajectory* (the actual path of the vehicle in the lane). If a driver has a trajectory that lies slightly to the left of the center of the road (part b in figure 5.1) he will not get more OA than a driver which drives in the middle

[1]The marking on the number 5 on a number pad.

of the road (part a in the figure) if the two drivers have the same deviations from their respective trajectories. In the figure 5.1 the a part would get a higher OA then the b part. The signals used for the calculation were described in section 3.1.2.

5.3.1 Overridden Area calculation

In order to calculate the OA as described above, the formula (5.1) was used:

$$A_{\text{overridden}} = \sum_{i=a}^{a+T} \left(\left| Y_{\text{offset}}[i] - Y_{\text{meanoffs}}[i] \right| v_{\text{ref}}[i] \right) \Delta t \tag{5.1}$$

Where a is the sample point of the start of the summation, typically the start of a secondary task test. $Y_{\text{offs}}[i]$ is the lateral offset signal as described in section 3.1.2. $Y_{\text{meanoffs}}[i]$ is the moving average over one second prior to i. Δt is the sample time, $0.02s$. The moving average was selected to 1s as a start value for the evaluation. It was considered a time before the start of a secondary task test under which the driver would not be distracted (as he just stated that he was ready, see section 4.3).
$v_{\text{ref}}[i]$ is the speed of the car at sample point i. The result of this calculation, the $A_{\text{overridden}}$ is in the evaluation also divided with the amount of samples for the secondary task test the T. This renders the OA per second during the task.

The figures 5.2 and 5.3 show the different parts of the calculation of the OA. In these figures the difference beteen the $Y_{\text{offset}}[i]$ and the $Y_{\text{meanoffs}}[i]$is shown. In equation 5.1 the absolute value of this difference is summed and not the difference.

5.3.2 Lane change and dropout detection

A simple lane change detection was made by checking when the lateral offset signal from the lane keeping system made a jump from a big negative value to a big positive value between samples (typically from $-1m$ to $+1m$). This was done in order to try to filter out the extra area which was overridden when a lane change took place. In order to do this the longest time of lane change of a test run was checked. This was then rounded up which gave $6s$. Since the moving average signal is taken over one second, the time after a lane change that was filtered away was set to one second more, i.e. $7s$.

The other difficulty that arose was that the quality of the signal of the lateral offset was not always reliable. In some places along the road a sudden jump in the detected lane width made the camera send out a zero offset from the lane center. These portions were removed from the OA calculation since they would otherwise produce an added area (because of the moving average calculation). The signal was checked for long periods of zero deviation and when such a section was found, it and a couple of seconds before and after was marked and left out in the later calculation. The lane change signal with a typical lane change and a dropout is shown in figure 5.4. The dotted signal in the picture is the lane change and dropout signal which has the following values.

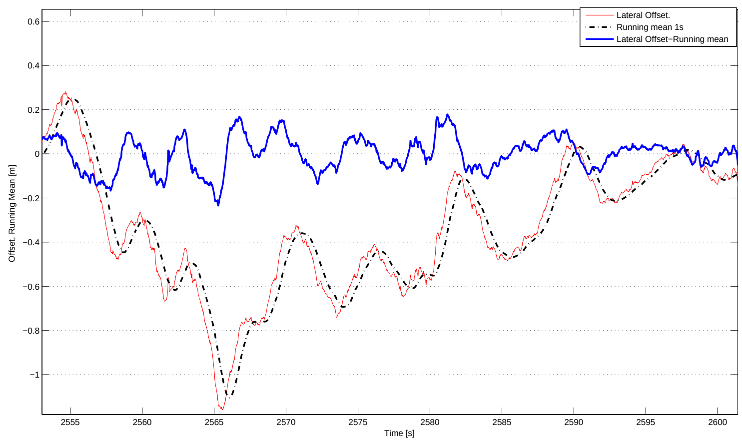


Figure 5.2. The calculation of the deviation from the current driving trajectory, normal straight ahead driving.The dotted line is the moving average over 1s and the thin solid line is the lateral offset signal. The result of the calculation (i.e. the difference between the offset and the moving average) is depicted as the thick solid line.

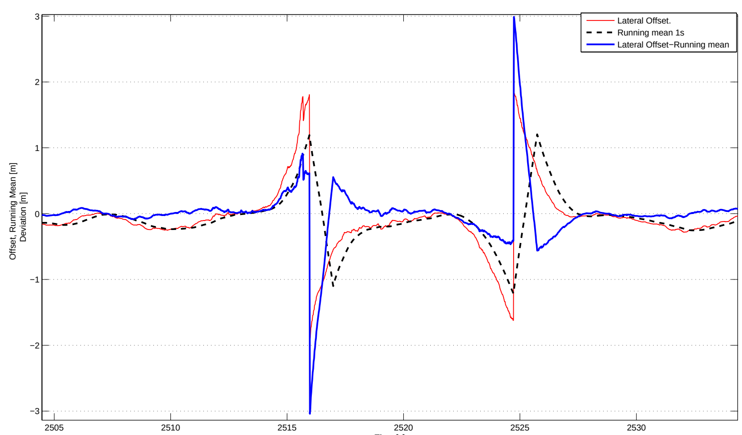


Figure 5.3. The calculation of the deviation from the current driving trajectory during an overtake. See figure 5.2 and the text for more explanation.

1. Lane change right detected
2. Lane change left detected
3. Lane change filter active (no area is calculated)
4. Dropout filter active (no area is calculated)
5. Dropout detection.

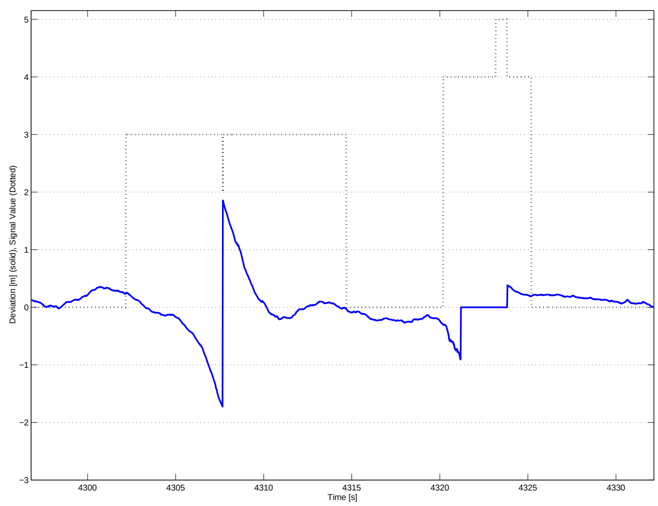


Figure 5.4. Filtering out the lane changes and the spikes. The solid line represents the lateral offset signal and the dotted signal shows where the lane changes and the spikes were detected and how much of the signal was filtered out in the calculation. When the dotted signal in the figure is ≥ 0 the Overridden Area is not summed up.

