CarSketch: A Collaborative Sketching Table with Self-Propelled Tangible Objects for Automotive Applications

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Abstract
We present CarSketch, a concept and prototype of a collaborative sketching table that supports interdisciplinary development teams during the early development phase of driver assistance systems. Due to the high costs caused by the use of physical prototypes, simulation is a common approach. Yet, the operation of state-of-the-art simulations is restricted to specialists, leaving the majority of stakeholders as passive observers. Our system for a collaborative and multi-perspective communication tool enables all participants to interact with the simulation. In particular, it (1) structures the ideation and development by providing a distraction-free environment with an easy-to-use drawing interface, (2) which is used by self-propelled tangibles to monitor and influence the simulation. (3) Additional information is provided by personal augmentation and (4) the simulation can be replayed in an immersive 3D environment. We expect the tool to be useful for multidisciplinary teams in fostering the ideation phase and finding conceptual mistakes more efficiently.

Author Keywords
Automotive; simulation; collaborative work.

CCS Concepts
•Human-centered computing → Interaction design theory, concepts and paradigms; *Participatory design;*

Figure 1: An iterative design approach has been used during the design process.

Introduction

Since over 90% of the innovations on nowadays' cars are related to electronics and software [2], conventional design methods used in car development are no longer sufficient. In order to deal with the rising complexity during the multidisciplinary development process, access to digital simulations in any stage of development is gaining importance [2]. These digital simulations are able to accelerate development by promoting understanding among collaborators involved [1, 4]. For this reason various concepts have emerged over the past few years. Recent concepts found in the literature [8, 9, 7] as well as real world examples[1] are a significant improvement in the field.

The use of these tools has traditionally been restricted to trained experts. Nowadays, however, a variety of stakeholders make up R&D teams, some of whom are engineers, psychologists and managers. Hence, current tools are likely to be neglected and replaced by classic tools like paper sketches or textual descriptions. Furthermore, most evaluated systems do not consider the communication processes between all stakeholders or are limited to a certain stage of development. They further limit the possibility to adjust simulation parameters. Additionally all assessed systems are arrays of in- and output devices, hence carry the risk of overwhelming the user with its complexity.

We propose *CarSketch*, a user-centred design concept, addressing the needs of multidisciplinary teams during simulation-based development. CarSketch incorporates the stages of the design process from early idea finding towards detailed simulation. It therefore serves not just as a simulator, but as a communication tool for teams.

[1] Audi Blog [German],http://blog.audi.de/2017/02/08/audi-virtual-engineering, retrieved July 5th, 2017

In this paper we describe our findings and conclusions which led to the final design. We conclude by discussing the qualitative feedback we obtained during an expert review, which gives us promising insights on the advantage of the system for the development process.

Requirements Analysis

Our proposed system is the outcome of an iterative design process, accompanied by an expert group. This group consisted of experts from the automotive domain, industrial designers as well as researchers in the field of computing and human-machine interaction. Every iteration was reviewed weekly and discussed with the expert group.

Initially, a focus group was conducted in order to gain insights into the fields of assistive, highly automated and fully autonomous driving. The brainstorming was supplemented by an on-site visit to a car manufacturer, where we collected subjective feedback from (1) experts at the R&D department and (2) a target group of potential users. The objective of these semi-structured interviews was to identify issues within the current development workflows and communication process as well as to analyze currently available tools.

The quantitative data obtained was structured using affinity diagrams and mind maps (Figure 1), from which we gleaned a number of key issues:

- Current tools require expert knowledge or are too time consuming, causing users to fall back on traditional tools like Powerpoint.
- Due to spatial inflexibilities, tools might not be available where they are actually needed.
- Developers consider creating presentations as a time consuming task which disturbs their workflow.

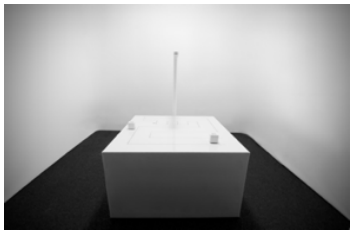

Figure 2: The clear design language of the ideation board provides a distraction-free work environment.

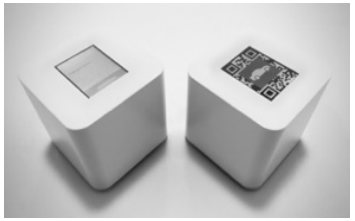

Figure 3: Self-propelled tangible objects with user assigned roles to provide motion.

Figure 4: A smartphone app augmenting the abstract scenario with an additional data layer (e.g. sensor data).

- Developers have difficulty trying to explain technical issues to non tech-savvy coworkers.
- Current tools are decoupled from the development process; reacting to short-term changes is difficult.
- Current tools do not provide documentation of findings. Therefore, documentation is often neglected.

