MASARYKOVA UNIVERZITA

Annex No. 11 to the MU Directive on Habilitation Procedures and Professor Appointment Procedures

Habilitation Thesis Reviewer's Report

Masaryk University Faculty	Faculty of Informatics
Procedure field	Informatics
Applicant	RNDr. Radek Ošlejšek, Ph.D.
Applicant's home unit, institution	Faculty informatics, Masaryk University
Habilitation thesis	Data-Driven Exploratory Interactions and Visual Analysis
Reviewer	Univ.-Prof. Dr.rer.nat. **Tobias Schreck,** M.Sc.
Reviewer's home unit, institution	Graz University of Technology, Institute of Computer Graphics and Knowledge Visualisation, Graz, Austria

In his habilitation thesis, RNDr. Radek Ošlejšek, Ph.D. presents research carried out in two main areas. In *Interactive Exploration of Images*, a set of techniques for presenting, searching and creating image content, designed specifically for impaired users, is introduced. In *Visual Exploration and Analysis in Cybersecurity*, the design and implementation of an architecture for conducting cybersecurity exercises is presented. In addition, requirements and best practices for planning and analysis of exercises, including use of data visualization techniques, are discussed. The thesis comprises an introductory chapter, summarizing the results in each area, which are based on eleven conference proceedings papers co-authored by Dr. Ošlejšek. Results in the former area are represented by six papers published between 2006-2014, and five papers published between 2015-2018. I will comment on both research areas in the following, and then summarize my report.

In *Interactive Exploration of Images*, a relevant and important problem, namely, supporting impaired users in working with digital images is addressed. The work assumes that users are not able to visually perceive image content, but are able to hear, speak, and type. The presented research is encompassing in that it covers a cycle of key tasks in image use: creation, presentation, and searching. The work requires that certain semantic data structures are given. These include parameterized shape creation methods, which allows blind users to render image objects by specification of object and appearance parameters. Also, the availability of natural language interaction methods is assumed, which is used to guide the user through the image creation process by means of a question-answer process. Thirdly, the work assumes that a suitable ontology of possible image elements is available. This in turn is used to automatically verbalize image objects to users. A set of methods for users to query image content is proposed; they include region-based navigation and relation-based navigation within the image, based on a grid of image regions, or metadata including image annotations and image segmentations. Besides the verbalization of image content based on ontologies and image annotations, sonification in proposed. Specifically, the pixel contents of a selected area in a raster image are

first mapped to a set of two basic colors. Then, the image area is serialized to sound by mapping the basic color values to frequency and timbre in the sound output.
The set of works shows how a complete workflow for image use by blind persons can be set up, including implementation details pertaining to the inclusion of annotations in the SVG file format. It describes well the proposed concepts, and design alternatives, e.g., for user navigation. Some of the approaches have been implemented and made subject to user evaluation. Based on feedback from users, including students and blind persons, the methods are shown to be applicable in principle. The framework relies on the availability of semantic information, including image annotations and procedural graphics. In that, the coverage of the image space accessible to users depends on the amount of semantic information predefined. The framework is a basis for potential interesting future work. I presume it could be easily extended by current machine learning and computer vision approaches, which may attenuate the approaches' dependability of semantic information, by automatic annotation and image classification techniques, and use of large-scale image content available on the web and in social media. A topic in its own would be the experimental evaluation of the sonification approaches considered. It would be interesting to conduct more evaluation on how well users can actually reconstruct a mental image from the sonified image pixels, how much training efforts is required, and which differences would exist between users born blind or who became blind later on. While the thesis presents the basic mechanisms for sonification, it leaves open to some extent the question of effectiveness of the chosen approach.

In *Visual Exploration and Analysis in Cybersecurity*, a relevant and challenging problem is addressed. The creation and conduction of cybersecurity exercises is a highly complex and demanding task, involving many organizational, technical and domain-specific challenges. Dr. Ošlejšek has worked with a team for several years in setting up an encompassing virtual infrastructure (KYPO cyber range) for running cyber exercises comprising cyber challenges worked on by teams of defenders, attackers, managers and observers. The presented publications address the variety of challenges in an encompassing way. The cyber range was built as a cloud-based infrastructure, and allows to model computer networks with applications to be defended and attacked by teams. The system is scalable an allows configuration for different scenarios. A set of use cases are described, which give a good overview of the types of exercises that can be run in principle. Dr. Ošlejšek gives a careful and encompassing discussion on existing cyber analysis infrastructure, placing KYPO in context. Design requirements are plausibly described, which have informed the design of KYPO.
In addition, this part of the habilitation thesis focuses on the use of visualization in analytical interfaces for running and evaluating cybersecurity exercises. Specifically, node-link diagrams are used to represent network topology and activity; a time-dependent 3D radar chart shows low-level network activity (bitrate, number of packets and flows); also, the participant success during an exercise in terms of penalties is visualized by an interactive line chart, which can be annotated with events. The techniques were deployed in several actual exercises, and user interviews were conducted on the usefulness of the visualization options. The results indicate that the visualizations are useful, including post-exercise discussion between students and trainers/observers. In addition, a number of relevant new requirements were identified from user interviews, such as adding context and detail to the event-based penalty view.
The contributions in this area are added to by framing cybersecurity exercises as a visual analytics problem. Following the knowledge generation model by Sacha et al., Dr. Ošlejšek identifies domain hypotheses and insights, which could be supported by visual analytics approaches. These include hypotheses about the previous knowledge of the exercise students,

