Visualizing Scheduling: A Hierarchical Event-Based Approach on a Tablet

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Abstract
The amount of logistical data in the automotive industry drastically increases due to digitalization and data that is automatically generated due to Auto-ID-Technologies. However, new methods need to be devised to make sense of this data, in particular when users are mobile, and when users need to collaborate to solve complex logistical tasks, such as resource scheduling. We propose a visualization method for hierarchical event data that is designed for tablets. The main design goals have been to foster collaboration and enable mobility. Our think aloud user study shows that both the event recognition and understanding of the participants improved with the proposed solution.

Author Keywords
Visualization; Tablet; Event Data; Industrial; CSCW

ACM Classification Keywords
H.5.3 [Group and Organization Interfaces]: Synchronous interaction.

Introduction
The automotive industry is one of the most complex industries [11] with both complex products as well as supply chains. To guarantee an optimal supply of parts, containers also have to be considered and managed. Our

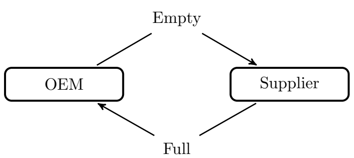


Figure 1: The OEM sends its empty containers, which have been ordered by the supplier, to its supplier via a forwarder. Afterwards, the supplier sends the filled containers back to the OEM.

important aspect of logistics is the scheduling of resources. In particular, we consider containers for parts. Container schedule ensures the container supply of all supply chain partners. The growing digitalization and the use of Auto-ID-Technologies lead to an increasing amount of data in the logistics [14]. This technology helps connect physical objects to the internet or IT-Systems using technologies like Radio Frequency Identification or the Bluetooth Low Energy-Technology [10].

In practice, a variety of events can occur that endanger the planned container schedule process. For instance, if a scheduler has ordered three trucks for transporting containers to a supplier, an internal consumer can take away containers a couple of hours before they arrive from the storage location without head-up notice. Only two trucks might then be needed. In order to avoid the cost of transportation, the scheduler needs to be informed immediately. He can then decide, if he uses the trucks for other transportation or calls them off. As the scheduler is not necessarily sitting at his office desk, a solution for a mobile device is needed. The incorporation of event data helps identify process deviations that endanger the scheduling and transportation process.

We derived the following questions regarding the previous example. How can a person working as a container scheduler handle event data? How should a user-centered visualization look like on a tablet? Is it possible to improve the collaboration between container schedulers with these visualizations?

Our literature review showed that there has been little research with regard to these questions. Therefore we conducted our own investigation and carried out a study with 6 participants in Wolfsburg, Germany. This paper contributes to a deeper understanding of the (container) scheduling process, how collaboration can be fostered with visualizations on tablets and and how a visualization for hierarchical event-based data should look like.

Currently, the scheduling process is carried out by combining information from (printed) static tables and IT-systems that do not take into account nor highlight events. Instead of informing the user about critical events, the user has to search for them or get the information from a colleague or supply chain partner. Therefore a solution on a mobile device is needed that still allows the user to carry out the scheduling process. This is a challenging task as tables are hard to operate with the gestures common on mobile devices and as it is not possible to easily access or switch between the programs the scheduler typically uses. As the screen size from a desktop to a mobile computer also decreases, fewer windows can be seen and compared side by side.

Use Case and its Generalization

The container management process by an Original Equipment Manufacturer (OEM) is a cyclic process between the OEM and his related suppliers (see Figure 1). In this process, the supplier has to order the required containers from the OEM weekly. The quantity depends on the parts ordered by the OEM from the supplier. The OEM has to send the amount of containers to the supplier within one week.

This process is very similar to other scheduling processes. There are orders with certain requirements like due date or destination and resource(s) which are required to fulfill the given orders. Because of that the current orders have to be allocated according to the current resource's quantity. This allocation has to satisfy the order's requirements. At first glance the process does not seem to be overly complicated but its complexity grows proportionally to corresponding data availability, number of suppliers and hierarchical steps/size of supply chains.

Related Work

A lot of research has been done to achieve new visualization approaches e.g. the very famous TreeMap by Shneiderman [12]. The majority of new approaches in visualization and event visualization focuses on more strategical or tactical concerns of users [3]. The approach by Suntinger et. al. uses the metaphor of a tunnel to provide an overview of occurred events [13]. Jo et. al. developed an inspiring approach for a desktop system to observe a large manufacturing schedule [7]. The paper solves the problem of unclear and invisible dependencies within a manufacturing schedule. However, it does not consider the mobility of a person working in this process who might require a mobile device. Furthermore, in our work we changed the point of view to a more operational and collaborative focus and aimed to close this gap.

