# Towards Improving Touchscreen Input Speed and Accuracy on Smartphones for Tremor Affected Persons

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## Abstract
People who are affected by tremor often have difficulties when interacting with smartphones. The uncontrollable shaking of the hands can complicate fast and accurate interaction with touchscreen based smartphones. Although recent work has shown that motion sensors incorporated in smartphones can be leveraged for detecting tremor, little work has been done to use this data to increase interaction time and accuracy for smartphone interactions. We show how motion sensor data can be used to gain higher accuracy and decrease interaction time for persons with tremor.

## Author Keywords
Tremor; touchscreen; accuracy; input methods; accessibility

## ACM Classification Keywords
H.5.2 [User Interfaces]: Input devices and strategies

## Introduction
Tremor in the hands can affect interaction with modern smartphones in a negative way. Tremor describes rhythmic, involuntary movements of limbs (in our case especially the hands), affecting about 0.4 % of the population. Its incidence increases with age [5]. The uncontrollable oscillation of the hands can cause complications when interacting with smartphones, leading to slower task completion times and less accuracy when selecting objects. Furthermore, the

tremor's frequency (usually between 6 and 10 Hz [3]) can vary depending on caffeine intake, medication, stress and other factors [2].

Recent work showed that motion sensors, such as are incorporated in modern smartphones, can be leveraged to detect and monitor tremor [1, 4]. Yet, little work has been done to correct users' input based on detected tremor. We have developed an algorithm which performs such a correction. By using a combination of the motion sensor data of a smartphone and a motion sensor placed on users' index finger, we aim at increasing both interaction time and accuracy. In this demo, we demonstrate our algorithm with a Fitts' Law test. To enable demo attendees without tremor to try our algorithm, we use tremor simulating gloves [8], which induce tremor with electrical muscle stimulation impulses.

## Related Work

Built-in motion sensors of smartphones like gyroscopes and accelerometers have successfully been used for tremor detection by Daneault et al. [1] and Kistikis et al. [4]. We also rely on smartphones' motion sensors to detect tremor, but rather focus on using this data to correct errors made because of tremor when interacting with smartphones.

Nicolau and Jorge analysed text entry performance of senior citizens depending on severity of tremor [9]. They found that error rates increased with the severity of tremor, and provided several guidelines for developing interfaces. Yet, we are not aiming at developing special interfaces for persons with tremor, but rather to enable them to use any interface by correcting their input.

Wacharamanotham et al. presented Swabbing, an interaction technique allowing persons with tremor to select objects with fewer errors [11]. In contrast to Swabbing, our algorithm allows users to use existing interaction techniques, thus it is not necessary to learn a new interaction technique.

Zhong et al. proposed Touch Guard [12]. Touch Guard compensates for tremor by providing additional visual content representations like magnifications and target lists. Opposed to this approach, we do not alter the existing user interfaces, but implicitly correct users input based on motion sensor data.

## Tremor Correction

Additional to the build in motion sensors of a smartphone, in our case a LG Nexus 5X, we used a Meta Wear RPRO sensor [7]. The sensor was placed in a 3D printed case that can be mounted on users' index finger using Velcro straps. The sensor can be seen in Fig. 1. Communication between smartphone and finger sensor was implemented using Bluetooth.

To correct input errors caused by tremor, we implemented the NoShake algorithm presented by Rahmati et al. [10]. NoShake was inspired by a physics model, were the screen content is considered as mass stabilized with springs and damper functions. The used parameters were derived based on empirical evaluations, and can be seen in Tab. 1. The al-

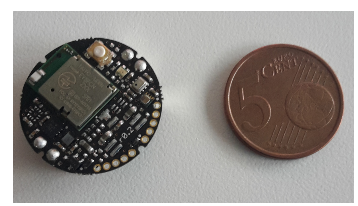

**Figure 1:** The used Meta Wear RPRO motion sensor used to detect tremor in the index finger.

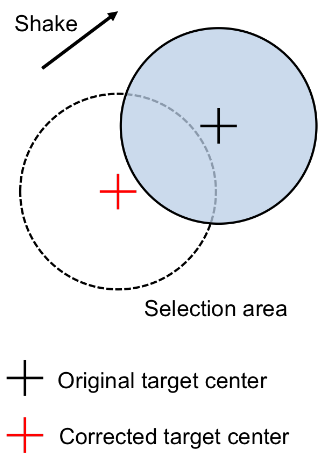


**Figure 2:** The original target with its centre (black cross) and the corrected target (red cross as centre). Since our informal tests showed that changing the user interface confuses people and does not lead to faster and more accurate selection, the visual representation of the user interface is not changed. Rather, the selection area oscillates around the original target according to our correction algorithm.

| Parameter | Smartphone | Finger sensor |
|---|---|---|
| circular buffer | 0.4 | 0.2 |
| shake window | 0.1 sec | 0.1 sec |
| shake threshold | 0.3 | 0.5 |
| spring damper | 0.000001 | 0.000001 |
| scale a | 10 | 20 |

**Table 1:** The parameters used for our implementations of the NoShake algorithm for both smartphone and finger sensor.

gorithm was implemented for both smartphone and finger sensor, the first used to stabilize the user interface position and the latter to stabilize the position of the tap. In contrast to the original implementation, we did not move the user interface, but rather move the touch detection areas of user interface elements, as visualized in Fig. 2. Informal evaluations showed that moving the user interface confused users and did not necessarily lead to faster and more accurate interaction.

To ascertain that only the motion data caused by tremor were included in the calculation of the correction, we implemented a tap detection based on the detected accelerations. We assumed that tabs have a larger acceleration than tremor shakes. We thus calculated the average acceleration over the last 0.4 seconds and compared the result to the current acceleration. If the current acceleration in one direction is three times larger, the detected motion is regarded as a tab and not considered for the correction.

Preliminary tests showed, that in cases were the corrected position of the touch missed the corrected target, a line drawn between the original and corrected touch position most likely intersects the target. Thus, the target intersected by such a line was considered as selected. Fig. 3 depicts this approach. To test our tremor correction, we incorporated our algorithm into FittsTouch, an Android application for conducting evaluations based on Fitts' Law [6].

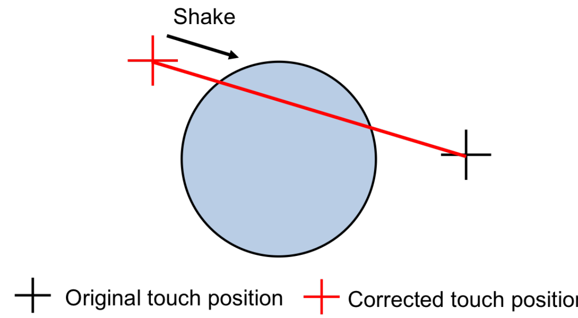


**Figure 3:** The corrected target intended to select (blue sphere), the position of the original touch (black cross) and its correction based on motion sensors (red cross). In cases where the corrected touch position does not hit the target, a line between the original and the corrected touch position is drawn. The target intersected by this line is then selected.

## Conclusion

Tremor in the hands can complicate interactions with touchscreen based smartphones. The uncontrolled oscillations of ones hands might impede fast and accurate target selection. We presented an algorithm designed to overcome this issues by detecting the tremor with motion sensors. The detected oscillations are then used to correct users input. In the future, we plan to conduct a user study to analyse exactly how much faster and less error prone persons with tremor can select items when using different versions of our algorithm.

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