Towards More Effective Data Visualization Methods Using Haptics

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***Abstract*— Cognitive overload in complex multi-dimensional data visualization can cause challenges for users to comprehend, navigate, and determine statistical measures. To address this problem, we tested the feasibility of integrating vibrotactile and force-feedback haptics with bubble charts to test several haptic rendering techniques for visualizing data. The preliminary results suggest that force-feedback was effective in quickly navigating to points of interest in the data, and vibrotactile feedback was effective in representing higher dimensions and locating statistical measures of data.**

I. Introduction

Data visualization tools and methods have significantly changed the way that we can look at complex data. However, the primary means of data presentation is the visual channel in many of these tools. While this modality can be considered the most effective, it can also become overloaded due to the complexity of the data. We hypothesize that the haptic modality can be leveraged to minimize the visual information overload for visualization tasks. While haptics has been used to represent line graphs, bar charts, pie charts, scatter plots, maps, signs, networks, and tables, further research is required in this field to identify the best methods of representing these types of graphs as well as identifying additional areas in which haptics could be used for visualization [1-4]. To understand the potential for using haptics, we explored the use of force-feedback and vibrotactile feedback to create several haptic visuals for representing bubble charts. We attempted to use haptic feedback as a tool to identify statistical measures of the data, to create user guided data navigation, to signify visually hidden data points, and to represent other hidden dimensions of the data.

II. Implementation

We used the Haply, a 2 DoF grounded force feedback device, and a 3V coin-type linear resonant actuator mounted on the end-effector of the Haply for vibrotactile feedback. A data set containing the name, life expectancy, average income, and population of each country was used to create the bubble chart in Processing 3. Our haptic visual contained four modes: navigation, vibrotactile, force-feedback, and story, as shown in Fig. 1. In the navigation mode, the user could input the name of a country through a search box, after which the end-effector would guide them towards the data point corresponding to that country. The vibrotactile mode was leveraged in two ways. The first was used to represent an additional dimension of data not shown visually. The user could roam freely to a data point to feel a vibration of an intensity directly proportional to the literacy rate of a country. The second was used for quick identification of percentiles. When the user crossed an "invisible wall" representing a quartile of the personal income, they felt a vibration corresponding to its intensity. In the force-feedback implementation, the user felt a "sticky" and "damped" texture created by the Haply as they crossed over overlapping clusters in the chart. Lastly, story mode was meant to convey a guided tour of "important" points in a graph. The end-effector moved sequentially to guide the user from one point to the next with a 3s interval between each jump while providing the "story" via a written text message. To test our prototype, we conducted internal user testing.

III. Results & Discussion

Based on our results, force-feedback-based navigation appears to be ideal for quickly navigating to points of interest in a densely populated bubble chart. The "sticky" texture felt useful in highlighting overlapping regions but did not perform any better than using the visual modality. Our results also suggest that vibrotactile feedback can be used to represent a hidden dimension in a multi-dimensional data set. We were able to notice clear differences in vibration intensities between low literate, medium literate and high literate countries, suggesting that the method provided a fast and intuitive indication of a country's literacy rate. Vibrotactile feedback also seemed suitable as an active guidance tool for quickly identifying specific points not usually shown on a graph, such as the mean and percentiles. For future work, we plan to conduct a formal user study and recruit participants to test our prototype.

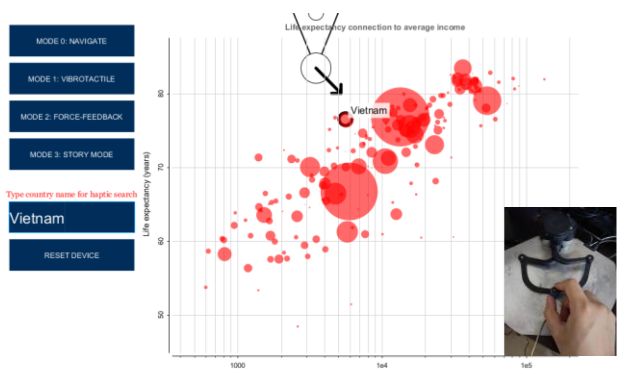

Figure 1. Bubble chart haptic visual. The modes can be accessed using the buttons on the left. The Haply is shown on the bottom right corner.

IV. References

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