Comparison of Touch and Touchless Zoom Control Methods for Single-Handed Mobile Interaction

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Abstract. We conducted a user study comparing the accuracy and speed of three zoom methods for touch-screen devices. The comparison was between touch and touchless zoom methods. One method is GyroZoom which uses the mobile phone's rotation to zoom in and zoom out. It is named after the gyroscope sensor in smartphones to detect the angle and amount of device rotation. We constrained our research to single-handed interaction. The pinch-to-zoom method, also tested, is the standard touch-screen gesture method. VolumeZoom was the third method and does not require the user to touch the screen. Instead, the user presses the physical volume buttons that are normally used to increase or decrease volume; they were reprogrammed to perform zoom operations. The user study engaged 12 participants and employed a Google *Pixel 3a* smartphone. GyroZoom was 18.1% faster than the traditional pinch-to-zoom method and it was more efficient. VolumeZoom was the most efficient method of the three but was 18.9% slower than pinch-to-zoom. Participants gave favorable and preferential ratings for using GyroZoom and VolumeZoom over pinch-to-zoom in a single-handed usage scenarios.

Keywords: GyroZoom · VolumeZoom · One-handed · Single-handed · Zoom method · Zoom control · Rotation · Volume · Mobile-interaction · Human-computer interaction

1 Introduction

Mobile devices offer multi-touch capabilities that allow users to perform gestures to perform various operations. Zooming is one of the most highly performed operations on mobile phones. It is vital to have a natural and smooth strategy to change levels of zoom. One notable interaction technique that was introduced in 1999 and later commercialized by Apple in the *iPhone* is commonly known as pinch to zoom [1]. It facilitates users to zoom by a two-finger pinch, which usually requires two hands: One hand holds the device while the other performs the pinch gesture. It is a widely used and works accurately until you are asked to operate it with a single hand. Holding the phone and using the same hand to do a pinch gesture to zoom in and out becomes difficult and inefficient. Furthermore, requiring two hands makes pinch gestures unrealistic when users are moving, walking, or on public transport. Although, other techniques of interaction such as double-tap and

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two-finger tap are available for zoom control they are not as intuitive and flexible and also are equally challenging to perform with a single hand.

There are multiple ways to perform pinch interaction for zooming. In Fig. 1a, the user holds the device in one hand and performs the gesture using the other hand. In Fig. 1b, the user holds the device in both hands and uses both thumbs to perform gestures. In Fig. 1c, the user single-handedly performs a pinch-to-zoom gesture and holds the device. However, this last procedure causes an abnormal and uncomfortable hand posture. Users are frequently compelled to play out the pinch-to-zoom motion using one hand. Most cell phones additionally utilize a double-tap gesture which takes into consideration zooming in or out by double-tapping a zone of interest. While this strategy functions admirably with one hand, it just considers zooming by a discrete amount instead of a flexible interactive zoom.

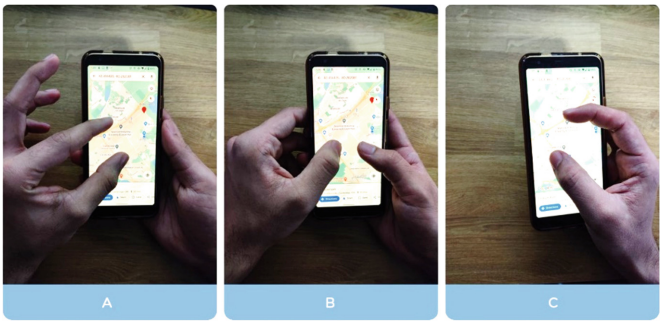

Fig. 1. Three ways to perform pinch-to-zoom gestures. See text for discussion.

According to a user survey on user habits and preferences on mobile usage, 66% of 228 users preferred using single-handed interactions while 9% of users preferred both hands for gestures and 23% did not express a preference [2]. We are currently constraining our research to strictly single-handed interaction.

In this paper, we introduce VolumeZoom as an alternative zoom method. VolumeZoom uses the volume keys in a mobile device to perform zoom interaction. In Fig. 2, the volume-up key is used to zoom in and the volume-down key is used to zoom out. This is potentially an effective way to utilize the volume keys for zooming, as the interaction is easily performed using a single hand.

