Eliciting Multi-touch Selection Gestures for Interactive Data Graphics

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Abstract

We report the results of a study in which we elicited selection gestures for multi-touch data graphics. The selection of data items is a common and extremely important form of interaction with data graphics, and serves as the basis for many other data interaction techniques. However, interactive charting tools for multi-touch displays typically only provide dedicated multi-touch gestures for single-point selection or zooming. Our study used gesture elicitation to explore a wider range of possible selection interactions for multi-touch data graphics. The results show a strong preference for simple, one-handed selection gestures. They also show that users tend to interact with chart axes and make figurative selection gestures outside the chart, rather than interact with the visual marks themselves. Finally, we found strong consensus around several unique selection gestures related to visual chart features.

Categories and Subject Descriptors (according to ACM CCS): Information Interfaces and Presentation [H.5.2]: Misc—, Computer Graphics [I.3.6]: Methodology and Techniques——Interaction techniques.

1. Introduction

We discuss the results of a study that elicited multi-touch gestures from participants for a range of data selection tasks. Our study assessed whether the choice of selection task and type of chart influenced the type of selection gestures people used. Our goal is to contribute to the eventual establishment of a gesture vocabulary for multi-touch data graphics. Dedicated multi-touch interaction techniques for data graphics are still rare, despite the fact that touch interaction is available on many types of devices. Moreover, many applications that run on touch-enabled devices include data graphics—such as bar or line charts—to show financial data, allow fitness tracking, overviews of energy consumption, etc. Yet, people's ability to really explore this data has been limited by the available multi-touch interaction capabilities of these charts. In most cases, people can only select single data items, pinch-to-zoom, or drag to reposition a chart. More complex range selections, for example, are hardly ever supported—likely because they are not available out-of-the-box in touch SDKs.

We contribute findings on how selection—as a fundamental interaction technique—can be supported with multi-touch gestures. As discussed by Yi et al. [YKSJ07], selection is fundamental to a variety of other interaction techniques in visualization such as filtering, detail-on-demand, or brushing-and-linking. Our study examined how people would naturally use multi-touch gestures for a range of different selection tasks on several different types of charts. We contribute an analysis that characterizes the kinds of gestures participants used and the chart elements they interacted with. We also highlight the high level of agreement between some of the gestures proposed by our participants, particularly in cases when the selection corresponds to a visual feature in the chart.

2. Related Work

Our work builds on prior research on multi-touch gestures and selection techniques for data graphics.

2.1. Multi-touch Gestures

We used a study methodology popularized by Wobbrock et al. [WMW09] who elicited gestures for digital tabletop displays. In this methodology, the facilitator shows participants the effect of a gesture and then asks users to perform a gesture that caused this effect. Wobbrock et al. found that participants favored simple selection gestures such as tapping on a target. Similarly, North et al. [NDL*09] captured a large set of uni- and bi-manual grouping gestures on circular tokens hinting at the richness of a possible multi-touch selection vocabulary. While the above studies tried to find sets of gestures, others have explored how to improve specific problems inherent in touch selection, such as occlusion

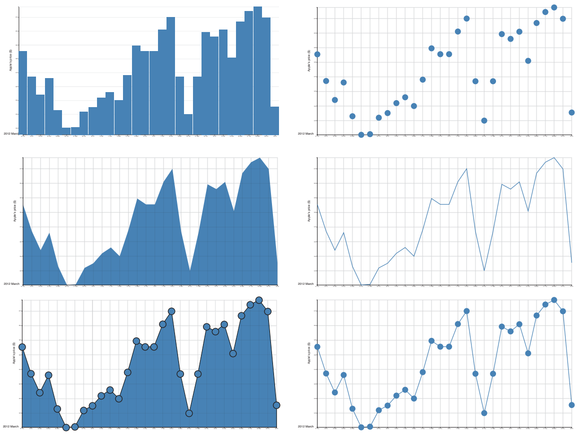

Figure 1: *The six different charts used in our experiment. (Points and lines are enlarged here to improve readability).*

(the “fat finger problem”). Past solutions proposed displaced cursors [BWB06, PWS88, VB07] or dedicated selection widgets such as lenses [RCBBL07, VST*09]. Our work relates most closely to the two studies of surface gestures mentioned above [NDL*09, WMW09] but focuses on selection tasks specific to data graphics. We focus on finding a set of gestures and do not, at this point, consider specific refinements such as those in [BWB06, PWS88, VB07], that might improve selection accuracy. We consider this important future work once a selection vocabulary has been established.

