Interaction Space of Chords on a Vertical Multi-touch Screen

Ioannis Leftheriotis
Ionian University
Tsirigoti sq. 7, Corfu, Greece
and
Norwegian University of Science and Technology
Sem Sælands cei 7-9, 7491
Trondheim, Norway.
iolef@acm.org

Michail N. Giannakos
Norwegian University of Science and Technology
Sem Sælands vei 7-9, 7491
Trondheim, Norway.
michailg@idi.ntnu.no

Konstantinos Chorianopoulos
Ionian University
Tsirigoti sq. 7, Corfu Greece.
choko@ionio.gr

Letizia Jaccheri
Norwegian University of Science and Technology
Sem Sælands vei 7-9, 7491
Trondheim, Norway.
letizia@idi.ntnu.no

ITS '15, November 15-18, 2015, Funchal, Portugal
ACM 978-1-4503-3899-8/15/11.
http://dx.doi.org/10.1145/2817721.2823506

Abstract
Despite the increasing use of Multi-Touch (MT) capable devices, novel interaction techniques need to be examined in order to swift from a single-touch WIMP interaction paradigm to a MT one.In this work, we focus on chord interaction on vertical MT screens. Chord is the simultaneous touch of more than one finger on the MT screen. Based on a user experiment with 12 users, we explore the positioning - interaction space of the chord technique, by investigating a relation among the type of the chord (number of fingers) and the position on the screen that the chord was applied. The empirical results have indicated an interaction pattern that demonstrates a significant relation between the type of the chord that was applied (number of fingers) and its position on the screen. Our results show that as the number of fingers needed for a chord increases, the nearer from the bottom left of the screen this chord is to be applied. Notably, our results give evidence of the fact that there is a threshold (five-finger-chord) beyond which the above relation is not strong.

Author Keywords
Multi-touch; chords; interaction area; interaction distance; vertical screen; action windows

ACM Classification Keywords
H.5.2. Information interfaces and presentation

INTRODUCTION

In recent years, multi-touch (MT) have become the standard way of interaction in many appliances in our daily lives. From small mobile devices to bigger MT screens using multiple fingers is almost always a key element of the interaction. In this work, we are focused on the simultaneous touch of more than one finger on the MT screen (chord interaction). Previous studies have investigated the use of chords along with the appropriate interface on larger MT surfaces. Most of the studies take advantage of the chord technique in order to help users to select things from a menu. There have been studies such as Bailly et al's [1] who investigated the Finger-Count Shortcuts or marking menus [9] and found that they perform better in menu selection, especially with expert users. Kin et al [6] proposed a finger registration technique and introduced the Palm Menus demonstrating that using finger chords has significant performance advantage. Recently, Ghomi et al. [3] introduced a method in order for the user to learn chord gesture vocabularies. Researchers have studied the mechanical constraints for finger combination and propose appropriate vocabularies. In an alternative context, Leftheriotis [7] propose a multi-touch chord password technique that allows for user authentication on MT screens. Based on the recent research on the field, it seems that chords have gained interest among interaction designers as a novel interaction technique for innovative use of MT screens. Researchers have already proposed a variety of chord interaction strategies such as directional chords [3,9], bimanual chords [6], finger combination chords or simple number-of-finger touch chord systems [4]. However, almost all studies focus on the posture of the hand and its affordances and usually compare the use of chords to other techniques (e.g. menus).

In order to further understand the chord interaction technique and support its use among developers and researchers, we explore its interaction space by trying to find whether there is a relation among the type of the chord and the position on the screen that the chord was conducted. In Nova's literature review [10], the importance of space in collaborative settings is thoroughly discussed. Erickson [2] claims that even when there are spatial constraints, activity might be generated. Since most multi-touch systems are intended for collaborative multi-user environments, the need for exploring the interaction space of chords seems apparent, especially for larger MT surfaces where interacting directly with the entire surface can be difficult for users [5]. In this research, mainly through quantitative analysis of an experimental task on educational context, we investigate whether there is a relation among the type of the chord that was conducted (number of fingers) and its position on the screen.

Our research hypothesis, based on our experience with users working with chords on MT screens, is that chords with fewer fingers will be conducted in different position patterns than the chords that demand more fingers due to complexity difference or due to comfort reasons. The results of this research can be valuable to MT developers and researchers since, if for example the increased complexity of multi-finger chords make them cumbersome for the users, then, other selection techniques should be preferred. On the other hand, if the interaction space of different chords has similarities or patterns that are being followed by the users, then this work helps us to understand them better in order to build more effectively MT interactive applications.

Methodology

Research design

We have developed a MT application supporting multi-user chord interaction in combination with personal action windows. It was developed in Python MT framework, using the chordiaction toolkit [8] and was part of a broader MT educational application dedicated to botanology.

