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MSCar: Enhancing Message Sequence Charts with Interactivity for  
Analysing (Automotive) Communication Sequences

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# MSCar: Enhancing Message Sequence Charts with Interactivity for Analysing (Automotive) Communication Sequences

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**Abstract:** Message Sequence Charts (MSCs) are a standardized and widespread form to visually describe interactions in distributed systems. Our approach proposes the enrichment of large scaled MSCs with novel interaction and design techniques used in the field of information visualization. Additionally, we show a graphical solution to visualize parallel, multi-directed communication processes in MSCs. Instead of the common application to specify system behaviours our interactive MSCs are aimed at exploring and diagnosing dependencies in network communication in general and, regarding our special requirements, within in-car communication traces. We implemented a prototype called MSCar with Focus and Context techniques, Dynamic Path Highlighting, Details on Demand and Colour Coding to support the users' cognitive abilities. A qualitative user study on MSCar gave us preliminary feedback and disclosed potentials of our approach.

**Keywords:** Message Sequence Charts, Information Visualization, Automotive, Interactivity, In-Car Communication

## 1 Introduction

MSCs have been and still are a very common technique in early design stages of distributed systems. In 1996, their popularity resulted in the standardization by the ITU [ITU96] and the incorporation in the UML visual specification language [Obj08]. The simple and understandable design with vertical lifelines and horizontal arrows showing the sequence of communication tasks gained a very high acceptance in the software as well as in the automotive engineering domain, where MSCs are used to model and specify dynamic aspects in communication systems. We, however, want to propose another way of applying MSCs, namely for the purpose of diagnosing and analysing existing communication systems and for our special purpose of in-car communication traces. Therefore, we use the MSC as a visualization technique and enrich it with novel interactive exploration capabilities to provide scalability and ease of understanding to large communication traces.

This contribution describes our work in progress, presents MSCar, a first implementation of a single view, Focus and Context MSC visualization for the interactive exploration of in-car communication traces, and reports our present experience. At first we will give a short description of the underlying automotive motivation and our preliminary work in this area. Thereafter we outline related work in the field of interactive MSCs and of techniques used by our approach and concepts. The body of the contribution illustrates the design and concepts of MSCar and our experience. Based on this, we will discuss future improvements and extensions of our approach.

## 2 Problem field and preliminary work

The motivation for our approach comes from difficulties encountered by automotive engineers when attempting to comprehend in-car communication networks. Within this domain, simulated systems and systems under construction are frequently tested during the (embedded) software engineering process and results have to be checked, interpreted and discussed by domain experts. Present domain specific forms of data representation, however, have reached the limits of human cognition. Characteristically these forms are based on textual information in lists and are only enhanced by some rudimentary visualization. This practice requires a lot of time and experience to gain insight into communication processes. In search of adequate visualization techniques, we developed MSCar, an interactive visualization of an MSC, to support the diagnostic experts with the task of exploring dependencies of so called *Functional Blocks* (FBs).

In the automotive context a FB can be seen as a small software unit responsible for a special task in the car, e. g., *move window*. FBs are located on hardware elements called *Electronic Control Units* (ECUs), which are distributed in the vehicle. The ECUs are interconnected over several automotive specific bus systems serving as carriers for information exchange. Figure 1 shows a simplified, schematic overview of this system configuration. In a communication process FBs “put some information” on a connected bus system where it can be “taken from by interested FBs”. This conforms to the broadcast communication model. The explanation of the in-car communication processes described ahead is simplified to a very high degree. For more information we recommend the reading of [Gmb07]. Regarding the communication processes in vehicles, there are a few important basic facts to understand the presented design and concepts of MSCar:

- *Inner-ECU communication*: Communication between FBs of the same ECU
- *Across-ECU communication*: Communication between FBs of different ECUs
- *Multiple receivers*: Messages are broadcast and could be read by other (interested) FBs
- *Parallel communication*: Different FBs can send at the same time