2.2. Selection Techniques for Data Graphics

Selection is a *fundamental* view manipulation [HS12, YKSJ07], often executed using mouse hover/click, region selections, and area cursors. Selection is usually implemented as a simple picking technique but researchers have also explored its power more deeply by extending underlying selection models or providing extensions to the common selection specifications. Heer et al.’s [HAW08] model defines selections as declarative queries to support selection with query relaxation. The model allows the system to maintain evolving selections of dynamic data, to reapply selections across representations, and to easily expand selections based on data properties. The model underlying TeddySelection and CloudLasso [YEII12] automatically determines bounding selection surfaces in 3D to spatially select particle subsets in 3D point clouds with 2D input. Examples for extensions to the standard selection specifications include those that use physics-based items such as magnets or rulers [RK14, YMSJ05] to separate data items from one another. These techniques relate to ours in their general application domain; yet, to the best of our knowledge, no previous work has expressly studied multi-touch gestures for selection in data graphics.

3. Selection Challenges for Data Visualization

Finding effective multi-touch selection gestures for data graphics includes a number of challenges. Data graphics can contain multiple data-driven subcomponents—including visual marks, axes, and legends, as well as the chart canvas itself—on which selection gestures can potentially be executed. Moreover, the semantics of selection may vary depending on the data type. For example, quantitative data may support continuous selections spanning ranges while ordinal or nominal data sets may not. Finally, because data graphics support visual pattern matching and filtering based on visual interpretation, they often need to support selection not just on data dimensions, but also on visual features like clusters, peaks, or trends in the chart. We do not yet know how the interplay between data-driven components, data semantics, and data layout influences how people think of and want to execute selections on multi-touch data graphics.

#	Selection Task	Prompt
1	Point, ordinal	*the (dp) on Friday 23, 2012*
2	Point, quantitative	*the (dp) with price 550*
3	Point, quantitative min/max	*the (dp) with the highest price*
4	Range, quantitative	*the range of (dp)s with price $580–590*
5	Range, ordinal	*the range of (dp)s between March 5–11*
6	Non-contiguous points, quantitative	*the three lowest price (dp)s*
7	Non-contiguous points, ordinal	*the (dp)s on March 1st, 4th, & 18th*
8	Non-contiguous points by property	*all the peaks*
9	Non-contiguous points, repetition	*all (dp)s on all Fridays*
10	Non-contiguous ranges by property	*all the downward trends*

Table 1: *The ten selection tasks used in our experiment. We instructed participants to “Perform a gesture to let the system highlight [prompt].” (dp) = data point.*

4. User-Elicited Selection Gestures

To identify a set of multi-touch selection gestures for data graphics, we conducted an experiment that elicited gestures from participants. This methodology ([SBCS*12, WMW09]) allows participants to express gestures without concern for whether they are implemented in current tools or if the gestures are compatible. We hypothesized that chart types and their visual marks (bars, lines, dots) as well as different selection tasks (single data items, ranges, visual features) would most strongly impact selection gestures that people propose. We therefore studied gestures under the following criteria:

Chart Types. Our study included six chart types (Figure 1). The first four were basic charts with different visual marks—bar chart, dot chart, area chart, and line chart. We suspected that participants might use dots as handles for interaction and also included two combined types—area+dot and line+dot charts. All charts showed the same financial dataset and used the same ordinal x-axis (31 time points) and quantitative y-axis (price, $530–$620, one tick per $10). A blank area below each chart could be used for off-chart interactions.

Tasks. We chose tasks (Table 1) that required participants to make three types of data selections: selecting individual data points (Tasks 1–3) and ranges (4–5), as well as multiple non-contiguous data points (6–7). We also included selections based on the visual semantics of the data (9) and visual form of the chart (8, 10). We specifically asked participants to "highlight" rather than just "select" items, to encourage them to produce general selection gestures (rather than gestures that assumed a subsequent action like moving or deleting).

