On the Interactive Visualization of a Logistics Scenario: Requirements and Possible Solutions

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ABSTRACT

In this paper, we describe the design and prototypical implementation of an interactive visualization in a logistics scenario for the needs of digital engineering. We applied the goals of digital engineering to realize an interactive visual browsing and analysis tool by a seamless integration of different data-sets. Furthermore, we take user requirements into consideration, which also come out of the virtual logistics scenario. Therefore complex information models were simplified in order to fulfill user goals in a comfortable way. Finally, we evaluated the implemented prototype by interviewing experts. The result contains valuable feedback to the suitability for typical logistic applications nowadays.

Categories and Subject Descriptors

H.5.m [**Information Systems**]: Information Interfaces and Presentation (I.7) – m*iscellaneous,* H.4.2 [**Information Systems**]: Information System Applications – t*ypes of systems, subject: logistics.*

General Terms

Human Factors, Design, Logistics, Visualization, Digital Engineering

Keywords

Design, Visualization, Logistics, Digital Engineering

1. INTRODUCTION

There are many very specialized information management tools that are used within the domain of logistics and goods transportation respectively. In most cases, these tools are presenting abstract and detailed information, e.g. the state of all active transfer orders in form of a textual list. Such lists are not efficient for tasks like monitoring and analyzing order states, for example. This work describes the development and implementation of such an information system, which provides easy access to complex information spaces by simplifying the content and providing an interactive and visual access. To do this we are following a human centered design process with respect to digital engineering recommendations. Therefore, we identified requirements such as application aspects in our data, elements to visualize, and search & filter methods. The concept was prototypically implemented using a fictional logistics scenario. Furthermore, we used the early stage prototype to interview experts in order to get first evaluation results. These results are used for a discussion, which is finally the base for improvements in our future work.

1.1 Motivation

In many domains, nowadays much more data and information is available than before. Beyond that, the goals for work, such as safety related decisions, cannot be found in a single value or data-set. Ordinarily, these kinds of goals are related to many values, which are only making sense in specific combinations. In such situations rather direct and simple data visualization is neither effective nor efficient. The reason for this is that either the visualization itself is difficult to read or various single visualizations are needed for displaying all required values. The concept of digital engineering tries to overcome such restrictions by many isolated applications and by the development of solutions, which are integrating complex digital environments.

Challenges for digital engineering. The concept of digital engineering includes a broad range of topics, such as embedded technology, efficiency in production, safety and security. However, in our view this includes the requirement for an improved transparency and access across various information spaces. This includes for example the support of digital systems over as many phases as possible of the product lifecycle. The system should support a seamless access to related information with the possibility for manipulating, searching and analyzing relevant information. Furthermore, in complex production environments the role of a user should be considered in application design. This includes the domain and role dependent information visualization, flexible interaction techniques and the support for digital communication of and interaction with work results.

Application: A Logistics Scenario. Our main application domain is the logistics for goods transportation. Basically, the data space contains information of payloads in a specific scope, e.g. orders to a logistic transport company. In doing so we are focusing on a future scenario that enhances the data space by various sensor data.

The technical part of the scenario basically includes sensors and the ensured transmission and storage of these data. In our scenario sensors are attached to the containers and register global position, temperature, airpressure, acceleration and the position in space. Also a contact-free identification of the container is possible, e.g. by RFID [9] or by NFC [10]. Furthermore, we take for granted that the containers have a radio link to a central computer system for data storage and logging at times. Most of these features are realized in research environments [13] and will possibly become standard in the near future (see also chapter 3). However, we are using synthetic and simulated data respectively for our research due to the high expense for a full-featured assembly.

As mentioned before we are focusing on the application domain of a transport company or similar. In this domain, we mainly indentified search and analysis tasks. One possible usecase is the quality inspection of specific orders and payloads, respectively. Here, the access to a definable selection of payloads as well as the free browsing within a list of orders should be possible. A definable selection could be typically the state of an order, a time range or a location. Furthermore, the free search for textual expressions is an often used method, especially if there is just a part of a product name known. Beyond that, the inspection of orders can serve the purpose of ensuring safety and security aspects. In this case, a user should have special privileges to access such sensitive information. These privileges must differ from normal user rights.

