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Short Papers

Ambient Grids: Maintain Context-Awareness via Aggregated Off-Screen Visualization

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Figure 1: *Ambient Grids example of the VAST Challenge 2011 microblog data subset. While an analyst follows the epidemic outbreak in the downtown area, she can keep track of the temporal development of the outbreak outside the viewport (to demonstrate the usefulness of this technique, we intentionally omit data within the viewport). On the left, the situation before the epidemic is shown. The three images on the right show the fast development of the epidemic over three days.*

Abstract

When exploring large spatial datasets, zooming and panning interactions often lead to the loss of contextual overview. Existing overview-plus-detail approaches allow users to view context while inspecting details, but they often suffer from distortion or overplotting. In this paper, we present an off-screen visualization method called Ambient Grids that strikes the balance between overview and details by preserving the contextual information as color grids within a designated space around the focal area. In addition, we describe methods to generate Ambient Grids for point data using data aggregation and projection. In a use case, we show the usefulness of our technique in exploring the VAST Challenge 2011 microblog dataset.

Categories and Subject Descriptors (according to ACM CCS): H.5.2 [Information Interfaces and Presentations]: User Interfaces—Graphical user interfaces (GUI), Interaction Styles

1. Introduction

The growing amount of spatial data often impedes obtaining *Overview and Detail* at the same time. This is a serious problem for analysts who monitor data in a focal area and concurrently keep track of surrounding changes. For example, during an epidemic outbreak (see Figure 1), the task of analysts is not only to trace the spread of a disease in a local district but also to understand precise situations about surrounding areas to make informed decisions.

Existing approaches, such as Overview-and-Detail and Focus-plus-Context techniques, offer expedient solutions but mainly operate in image-space. Overview-and-Detail techniques force the user to split his attention to multiple viewports. As a consequence, the discontinuity of overview and detail results in an increased cognitive load [Gru01]. In contrast, Focus-plus-Context techniques result in partial information loss due to distortion. By design, distortion-oriented techniques interfere with any task that requires precise judg-

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ments about scale or distance [BR03] and are restricted by means of zoom levels [MCH*09].

We therefore contribute Ambient Grids, a data-driven off-screen visualization technique, which enhances context-awareness while providing maximum focus. The viewport is augmented by a border, which is used to represent off-screen objects in a clutter-free way, while the viewport can be utilized to show detailed visual data representations. Topology within the border is preserved by mapping off-screen objects to the border region and thus preserve relative distances. The use of a topology-preserving border region further helps to overcome the desert fog problem [JF98]. In contrast to distortion-oriented techniques, we are able to handle data values and characteristics separately. Ambient Grids is suitable for displaying point data as well as shape data, which is a design decision based on the application requirements and analysis task at hand. We further show the usefulness of Ambient Grids in a use case.

2. Related Work

Various techniques aim to provide context while investigating a dataset in detail [HS12]. Cockburn et al. [CKB08] give a comprehensive overview on related techniques and bring out that both focused and contextual views can improve interaction but it is not clear which interface style to use for what tasks and under what conditions.

2.1. Distortion-Oriented Techniques

Distortion-oriented techniques mainly operate in image space and thus perform graphical distortions. Prominent examples [MRC91, RJS01, EHRF08] follow the approach of Apperley et al. [ATS82]. Then, the degree-of-interest function [Fur86] was introduced as theoretical foundation for Focus-plus-Context systems [RM93, CM01]. Despite recent improvements [Gut02, CLP04, PA08], some weaknesses are inevitable in large data spaces, as for instance the distorted transition between focus and context resulting in partial information loss. Cockburn et al. [CKB08] outline this by "distortion-oriented displays are likely to impair the user's ability to make relative spatial judgments, and they can cause target acquisition problems" (p. 2:27). Also distortion-oriented techniques are restricted by means of zoom levels [MCH*09].

2.2. Off-Screen Visualization

Unlike distortion-oriented techniques, cue-based off-screen techniques are data-driven and use the border region of the display to visualize points of interest (POIs) which are located off-screen. However, established techniques are limited in visualizing context. We refer context to topology and data characteristics such as density, data value, among others. Zellweger et al. [ZMG*03] present a family of techniques called City Lights: City Light cues and Halos. City Light cues do not encode distance. Halo [BR03] uses arcs which intersect the display and enables the perception of distance, location, and existence, but also produces noteworthy clutter. Burigat et al. [BCG06] showed that arrows outperform Halo in certain tasks using a small dataset. In spite of improvements to Halo such as Wedge [GBGI08], the evaluation pointed out issues such as distance perception. To improve scalability, HaloDot [GACP11] aggregates POIs on a grid with color, transparency, or thickness for its relevance. According to Gonçalves et al. [GACdM11], aggregation combined with relevance clues improves search for relevant POIs, yet does not consider different classes of POIs. Besides navigation or orientation, visual cues have recently also been used to support representations of statistical diagrams. Games et al. [GJ13] take first steps and apply cue-based visualization to barcharts and scatterplots with restricted view space.

