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Assessing Immersive Analytics to Guide Decision-Making in the Railway Safety Sector

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Abstract

This short paper presents the research conducted on immersive analytics (IA) and proposes that IA can support decision making in the railway sector. The first section highlights the railway safety data challenges and the complexity of data visualizations. In the following sections, we present the design science research methodology, the created 3D IA prototype and experiment outcomes to evaluate the effects of IA in the railway safety sector. Lastly, we present the results and contributions of the IA experiments.

Keywords: railway, safety, immersive analytics, 3D, visualizations.

1 Introduction

Lee et al. [1] define immersive analytics (IA) as an investigation of how new interaction and display technologies can support analytical reasoning and decision making. IA aims to create and provide interfaces that allow users to support real-world analytics activities using virtual reality, augmented reality and mixed reality applications. This paper investigates whether immersive analytics through a head-mounted display (HMD; i.e. mixed reality headset) helps decision-makers understand railway safety data, particularly driver behaviour in foreign language communication [2].

The railway sector today collects a large amount of data, which is why the topic of data analysis has become of considerable interest [3]. The infrastructural characteristics of railway systems allow the collection of different types of data from various sources. For example, audio, video, image or numerical data are collected from the train and the infrastructure [4]. Mainly, the collected data is used for three purposes: *(i) to organize the proper maintenance of the infrastructure, (ii) to enable the best functioning of the processes,* and *(iii) to ensure that the company has the highest safety standards [3].*

Even though various visualization tools exist today, dealing with a large amount of data from different sources creates challenges in visualizing information during safety-related decision-making processes. In fact, according to Dimara et al. [5], who conducted studies on decision-makers, the main problem with data visualization during decision making is that analysts have to present data from different sources using complex visualizations techniques, thus leading decision-makers not to understand the information correctly. There may be various reasons why a visualization may be complex, e.g. selecting a representation that is too complex, ambiguous or difficult to understand or understandable only by specific users [6].

To curb the problem of data visualization complexity in all aspects, there is a need to assess visualization tools that facilitate the understanding of information. In this paper, we propose immersive visualizations to address these issues. The main advantage of using an immersive visualization is to add various layers of information using spatial representation through an HMD atop the viewer's point of view. According to Donalek et al. [7], showing data in 3D make the data and its relationships more intuitive to understand the content. Dodge et al. [8] state that using an additional dimension gives the user the ability to see objects in a familiar way reducing the cognitive effort required to interpret the image [9].

2 Methods

We implemented the design science research methodology [10] with a pragmatic and deductive approach to determine the veracity of the hypothesis: An immersive analytics system as a data visualization method increases decision-makers' understanding of driver behaviour information in railway safety. In order to study the statement comprehensively, a tentative design and prototype are suggested.

In the literature review, the limitations and shortcomings of traditional information visualizations are analyzed [5, 6, 11], how the transformation of information from data interpretation to decision making occurs [9, 12, 13] and what actors are involved in this process [5, 14]. Moreover, the capabilities and potential of immersive systems for information visualization to lay the foundations for creating the prototype have been documented [1, 7, 8, 15, 16, 17].

Subsequently, a prototype is created with a model railway safety scenario highlighted with 3D visualization projected through HMD. Simulation-based model railway data contained helpful information for making train- and infrastructure-related safety decisions, highlighting data points on the driving behaviour of a train driver in terms of driving speed, communication with the dispatcher, signaling and geographical data.

In order to evaluate whether the use of HMD helps decision-makers understand data on rail safety, a two-hour focus group session was conducted with six decision-makers from the railway company who were shown the information first in 2D and then in 3D visualization format using the prototype. Participants in the study included: a security expert, an analyst, two project managers, a management consultant and a chief engineer. Eleven open-ended questions were asked during the focus group about the highlights and nuances between the two visualizations. The session audio is recorded and transcribed in electronic format and analyzed and coded with the qualitative research method.

Moreover, to better understand the 3D spatial visualizations, four problems of visualization complexity based on Bresciani & Eppler [6] were analyzed: *(i) over complexity due to the chosen design*, *(ii) difficult to understand due to the complexity of the data*, *(iii) ambiguity of the visualization due to the choice of objects displayed*, and lastly, *(iv) cryptic encoding whereby the visualization used is not understandable by every audience.*

3 Results

Prototype:
The prototype is designed on first generation Microsoft Hololens using a 3D viewer application to display the terrain map, railway tracks and corresponding velocity of the train through a traced 3D line graph. Additionally, audio from the dispatcher communication, signals and signage from the track are positioned on the precise spot (Fig. 1). The prototype uses the full potential of the HMD system to simplify the complexity and avoid the visualization problems identified in the previous section. In order to assess the support of IA in railway safety, the prototype is positioned between the knowledge and decision-making phases, i.e. at a state when the user synthesizes the data, prioritizes the information and transforms it into knowledge with which to make decisions [13].