their learning success, behavioral analysis, and situational awareness. Furthermore, relevant data, models and visualizations of exercises are framed for the model. A use case description concludes the discussion.
Besides the proposed infrastructure, this part of the thesis shows how data visualization can help to support the effectiveness of cybersecurity exercises. Several existing, possibly helpful visualization techniques are applied and evaluated in a rather new application context, and discussed accordingly. The part gives a careful application domain characterization and the evaluations show that visualization may be helpful for different user roles in exercises. As the application domain space is large, the proposed visualizations can naturally cover only some aspects of the problem, and they represent a choice made from a larger set of possible visualizations. For example, in network analysis also matrix- and pixel-oriented techniques or focus-and-context type interactions could be scalable alternatives. One detail I wondered about is the choice of the time-dependent 3D radar chart approach, and its acceptability and effectivity observed from users. Given possible occlusion and 3D interaction issues, alternatives like side-by-side layouts, or use of semi-transparency (see e.g., Fanea, Carpendale and Isenberg, InfoVis 2005) could be alternatives. While this thesis chapter gives an encompassing review and comparison of existing cyber exercise infrastructures, in general the design rationale of proposed visualization techniques is discussed at less detail. A more detailed survey and comparison with visualization techniques researched e.g., within the IEEE VizSec community, could have enriched the work, and offer additional options to explore.

To summarize my report, Dr. Ošlejšek has made contributions in two important applied research areas in Informatics. The publications show that a range of challenges was analyzed, and suitable solutions were proposed, and evaluated to some degree. A characteristic of the thesis is the central role of the domain user for understanding data. In that, the thesis contributes to several scientific areas, including visual computing, human-computer interaction, software architecture, and E-learning. I recommend **accepting** the presented habilitation thesis.

Reviewer's questions for the habilitation thesis defence (number of questions up to the reviewer)

ad Interactive Exploration of Images:

- Could you please discuss the scalability of the approaches based on semantic information? How large of an ontology is needed? Were users satisfied with the coverage of the image space they could work with?
- Could you please comment how your framework could accommodate recent results from computer vision and machine learning? Especially, considering automatic image classification approaches, and existence of databases like imagenet. How could the framework and users benefit from such developments?
- Social media is relying on a large degree on image content, but also, on user annotations and user relationships. It would be interesting to ask how the question-answering navigation could be extended to accommodate image and user relationship information for exploration of social media data. Could you please comment?
- How would you evaluate the sonification approach if you had more research resources? What are your expectations regarding comparison of sonification as compared to tactile approaches like applying pressure fields on human skin?

- Users often use recommender approaches for media access. How could you include recommender approaches to your framework?

ad Visual Exploration and Analysis in Cybersecurity:

- I found it interesting to use the Leapmotion tracker to support collaboration within a team. Could you please explain the interaction design you applied, and why? Are there evaluation results on the interaction design?
- Eye tracking has recently become of interest as a natural user interface device, besides being useful for application evaluation. Would it be possible to use eye tracking to infer on the current user tasks during a cybersecurity exercise?
- Users commented they would like to have more detail information on the penalty charts, including explanations why penalties were given. How do you see the line chart could be extended to this end? Which kind of data needs to be captured to this end?
- Regarding the knowledge generation model, you mention typically, statistical models are used, while more complex models of the user and the challenge are not yet. Could you please give some examples of which model (data analytics model) you would see as important to support in the future?

Conclusion

The habilitation thesis entitled "*Data-Driven Exploratory Interactions and Visual Analysis*" by Radek Ošlejšek ***fulfils*** *the* requirements expected of a habilitation thesis in the field of Informatics.

In Graz on 25.3.2019