A virtual on-screen input in large touch-screen devices

Mohammad Hossein Parastar
Department of Computer Science
University of New Brunswick
Fredericton, Canada
mparasta@unb.ca

ABSTRACT
We present a new technique to use large touch screen devices with one hand and solve the reachability problem of large touch screen devices. We use three different cursor types based on previous studies on area cursor and bubble cursor. Area cursor uses an area as the pointing and performing selection while bubble cursor is an area cursor that can be increased and decrease in size to have at least one target in range. Our experiment shows that bubble cursor and small area cursor perform well in this technique while the best results are for small area cursor, but participants like to use bubble cursor mostly.

Author Keywords
Fitt's Law; HCI; Cursor; Touch Screen; Large Touch Screen.

INTRODUCTION
We use different kinds of touch screen devices in our everyday life. The main reason for using touch screen devices is easily touching the target on the screen but what should we do if there is a limitation to reaching the target and we cannot touch the whole screen. For example, when using a large touchscreen cellphone, that whole screen is not reachable just by one hand, and we cannot use our both hand to hold or interact with the device. There are different methods in cellphones with the different operating system to solve this problem, in iPhone devices you can double press the home button. Tapping the Touch ID button (home button) twice will bring the top half of the iPhone screen down to the middle of the display. This means that controls or apps at the top of the screen can be reached without using a second hand. Android devices have a different type of one hand use that you can activate differently; it is mostly resizing the screen, so it is in reach of your finger while using by one hand. The technique that will be review in this paper is using a small, reachable part of the screen as a touch input that can move a cursor on the screen this cursor can move and perform selecting on different target on the screen by double touching on the input area by the user. There are three different cursor types implemented in order to use this input method: 1-Small cursor, 2-Large cursor with larger target 3-Bubble cursor.

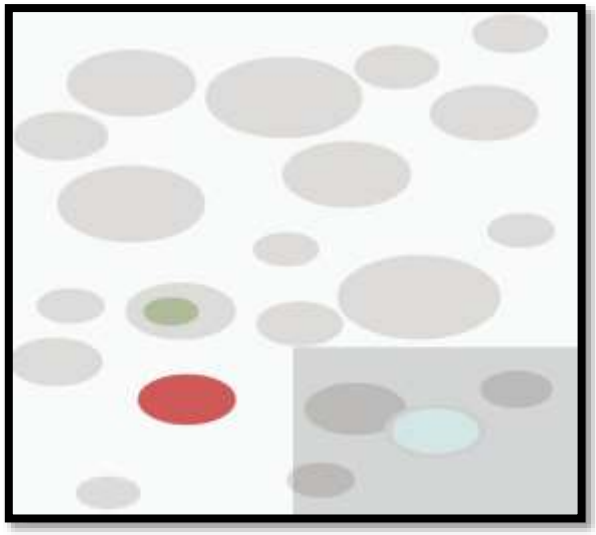


Figure 1: implemented one hand technique screenshot, a grey area at right bottom is the input area. The green circle on the screen is a cursor.

As you see in Figure 1 user should touch and hold the white circle inside the grey area and by moving the circle the cursor will move on the screen.

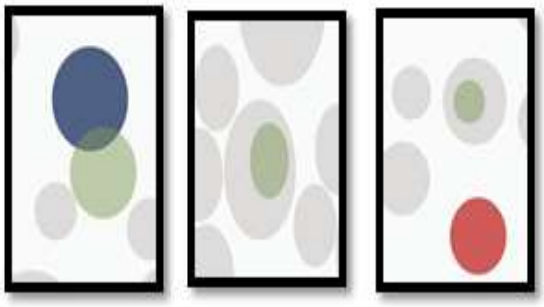


Figure 2. (From right) 1-small cursor 2-large cursor 3-bubble cursor.

Because we are using pointing techniques we can use Fitt's law [1] in the experiment:

$$ID = \log_2 (A/W + 1)$$

From this, we see that the index of difficulty (ID) of a target acquisition task is a function of the amplitude (A), or distance, of the target from the cursor, and the width of the target (W). The index of difficulty rises as the width of the target gets smaller.

To improve the performance of using this input technique I used two different area cursor in the shape of a circle that can have better pointing [3] in comparison to other shapes. The small and large cursor have a difference in the radius of the cursor and also the radius of the targets so we can find how larger area cursor effect. The bubble cursor does not have a constant size so it will change in size in order to have one target in range, It will stop increasing in size. in my implementation, the target that the bubble cursor is pointing will change in colour so the user knows which target will be selected after the click and this will solve the problem of double targeting in a range that can happen in area cursor [2,3].