Since 2005, research to improve collaboration through visualization is growing as the analysis by Isenberg et. al. indicates [5]. Bohmer et. al. show the potential benefits in using smartphones to improve collaboration in meetings via gamification [2]. In our approach, we considered the tablet as the main working platform, instead.

Current research discuss the mobile device's suitability for visualizations [6]. However, Johnson et. al. showed by their study that visualizing CT-data is even applicable on an iPad [8]. Similar to a medical doctor who needs patient's informations on his ward round, the worker in our domain needs the information about current resources availability, even if they are not in their office.

Visualization Composition

With the intention to get a satisfying and usable concept we applied an iterative user-centered development process starting with a domain analysis. We first analyzed the existing data attributes. Our analysis showed an overhead of unnecessary and unused data. As a result we received a reduced information space containing 5 out of more than 12 different data attributes. These are: resource ID, order ID, order quantity, current quantity, supplier ID. Furthermore, the domain experts were asked to order these data attributes by the degree of interest.

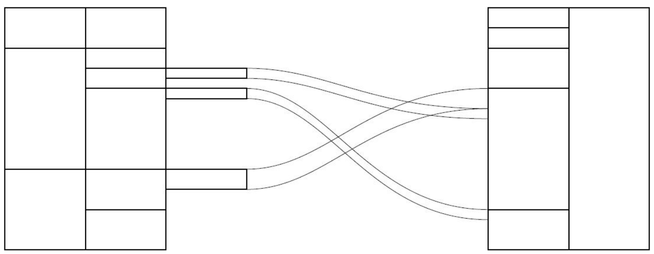
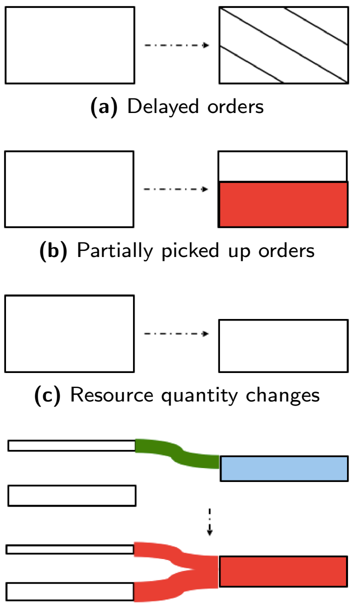


Figure 2: This visualization is a result of separating the main data categories (orders and resources), using hierarchies within the order and resource data, connecting both sides using flows and mapping the main quantitative data attribute (resource quantity) on an element's height.

Depending on the mobile devices' display size, we decided to use a hierarchically space-filling approach as shown in Figure 2. Furthermore, we designed a FLUID-interface to take advantage of the benefits of a gesture-based visualization [4].

Our main quantitative data attribute is the considered resource's quantity. It is the most important data attribute within the information space for the purpose of different orders and resource types. We used the data



(a) Delayed orders

(b) Partially picked up orders

(c) Resource quantity changes

(d) External schedule

Figure 3: Four different event visualizations, each for a different event type.

hierarchies within the order and resource data. An order can be grouped in two different ways. First by required resource type and second by supplier. A resource can be grouped by its type on the resource side. Instead of using flows between each level, we used side by side positioning of visualization's elements. We used this method for space saving reasons, because display size is a constant problem designing a mobile application.

We implemented the four interaction techniques of one-finger scroll, pinch-to-zoom, tab for details and a gesture to connect orders with its required resource to enhance the visualization. To help the user to navigate within the data, we implemented a default pinch-to-zoom gesture combined with a default one finger scroll gesture on each side. The highlighting function is a single tap gesture on a visualization element. The element itself and its corresponding elements e.g. directly connected or lower hierarchic elements are highlighted by this gesture. The establishment of a connection between an order and a resource is implemented by combining a long press on the order with a single tab on the resource.

Event Visualization

We considered four different events (see Figure 3): delayed orders, partially picked up orders, resource quantity changes and an external schedule. Every event type gets its own specialized representation. According to Aigner et. al. [1], an event should only be presented to a user if it is important to the user's concerns.

