Taking Reality for a Drive in the Lab: The Makeup of a Mockup for Automotive HMI Research

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ABSTRACT
In this paper we introduce our ongoing efforts constructing a hardware simulator car mockup for automotive HMI research. We achieved a solution suitable to conduct controlled experiments resembling the ergonomic properties of a real car while still allowing reasonable flexibility for a quick explorative prototyping of interfaces. In contrast to existing solutions in a comparable price range our mockup not only seats a driver plus front seat passenger but also three rear seat passengers. We show how the combination of a modular construction system with car repair parts and off-the-shelf consumer electronics allowed us to keep the cost below EUR 10.000.

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Car, Mockup, Simulator, DIY

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation (e.g. HCI): User Interfaces – Benchmarking, Evaluation/methodology, Prototyping

INTRODUCTION
Car simulators have shown to be a valuable tool in automotive HMI research with a wide range of possible solutions [3]. In terms of the car representation itself, the highest level of realism is achieved by using real cars, half cars, or their cockpits that can be referred to as high fidelity driving simulation environments (see e.g., [2]). These settings can suffer from high costs and a reduced flexibility for prototyping. Installing, for example, a prototype in a central console position in a real car dashboard requires skills and time (e.g., wiring, mounting) and may be hard to revert. Identifying a gap between high and low fidelity car mockups, we decided to go into a new direction creating a medium fidelity solution.

MOCKUP
Our approach on creating a medium fidelity car mockup for automotive user interface research is based on the combination of three types of components: (i) a building kit system for industrial applications; allowing for flexible adaption of the spatial and ergonomic conditions as well as quick adaption in prototyping efforts (ii) off-the-shelf consumer electronics, and (iii) car spare parts, allowing us to achieve the look and feel of a car and maintain a reasonable level of fidelity and immersion while keeping the costs low. As shown in figure 1 we use the mockup in front of a projection, utilizing different kinds of simulation depending on the experimental setup.


Figure 1. The car mockup, situated in a simulation environment

Mockup Form Factor and Dimensions
We chose to follow the basic shape as well as the dimensions of a very common middle-class car, namely a 2009 Volkswagen Golf. This allowed us to achieve realistic ergonomics with a reasonable effort by maintaining the main dimensions of this real world blueprint, e.g., point-to-point clearances.

Mockup Structure and Chassis
The chassis is custom built using the ITEM building kit system for industrial applications[1]. Using a industrial grade building kit enabled us to quickly build robust structures while maintaining a high level of flexibility, as all conjunctions are kept adjustable and every part of the mockup can be replaced at all time. Installing and uninstalling a screen, for example, is thus possible at nearly all locations in the mockup without leaving a permanent damage.

Seats
As the seating position is crucial for any considerations of ergonomics in the car we selected a pair of spare seats from

[1]http://www.item24us.com

a van. These seats offer an increased range of adjustment compared to more common types of seats. e.g., from compact cars. This was essential as it allowed us to go for a simpler, non adjustable design of the steering wheel mount while still maintaining a reasonable degree of adjustment of the seating position in respect to steering wheel and pedals. Moreover, the seats' extent flexibility has also shown to be very valuable when incorporating technology that to a certain extend needs to be coherent with the position of a study participant's head and eyes, e.g., head up displays or eye trackers.

Primary Controls
The primary controls are based on the ClubSport Wheelbase from Fanatec[2] that features a wheel rim that can be quick-released from its base and exchanged with rims of different size and style. This mounting solution allowed us to not only use the different rims provided by the vendor, but moreover adapt wheels from real cars for their usage with our mockup. Custom modifications of the system enabled us to design and implement tailored prototypes of interfaces on dedicated wheels using prototyping platforms (e.g., Arduino[3]). At the same time the wheelbase stays fully functional and allows us to take those prototypical wheels for a drive with off-the-shelf driving simulation software and even driving games without the need for any additional fitting.

Dashboard
To experiment with various dashboard designs we utilize a USB-driven screen combined with custom in-house software that allows us to wire up the dashboard to a growing collection of available simulation software as well as interface prototypes under development. In order to compare novel dashboard designs with state-of-the-art dashboards the display can easily be replaced with a dashboard from a current car we retrofitted by replacing the manufacturer dependent electronics with an Ethernet capable Arduino.

Central Console
Our design of a central console followed a similar approach: The horizontal clearance of the skeleton we built for the central control is based on standard size for car audio head units as specified in ISO 7736 [1]. This allows us to quickly install various head units and other hardware from OEMs (original equipment manufacturers), aftermarket solutions, as well as custom built prototypes, e.g., a panel with controls for the color of the interior light.

Rear Seat
Our research interests around social aspects in the car asked for the incorporation of a rear seat area into our mockup. Similarly to our considerations for the front seat area, we selected seats for the back of our mockup that feature multi-axial adjustability of the back rest as well as the individual seat. This adds flexibility for the positioning of interface elements in respect to the passengers. The front and back seat area are built upon two separate base units on casters. Thus the whole rear part can be detached from the front of the car whenever suitable, allowing for easier access during modifications.

[2]http://eu.fanatec.com/
[3]http://www.arduino.cc.

Basic electric facilities
While the focus of this mockup lies on its physical characteristics as a platform for prototyping, a well-balanced level of basic electric equipment is still sensible as some components and features come in handy in many use cases. We chose to integrate a linear power supply providing 13.8V that fits the current supply of most modern cars and thus allows for the straight forward integration of most automotive electronic devices and accessories. We installed interior lighting in both front and rear seat area (see figure 1) using RGB LED strips. Custom controls in the central console are used to adapt color and brightness to the necessities of a particular system or interface studied in the mockup (e.g., different screen configurations or face-tracking ask for certain illumination of the modalities respective a study participant's face.)

Study Equipment
The mockup provides mounting options and all the wiring necessary to quickly (un-)mount optional study hardware. As an example we installed wiring concealed inside the mockup's structure for the installation of an eyetracker. In a similar fashion we installed wiring for optional cameras and microphones in multiple locations.

Odds and Ends
The building kit system used allowed us to quickly add small details and widgets present in most cars, e.g., a rear view mirror or handle bars. While the rear-view mirror is not functional as of yet, i.e. there is no simulator content shown in the mirror, it is valuable considering the contiguity between front and rear seat area. While some of those small parts might not seem relevant at first glance, we found that they add to the immersion achieved by the mockup. The described components allowed us to fulfill the presented requirements while sticking to the target costs of approximately EUR 10,000. The main costs were the parts of the building kit system (EUR 5,500) as well as the required special tools (EUR 800). Second-hand car components, i.e. seats, steering wheels, rear-view mirror, etc. added EUR 500, various material for outfitting the interior EUR 600. The used consumer electronics (i.e. steering wheel base, screens, etc.) caused costs of EUR 2,000.

CONCLUSION
We present a flexible and low-cost car mockup combining the benefits of adjustable hardware elements, standard electronic equipment, as well used car parts. It aims at filling the gap between high-fidelity car simulation environments based on real cars often lacking flexibility and low-fidelity simulators providing a low degree of ergonomic reality.

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