I used Area cursor technique introduced by Kabbash and Buxton [2] to design the first two cursors and also Bubble cursor using the technique described by Tovi Grossman and Ravin Balakrishnan [3].

RELATED WORK

The common approach in developing new selecting technique is using Fitt's law. Different researches are using Fitt's law in order to measure the throughput or index of difficulty, but there is not any research available for using Fitt's law in cursor on cellphones. Kabbash and Buxton used area cursor in 1995 [2] to introduce a new selecting technique that instead of selecting a point it will select an area. The performance would be higher, and it would be easier for users to click on different target with different width. However, this technique can lead to problems like when there are two targets in the range of area cursor, so later on 2005 Tovi Grossman, Ravin Balakrishnan used bubble cursor as a selection method to solve this problem and also get a better result in order to Fitt's Law. They introduced a technique that the size of cursor would change in order to have a target in range and then it will stop by moving the cursor it will find the nearest target and will change the size to appropriate size.

DESIGN AND IMPLEMENTATION

The development of the system was done in Android Studio IDE by using JAVA programming language, and the three different cursors were implemented in one android application.

1-Small Cursor

The Small cursor implemented in the application as one of the conditions. In this cursor type, the cursor shape is a circle with a radius of 35 pixels in green colour.User can move the cursor as mentioned before by dragging the white circle inside the grey area to move the cursor on the screen. Circles on the screen are larger than the cursor so more than one target in range problem not occur.

2-Large Cursor

The Large cursor implemented in the application as one of the conditions. In this cursor type, the cursor shape is a circle with a radius of 65 pixels in green colour.User can move the cursor as mentioned before by dragging the white circle inside the grey area to move the cursor on the screen. The targets on the screen while using this type of cursor is larger than the cursor size so there would be no difficulties when more than one target is inside of the cursor this technique can be presented in touch devices like a zoomed in the situation that every selectable target gets larger.

3-Bubble Cursor

The Bubble cursor implemented in the application as one of the conditions. In this cursor type at first the cursor will be displayed on the screen and if there is not a target in range it will start increasing the size after a target is in range it will stop increasing, and the target colour will change to blue, so the user will know which target is selected. User can move the cursor on the screen by dragging the white circle inside the grey area and do a click by double touching on the grey area. By using this system user have access to all the screen, and all of the screen is reachable.

EXPERIMENT

To measure and compare these different types of cursors I developed a system that displays 20 different random in size and position circles on the screen and one of the circles will change to red and the user should move the cursor to the red circle and perform selecting by double touching the grey area. The distances between targets, the width of targets, time for every click and errors will be collected to analyzing the results using the Fitt's law. We can have throughput and timing to compare different type of cursors.

This experiment is within-subject and each participant will click on 20 different targets in each condition, and the data would be stored in an excel file in memory. The order of assigned tasked to do is based on the Latin square table. Because these techniques are new to participants, they were asked to do each assigned task twice to reduce learning effect so the first trial of each task would not be used to collecting data and analyzing.

The drawing of the different random circle's radius would be in respect to the following formula:

((Randomnum * (cursorRadius * 2)) + (cursorRadius + 5))

To find out the difficulty and task load of the experiment NASA-TLX application in iOS used to collect participants opinion. Also, a questioner designed by the author was available.

Apparatus:

A Samsung Galaxy E7 device with android 5 and screen size of 5.2 inches was used to experiment. The experiment location was in a lab and participants sit on a chair, and they used the device with one hand while their hand rest on the table.

Participants:

Eight volunteers (two female, six male) participated in this experiment. Participants ranged in 24 to 33 were all university student, and all had previously used touch screen device with size more than 4.7 inches.

Procedure:

The participant will get a paper of instruction and a form which in the form the order of choosing a condition and also participant ID is available. Based on the instruction provided the participant enter the assigned ID and press next, then he/she should select the condition based on the provided sheet as mentioned before each condition should be done twice to reduce learning effect. There are three different conditions available on the menu named: condition 1, condition 2 and condition 3.

Based on the assigned condition they will see a screen with 20 different size circles and one red target circle and one green circle in the middle of the screen as a cursor that the size of it depends on the condition. The first trial of each condition would be done after 20 correct select of the red target, and then they will see a pop up that will show how they did and play again button. Then they should do the same condition again, and this time data would be collected for future analyses.

