Alternative Mobile Input Methods via Onboard Hardware a Usability Study

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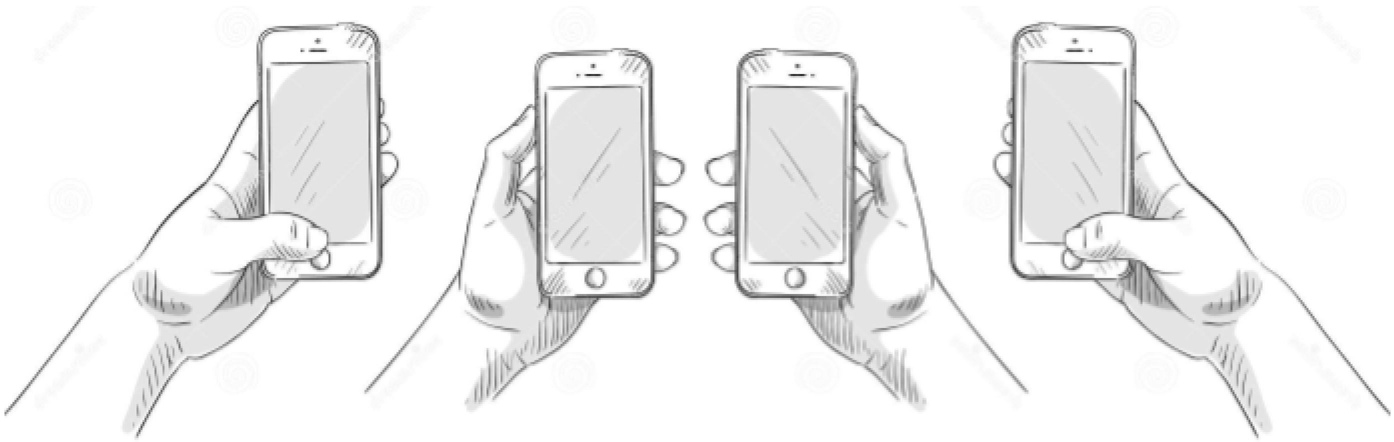


Figure 1: Unimanual phone use. The standard gripping procedure is using the thumb on one side, the index finger supports the back of the device and the remaining three fingers grip the phone from the other side.

Abstract — **Touch input is a predominant input modality on modern mobile devices. Although a large front-facing touch sensitive display is useful for mobile interactions, this study explores alternative input modalities that can supplement or extend touch. These modalities are limited to a device's onboard hardware peripherals and include volume rockers, fingerprint scanners, front facing cameras and an IMU (i.e. accelerometer+gyroscope).**

Keywords — **Alternative mobile interactions, Usability study, Unimanual input methods, Fingerprint Reader as Touchpad, Back of the device interaction.**

The Problem

Karlson et. al. [1] validates that most users prefer to use their mobile devices by applying one-handed strategies (see Figure 1). The main reason for this user preference is that it leaves the second hand free for other tasks, e.g. while drinking a beverage, it is easier to use phone single handedly.

Guiard's Kinematic Chain (KC) theory [2] applies to the unimanual use of mobile devices. Guiard observed that the hands work as links in a serially assembled kinematic chain, where the non-dominant hand works as an anchor and the dominant hand works as a terminal link. This theory suggests that during the unimanual use of a mobile device, the four fingers gripping the device in place are the non-dominant anchors and the thumb acts as a terminal link for interacting with the device.

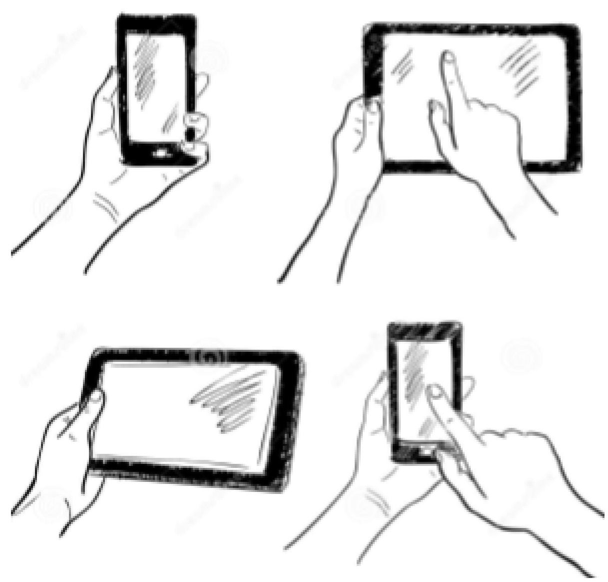


Figure 2: Bimanual and alternative hand grips used to interact with mobile devices.

At times, touch input can be problematic in unimanual (single handed) scenarios, e.g. using the phone while in the bed. Bimanual or alternative hand grip positions may enable other interactions (see Figure 2), but that is not preferred by most of the users as mentioned above.

