Applying Pen Pressure, Tilt and Touch Interactions to Data Visualizations

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ABSTRACT

Bimanual interactions using pen and touch are natural to humans and have proven and explored in previous research. However, most of the previous work has been limited to using cartesian coordinates of fingers and pen tip. In this work, we go further by exploring additional pen data, like pressure and tilt, combined with multi-touch inputs. We apply this combination to two data visualizations: Bubble Chart and Linear Regression combined with a Radar. We have performed a preliminary user study comparing Pen and Touch interactions with Mouse input. We have found the Pen and Touch interactions can consume less time while looking for specific values in the Bubble Chart, whereas Mouse can be faster while looking for specific relation in Linear Regression and Radar.

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**; *Information visualization.*

KEYWORDS

Pen + touch; bimanual input; data manipulation; data visualization

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1 INTRODUCTION

Data manipulation is still primarily focused on the use of a mouse and keyboard for interacting with data [5]. However, interactive displays are quite popular on mobile phones and tablets. Pen and touch interactions are proven to be natural and efficient [1]. Its combination allows interactions that imitate physical pen and paper. This familiarity of pen and touch was already applied to data manipulation in previous research [4, 6, 8, 9, 11, 12]. Nonetheless, most of the previous approaches that combine pen and touch inputs are limited to use display cartesian coordinates for these modalities and traditional data visualizations like bar charts. Pen pressure and tilt can also be used for novel interactions [3, 7, 10]. Thus, which interactions can be promoted through the combination of other pen data, like pressure or tilt, touch input is still an open issue. In this work, we explore such a combination of inputs applied to two different non-traditional data visualizations. We have performed a preliminary user study comparing the two visualizations while using the mouse and pen + touch inputs.

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2 DATA MANIPULATION WITH PEN PRESSURE, TILT AND TOUCH

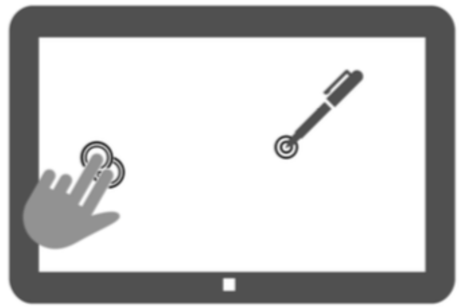
We have used two non-traditional visualizations from D3.js: the bubble chart and a linear regression chart combined with a radar. The bubble chart was used to visualize the different data regarding JAVA classes that compose the D3.js software, while the linear regression chart and radar were used to visualized different data regarding electric cars.

Figure 1: Bubble Chart

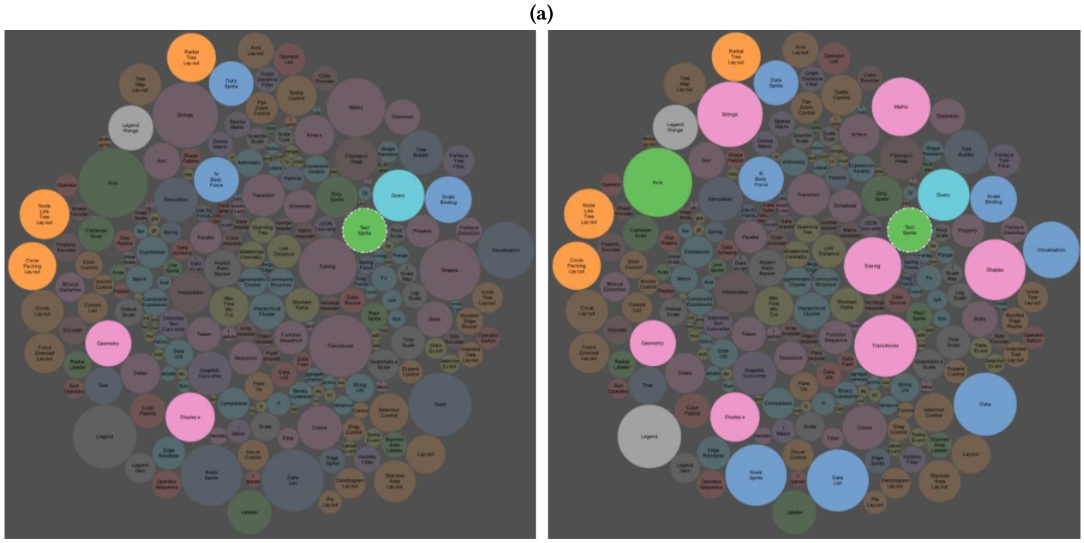
In the bubble chart (Figure 1), the color of bubbles shows the subclasses that share the same superclass. The size of each bubble is proportional to the number of code lines inside each class. While pressing inside of a bubble, a pop-up window shows the class name and the number of code lines.