Application Interaction Design

We developed a connect-the-dots drawing application with a focus on MT chords. The idea is simple and intuitive: Users have to apply the appropriate number of fingers in order to select the respective brush and draw inside a new action window. There are four brush types: a) thick black line, b) bold black line, c) thick colored line, d) bold colored line. Each brush has its own chord identifier in order to be selected. Since we have reserved the single touch and two touch interactions for moving action windows and pinch gesture (zoom in and zoom out of action windows), we have matched the three fingers chord to the thick black brush, the four fingers chord to the bold black brush, the five fingers chord to the thick colored brush and the six fingers chord to the bold colored brush respectively. Users used both their hands in the six fingers chord. Since there is lack of research dealing with chords from both hands in the relative literature, we wanted to explore the broader interaction space of chords.

Apparatus

In order to minimize the possibilities of something to go wrong, our experimental setup was based on a robust 27” inch all-in projective capacitive monitor with 5ms response time, which was placed vertically in front of the two seated users. The screen was connected via USB to a Windows 7 environment installed on a Mac mini hardware. There was a camera just behind them capturing their interaction strategies and patterns and the system was logging every touch of the screen.

Sampling

Twelve users participated in our study, of which two were male and ten were females. Users were 17-18 years old. All participants were right-handed so as to all feel comfortable with our interaction technique. The experiment took place during an extracurricular activity for botanology in a museum in Trondheim, Norway.

Procedure

In the exploratory phase of the application there was an educational task with one and two-finger-chord interaction so as the user get acquainted with the MT technology in general. Next, we showed the dot-to-dot - drawing application to the users and explained them how to apply the chords in order to create the action windows inside which they would draw. We let the users to understand how the system works for five to ten minutes until they would feel confident to interact.

The experimental task begins with a number of dots that represent a flower on a white background. We asked from the users to connect the dots and then draw inside the flower with the colors they wanted. There was no limit to their imagination or their time, since we wanted to investigate the interaction space of chord interaction technique. Users had to apply a chord every time they wanted to change their brush or change the color they are painting with.

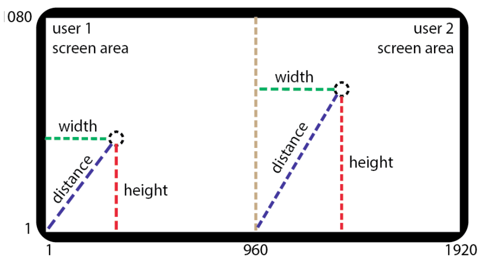

Figure 1. A representation of the MT screen showing how we calculated the Euclidean distance of every position where a chord/window was created. The measures that we used so as to explore the interaction space while two users are working with chords and windows on a 1920 x 1080 MT monitor.

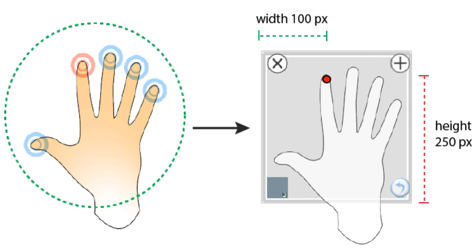

Figure 2. The chord interaction area is enabled in accordance to the pointer finger. This illustration shows the distance from the lower left corner of the (transparent) action window to be created when the appropriate chord has been formed in relation to the positioning of the pointer finger. The action window size could be changed with the pinch gesture (two fingers) and it could be moved all over the screen (one finger).

Measures and Data Analysis

The study was designed to collect both quantitative and qualitative data, including video and observation notes. The majority of the quantitative data used in the statistical tests was obtained by the log-files of the application. After the game play, users completed a paper-based survey. The survey captured users' experience with technology and in particular touch and multi-touch devices.

Positioning of chords/action windows

The active interaction space of the screen was 1 – 1920 pixels in width and 1 – 1080 pixels in height. We had two users in each session seating side by side in front of the vertical screen. Hence, we make an assumption that chord interactions happened in the left side of the screen (1-960 pixels) belong to user one and chord interactions happened in the right side of the screen (961 - 1920 pixels) belong to user two because: a) personal territories are most often located directly in front of people [11], b) there was no need for storage or group territories [11] in our dot-to-dot drawing application and c) the personal windows that would pop-up after the appropriate chord interaction are free to move all over the screen. That is why users are supposed to articulate the chords to their most convenient spot, which reasonably would be in front of them. Having the spot where the chord was articulated, we then calculated the distance from the bottom of the screen (height) and the distance from the left side of the screen (width) (Figure 1). As such, we ended up with the exact height and width of every chord (actually the positioning of the index finger while articulating the chord). Users had to firstly touch their pointer finger so as to trigger the chord interaction technique and thus we logged the positioning of their first touch. The index finger is the most common hand gesture and it is used in more than 70% of the times a user interacts with touch screen devices. In a drawing application like ours, this percentage reaches 90% of interaction. Users' index finger was mainly used as the basis of the chord. Users were free to also include any other finger they wanted in order to form the chord they wanted. Figure 2 exhibits the positioning of the chord in relation to the action window that pops up when users articulate the chord.