Furthermore it is important to know that the actual version of MSCar described in this contribution is aimed to illustrate *Dependency Chains* within in-car communication traces. After a selection of a FB MSCar shows all FBs of the transitive closure regarding the selected FB, which are all successor and predecessor FBs in a dependency graph (cf. Figure 2). The selection of FBs to trigger the presentation and the different ways how to select a FB are not treated in this contribution. For more information we recommend the reading of [SHS<sup>+</sup>08]. It describes our preliminary work in this field and presents a prototype of a dual view visualization for exploring functional Dependency Chains. Whereas [SHS<sup>+</sup>08] focuses on the general automotive problems and visualizability with the proposed dual view visualization approach we now explicitly emphasize the usage and potentials of MSCs for analysing communication traces and discuss our developed concepts in detail.

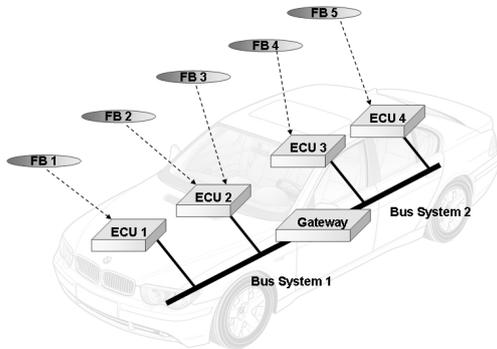


Figure 1: Simplified topology of an in-car communication network

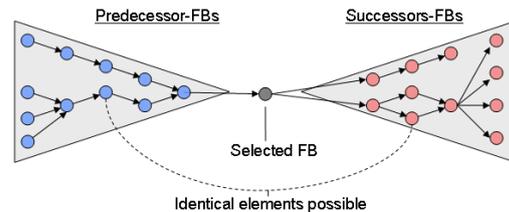


Figure 2: Schematic representation of a Dependency Chain

### 3 Related work

Some primary work in the field of interactive MSCs was done by Eick et al. [EW96]. To display large-scaled MSCs occurring in telecommunication networks they introduced a multiple view, Zoom and Filter concept for MSCs. The proposed system included on the one hand a reduced overview of the MSC and on the other hand linked views for showing details, where selected life-lines could be explored uncoupled from the entire MSC. In a small user study they documented their positive experience compared to printed MSCs and revealed potentials for time saving and better understanding.

Compared to the work of Eick et al. we propose a Focus and Context approach. Our goal is to create a stand-alone, single view MSC-visualization because we plan to use this form of visualization in a superior *Multiple Coordinated View* system [Rob07] to master the high complexity in the in-car communication domain. In this scenario the MSC visualization would serve as one equal module coupled and combined with other visualization forms, so a single view visualization for the MSC is desired to reduce context switching [BWK00]. Based on this background we integrated *Focus and Context* techniques in our MSC visualization because the basic idea of Focus and Context is to show both overview (Context) and detailed information (Focus) simultaneously within a single view [CMS99].

Another important approach of our work is the target-oriented application of static and dynamic visualization techniques to support preattentive processing in human cognition [HBE93]. Specifically we use colour and animation to focus the users' attention.

Due to the underlying problem of dealing with in-car communication traces our MSC visualization has to support the presentation of parallel as well as multi-receiver communication, like broad- or multicast. Krueger et al. [KPS04] demonstrated an extension to MSCs for the modelling of broadcast interaction scenarios with circles visualizing the multiple communication drains. We, however, have to proceed to clearly visualize the combination of broadcast and time parallel communications as operated in vehicles.