5.4 Simulink Model

This chapter describes the complete Simulink model for the solution of the problems. The parts of the models are described in the subsections s 5.4.1–5.4.3. The complete model with marked sections can be seen in the appendix B. The object of this model is as described earlier in this thesis to generate a value of the current driver inattentiveness level

5.4.1 Bus data input and CAN signal interpretation

This subsection describes the a part of the model (as in appendix B)

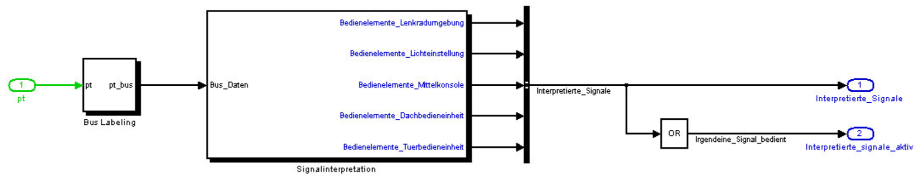


Figure 5.5. Modeling of the OE signal. The output is OR:ed together for test purposes.

Bus Labeling

The block `bus_labeling` was automatically generated from an existing Matlab script. It gives names to the signals from the CAN vectors and divides them in a bus structure. The block can be remade for different types of CAN vectors, e.g. when testing on another car type.

Filtering out a used OE signal – `SignalInterpretation`

The signals were first divided into blocks in respect to their positions. This rendered 5 different groups; Steering Wheel, Light, Middle Console, Roof and Door (see figure 5.5). With small test data as well as a list of CAN-Signal names which were accessible from the saved CAN data from the car, the different OE were examined to check their function. This basically involved taking a protocol to the car and going through the possible states of a particular OE, this also helped finding out and testing the settings for the longer tests described in chapter 4.

Only a few of the CAN signals are actually OE. Reversely not all OE are directly represented as CAN signals, or at least not the usage of all OE are directly represented.

In the example of the COMAND controller, as can be seen in the figure 5.6, the signals that were sent did not specifically state that the COMAND Controller was turned, instead information about the menu system was sent. This information, was the amount of menu states and the number of the current (selected) menu item. As can be seen in the figure, not all of the changes are actual turn operations. This is due to that the amount of states was also changed when the driver pressed a menu related button. The state could also change when the joy stick function of the COMAND controller was used in order to navigate in the menus.

5.4.2 Task-, active task and group selection

This subsection describes the *b* part of the model (as in B.) In order to complete a secondary task the driver some times uses only one OE, for example when indicating a turn or pressing the horn. Other tasks are more complex and require the use of several OE in order to finish them. Since the interest lies in finding out how inattentive the driver is at a particular time and that it is clearly quite a big difference in task difficulty even between two tasks that use the same OE, it proved more important to divide into potential secondary tasks than actual OE. Added to that was also the fact that there existed a few signals that sent special

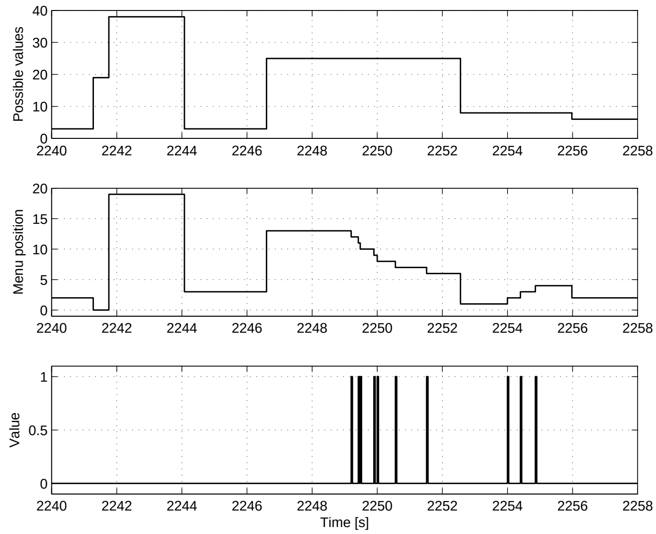


Figure 5.6. Example of state signals, the COMAND controller. From the top are the possible menu values, the current menu position and the resulting OE signal.

information on different tasks that were performed. An obvious example of this was the setting of the multi contour seats[2] which as well as many other things was done via the COMAND. For these the signals that were sent were the values for the actuators in the seat. This meant that the performance of the task concerned with the multi contour seats could be found directly. A perhaps more unclear example is that the window buttons send different signals when pressing once (for a complete opening of the window) and when pressing and holding (for opening the window to a specific level). This could be considered being two different tasks. Important to note here is that not every task could be filtered out. It is probably possible to get every possible task by creating state machines that start on undefined states and then successively when passing known states, also figure out the unknown states. The amount of work needed for that was however considered too much to add to this master's thesis. It is possibly much easier to add some extra hardware in order to get these signals direct from the actuators or from the on board computers.

Below is a brief explanation of each different block in this part of the model (see figure 5.7).

Active signal group – `Aktiv_signal_bestimmen`

The active signal group combines the OE signals to groups according to the ADAM project description i.e. the same groups as were done in the objective assessment.

[2]Seats in the car which has air cushions for massage and dynamic change during driving.