After they did each condition twice, they will answer NASA-TLX questioner using NASA-TLX application provided for iOS in an iPhone device. Then they start the next assigned condition and will do the same procedure until they are done with a total of six trial and three NASA-TLX questioners.At the end they will answer the questioner provided by the author and their data would be stored on the device storage by touch and hold on the screen for three seconds.

Design and Analysis

In this experiment, 8 participants were asked to do three different conditions, each condition twice. Each condition represents a different type of the cursor, so it is the independent variable in this experiment and the errors, times, distances, the width of targets, NASA-TLX and how much they like each condition would be the dependent variables that we are going to analyze in this experiment. The analyzes are done on 20*3*8*4 (targets * conditions * participants * dependent variables), 1920 data by ANOVA one-way test and Sheffe post hoc test to find pairs that have a significant effect.

RESULTS

Throughput

One of the most important comparable variables could be Throughput that will define based on Fitt's Law. As mentioned before the Index of difficulty is "log2(A/W+1)," and the throughput would be Average movement time divide by Index of difficulty.

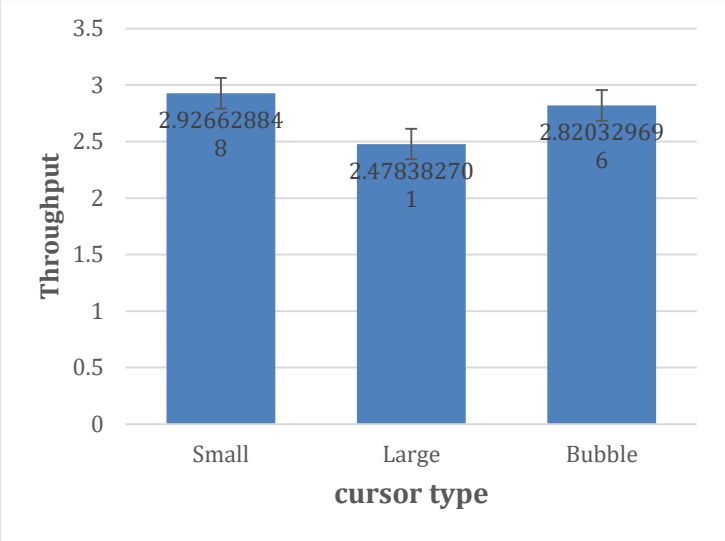


Figure 3 Throughput chart for three different cursor type

Based on ANOVA the p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different (F-statistic=13.0595 and p-value = 0.0002). Moreover, based on Sheffe result the two pair Small and Large, Large and Bubble are a significant difference and based on throughput the small cursor performed best and after that without significant difference Bubble cursor and then the large cursor with a significant difference in compare with two other technique.

Time

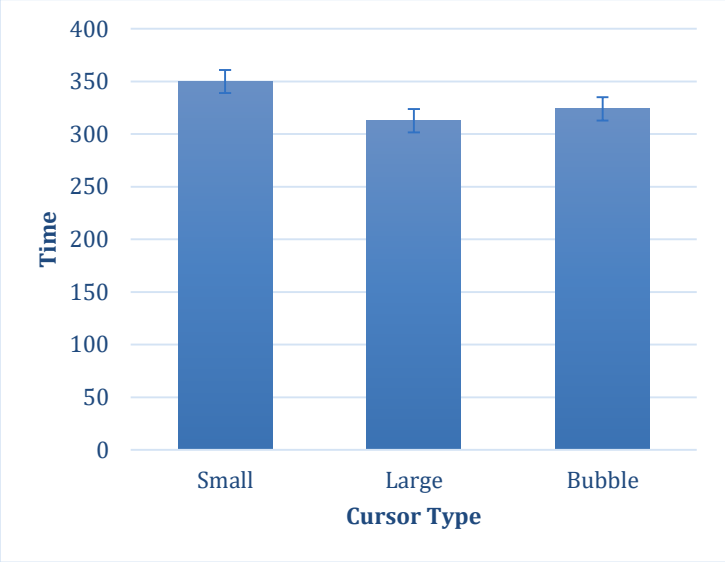
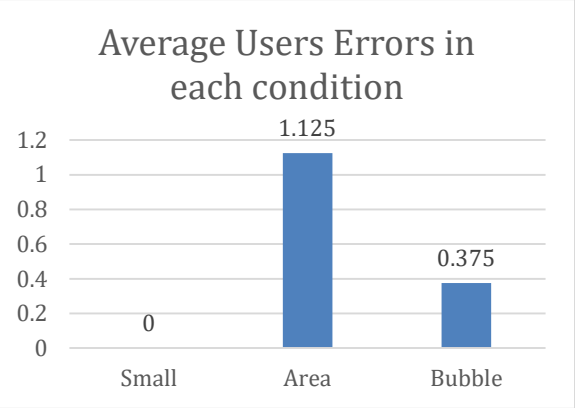


Figure 4 average time for each type

The small cursor has most average time, but according to the ANOVA test, there is no significant difference between times of different cursor types.