The domain experts rated delayed orders as necessary but less interesting. We mapped this event type (Figure 3a) on the visual variable [9] of the pattern. It is a binary event representation with the states "delayed" (pattern) and "not delayed" (no pattern). Partially picked up orders (Figure 3b) are represented as partially filled corresponding order elements, because the resource's quantity is already mapped. Changes of the resource's quantity (Figure 3c) are represented as a combination of dynamically adjusting element's height and a color-change if the new quantity won't last for the allocated orders. An external schedule (Figure 3d) from a co-worker is displayed as a new flow. Depending on the influence of this event on the resource and other orders, the color of the resource and its corresponding flows changes.

Study Methodology

We conducted a two-part think aloud study lasting approximately 60 minutes per participant and used an original historical data set of one month and 300 container types. We suppose that this real data set improves the participants' trust in our visualization and reduces the results' bias. The study started with a practical part and ended with a short questionnaire including the System Usability Scale (SUS) and a demographical question about tablet experience. For reasons of data protection, we noted age $(< 30, \geq 30)$ and gender separately. The practical part was subdivided into five scenarios, each containing a couple of tasks.

The participants started with the learning scenario in order to get familiar with the visualization and its interactions. The goal of this scenario was to get the users acquainted and observe their understanding of basic visualization elements e.g. the object's height. The first scenario contained events of delayed and partially picked up orders. The participants were asked to identify all delayed orders (Figures 3a and 3b). The second scenario's purpose was to check the suitability and understandability of encoding the quantity through the object's height. Quantity change events were planted in the third scenario

Scenario	Fulfillment (%)
1	40
2	83
3	100
4	83

Table 1: The fulfillment per scenario shows that only in the first scenario a misunderstanding in event visualization existed.

(Figure 3c). They differed in the degree of user's interest, therefore we observed which ones were noticed by the participants and which ones were not. In the fourth and last scenario, we investigated the events of the external schedule (Figure 3d). First we were interested if the participants even noticed the events and second if they understood the event's meaning and its consequences to their collaborative work environment.

In our study 6 persons (2 female, 4 male) participated. They were between 20 - 60 years of age. All of them were domain experts working in the container scheduling department of an OEM's factory. Furthermore, everyone was experienced in the use of tablets.

Results

The system received an overall SUS score of 73.3. The majority of the participants liked the clear visualization. They didn't have any problems with finding the desired information within the visualization. Moreover, they used the available interactions intuitively. *"I can clearly see the relations"* one participant mentioned.

Most events (except events of the first scenario) were noticed by participants in case of being interesting in a participant's point of view, as shown in Table 1.

60 % of our participants mismatched the events of delayed orders and partially picked up orders which were planted in the first scenario. They misunderstood the pattern's meaning as a cancellation of an order instead of a delay. Based on this misunderstanding they misinterpreted partially filled orders as delayed ones.

The participants' positive reaction in the fourth scenario showed the usefulness of visualizing the cooperative workflow. 5 out of 6 participants interpreted the events occurred right. They mentioned, that it is nice to see what their colleagues do and how this influenced their own working process.

Implications for design
Based on our insights we could draw some implications for the design.

Use side by side positioning: The limited display size regarding designing a mobile application is a constant problem. One valid solution of visualizing hierarchies is the side by side positioning. This method enables the user to understand relationships while reducing the required space.

Use event informations through dynamic elements: Enrich your static visualization through dynamic visual variables triggered by event informations.

Reduce the information space as far as you can: Instead of transforming an application from desktop to mobile, we recommend to rethink which informations are necessary for the user and which aren't. The new information space might fit into a new mobile application.

Consider previous visual variable's forming: We observed misunderstandings of certain visual variables influenced on previous visual variables' forming. To avoid such problems, we recommend a mapping of data attributes on visual variables that consider user's mental model, current context and the design of older systems.

Conclusion and Future Work

We presented a hierarchical event-based visualization concept for a human-controlled resource allocation process. We evaluated it through a think aloud user study with domain experts in a realistic use case. Furthermore, we showed that the new visualization concept was positively judged by the users. Especially the participants' reactions and statements in the last scenario indicate prospects of event-based visualization in a collaborative work environment.

Future research is needed to discuss new approaches to enhance the concept by using mobile sensors. One approach might be the improvement via location-awareness. Imagine, a user moving around in a factory to observe the current resources. If e.g. the resources are equipped with Bluetooth Low Energy-transponders, the tablet could detect them and automatically filter the visualization to all resources within a radius.

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