

FACULTY OF ENGINEERING & IT

The Design of Touchable Interactions for Data Visualization

Thesis of Master by Research Degree

Shizhe He

Supervisor: A/Prof. Mao Lin Huang

Year of submission: 2016

Acknowledgement

On the completion of my thesis, I would like to express my deepest gratitude to all the people whose kindness and advice have made this work possible.

First and foremost, I would like to thank my supervisor A/Prof. Mao Lin Huang, for his expertise and patience. His effective advice and shrewd comments kept my research and the thesis in the right direction.

Thanks to my research fellows Wenbo Wang, Jinson Zhang, Jie Hua, and Phi Giang Pham for their invaluable advice and encouragement. And I would like to extend my thanks to Bowen Xu and Lin Zhu for their help and support during the implementation and tests.

Thanks to my parents for their unconditional support and trust.

CERTIFICATE OF ORIGINAL AUTHORSHIP

This thesis is the result of a research candidature conducted at University of Technology as part of Masters by research degree. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the Masters by research degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student:

Date: April 22, 2016

Table of Contents

LIST OF ILLUSTRATIONS AND TABLES

ABSTRACT

CHAPTER 1 INTRODUCTION	1
1.1 DESCRIPTION OF KEYWORDS IN TITLE	1
1.2 BACKGROUND	1
1.2.1 DEVELOPMENT OF HCI AND TOUCH INTERACTION	1
1.2.2 WHY TOUCH/WHY NOT TOUCH?	2
1.2.3 BACKGROUND OF DA-TU: CLUSTERED GRAPH VISUALIZATION	3
1.3 AIMS, OBJECTIVES AND SIGNIFICANCE	5
1.4 OUTLINE OF THIS THESIS	6
CHAPTER 2 LITERATURE REVIEW	8
2.1 EXISTING TAXONOMIES OF TOUCH STYLES	8
2.2 DATA DEPENDENT TOUCH ACTION STYLES	10
2.2.1 DIRECT-ON-DATA MANIPULATION	10
2.2.2 VIRTUAL INSTRUMENT	11
2.2.3 UNIQUE TECHNIQUES: DATA SPECIFIC	11
2.3 DATA INDEPENDENT TOUCH ACTION STYLES	12
2.3.1 TOUCH PANEL	12
2.4 MIXED TOUCH ACTION STYLES	13
2.4.1 MULTI-MODAL INTERACTION	13
2.4.2 GESTURAL TRIGGER	14
2.4.3 DRAWING GESTURES	14
CHAPTER 3 RESEARCH METHODOLOGY	16
3.1 DESIGN RESEARCH AND DESIGN STUDIES AS PROJECTS	16
3.1.1 PRECONDITION: LEARN, WINNOW AND CAST	16
3.1.2 CORE: DISCOVER, DESIGN, IMPLEMENT AND DEPLOY	16
3.1.3 ANALYSIS: REFLECT AND WRITE	17
3.2 DATA ANALYSIS METHODS	17
3.2.1 PROBLEM DEFINITION	17
3.2.2 GETTING AND CLEANING DATA	18
3.3 EVALUATION	20
3.3.1 EVALUATION DESIGNS	20
3.3.2 MEASUREMENTS	22
CHAPTER 4 MERITS AND LIMITATIONS OF TOUCH INTERACTION	23
4.1 UNIQUE VALUES INTERACTIVE SURFACES OFFER	23
4.2 LIMITATIONS AND TRADEOFFS COMPARED TO WIMP	29
CHAPTER 5 DA-TU ON IPAD: CLUSTERED DATA VISUALIZATION WITH GESTURAL INTERFACE	31
5.1 DESIGNING A MULTI TOUCH GESTURES SET	32

5.1.1 CLASSIFICATION BASED ON ACTION SCOPES	32
5.2 EVALUATION	35
5.2.1 STUDY ONE: EVALUATE THE RELIABILITY AND USER SATISFACTION	35
5.2.2 STUDY TWO: EVALUATE THE EFFICIENCY	38
<u>CHAPTER 6 RADIAL CURSOR: AN EFFICIENT INTERACTION TECHNIQUE TO EXPLORE RADIAL HIERARCHY VISUALIZATIONS ON TOUCH SCREENS</u>	40
6.1 DESIGN AND IMPLEMENTATION	41
6.1.1 ITERATIVE PROTOTYPING AND TESTING	42
6.1.2 VISUAL COMPONENTS OF RADIAL CURSOR	42
6.1.3 ACCESS ALL THE NODES BY BIMANUAL OPERATION	43
6.1.4 RADIAL LAYOUTS: NODE-LINK AND SUNBURST	43
6.2 USE CASES	43
6.2.1 FLICKR PERSONAL TAXONOMIES	43
6.2.2 OTHER APPLICABLE DATASET	44
<u>CHAPTER 7 CONCLUSION</u>	46
<u>PUBLICATION</u>	48
<u>REFERENCE</u>	49