We introduce another new method called GyroZoom which does not involve any button press or touch gesture on the screen. In Fig. 2, it is shown that GyroZoom utilizes the gyroscope sensor of the mobile device to calculate the rotation of the device in real-time. Depending on the angle and direction of rotation, it zooms in or out by a corresponding amount. Clockwise rotation results in zooming in and the angle of rotation controls the amount of zoom. Similarly, anti-clockwise rotation results in zooming out and the angle of rotation controls the amount of zoom.

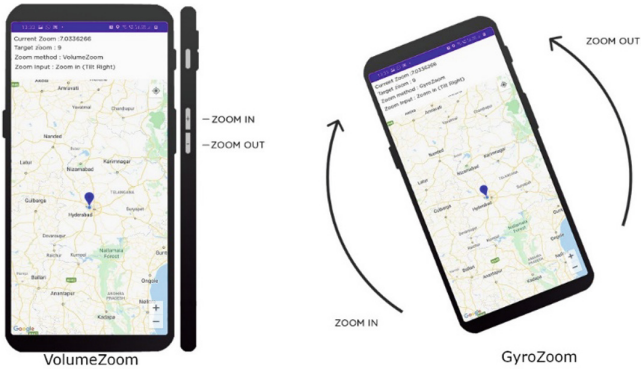

Fig. 2. VolumeZoom and GyroZoom method demonstration.

In this paper, we evaluate and compare the performances of touch and touchless zoom control methods. Hence, user performance for VolumeZoom (touchless button control) and GyroZoom (touchless) are evaluated. The results are compared to the standard pinch-to-zoom (touch) method demonstrated above when performed single-handedly.

2 Related Work

Table 1 summarizes the results from five publications where user studies were performed utilizing zoom methods to interact with the device.

Farhad and MacKenzie [3] compared the performance of two zoom methods when performed with a single hand. The results from tap-and-drag were generally good for single-handed usage. Also, tap-and-drag performed slightly worse in accuracy but over time, as participants become more familiar with tap-and-drag, performance improved.

Ti and Tjondronegoro [4] assessed a collection of tilt-based input methods for single-handed zooming. They analyzed the outcomes against traditional touch-based zooming and found that tilt-based methods are better than touch-based methods when performed with one hand. All participants found the traditional touch-based methods inferior due to the uncomfortable hand posture when performed with one hand. Nonetheless, they favored using pinch-to-zoom when two hands were accessible.

Lai et al. [5] assessed a single-handed partial zooming procedure. ContextZoom permits users to point to any spot on a display by long-pressing the location as the zooming focus (i.e., focal point). When the area is set, the user moves their thumb on the display to zoom in or out. Panning is disabled while zooming. The results were acceptable, with the completion time and the number of discrete activities, by and large, low. Participants likewise announced more significant levels of apparent adequacy and overall satisfaction.

Boring et al. [6] proposed Fat Thumb, a single-handed method that utilizes the thumb's contact size as a type of recreated pressure. The contact size takes into consideration toggling between panning and zooming relying upon the contact area.

Harrison et al. [7] presented a technique called Lean and Zoom that detects a user's proximity to the display using a camera and magnifies the on-screen content proportionally. Results from the user study indicate that users believe this interaction technique is intuitive, increases comfort, and improves performance.

Table 1. Summary of zoom interaction user studies

1st Author	Type	Handedness	N	Notes
Ti [4]	Touchless	Single	15	Flip Gesture performed significantly better than touch-based controls (1.83 s faster). Tilt and Hold was slower than touch-based control, but their difference was not significant
Lai [5]	Touch	Single	23	ContextZoom outperformed two-finger tap in both task completion time and number of discrete actions
Farhad [3]	Touch	Single	12	Tap-and-drag performed 17.9% better in terms of speed and 47.2% better in terms of efficiency as compared to the traditional touch method (pinch-to-zoom)
Boring [6]	Touch	Single	24	User study of panning/zooming revealed that Fat Thumb is fast (especially when large zoom factors are required), non-fatiguing, and the preferred technique, all while maintaining the offset rates of other techniques
Harrison [7]	Touchless	Hands-Free	10	The Lean and Zoom system detects a user's lean position and proportionally magnifies on-screen content. Results from a study indicate that users believe this interaction technique is intuitive, increases comfort, and improves performance

3 Method

A user study was conducted to compare the three user-interactive zooming methods for one-handed interaction. The goal was to compare the three zooming methods in terms of quantitative measures, user preference and ease of use.

3.1 Participants

Twelve participants were recruited remotely from different universities across Canada. Six were male, six were female. Ages ranged from 22 to 26 years. All participants were comfortable using smartphones. Participants were compensated with $20 for their assistance.

