A Study of On-Device Gestures

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Abstract

Regardless of how gestural phone interaction (like pinching on a touch screen for content zooming) is implemented in almost any mobile device; there are still no design guidelines for gestural control. These should be designed with respect to ergonomics and hand anatomy. There are many human-side aspects to take care of when designing gestures. We evaluate gestures regarding the ergonomic aspects while interacting with mobile devices and present ergonomic requirements of finger gestures on the back and side of a vertically and as well as horizontally hand-held phone, such as dragging and lifting fingers from the surface. The results suggest that drag and lift gestures have the potential to be executed one-handed while using the phone and that certain device configurations may be accessed seamlessly with that type of gesture control.

Author Keywords

Gesture; back-of-device; around device; probe.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces.

Figure 1. Pitch, lift, drag & yaw gestures that were tested for controlling horizontally and vertically held phones.

Introduction

In contrast to the traditional desktop GUI interaction, design guidelines for gestural phone control have not been established yet. We propose an interaction probe design method for exploring single-handed finger gestures, which are executed with the grasping hand. An interaction probe allows us to investigate interactions with gestures for exploring their feasibility in two device orientations: vertical and horizontal. This method allows us to evaluate gestures before effort is spent in implementation.

The hand-held use case we tested in the presented interaction probe is taking pictures with a mobile phone, which represents a major mobile use case, but can also be scaled to any mobile phone control that concerns continuous commands, such as sliding and scrolling. We decided to explore the photography use case, because this scenario requires a stable device position while performing gestures and the gestures that are feasible without tilting the device can afterwards be generalized to much more use cased with less limitations.

The feasibility of grip gestures depends on various aspects, such as the task or grasp goal, the anatomy of the hand and the properties of the grasped object, the relationship to the objects and situational parameters like where and how the grasped objects is placed according to the grasping person [8]. These aspects make it difficult to design gesture interactions that are feasible while grasping a device. The proposed interaction probe supports designing ergonomic on-surface for phone control.

In this paper, after presenting the related work, we present the interaction probe method for evaluating the ergonomics of gestures before any effort is put into implementation. We explore and evaluate the feasibility of four gestures (drag, lift, pitch, yaw) when performed with three fingers of the device-holding hand compared to two-handed interactions. For the promising gestures, we identify the spatial dimensions and conclude with design implications for a gestural mobile UI.

Related Work

For two-handed interaction, when one hand is holding a mobile device and the other one executes the gesture; there are not too many ergonomic limitations for gestural control. There is quite a large design space for on-touchpad gestures that are executed with a "free" hand, such as the Apple pinch. Furthermore around-device-gestures through for instance, hovering the hand above the device [2] or moving a metal made object around it [3] are easily feasible.

One-handed interactions allow much less gestures because the gesture-executing hand primarily has to grasp the device. This limits the gesture design space significantly; the free hand can be used for other tasks, such as carrying a bag or (even though there are some safety issues) steering a car. One way to perform a gesture while grasping a device is to move it. The game console wii-mote uses lots of pointed in-time movements for e.g. simulating hitting a tennis ball with a bat. Moreover the hand grasp can be slightly modified without releasing the hand-held device. Essl *et al*. [1] used pressure sensors for detecting the grasping force to control music. Miyaki and Rekimoto [4] as well as Wilson *et al*. [7] used pressure for controlling common scroll widgets, and Wilson *et al*. is systematically investigating the design space for pressure gestures in terms of the amount of force, the pressing fingers, and the control type (rate versus position control). The mentioned researchers investigated many gesture design aspects through implementing an interactive

	1 hand	2 hands
Lands -cape		
Por-trait		

Table 1. Four conditions under those the participants were asked to perform four pre-defined gestures in session 1.

	1 hand	2 hands
Lands -cape		
Por-trait		

Table 2. Gesture placement (drag, lift, pitch, yaw) performed with a single finger at the same place & time.