2. REQUIREMENTS

The mentioned scenario was developed and discussed with domain experts. We considered possible requirements of future end users and logistic operators as well. Based on interviews with logistic experts the following functional requirements have been identified:

The overall goal of development by digital engineering in the logistics domain is to provide customers and service providers with a high degree of transparency within the heterogeneous environment. With transparency we mean to cover complex information and integrate these data sources into goal oriented views. Such user groups are not primarily interested in textual details of transported goods and their states. They rather want to see answers for everyday problems, such as to clarify responsibilities in case of intermodal transport chains. Here, different service providers are responsible for a specific payload.

Furthermore, different transportation goods vary in quality, quantity and other specific characteristics. Usually, users need to deal with a high amount of heterogeneous data, which need to be managed. An ergonomic possibility of direct manipulation in order to navigate, browse, search, filter and explore these data-sets is needed.

Since this system is supposed to be used for monitoring purposes also a single user should be able to use the application.

3. RELATED WORK

The used scenario is often content of research work. For example Jedermann et al. [13] described an autonomous sensor system in logistics. In technical manner, this situation is similar to ours. However, the article describes less visualization work than an agent environment for intelligent freight control. In this work, the presentation of the state of each container for an interactive application is in focus. Therefore the visualization of complex information is important to preserve an easy access for interactive task achievement in means of browsing, searching and filtering. Another example for a browsing application on tracked transportation goods, which are identifiable by RFID, is described in by Siror et al. [26].

3.1 Data Description and Exchange

The storage of data in the domain of logistics depends on the used management system, such as [3]. Therefore, various storage formats can be found in practice. However the EDIFACT [28] standard is commonly used for data exchange for administration, commerce and transport. This standard regularizes the electronic communication for economy applications. There are also subsets of messages defined, which are domain-specific. The subset for transportation and logistics is the EDIFOR standard, which is also defined in XML [11].

3.2 Visualization

To our knowledge, the information visualization as well as the interactive visualization is sparsely applied in the domain of logistics. However, the work of Wenzel et al. [29] shows a fundamental taxonomy of visualization techniques for simulation in production and logistics, which also considers different application fields and target groups. For this work, solutions are of interest, which are in particular using geo-referenced visualization.

Geo-referenced Visualization in Logistics Systems for the visualization of geographic data can be found within the domain of geographic information systems (GIS). Such information systems often work solely with geographic data, such as ground elevation, soil composition or climatic and weather data (e.g. Schreier et al [24] and Nikolaou [17]). Beyond that, information and statistics of populations are connected with locations and areas. In this work, used information has no geological origin. Furthermore the information is referenced to items like streets and similar infrastructure.

An overview for the geo-referenced visualization of a complex information space gives Chen et al. [4]. In this work, the application domain is public health surveillance. However, many examples provided in [4] are showing the importance for providing many different references for visualization, such as time or abstract hierarchical structures of organizations, to supply task- or goal-oriented work in complex information spaces

An application for routing simulation for city logistics can be found in Bacelò et al. [1], which mainly uses street map visualizations. Furthermore, georeferenced visualizations for logistics using three-dimensional content can be found in [14]. An interactive visualization application on mobile devices can be found in [11].

Process Visualization Process visualization is manly applied on business, softwareprocesses and other engineering domains [2][22][23]. Thereby, graphs are often used to show sequences, procedures and correlations [22]. Furthermore, existing visualizations are visually encoding rules and tests, such as are known from traditional UML diagrams [19].

3.3 Searching and Filtering

Current logistics monitoring systems like [3][16][27] allow navigating through item lists. When users search for a specific item this is the most inefficient method because of its sequential character. Open text search on the other side is rarely used since complex and dynamic index structures, which will be updated every time the data is changing, are needed. Therefore in most cases the data is organized in a database. A huge disadvantage of database queries is that they return just perfectly matching results to users [25]. They do not build ranked lists like in information retrieval. Therefore users do not get similar results to their query and typing errors, similar terms and specific use contexts will not be considered. But this can be extremely helpful to solve complex problem analyzing tasks as focused on in our scenario (also mentioned in [15]).

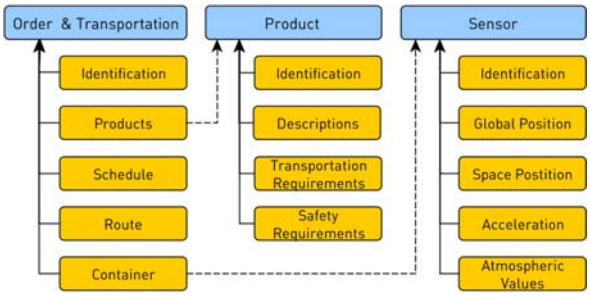

Figure 1. Schematic illustration of the information categories.