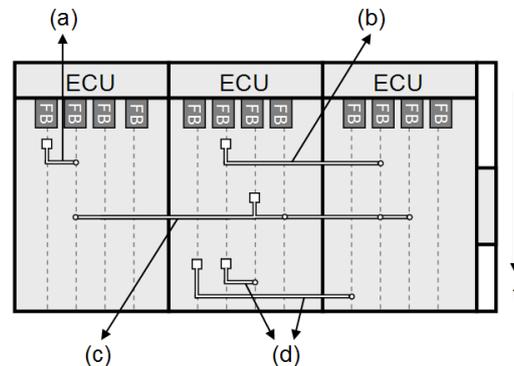


Figure 3: Schematic of MSCar

(a) Inner-ECU com. (b) Across-ECU com. (c) Multiple receivers (d) Parallel com.

## 4 MSCar

Preliminary interviews with automotive engineers about their routines and an accurate analysis of the problem field led us to the idea of using MSCs for visualizing in-car communication traces. During the guided interviews it has become clear that MSCs in the automotive development domain states a very common technique and that the engineers could well imagine a corresponding visualization form for the underlying problems. Their main reason was the suitability of this presentation form to simultaneously focus on time and dependencies to e. g., identify time parallel events and cycles in dependent communication processes. Therefore we decided to use and investigate MSCs for solving our problem and benefit from the high level of familiarity by supporting the engineers mental model with common presentation forms.

### 4.1 Design adaptations

Based on the special requirements described above, we designed MSCar, a visual variant of MSC representation, to enable the interactive presentation of automotive communication tasks. The general appearance of MSCar is structured regarding the automotive background of the hierarchical correlation of ECUs and FBs. FBs are visualized as vertical lifelines and are grouped according to their affiliation to a certain ECU. The result is a basic design of columns (ECUs) containing a set of dashed lifelines (FBs). Based on this, each communication is displayed with three graphical elements. A rectangle represents the sending action, a circle the receiving action and the orthogonal plotted connecting line the communication flow. To avoid undefined crossings, we vertically shift overlapping lines in case of problematic parallel communication tasks. These design-rules help us to enable the representation of the automotive specific requirements listed above. Figure 3 shows a schematic sketch of our design representing three ECUs with four FBs in each case and examples for the different communication options.

The ordering of the MSCar elements is loosely based on causal relationships instead of bounding it to an accurate mapping of time intervals. So, on the one hand we still provide the correct ordering of communication activities regarding the desired information on parallelism and cycles.

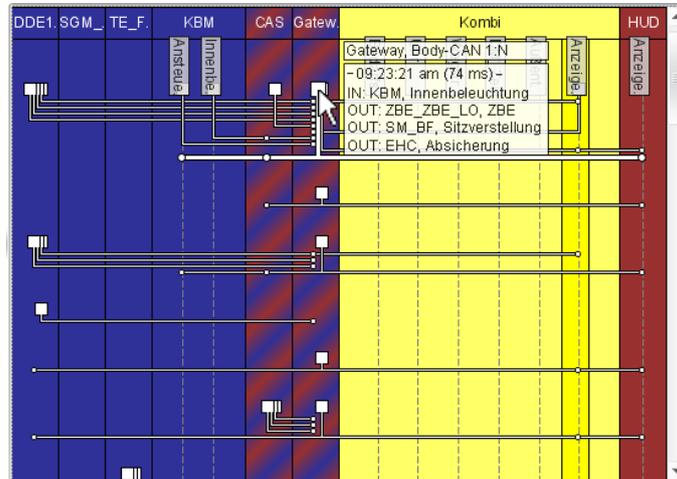


Figure 4: Screenshot of MSCar showing Colour Coding, Semantic Zoom, Dynamic Path Highlighting and a Details on Demand Hover

On the other hand this structure avoids visual waste of space in case of sparse communication phases, which are common for in-car communication traces. The result is a compressed and homogeneously distributed MSC design (cf. Figure 3).

If the MSC to be presented exceeds the available vertical amount of space, MSCar will automatically add a scrollbar. A benefit of our scrolling approach is the detached position of FB and ECU labels. The labels on top of the visualization remain unaffected by scrolling and are therefore constantly displayed.

