Comparative analysis of prototypes for two-touch finger interfaces of smartwatch

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Abstract. Two factors are important when the Smartwatch interfaces are developing - the small size of the display and the limited area for input control. The proposed by the authors prototype take them into account and aim to solve the "fat finger" problem and the difficult observation that affects the usability of the touch screen. It propose two fingers touch interface for smartwatch. The paper presents a comparison study of it for with two other prototypes. The results of complex evaluation of prototypes are given.

1. Introduction

Nowadays the smartwatches become more and more popular. According to the Canalys [1] the worldwide smartwatch sales reached 14.3 million units in Q1 2020, with an increase of 12% year on year, despite COVID-19. The main vendors and their market share are presented in figure 1.

![Market share of smartwatch by vendors.](image)

The smartwatches have different features in addition of function watch - receiving calls or messages, making payments, counting the number of steps taken or monitoring the quality of sleep and heart rate. Most smartwatches are connected to a smartphones via Bluetooth or Wi-Fi. In all of these cases, there is a need to switch (and choose the proper function) from watch to another function. Smartwatches use mainly two methods for these switching functions – push buttons (like in classic watches) or touch screen (like in smartphones).

At the beginning of smartwatch era, the navigation was only with buttons (full push, half push, simultaneously push), but nowadays the most of the vendors use the touch AMOLED displays in
smartwatches. For example, Apple Watch Series 5 has a touch display that is always on, but the display dims when the wrist is down, yet key features, like watch hands, remain visible at all times [2].

The watch face can be personalized by selecting apps or shortcuts to features (up to nine). Huawei watch GT2 46&42mm has 3D curved bezel-less watch face with touch AMOLED display [3]. In addition, some vendors use combination of technologies. For example, Samsung Galaxy Watch Active2 44&42mm has a touch AMOLED display, but adds a touch frame for quick control [4]. In smaller number of cases, the vendors as TicWatch, made the navigation with capacitive interface in bezel ring [5]. Touch-based interfaces are more efficient and intuitive, but when performed on a small surface such as a smartwatch display, there is a problem with the "fat finger" [6] - the user can’t properly select the small target interface controls. Due to the fact that the user covers the screen with his finger, the visual control is lost to confirm the taken action.

In this paper, the authors present a prototype for a two-finger touch interface activation method for smartwatch and a comparison study of it and two other prototypes.

2. Related works
Many authors research and evaluate the touch-based interaction with smartwatch. Some researchers evaluate the touch or pressure technologies on the device components different from the display like devices’ sides [7], band/strap [8], back side [9, 10]. The other ones have explored the area and surfaces around the device like touches on user’s skin close to the wearable device [11] or using touch sensitive fabrics close to the device [12]. There are also researches about replacing standard touch interfaces with those based on taps [13] or joystick sensor control [14].

The authors in [15] research the interaction at the edge side of round smartwatches (with diameter of 60mm), where the sensors’ position place is on the edge of round, but the two-finger multi-touch positions haven’t been researched and evaluated.

3. Creation of two-finger touch interface prototype of the smartwatch
The process passed in four stages:

1. Choice of the dimensions of the 3D model
The authors designed and printed 3D model of smartwatch to observe the touch areas on the bezel. This mechanical prototype is as close as possible to real smartwatch according to its size and form. The diameters of the real smartwatches vary between 34.5mm and 58mm [2, 3, 4, 5], but 73% of them are between 42mm and 46mm. The height of the real smartwatches depends on kind of functions, but vary between 10,9mm and 16mm. Almost 80% of them are between 14mm and 15mm. Based on this statistics, the chosen dimensions of the 3D model are - diameter: 44mm, height: 15mm, bezel angle: 450, bezel width: 4mm; color: white; material: PLA (figure 2). A push buttons or a crown are not added. The surface is divided on 12 equal sectors - on the same places where are marked hours on the analogue watch. The model has lugs for standard 18mm watch strap (to be closer to the standard watch). The diameter of each sensor is 3mm and the space between them is equal.

![Figure 2. 3D Model for evaluation of two-finger touch interface activation.](image)

2. Evaluation of the two touch sectors on the prototype
The authors register which two separate sectors on the device bezel are activated. The detailed results from this evaluation are presented from authors in [16], but in figure 2 is presented the radar chart of the number of touches per sensor (statistics is about users with right leading hand).

3. Comparison of activation of a function sequence for this prototype and prototype with buttons

The authors made this comparison [17] and the main conclusion is – the touch prototype outperformed the prototype with buttons in speed of operations, especially when the set of the interface commands is longer.