Error



The small cursor had no error and ANOVA test results no significant different in average errors in each condition.

Like

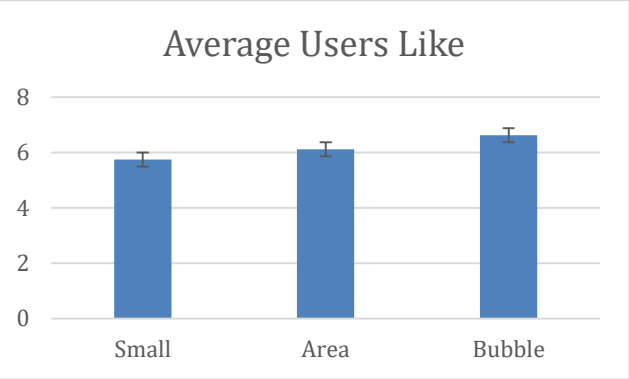


Figure 5 Average users score to each cursor type

At the last questioner that each participants answered they were asked to give a score to each cursor type in scale of 1 to 10 and 10 means better. There are no significant difference between the users like score but in average bubble cursor had most participants score.

NASA-TLX

	Small	Large	Bubble
Mental Demand	45	40	36.25
Physical Demand	48.125	54.375	43.125
Temporal Demand	48.125	42.5	43.75
Performance	45.625	25	26.25
Effort	44.375	53.75	40.625
Frustration	40	45	47.5

Figure 6 NASA-TLX Average user opinion

As mentioned before participants answered NASA-TLX questioner after each condition is done. Based on participants average opinions Bubble cursor had less average mental demand and Physical Demand although ANOVA shows no significant difference in the result.

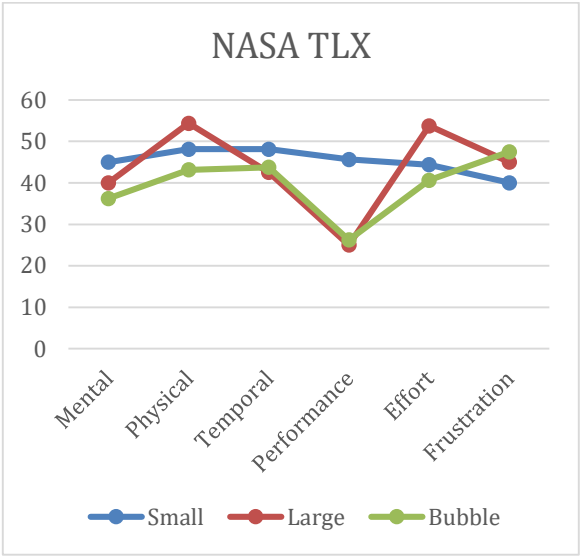


Figure 7 NASA-TLX average participants opinion

DISCUSSION

We have presented three different cursor type that can be used in touch screen devices. These three cursor type designed and implemented based on the previous studies on area cursor and bubble cursor.

Based on experiment results interestingly small cursor had the best throughput with no significant difference with bubble cursor and large area cursor had less throughput in comparison with two other cursor types. The ANOVA and Sheffe tests show the significant difference between the large cursor and two other cursors. Large cursor had less average movement time with no significant difference with other types. Small cursor had no errors in all trials and had the highest average movement time. The participants put much effort in order to place the cursor inside targets so it could be the cause of higher movement time and no error in this experiment. However, based on their opinion about the different cursors type which they answered at the end of the experiment in the questioner they gave the lowest mark to the small cursor. In most dependent variables there was no significant effect, and the null hypothesis mostly accepted except in throughput that ANOVA test showed a significant difference.

FUTURE WORK

This type of pointing in touch screen devices is new and can be more studied by using real situation experiments like

asking the participants to dial a number or click on a specific part in an emergency. Also, one exciting experiment can be comparing different available reachability functions in touch screen devices like Android and iOS cellphones with the technique introduced in this paper.

CONCLUSION

The technique introduced in this paper can be used in touch screen devices and based on throughput results the small cursor can have good performance and fewer errors. Using the small cursor and touch input area can be useful although in other dependent variables we did not have significant differences so all three cursors could be used in real-world app design.

ACKNOWLEDGEMENTS

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