3.2 Apparatus

The experiment was conducted on Google *Pixel 3a* running the Android (11.0) operating system. The device has a 5.6-inch OLED display with a resolution of 2220 × 1080 pixels and a density of 441 PPI. The weight of the device is 147 g.

The software was developed in Java using the Android SDK in the Android Studio environment. The experimental application was developed specifically for this research. Three zooming methods were implemented in the application.

The application begins with a configuration activity that prompts the user to select the participant code and other experimental parameters, like the zoom method and a group code (for counterbalancing). Once configured, the user presses a START button to initiate the testing process. The main activity contains a map zooming user interface.

The text software presented the participant with the desired zoom direction and target zoom and stated the direction and amount of zoom required for completing the trial successfully. The user interface also displayed the real-time current zoom for the user to match with the target zoom. After the current zoom matches the target zoom, the user pressed the FINISH button to end the trial and advance to the next trial.

3.3 Procedure

Participants were informed and explained the purpose of the user study. They were requested to keep the Internet switched on during the entire experiment. They were shown videos explaining each zoom interaction method. They were also given a few practice trials. For testing, participants were seated and instructed to do the trials single-handedly. They were also asked to use whichever hand they feel comfortable with within trials. Arm support or any kind of armrest was not allowed.

With this brief introduction, testing began. Participants completed five trials per zoom method. Each trial consisted of a randomized sequence of combinations of zoom direction (in or out) and zoom level (low, medium, high). Each participant took about 15–20 min to complete the experiment. The data were stored in a remote database in Google *Firebase* over the Internet. The data were analyzed later for meaningful insights.

After the testing was complete, the user was prompted with a questionnaire to gather feedback on their preferences of the zoom methods.

3.4 Design

The user study employed a 3 × 3 × 2 within-subjects design. The independent variables and levels were as follows:

- Zoom method (GyroZoom, VolumeZoom, Pinch-to-zoom)
- Zoom level (low, medium, high)
- Zoom direction (in, out)

Each participant completed 5 trials for each zoom method. The total number of trials was 12 participants × 3 Zoom Methods × 3 Zoom Levels × 2 Zoom Direction × 5 Trials = 1080.

To offset learning effects, participants were divided into three groups to counterbalance the order of testing the zoom methods. The zoom level and zoom direction conditions were chosen at random. The dependent variables were completion time per trial and efficiency. A detailed explanation of the calculation of efficiency is given in the results section.

4 Results and Discussion

All trials were completed successfully. The data were later imported into a spreadsheet tool where summaries of various measures were calculated and charts were created. The analysis of the variance test was performed using the GoStats [8] application.

4.1 Completion Time

The grand mean for completion time was 7.45 s. By zoom method, the means were 6.58 s for GyroZoom, 8.26 s for VolumeZoom, and 7.51 s for Pinch-to-zoom. As seen in Fig. 3, trials using GyroZoom were 18.1% faster than the traditional pinch-to-zoom method. VolumeZoom was seen 18.9% slower than pinch-to-zoom. There was a clear pattern in the data showing that the zoom-out operation in VolumeZoom was always faster than zoom-in. This could be due to the ease of accessibility and reach to the volume-down button compared to the volume-up button.

An analysis of variance was done to examine the mean completion times of the 12 participants while doing the zoom trials. The effect of zoom method on completion time was statistically significant ($F_{2,22} = 110.6$, $p < .0001$). The effect of zoom level on completion time was also statistically significant ($F_{2,22} = 888.0$, $p < .0001$). However, the effect of zoom direction on completion time was not statistically significant ($F_{1,11} = 1.27$, $p > .05$). The zoom method $\times$ zoom level interaction effect was statistically significant ($F_{4,44} = 9.46$, $p < .0001$), as was the zoom method $\times$ zoom direction interaction effect ($F_{2,22} = 5.71$, $p < .05$). The zoom level $\times$ zoom direction interaction effect was not statistically significant, however ($F_{2,22} = 1.002$, $p > .05$). Group effects were not statistically significant.

4.2 Efficiency

Efficiency is a measure of how usable or effective a zoom method is. It is defined as the number of zoom switches performed per trial. For example, if a user is required to zoom-in until the current zoom equals the target zoom, but, by mistake, the user zooms in more than required, then performs a zoom-out operation to finish the trial successfully, the extra zoom transition is counted as 1. Obviously, lower scores are better.