In this context, the bimanual interaction of pen and touch can be used to highlight bubbles higher or lower a certain threshold of the number of code lines (Figure 2). Touching the display with one finger selects higher values, while touching with two fingers selects lower values. The pen pressure varies the threshold. The initial value of the threshold is the one selected with the pen.

On the radar, one can see the relation between cost, range, battery size, horsepower, and cur weight of different electric cars. The



(a)



(b)

Figure 2: Highlight values using two fingers and pen pressure: (a) Two fingers touching the display and using pen pressure; (b) Left - Less pressure, less highlighted values, Right - More pressure, more highlighted values

linear regression shows the correlation of two of these factors and selecting a particular car model to add to or remove it from the radar (Figure 3).

In this context, one can select the car model in the regression chart and add it to the radar, displaying the relation between that particular model's different factors. It is possible to change the regression chart's factors by touching with three fingers on the display and tilting the pen horizontally (x-axis) or vertically (y-axis). On the radar, one can hoover the pen over a dot, and a pop-up will show the model and the value of the particular factor. In addition, by touching with one finger and the pen tip on the display, the radar will show the values regarding the global maximum, i.e., the maximum value between all car models in the database. Two fingers and the pen tip will change the scale to the selected maximum, i.e., the maximum value between the models added to the radar (Figure 4).

3 PRELIMINARY USER STUDY

We have performed a preliminary user study to assess the bimanual interactions applied to the two visualizations and compare it with regular mouse interactions. In the study, we have used a Windows 10 laptop with a Wacom Cintiq DTH-1300 tablet, which recognizes simultaneously touch and pen inputs, 2048 pen pressure levels, and has 40 degrees of pen tilt range. The study included 8 participants, 2 of them were female, and the average of ages was M = 28.13 (SD = 12.12). The study followed a within-subject design, and the conditions were counter-balanced following the latin square method. As part of the study, the participants were asked to perform two groups of tasks: one based on a search for a particular value, the other based on a search for specific data relations. Since the study included four conditions, two visualizations, and two input modalities, the within-subject design made the participants repeat the same visualization with two input modalities. In order to avoid that the participants would know the answer in advance while performing the second modality, we decided to include for each group of task two similar but different searches. Thus, in the bubble chart, we asked the following questions to the participants:

- Task 1 - Specific values
  - How many code lines has the class "Easing"?
  - How many code lines has the class "Tween"?

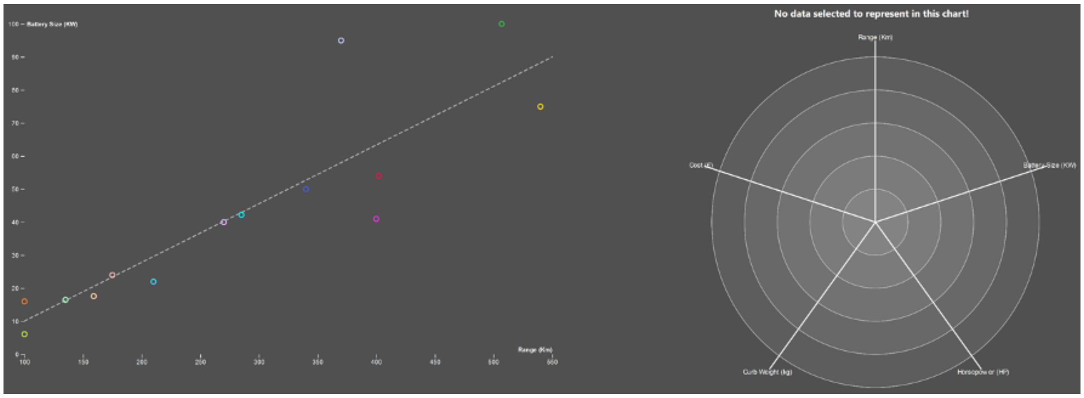


Figure 3: Linear Regression and Radar

- Task 2 - Specific relations
  - Please, write the name of classes that have more code lines than the class "Query"?
  - Which classes have less code lines than the class "Sort"?

In the combination of the linear regression chart with the radar, we have asked to the participants:

- Task 1 - Specific values
  - What is the weight of Peugeot e-208?
  - What is the the cost of Nissan Leaf 1st Gen?
- Task 2 - Specific relations
  - Please, choose the model with the lowest price but with highest range possible.
  - What happens to the car cost, when there is an increase of battery size?

After each condition, we have asked the participants to answer the SUS questionnaire [2]. Thus, we have measured the usability through the SUS, the time the participants took to complete the task in each condition, and accuracy of participants' answers for each task and condition.

3.1 Results

The SUS scores show slightly higher values for Bubble Chart and for Mouse usage, as shown on Table 1.

Table 2 shows the percentage of correct answers for each task and condition. Task 1 - Specific Values presents higher percentages of correct answers than Task 2 - Specific Relations, particularly for Radar visualization. In the Linear Regression and Radar, the Mouse usage shows a higher percentage of correct answers on Task 2. This second task also led to fewer correct answers.

