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PoPI: Glyph Designs for Collaborative Filtering on Interactive Tabletops

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Abstract

Filtering data on a visualization can be a challenge when multiple people work on a shared visualization, for instance on an interactive tabletop. Visualizations can present data that satisfy the union of all user filters, or data lenses can provide individual views on parts of the data. To support per-user filters simultaneously across a shared visualization, we explore different glyph approaches that complement data points with per-user filter status information. Adding physical positions of users around the tabletop as an extra attribute to the glyph, we attempt to lower the cognitive load required to map filter statuses to corresponding participants. This work presents the design choices, briefly covers technical development, reports on the evaluation results and points out possibilities for future work.

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

1. Introduction

Interactive tabletops provide an interesting workspace for collaborative sense-making activities using data visualizations. We build on the previous work of Verbert et al. [VGD*14] which focuses on small groups of people, specifically teachers and students, using learning dashboards (i.e. visualizations of learner activities) in an attempt to gain insights that can impact learning behavior. Flexible visual analysis tools must provide appropriate controls for specifying the data and views of interest [HS12]. Filtering out unrelated information to focus on relevant items is the key control in our learning dashboards due to the abundance of traces learners leave behind.

Figure 1 shows an early prototype of a learning analytics visualization where 5 participants can simultaneously filter the data presented on the tabletop. Using the multivariate attributes of a glyph-based visualization [BKC*12], the filtered data of each participant is highlighted in the color corresponding to their filter user interface.

Collaborative tasks on tabletops require support for both individual and group work [GG98]. Transition between both should be fluid [TTP*06], which our work attempts by limiting the workspace to one shared visualization of the data. However, visualization interactions such as sorting, filtering and navigating the data can disturb the workflow of others. One participant's filter activity could remove data from the visualization another participant is working with. This paper explores different design possibilities to create a useful glyph representation to support such global filtering around an interactive tabletop.

Section 2 presents related work that has lead to our glyph proposal. Section 3 defines a basic glyph design supporting filter activities of multiple users. Section 4 introduces the position-based glyphs, their design and implementation. Section 5 presents our evaluation results and we discuss our findings and future work in section 6.

2. Related Work

Personal territories [IC07] on interactive tabletops support individual activities separated from group work. Data or subsets of the data can be visualized, filtered and sorted on individual basis. Visualizing activities of contributors across personal spaces [IF09] can help participants remain aware of group activity and maintain a common ground.

When all collaborators work on a single, shared visualization, awareness of group activity is straightforward. To

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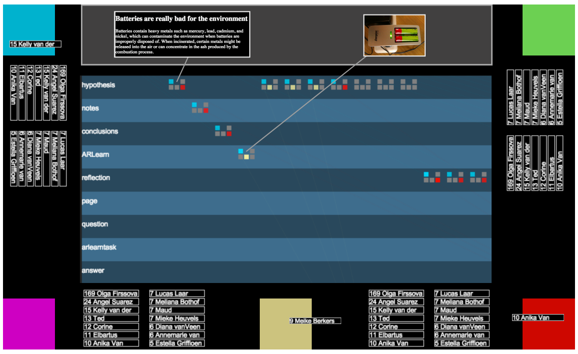

Figure 1: *A prototype with 5 filter "drop zones". Dropping a filter value into the blue (top-left) drop zone highlights data points matching the filter result by coloring the top-left part of the glyph.*

support individual work, virtual lenses facilitate personal exploration and filtering [vZDSK12, MRSMC14]. Tang et al. [TTP*06] reports users' preference for enlarging lenses to create global filters, which also resulted in more tightly coupled collaboration. Our glyph design supports both personal filtering as well as global filtering, facilitating individual and group work simultaneously.

McGrath et al. [MBM*12] describe the use of a glyph to indicate filter status of collaborators with tablets, but does not provide any details on its effectiveness and expects collaborators to stand at fixed positions. We propose a glyph approach that puts few limitations on the positioning of collaborators through user position tracking, and compare and evaluate different design choices.