## 4.2 Concepts supporting preattentive processing

With MSCar we use problem specific *Colour Coding* to emphasize dependencies on the layer of ECUs. During interviews with engineers we detected a conventional three colour scheme for Dependency Chains, which we reuse in MSCar by attaching it to the columns:

- *Yellow*: Denotes the selected ECU and within the column the selected FB in a more pronounced hue
- *Blue*: Denotes predecessors of the selected FB, this means all ECUs containing FBs sending to the selected FB
- *Red*: Denotes successors of the selected FB, this means all ECUs containing FBs receiving from the selected FB

For ECUs, containing both predecessor and successor FBs, we use a blue-red striped brushing. Additionally, this coding is backed by the horizontal ordering of the ECUs, predecessors left-aligned, successors right-aligned and hybrid ECUs left-adjacent to the selected ECU (cf. Figure 4). By using these two powerful, preattentive well perceptible approaches to code, we actively stress the users' focus on the role of the ECUs within the Dependency Chain - selected, only

predecessors, only successors, both predecessors and successors. This is important because in practice it is often necessary to explore dependencies in “one direction”, for example only all predecessors, to trace impacts of errors, or only all successors, to locate undetected error sources. Another concept we integrated to support the users’ preattentive abilities is the *Dynamic Path Highlighting*. The underlying problem emerged from the nature of parallel and multi-receiver communication which leads in some situations to complex line formations. In this case we observed that users followed paths physically with their fingertips on the display. To support and simplify this practice, we designed a mouseover interaction to provoke a minimal growth of the relevant path. According to our definition, a path is a cohesive communication element composed of one rectangle, one or more circles and the related orthogonal connecting line. The swelling of the path attracts the users’ attention and directs the focus. The retaining highlight after the size modification enables an easy traceability of the path (cf. Figure 4). The correlative rollout mouseevent causes the highlight to vanish and the path to appear in its normal format. In addition to Dynamic Path Highlighting the mouseover provides the indication of *Details on Demand* information a second functionality. By moving the mouse over a sending or receiving element a semitransparent, location aware tooltip window, the *Hover*, appears showing two kinds of detailed information (cf. Figure 4):

1. *Shortcut Information*: This is redundant information which already can be found in the visualization. To reduce searching costs and eye movements we interactively provide this information near its relevant source. Shortcut Information in MSCar: Name of the FB, Name of the ECU.
2. *Additional Information*: This is further detailed information not provided in the basic visualization. Additional Information in MSCar: Exact timestamp of the events, sending activities beyond the actually presented Dependency Chain.

### 4.3 Focus and Context with a Semantic Zoom

To control scalability and to simultaneously avoid multiple views we integrated a horizontally operating *Semantic Zoom* in MSCar. Our Semantic Zoom enables an interactive selection of ECUs to focus and the other way around to defocus them to context information. By clicking on the header of an ECU column the user can toggle between two modes and so alter the degree of shown information. In focus-mode the information is presented in the way described above, viz. FBs are shown as dashed lifelines incorporated within the ECU (cf. Figure 5-b). In the context-mode on the other hand the ECU columns are “folded” to a minimum horizontal dimension and the dashed lines of the FBs vanish. Hence, the statically shown information in the MSC diagram regarding this ECU is reduced to drawing the physical dependencies and so is semantically downscaled from detailed FB to overview ECU information (cf. Figure 5-a). A specific feature of our Semantic Zoom - in relation with the Details on Demand concept - is the continuity of all information in different modes. So in both modes the same information is available but has to be accessed in different ways. For example the name of an FB is provided in the focus-mode via label and via mouseover (as Shortcut Information). In the context-mode it is accessible exclusively via mouseover (as Additional Information).

