Comparative Analysis with Heightmaps in Virtual Reality Environments

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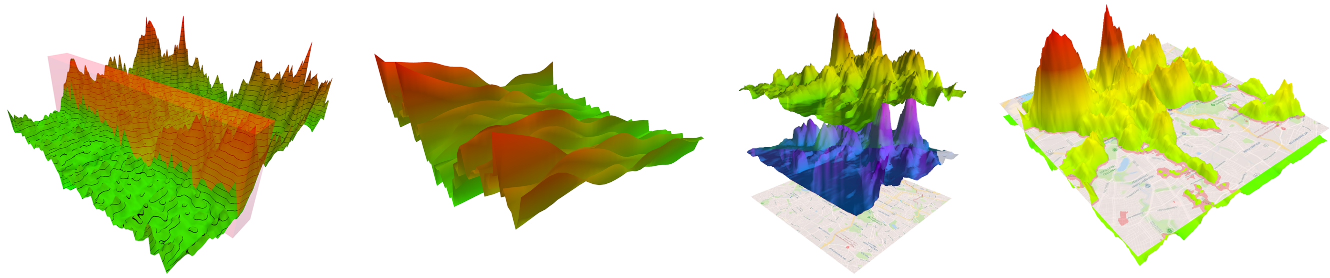

Figure 1: *Heightmaps in VR. We investigate the design space of VR heightmaps, discuss interaction techniques, such as interactive color adaption, selection (left), and zooming/filtering (center left). The overall focus is set on comparative heightmap visualizations. We use a stacked multi-layer design (center right) and enable the user to interactively position layers of heightmaps (right).*

Abstract

3D heightmaps can be considered as an extension of heatmaps using the third dimension to encode the respective value by height, often in addition to encoding it by color. In contrast to 2D heatmaps, 3D heightmaps allow a superposition without aggregation. However, they also have the general disadvantages of 3D visualizations, such as occlusion and perceptual distortion. Previous research has revealed various advantages of stereoscopic displays and virtual reality (VR) in the context of 3D visualizations, for example, concerning memorization, depth perception, and collaboration. In this paper, we present a novel technique to compare heightmaps in VR by introducing a multi-layer approach of stacked heightmaps. We demonstrate the applicability and usefulness of our method by means of a use case on comparative crime data analysis.

CCS Concepts

• ***Human-centered computing*** → ***Virtual reality;*** • ***General and reference*** → *Design;*

1. Introduction

Heightmaps deploy the visual variable position (3D) in order to encode information [BRLD17]. Additional variables, such as color, texture or transparency, can be used to encode even more attributes. Although the applicability and usefulness of heightmaps have been demonstrated on conventional 2D monitor screens, their deployment in augmented or virtual realities has rarely been investigated. One challenge we are mainly concerned with is the use of heightmaps in comparative visualizations. There are three established approaches for comparing multiple heightmaps. One approach is juxtaposition, that is the display of small multiples which can be visually compared with each other [vdEvW13]. With this approach, the user has to find the same position in each visualization and compare its value (color, height or both). Another approach is to create a new visualization that combines the data of all heightmaps which are to be compared [KF13]. For instance, a difference view could be created in which values of the first heightmap are subtracted from values of the second one, resulting in a heightmap that shows the differences between the two heightmaps at each position. As a result, absolute values are lost and only the relative offset between the two heightmaps is displayed. We make use of the third option - superposition - by introducing a multi-layer heightmap approach for comparative analysis in VR environments (VREs).

2. Prototype

Our base visualization environment consists of a virtual room with white walls and a table in the center. The heightmap visualization is placed on top of the table (Figure 2) and the walls can be used to place 2D visualizations. As basic interactions, the user can navigate the VRE by walking and rotating the head-mounted display (HMD). For our prototype, we deployed the HTC Vive Pro HMD

in combination with two Vive Controllers [Viv]. The prototype was programmed in the game engine Unity3D [Uni]. Labeled axes describe the displayed data. By hovering over an axis, the exact value at the selected point is displayed as a tooltip. The user can select specific data ranges by clicking and dragging along an axis. A blue bar under each axis depicts the filter currently applied to the original data (see Figure 2). To facilitate readability, isolines that mark uniform levels of height can be inserted.
The user can thoroughly investigate subsets of the data by clicking on a selected area. In doing so, the displayed meshes are cut to the bounds of the selected area and expanded to the size of the table, creating a zoom effect. Instead of zooming into the data, the analyst is also able to create a 2D projection from a selected data range. By hovering over a selection, holding a trigger and moving the controller towards the walls, a 2D aggregation of the selection appears, which can be placed on any wall. The way in which the aggregation is carried out depends on the side of the selection that is targeted by the user.