Regarding the task completion times, Table 3 shows that the Bubble Chart was fastest for both tasks, when compared with the Linear Regression. It is interesting to note that the Pen and Touch were fastest for Task 1 - Specific Task, particularly on the Radar visualization. However, using the Mouse in the Linear Regression and Radar was the fastest for Task 2 - Specific Relations.

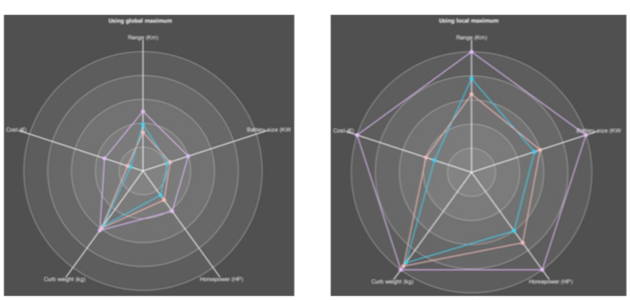


Figure 4: From global to local maximums

Table 1: SUS Results

		M (SD), N = 8	Mdn, N = 8
Bubble Chart	Mouse	72.81 (15.55)	71.25
	Pen and Touch	69.69 (20.20)	72.50
Linear Regression and Radar	Mouse	75.31 (12.13)	70.00
	Pen and Touch	61.56 (20.13)	68.75
		M (SD), N = 16	Mdn, N = 16
Bubble Chart		71.25 (17.49)	72.50
Linear Regression and Radar		68.44 (17.56)	70.00
Mouse		74.06 (13.54)	71.25
Pen and Touch		65.63 (19.93)	72.50

Table 2: Percentage of correct answers for each task

		Task 1 (%)	Task 2 (%)
Bubble Chart	Mouse	100	50
	Pen and Touch	100	50
Linear Regression and Radar	Mouse	75	87.5
	Pen and Touch	75	75
		M (SD), N = 4	Mdn, N = 4
Bubble Chart		75.00 (28.87)	75.00
Linear Regression and Radar		78.13 (6.25)	75.00
Mouse		78.13 (21.35)	81.25
Pen and Touch		75.00 (20.41)	75.00

Table 3: Task completion time in seconds

		Task 1 (sec)		Task 2 (sec)	
		M (SD), N = 8	Mdn, N = 8	M (SD), N = 8	Mdn, N = 8
Bubble Chart	Mouse	46.75 (31.00)	43.00	63.13 (26.23)	59.00
	Pen and Touch	34.75 (43.61)	15.50	108.38 (77.29)	82.00
Linear Regression and Radar	Mouse	81.00 (55.43)	61.50	55.88 (19.53)	56.50
	Pen and Touch	83.78 (55.29)	66.00	151.75 (86.64)	133.00
		Task 1 (sec)		Task 2 (sec)	
		M (SD), N = 16	Mdn, N = 16	M (SD), N = 16	Mdn, N = 16
Bubble Chart		40.75 (37.07)	37.00	85.75 (60.45)	67.00
Linear Regression and Radar		82.19 (53.49)	61.50	103.81 (78.31)	71.00
Mouse		63.88 (46.85)	50.50	59.50 (22.65)	59.00
Pen and Touch		59.06 (54.26)	39.50	130.06 (82.41)	97.00

4 DISCUSSION

Although the Mouse presented slightly higher usability scores in both visualizations, Pen and Touch were faster in the Bubble Chart while looking for a specific value (Task 1), and keeping the same accuracy as the Mouse. The time took to complete a task using the Linear Regression and the Radar for the same task was similar for both input modalities. On the contrary, while looking for specific relations (Task 2), the Mouse was faster and even led to more accurate answers in the Linear Regression and Radar visualization. It is also important to mention that the longer completion times during the second task presented in Pen and Touch with the Linear Regression and Radar visualization might be related with the fact that this task required a selection with the pen tip of small targets in the display, making harder to hit them.

These results show the importance of choosing the right visualization and the different input modalities for the right task.

5 CONCLUSION

In this paper, we present the usage of Pen and Touch interactions in two different visualizations: a Bubble Chart and a Linear Regression combined with a Radar. In addition to the traditional with the pen tip, we explored pen pressure and tilt combined with multitouch interactions. We have performed a preliminary user study comparing the developed interactions with similar ones but using the Mouse. The user study was based on two main tasks: looking for a specific value and looking up specific relations. We have found that Pen and Touch were faster in the Bubble Chart while looking for specific values, whereas the Mouse was faster in Linear Regression and Radar visualization while looking for relations. Nonetheless, further studies combining data visualizations and interaction techniques are required to find the multimodal tools that foster creativity and sensemaking tasks.

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