Final Concept

In line with our findings and requirements identified we propose CarSketch, a concept for an interdisciplinary collaboration platform to enhance development and in-team communication. The concept consists of four levels of abstraction we refer to as follows:

Ideation
The ideation board is a shared workspace centrally placed within the work environment (Figure 2). Serving as a meeting point, the shared setting encourages team communication and fosters collective elaborations. The clearly structured nature of the board supports its function as ideation catalyst and impedes distraction. Besides a blank sketching surface, the ideation board consists of pens and erasers, which can be used to structure the design process by assigning tasks or responsibility to certain team members. The scenario's environment can be modified by drawing streets, intersections, and objects for traffic guidance, such as traffic signs or pedestrian crosswalks and simulation markers e.g. pick-up spots, starting points and destinations. Through its utilization at an early stage of development, the ideation board merges conception and demonstration processes and thereby allows changes to be performed at any time.

Motion
The 2-dimensional sketches (scenarios) created during ideation are extended by motion using moving tangible objects (Figure 3). These abstract objects add visual information about the simulated behavior and foster interactivity. Several objects can be freely positioned on the ideation board and offer an abstract illustration of various road users e.g. cars, bikes or pedestrians.

Augmented Reality
To provide additional data while avoiding visual overload, the concept includes user-personalized augmentation using a smartphone app (Figure 4). Hence, every user is able to access additional information (e.g. sensor data or environment parameters) on demand by superimposing the tangible objects. For instance, distance data from an ultrasonic sensor might be visualized using color-coded waves, changing from green (free road) to red (obstacle detected).

Immersion
Using computer vision and image processing, the sketch and the aggregated position data from the tangible objects can be used to render enhanced 3D environments, including digital representation of streets, houses and traffic. It is further possible to map car characteristics and the behavior of accompanying road users accordingly. This layer provides access to different perspectives and viewing angles, thus offering the possibility of a fully immersive experience within a head-mounted display. The 3D animation generated is stored for documentation purposes and can be accessed for debriefing and further analysis at any time.

Final Prototype

A very simple setup comprising a rewritable whiteboard film, water-soluble pens and rags is being used for the final prototype (Figure 6). A tracking unit placed on the side of the ideation surface captures the scenery and controls the tangible objects according to the sketches drawn. The moving objects are equipped with two motors, an ARM proces-

„I like the clear and structured environment, it supports me to keep my focus."

„It is so quick and easy to change the scenario using marker and rag."

„This is… awesome, may I take it with me today?"

„I would like to be able to adjust different vehicle characteristics like the turning radius."

„Working on our display based system distracts me, this approach seems to be very promising in this respect."

„An aesthetically appealing work environment."

Figure 5: Quotes from the qualitative evaluation

sor as well as a touchscreen which enables a fine-grained configuration. Fiducial markers displayed on the screen increase tracking precision and enable augmentation using a smartphone application.

The immersive layer and the rendering engine, in particular, have not yet implemented. We plan to do so by drawing from prior work [3, 5, 6, 10]. To provide a representation of the concept to our experts that is as realistic as possible, we currently refer to a tablet application with pre-rendered animations in first-person, second-person, and bird-eye view.

Qualitative Evaluation

The final prototype was presented to two groups through role-plays from which we gained qualitative feedback by conducting unstructured interviews. These groups are (1) the board of directors of the R&D department of a car OEM and (2) a target group of potential users (including but not limited to engineers, psychologists & managers).

The overall feedback is very promising (Figure 5). Experts as well as our target group showed a very positive response to our system. In particular, the simple interaction using markers and rags as well as the clean structure were highlighted by the participants.

Conclusion and Future Work

We presented CarSketch, an early stage of a novel concept for a collaborative prototyping and presentation tool in the automotive field. By introducing four dimensions of abstraction, the goal of our system is to support the ideation process and to promote team communication.

By providing access for all stakeholders in the early development stage of applications, this work provides a significant improvement on the development process in the automotive industry. The feedback gained from expert and target group interviews were positive throughout.

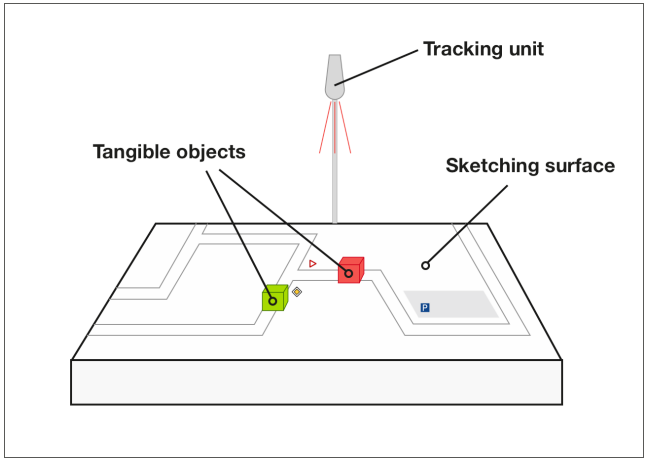

Figure 6: The conceptual drawing: A rewritable surface on which self-propelled tangible objects move, controlled by a tracking module mounted in a tripod.

For future research, we will conduct a real-world evaluation of our system. Furthermore, we will evaluate appropriate metaphoric representations, in particular for traffic signs and urban objects, aiming to develop a "symbol toolkit" that can be used during ideation. In addition, the feedback received points towards the usefulness for an interface to automate the conversion of proprietary data from the vehicle's control units to tangibles.

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