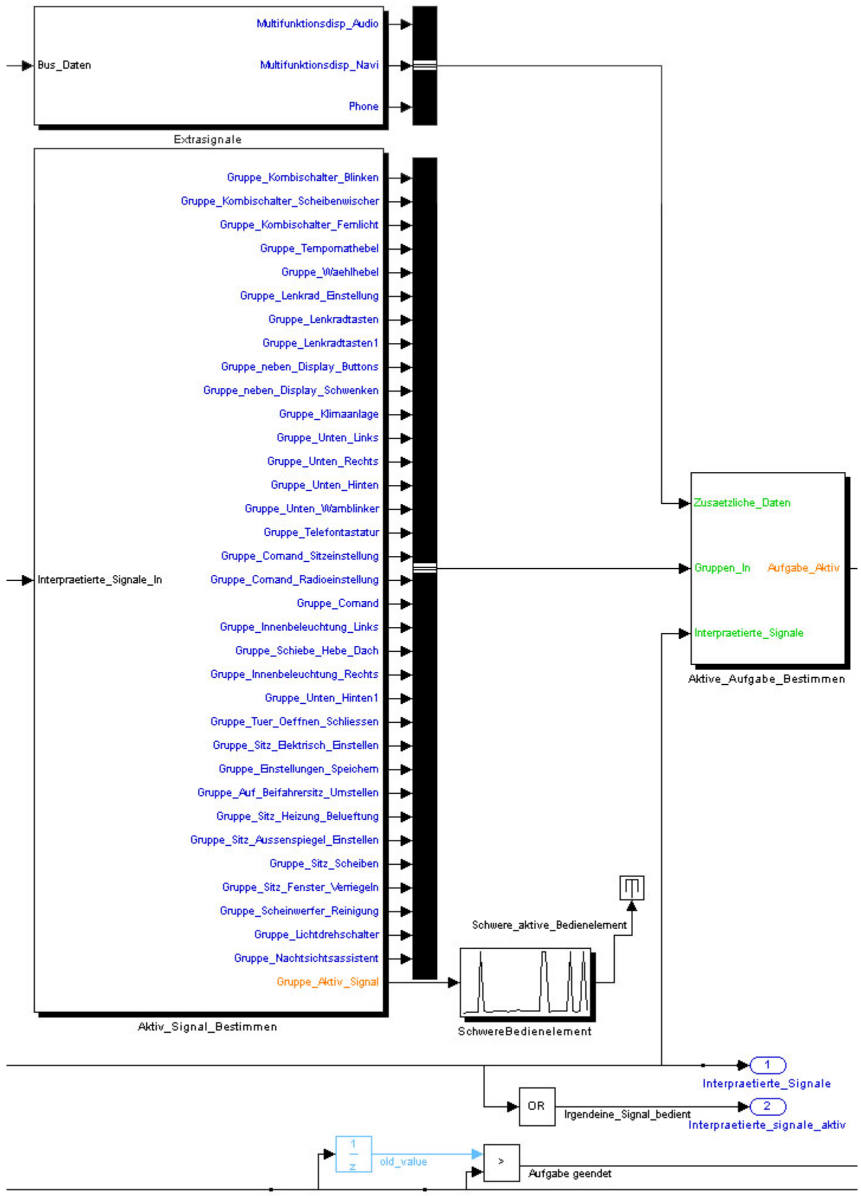


Figure 5.7. The part of the model which contains the task-, active task and group selection.

extra signals – `Extrasignale`

In order to take care of CAN signals that state for example in which menu the driver currently operates, this block was added. In the current model as seen in the appendix these are the signals which states in which sub menu in the instrument cluster[3].

Difficulty for the active signal group – `Schwere_Bedienelement`

The block is a look up table for the result of the objective assesment (see section 5.1).

Active task – `Aktive_Aufgabe_bestimmen`

This subsystem combines the signals and sends out a unique number about which task currently is active. This is done by connecting switches. Only one signal at the time can be switched through.

5.4.3 The Distractedness Calculation

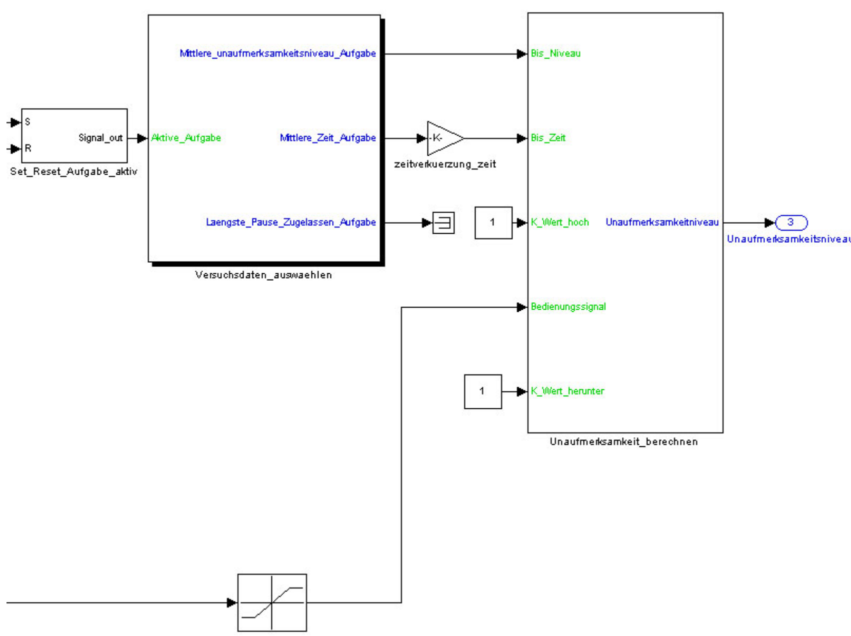


Figure 5.8. The part of the model which contains the distractedness calculation.

[3]The area where the speedometer, rev counter and status lights are. These signals could be used for the tasks 4, 12, 15, 27 and 28

This subsection describes the *c* part of the model (as in B.) The calculation of dynamic distractedness level is done using the parameters from the trials. When a button is pressed the Simulink blocks first creates a used operating element signal which is then connected to the tasks from the OE block (see figure 5.8). If the operation of an OE is connected to a viable task (i.e., a task that has a result from the trials), the corresponding mean task time and mean distractedness level for that task are selected and used as inputs.

Set and reset of active task – `Set_reset_Aufgabe_Aktiv`

This block waits for a falling edge on the signal which states that a task is active (i.e an end of a task). This resets the active task and a new active task can be input from the prior block.

Selection of trial data – `Versuchsdaten_auswaehlen`

This block selects the data from the evaluation of the trials. These are the subjective assessment, mean TTT and the longest allowed interruption (pause). As can be seen only the mean TTT and the subjective assessment data are forwarded to the distractedness calculation block.

Distractedness calculation – `Unaufmerksamkeit_berechnen`

These levels are then used to create a simple signal that counts up until the mean distractedness level is reached. It keeps this level until close to the mean TTT of the task and starts counting down in order to reach zero before the mean TTT is reached. The Simulink block is made in such a way as to be able to count up and down with different speeds. These speeds can be set with the inputs k_wert_hoch and k_wert_herunter for up and down respectively. In this model the mean time for the task is multiplied by a factor 0.8. This is done in order to remove the count up and down times.

5.4.4 Input from evaluation

This subsection describes the *d* part of the model (as in appendix B). It can also be seen in figure 5.9

Input of the created task signal – `Aufgaben_vektor`

The signal stating that a task is active during a trial and which task it is (see the section 6.1). It is the result of the trial evaluation.

The information about which task it belongs to goes lost when the signal is run through the further blocks. This means that the signal only states that a secondary task is active.

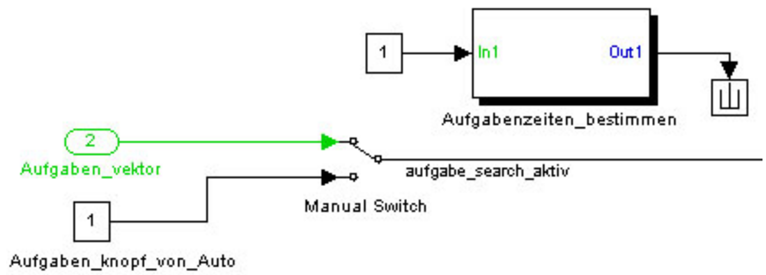


Figure 5.9. The part of the model which contains the input from the evaluation.

Deciding the start of a task – `Aufgaben_zeiten_bestimmen`

This is merely put there as a pointer for further development (see the discussion in chapter 7).

Chapter 6

Data Compilation and Evaluation

In this chapter it is described how the data from the objective rating as well as how the data from the tests were compiled and evaluated. This chapter is divided as follows (see also figure 6.1):

- Description about the way the data was compiled and problems that arose. Example of the data compilation is given.

- The method and the resulting signals, plots and histograms from the data evaluation is described.

- Model evaluation of the distractedness model.

