CARS - Configurable automotive research simulator

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Abstract: This paper introduces CARS, an open source driving simulator tool for evaluating driver distraction. We present the map editor, the driving simulation tool and the analysis tool included in CARS. Based on initial results from initial user studies we illustrate the effectiveness of CARS in evaluating different secondary tasks (e.g., compare different UIs for navigation systems) with regard to driver distraction.

1 Introduction

The number of in-vehicle entertainment and information systems, such as radio, telephone, navigation system, etc., has continually increased in the last decades. Driving a car includes nowadays often secondary tasks (e.g. selecting a radio station or making a call). Since secondary tasks often causes distraction from the primary task "driving", it is important to quantify how much distraction a new entertainment or information system will cause. Over recent years car manufactures and research groups have suggested different techniques to measure driver distraction, ranging from simple laboratory tests to high fidelity driving simulators.

Drawing on this work and targeting towards new requirements we developed CARS, a driving simulator tool which has integrated means for measuring driver distraction. The system is open source and available on our website[1]. CARS's analysis tool delivers detailed information about driver performance and calculates parameters that describe the level of driver distraction. In some preliminary user studies, we currently aim to discover a formula for calculating a single value from the driver performance as basis for comparison of different conditions, tasks and devices. We hope such a value could become an indicator for the level of driver distraction. We suggest that this indicator could then be used to quickly compare the driver distraction level of different secondary tasks or conditions.

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[1] For information on CARS visit https://www.pcuie.uni-due.de/projectwiki/index.php/CARS

2 Background

Research in the field of driving simulators is not new; for instance, Daimler-Benz presented a high-fidelity simulator in 1985 (Drosdol & Panik 1985). The complexity of driving simulators varies from low-cost static PC-based simulators like (Kang et al.) to advanced, dynamic simulators like (UoLDS 2008). For our in-vehicle user interface research we need to measure driver distraction on a detailed level. In a first step we explored the LCT (Lane-Change-Task) (Mattes, 2003). This tool supported driving at a constant speed on a straight road and requires the user to change lanes on a visual signal. Our initial tests showed that this task is not well suited to compare user interface tasks (e.g. it cannot be used to test new interfaces for navigation systems). To overcome some of these limitations we developed an open source driving simulator that allows evaluating driver distraction in user studies of new automotive User Interfaces at a quantitative level.

3 CARS – open source driving simulator

CARS is an open source, low-cost, PC-based driving simulator. The system requires a consumer PC, a game steering wheel, a brake-and-gas-pedal gaming device, at least one display (monitor or projector), see Figure 1. The setup shows a 47" display which renders the road and environment, steering wheel and pedals and an additional, 8" display (secondary display) for the speedometer. The simulator shows a road with roadside markers and grassland in 3D. The driver controls the car by using the steering wheel and the pedals. CARS is designed to support the early stages of a development process for in-car systems by providing a concrete basis for making design decisions. So far CARS does not provide an absolute and proven measure of real driver distraction. Further tests and comparisons with a high-fidelity driving simulators or field tests will be needed to provide calibration for real driver distraction. CARS consists of three main components: a map editor for creating the route according to specific requirements with different street elements, speed limit signs, etc., the driving simulation tool and an analysis tool for calculating driver's performance.

Fig. 1: Simulator setup.

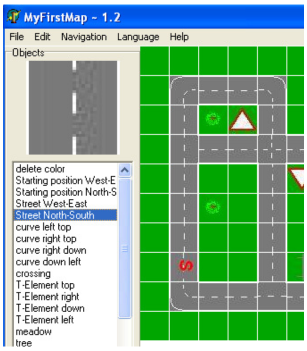

Fig. 2: Map editor's GUI.

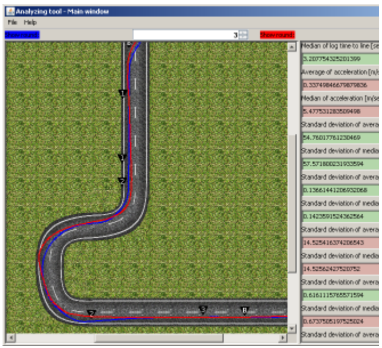

Fig. 3: Analysis Tool's GUI.

3.1 Map-Editor

The map editor offers the opportunity to create several routes with different types of road conditions, e.g., a straight road or a winding road. It has a graphical user interface which allows an easy, intuitive way to create a map with a series of mouse clicks (see Figure 2). It provides straight street elements, curves, intersections, and signs for creating a map. Additional elements can always be added, but additionally to graphics each map elements must have corresponding models in the simulation. The map editor generates a text file with a matrix describing the elements. This is used by the simulation tool to create the virtual world.

3.2 Driving Simulation Tool

The driving simulation tool is implemented in Java and is based on the JMonkeyEngine[2]. JMonkeyEngine (JME) uses the Lightweight Java Game Library (LWJGL)[3] as an interface to OpenGL. Thus, the driving simulator is available for all platforms that are able to run a Java Virtual Machine and render OpenGL scenes. In addition to JME, we use the JME physics engine[4]; this framework simulates physical interactions in a world scene, like gravity. To create the virtual driving environment, the simulation tool first reads the map/world information stored in a text file and generated by the map editor. Then the simulation tool renders a view of the world from a driver's perspective. The initial view is determined when setting up the map in the editor. A user can then start the driving task and drive using the controllers. For analyzing the driving performance the position in the virtual world (x,y,z), speed, time, steering wheel position, pedal position, breaking activity and deviation of the lane position is stored in a log file with 20Hz rate.

