Requirements for a MDE System to Support Collaborative In-Car Communication Diagnostics

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ABSTRACT

Modern automobiles come with a high degree of electronic and an enormous amount of in-car communication activities. This leads to an increasing complexity which challenges automotive engineers in detecting and analyzing erroneous communication processes. In this contribution we present results of our studies on current working behaviour and environments of analysis and diagnosis experts in the automotive industry. While we found a sufficient hardware and software support in single user environments, co-located collaborative environments are characterized by multiple hardware devices but by a lack of specific software to support collaborating in these multiple display environment (MDEs). After a detailed user analysis and evaluation we derive system requirements for this new MDE application area and discuss its challenges.

Categories and Subject Descriptors

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces—collaborative computing

Keywords

Automotive, Collaboration, System Requirements, Group Work, Multiple Display Environments

1. INTRODUCTION

Modern automobiles are constantly enhanced with new, highly networked functions to enable a safer, more efficient, and enjoyable driving. The communication between the functions is realized over an *in-car communication network* whose complexity has risen enormously over the last few years. Current in-car communication networks have to deal with up to one million messages per minute to distribute all control and content information in the vehicle. The messages contain, for example, engine controls, information about driver interactions or multimedia data and hence are subject to different timing requirements. This flood of information challenges analysis and diagnostic experts in development, testing and maintenance.

In most cases the complexity of analyzing and diagnosing these networks exceeds the skills of a single person by far. Hence, several experts have to collaborate to find adequate solutions: They gather, for example, around a colleague's workstation, bring their laptops to meeting rooms, or discuss and analyze the data during projected presentations. So what we actually have is an alternation between individual work and collaboration in their daily working process. But while the individual work is characterized by a high usage of specialized tools and software systems, there is no explicit software for supporting the collaborative work.

The remainder of the paper describes the current working behaviours and environments of automotive analysis experts derived by results of interviews, task observations and a questionnaire. Then we focus on synchronous co-located collaboration and analyse how it could be digitally supported. We acquire system requirements for adequate software supported multiple display environments (MDEs) for the collaborative analysis process in such situations.

2. CURRENT PRACTICE

We conducted two user studies to get a clear understanding of the current work practice around in-car communication diagnostics and to reveal the situations where collaboration could be supported by MDEs. We started with guided interviews and task observations to get an insight into the daily routines of eight analysis experts.

In doing so we observed each subject's individual work, which and how specific tools were used, why they were used, and when the subjects had to cooperate with their colleagues.

Table 1: Dependency matrix between categories and locations

	No devices No interaction	One device Interaction by one user	One device Interaction by many users	Many devices Interaction by many users
Meeting room	Yes	Yes	Yes	Yes
Colleagues desk	Rare	Yes	Yes	Sometimes
Informal venues	Yes	Sometimes	Sometimes	Rare

During these studies we detected a lack of visualization. All of our subjects expressed a strong demand for new visualization forms, especially to compare in-car communication information. Also we identified a lack of digital support for collaborative work. Motivated by this finding, we additionally designed an online questionnaire to contact a wider range of analysis experts and to directly adress the aspect of collaboration in their daily practice.

As we assumed, the results of the study showed a constant alternation between individual and group work. The reasons for mingling with colleagues are mostly based on the underlying complexity of the problems: combination of different expert knowledge, different perspectives to complex problems, missing detail information, demanded support and confirmation. All these tasks are associated with a certain degree of discussion which is performed either in a distributed setting via email or telephone or co-located via face-to-face communication. We observed that in most of the cases a constant connection to the analysis tools is crucial and that different sets of data and information have to be transferred to solve the problems (mostly via email attachment, shared folders, or USB memory drives).

