Prototyping Novel Automotive UIs with the ROADSAFE Toolkit

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Abstract – In this paper, we present the ROADSAFE toolkit which has been designed to support efficient user-centered development and on-the road evaluation of the human-machine interface of safety services. The toolkit includes features for the investigation of future in-car applications, such as real-time multimedia supplements on different quality levels, interactive scenarios requiring user input, and deployment on arbitrary end devices. The developed toolkit has been validated within the ROADSAFE project, a scientific cooperation between FTW, ASFINAG, Kapsch TrafficCom, Fluidtime, and TU Vienna, to improve vehicular communication systems.

Introduction

In-car human-machine interface (HMI) technology is currently facing a rapid evolution, increasingly incorporating features like Augmented Reality (AR) visualizations, multimedia entertainment, and context-aware notifications [1]. A challenge related to this trend is to develop suitable HMI designs for advanced driver assistance systems [2]. With technological advances such as Vehicle-to-Infrastructure (V2I) environments collecting and exchanging relevant traffic data in real-time, vast amounts of new information are and will be available. However, corresponding warnings and instructions need to be communicated to the driver in a safe manner, informing about relevant details in an efficient, non-distracting way. To enable an efficient user-centered development HMI researchers and developers need a rapid prototyping toolkit in order to test novel interfaces under real-world conditions on the road to complement respective in-car HMI lab studies. Existing appropriate solutions are mainly targeted at automotive manufacturers and are executed on a vehicle's embedded processor (e.g. FLUID by BMW Car IT [5]) or do not provide any special support for the conduct of road-tests and the evaluation of future in-car use cases (e.g. Automotive UI Toolkit of Windows Embedded Automotive [7]). Related projects considering flexible UI models for in-car HMIs focus on other aspects of advanced in-car HMIs such as seamlessly integrating external applications [6].

A suitable road-testing toolkit for HMI researchers must run on an off-the-shelf laptop computer for easy in-car usage and should be highly flexible and extensible, allow for short design iterations without writing code and offer built-in support for validating future in-car use cases involving multimedia applications and interactive elements.

Toolkit Features

The presented ROADSAFE software toolkit offers a number of features that support user studies investigating in-car HMI research questions under real-world conditions. We implemented it in Python enabling the easy extension in future utilizing concepts of a dynamic programming language. We put emphasis on its easy configuration for different visual appearance and usage scenarios not requiring any programming know-how. In the following, the core features of the ROADSAFE toolkit are introduced.

Reusable widgets

In our prototyping toolkit, user interface elements are organized within widgets which define the element's appearance and behavior. Applying an object-oriented implementation approach, such widgets are derived from a widget super class containing general attributes such as position and size. To access contextual attributes such as the current location and a list of currently relevant safety messages, each widget has access to a central data repository. For example, a system can easily adopt different presentation widgets, such as a traditional bird's eye map or an AR widget. Having such reusable vehicle HMI widgets shortens the prototyping process.

Flexible HMI configuration

The HMI presentation layout is defined by so-called skins which position widgets at certain screen locations and define some of their visual and behavioral properties. For each test person, a scenario is prepared which sets different sections of the respective test drive and specifies which skin to use for each section. Skins specified in a scenario can either be manually switched by the test manager during a test drive or may be automatically changed at predefined trigger locations. Both skins and scenarios are formulated in easily interchangeable XML files (Listing 1). Hence, the toolkit allows for the quick and easy adaption of visual appearance and behavior.

Multimedia content presentation

Our toolkit can integrate custom multimedia content via dedicated widgets, thus allowing us to investigate end user requirements for future V2I multimedia services which, for example, may include live videos from traffic cameras. The toolkit allows for the creation of distinct multimedia configurations for test drivers (again in XML) to confront them with different quality settings from still images up to high-quality videos for investigating the required quality levels as well as evaluating the overall usefulness of such upcoming (real-time) multimedia services. Furthermore, a high-quality text-to-speech engine or providing traditional turn-by-turn instructions and testing various auditory feedback solutions is available.

Listing 1: Specifying a set of skins in form of a scenario for a test user.

```
<roadsafescenario testperson="27">
   <section order="0">
      <skin>study_2011a/800x600_default_animated.xml</skin>
   </section>
   <section order="1">
      <skin>study_2011a/800x600_multimedia_small.xml</skin>
   </section>
   <section order="2">
      <skin>study_2011a/800x600_augmentedreality_animated.xml</skin>
   </section>
   [...]
</roadsafescenario>
```

Interactive scenarios

Beyond driver assistance with classical turn-by-turn navigation and real-time safety messages, new interactive in-car use scenarios are emerging. The ROADSAFE toolkit supports the investigation of such scenarios: again, without programming know-how, interactive elements such as buttons can be integrated and defined in skins using XML (Listing 2). Triggered actions include the change to another skin (e.g., to switch between different views) and playing of sounds and speech messages (e.g., to provide an auditory route description).