Gesture place-ment	Side	Rear
1 hand, landscape	50.0	50.0
1 hand, portrait	25.5	75.0
2 hands, landscape	87.5	12.5
2 hands, portrait	87.5	12.5

Table 3. Preferred placement (in %) for executing drag, lift, pitch, and yaw (if possible, see Tab. 4).

prototype that is augmented with pressure sensors, which can for instance be actuated while grasping the device. The decision of placing sensors is often made through suiting those according to the developer's hand size. In case the participants of the later user study have different hand sizes, that fact could decrease their task performance and affects the results of the study.

Our approach focuses on rapid rather than interactive prototyping for ensuring an earlier and greater user-involvement in the prototyping design. This is meant to avoid errors in the prototype setup. We aim involving users' gesture performance test in the decision process about the sensor placement at regions that are easily reachable while holding the device for one-handed interactions for designing in respect to the strong dependency of the device's form factor and the human hand's anatomy. In the presented study, we use a switched-off phone as prop instead of a fully interactive prototype. This will not replace user studies with interactive prototypes. But we propose testing the feasibility of gestures before any effort is put into implementation for avoiding design errors and effort wasting.

Method

The proposed an interaction probe method for investigating human interaction. Compared to user studies with fully interactive prototypes, an interaction probe does not focus on improving novel technologies but instead on users' interaction behavior when performing novel interaction techniques. This is especially useful for gestural interactions as the probe allows simulating a situation. Other early-prototyping methods, like paper prototypes often fail in that context. There are some advantages of interaction probes in contrast to traditional user studies: no technology-based errors interrupt the human interactions and limit the quality of the results. Furthermore, there are no implementation costs, but on the other hand, there are also no findings about the technology generated. That limitation is common for early prototypes and therefore an interaction probe is a user study that simulates an interaction context in which participants use non-tech prototypes, such as props, dummy devices or imaginations of those. The questions an interaction probe can investigate are evaluations of user experience, interaction feasibilities (especially movement-based), and qualitative as well as quantitative measurements of interactions, e.g. when tasks are solved.

Research Questions

Our goal was to investigate the following research questions:
Q1: At what device side would users prefer to place surface gestures?
Q2: What feasibility does the execution of drag, pitch, yaw, and lift gestures have if executed on the device's surface without tilting it?

Tasks

We asked eight right-handed volunteers, two female and aged 23-31, to solve 4 tasks in 2 sessions. In the first session, the participants were asked to choose a finger or the thumb and a location at the device for performing the four gestures (drag, pitch, yaw, lift; see Fig. 1) without occluding the screen under four conditions: one-handed / two-handed and for taking a picture in landscape as well as in portrait format (see Tab. 1). In the second session, we asked our volunteers to execute these gestures one-handed because that has

	Drag	Lift	Pitch	Yaw
●	100.0	100.0	35.7	0.0
●	100.0	100.0	50.0	0.0
●	100.0	100.0	100.0	100.0
●	100.0	100.0	100.0	100.0

Table 4. % of subjects that was able to execute the gesture without unintentional device movements (at the favored surface area, see Tab. 2).

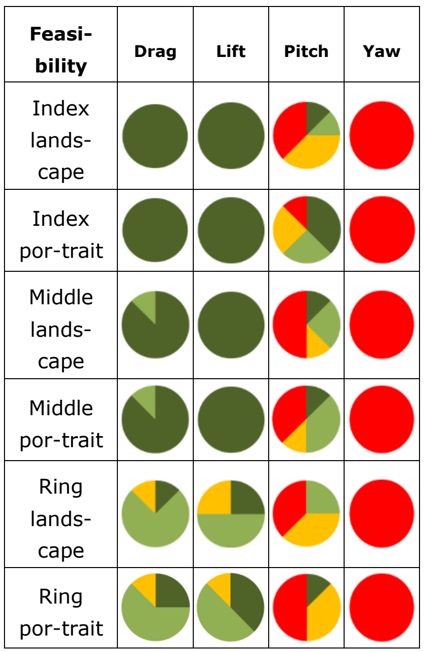

Table 5. 1-handed gesture feasibility for each finger: index, middle, and ring finger in landscape and portrait device orientation on the device rear. Ratings are easy ( ), feasible ( ), difficult ( ), & impossible ( ).

more limitations in mobile situations. We asked the volunteers to execute the easily feasible gestures on the back of the device with three fingers: the index, middle, and ring finger, but not with the little finger as we observed that this finger is often used to rest the device on when finger gestures are performed on the back of the device.