3. Filter Ownership

To support simultaneous filtering of a shared view of a data set, each data point representation must contain information regarding the filter status of each collaborator. A data point is either part of the filter result of a specific participant, or it is not. Our glyph thus represents 1) the underlying data point (e.g. a point representing data in X/Y space) and 2) information regarding the filter status for each collaborator.

Our first design deals with the essentials. The data point, represented as a large white circle, is accompanied by smaller circles indicating the filter status of each collaborator (see Figure 2.A). Because of the Gestalt law of proximity, a glyph can consist of multiple points in vicinity of each other and will be perceived as one whole.

The number of smaller circles indicates the number of collaborators. Glyph A has 5 circles, each representing an individual. Every collaborator is matched to a color, which is either indicated by a legend or a matching color indication in the personal UI (e.g. see Figure 1) used to interact with the visualization.

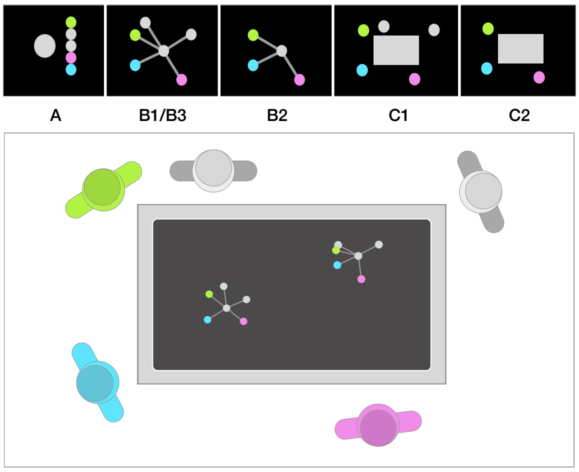

Figure 2: *Overview of how collaborator position maps to different glyphs. B1 and B2 place users at equal distance from the tabletop center. C1 and C2 use a direct mapping of position to glyph. B3 points towards users, therefore the position of the glyph alters its shape (pictured on tabletop).*

When the data point is contained within the filter of the user, the matching circle is highlighted (e.g. green, pink and blue in Figure 2.A). This creates a process feedthrough [GG98], i.e. it visualizes changes in filter activities which all collaborators can perceive.

While this design is independent of collaborator position, it does require each user to learn and remember the colors of each collaborator. When collaborators join and leave the table, this task becomes even more difficult. To eliminate the need for legend and lower the cognitive load of the user, we propose inserting more information into the glyph to identify and thus map the users to their actions. Section 4 explains how user position can help identify participants and elaborates on the technical requirements to support our glyph design.

4. Position of Participant Indication

McGrath et al. [MBM*12] presented a glyph design that shows the filter status of 4 participants around a tabletop. Using a static quadrant design, every quadrant maps to a person's position at the tabletop. In collaborative work, however, people tend to move around according to their coupling style (e.g. people working on the same problem will move closer together) [TTP*06]. A static design forces participants to remain at predefined positions in order to avoid a mismatch with their filter status indication. The Position of Participant Indication (PoPI) design attempts to overcome this by providing an up-to-date mapping of participant's physical location to a visual channel.

To come up with a useful and usable glyph design, we tested different visual channels taking into account known glyph design guides [BKC*12]. Figure 2 provides an overview of 5 tested designs. We look at angle (glyph B1 and B2), direction (glyph B3) and position (glyph C1 and C2) as possible channels to add this attribute. Do note the PoPI is not static. Collaborators can move around the tabletop which is instantly reflected by the glyph representation.

Section 4.1 explains the technical requirements to provide the glyphs with the position information. Section 4.2 presents the reasoning behind the 5 glyph designs.