Off-screen visualization is also very prominent as application to node-link diagrams. Techniques, which support navigation tasks and do not compulsorily demand topology preservation, were presented by Frisch and Dachselt [FD10] or May et al. [MSDK12]. In contrast, Moscovich et al. [MCH*09] preserve topology by zooming off-screen located nodes. However, the context around off-screen objects is not preserved. Ghani et al. [GRE11] therefore proposed Dynamic Insets. Yet, we aim at a visualization of points and shapes and not relations between objects, such as in node-link diagrams.

We see Ambient Grids as improvement to City Lights and EdgeRadar [GI07]; we enable context-awareness by preserving topology and address clutter issues through aggregation.

3. Ambient Grids

Ambient Grids surrounds the *viewport* with a *border area*, which is used to display data objects located outside the viewport (*off-screen* objects). In order to meet the requirements of preserving data topologies, rectangular or circular shaped viewports are possible. However, Zanella et al. [ZCR02] claim that radial distortions lead to misinterpretations and there is a "lack [...] of adequate support that allows people to comprehend the manner in which the information is being presented" (p. 119). Hence, we use a rectangular viewport to maximize the focus. Some tasks may require to visualize shapes instead of points. That is why we designed Ambient Grids to be compatible with points as well as shapes.

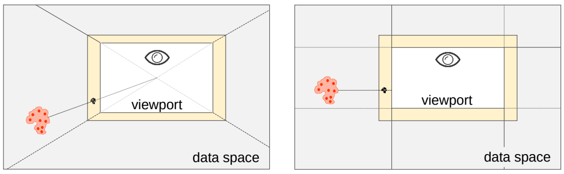
The creation of Ambient Grids follows a four step pipeline:

1. **Preprocessing:** examination and analysis of the data space.
2. **Space Partitioning:** separation of the off-screen space into partitions to map them to the border of the display.
3. **Projection:** mapping off-screen objects to the corresponding border areas.
4. **Visualization:** creation of graphical primitives in the border areas to represent off-screen objects.

Based on this pipeline, we will outline our technique in the remainder of this section.

3.1. Preprocessing

The preprocessing represents the first step of our pipeline and comprises any computational effort that is needed to visualize



(a) (b)

Figure 2: *Partitioning the off-screen space and projection to the border region. In (a), each area of the off-screen space is mapped equally; it is an approximation to radial distortion. To preserve exact locations and distances, we partition the space according to (b).*

the data. This step strongly depends on the task the analyst wants to perform including preceding operations such as sampling or filtering, among others. We designed Ambient Grids to be suitable for spatial point-based as well as shape-based data. In this paper, we utilize preprocessing to generate spatial data of arbitrary shapes to demonstrate the application of our technique to shapes. We therefore create arbitrary shapes, based on the VAST Challenge 2011 microblog dataset, using DBScan [EKSX96]. The parameters *minpoints* and ε are chosen in a way that the number of large and small clusters are roughly equal, leading to a border area with a balanced number of large and small colored areas. After having determined the clusters, we determine the hulls which are then used to visualize the extend of all data points in the clusters.

3.2. Space Partitioning

There are two intuitive ways of partitioning the space in the border area, which are depicted in Figure 2. In Figure 2(a), the space is partitioned into four areas by starting at the center of the viewport. This way, distances of off-screen objects are measured originating at the viewport center. This partitioning scheme represents an approximation of a radial distortion. Due to distorted locations and distances, relations between off-screen objects are hard to interpret correctly. The second possibility, dividing the border region into eight different areas, is illustrated in Figure 2(b). The space is partitioned according to the area which is adjacent in the border region. For each of the areas, the partitioning is performed separately which ensures global distance preservation. Instead of adapting the border size, we determine the global distance scale and map objects accordingly.

3.3. Projection

A correct mapping of the converging parts of the four dedicated edge areas in the border is challenging, because they represent a potentially large share of data space in little space on the border region. Possible solutions include circular distortions that do not have the issue of corner mapping, but have other drawbacks like radial distortion [ZCR02]. Another possibility is to increase the size of the border region in order to give corner regions a bigger portion of the display, which would reduce the area of the viewport and is not desired.

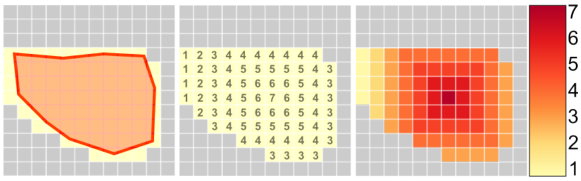


Figure 3: *The mapping of a shape (left) to numbers (middle) to colors (right) determining the off-screen grid cell color.*

3.4. Visualization

We visualize off-screen located points and shapes using grid-based aggregation. The regular grid cells are visualized within the eight border regions. Each of these cells is mapped to the adjacent partition of the data space. The usage of a grid-based approach yields various benefits regarding point-based and shape-based data. In order to overcome clutter issues which might occur when visualizing point data, we use the grid to bin data points; but also the individual representation of points is conceivable. The idea of binning is adapted from HaloDot [GACP11], which also uses a grid to aggregate off-screen located points but then lacks of presenting the topology.