6.1 Data Compilation

The CAN data from all test rides was saved together with the equivalent video data. The CAN-data from the buttons was then compared to the test protocols off line and a new signal was created which stated when a secondary task was active and which task it was. This was done in order to simplify the automatic processing of the data. The original button signal and the created one can be seen in figure 6.2.

In a few cases the pressed buttons were not to find in the data. This was probably due to that the button was pressed to quickly or not pressed hard enough. In these cases the actual tasks were compared to other tasks to see the normal length. The can data from the OE which belonged to that task was also examined to locate the actual occurrence of the start.

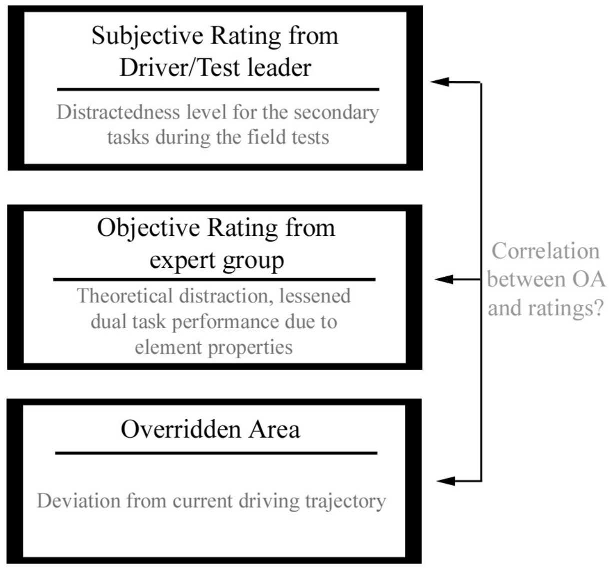


Figure 6.1. Overview of the evaluation. Is there a correlation between OA and the objective/subjective ratings for the OE?

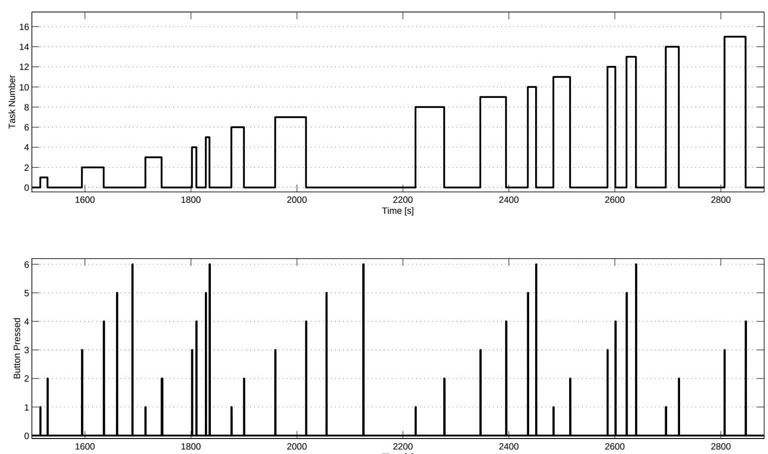


Figure 6.2. The registration buttons and the created task signal. Above is the created task signal and below is the original button signal.

6.2 Data Evaluation

The evaluation of the trials was done by Matlab scripts which were run off line and checked the CAN signals during the tasks (separated by the registration buttons, as pictured figure 6.2). The signals in the respective tasks were then compared over all tests. In a few of the cases the evaluation required that the OE signal (as described in section 5.4.1) was first created. This simulation for was done for all of the data and saved separately. The objective assessment evaluation was done by hand.

6.2.1 Objective assessment

Quite a few of the OE in the car were considered in the objective assessment. As already explained the objective rating was done on groups of buttons according to the ADAM guidelines and are therefore not exactly compatible with the subjective assessment. The list of the evaluation will not be presented in the thesis.

6.2.2 Total Task Time (TTT)

The TTT was at first measured by evaluating the times between the pressed start and end buttons by the trial leader. These times are probably longer than the actual TTTs since the time from the pressed buttons to the actual start of the task also are contained in this time. There is probably also a short extra time at the end of each task since the test person first orally confirms that the task was finished. The lengths of the total task times can be seen in the box plot in figure C.2 in appendix C. The longest task times belong to the tasks connected to the input to the navigation system.

it is clear to see that the task lengths are longer than they “should” be when using the same discussion as Green does, see 2.2.4 and [6]. Possible causes to this will be discussed in chapter 7.

6.2.3 Pauses between task operating parts

The script also checked pauses in the tasks. This was done as follows: One run was made which only checked the pauses ignoring which OE types that were represented in the task (State Signal or Duration Signal). Since the State Signals do not register the actual usage times these were examined separately. An example of the analysis can be seen in figure 6.3. The search and return times were filtered out from this analysis since these times are due to properties that are not considered in this evaluation as they do not represent a pause between operations. In this case 95% of all pauses are shorter than about $3.5s$.

6.2.4 Usage times of Duration signals

This evaluation was done in order to see if there were any trends in the times of the Duration Signals. Some OE are pressed and held and some are more used by a short press. Some of the buttons lie close to each other and it might be easy to

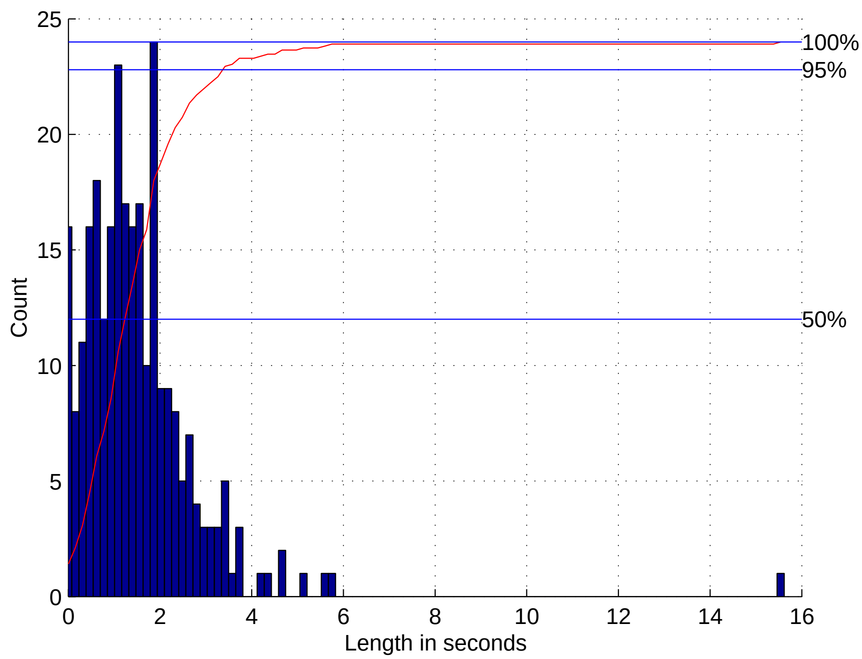


Figure 6.3. Figure showing a histogram over the pauses between the task operating parts of task 3, number pad. Blue lines show the level where the probability density function (thin curve)is 50%, 95% and 100%.

accidently press a button. As can be seen in the histogram in figure 6.4 95% of the times are shorter than about $0.25s$

