
Simple Touch Prediction with Built-In IMUs

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ABSTRACT

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CCS CONCEPTS

• **Human-centered computing** → **User studies; Ubiquitous and mobile devices;**

KEYWORDS

Smartphone; IMU; touch prediction; LSTM; regression.

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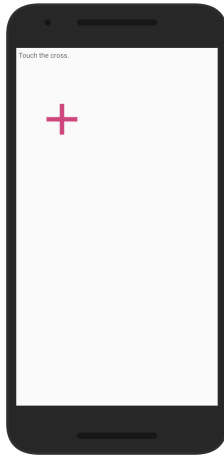


Figure 1: Touch task with one cross displayed.

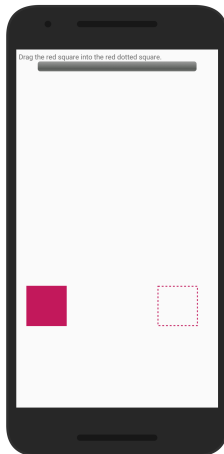


Figure 2: Fitts Law task with a progress bar displaying the current progress.

Story finden und dann umstellen/umschreiben

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1 INTRODUCTION

Touch is the preferred input method on smartphones today. Current research and manufacturers are constantly trying to improve and enhance the interaction on smartphones. Enhancing smartphones with new, rich interaction methods allows users to operate their phone faster and more accurate, thereby increasing the usability and user-experience. One way can be the extension of interactable space with interaction possibilities on the back of device (BoD) [1, 9, 11, 18]. E.g. unlocking the phone by using gestures on the backside, or explicit touches on the backside to reach for unreachable targets on the front side may be possible applications of this technique. However, some of these solutions do not conform with the form factors and weights of ordinary phones [2, 3, 16, 17]. Another way to extend interaction is the introduction of additional touch gestures and touch recognition on touchscreens [7, 8, 10]. Previous work tried predicting touch positions on the touchscreen based on sensor data from either built-in or additional sensors [4, 12, 14].

Accurately predicting touch positions could offer many use-cases:

Preloading Content: Preloading certain content that a user might request in the near future, e.g. a web page, reduces the waiting time and thus improves the user experience. Removing the latency and thereby getting rid of the delay between certain actions greatly enhances the usability of a system. However, when navigating on websites and preloading content from small links a high and precise accuracy is required. Inaccurate prediction would require to preload more data around the predicted point.

Highlighting Objects: When navigating through folders, predicted future positions of a touch can be used to highlight information about the to be touched folders. Navigation through a picture gallery on the phone can slightly enlarge the to be touched pictures to give a small preview, maybe showing picture information of where and when the picture was taken. The accuracy required for this approach does not necessarily have to be very high as elements are usually larger than small weblinks.

Despite its novelties, accuracy of some of these solutions has been low. In this paper, motivated by related work and its unexploredness, we present a machine learning model for predicting touches on smartphones using only the phones' built-in sensors.

2 RELATED WORK

Our work

Device	Release	Weight (g)	Screen Diagonal (in)
S3 Mini	2012	113	4.
S4	2013	130	5.
Nexus 5X	2015	136	5.2
Nexus 6	2014	184	6.
	Height (cm)	Width (cm)	Depth
S3 Mini	12.16	6.3	0.99
S4	13.7	7.0	0.79
Nexus 5X	14.7	7.26	0.79
Nexus 6	15.93	8.3	1.01

Table 1: Data about the smartphones that were used in the study.