Ambient Grids also makes use of the grid for the representation of shapes. Shapes are rasterized using the grid and are then projected to the border region. The design decision to rasterize given shapes is based on two reasons: (1) Rasterization speeds up the rendering process and (2) provides the possibility to select a level-of-detail based on the cell size. Rasterization is achieved by intersecting a shape with the grid cells. All intersected and included cells form the rasterized shape. The level-of-detail can be steered by increasing or decreasing the cell size respectively with direct impact on the rasterization. We are aware of the fact, that the level-of-detail depends on user and task.

According to Harrower and Brewer [HB03], we use a sequential color scheme to represent data that range from low to high values on a numerical scale. We follow the convention "Dark equals more", which means that a cluster containing lots of points is colored darker compared to the one containing less points. Based on the application, the grid coloring can be adapted to support the requirements and tasks accordingly. We propose to align the colors with the number of binned points or to apply a color gradient in case of shapes. In our example, we derive the color of the shape by the amount of points which were combined into a cluster by DBScan. To assign the color to the cells we use a radial cell-based color gradient, which is illustrated in Figure 3. Starting at the cell which contains the shape centroid, we radially assign the colors in the adjacent cells depending on the distance to the centroid cell. The color of the starting cell is determined by the number of points in the cluster. In case more than one shape intersects a cell it is unclear which color to assign. A possible solution of this problem is to first compute the corresponding cell color derived by each shape separately, and then to interpolate between the computed colors respectively.

4. Use Case: Epidemic Monitoring

In this use case, we demonstrate how Ambient Grids can be applied in context of a geo-spatial visualization. We use the dataset of the VAST Challenge 2011 (Mini Challenge 1), which contains microblog entries of 21 days. All messages are geo-referenced in the extent of the fictive city "Vastopolis". The given scenario is an epidemic outbreak in Vastopolis, and participants were asked to determine the epidemic spread as well as the outbreak, location-based on the provided message data.

We collected a number of general symptoms of various diseases, such as *pneumonia*, *fever*, and *flu*, and use these to filter the microblog messages. Every message which does not match at least one symptom is excluded from the dataset during preprocessing. After applying the symptom filter, we separate the whole dataset in 21 smaller ones, each containing the data of a single day. We use this separate datasets to simulate a time context by applying Ambient Grids on each dataset separately. Before visualizing the data, we run a density-based clustering algorithm to generate areas that contain many disease related messages. In this scenario, we use Ambient Grids to visualize resulting shapes.

Our goal for the visualizations shown in Figure 1, is to focus on downtown Vastopolis, while the epidemic spread in the outer area of the city can still be observed in the border region. Focusing on downtown is primarily motivated by the fact, that many events take place in that area, for example an antique convention or a basketball game. These are worth observing, because emergencies or other events that require immediate action of law enforcement do happen often on those occasions. This illustrates that Ambient Grids allows to focus on one particular type of data, while it is still possible to be informed about other aspects of data thanks to the visualization in the border region.

On the leftmost visualization of Figure 1, the off-screen visualization area is almost empty. This means that we have very few cases of the disease on April 30. More than two weeks later on May 18, Ambient Grids shows the beginning of the epidemic. Yellow grid cells are popping up over the entire surrounding areas. In particular, the red areas emerge on the west and the east sides. This shows that the disease spreads out from the downtown toward both sides. On May 19, a majority of grid cells is colored, which indicates the disease was spread out to the entire city by this time. On May 20, the epidemic is on its peak. There are several additional areas that show darker yellow than the day before (see black circles in Figure 4). These areas have been identified to be the hospitals of Vastopolis. Now we can understand that many people start visiting the hospital to treat the disease.

(a) May 19 (b) May 20

Figure 4: *Black encircled off-screen clusters depict temporal changes of the epidemic spread.*

5. Conclusion and Future Work

In this paper, we presented Ambient Grids, a highly adaptable off-screen visualization technique for point and shape data. Our technique preserves the topology of off-screen located objects. The proposed projection of off-screen objects to the border region preserves the spatial context and distribution of data points with grid precision. We also presented a color mapping algorithm, which assigns meaningful colors to the cells mapped to the border region. Each step of the Ambient Grids pipeline is adaptable to the requirements of the task at hand, which makes our technique suitable for visual analytics applications in particular. Furthermore, we presented how Ambient Grids can be applied to a monitoring application using the VAST Challenge 2011 microblogs dataset.

Compared to state-of-the-art off-screen visualization techniques, Ambient Grids has the advantage of visualizing point as well as shape data. In addition, Ambient Grids solves the desert fog problem by projecting and visualizing the whole data space in the border regions. This makes it feasible for analysts to be aware of the whole data space, while still being focused on a specific, potentially very small section of the data space.

For future work, we plan to systematically explore and evaluate the design space, which would give us the possibility of providing meaningful parameter settings and recommendations based on the task at hand. In particular, we are interested in examining the effect of the border size on the navigational and analytical performance of users; either we use an adaptive border size based on the zoom level, or we calculate a distinct size per border side based on the area the corresponding side aggregates. The examination of the influence of the visualized level-of-detail to the user's perception and his ability to perform different tasks, such as identification or comparison of data values, would also be of interest for future work.

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