4.1. Participant Position Tracking

The location of the participant, or the proxemic state, can be tracked and identified through different techniques [AGWF11, ACMK12]. Our setup uses a Microsoft Kinect v2 which can track up to 6 people. We developed a tracker application using the .NET Framework. Once calibrated, the application will recognize people within the defined vicinity of the tabletop. The coordinates are transformed into the [0,1] space for both width and height, where (0,0) is the top-left of the tabletop's surrounding area, and (1,1) the bottom-right. These coordinates together with an identifier per person are stored in a JSON format.

A Node.js server application uses the Socket.IO protocol to listen to incoming events and lets applications subscribe to broadcasting events. The tracking application updates the server with identifiers and coordinates every 300ms. With every update, the server broadcasts this information to listening applications. This update interval can be altered depending on network circumstances but was found to create a good balance between network usage and animation update. This information is digested by our glyph visualization but applications for analysis, or plain replay of the participant locations can also benefit.

4.2. PoPI variants

4.2.1. Design B1/B2

Figure 2 shows how B1's design relates to participant location. Every collaborator's physical position is transformed to the angle at which he stands relative to the center of the tabletop. This is mapped onto a radial design, where the data point is the center and satellite circles are the collaborators located at equal distance of the data point. As with glyph A, every circle is colored when the data point is contained within the filter of the corresponding user. Color provides an extra identifier for participants.

When the participants move, the satellite circles will mimic this behavior by moving along the circle. The glyph follows the rule of viewpoint independence [BKC*12], i.e. the interpretation of the glyph is independent of the location from where it is perceived.

The user is required to create a mental abstraction of the situation around the tabletop. Collaborators can be identified by the angle, relative to the tabletop but also to each other. Collaborators pairing up will be presented by a small angle, while collaborators far away will be separated by a large angle, following the perceptually uniform glyph property guideline [BKC*12].

Glyph B2 follows the design of B1 but removes information about collaborators who are not highlighted, i.e collaborators whose filter results do not contain the data point. With this design, data points included in the filter results of many users stand out more compared to those who are not contained within anyone's filter result. While this design choice removes what may be perceived as redundant information and clutter, the lack of information on all participants could make it more difficult to map participants to the abstract representation.

4.2.2. Design B3

To lower the cognitive load, we replace angle by direction. Every branch of the glyph points to the position of one user. Note that glyph position impacts the representation of the glyph (see Figure 2). Design B1 and B2 follow the Gestalt principle of similarity, i.e. glyphs representing identical filter statuses are identical in shape and color. This is not true for B3. We however hypothesize that pointing towards the participant instead of creating an abstract representation, will make design B3 easier to interpret.

4.2.3. Design C1/C2

Glyph B1/B2 requires the user to map a realistic situation to an abstract glyph. Natural mapping can however improve recognition of a glyph [Sur05]. The design of C1 therefore attempts to represent the position of collaborators around a tabletop in a more realistic way. Figure 2 illustrates how C1 represents user position. The data point is an abstract representation of the table. Location of the circles, representing the collaborators, matches the perceived distance between participants and the table, following the perceptually uniform glyph property guideline [BKC*12].

As B2, C2 removes the information about collaborators who are not highlighted. We hypothesize that this could be less of an issue with a more natural mapping.

5. Evaluation

We performed a think-aloud evaluation with 4 experienced data visualization users (all male, age 23 - 33) to validate the design and evaluation. We then evaluated all glyph designs with 14 participants individually (13 male, 1 female, age 21 - 38) consisting of Computer Science researchers and students.