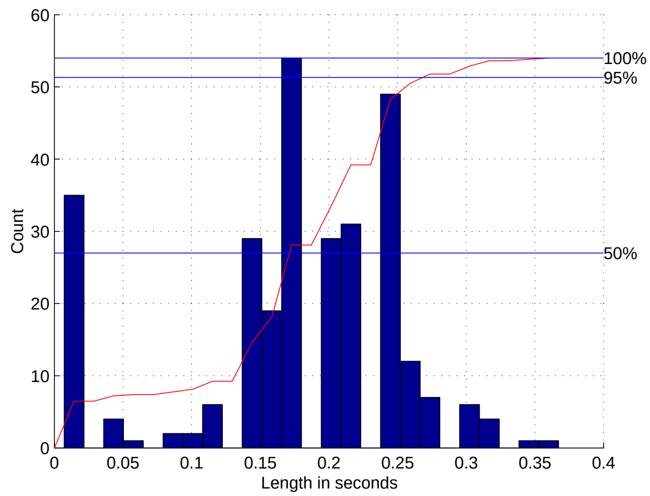


Figure 6.4. Figure showing a histogram over the lengths of the task operating parts in the task 3, number pad over all trial runs. Blue lines show the level where the probability density function (thin curve)is 50%, 95% and 100%.

6.2.5 Overridden Area

The calculation of the OA as described in equation (5.1) in section 5.3 was used on all the test data. In order to examine the quality of the signal a few extra signals were saved too. In table 6.2.5 is an example of the saved variables for the number pad example (task 3 trial run 3).

Even though this particular example contained no dropout or lane changes, there are tests that do. In total in the example of the test 3, 13 tests had no lane changes or dropouts. The lowest percentage of used task time was just over 60%. The OA without lane change and dropouts was still used for the further evaluation. Worth mentioning is perhaps also that the mean speed naturally differed between different trial runs and different tests.

OA statistical tests

The Overridden Area of the two hardest tasks (the two which induced the highest distraction according to the objective and subjective assessment) was compared to two tasks that were comparatively easy. The easy tasks were task 4 and 17. These tasks were for the easy tasks longer than usual[1] and was therefore chosen.

[1]It is considered that a task gets more difficult the longer it is as in the theory chapter (in section 2.2.4).

Variable Name	Value
OA	186.2946
TTT	23.88
OA [1/s]	7.8013
OA [1/s]	7.8013
Mean speed	108.1733
Amount of sample points with lane change	0
Amount of sample points with dropout	0
Percent of task used (without lane change or dropout)	100%
Start button	5
End button	6
Task	3

Table 6.1. Example of saved variables from trial evaluation.

The hard tasks were task 3 and 9. A T-test was done on these with a result of no significance. This can also be understood by examining the box plot in appendix C.3. No further testing with other parameters were made since the OA was considered as being only a small goal of the master's thesis and that the signal was too noisy.

6.2.6 Distractedness model evaluation

The distractedness model was made in order to connect the different pieces of the data evaluation. As described earlier in section 5.4.2 it was not possible to discover all of the tested tasks specifically by using the CAN-signals as they were given. Possible ways of distinguishing between the remaining signals will be discussed further in the next chapter.

The result of a simulation with existing data can be seen in figure 6.5. It is there easy to see which ones of the tasks that were not able to be filtered out in this first model. These do not have a corresponding distractedness level to the task number active.

In the figure 6.6 a zoom in on figure 6.5 is shown. The figure shows the function of the current model. When a new task is active the task number found is reset and at the first number connected to an OE which has been operated, the distractedness level starts to count up to the level defined by the mean distractedness level of the corresponding trial task (i.e. the mean subjective rating).

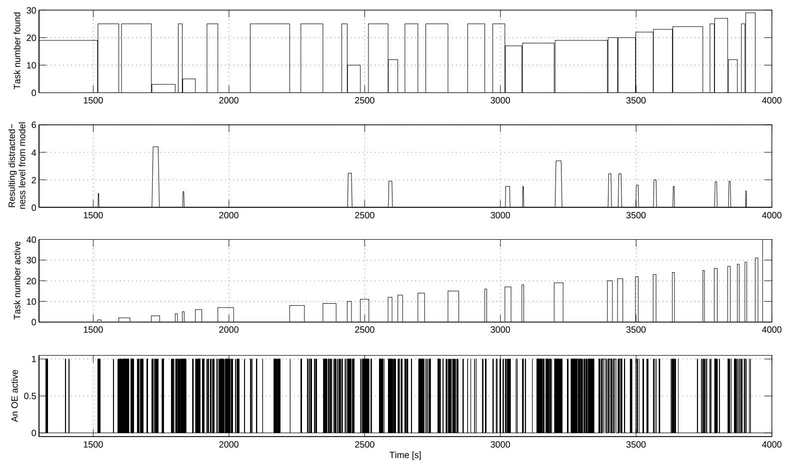


Figure 6.5. Simulation of the distractedness calculation. The top plot represents the found task number. A complete solution would render the same plot as the third from the top, i.e. where all the tasks would have been uniquely found. The fourth signal from the top shows all of the used OE signals. The second signal from the top is the resulting distractedness signal.

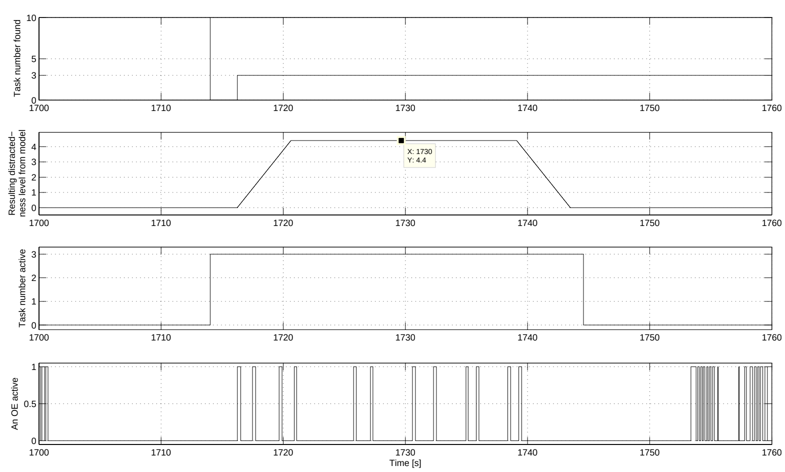


Figure 6.6. Zoom in on the distractedness calculation of task 3. For description of the different signals see figure 6.5.

Chapter 7

Discussion

In this chapter the parts of the thesis are discussed. What parts of the theory could have been tested with more time? How could one continue with the model? What is important in trial design and where are there possible obstacles. Which possible use of the model in parameter settings are there? Finally the aims of the thesis are followed up.