We then calculated the Euclidean distance between each logged spot and the bottom left of the appropriate part screen – the left for user one and the right for user two. In order to identify any potential difference on the spot creation of 3, 5 and 6 chord windows, an independent samples t-test was conducted. Hence, we were able to compare the Euclidean distances of the respective chord type windows.

Research Findings

As it is shown in Table 1, users opened 69 chord windows in total. The mean spot was positioned in (413,544) of the screen (considering its size as 960 x 1080 pixels since it was used by two users and was divided in half). In Figure 3, there is a visualization of the average spot in which a chord was formed in order to open a window. The center of the ellipse is the average point for each chord while the major radius represents the standard deviation in x axis (width) and the minor radius the standard deviation in y axis (height). Based on Figure 3, the distance from the bottom left corner of the screen to the average center of the three-finger-chord seems greater than that of the average center of the five-finger chord or the six-finger-chord. Concerning the four-finger-chord, our

Euclidean Distance			4 finger chord (N=6)	5 finger chord (N=20)	6 finger chord (N=23)
3 finger chord mean = 779.98 SD=172.01	t-test between chords T(p)	3 finger chord (N=20)	0.62 (0.535)	**2.01 (0.049*)**	**2.19 (0.032*)**
4 finger chord mean = 730.77 SD=160.08		4 finger chord (N=6)		0.76 (0.760)	0.84 (0.404)
5 finger chord mean = 670.70 SD=171.44		5 finger chord (N=20)			0.08 (0.935)
6 finger chord mean = 674.55 SD=138.04		6 finger chord (N=23)			

*p < 0.05

Table 1. Results of a t-test between the different finger chords for the Euclidean distance from the lower left point to the point where the chord was conducted.

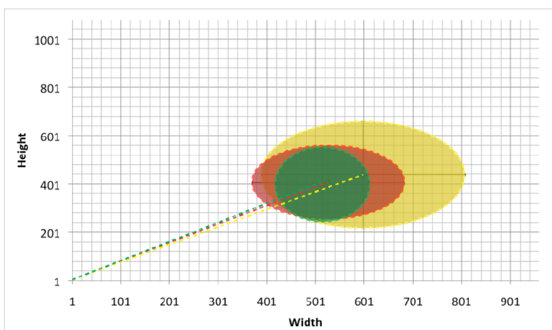

Figure 3. Three (with yellow), five (with green) and six finger chord (with orange) and their average distribution in the MT screen space.

users did not use it extensively and we decided to exclude it from our results despite the fact that it also followed the distribution of five-finger and six-finger-chord having its center in smaller distance than that of the three-finger-chord.

To examine our research hypothesis, we performed a t-test including the Euclidean distance between the bottom left of the appropriate part of the screen - (1,1) for user one and (960,1) for user two - and the position where chord interaction took place as dependent variable and the type of chord as independent. All statistical analyses reported were conducted with a significant level of 0.05. As we can see from the outcome data in Table 1, increasing the fingers of the chord from three to five or from three to six indicated a significant difference on the distance from the lower left bottom of the screen. That said, users preferred to form the three-finger chord in larger distances than when they formed the five and the six finger chord.

Discussion and conclusion

In this study, we explore the interaction space of the chord technique and relations between chord type and its position. Our results indicate that there is a significant difference between the position of the three-finger-chord articulation point and the five-finger-chord and six-finger-chord articulation point respectively (based on the Euclidean distance from the (0, 0) point of the screen). Our four-finger-chord limited inter-actions cannot support this result, however, it is clear from our data that the more fingers needed for the chord, the nearer from the screen edge the chord was created. In Figure 4 we show the average distances for the three, five and six finger-chord.