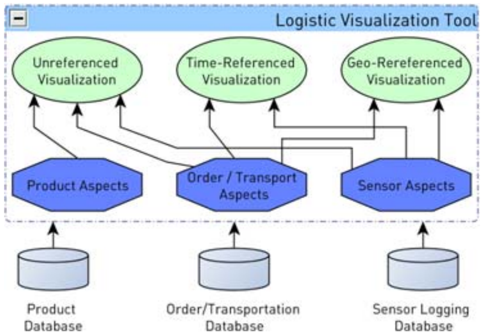

Figure 2. Database management.

4. CONCEPTUAL DESIGN

Based on the requirements we designed the whole system environment for our research. We started with the data and information design as foundation for all further work. After this, we choose visualization methods to provide the contextual access to the information. Finally, we designed the linkage of visualizations by user interaction.

4.1 Data Model

Basically, there are three important data spaces that we identified in our scenario: product items, information and processes of transportation, and the data of sensor logging. A simplified overview of the spaces and their main content can be found in Figure 1 and Figure 2. All three data spaces are integrated while working on typical tasks. Similar to general information visualization tasks we are focusing on the tasks browsing, searching and analyzing.

Therefore, a central role plays the data space containing information regarding order and transportation because it semantically connects all available spaces. As illustrated in Figure 1, this space stores data to handle transportation orders, which includes the item type, container for transportation and the processing state. Furthermore the route and scheduling information are stored within this space. We assume that the route is already defined, for example using criteria like in [1]. However, we include types for the order like “express” or “security” in order to differentiate types of processing from logistic processes. We strongly simplified the possible status of order and payload, respectively.

The data space of products basically contains information regarding special needs for transportation. All related requirements, such as the safety requirements of an order, are derived by descriptions here. Beyond that, the interpretation of sensor data is also related to the declared requirements for transportation in this data space.

As mentioned before, we assume that every container for product transportation is equipped with sensors. These sensors are logging relevant values over the whole transportation process. Based on product requirements, atmospheric conditions (e.g. temperature, humidity, and air pressure), slope of the underground and accelerations by shocks or collisions are needed. Furthermore the global position is logged so that all other measurements have a geographic reference. By using signals like from GPS [7], all values also have a globally unique timestamp.

4.2 Support for multiple views

We intend to support multiple views on the used information model for logistic purposes simultaneously. As mentioned in the section before, the date model allows us to express various aspects within different visualizations.

View on global positions. Every item of our data space contains or can be linked to a global position. The data-set of a transportation order (including the process status) as well as sensor-events contains a global position, whereas the product items can be manually linked with a position, for example by retrieving the approximate position of a postal address. However, the omnipresence of global positions allows us to display all items of our data space within geo-referenced visualization.

View on time. All information in the described data space, except for the product descriptions, contains both: a position and a point in time. Therefore, we can show all these information also in the context of time, e.g. by using a timeline containing representations of the sensor events or transportation statuses.

Views on processes. The transportation of goods must fulfill various requirements from the client, which include special work steps and inspections. The resulting process model is often quite complex. Furthermore, the process oriented order management is a criterion for quality rating within this domain. Therefore, the logistic of goods transportation uses process plans to define the handling of all possible orders. The described processes are important for monitoring and analysis of current transportations and completed orders. Basically, the display of a process status can be different. On the one hand, it is possible to display the *actual* status of an order. On the other hand, it is possible to display the *change* of a process status, for example as an event. A combination of both cases is also possible, to highlight the phase transition of an item. However, the number of phases and statuses depends on supported transportation options and their regarding processes. To keep the scenario simple at the beginning, we designed a simplified status model, which includes the states: start, pause and end. Such events can be visualized in a geographical context, within the timeline and in a specialized status log.