7.1 Concerning the test planning

The tests that were made in this master's thesis were made in real traffic with the uncontrollable parameters that are connected to these conditions. These parameters are many and also probably correlated. For example the weather, traffic density and the specific driver: the weather may cause increased traffic density, but also a driver with lessened dual task performance since the primary driving task would take up more resources. The heightened traffic density might also affect the driver's dual task performance as this would also make the primary driving task more difficult. The real traffic conditions also affect the reproducibility of the tests. Even with the same driver a lot of parameters were uncontrollable. Perhaps the leap from PDT, LCT and other tests in simulators directly to real traffic is too long. It might have been interesting to test secondary tasks on an oval test course first to remove the effects of uncontrollable parameters. The tests did however still render reasonable results about the distractedness level. The tasks that were awarded the highest level were also the ones *considered* most difficult (i.e. the setting of the navigation system).

7.2 Concerning the modeling

The first important topic concerning modeling distractedness is the way inattentiveness affects distractedness. When modeling driver distractedness based on user interaction only, one must consider these effects. Even though the baseline tests are done as described in section 2.3, the PDT and LCT might also measure some of the inattentiveness of the driver. The PDT is not designed to be used in real traffic in the first place. When one registers the actual pressed buttons in a car, one must take in to account the span of driver inattentiveness and possibly try to estimate this.

7.3 Concerning the results of the evaluation

7.3.1 Total Task Lengths

The lengths of the tasks as tested in the 18 trials were longer than the longest TTT which normally should be existing according to [6]. This is probably due to that the search and return times contained in the TTT from the trials are longer than the actual ones. This since the driver confirms that he finished the task. The longest tasks are also not supposed to be performed while driving [2]. As can be seen in the histogram–evaluation in figure 6.3 the pauses are also quite long. It is perhaps not realistic to assume that the tasks that have pauses over $4s$ really are tasks with distracted drivers the whole time, but rather two distracted sub tasks with an alert pause in between.

7.3.2 Usage times

The long usage times are interesting since they state that the driver has the hand off the wheel. These long times are generally not from OE that are very distractedness–generating though.

7.3.3 Pauses between task operating parts

The evaluation of these are interesting because they can both be used for further modeling. The small pauses can be used to further evaluate state signals and examine the operation of a state signal generating element. An example already looked upon is that of the COMAND controller in figure 5.6. The resulting signal in the third plot from the top could be seen as two operations, separated by pauses.

7.3.4 Overridden Area

The lane monitoring system could have been tested more, including the parameters for the moving average calculation. There is perhaps a possibility to get a better value (i.e., a less noisy one) by using more signals and a state observer for the unknown area. In that case the problem would have grown out of the limits of this master's thesis and was therefore left as further work. The use of an existing lane monitoring system for distractedness detection could probably still be used but in a more heuretical way. For example detecting the passing of a lane marking at the same time as a cognitively hard task is operated. It does not matter if the car returns to the same lane or passes the lane and completes the lane change. This should perhaps still render a very high distractedness level.

7.4 Further work

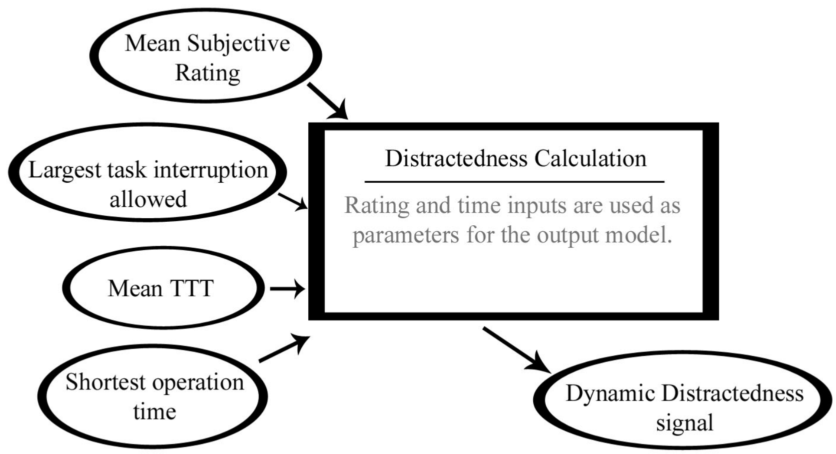


Figure 7.1. Overview of the possible and current inputs to the current driver distractedness model.

In the Simulink model a few preparations for the next step is taken. As can be seen in appendix B, Aufgaben-knopf-von-Auto is connected to a manual switch. As a next step the off–line calculation of the distractedness level could be replaced by a button in the car which will be used by a passenger to state that a secondary task has started and ended.

For a functioning distractedness model a few other things must be applied as well. The actual operation of an operating element can of course always be considered connected to a distractedness level. The problem occurs for example when the driver interrupts a task and starts another task. The way the modeled distractedness level should wear off needs to be examined. As a first step the longest task interruption might be used.

The type of signal also needs to be taken into account in the model. This is also done with a Simulink block in the model. This is however not in the complete model in the appendix. Perhaps the shortest pauses between task operating parts could be used for this. The signals could be lengthened and be considered as one task operating part (i.e., an operation of the corresponding OE, e.g. one turn of the COMAND controller).

Other Tasks

In order to be able to make the model work for other OE the results from the objective assessment will be used. This is prepared in the block `SchwereBedienelement`. The signal from this block could be used to control parameters about the climb of the distractedness signal and other properties.

Longest Task Interruption

The longest task interruption could be used in the model as well. As seen in the tests the TTT of the tasks are in many cases quite long. This does not mean that the driver constantly has his attention diverted to a button and is using it. There are interruptions in order to get a view on the current traffic situations. These interruptions could be seen as ways for the driver to see to it that he is completing the primary task according to the rules (i.e. is driving within lane borders, with normal speed etc.). In the figure 6.6 longer interruptions can be seen after the fourth and sixth digit (the fourth and sixth spike on the 4 signal from the top). Is the driver really distracted during a section like that?

Speed Effect

The speed varied between different tests and different trials. This is probably due to several things. Drivers slowing down when doing a difficult task (this is sometimes measured while testing the PDT in simulators). Some times the result was probably due to that the task was too hard for the driver to cope with while keeping the safety margins. More difficult to model is however that the driver might get more structured in his driving when faced with a difficult task. Accelerating and overtaking in order to get a clear road for the duration of a secondary task might make a hard task easier. This could also be the same when braking and keeping the vehicle behind a truck at a lower speed where changes are relatively easy to notice.

7.4.1 Concerning the design of IVIS

Should it be allowed to use all of the OE in modern cars while driving? The S500 has adaptive cruise control which automatically keeps the distance to the car driving in front. Even though this probably eases some dangers of the performing of hard tasks (i.e., distractedness inducing) it is still pretty difficult to drive at the same time as selecting the goal on a map with a joy stick. The car manual specifically states that these task should not be performed while driving and perhaps the driver's adhere to that. An interesting part to look on is the effects of many different OE during a short period of time on distractedness as well as started tasks that are not finished. Which points should one consider when designing for distractedness measurement? Most of the IVIS's in new cars have probably already been tested in simulators. If the menu systems are set up in such a fashion that they send the information, it is probably possible to construct a working model for all tasks. Together with sensor values from for example front radar changes in the traffic may also be considered.