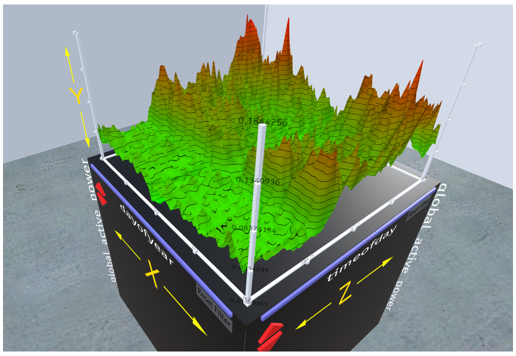

Figure 2: *Power consumption of a household (one year). The x-axis encodes the day of the year (1-365), the z-axis encodes the time of the day in 5-minute steps (0:00-23:55) and the y-axis (height) encodes the power consumption at the respective day and time.*

3. Comparison of Multiple Heightmaps

For side-by-side comparisons, the cognitive load of comparing two or more small multiples is high, since the user has to direct his attention (spatial attention) to two remote points on the screen and remember the value of the points or areas to be compared [NBF18]. Bringing heightmaps into a VRE, we propose interaction techniques that allow comparisons of two or more heightmaps by stacking them on top of each other, as shown in Figure 3. We enable the user to interactively shift the heightmaps along the y-axis (up/down) into each other. As shown in the rightmost heightmap in Figure 1, the base map can provide a further spatial reference by outlining the area of the peaks in red when being shifted through the map. Besides changing the color map, the user can change the appearance of the heightmap surface to be semi-transparent or meshed. For better readability and comparability, the user can interactively place labels anywhere on the map to compare values from one or more different points between all displayed heightmaps (see Figure 3, labels A and B). The purple lines vertical to the map support the comparison as visual indications of the position of the selected points on the heightmap and base map.

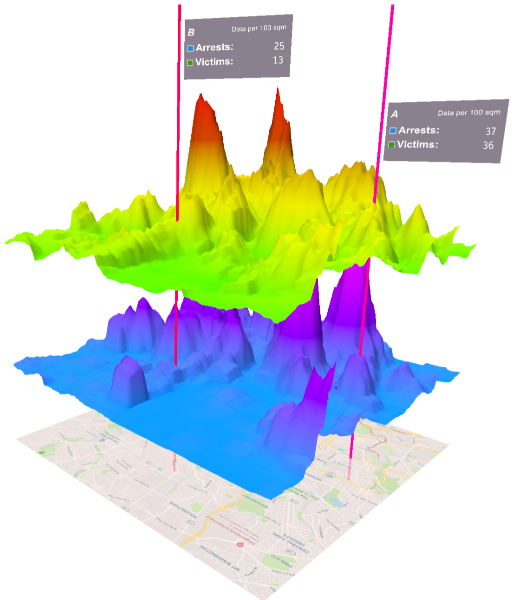

Figure 3: *Stacked heightmaps for comparative visualizations. The user can select arbitrary points on the surfaces of the heightmaps. For each selection, a pillar is inserted vertically so that the same position can be identified quickly in all other layers. A small info board provides details about all layers at the selected position.*

4. Discussion & Future Work

Based on subjective experiences and initial pilot studies with our framework, we were able to gain the following insights. In contrast to 2D heatmaps, heightmaps are suited for superposition without aggregation. Transparency and meshing can help to overcome problems caused by occlusion in superpositioned heightmaps. Our subjective impression is that meshes can more easily be attributed to layers when observed in VR, possibly due to improved depth perception.
Furthermore, an extension of 3D data visualizations by 2D abstractions appears promising to mitigate disadvantages of the 3D representation. In this way, for instance, the user could aggregate values from a heightmap into a 2D representation that is better suited to identify global trends or extract overall statistics. In our scenario, walls aligned around the main visualization in the center can be used to arrange the 2D visualizations.
Based on our initial exploration, we will extend our framework in future research with additional features, such as vertical cutting planes and linking and brushing, and evaluate specific properties of our proposed framework. For example, it would be interesting to measure if and to what extend superposition of heightmaps can outperform alternative comparative visualization techniques and if potential benefits of VR, such as improved depth perception, can outweigh drawbacks inherent to VR (for instance, increased physical and mental workload, fatigue).

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