4.1. Procedure

Each participant completed a practice task and all ten selection tasks on each of the six charts (66 tasks in total). We used a Latin Square to randomize the order of the first four chart types and then presented the area+dot and line+dot charts last in a randomized order. We presented the selection tasks in the same consistent order to all participants. Participants interacted with the charts on a vertical 32" 3M multi-touch display. We showed the charts at full-screen (1920 × 1080), with a one-line text description just above the chart and blank space for interaction below. Participants were not trained but had as much time as they wanted to complete each task. We used a think-aloud protocol in which participants verbally explained each gesture to the experimenter. We also filmed each participant's interactions and logged touch events from the display. On average, each session took 23 minutes. Sixteen participants volunteered for the study (13 male; 3 female; mean age 25.7 years (SD=4.4)). All participants were right-handed and all were very familiar with our four basic chart types. Four participants had never used multi-touch devices, six were only familiar with the basic press and pinch-to-zoom gestures, and the remaining six had more experience with multi-touch. Due to camera failures during three trials, we reduced our data analysis to 12 participants in order keep our chart order permutation-balanced.

5. Results

We recorded 720 total gestures from the 12 participants and classified each gesture based on: hand(s) used, number of fingers used, touch targets used in the gesture, and a textual description of the gesture form. Where possible, we reused established vocabulary [WMW09] to described our gestures.

5.1. Multiple Hands and Fingers

While participants were aware that the display supported multiple touches, they almost exclusively used their dominant hand (90% of gestures), and most used only one finger (86% of gestures). Only 7% of gestures used both hands. Multi-finger gestures were mostly restricted to the vertical range selection in Task 4, where 46% of gestures used 2 fingers. No other task saw more than 21% of participants use multiple fingers. Across all tasks, 79% of the gestures consisted of a *one-point touch* (23%), a *one-point path* (39%), or a linear combination of multiple one-point touches and/or paths (18%)—all of which can also be accomplished using a mouse.

Takeaway: Our participants overwhelmingly selected with one hand/finger, even when selecting multiple items, and tended to use mouse-friendly gestures.

5.2. Gesture Targets

Participants performed their gestures on a variety of chart targets. The largest share of gestures (48%) targeted chart axes and axis labels, while 23% targeted the box below the chart, 13% involved the visual marks (bars, lines, dots, or areas), and 4% used the chart canvas itself. The remaining 12% involved transitions between an axis and another target. For range-selection tasks, almost all gestures involved the axes (99% in Task 4 and 97% in Task 5). Meanwhile, nearly all participants carried out visual feature selection tasks by gesturing below the chart (79% in Task 8, 81% in Task 10) or on the canvas (14% in Task 8, 17% in Task 10).

Takeaway: Participants favored touching the axes when selecting ranges and individual data points. However, when selecting visual features (peaks, trends) they most commonly performed gestures outside of the chart.

5.3. Gesture Agreement

For each chart+task combination, we quantified the level of consensus among our participants by computing an agreement score for the set of gestures they proposed. We used the same method as in previous work [SBCS*12, WMW09] and specifically computed:

$$\text{Agreement } A = \sum_{P_i \subseteq P_r} (|P_i|/|P_r|)^2$$

with P_r = total set of proposed gestures for a chart-task combination; each P_i = a subset of identical gestures from P_r.

We observed high agreement between participants on some of our complex tasks (Figure 2) with several tasks showing a clear consensus for a single popular gesture (Figure 3). Across all charts, we saw especially high agreement for selections based on visual properties like peaks (Task 8) and trends (Task 10), as well as for ordinal range selections (Task 5). In all three cases, the majority of our participants

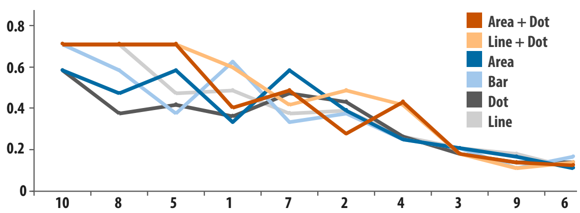

Figure 2: *Agreement scores by task/chart. Tasks are ordered based on the average agreement score across all charts.*