In Fig. 4 it is clearly seen that VolumeZoom has higher efficiency than the GyroZoom and Pinch-to-zoom. Pinch-to-zoom is the least efficient method according to the user data. From the analysis of the variance, we found that the effect of the zoom method on efficiency was statistically significant ($F_{2,22} = 162.2$, $p < .0001$). The remaining effects were not statistically significant.

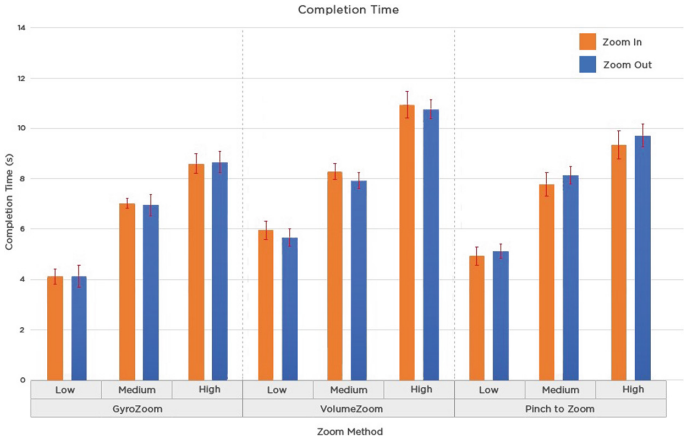

Fig. 3. Completion time (s) by zoom method, with error bars shown in red.

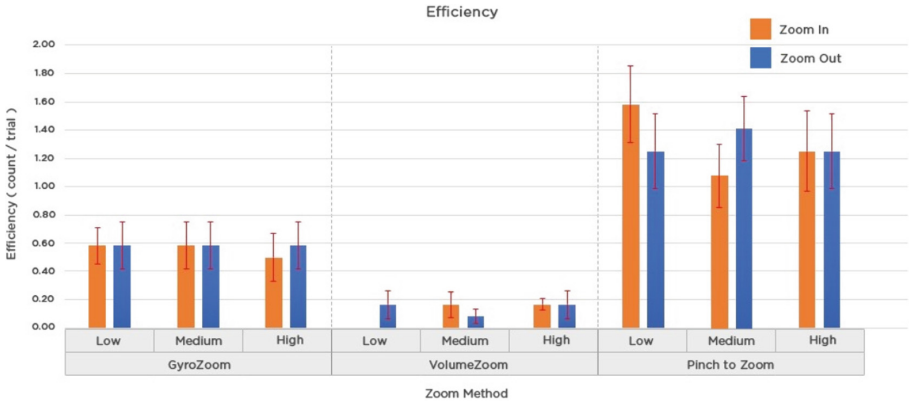

Fig. 4. Efficiency by zoom method, with error bars shown in red. Lower scores are better.

4.3 Participant Feedback

In the post-experiment questionnaire, participants were asked their preference of the zoom method on a scale of 1–5. A Friedman test was performed using the GoStats [8] application. The differences by zoom method were significant ($\chi^2 = 15.395, p = .0005$). Using a post hoc test, it was observed that the pairwise comparison of GyroZoom with Pinch-to-Zoom and VolumeZoom with Pinch-to-Zoom were statistically significant.

Most participants stated that they find single-handed pinch-to-zoom extremely frustrating to use as it results in an awkward hand posture. They found it easier using both hands. Some expressed concerns about dropping the phone while performing pinch-to-zoom by a single hand. One participant noted.

GyroZoom is an innovative method while I am walking, and I need to single-handed perform zoom operations. I also find VolumeZoom to be easy to use.

Overall, participants praised both VolumeZoom and GyroZoom in subjective feedback and indicated a preference for these over the traditional pinch-to-zoom method. The average ratings for GyroZoom and VolumeZoom were 4.3 and 4.2 on a scale of 1–5.

5 Conclusion

An experiment was conducted comparing the performance of three zooming methods when performed using a one hand. The results for our newly introduced methods were significantly better compared to the traditional pinch-to-zoom method (performance using a single hand). GyroZoom performed 18.1% faster than the traditional pinch-to-zoom method and was more efficient. VolumeZoom was the most efficient method of all three, but was 18.9% slower than the pinch-to-zoom. Overall, the participants gave a favorable and preferential ratings for using GyroZoom and VolumeZoom over pinch-to-zoom for one-handed interaction.

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