List of Illustrations and Tables

Figure 1-1 Navigating a clustered graph C in DA-TU.....	5
Figure 2-1 Visualization of correlations between investigated works (1 st axis), data type (2 nd axis), data representation (3 rd axis) and our proposed classification styles (4 th axis).....	9
Figure 2-2 pluck a single edge (a-c), flick an edge (d-e) proposed by Shimidt et al. [16]	10
Figure 2-3 right: ruler from TouchWave [17] left: virtual lens from FingerGlass [20].....	11
Figure 2-4 Navigating a data item temporally along its hint path [22]	12
Figure 2-5 left: fractal perspective right: corresponding node-link representation	12
Figure 2-6 operating multiple sliders simultaneously	13
Figure 2-7 use pen to annotate [9] (a), create charts [28] (b) and employ a token to do query [30] (c)	13
Figure 2-8 drawing gestures used to manipulate diagram	15
Figure 3-1 Pipeline of data analysis [35]: 1. Statistical methods development 2. Danger zone!!! 3. Proper data analysis.....	18
Figure 3-2 result of “plot(log10(trainSpam\$capitalAve + 1) ~ trainSpam\$type)” in R	20
Figure 4-1 funnel gesture in graph visualization [16]	23
Figure 4-2 multi-point input in scatter grid (a) and parallel coordinates (b, c)	24
Figure 4-3 Exploring larger areas of the dataset using a fist (left) Glyph de-emphasis & erasing using the flat hand (right).....	25
Figure 4-4 advantage of space utilization, screen shots from [11]	26
Figure 4-5 effectively interact with map visualization.....	26
Figure 4-6 “playful exploration” in Bohemian Bookshelf.....	27
Figure 4-7 occlusion caused by hand.....	29
Figure 5-1 Screens collected from user studies	31
Figure 5-2 Confirm selection and finish create operation.....	35
Figure 5-3 Trojan War Dataset.....	36
Figure 5-4 Ratings of Goodness.....	37
Figure 5-5 Ratings of Ease	37
Figure 5-6 Time (seconds) spent by the participants on each task.	39

Figure 6-1 Screenshots and photo of radial cursor	41
Figure 6-2 Use case studies	45
Table 2-1 Categories of touch action styles.....	8
Table 3-1 list of public open data sources	18
Table 3-2 Basic characteristics of evaluation designs. Modified from [36]	20
Table 3-3 evaluating methods for evaluation, partially derived from [37].....	21
Table 5-1 10 operations are categorized based on number of target	32
Table 5-2 List of proposed gesture vocabularies in DA-TU	34
Table 5-3 Tasks designed for character map from Trojan War	38

Abstract

Natural User Interfaces (NUIs) are gradually becoming universal in modern user interface design. Researchers are attempting to apply novel Computer-Human into the design of interactive data visualization. Touchable interaction, an affordable and relatively mature member of NUI, has drawn much attention in today's design of personal computers. And it has been proved to be effective and efficient in accomplishing some certain tasks, for example, pinch and stretch to zoom or scale. However, the values of Interactive Tabletops and Surfaces (ITSs) that could offer to the field of data visualization still remain unclear. The derived questions become how to best leverage touchable interaction into data exploration, navigation and manipulation.

We reviewed over fifty papers and proposed a classification of touch interaction styles, based on how fingers interact with data. And then we organized the literature review according to the proposed category. Following this, we listed where touch interaction outperforms desktop and mouse, along with where the limitations and tradeoffs are. Any combination of the merits or limits could become a research question, but we are only focusing on the ones applicable with tablet-sized touch screen.

As a pioneer research, we designed a set of gestural commands to replace keyboard-mouse interactions in DA-TU. Clustered graph visualization, such as DA-TU, has been successfully applied in the field of large scale relational data visualization for data analytics. But it was very inefficient in interactions, in which a control panel was required to swap among eight different modes of operation. The proposed design was implemented on iPad, and we conducted user tests to demonstrate its higher efficiency and better user experience.

Mouse hover is a common and effective solution in data visualization applications to deal with the "representation problem". We proposed an interaction technique named Radial Cursor to address this problem on touch screens. It stimulates 'mouse hover' interaction with radial hierarchical data, coupled with a level switch, Radial Cursor provide intuitive and effective controls of 'hover to see more detail' or 'hover to highlight' over every data node. We also applied real dataset to show that Radial Cursor helps user to quickly get a general sense of an unfamiliar dataset, or review an already-known dataset.

We integrated the methodology from visualization project design study, industry of Human-Computer-Interaction, and data analysis process. Hopefully our work can contribute to clarifying why we need touch displays to support data visualization, and how to best leverage touch interaction in visual data analytics tasks.

Keywords: interactive data visualization; multi-touch; natural user interface (NUI); playful data analysis; design research