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Evaluation of Doctoral Dissertation
“Automatic Point-feature Label Placement”
submitted by Ing. Petr Bobák.

Based on the appointment dated October 4, 2024, I am providing the evaluation of the doctoral dissertation submitted by Ing. Petr Bobák, entitled “Automatic Point-feature Label Placement” to the Faculty of Information Technology, Brno University of Technology.

Let me introduce myself. I am a Professor at King Abdullah University of Science and Technology (KAUST), affiliated with the Computer Science (CS) academic program within the Computer, Electrical and Mathematical Sciences and Engineering (CEMSE) division. My research expertise lies in 3D visualization and computer graphics, more broadly encompassed by the field of visual computing. I serve as an associate editor for IEEE Transactions on Visualization and Computer Graphics (TVCG), as an area chair for the IEEE VIS 2024 conference and as a chair for the IEEE Pacific VIS 2025 conference (TVCG journal track) – all leading venues for disseminating visualization research. I teach graduate-level courses at KAUST and served as Program Chair for CS during 2022-2023. During my academic activities, I have followed the scholarly outcome of Ing. Petr Bobák. Therefore, I am familiar with his research work.

The thesis is based on three research articles. One paper is published in *Elsevier's Computers and Graphics*, an international peer-reviewed scientific journal disseminating computer graphics and visualization research. The second paper has been published in *IEEE Transactions on Visualization and Computer Graphics*, a flagship journal for disseminating visualization research. This work was also presented at this year's IEEE Pacific VIS 2024 conference. The third article is currently submitted for publication. While the peer review process for this research article is not completed yet, I rate it as high-quality research upon reading the thesis. In summary, the thesis is based on new novel labeling data visualization techniques and their evaluation that go significantly beyond the state of the art. Every research project was conducted very rigorously. I do not doubt that Ing. Petr Bobák has become an experienced scholar capable of conducting high-quality research independently.

The thesis has an excellent structure. The introduction describes text labeling and how it evolved from scientific illustration, cartography, and technical drawing to today's use in graphics overlays during broadcasted sports events. The next chapter is a deep and rigorous review of existing labeling work covering nearly 200 prior works and presenting a very useful taxonomy. While there are survey articles on labeling in visualization, I rate

this survey as the best and suggest publishing it as a separate survey article in the future. The techniques are separated into internal and external labeling techniques with a broad spectrum of methods based on exhaustive search, greedy methods, or formal algorithms. Dynamic techniques are discussed separately for both internal and external labels. The literature review concludes with an overview of existing labeling guidelines, which are later contrasted with the third research work of the thesis.

The first presented research technique is based on external boundary labeling, which has better temporal stability than baseline methods. This paper presents a compelling and appealing label placement design coupled with a valuable technical contribution based on mixed integer programming. There are two scenarios, offline and online optimization processes, for placing the labels. The placement is effective in both cases and takes less screen estate than the baseline methods. On top of the solid technical contribution, this work has been rigorously evaluated by running multiple user studies, which have been very well designed, and the consecutive analysis has been well done, demonstrating the superiority of the label assignment to a related anchor when using the newly proposed method.

The next chapter is timely research and is my favorite among the presented research projects. The authors investigate whether the label placement, this time internal labeling in a cartographic scenario, can be formulated as a reinforcement learning problem. They propose their label placement learning strategy based on Multi-Agent Deep Reinforcement Learning. The policy is only trained on two agents; however, reinforcement learning can be generalized to configurations for hundreds of anchor placements with identical policy parameters. This capability is surprising and valuable. The reward structure is based on label overlap, quantified locally for each agent and globally for the complete set of agents. This shared policy leads to agents' collaborative behavior being achieved without explicit communication among the agents. Overall, reinforcement learning outperforms greedy approaches as it converges to a conflict-free layout. However, the processing is associated with high computational costs. The user study also reveals a strong user preference for reinforcement learning-based label placement compared to the greedy baseline methods. On a meta-level, this paper shows how complex reinforcement learning approaches can tackle visualization layout problems.

The fifth chapter presents a paper currently under review that evaluates the optimal placement of labels. Currently, the labels are placed inconsistently in referenced literature, and there needs to be a consensus on the labeling preference regarding where the label should be with respect to its anchor. The so-called "Position Priority Order" has been reviewed. A large-scale user study has been designed and conducted to reveal the actual user preference regarding label placement and the density of the textual labels. The study's outcome shows that users prefer approximately 12% of the screen estate to be occupied with the label information. In contrast, the label placement priority order is top, bottom, right, top-right, bottom-right, left, top-left, bottom-left. While peer-reviewing of this work has yet to be completed, it is worth publishing, as it is methodologically valid and asks a relevant visualization question. Importantly, it provides a guideline for using internal labels for various visualization applications.

Three research works presented in the thesis substantially contribute to visualization. Additionally, the survey is valuable on its own and is an additional contribution of this dissertation. In all presented research projects, there is always a valid problem to tackle, the technical solution is appropriate and novel, and it is exhaustively compared to the state-of-the-art methods in quantitative performance evaluation and user studies. Ing. Petr Bobák has clearly demonstrated his capacity as an independent researcher. In conclusion, from the position of an external reviewer, I propose to approve the dissertation in its current form and support the candidate in defending his thesis.

Sincerely,
Ivan Viola