Appendix: Comparative Analysis with Heightmaps in Virtual Reality Environments

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Abstract

In this appendix, we present a use case for our proposed framework, as well as full-sized images to the extended abstract.

Use Case: Crime Data in Geo Context

Visualizing data in geographic contexts adds spatial relation as a fixed constraint that cannot be easily changed, compressed or aggregated. Comparing and relating continuous information on maps can be challenging because, unlike in point comparisons, the whole map has to be compared. In most scenarios, this requires a direct side-by-side comparison of two visualizations.

Figure 3 depicts locations of crime reports and locations of arrests in Baltimore, MD (USA) in 2017 (data set obtained from Baltimore Police Department [†]). The figure shows three stacked layers that can be moved up and down (switching their order is also possible). On the bottom, a geo-map is displayed for georeference – in this case, it is a map of Baltimore. Above, two heightmaps are fixed in the same horizontal position. The lower one (bluish colors) depicts the total number of arrests for each position in the inspected segment of Baltimore. The upper layer encodes the total number of crime reports for each location on the map. As depicted in Figure 2, the heightmaps can be superpositioned interactively. Transparency (left) and meshing (center) allow the analyst to identify overlapping areas. A cutting plane (geographic map, right) can be inserted to pose as a common baseline to ease the comparison of peaks.

For comparison, Figure 1 shows the same data *min-max* normalized in heatmaps. The normalized quantity of occurrences of the respective incident at the respective position is colored from green to red (0 to 1). For comparative analysis, juxtapositioned heatmaps (left, center) pose the difficulty that each point in one heatmap has to be located accurately in the other to allow correct comparisons. Also, the analyst has to remember the color value of one point in one heatmap to compare it to the respective point in the second heatmap. Patterns that appear in both heatmaps, but are shifted, can even impair spatial coordination. Figures 2 and 1 display the same data. Whereas in Figure 2 one can observe that most peaks are shifted, this becomes more difficult in the side-by-side heatmap visualization (Figure 1). For instance, a user could mistake the dominant peaks at the top in both heatmaps as a common peak at the same location.

Figure 1 presents a difference view in the rightmost image. It represents the difference of the normalized values of both heatmaps ($H_{arrests} - H_{reports}$). Negative values are colored from blue to green (-1 to 0) and positive values are colored from green to red (0 to 1). Figure 1 (bottom) points out some artifacts that are introduced when creating difference views of heatmaps. For instance, when two peaks intersect (A), at the point of the intersection, the displayed value is zero, even though the overall value is relatively high in both heatmaps. This leads to the impression of a valley between two distinct peaks. Moreover, it illustrates that the absolute level of values is lost in each map (only the offset between the two maps is shown). In case both heatmaps are peaking at the same position (B), the difference map only depicts the higher one, making it impossible to detect the occurring correlation between the heatmaps at that position. Moreover, strong correlations (that is, when both heightmaps have similarly high peaks at a certain position) are balanced and result in zero values in the difference map (C). Of course, some of these phenomena can be compensated by additional aggregations, such as summing up values, but this, in turn, leads to multiple visualizations or the absence of something else. For instance, in a map of summed or averaged values, the two original maps cannot be distinguished any more.

With our approach of stacked heightmaps (see Figure 2), none of the above-mentioned artifacts occur. Heightmaps can be shifted interactively into each other, preserving their original structure. To overcome occlusion, transparency or meshing can be toggled, so that it is possible to look through the heightmaps and detect underlying structures. To enable an accurate comparison, the heightmaps can be snapped into their common baseline. Additionally, filtering to a certain y-range or the insertion of a horizontal cutting plane can be deployed, allowing the user to focus on specific parts of interest.

[†] Baltimore Police Department open crime data. https://www.baltimorepolice.org/crime-stats/open-data/ Accessed: 2019-04-12

