Visualization For Train Management: Improving Overviews in Safety-critical Control Room Environments

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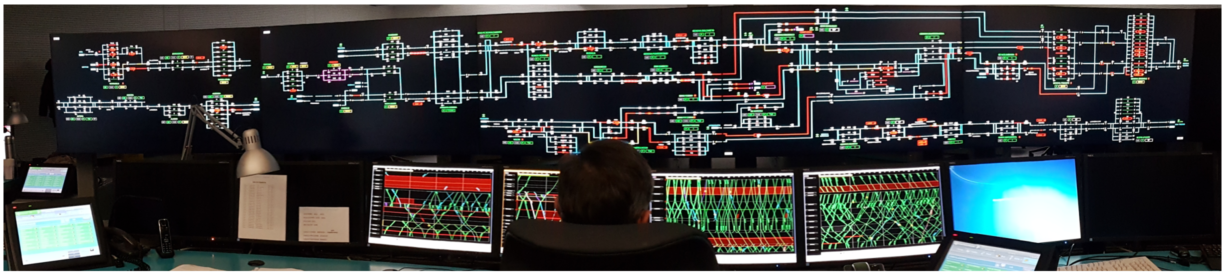

Figure 1: Rail System Operator in front of multiple complex displays. Keeping an informed overview is challenging.

Abstract

Control centers for safety-critical infrastructures such as train systems rely on proven, time-tested visualizations to support the decision-making process of the operators. Yet, increasing traffic poses new challenges these systems were not designed for. We describe an incremental visualization design process to adapt Train Management Systems to new tasks, while carefully building on existing techniques to ensure a continuous work environment for operators without or little additional training. The main focus of this work-in-progress is to unobtrusively provide additional contextual information to operators and to incorporate multi-perspective prediction models helping operators to efficiently make informed decisions.

Index Terms: Visual Analytics; Visualization Systems and Tools

1 Introduction

Managing critical infrastructures is a sensitive task mostly carried out in control centers. Operators in complex systems such as air traffic management or rail service organization work with time-tested, proven visualization systems that were specifically designed to support an operator's task as efficiently as possible. Thus, as changes to these systems could potentially have fatal consequences, the continuous development is a highly conservative process and the control room design process guided by exhaustive guidelines [3]. Yet, with increasing demands, especially in the transportation sector, current systems are reaching their limits in supporting operators in efficient decision making.

The limitations of common approaches are mainly caused by the way the role of an operator is seen: The information presented to an operator is purely about the current status of the system, and no automatic interpretation is provided to aid the user, as an operator should not depend on conclusions drawn by a possibly error-prone algorithm.

Yet, a paradigm shift stands out: While the operator will still be in charge to meet final decisions, data sources and machine learning approaches have become reliable enough to provide recommendations and alternatives to operators to verify or change his judgment [1]. For example, integrating a delayed train into the regular schedule can have consequences for many other trains, too. When trying to find a solution to the problem, there is no single ideal solution, but often, several scenarios are conceivable. For example, the operator could optimize for the lowest aggregated delay in the rail network, or for the least additional cost or least affected passengers. Overseeing several complex solutions and comparing them is very challenging to do manually, so prediction models could help to provide alternatives for operators.

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2 The Stateless Operator

Ideally, an operator would make decisions only on raw information provided to her and would not need to resort to his knowledge of previous similar cases. We call this the concept the *stateless operator*, who is seamlessly able to continue managing his tasks even after interruptions. To achieve this goal, it is not only necessary to provide the operator with the right information at the right time, but also to efficiently steer her attention through large and complex displays as shown in Figure 1.

3 Approaches

Figure 1 shows that the workstation of the operator consists of multiple systems and visualizations. The systems are a separation of concerns. Each system supports the user in specific tasks. We concentrate our efforts in three different tasks. In general, we aim to include additional information, reduce clutter and distracting elements, and include measures to steer the awareness of the operator.

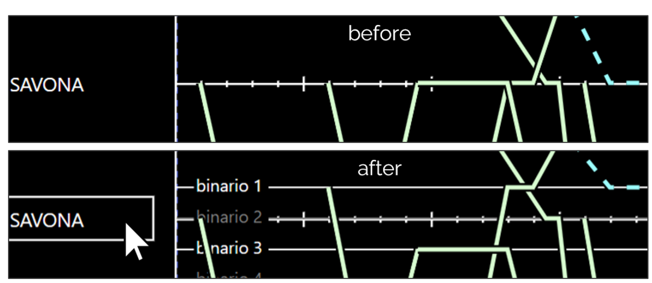

Figure 2: Improved schedule view with interactive platform visualization and adapted layout.