In MSCar by default MSCs beyond 20 involved FBs are semantically zoomed and all ECU

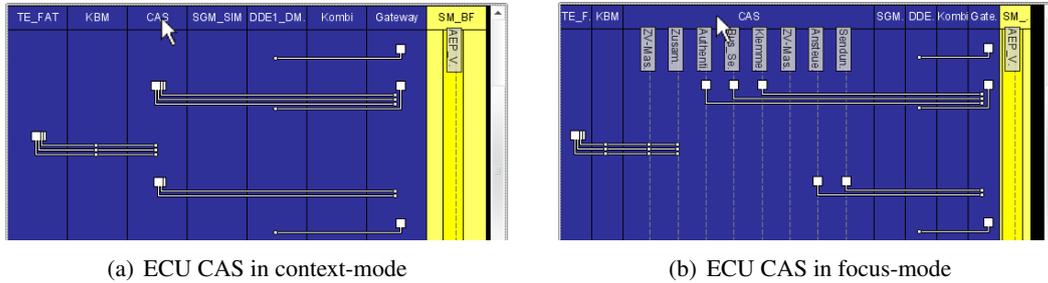


Figure 5: Semantic Zoom

columns except for the selected one are shown initially in the context-mode. MSCs below this limit are shown in full. To avoid annoying comprehensive zooming interactions on all ECU elements by clicking each one, we also integrated a function to globally collapse and accordingly expand all.

#### 4.4 User Experience with MSCar

In the scope of [SHS<sup>+</sup>08] we had the chance to get preliminary feedback to our MSCar approach. We conducted a qualitative user study with three automotive diagnostic experts and three students. The study was organized as a think aloud protocol where the subjects had to handle different tasks and were asked several questions. The MSCar approach was included in a dual view approach and was surveyed detached in a special, 15 minute long section of the study. The subjects had to interact with MSCar and find FB and ECU dependencies of different complexity. Thereafter they were asked questions about the interaction concepts, the usability and the understanding of MSCar.

The results of the study showed that all interaction and visualization concepts we integrated in MSCar were accepted very well and were frequently used to solve the tasks. A very high ranking was given to the Dynamic Path Highlighting because it helped the users to manage large and complex MSCs. Also the Semantic Zoom was accepted very well and was used to explore the dependencies between two or more ECUs in detail. E. g., one subject estimated in this regard: “The opening and closing of the ECUs is enormously helpful and understandable to get a grip on this high complexity”. Moreover, we observed no major problems regarding usability and understanding. After a short instruction every subject was able to handle MSCar without difficulties. Some problems, however, were discovered with the Details on Demand Hovers displayed on mouseover. Few situations turned out to have elements with very much additional detailed information, so the Hover increased to an unpredictable size with strong overlap to other elements. We also observed comprehension problems with highly branched MSCs. The subjects saw the responsibility for this not in our MSCar design but in the underlying complexity of in-car communication traces.

The overall results and impressions of our first user study were very encouraging, especially the positive estimation of the domain experts to save time with our MSCar approach compared to

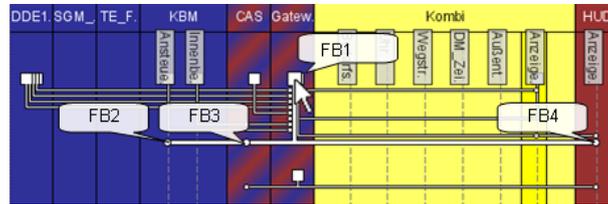


Figure 6: Concept of Multiple Hovers

former technologies. However, it also showed us the need for further extensions and improvements.

## 5 Future Work and Considered Concepts

Based on the findings of our first user study as well as on a critical review of our own concepts, we plan future steps regarding our approach of interactive MSCs in the in-car communication domain. On the one hand we have designed several interesting new concepts to integrate into MSCar. On the other hand we see a strong need to further evaluate our design and concepts. In the following we give a brief outlook at some ideas for improvements and new concepts for MSCar solidified during several roundtable discussions with automotive engineers.