Also, research suggests that using touchscreens in unimanual mode can cause thumb fatigue and may lead to other repetitive stress related injuries [3]. This strain also causes the user to have a deteriorating grip around devices which causes the device to fall from hands after using it for too long.

A Possible Solution

By delegating tasks to the other fingers that are gripping the device, fatigue on the thumb muscle can be reduced. This should provide a better and prolonged grip around the device while using the phone unimanually. The current approach to use mobile devices tend to ignore the fact that we have four other fingers wrapping around the device and are designed primarily to keep the user interaction limited to thumb. Research by Holman, David [4] focuses on augmenting the devices with additional hardware on the edges to perform extra actions. My study aims to make use of commonly available on-board hardware only.

Proposed Ideas

I plan to use other onboard hardware available in the following fashion:

1. **Volume Rockers (VRR):** In many devices, the VRR is placed as in such a manner that it is always accessible by the index finger. Exploiting this feature to perform extra gestures like scrolling pages, zooming in/out and clicking based on a combination of key presses can prove to be useful.
2. **Fingerprint Scanner (FPS):** Since 2015 cheaper mobile devices with an inbuilt FPS have been released[5] making it a mainstream feature. Most of the FPS are placed at the back of the devices just below the camera. This seems to be the most comfortable position for the index finger. Under right conditions, FPS can detect swipes which can be later developed into gestures that can be used to control on screen elements like scrollbars.
3. **Front Facing Camera (FFC):** During typical use, the front facing camera is positioned towards a user. Based on user's orientation, we can detect in which direction they are looking. We can use this to implement a coarse gaze based gesture system.
4. **Accelerometer + Gyroscope (IMU):** These two sensors in combination are interesting because they can help determine the change in the device's position in 3-Dimensional space. Using this knowledge we can have 3D gestures which can be further translated as input commands for onscreen changes.

Study Design

Almost all the modalities mentioned in the previous section have not been explored enough to be used as a form of input to mobile devices. The most simple task that can be tested is scrolling through pages. Pages can contain text, images, galleries, etc.

Figure 3: User using the mobile device while in bed.

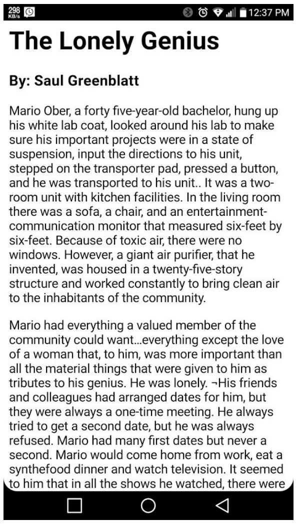
While sitting straight almost all of these actions can be performed with equal ease, but the dynamics of gripping the mobile device changes when the user is in bed (Figure 3). The arm holding the phone in hand also supports the body's weight to maintain side posture. This makes the arm muscle fatigue faster. Holding the phone in the free arm is hard as it needs to suspend the weight of itself and the phone. I focused only on the use of the device while laying in bed. The experiment can be broken down as follows:

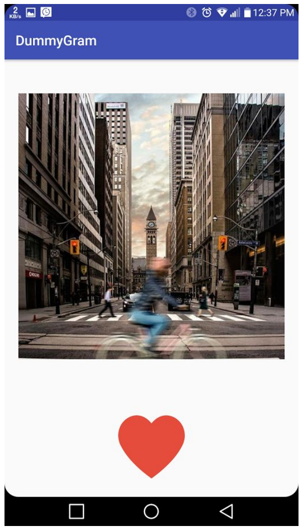
- Test Subjects: 5
- Test Scenario: Lying in bed
- Types of apps to be tested: 3
  - Reading Articles (3x pages)
  - Browsing Image Galleries
- Input Modalities to be tested: 5
  - Touchscreen (TS) (baseline)
  - VRR
  - FPS
  - FFC
  - IMU
- Factors to be recorded: 3
  - Problems faced by users.
  - Ease of use of the new modalities.
  - User Satisfaction and Fatigue.

Preparations

For testing, I wrote two android application that present the user with different tasks:

Name: Alternative Scroll Reader [7]	**Name:** Dummy Gram[8]
Description: A simple text reading app with high contrast which implements the discussed interaction.	**Description:** Inspired by Instagram[9] this application works in a similar fashion using alternate modality.





Features:	Features:
- Swipe Gesture on FPS scrolls page down. - Tap Gesture on FPS scrolls up. - VRR Up scrolls page up. - VRR Down scrolls page down.	- Swipe Gesture on FPS scrolls through gallery. - Tap Gesture likes the current image. - VRR Up scrolls gallery back. - VRR Down scrolls gallery forward. - VRR Up + VRR Down: Like the image

In both of these applications the Touch Screen works normally as a user expects them to work. While testing the modalities on myself, I discovered that while in bed the eyes were not open enough make use of the FFC for gaze detection. It was highly inaccurate and not worth testing with test subjects. Also because of the orientation of the device, IMU was highly unreliable and added unintended actions. Using IMU would require flick from the user's wrist and might add additional strain on the wrist, it was highly uncomfortable to use.In both of these applications the Touch Screen works normally as a user expects them to work. While testing the modalities on myself, I discovered that while in bed the eyes were not open enough make use of the FFC for gaze detection. It was highly inaccurate and not worth testing with test subjects. Also because of the orientation of the device, IMU was highly unreliable and added unintended actions. Using IMU would require flick from the user's wrist and might add additional strain on the wrist, it was highly uncomfortable to use.