Prop

For simulating a realistic situation we asked the participants to hold a prop that was a real mobile phone in their hand while performing the gestures. This was switched off but had the same form factor as final devices would have: 122mm/4.8inch x 68mm/2.7inch x 11.2mm/0.44inch.

Measurements

During the first session, the participants marked their favored surface area for gesture placement with sticky paper dots. In the second session, the gesture feasibility was rated in a four level Likert scale (easy, possible, difficult, and impossible). Furthermore, we took pictures while the gestures were executed to record the spatial dimensions of the gestures for allowing measurement afterward of how far the fingers were lifted above the device. The dragging paths were again marked on their start and end point with sticky paper dots by the participants.

Results

Gesture placement

The gesture location should allow performing all four gestures at the chosen area. When a gesture was not executable under a certain condition, such as one-handed yawing, this gesture, of course, was ignored for deciding the favored gesture position. For the one-handed conditions, the gesture placement was (according to our observations and hand anatomy) limited through the finger length. All participants grasped the device in a way that the thumb is abandoned from the other fingers, which were placed on the devices rear. The thumb was placed on the user facing device surface or on the side by all participants. In general the participants choose the side more often for one-handed device control and slightly more often the rear for two-handed control (see Tab. 2, 3). This is true only if the gesture was feasible (see Tab. 4). Six of eight subjects (75%) choose the rear at least once. All participants chose at least once the side.
The gestures for the one-handed tasks were placed close to the point where the fingers of the participants were already rested for holding the device. If a device side was chosen for placing the gestures, that was mostly the horizontal top side for landscape orientation or the right vertical side for portrait format, which are interestingly the same because the device rotation (see Tab. 2).
We also analyzed the decision making arguments given in the open post-experiment questionnaires for the favored gesture placement. The dominant reasons for placing the gestures on the device's right side (portrait format) or top sight (landscape format) in contrast to the rear were the visibility of the gestures and the fact that the participants are used to having buttons at these locations when using common mobile phones or digital cameras.
The limitations of the top or the right device side, in the participants' point of view, were the small degrees of freedom for dragging gestures. Moreover the device felt for some participants more safe and natural when fingers were placed on its rear, even if they released them temporary for executing the gestures. The rear

Figure 2. Dragging paths for 3 fingers & 2 device orientations (left), and mean, sd, min, max of dragging lengths (right).

surface of the device allows dragging in two dimensions. The side areas allowed just one-dimensional dragging because a fingertip has more or less the same size as the device sides. The main limitation of placing gestures on the device rear was the invisibility of their execution because of occlusion. However, the participants chose the side for placing the gestures rather than the rear, in the following tasks we decided to investigate the gesture performance at the back of the device. That provides more degrees of freedom and allows performing gestures with three fingers at the same time. The argument that this side area is more common would become weaker if users get used to back-of-device interactions. Finally, the invisibility of the gesture performance might be unusual for common UIs; proprioception however can take over the guidance feedback function of vision if required [6].