### 5.1 New Concepts

There are several ideas for additional concepts to integrate in a next version of MSCar:

- *Readjusting Hover size and details position:* We plan to reduce the dynamically shown information in Hovers. Though the detailed information of these elements shown via mouseover was rarely used, we are aware that it is, however, significant. Hence we want to develop concepts to deal with user triggered, fixed positioning of extensive detailed information. These concepts also will solve the overlapping problem (cf. section 4.4). The basic idea is to decouple some parts of the detailed information (e. g., the information about the sending activities beyond the actually presented Dependency Chain) and offer it on demand in an extra view integrated in a superior Multiple Coordinated View system as we mentioned in section 3.
- *Multiple Hovers:* We want to investigate the potentials of using multiple Hovers for additionally attaching Shortcut Information to *next neighbour elements* (sender and direct receivers of a message). Hovering one element of the message then also would cause the next neighbour elements to show their Shortcut Information (cf. Figure 6). The advantage would be that this facilitates the cognition of correlations and that the user can save mouse and eye movement by directly showing the details of the next neighbour elements. On the other hand the Multiple Hover concept is not scalable in the case of many receivers. So in a first step a scalable definition of “next neighbour elements” has to be found. We assume a natural limit of showing maximum 3-4 Hovers at once, but this also has to be

investigated. To exactly allocate the different Hovers our idea is to use speech bubbles and link them to their related elements.

- *Direct Manipulation to readjust ECU positions:* To further support the interactive exploration of highly complex MSCs we plan to experiment with decoupling the ECU columns from their fixed position. After the initial arrangement the user should be able to relocate the ECU columns and in doing so change the entire MSC perception. It has to be considered that this free adjustment will lead to a rejection of the position concept we presented in section 4.2. Therefore only the colour would code the position of the ECU in the Dependency Chain. The pros and cons have to be investigated.
- *Integration of a vertical (semantic) zoom:* To completely avoid scrolling we are considering extending our Focus and Context concept and offer an eligible solution for vertical zooming. The advantage of this approach would be that the user gains the possibility to show an entire overview of large MSCs.
- *Toggle between causal and time dependent presentation:* As we founded out in roundtable discussions it could be helpful in some situations to have a time dependent presentation of the MSC. To retain the benefit of the causal presentation (cf. section 4.1) we will investigate the potentials and concepts of switching between these two presentations.

## 5.2 Further Evaluation

After our positive, preliminary feedback we will integrate the new concepts and evaluate MSCar more extensively.

We are very interested in comparing MSCar to other solutions. On the one hand we want to contrast MSCar with conventional text based working practice. The goal is to scientifically prove the benefit of the MSCar approach and to measure the amount of time that could be saved. In this context it is important to address a wider audience and to test MSCar according to a variety of conventional approaches. On the other hand we are interested in a comparison to other visualization approaches. An obvious alternative is an interactive graph visualization. Thereby Dependency Chains are shown in node-link diagrams, which could be enriched with plenty of interaction. It seems very interesting to compare the MSC to other visualization forms to get information about the applicability and the different advantages of the forms, especially for the use in a superior Multiple Coordinated View system.

In addition we want to gain more insight into HCI and perceptual aspects. Many methods and frameworks already exist for this purpose, e. g., Heuristic Evaluation, Cognitive Walkthrough [Nie95] or the Cognitive Dimension Framework [GP96]. The most interesting point will be the suitability of the methods and the need for extra adaptations in the field of information visualization and interactive diagrams.

## 6 Conclusion

We have presented our work in progress on a design approach and interaction concepts for a MSC visualization to explore in-car communication dependencies. The special requirements

of automotive bus communication provoked an adaptation of MSCs to simultaneously visualize parallel and multi-receiver communication. Furthermore we described measures to interactively manage the underlying complexity and support the users' understanding. In an expert evaluation with MSCar - a prototype of our design - we received very positive feedback from domain experts. Encouraged for further investigation we introduced improvements and new concepts for future work on MSCar. Concluding, we also strive to indicate and motivate our approaches' potentials for generalization.

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