3.3 Analysis Tool

The analysis tool is designed to calculate various statistics based on (Reed & Green 1999) and (Green et al. 1993). Currently, the tool calculates mean distance to the racing line, standard deviation of the mean distance to the racing line, mean lateral speed, mean speed, standard deviation of speed, mean deviation of the steering wheel position, frequency of steering correction, standard deviation of gas pedal position, frequency of speed corrections, and off-road time. These parameters are the basics for analyzing results of user tests and eventually for calculating the driver distraction. The analysis tool provides the parameters, nevertheless researchers must determine which of these data are most relevant for each test. Two data files generated by the simulation tool can be read by the analysis tool at the same time to show the comparisons of different rides, e.g. one set while on the phone and one without distraction. The data are represented graphically on the left side of the Analysis Tool's GUI and calculated data values are shown on the right side (see Figure 3).

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[2] http://www.jmonkeyengine.com/
[3] http://lwjgl.org/
[4] https://jmephysics.dev.java.net/

4 Evaluation / Distraction Factor

Two studies were conducted to evaluate CARS and to find out which of the calculated values from the Analysis Tool had significant relevance in drawing conclusions about driver distraction while secondary tasks are being performed.

In the first study, 10 participants (9 male, 1 female, average age 25.1) were asked to drive three times with the CARS driving simulator after an initial test drive. Each trial was four minutes long. The participants drove one ride without participating in secondary tasks (R) and two with secondary tasks (T1 and T2). The order of the tasks was counterbalanced. The first secondary task (T1) was to sort yellow sweets from a bag of colored sweets into a tray. All items lay next to the driver on the front passenger's seat (see Figure 4). The second task (T2) was to identify and take specified coins out of a purse and then putting them back into the purse. T1 and T2 are based on secondary tasks used in (Mattes, 2003). Our observations, as well as the results, indicate that the drivers tended to reduce their speed while participating in secondary tasks. Users were driving significantly slower while performing T1 and T2 in comparison to driving without distraction (R: 42.021 km/h, T1: 37.854 km/h, T2: 35.95 km/h, $p_{R:T1}$=0.0056, $p_{R:T2}$=0.0003). When we looked at the standard deviation of the mean distance to the racing line with taking the knowledge of the speed variations into consideration, it was not surprising that there were no significant differences ($p_{R:T1}$=0.207 and $p_{R:T2}$=0.069). We predicted that the relation between standard deviation of the mean distance to the racing line and the mean speed would be an appropriate factor to compare driver distraction. This was confirmed by calculating the quotient of the two and comparing the results (R: 1.77, T1: 2.2, T2: 2.5, $p_{R:T1}$=0.0046 , $p_{R:T2}$=0.0029). Because of the similarity of the two different tasks, the results show no significant differences between T1 and T2.

We conducted a second study to verify the significance of the distraction factor, based on the same physical setup. T1 was the same as in the previous study. In T2 participants had to answer questions like “Which city is closer to city A: city B or C?“ by referring to a paper road map of Germany (placed on the front passenger's seat). 9 people completed the study. Analyzing the driving performance we have evidence that T2 is more distractive than T1.

Fig. 4: Participant busy with secondary task

In these two studies, we concentrated on the standard deviation of the mean distance to the racing line and the mean speed to calculate a distraction factor. In future work, we would like to look more closely at other values measured by the analysis tool. Although the significance and the accuracy of the defined distraction factor still need to be verified with further user studies, the two user studies we have presented indicate that a good estimate of the distraction factor is given by *df=(standard deviation of the mean distance to the racing line)/(mean space)*. We will verify this estimate with further user tests.

5 Conclusion and Future Work

We presented CARS, a tool for evaluating driver distraction. CARS is an open source project. CARS's map editor tool allows researchers to create test courses that satisfy their needs. CARS's analysis tool calculates and records driving performance data like mean speed, mean distance to racing line or mean lateral speed. This data can then be used to determine driver distraction.

We conducted two user studies using CARS in order to discover a formula for calculating the distraction factor, which could be used for comparing how much different secondary tasks distracted the driver and affected driving performance. We discovered that maintaining lane keeping (represented by the standard deviation of the mean value to the racing line) alone is not an appropriate measure, because the drivers reduced their speed while performing secondary tasks to maintain lane position. Therefore, we define the distraction factor as the quotient of the standard deviation of the mean distance to the racing line and mean speed. The results of the two user studies indicated that this formulation provided a strong indicator of distraction that could be used to compare distraction of two different secondary tasks. The significance and accuracy of this conclusion remain to be verified in further user studies.

In the next version of CARS, several additional features are planned, including providing navigation information, simulating other cars driving around, and dynamic scene elements, such as a ball rolling on the street, in order to measure reaction times. Furthermore, the environment should be configurable with more real-life scene elements, such as trees or buildings, in order to better simulate real-world driving conditions.

6 References

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