# 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 electronics and an enormous amount of in-car communication activities. This leads to an increasingly complex data volume which challenges automotive engineers in detecting and analyzing erroneous communication processes. In this paper, 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 lack specific software to support collaboration. In particular, we observed a need for support of multiple devices in collaborative multiple display environments (MDEs). After a detailed user analysis and evaluation we present system requirements for information analysis applications in MDEs as required for the analysis of in-car communication activities.



### 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. Analysts are this constantly alternating between individual work and collaboration in their daily working process. While the individual work is characterized by a high usage of specialized tools and software systems, there is little explicit software for supporting the collaborative work.

The remainder of the paper describes the current work processes and environments of automotive analysis experts derived from results of interviews, task observations, and a questionnaire. We focus on synchronous co-located collaboration and analyze how it could be digitally supported and discuss system requirements for adequate support of the collaborative analysis process in multiple display environments (MDEs).

## 2. CURRENT PRACTICE
We conducted two user studies to get a clearer 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 participant's individual work,

**Table 1: Dependency matrix between categories and locations**

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

which and how specific tools were used, why they were used, and when the participant had to cooperate with his or her colleague. During these studies, we observed a lack of visualization support. All of our participants expressed a strong demand for new visualization forms, especially to compare in-car communication information. We also 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 address the aspect of collaboration in their daily practice.

The results of the study showed that analysis constantly alternate between individual and group work. The reasons for mingling with colleagues were mostly based on the underlying complexity of the problems: combination of different expert knowledge, different perspectives on complex problems, and missing detail information demanded support and confirmation. All these tasks were associated with a certain degree of discussion which was 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 was crucial and that different sets of data and information had to be transferred to solve the problems (mostly via email attachment, shared folders, or USB memory drives).

Having a closer look at the synchronous co-located collaborative work situations, 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), but also PDAs or other 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 was the most natural but scarce form of a meeting without any access to digital analysis support. This face-to-face form was mostly used to clarify simple or general questions without the need to be connected to any tools and the data.

2. *One device, interaction by one user:* This situation was fairly common. Several users gathered around a colleague's laptop or desktop screen or a projected presentation and discussed a problem whilst one person interacted with an analysis software. This form of collaboration occurred, for example, due to spontaneous upcoming specific questions and problems which could be clarified in a collaborative manner.

3. *One device, interaction by many users:* The same situation and devices as in the previous situation but with more than one user interacting with the device. This situation occurred when the solution of the problem was more complex.

4. *Many devices, interaction by many users:* Several people brought their own devices, interacted and presented with them. Changes in the user-device relationship were rare in this setup. This form was mostly used to handle really complex problems which required a lot of discussion. The combinations of devices could include several laptops or PCs and sometimes an additional projected presentation. PDAs or mobile phones were used as well. A typical constellation we observed in this setup 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.

We spotted three main locations for the co-located collaborative part of the analysts' work with a tendency to specific group sizes:

- *Meeting room:* This was the most common location for discussion of complex problems (in order not to disturb other colleagues); often larger groups gathered in meeting rooms (>= 3).

- *Colleague's desk:* This location was typically used for ad-hoc meetings for the discussion of light- and mid-weight problems as well as short questions. Mostly pairs collaborated in this situation but we also observed small groups of up to four people.

- *Informal venues:* Shorter informal discussions and meetings took place in informal venues like a coffee bar. Mostly frequently pairs met and discussed in these situations but we also observed small groups of up to four people in this location.

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

By having a closer look at hardware and software support for individual work and co-located collaborative work, we encountered an unbalanced situation: On the one hand, the individual work was strongly characterized by a high degree of electronic support with multiple displays, multiple different devices and a high connectivity to distributed colleagues. Also there were 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

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

co-located collaborative work we also found good conditions regarding the hardware support. The personal mobility was 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 could and did carry around their equipment, met in meeting rooms and used stationary projectors to collaborate with their colleagues. Looking at the software side, we could not find any special support of the collaborative process in these dynamically forming MDE environments (cf. Table 2). The software which wass used for collaborative work was exactly the same as in the individual environment—and designed for single user analysis and interaction. This leads us to believe that more research into MDEs for collaborative data analysis processes is required to further support the problem solving activities of data analysts.

**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 our observations we conclude that although the hardware (multiple displays) was readily available and used in the company, an appropriate software environment is still missing.

## 3.1 Design Implications

Our study results suggest that collaborative data analysis activities appeared mainly in two different cases:

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

Based on our observations, a software system for collaborative analysis should support the following three tasks: *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 likely 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 present.

*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 can be 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) [6], 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 new software infrastructure we intend to build.

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 these in a co-located collaborative environment, though, requires easily 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 access to the 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. Ideally, each display would 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 wanted to manipulate visualizations while they are located on the public screen. Hence, a new system 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<br>Mouse | Pen<br>Finger |
| Number of inputs | 1 | Arbitrary |
| Interaction | Content only | Content<br>Container |

The input however bears a much greater challenge. Compared to a standard PC, the input on 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 movable, resizable and rotatable. For this, certain gestures are imaginable to distinguish *content-operations* from *container-operations* (for example, two fingers for *container-manipulation*, single 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 [8].

Shen and Everitt explored sharing documents between devices using horizontal surfaces [7] 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. We will further investigate how solutions presented in these applications would transfer to our usage scenario.

# 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 identified the need for more visualization in this field. We considered two novel aspects for MDEs, namely portable visualizations on multiple displays as well as support for a flexible transition between individual and group work. 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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