Views on signal data. We do not want the support of a direct and abstract view to logged signal data, because we try to keep up the concept of visualization by context. Basically, we show abnormal signals in form of events, which are finally displayed. An abnormal signal is a sensor value that is out of a defined interval of normal values. Furthermore each event implies a reference to the sensor type, which allows to find events by sensor type. A signal event can be seen and accessed in one of the provided visualizations and within the search results. The

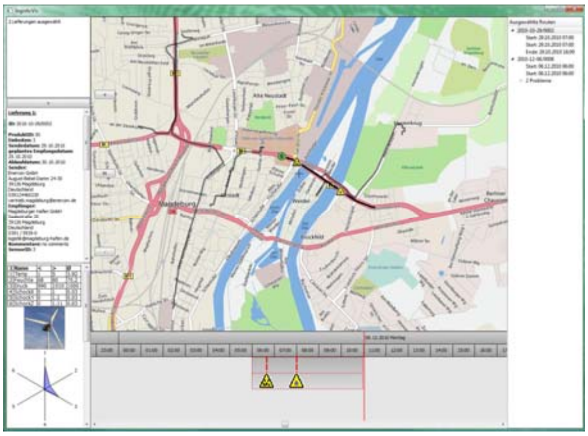

Figure 3. The main window of the prototype.

visualizations are displaying a type-describing icon (see Figure 3), whereas items at payload lists get a general visual mark to show conspicuity.

Interaction and view linkage. Basically we provide almost exclusively a visual access to the displayed transport and ordering information. This means that all views on the data do not use abstract lists or descriptive selection or navigation functions. Our environment for interaction primarily includes mouse and keyboard, because this is commonly used in business environments. However, selection and navigation activities should not result in the change of a single view, but rather all views should fit to these activities. For example, if a user selects a geographic area containing many routes of transportation orders by the mouse, the timeline also changes the view to show the selected orders (and vice versa). This allows an easy to use brushing technique by different contextual visualizations.

5. PROTOTYPICAL IMPLEMENTATION

We implemented a prototype to proof our concepts (see Figure 4). This prototype is implemented in C++ using the Qt Framework [18]. During the development of the prototype we were mindful to keep up a modular concept that allows us a flexible combination and rearranging of interface and software components.

5.1 Data Handling

The logistic data used by our prototype is locally stored in files, which follow a self-defined XML scheme. The used XML scheme is also useful for basic safety and verification checks. We do not adopt existing standards to maximize flexibility for this prototype. However, this type of data description allows us to easily adapt for potential future requirements, such as transformation in other XML dialects, the enhancement of the data space or the use of databases over a computer network.

We have two stages of data-sets within the application. The first data-set includes the loaded data and is the base for all further selection and filtering functions. The second data-set includes the result after a filter action. All views are displaying and highlighting a single selected payload or the filter results if available.

5.2 Views on data space

We realized the following views to provide a complete visual access to the available information: overview on all payloads, a detailed view of selected payloads, a geo-referenced view, a time-related view, and a visualization of the status log.

Figure 4. Geo-referenced visualization of route data and sensor events.

The detail view contains basic details of the order and the transported products. Therefore, the view shows general information of the product, such as size, weight and a photo. Furthermore, the condition of the container is displayed by a table as well as a star graph, which shows averaged sensor values.

5.3 Linking logistic data to geoinformation

As mentioned in section 4.2, we are able to use logistic data from transportation scheduling plans and logs as well as sensory data to visualize positional information.

Basically transportation routes like streets and railways are suitable geographic references for our scenario. Therefore we use public services in the World-Wide-Web to visualize street map information. Such maps are provided for example by services like OpenStreetMap [21], Google Maps [6] or Yahoo Maps [30]. In particular we are able to use web map services (WMS) [20], which provide more specialized and configurable maps.

Within the map view routes are visualized by line paths. Additionally, process states such as start, end and waiting positions are displayed by icons. Beyond that additional icons show events of critical sensor values. The icons are corresponding to the type of the critical sensor event, such as a strong shock or high humidity.

5.4 Providing time references

Our prototype uses the commonly used timeline metaphor to provide a time related view on the data space (see Figure 5). Following this method all transportation orders can be displayed by their temporal order from left to right. A vertical line indicats the current position in time. Concurrent orders will be displayed with a vertical shift. This view contains all orders in scope. Therefore finished orders as well as planned transportation in future are also visible. The timeline shows all sensor events by icons. The icons are the same as in all other views for better recognition.