4. Evaluation of the prototype in comparison with the similar prototypes.

4. Comparison study of the authors’ prototype with other prototypes with same interfaces

To be possible to make a comparative analysis of the authors’ prototype with others, the same criteria for evaluation as in [14] and [15] are used. In [15], physical touch with the device edge was integral to the vast majority of inputs – only 17% are with two fingers. Participants also favored their dominant hands and use of their thumb and index fingers. The authors gave the results for eight ordinal directions, but in this comparison study only results for matching direction are used. In [14] the authors use multiple fingers to move the whole prototype, which is with a typical size of smartwatch. They showed that their prototype is close to the commercial smartwatches of the same size while input events are generated responsively (55-61ms) and accurately.

The experimental data for authors’ prototype are presented in comparison with [14] and [15] in table 1.

Table 1. Comparison of prototypes for two fingers touch interfaces for smartwatch.

| Criteria                  | Prototype of [14] | Prototype of [15] | Authors’ prototype |
|---------------------------|-------------------|-------------------|-------------------|
| Satisfaction of participants | 0.5               | 0.76              | 0.55              |
| Number of sensors     | 12 (3 by side)   | 24 (every 7.5 degrees) | 12 (every 15 degrees) |
| Touch time [ms] short sequence | 39               | 5.95              | 10.5              |
| Touch time [ms] long sequence | 61               | 50.37             | 14.01             |
| Number slip-offs       | 0.37             | 0.02              | 0.33              |
| Number misses          | 0/100            | 0.175             | 0.27              |
| Simple touch average error ratio | 0                | 0.1               | 0.6               |
| Complex touch average error ratio | 0                | 0.3               | 2.4               |
| Size [mm]              | 49/46/16.5 (rectangle) | 60/18.85 (circle) | 44/15 (circle)    |

Due to the obvious diversity of indicators for evaluating the two fingers touch interfaces, it is impossible to define a specific function for the quality of the proposed by authors’ prototype. In such cases, average complex indicators are used. Based on the data, presented in the table 1, the average arithmetic (1) and average geometric (2) estimation is made.

\[
R_a = \frac{\sum_{i=1}^{n} b_i d_i}{\sum_{i=1}^{n} b_i}
\]  (1)
In (1) and (2) the normalized quantitative assessment of the $i^{th}$ indicator (measure of a criterion) is

$$\rho_g = \left( \prod_{i=1}^{n} d_i \right) \frac{1}{\sum_{i=1}^{n} b_i} \quad (2)$$

In (1) and (2) the normalized quantitative assessment of the $i^{th}$ indicator (measure of a criterion) is

$$0 \leq d_i \leq 1 \quad (3)$$

$n$ – number of indicators, and $b_i$ is the $i^{th}$ weighting coefficient, as

$$\sum_{i=1}^{n} b_i = 1 \quad (4)$$

These coefficients ($b_i$) are selected on the basis of expert assessments or statistical methods. When the values cannot be obtained in this way (insufficient number of analyses or expert assessments in the research area), the coefficients are chosen to be equal.

Due to the heterogeneous nature of the selected criteria, the absolute values given in table 1 must be converted into relative values (dimensionless quantities). For example, for the prototype interfaces studied, if the average number of errors is higher, this means a worse implementation, while the shorter times for selecting the required function shows a better implementation. To obtain comparable results, the conversion into relative values is done so that the higher values for each of the criteria are considered better. If the complex estimations (arithmetic and geometric) are higher, this means more effective prototype. The complex evaluation according to a selected list of criteria gives a possibility to eliminate the shortcomings of the prototypes according to a single criterion.

The results of the comparative analysis are presented in table 2.

| Evaluation | Prototype of [14] | Prototype of [15] | Authors’ prototype |
|------------|-------------------|-------------------|-------------------|
| $R_a$      | 0.463             | 0.342             | 0.762             |
| $R_g$      | 0.465             | 0.214             | 0.546             |

The results obtained for the complex evaluation present fact, that the prototype for two fingers touch interfaces for smartwatch proposed by the authors is better than these proposed in [14] and [15]. The main advantage of the authors’ prototype is its standard size and less touch time in long sequence of touches.

5. Conclusions

This paper presents a prototype of smartwatch with two fingers touch interface and a comparative analysis of them and two others [14, 15]. A system of criterion for comparing two fingers touch interfaces for smartwatch has been proposed. Based on them, a complex evaluation of these prototypes was made. When examining the criteria separately, it can be seen that in the case of “Simple touch average error ratio” and “Complex touch average error ratio” the proposed prototype does not provide good results. Despite this fact, the complex assessment of prototypes presents the highest value for the authors’ prototype and it is better than others.