Listing 2: Defining an interactive element in XML.

```
<buttonwidget>
   [...]
   <backgroundimage>newicons/button_template_127x74_info.png</backgroundimage>
   <click>
      <action>play</action>
      <param>speech/multimodal/floridsdorf_basic.wav</param>
   </click>
</buttonwidget>
```

Arbitrary interaction devices

To facilitate the comparison of different target devices in road tests, the system not only enables attaching an external display for the driver via a video connector, but also offers a video streaming module. This enables us to provide a smartphone or tablet PC with visualizations by the same rendering engine, conveying the impression of a fully functional mobile application for the test driver. Interactive scenarios are also supported in this setup: touches on the mobile end device are forwarded to the laptop computer where respective mouse actions are triggered.

Demo mode

Development and validation of road-test scenarios can be resource-intensive in terms of time and money. To reduce efforts, the ROADSAFE toolkit offers a demo mode for reviewing the defined route and occurring events: GPS traces (e.g., recorded by a GPS mouse or created by a route planner) can be easily integrated in our toolkit to simulate test drives apriori in the lab and prepare testing scenarios, e.g., to finetune trigger locations of messages for the road test.

Case Studies

In order to demonstrate the potential of the toolkit, we describe how it was used to prepare and conduct four example studies within our research project.

Developing conceptual screen designs for safety recommendations

One of the first research activities within the ROADSAFE project that the toolkit supported was the development of suitable screen designs for safety-related driving recommendations and information. In user interface design workshops together with stakeholders, different user interface behaviors and designs could be tested in order to find a suitable combination of necessary elements. We came up with a split-screen design with safety recommendations on the right side and a map on the left side. The safety messages were divided in driving recommendations, such as a speed limitation or an emergency stop (upper part) and the related traffic information, such as a congestion or accident (see Figure 1). Apart from the visual design, also the design of the spoken safety messages and their synchronization with the visual screen elements was designed and optimized with the toolkit within several iterations.

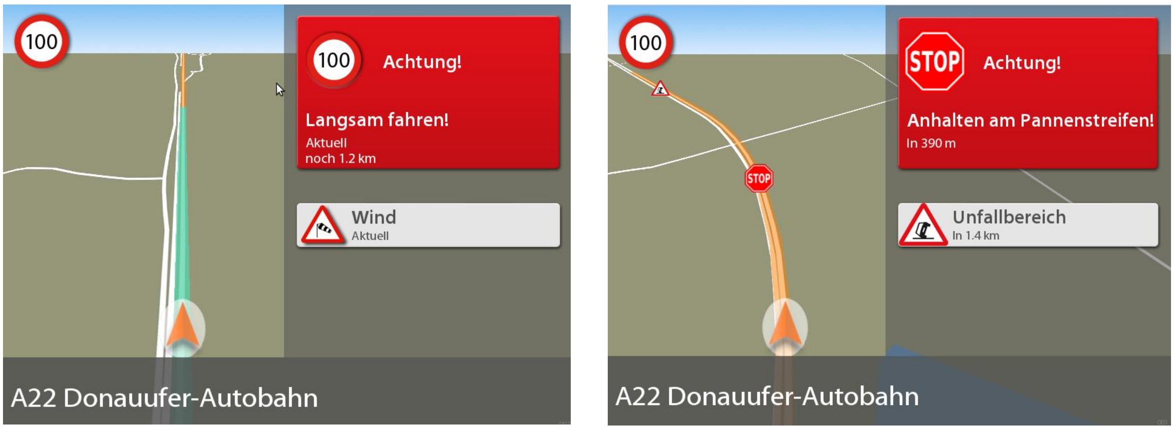

Figure 1: The final conceptual design of the ROADSAFE real-time safety service.

Investigating Augmented Reality on the Motorway

One of the major benefits of the toolkit is that it allows for the investigation of advanced forms of visualization. It is important to test the usefulness of novel interaction or visualization techniques already at an early stage, so that efforts for technology developments are not wasted. A recent example is a road user study that we conducted on the suitability of Augmented Reality (AR) for providing real-time driving instructions, such as changing lanes in preparation for taking highway exits or making emergency stops [3]. We compared the AR version with the conventional map version (Figure 2). The AR mode was implemented as a one dedicated widget accessing the video stream of a webcam (installed directly behind the windshield) and overlaying this live video with semi-transparent tapering trajectory.

Figure 2: Prototypes for the experimental investigation of Augmented Reality on the motorway.

To simulate a reliable ‘system behavior’ that could be expected for future AR systems enhanced by computer vision algorithms, we therefore chose a Wizard-of-Oz approach, where a human operator manipulated the route trajectory manually in real-time. The operator was a researcher in a back seat using a trackball device for manipulating the trajectory overlay.

The methodological conclusion with regard to the use of our toolkit is that usage of our Wizard-of-Oz approach could avoid virtually any functional limitations, such as jitter or inaccurate positioning of the overlay. Participants thus experienced the behaviour of a mature AR system that could be realizable, if the necessary research and tuning is invested (such as advanced visual matching algorithms, improved location sensing and road maps). This way, we could gather information about the suitability of the overall *visualization concept* of AR, without the confounding factor of technical immaturity. For more detailed methodology descriptions and the results, please refer to Fröhlich et al. [3].