Usability Study

The test subjects for the experiment were between 20-25 years of age and frequent mobile device users. I asked them to use these applications like they normally do and then presented them with using the FPS and VRR as input. During the experiment they spoke continuously about what they felt and I took notes.

Study Results

Based on the responses collected (See Appendix: Study Notes) I found that users felt that FPS was unnatural way of communicating with the device, but felt really satisfying. VRR on the other hand caused users to stretch their index fingers around the device which did not feel comfortable while pressing keys continuously. While using the DummyGram application users felt that the FPS was actually far more superior than using the touchscreen. One possible reason is that the thumb does not cover any portion of the screen allowing the user to view the images without being blocked by the thumb. The users felt that Instagram should have this feature built in and they would tend to use the instagram app more. The results show that using FPS as a touchpad on the back of the devices is really promising and can be improved by incorporating a larger footprint FPS and building interactions directly into the operating system (OS).

Future Work

As of now the source code for the application is available as open source projects. Based on user recommendations I intend to pursue the idea of DummyGram as a full-blown instagram clone which implements FPS as an interaction method. I also intend to release the FPS gestures as a free library for any Android developer who wants to implement these gestures in their app.

The effort however is highly compromised due to the limitations of how Android Operating System implements the FPS services[10]. Developers cannot actually access the images recorded by the FPS. Developers can only access whether the fingerprint was captured properly or not. In order to have a deeper integration we either need to use a Rooted Android Device[11] or wait till the Android team decides to provide these gestures as a part of the Android API in future.

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Reference images and figures used were obtained from Google Image Search, modified as per context.

Appendix: Study Notes

Questions	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Introduction Questionnaire					
Do you use your phone in your bed?	Yes	Sometimes	Yes	Couple of hours	Around 1hr
What kind of apps do you use in bed?	Messenger, Instagram	Email, Facebook	Chess	Web Browsing, reading, Youtube	Youtube, Facebook, email, linkedin, Web browsing
Do you read articles on your phone?	Yes	Sometimes for short periods	No	Yes	No
Do you use Instagram before going to bed?	Yes	yes	No	Sometimes	No
How do you use your phone, bimanually or unimanually?	Unimanual	Both	Bimanually because it's a big phone	Unimanual	Unimanual
Which do you find more comforting and satisfying?	Unimanual	While moving I use the phone unimanually, when typing a lot, use bimanually	Hard to say	Unimanual	Unimanual
Did you lose the grip on the phone and it fell on your face or otherwise?	Yes	Yes, I stopped using the phone after that in bed.	Yes	Not a lot times on the face, but it usually falls from hands	Never
What do you think was a reason?	When I am Tired I tend to drop the phone more	Fatigue	The phone is too big for my hands	I have no idea.	fatigue in thumbs and arms
Task 1: Reading text unimanually while you're in bed.					
FPS	Doesn't feel natural, but feels satisfying, better than using TS	This is satisfying	This is amazing	doesn't feel natural	with one hand it's amazing
VRR	Needs bending the finger, but NOT better than TS	The finger feels awkward	This is still better than touching the screen.	In middle school, I had a phone with a dial on the left which did something similar.	Definitely better than the fingerprint
Which one did you find more satisfying of the three?	FPS > TS > VRR	FPS==TS > VRR	FPS > VRR > TS	VRR > FPS > TS	VRR > TS > FPS
Task 2: Browsing images unimanually while in bed.					
FPS	I love it. why wasn't this inbuilt to Instagram,	Instagram Rocks with this FPS	This definitely is satisfying	Instagram would be really useful with this feature.	This feels nice.

VRR	I would still prefer using the TS.	No I did not like this	The VRR makes my index finger hurt	Not volume buttons	Can I use VRR for scrolling and FPS for liking?
Which one did you find more satisfying of the three?	FPS > TS > VRR	FPS > TS > VRR	FPS > TS > VRR	FPS > TS > VRR	Scrolling : VRR Liking: FPS
Extra Questions					
What are your views on using this regularly	It sounds like a good innovation, but needs maturity.	This is promising, I like that It does not causes fatigue.	There is potential in this technology. but you want use a larger touchpad. FPS is too small	The tech looks interesting but needs polishing	the tech look interesting but the trackpad on the back of the device would be better in my opinion. Increase the touch area will be better.
How would you think this can be improved?	If there was a touch pad on the back it could have been a much more nice approach.	Can be used for camera switching, I get a better grip this way.	Needs more development.	Can we use the edges of the device to have more interactions	This should be a standard feature in the OS.