Having a closer look at synchronous co-located collaborative work, we observed a typical constellation of small workgroups with 2–4 people and classified four main setups by considering the amount of digital devices used for analysis reasons – like laptops, PCs, projector(+laptop), also PDAs or interactive surfaces – and the human-device interactions – like using mouse or keyboard but also indirect interaction like pointing to the screen:

1. *No devices, no interaction:* This is the most natural but today scarce form of a meeting without any access to digital analysis support. This face-to-face form is mostly used to clarify simple or general questions without the need to be connected to the tools and the data.
2. *One device, interaction by one user:* A common situation where several users gather around a colleague's device and discuss a problem whilst s/he interacts with an analysis software on the device. This form occurs, for example, due to spontaneous upcoming specific questions and problems which could be clarified without or with little difficulty. We mainly observed two kinds of devices used in this setup, firstly the device is the colleague's laptop/PC, and secondly this constellation occurs with a projected presentation.
3. *One device, interaction by many users:* The same situation and devives as in 2 but with more than one user interacting with the device. Occurs when the solution of the problem is more complex.
4. *Many devices, interaction by many users:* Several people bring their own devices, interact and present with them. Changes in the user-device relation are rare in this setup. This form is mostly used to handle really complex problems which require a lot of discussion. The combinations of devices varies from several laptops(/PC) to an additional projected presentation. PDAs or mobile phones are used as well. A typical constellation we observed in this setup, e. g., was a meeting were a subgroup (or all participants) brought their laptops and alternately connected it to a projector based on the current needs and interests.

Regarding the locations of the co-located collaborative work we spotted three main locations with a tendency to specific group sizes:

- *Meeting room:* Most common location for discussion of complex problems (in order not to disturb other colleagues); often larger groups >= 3.
- *Colleagues desk:* Ad-hoc meetings for light- and midweight problems and short questions; mostly 2 Persons, also small groups <= 4.
- *Informal venues:* E. g., meetings at the coffee bar; mostly 2 Persons, also small groups <= 4.

Table 1 shows a matrix of our categories and the locations and gives information about the occurrence of each combination.

By having a closer look at the hardware and software support for individual work and co-located collaborative work we encountered an unbalanced situation: On the one hand the individual work is strongly characterized by a high degree of electronic support with multiple displays, multiple different devices and a high connectivity to distributed colleagues. Also there are several specific software tools, for example CanOe[1] or Tracerunner[2], supporting the process of analysis in a single user environment. On the other hand, for co-located collaborative work we also find good conditions regarding the hardware support. The personal mobility is directly supported by the company by equipping employees with mobile devices (100% of the questionnaire's subjects quoted to have a laptop for work). So the experts can (and really do) carry around their equipment, meet in

[1] www.vector-informatik.com
[2] www.tracerunner.com

meeting rooms and use stationary projectors to collaborate with their colleagues. But if we look at the software we can't find any special support of the collaborative process in these dynamically forming MDE environments (cf. Table 2). The software which is used for collaborative work is exactly the same as in the individual environment - and in this case designed for single user application and interaction. So that is basically the point we have to focus on.

Table 2: Current situation of HW and SW support

	HW	SW
Individual Work	Very High	Very High
Co-located Collaborative Work	High	Low

3. DIGITAL SUPPORT

Based on the above observations we conclude that although the fitting hardware (multiple displays) is readily available and used in the company, a fitting software environment is still missing.

3.1 Design Implications

As the main part of the work is performed individually , we conclude that group situations appear in two different cases:

- Informal meetings where one engineer has to consult another one either via phone or in person
- Scheduled meetings where complex problems, progress and future tasks are discussed

Tasks for a supporting software system we extract from these situations are *presentation*, *exploration* and *sharing*.

Presentation tasks describe situations where one participant is presenting results and analyses to other participants. It corresponds to the above *one device, interaction by one user*. The hardware support is straightforward: As only one person is interacting with the system the current default laptop-and-projector is sufficient.

Data Exploration is an interaction of multiple users with the same data where different scenarios are explored and different data sets compared to, for example, find an error. This normally happens at one PC/Laptop with one or more users at the moment.

Sharing in our case describes handing over a certain item from one person or one usage context to another and thus forms the bridge between collective and individual explorative situations. Data is at the moment shared via a shared folder on the file system or an USB flash drive.

The three identified tasks are normally flexible in their occurrence and order: A presentation situation might switch to exploration if other participants are contributing their own ideas and might conclude with a sharing of work tasks. Individual explorative situations might lead to a short presentation and then a collaborative exploration as soon as other co-workers join in. One main factor in supporting engineers in their work is thus to provide them with the necessary flexibility to easily switch between these different working situations.