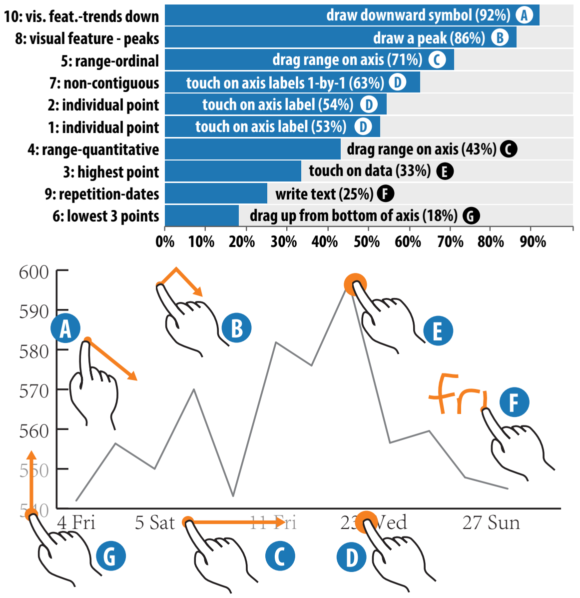

Figure 3: *(Top) Most common gestures used in Tasks 1-10. (Bottom) Examples of each common gesture type.*

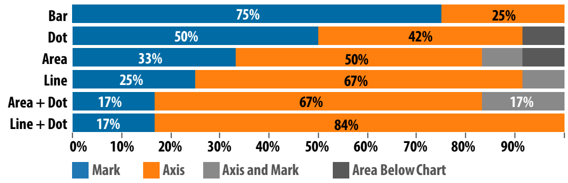

Figure 4: *Gesture targets by chart type (Task 1).*

used figurative gestures similar to those proposed by Kong & Agrawala [KA09]—drawing or tracing the shape of the desired feature or area. Meanwhile, abstract tasks like selecting minima/maxima (Tasks 3, 6) and selecting based on repetition (Task 9) showed little consensus.

Takeaway: Participants agreed strongly on selection tasks related to visual features (using mostly figurative gestures) and ranges (mostly dragging on axes), making these gestures good candidates for inclusion in a gesture vocabulary.

5.4. Differences by Chart Type

For most tasks, we observed very similar gestures across all six chart types. The one major exception was Task 1, where we asked participants to select a single data item corresponding to a date on the x-axis. When presented with a bar chart, 75% of our participants touched the bar itself. In contrast, when presented with a line+dot chart, 84% touched or circled the axis label corresponding to the date instead. Behavior for the other four chart types (Figure 4) had less of a clear split, but gestures on the axes were much more common overall.

Takeaway: For single-item selections, participants chose different gestures when the value was represented as a discrete mark—touching the bar or dot itself instead of the axis labels. No other task showed a strong difference based on chart type.

6. Discussion

The high average agreement and low number of unique gestures across all our tasks suggests that building a common multi-touch gesture vocabulary across a variety of data charts is indeed a possibility. Such a unified touch selection vocabulary should support touches on axes, the area surrounding the chart (if available), and—to a lesser degree—the chart canvas and marks. Further study is needed to find optimal gestures for tasks that involve more abstract concepts like minima and maxima, as well as selections using repetitive properties (e. g., "all Fridays"). A final challenge involves choosing gestures that are unambiguous and which do not conflict. Our results are promising in that participants favored gestures that are separable into categories: touches on axes or marks, dragging on axes, and drawing symbols on the background or periphery. Although we saw little use of multi-touch functionality in our experiment, we do not mean to imply that good sets of selection gestures should not use it. In fact, we believe multi-touch may still be very valuable when designing selection gestures—particularly more complex gestures that involve generalization [HAW08], excluding points within selections, refining selection, or mediating intersections between them.

7. Study Limitations

Further study is needed to draw strong conclusions about the effect of data type (e. g., ordinal vs. quantitative) on selection gestures as we hypothesize that our results for Task 1 & 2 and Task 4 & 5 could also be explained by the axis location (horizontal vs. vertical). More study is also necessary to assess whether the preferred gestures on small mobile devices are the same as to those on the desktop display we studied. Finally, all studies that use the user-elicitation methodology share a common limitation: users are not designers and therefore any proposed gestures still have to be carefully considered, designed, and tested further (see [HFD11, WMW09]).

8. Conclusion

Our analysis of 720 user-elicited selection gestures found a strong preference for simple one-handed gestures. Participants applied those gestures consistently across several standard chart types. We saw that participants focused their selection gestures on the axes and the area around the chart, rather than on the marks themselves. Moreover, in contrast to previous user-elicitation studies, we found a number of selection gestures that were agreed upon by the majority of our participants—particularly when the selection gesture related to a visual feature in the chart. Going forward, we hope that this analysis will help visualization designers create better sets of selection gestures motivated by user behavior.

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