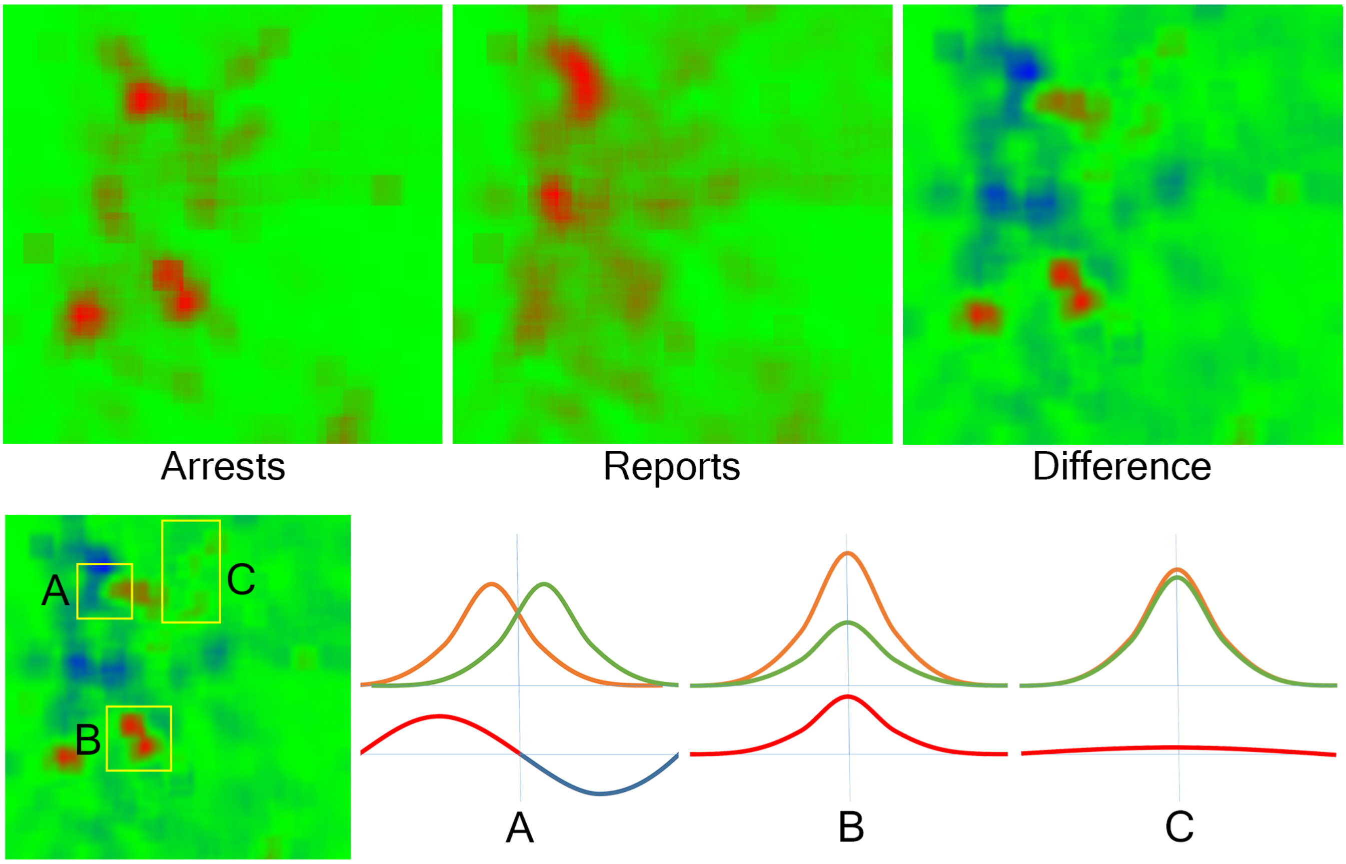

Figure 1: *2D heatmaps of crime data. Top left: heatmap depicting all arrests in Baltimore (green to red; few to many). Top center: heatmap depicting all reported crimes in Baltimore. Top right: difference map of both heatmaps (negative values in bluish colors). Bottom: typical artifacts introduced in difference maps. A) Values compensate each other and the absolute value is lost at each position. B) If two peaks overlap, only the higher one is recognizable in the difference map and correlations are lost. C) Strong correlations are balanced.*