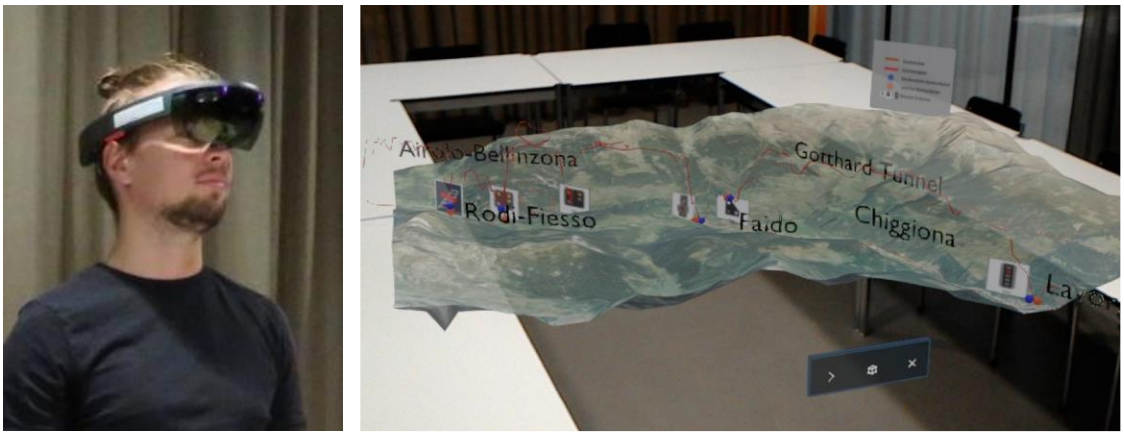

Figure 1. User with first generation Microsoft Hololens (left). 3D visualization as seen through the HMD (right).

Experiment:
Focus group participants stated that 2D visualizations are broadly used within their company, and for them, it was the first time someone proposed a 3D map visualization with the corresponding geo-location of the sourced information. The visualization was perceived with novelty as a mixture of the line graph and mapping in a spatial context. Participants discussed that the technology helps to display information more intuitively. However, arguments of doubt were expressed regarding the use of HMDs in the working environment in terms of social acceptance.

The security expert and project manager stated that 2D visualizations utilized to represent space, time, and events are too slow and that a 3D visualization allows a faster understanding of information. They also stated that mapped data points allow users to understand better the events taking place in the selected area of the railway. This statement has also been confirmed by Bravo & Maier [17], who expressed that immersive systems improve the understanding of data. Despite considering 3D visualizations more straightforward, only the analyst stated that he preferred to interpret data in 2D.

4 Conclusions and Contributions

The results of the focus group showed that most of the participants found the visualization helpful in analyzing the drivers' behaviour, both as a prevention tool and as a post-accident analysis tool. Furthermore, most focus group participants agreed that visualizing information with HMD was more understandable, quicker, and more intuitive than 2D visualization, with only one participant having a contrary opinion. Finally, 3D visualization proved to be a more comprehensive tool even for an audience with different backgrounds, including those not experts in railway safety.

For the characteristics of the focus group, the four previously mentioned visualization complexity problems were not observed independently. From the analysis of the evaluation session, it can be suggested that the prototype does not incur the problem of *difficulty of comprehension due to the excessive relationships of the data* and *the problem of the excessive complexity of the visualization*. As far as *the problem of cryptic coding* is concerned, there was a statement by one participant that rules this out. The analyst stated that the IA can be a useful method for non-experts because it ensures that those unfamiliar with the topic can understand the reports well. The last point stating that visualization may not be understood due to *ambiguity*, was also missing. No participant asked or questioned the objects displayed in the tool.

Complexity can be caused by various factors such as the representation being too complex, ambiguous, difficult to understand or only understood by a particular audience [6]. Dealing with a large amount of data from different sources can be a challenge in terms of visualization [11]. However, various visualization methods and tools can be used during decision-making processes. According to Dimara et al. [5], analysts have difficulties showing data in a simplified way, and decision-makers complain about the complexity of the data shown. The broader use of novel visualization techniques such as IA seems to be the solution to these types of issues, as, according to Donalek et al. [7], it can help the understanding of information.

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