Concepts and Techniques for 3D-Embedded Treemaps and their Application to Software Visualization

Dissertation

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submitted by **Daniel Limberger**

Potsdam, Germany

supervised by Prof. Dr. Jürgen Döllner
of the Computer Graphics Systems Group at the

Hasso Plattner Institute | Faculty of Digital Engineering | University of Potsdam

Abstract

This thesis addresses concepts and techniques for interactive visualization of hierarchical data using treemaps. It explores (1) how treemaps can be embedded in 3D space to improve their information content and expressiveness, (2) how the readability of treemaps can be improved using level-of-detail and degree-of-interest techniques, and (3) how to design and implement a software framework for the real-time web-based rendering of treemaps embedded in 3D. With a particular emphasis on their application, use cases from software analytics are taken to test and evaluate the presented concepts and techniques.

Concerning the first challenge, this thesis shows that a 3D attribute space offers enhanced possibilities for the visual mapping of data compared to classical 2D treemaps. In particular, embedding in 3D allows for improved implementation of visual variables (e.g., by sketchiness and color weaving), provision of new visual variables (e.g., by physically based materials and in situ templates), and integration of visual metaphors (e.g., by reference surfaces and renderings of natural phenomena) into the three-dimensional representation of treemaps.

For the second challenge—the readability of an information visualization—the work shows that the generally higher visual clutter and increased cognitive load typically associated with three-dimensional information representations can be kept low in treemap-based representations of both small and large hierarchical datasets. By introducing an adaptive level-of-detail technique, we cannot only declutter the visualization results, thereby reducing cognitive load and mitigating occlusion problems, but also summarize and highlight relevant data. Furthermore, this approach facilitates automatic labeling, supports the emphasis on data outliers, and allows visual variables to be adjusted via degree-of-interest measures.

The third challenge is addressed by developing a real-time rendering framework with WebGL and accumulative multi-frame rendering. The framework removes hardware constraints and graphics API requirements, reduces interaction response times, and simplifies high-quality rendering. At the same time, the implementation effort for a web-based deployment of treemaps is kept reasonable.

The presented visualization concepts and techniques are applied and evaluated for use cases in software analysis. In this domain, data about software systems, especially about the state and evolution of the source code, does not have a descriptive appearance or natural geometric mapping, making information visualization a key technology here. In particular, software source code can be visualized with treemap-based approaches because of its inherently hierarchical structure. With treemaps embedded in 3D, we can create interactive software maps that visually map, software metrics, software developer activities, or information about the evolution of software systems alongside their hierarchical module structure.

Discussions on remaining challenges and opportunities for future research for 3D-embedded treemaps and their applications conclude the thesis.