As different situations demand different types of hardware (e. g., vertical surfaces for presentation, personal computers for individual exploration, horizontal surfaces for collaborative exploration) MDEs naturally fill this gap. A fluent transition between different tasks is closely coupled with a fluent transition between different displays. Remote control becomes an issue as well, as not all displays might be interactive in nature.
Additionally, the highly complex data sets that are used by the observed engineers in their work require sophisticated visualization tools to handle them. So as the results of our user studies showed visualizing data has to be a central aspect of our proposed design as well.

3.2 System Requirements

After defining and understanding the tasks and situations in meeting scenarios (i.e. *Presentation*, *Data Exploration* and *Sharing*), in this section we derive the requirements for a software infrastructure. This environment should cover all the needs in these situations.

At first, based on the need for much higher support of visualization a new system to allow an easy way to generate visualization from the data is required. With this system all persons should be able to work separately to create their own visualizations. To use this in a co-located collaborative environment though requires transferring an active visualization to another, public screen in order to avoid all attendees gathering around a single person's laptop. For this, the underlying software needs to support the users with easy tools, e.g. icons for surrounding public screens. To do so, the infrastructure first needs to scan for surrounding displays and their capabilities such as public vs. private, screen resolution or input opportunities. Hence, each display has to describe itself to the environment.

Table 3: Possible restrictions in MDEs

	Priv → Priv	Priv → Pub	Pub → Priv
Owner	No	Yes	Yes
All others	No	No	Yes

As we strictly separate private (PC/laptop/PDA) and semi-public (projections/interactive tables) workspaces several restrictions are introduced in the environment. Table 3 summarizes the restrictions. As shown in this table, the transfer from a private onto a public screen is only possible by the person located on the private laptop whereas the transfer from public to private can be done by any person near the public screen. Unwanted transfers, however, should be solved by social protocols during the meeting. The only strictly suspended option is shifting data from one private to another private screen in order to avoid disturbances on other person's screens. If a user wants to shift information to another private screen, s/he first needs to place it on the public screen from where it can be transferred to another private screen. The public screen then acts as a transaction mediator.

In our scenario, most of the users also want to manipulate visualizations while they are located on the public screen. Hence, it needs to support multiple simultaneous inputs and, in case of horizontal directed public displays, rotatable representations of the single visualization instances to downsize the orientation problem.

Table 4: Possible input opportunities

	Private	Public
Input	Keyboard Mouse	Pen Finger
Number of inputs	1	Arbitrary
Interaction	Content only	Content Container

The input however bears a much greater challenge. Compared to a standard PC, the input of interactive surfaces is limited to a subset of interaction options such as very basic pen events (for example, down, move, up) and no text input at all. Hence, the set of possible interactions needs to be adapted to the input capabilities of the public screen. To allow text input on a public visualization for example, the linking of a personal keyboard from the user's laptop to it should be possible. Besides interacting within the visualization containers, they should also be freely moveable, sizeable and rotatable. For this, certain gestures are imaginable to distinguish *content-operations* from *container-operations* (for example, two fingers for *container-manipulation*, singler finger for *content-manipulation*). Table 4 illustrates the differences regarding the input on private and public screens.

4. RELATED WORK

The three tasks *Presentation*, *Exploration* and *Sharing* are supported in different ways in existing work. Forlines et al. presented systems for visualizing geographical data [3] and molecules [4] on multiple displays. Several aspects of Information Visualization on tabletop displays were investigated in [5] and [7].

Shen and Everitt explored sharing documents between devices using horizontal surfaces [6] as well as flexible switching between workspace configurations in MDEs [2]. IMPROMPTU [1] allows the sharing of whole applications in the context of software development in a MDE.

5. CONCLUSION AND FUTURE WORK

We have presented an analysis of the working behaviours and environments of automotive analysis and diagnostic experts. During several studies we encountered a lack of software support in collaborative MDEs and the need for more visualization in this field. We approached two novel aspects for MDEs, namely portable visualizations on multiple displays as well as support for a flexible workflow. Several questions arise from these topics: As the related work section showed, not much research has been done in the area of visualization on non-desktop and multiple displays. The affordances of such devices therefore become important: On the technical side the input and output capabilities, on the social side attention to collaboration, territoriality and rights management. A flexible switching between different kinds of devices and settings needs robust infrastructure and protocols on the network, but also understandable input mechanisms to perform this task from the users' side and a reasonable remapping of inputs depending on the currently active display. We would be happy to discuss these questions at the workshop.

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