Interestingly, the above results contradict our initial expectations that more complex chords (e.g. those with multiple fingers) would be more easily applied in a more comfortable spot for the users – e.g. in the top right position of the screen, where their wrist posture might have been more natural. However, users preferred to interact in more central positions. Extending arm to reach far top right positions might be even more cumbersome (introducing higher level of muscle activations) for the users than articulating the chord in lower positions. As Figure 3 exhibits, users applied the most easy-to-conduct chord of our experiment (the three-finger-chord) within the largest and more centered interaction area. Our observations along with the results of this study show that users feel more comfortable to conduct the chord in larger distances. Figure 4 demonstrates the difference of the mean articulation point, which is an Euclidean distance of more than 100px, that said 10% of our screen interaction area. Considering the largest standard deviation that also occurs in the 3-finger-chords, we conclude that our initial hypothesis that there is a relation among the type of the chord that was conducted (number of fingers) and its position on the screen is valid. Furthermore, the larger deviation denotes higher degree of freedom for the user in order to articulate the chord wherever it feels more convenient for him/her. On the other hand, our results also describe an insignificant difference between the distance of five-finger-chord and six-finger-chord articulation point from the lower left position of the screen. The interaction area of the five-finger-chord seems to be a subset of that of the six-finger-chord

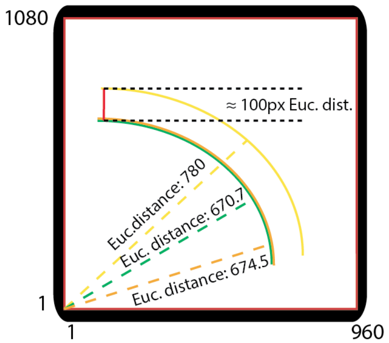

Figure 4. The average distance for three (with yellow), five (with green) and six finger chord (with orange). The difference between the average of three-finger-chord and five or six-finger chord is approximately 100px.

(Figure 3). That is why we propose that there might be a threshold in the number of fingers for a chord beyond which users respond similarly. Both five-finger-chord and six-finger-chord are very close in terms of the distance from the edge (Figure 4). Considering the limited data of the four-finger-chord that would position the four-finger-chord distance in between the three-finger-chord and five/six finger-chord, we can support further this finding.

The initial results of this study build on the potential of using chord interaction in a MT environment. We identify the differences between the diverse finger-chords and shed light on mapping user-centered design requirements for chord interactions. However, there are some limitations such as the fact that we were focused on an in-vitro drawing application with three, four, five and six finger chord options. Further research has to be done in order to make sure that our findings can be extended to apply to chords that demand more fingers. In addition, further research might be also needed in order to investigate the stress that multi-finger chords can cause to users and the connection between this and the positioning of the chords on the interaction surface.

Acknowledgements

We would like to thank Aleka Angeletaki for assisting us during the data collection and Gabriella Papastefanou for the content of our experiment. This work was partially funded by ARK4 project of the National Library of Norway and the NTNU UB.

References

[1] Bailly, G., Lecolinet, E., Guiard Y. (2010). Finger-Count & Radial-Stroke Shortcuts: Two techniques for Augmenting Linear Menus on Multi-Touch Surfaces. In Proc.of CHI ’10, ACM Press.

[2] Erickson, T. (1993). From interface to interplace: The spatial environment as a medium for interaction. In Spatial Information Theory A Theoretical Basis for GIS (pp. 391-405). Springer Berlin Heidelberg.

[3] Ghomi, E., Huot, S., Bau, O., Beaudouin-Lafon, M., & Mackay, W. E. (2013). Arpège: learning multitouch chord gestures vocabularies. In Proc. of ITS’13. pp. 209-218. ACM Press.

[4] Haller, M., Brandl, P., Richter, C., Leitner, J., Seifried, T., Gokcezade, A., & Leithinger, D. (2009). Interactive displays and next-generation interfaces. pp. 433-472. Springer Berlin Heidelberg.

[5] Hawkey, K., Kellar, M., Reilly, D., Whalen, T., & Inkpen, K. M. (2005). The proximity factor: impact of distance on co-located collaboration. In Proc. of GROUP ’05. (pp. 31-40). ACM Press.

[6] Kin, O., Au, C., Tai, C., (2010). Multitouch Finger Registration and Its Applications, In Proc. of OZCHI’10. ACM New York, NY, USA.

[7] Leftheriotis, I. (2013). User authentication in a multi-touch surface: a chord password system. In Proc of CHI'13 Extended Abstracts. 1725-1730. ACM.

[8] Leftheriotis, I., & Chorianopoulos, K. (2011). Multi-user chorded toolkit for multi-touch screens. In Proceedings of the 3rd ACM SIGCHI symposium on Engineering interactive computing systems. pp. 161-164). ACM.

[9] Lepinski, G. J., Grossman, T., Fitzmaurice, G. (2010). The Design and Evaluation of Multitouch Marking Menus, In Proc. of CHI ’10, ACM Press. pp. 2233-2242.

[10] Nova, N. (2004). Socio-cognitive functions of space in collaborative settings: a literature review about Space, Cognition and Collaboration.

[11] Scott, S.D., Carpendale, M.S.T, & Inkpen, K.M. (2004). Territoriality in Collaborative Tabletop Workspaces. In Proc. of CSCW '04. ACM.