The presented in the paper two fingers touch interface is suitable for smartwatches, designed for sports and fitness, as it offers the shortest time to activate a long sequence function.

The goal of the further research could be to develop a software, which will recognize the user body pose. Depending on of the body pose (straight, sitting, lying down), the smartwatch should provide the user with context menus with certain functions.

References

[1] Canalys: Worldwide smartwatch shipments grew 12% in Q1 2020 despite coronavirus

https://www.canalys.com/newsroom/canalys-worldwide-smartwatch-shipments-q1-2020 Last visited on 15.07.2020
[2] Apple Watch Series 5 Available at: https://www.apple.com/apple-watch-series-5/design/ Last visited on 15.07.2020

[3] Huawei watch GT2 Available at: https://consumer.huawei.com/en/earwears/watch-gt/ Last visited on 15.07.2020

[4] Samsung Galaxy Watch Active2 44 mm, Stainless Steel Available at: https://www.samsung.com/bg/earwears/galaxy-watch-active2-r820n/SM-R820NSKABGL/ Last visited on 15.07.2020

[5] TicWatch C2+: https://www.mobvoi.com/en/pages/ticwatch2plus?gclid=EAIaIQobChMI8pHnu4PP6gIVap3VCh2R-Q3cEA4YASAAEgLfybD_BwE Last visited on 15.07.2020

[6] Siek K, Rogers Y and Connelly K 2005 Fat finger worries: how older and younger users physically interact with PDAs, Human-Computer Interaction - INTERACT 2005. Lecture Notes in Computer Science, 3585, ed M Costabile and F Paternò, (Springer, Berlin, Heidelberg) https://doi.org/10.1007/11555261_24

[7] Darbar R, Sen P and Samanta D 2016 PressTact: side pressure-based input for smartwatch interaction, Proc. 2016 CHI Conf. Ext. Abstr. Hum. Factors Comput. Syst. pp 2431–2438, https://doi.org/10.1145/2851581.2892436

[8] Ahn Y, Hwang S, Yoon H, Gim J and Ryu J 2015 BandSense: Pressure-sensitive Multi-touch Interaction on a Wristband Proc. 33rd Annu. ACM Conf. Ext. Abstr. Hum. Factors Comput. Syst. pp 251–254, https://doi.org/10.1145/2702613.2725441

[9] Lim S, Shin J, Kim S and Park J 2015 Expansion of smartwatch touch interface from touchscreen to around device interface using infrared line image sensors, Sensors 15(7) https://doi.org/10.3390/s150716642 pp 16642–16653

[10] Xiao R, Laput G and Harrison C 2014 Expanding the input expressivity of smartwatches with mechanical pan, twist, tilt and click Proc. 32nd Annu. ACM Conf. Hum. Factors Comput. Syst. pp 193–196, https://doi.org/10.1145/2556288.2557017

[11] Zhang C, Bedri A, Reyes G, Bereik B, Inan OT, Starner TE and Abowd GD 2016 TapSkin: Recognizing on-skin input for smartwatches, Proc. 2016 ACM Interact. Surfaces Spaces pp 13–22, https://doi.org/10.1145/2992154.2992187

[12] Schneegass S and Voit A 2016 GestureSleeve: using touch sensitive fabrics for gestural input on the forearm for controlling smartwatches, Proc. 2016 ACM Int. Symp. Wearable Comput. pp 108–115, https://doi.org/10.1145/2971763.2971797

[13] Yoon H and Park S 2020 A Non-Touchscreen Tactile Wearable Interface as an Alternative to Touchscreen-Based, Wearable Devices Sensors 2020 20(5) 1275 https://doi.org/10.3390/s20051275

[14] Yeo H, Lee J, Bianchi A and Quigley A 2016 Sidetap & slingshot gestures on unmodified smartwatches, Proc. 29th Annu. Symp. User Interface Softw. Technol. pp 189–190, https://doi.org/10.1145/2984751.2984763

[15] Oakley I and Lee D 2014 Interaction on the edge: offset sensing for small devices, Proc. SIGCHI Conf. Hum. Factors Comput. Sys. pp 169–178, https://doi.org/10.1145/2556288.2557138

[16] Dimitrov Y 2018 Two-finger touch interface activation method for wearable devices Proc. ICEST 2018 ISSN: 2603-3259 pp 146-149

[17] Dimitrov Y, Aleksiieva V and Valchanov H 2019 Wearable device interfaces comparison, 16th Conference on Electrical Machines, Drives and Power Systems (ELMA), Varna, Bulgaria, 2019, pp 1-4, doi: 10.1109/ELMA.2019.8771545

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