7.4.2 Follow up on the aims of the master's thesis

- The side track of the overridden area took a long time and was still not examined thoroughly. This could have been left in favor of more modeling time.

- The scripts that were made are easy to extend to be used on other CAN-Data. It is easy to start further testing since the task markers are saved together with the trial data. Some of the downside of the time put to the OA calculation made the evaluation easier in the end.
- The model created is only a start and a pointing in the direction of one possible solution of the problem.

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Appendix A

List of the tasks

Nr.	Beschreibung Nebenaufgabe
1	COMAND anschalten, Display Richtung schwenken, Helligkeit COMAND/MFD anpassen
2	Eingabe einer 12 stelligen Telefonnummer (A) (Command)
3	Eingabe einer 12 stelligen Telefonnummer (A) (Ziffertastatur)
4	Anpassen der Lautstärke über Lenkradtasten (A)
5	Anpassen der Lautstärke über Rändelrad
6	Klang einstellen über ZBE/COMAND (A)
7	Zieleingabe (Ort, Straße, Hausnummer) über Speller über ZBE/COMAND (A)
8	Zieleingabe (Ort, Straße, Hausnummer) über Sprachbedienung
9	Zieleingabe über Kartendarstellung über ZBE/COMAND (A)
10	Anpassen der Temperatur Fahrer u. Beifahrer, Gebläsestufe und Zusatztaste (Umluft-, Heckscheibenheiz.) über Direkttasten (A)
11	Anpassen der Temperatur Fahrer u. Beifahrer, Gebläsestufe, Luftverteilung über ZBE (COMAND) einstellen
12	Auswählen einer Telefonnummer aus einer Liste mit Lenkradtasten/MFD (A)
13	Auswählen einer Telefonnummer aus einer Liste mit ZBE/COMAND (A)
14	Suchen eines Titels auf einer CD (Lange Nebenaufgabe wegen Anspielens aller Titel, A)
15	Wechsel Radiosender mit Lenkradtasten/MFD
16	Wechsel Radiosender mit ZBE/COMAND
17	Sitz (Höhe, Position, Kissen, Kopfstütze) einstellen über Direkttasten in Fahrertür
18	Sitz-Belüftung/Heizung einstellen über Direkttasten in Fahrertür
19	Multikontur-Sitz Seitenbacken Oberschenkelpolster und Rückenlehne einstellen mit ZBE (COMAND)
20	Außenspiegel links einstellen über Direkttasten in Fahrertür
21	Außenspiegel rechts einstellen über Direkttasten in Fahrertür

22	Fenster vorne links komplett öffnen/schließen und Fensterhöhe einstellen über Direkttasten in Fahrertür
23	Schiebedach komplett öffnen/schließen anheben/absenken und Position einstellen über Direkttasten an DBE
24	Abblendlicht, Nebelscheinwerfer und Nebelschlußleuchte ein- und ausschalten
25	Scheibenwischer auf Aus, Intervall 1, Intervall 2, Stufe 1, Stufe 2 schalten, Blinker benutzen
26	Distronic ein/auschalten und Setzgeschwindigkeit vorwählen über Tempomatbedienhebel
27	Abstandsanzeige über Lenkradtasten/MFD aufrufen und Sollabstand über Abstandswählrad am Tempomatbedienhebel verändern
28	Im Reiserechner Daten ab Start/Reset und Reichweite über Lenkradtasten und/MFD abrufen
29	Fahrprogramm einstellen, Fonds-Kopfstützen hochklappen, Warnblinker ein-/ausschalten
30	Auspacken eines Papiertaschentuches
31	Einstellen des Innenspiegels
33	Keine Aufgabe

Table A.1: Secondary tasks performed during the trials. An (A) behind the description states that the secondary task was taken from the specifications in the ADAM project (see the introduction on page 1). The description is intentionally left untranslated.

Appendix B

Simulink Models

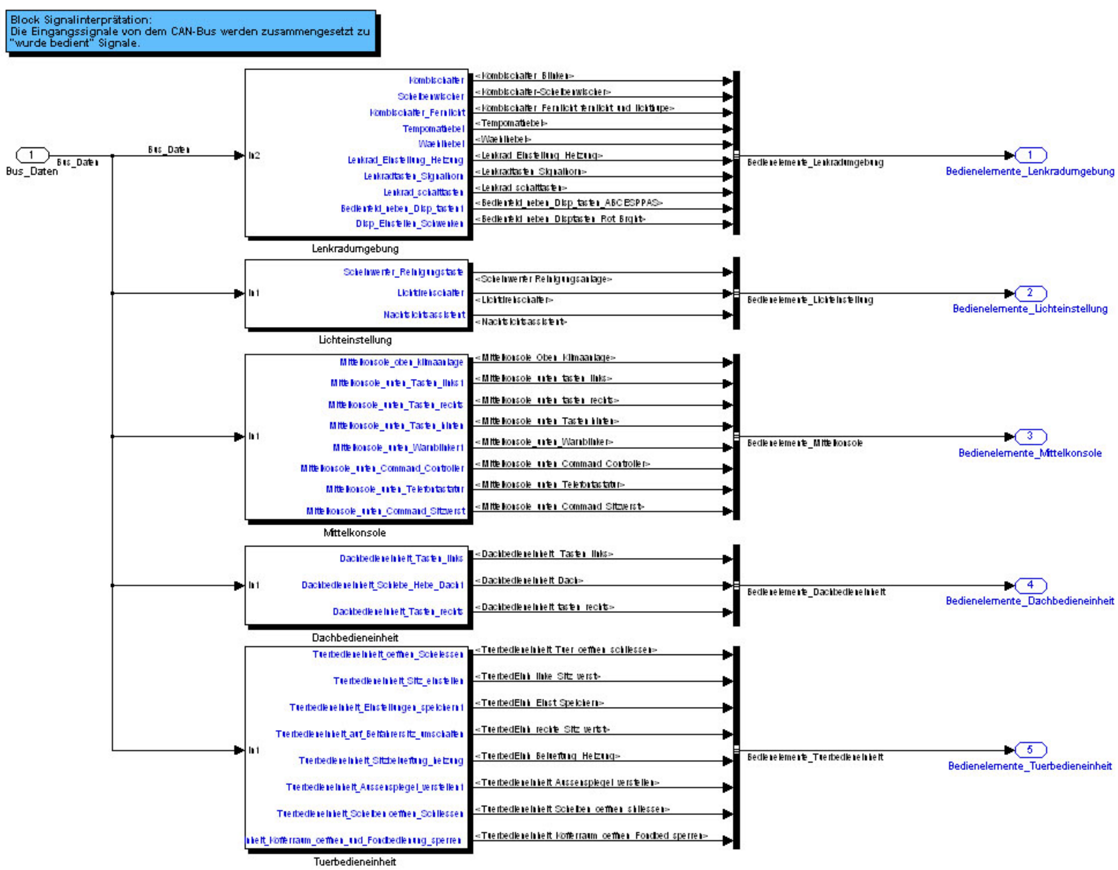

Figure B.1. Signal interpretation block, further described in chapter 5.