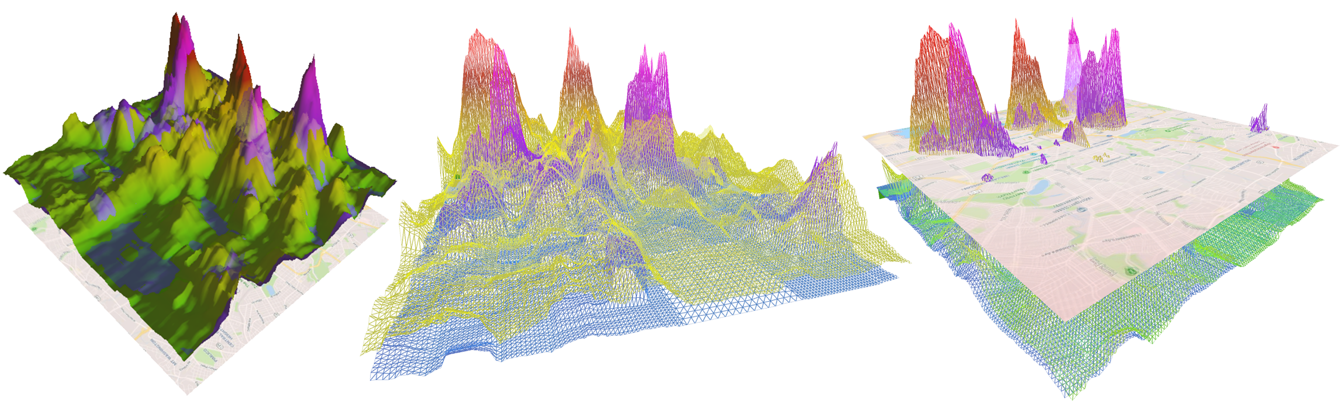

Figure 2: *Superpositioned heightmaps, one encoding arrests (rainbow-colored) and the other reported crimes (purple). Transparency (left) or meshing (center) can be used to overcome occlusion. The geo-map layer can be used as a cutting plane to serve as a common plane of reference for shifted peaks (right).*

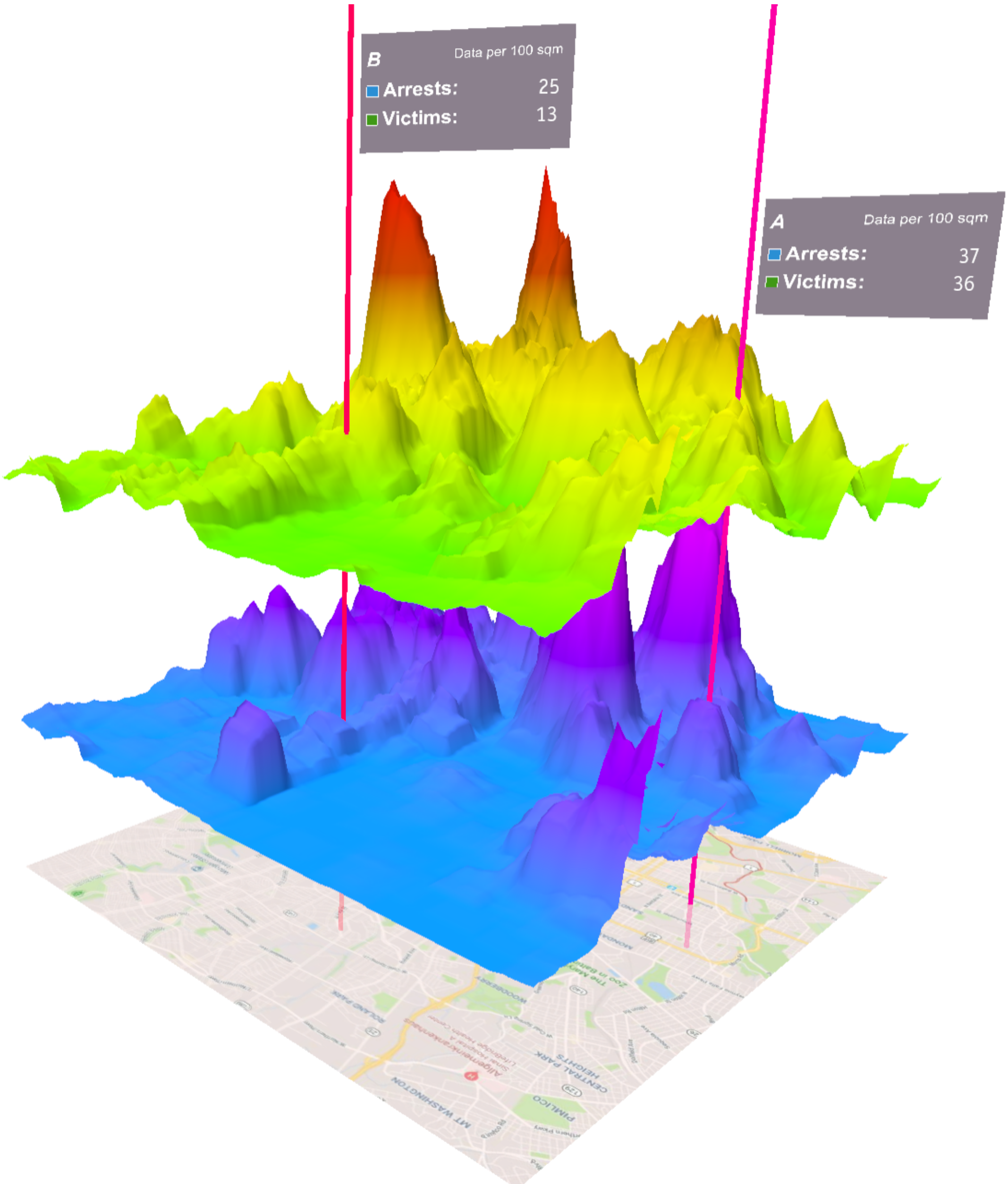

Figure 3: *Stacked heightmaps for comparative visualizations. The user can select arbitrary points on the surfaces of the heightmaps. For each selection, a pillar is inserted vertically so that the same position can be identified quickly in all other layers. A small info board provides details about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