Every participant was placed at an interactive tabletop. After being familiarized with the glyph designs, participants were given 2 tasks per glyph design. For each task,

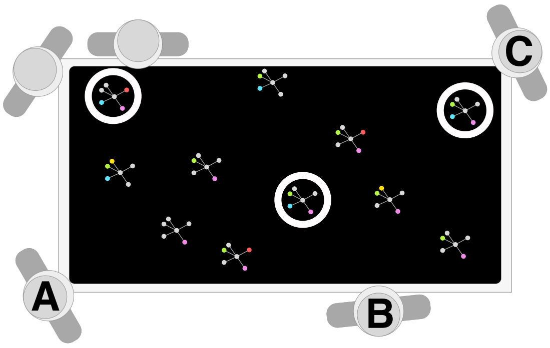

Figure 3: *Evaluation setup: the participant needs to find (here highlighted) 3 glyphs filtered by user A and B.*

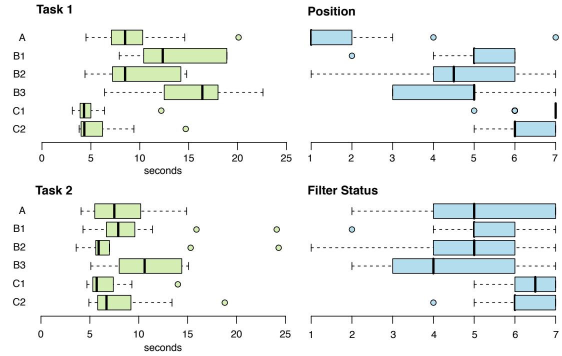

Figure 4: *Left: Time to task results for identifying 3 data points within 1 user's filter results (task 1) and 3 data points within 2 users' filter results (task 2). Right: Questionnaire results per design. Perceived usefulness for finding the location of a participant and perceived usefulness for finding who had the data point within their filter result.*

a set of data points were visualized. We provided the participants with filter criteria and asked them to identify the data points that met the criteria. The first task was identifying 3 data points contained within the filter result of 1 fictitious person at a specific position around the tabletop. The second tasks required participants to identify 3 data points contained within both the filter results of 2 specific fictitious people (see Figure 3). The completion time for every activity was tracked. Detailed information about the dataset and the evaluation application code is available at http://github.com/svencharleer/PoPI.

C1 and C2 clearly performed best at task 1 (see Figure 4, Task 1). Participants completed task 2 faster with C1, C2 and B2 (see Figure 4, Task 2). B3 performed worst for both tasks.

While participants would use the positional information to identify a first data point, the shape and color was used to identify the remaining 2 data points. Color alone seemed less effective as the results of A and B3 show. When first introduced to B3, participants perceived it as more logical and easier to understand. After the tests, they reported that the lack of consistency in shape made it difficult to find subsequent data points e.g. the glyph representation for 2 identical filter statuses differed depending on the data point's position. This seemed important to identify the remaining 2 data points once the first was found. We must further investigate whether similar results can be achieved without the individual colors.

Showing only active filter statuses made it more difficult to find the correct C2 glyph. The non-active statuses helped distinguish users standing close to each other. This seemed not the case for the B variations, where B2 performed better than B1.

Every evaluation ended with a questionnaire. Two 7-scale Likert questions (1 - strongly disagree to 7 - strongly agree) questioned the perceived usefulness of every glyph design.

Question one asked about the perceived usefulness of the glyph for finding the location of participants around the tabletop. The C variants were perceived more useful than the others (see Figure 4, Position). The same goes for the second question, which asked about the perceived usefulness of the glyph for finding who had the data point within their filter set (see Figure 4, Filter Status). C1 rated highest for aesthetic preference (followed by C2, A/B2, B1/B3).

6. Conclusion and Future Work

Our results indicate that PoPI glyphs have potential as a multi-user, global filtering mechanism on interactive tabletops. During our evaluations, the C1 PoPI design was perceived most useful and performed best overall, which confirms the importance of natural mapping [Sur05] and the addition of location information of every user.

Using the aforementioned Kinect setup, an important next step will be to evaluate in real-life settings to understand the impact of a dynamic environment, and thus animating the position information across an entire visualization. Our designs should also be further evaluated for 1) different types of visualizations, e.g. scatter-plots, node-link graphs, 2) other visualization dynamics, such as selecting, panning, zooming, and 3) different screen setups (larger screens, vertical displays).

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