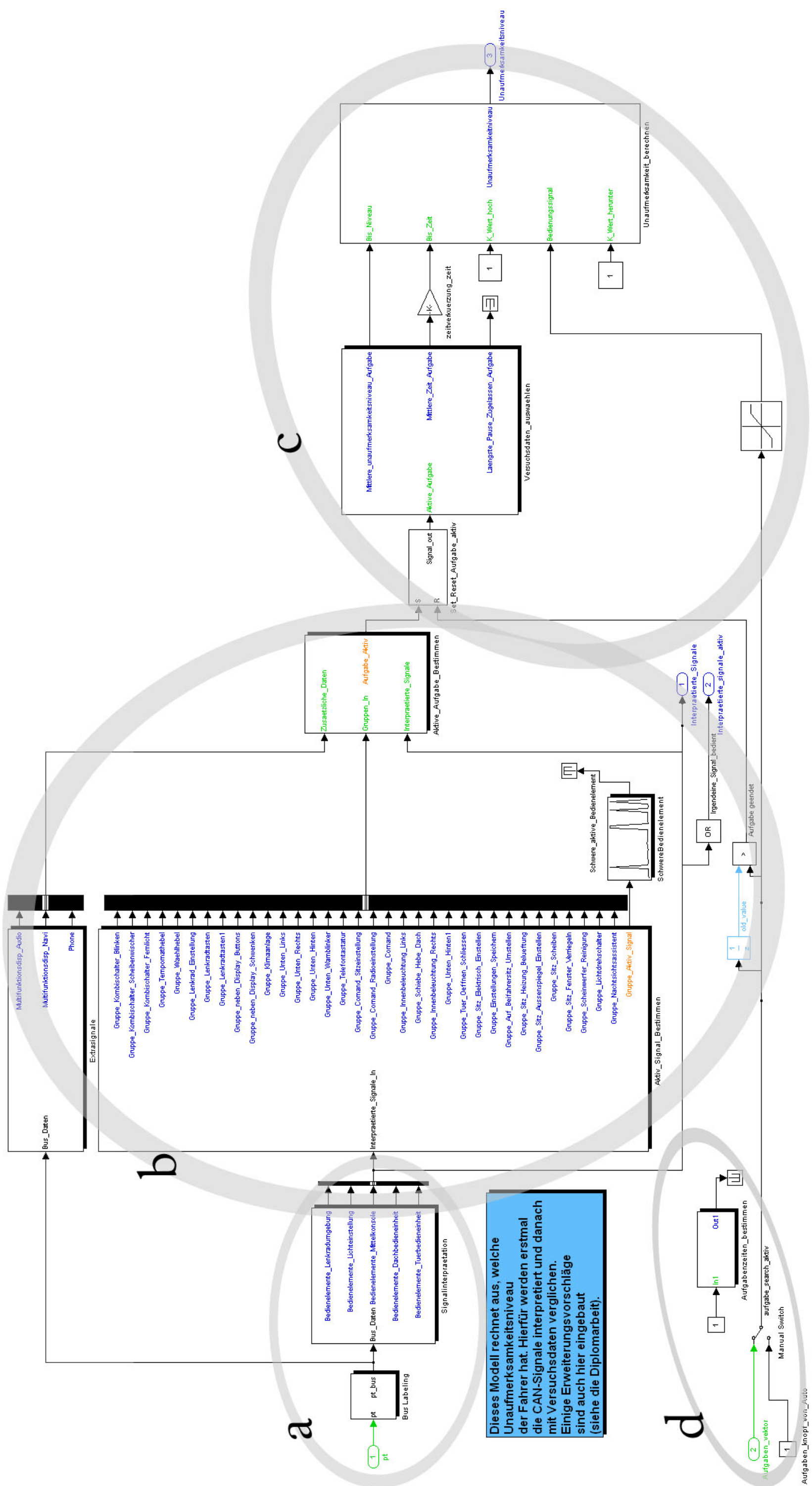

Figure B.2. Complete Simulink model. The parts are described in the chapter 5.

Appendix C

Boxplots

C.1 Description

A boxplot is mearly a way of describing statistical data. Figure C.1 shows a box plot and describes the different parts of the box. The whiskers show the smallest and largest non-outlier value and the actual box show where the top and bottom quartile is. The box bottom and top value specify what is called the Inter Quartile Range (IQR) in which where 50% of all non outlier values are. There are two types of outliers, mild and extreme. The mild outliers lie inside IQR$*$1.5 and the extreme lie outside of IQR$*$3. The + is the median value and the line in the box is the mean value [5].

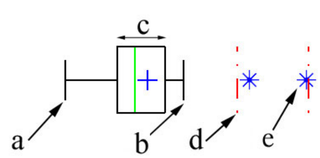

Figure C.1. Single box in a boxplot. *a*, is the lower- and *b* is the upper whisker. *c* shows the Inter Quartile Range (IQR) and *d* and *e* is are the mild- and extreme outliers respectively.

C.2 Total Task Time

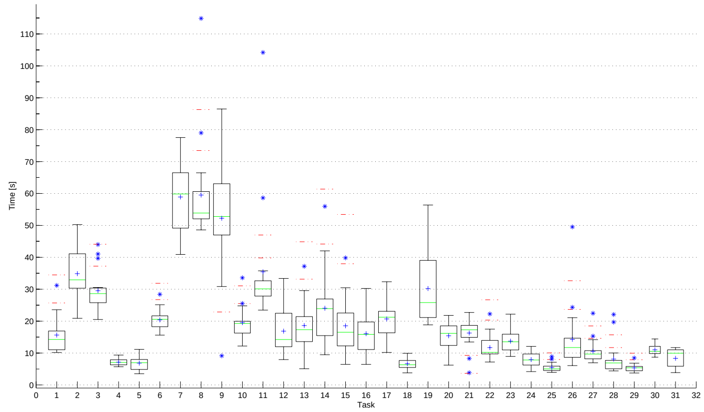

Figure C.2. Boxplot showing the Total Task Times measured between the pressed buttons signaling Task Start and Task End

C.3 Overridden Area

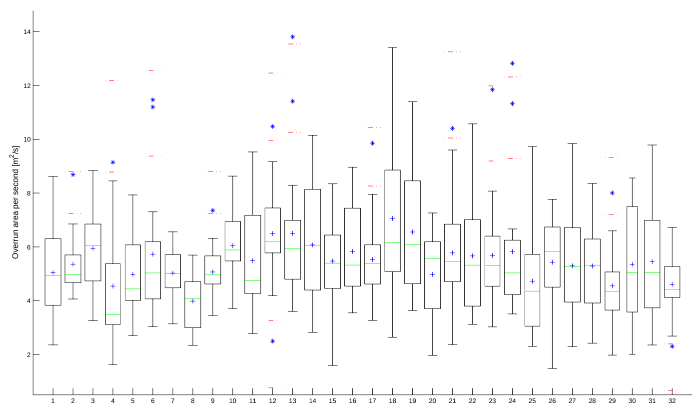

Figure C.3. Boxplot showing the OA per second between the pressed buttons signaling Task Start and Task End