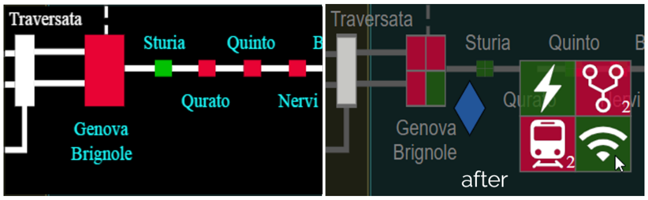

Figure 3: Left: Old layout. Right: Added contextual icons and semantic alert view. The numbers relate to the amount of alerts present at this station, the color to their severity.

3.1 Task 1 - Decision Support System for Rail-Conflict Resolution

The purpose of this visualization (Figure 1, four monitors on the bottom) is to inform the operator about the past and future train schedule in a specific region. The temporal dimension is mapped onto the x-axis whereas different stations are vertically separated. Trains and their schedules are visualized with colored paths that connect the stations. The colors separate the type of train (e.g., person & freight). The visualization displays conflicts in the schedule. If these conflicts cannot be resolved automatically, the operator has to decide the precedence of the trains. The visualization is cluttered as the time schedule of the trains is typically tight. We are extending this visualization with interactions such as zooming and panning enabling the operator to focus on details in the schedule. Currently, the operator does not receive any information about the platform (it: binario) the train is using in a train station. Adding this information in a static visualization would increase the clutter. Instead, the operator can hover station labels to trigger the appearance of the contained platforms. The paths of the trains are transformed in an animation to their respective platforms (Figure 2).

With the provided prediction models, we are currently working to show alternatives to the current future schedule. This will help the operator to see the impact of her decision in a detailed manner and for specific trains. We also aim to visualize additional metrics of the prediction models to assist the operator with the overall impact of an decision such as global delay and costs.

3.2 Task 2 - Alert Management and Prioritization System for AMS

Every day, thousands of alerts about broken assets reach the control center. Currently, no difference is made between a broken light and a major power failure, leaving operators in the dark on how to prioritize the incoming alerts. We propose multiple improvements in the alert overview display (excerpts in Figure 3): We visualize four semantic categories representing the first level of a hierarchy to inform the operator what kind of system is currently failing in a train station. A dynamically provided glyph shows additional information of the hierarchy and can be navigated through rubber-sheet navigation [2]. Stations can be annotated with general information icons, such as ongoing maintenance or external impact factors such as high temperature Further, we provide temporal pattern analytics for each station to detect non-observable second-level faults causing the displayed alerts. As well, a sunburst-based hierarchy exploration visualization is employed to determine fault dependencies. Both extensions help the operator in finding root-causes for failed systems.

3.3 Task 3 - Improving the TMS and Directing the Awareness of the Operator

Focusing on single points of interest in a large topological overview such as in Figure 1 (screens on top) is strenuous and time-consuming for operators. Current displays do not support any kind of specific highlighting and are hardly able to raise an operator's awareness in case of unexpected events. As suggested in the comparison in

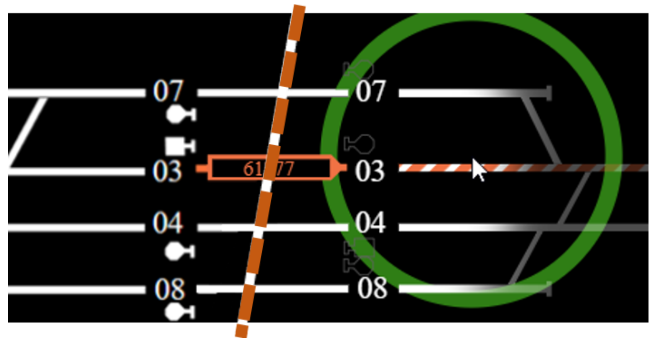

Figure 4: Left: Old layout. Right: View fades out in uninteresting areas with no trains, unused signals are only outlined and a reverse-ping metaphor attracts the analyst's attention.

Figure 4, we introduce a green inverted radar ping metaphor to attract the operator's awareness to points of interest. Further, we reduce the opacity of parts of the display where no train or event is present, thus allowing an operator to focus on important areas faster. As well, inactive symbols such as unused signals are reduced visually by only rendering their outlines. In the current systems many alternating state-changes are visualized through blinking segments of the rails or trains. We employ less obtrusive animations such as a slowly transitioning stripe pattern to visualize the occupancy of segments.

4 Conclusion

The challenge in our work is to satisfy requirements for improvement while keeping as much as possible to the existing system for safety reasons. We are at the beginning of a careful, feedback-driven and iterative design process and envision to roll out our improvements in small steps over longer periods of time. During this process, constant monitoring and evaluation of the operator's ability to make use of the added functionality and the improvement in efficiency are needed. The long-term goal is to develop a system which presents only the information relevant to a decision and possible solutions under different optimization aspects. The operator should ideally not require any contextual or previous knowledge, and be able to take over a complex management scenario within seconds.

Acknowledgments

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