The timeline provides an interactive access for the user. The view automatically zooms and pans to items, which have been selected outside of this view. Furthermore every displayed item can be selected separately or in a group. For group selection the user can freely mark a time interval. Of course, after a selection, all other

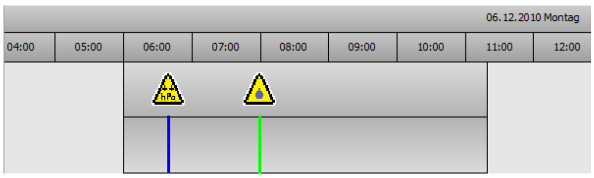

Figure 5. Screenshot of the interactive timeline view.

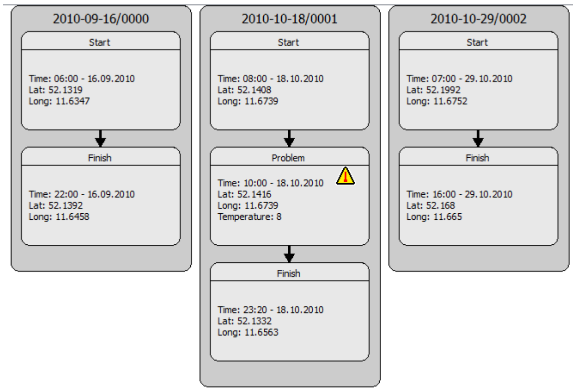

Figure 6. Visualization of the status log including state and sensor events.

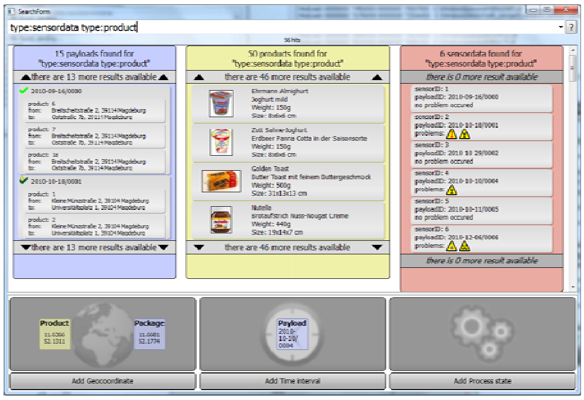

Figure 7. Screenshot of the text and keyword search interface. On top is the text input line, below the retrieved results from the databases and at the bottom the area to define the filter.

views are updating their focused items.

5.5 View on process information

As mentioned before logistic processes can become complex to cover the broad range of requirements on goods transportation. Because of this complexity we simplified the representation of processes in the system. We decided to present process events only in order to display the transition from one process phase to another. The view on processes shows these events in form of a status log for first tests (see Figure 6). The simplified view shows a box for each reached process phase and all statuses of a transportation order. Furthermore, we add sensor events as special status items. Future orders are displayed with the planned schedule information.

Basically, the horizontal order of the displayed payloads is based on the chronological order if no payload was selected or no filter is defined. Selected items are always displayed on the left. The result set of a filter operation uses a combination of both sorting methods. Every change of the order happens in an animated way to keep up the orientation for the user.

5.6 Information Management

The complete content within the information space, which is described in section 4.1, is used to create a search index. We used CLucene [5], an open-source text search engine, in order to index all the information items used in this logistics scenario. Furthermore, we used this search engine for realizing the search and filtering features.

Searching and Filtering Approach. The proposed tool features a basic text search with auto complete functionality shown on top of Figure 7. Presented results can be filtered in a next step. Setting filters gives users the opportunity to refine their information need. In contrast to other filtering approaches, as mentioned in [8], our tool enables users to choose from hard and vague filters. Unlike hard filters, vague filters offer fuzziness functionality. This is also supported by the free text search. To create filter criteria, the user can drag single items like a product, a payload containing several products or single sensor events from the result listing to a drop area at the bottom of the screen (see Figure 7). Here, the user chooses from location-based, time-based or process-oriented filters (from left to right). For example, a user might be interested in a timeframe, which covers three specific payloads. To filter for this time interval the user needs to drag those payloads onto the drop area showing the time symbol. The user is able to refine the filter by dropping further items such as product items onto the area. Furthermore it is possible to define filter criteria by pressing one of the buttons that are placed below each filter area (see at bottom of Figure 7). Each time a dialog window asks for filter parameters and after confirmation a filter element will appear. Every filter element can be removed and exchanged by simple drag-and-drop. The filter result will be immediately shown in the geo-referenced and time-oriented visualizations.