Assessing the Suitability of Smartphones for Real-time Safety Information Services

As described before, the ROADSAFE toolkit also offers the possibility of rendering the prototypical visualizations to different screens. In a further road-based field experiment, we investigated whether smartphones are recommendable as a means for presenting real-time safety information. We were especially interested in understanding the visual demand that may be imposed by the smaller screen and font sizes.

The methodology was consistent to the above-mentioned setup but the main experimental factor was screen size, instead of visual presentation style. The 'large screen' setup consisted of a 12" screen, thereby representing a built-in driver information system (Figure 3, right). The 'small screen' setup was a smartphone that was attached to the PC-based prototyping platform, using the built-in video streaming module (Figure 3, left). Thus, we were able to display visualizations by the same rendering engine on the smartphone, conveying the impression of a fully functional smartphone application for the test driver. With this setup, the same conceptual design that had originally been developed for the large screen could be adapted for a smartphone screen size, without the need to re-implement it from scratch in a smartphone software environment, such as Android or iOS. Please refer to the results of that study in Fröhlich et al [4].

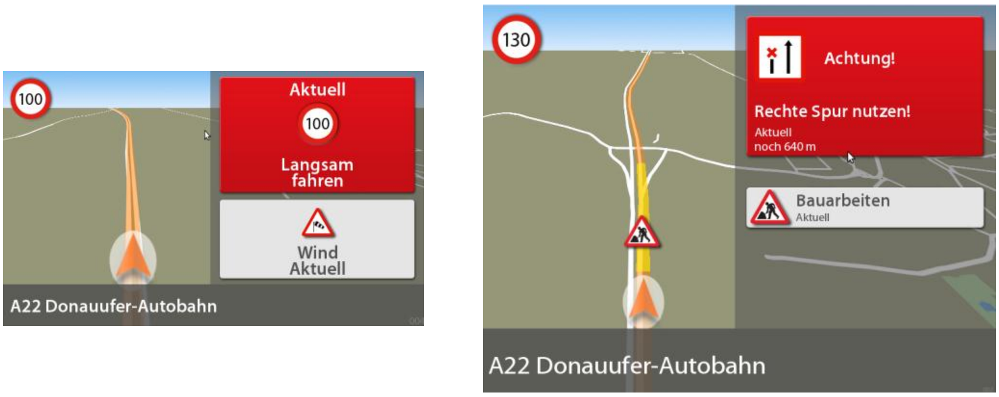

Figure 3. Prototypes for comparing screen sizes. Left: small screen setup, right: large screen setup.

Investigating Use Cases for In-car Real-time Multimedia

We conducted a further road study in which we employed the multimedia content presentation capabilities of the toolkit [**Fehler! Verweisquelle konnte nicht gefunden werden.**]. Our research motivation was that increasing amounts of traffic-related multimedia (especially live traffic camera streams) are available but that it is unclear in which way such material can be made useful and attractive for drivers in on-trip situations. We added a live traffic picture to illustrate the situation on the road ahead, especially with regard to events that are reported to the driver, such as traffic jams or congestions (see Figure 4), and we compared these to a standard presentation without multimedia. A further design question was whether the picture should appear as a further detail on the screen, or whether it should cover the whole screen, which could especially be necessary on smartphones for readability reasons.

Figure 4: On-trip multimedia research prototypes. Left: Picture as a part of the screen, right: picture as full screen.

A further question was how much quality of the provided multimedia information is recommendable. For this purpose, we compared several prototype versions within the road trial that varied in the characteristics of the provided multimedia material, concerning picture quality, dynamicity, and realism. The following five test conditions were selected for this purpose: (1) a high quality video (lossless compression), (2) a compressed video (5fps / 80 kbps), (3) a sequence of pictures (0,5fps), (4) a still picture, and (5) an abstract animation 8. Also here, the flexibility of the toolkit enabled us to quickly integrate such additional test cases into the prototype (see [8] for an illustrative video).

Planned toolkit extensions

While the abovementioned use cases were mainly restricted to information presentation, we are integrating advanced user interaction capabilities. Basic input was already required for a study on in-car intermodal routing, in which drivers could access additional information via the HMI, in order to get more detailed decision support (compare [9]). In future studies, we will experiment at a wider scale with possibilities for drivers to provide early indications about traffic incidents directly to the highway traffic control center.

Project Background

Parts of this work were performed in the project ROADSAFE, a scientific cooperation between FTW, ASFINAG, Kapsch TrafficCom, Fluidtime, and TU Wien, to improve vehicular communication systems. Main research topics of the project are (a) the improvement of the robustness of the data transmission on the wireless link based on the IEEE 802.11p standard, (b) disruption-tolerant service architectures for the transmission of long messages, and (c) strategies for robust Human-Machine Interaction with real-time safety services. The project is co-funded by the industry partners, the Austrian Government, and the City of Vienna within the competence center program COMET.

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