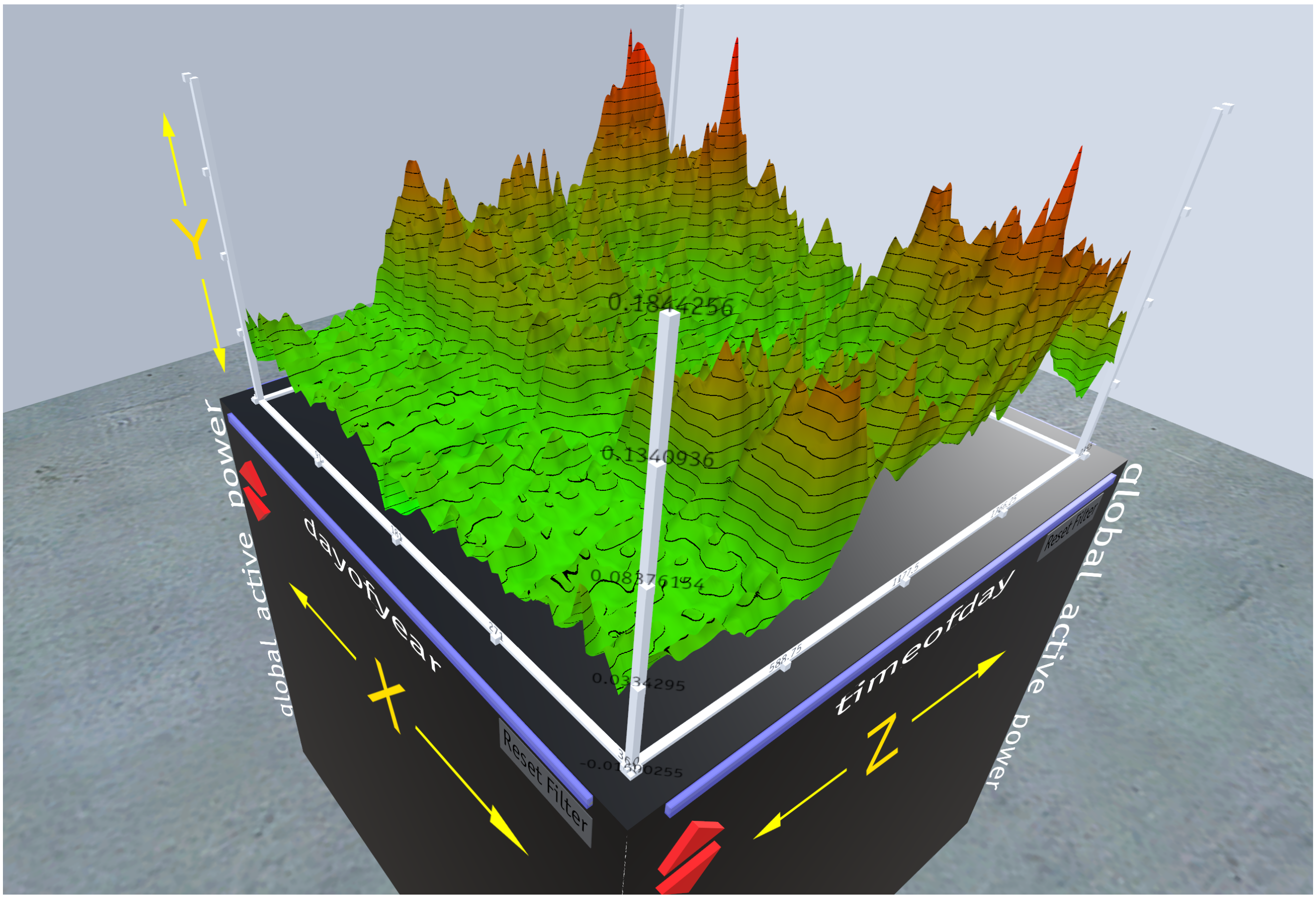

Figure 4: *Power consumption of a household (one year). The x-axis encodes the day of the year (1-365), the z-axis encodes the time of the day in 5-minute steps (0:00-23:55) and the y-axis (height) encodes the power consumption at the respective day and time.*