Result Presentation. Unlike ordinary text listings, the user of our tool gets results in multiple ways. The search results within the database are grouped in three result categories following the database management: payload results, product results and abnormal sensor-event results. Furthermore, each result is highlighted in each type of visualization. Related information will be shown in a map by route highlighting, in the timeline and within the process visualization.

6. EVALUATION

We evaluated the prototype by using the method of *free interviewing.* We asked three experts, who covered the domains information retrieval, interaction design and logistics. We presented and explained all features of the system mentioned in this work. All experts saw the same presentation. After this presentation, all experts were asked to name problems and possible solutions. Furthermore, all experts were interviewed alone to get more detailed feedback. The following list shows the summarized feedback.

Search The expert emphazised the interactivity between searching, filtering and item selectition in different areas as a good concept. However, he wishes a more integrated view between the two windows, searching & filtering and browsing & navigating, and no separation into two single windows. This might improve the interactive and context sensitive character of this application. Furthermore, he asked for some missing functionality: Saving past searches and their coresponding results, backtracking functionality (undo), possibility to identify comparable problems or familiar events in the past and representation of limited ressources (e.g. the limited number of trucks owned by a logistic company).

Result presentation The expert liked the possibility of switching between different visualizations like from map view to process view and back. This supports different types of users and use contexts. But he critically mentioned the missing function keep a certain view as frozen in order to browse another aspect without directly changing the view. This might be helpful for users to fulfill subtasks or to compare certain information to each other.

Domain application The expert rated the general functionality of the prototype as very good. The prototype might be helpful especially for controllers and departmental managers. But the expert identified a need for improvement with regard to the support of an internal logistics scenario, which considers stockpiling time, place and mode. For example, the support for storage protocols is currently missing. Also the initial map view was found to be more likely a second level view mode. The first view mode for logistics should be the process-oriented view. Furthermore, he stated that there might be intermodal transportation chains, which require the support of different roles of users since different users might not be allowed to see each single step of a more complex transportation process. An examplary use case mentioned by the expert is the transport of temperature sensitive products which need to be cooled or even stick to a certain temperature during delivery, such as pharmaceutic products like vaccines.

7. DISCUSSION AND FUTURE WORK

For this prototype we started with a rather simple scenario and combined it with the needs for digital engineering. With these requirements we developed a concept to provide a user with visual access to the complete data space. However, the feedback of the experts shows that the approach for the concept seems to be valid. Otherwise, we need to enhance the scenario by more user roles and requirements from logistics. With these enhancements this prototype could be a more valuable example for real applications.

In order to overcome problems by the separate filter interface, we plan to create a more integrated application screen. Therefore, we enhance the browsing feature through payloads by a slot for searching & filtering. Furthermore, we want to enhance the logistic environment in our scenario by the support for intermodal transportation chains, which is also useful to enhance our process and status model. Finally, we need to take different user roles into consideration to underline security aspects. Although the differentiation of user rights was originally included in the scenario, the actual prototype does not support this feature. The expert feedback underlines the need for rights management. Therefore, we will create an enhanced scenario, which takes more safety and security aspects into consideration, for example when delivering sensible drugs.

Moreover, the source can switch from files to XML databases without changing the description scheme to enhance performance and flexibility of data storage. Since the presented work is still in progress, we are currently focusing on system enhancement and stabilization following the results. Within the next improvement steps we will also include end user participation and usability tests to proof our prototype.

8. CONCLUSION

In this paper, we presented an information system for a logistics scenario that includes geo-referenced visualizations as well as time-referenced visualizations. We considered the requirements for digital engineering as well as for user centered development. The realized system seamlessly integrates various data sources and provides visual access to the large and heterogeneous data space. The resulting data space is visualized by different referenced views. Furthermore, we realized an interface, which supports users by search and filter tasks. Thereby, all provided views are immediately reacting on a user's selection or a changing filter result. Furthermore, we evaluated the prototype by interviewing experts. The results of the evaluation provided us with valuable feedback for the improvement and further development of the system.

9. ACKNOWLEDGMENTS

The authors are funded by the German Ministry of Education and Science (BMBF) within the ViERforES II project (no. 01IM10002B). We thank Patrick Saalfeld for his implementation work.

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