Gesture feasibility

Unsurprisingly all gestures are easily feasible when the participants could use two hands: one hand for holding the device and the other for performing the gesture (see Tab. 4). Performing gestures with the hand that grasps the device was still easily feasible for dragging a finger above the device or lifting one from its surface, even without losing any control of the grasp that was indicated by the users. Unacceptable device movements were indicated for the one-handed pitch performance from 35.7% of the participants when the device was held in landscape format and from 50.0% when it was held in portrait format. A yaw gesture was for none participant executable with the grasping hand and without moving the device.
The gesture feasibility for each gesture with each finger with the grasping hand (one handed, see Tab. 5) on the device rear was mainly rated to be easy for the index and middle finger, and still feasible for most participants when executed with the ring finger. Yaw was not possible at all, and pitch was rated with a wide variance, but seams in summary also not suitable as input gesture while grasping a mobile device. The wide variance in rating the feasibility of yaw and pitch gestures might depend on individual different fine motor control abilities.

Gesture dimensions

We visualize the dragging lengths positions of all participants at the user-defined surface location in the left column of Fig. 2. These graphics are generated by taking and merging pictures of the prop at that surface the dragging paths were market with colored sticky paper dots at their start and end points. The drag paths (Fig. 2, left) were executed for each finger have roughly a similar surface position for all participants and allow a spatial differentiation.
A repeated measure ANOVA showed a significant difference for the dragging path lengths between the fingers ($F(2,41)= 3.686$, $p=.0337$). Holm corrected pairwise comparison yielded significant differences for dragging between the ring and both other fingers (see Fig. 2). The device orientation did not show any significant difference in the performance of finger movements while holding a device but without moving it.
We were also measuring the maximum angle between the finger and the device that occurred when the participants released their fingers from the phone’s rear. A repeated measure ANOVA again showed a significant difference between the fingers for lifting. ($F(2,41)= 25.486$, $p=.6.42e\text{-}08$). For lifting, Holm corrected pairwise comparison yielded significant differences between all fingers: for the ring and index,

ring and middle as well as between the index and the middle finger (see Fig. 3). The device orientation again never showed any significant difference in the performance of finger movements while holding a device but without moving it.

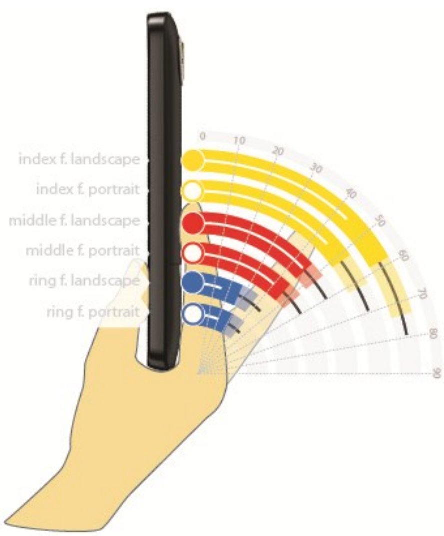

Figure 3. Mean, sd, min, max of lift angles.

Discussion

However yaw gestures were hardly or not executable, drag and lift gestures were feasible with the index and middle finger but these gestures were rated to be more difficult when executed with the ring finger. That harder gesture performance of the ring finger is in line with the executable gestural dimensions. A reason for that effect might be a human's hand anatomy and a different physical connection between our fingers [5], which gives the index finger the largest and the ring finger the smallest movement degrees of freedom. Interestingly the device orientation did not show any performance differences. For designing back-of-device widgets that can be controlled through drag or lift gestures; we argue for using the minimum values of our measures as maximum of the widgets, because then everybody should able to interact with them, regardless of finger and hand size or individual finger feasibility problems because of age or physical problems. Therefore we propose follow drag lengths: index finger: 2 cm, middle finger: 2.2 cm and, ring finger: 1.7 cm; as well as these lift angles: index finger: 45°, middle finger: 40°, and ring finger: 15°.

Conclusion

We identified in an interaction probe dragging and finger lifting as easily feasible gestures on the back of the hand-held device while holding it stable. We argue that continuous spatial gesture widgets, such as sliders that are controlled through finger movements of the device-holding hand, should be sized in respect to general feasibility. The index and middle finger allow easy back-of-device control. Just the ring finger is less flexible because of anatomic reasons and using it for device control might be perceived as harder.

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