Motivated by overcoming the lack of input modalities, related work presented touch prediction as a new interaction possibility on smartphones. Mohd Noor et al. [14] presented *28 Frames Later*, a system that predicts future touch positions on smartphones. Based on grip data they gathered from a total of 24 capacitive sensors built inside the BoD and on the laterals while performing touches on the touchscreen they built a machine learning model that was able to predict touch positions 200ms before the actual touch with an offset of 18mm to the actual touch position. However their system required the 24 built on sensors which is not feasible for ordinary usage. *BackXPress* by Corsten et al. [2] is a method that enhances touchscreen input by users applying pressure to the BoD with certain fingers to trigger specific actions on the screen. Their built prototype did not confirm with the weight and form factor of ordinary phones and the system is only meant to be used in landscape orientation. Löchtefeld et al. [13] used the internal sensor units to distinguish between left, right, and double handed interaction on smartphones. The distinction was made based on different patterns during the unlocking of the cell phone. Goel et al. [6] presented *GripSense*, a system that can imply pressure and infers hand postures on phones based on inertial sensor measurements by the gyroscope with an accuracy of 84.3%. *WalkType* [5] used the phones' built in accelerometers to adapt keyboards while walking. With *WalkType* reduced uncorrected errors by 45.2% and increased input speed by 12.9%.

3 DATA COLLECTION STUDY

We conducted a data collection study to gather IMU data while performing touches on a smartphone. Our collected data set consists of 6 smartphone sensors that were sampled while participants performed successive touches on the smartphones front side. For our data collection study we used a repeated-measures design with one independent variable: PHONE, which was counterbalanced using Latin Balanced squares. The total amount of conditions was: PHONE = 4.

Apparatus

Our dataset was generated using four different sized smartphones on which participants had to perform a certain amount of touches (for further information see Section 3). The phones we used were a Samsung S3 Mini, a Samsung S4, a Google Nexus 5X, and a Motorola Nexus 6. For more technical details about the used devices see Table 1. Our used phone sizes range from 4" (S3) to 6" (N6). Using phones of these sizes we were able to cover the sizes of everyday smartphones, including some high-end devices and create a generalizable machine-learning model.

Tasks

For our data collection study participants had to touch points displayed as crosses in a 16×9 grid on the touchscreen (see Figure 1). To achieve a high variance, we randomized the positions of the crosses within all the cells. To avoid sequential effects, we randomized the order in which the crosses were

displayed. There were a total of 3 repetitions, resulting in a total of $16 \times 9 \times 3 = 432$ touches on one device.

Between two touches our study participants had to perform a simple *Fitts' Law task* (see Figure 2). Here participants had to drag a filled rectangle into a dashed contour of a rectangle. This task was mainly implemented to reset the participants grip to the bottom half of the device. Because a previous shifted grip of the hand to the upper half of the phone influences the recorded sensor data when reaching for the next target in the lower half and vice versa.

Procedure

Participants were either invited within the course *FIS'18* or orally. All appointments were discussed orally. After participants have arrived they signed a consent form. We then continued measuring their hand length. We asked the participants to take a seat on a chair without armrests and explained the study procedure and its sense. We started carrying out the study and handed out the first phone accordingly to the balanced Latin Square order. After participants finished the tasks (see Section 3) on the first phone, we asked them if they need a short recovery break and then continued with the next phones. Additionally, we allowed participants to rest and put away the phone during the *Fitt's Law task* because we specifically deal with this task in our preprocessing step (see Section 4). The study duration was 54 minutes on average.

Participants

We invited 20 right-handed fellow students as participants (15 male, 5 female). Their age ranged between 21 and 27 ($M = 24.25$, $SD = 1.58$). We measured the hand length of participants. The size was measured from the tip of the middle finger to the wrist crease with fingers stretched out. Hand lengths ranged from $16.0cm$ to $21.3cm$ ($M = 19.3cm$, $SD = 1.47cm$). Our measured data covers samples from the 5th and 95th percentile of the anthropometric data reported in previous work [15].

4 RESULTS

Data Set & Preprocessing

We recorded a total of 1079 minutes of sensor data from the *touch* and *Fitt's Law task* task. Due to the high sampling rate of the sensors we first removed occurring duplicates by keeping the last sensor value and timestamp. We then up-sampled the sensors to 333.33 Hz, resulting in 1 sample given every 3ms. Finally, we saved 100 samples before each touch resulting in a total of 3.456.000 samples.

Up-sampling the sensors to 1 sample every 3ms resulted in a discontinuous function for each sensor axis. We have therefore tried applying several smoothing procedures.

2

	S3M 0ms	S4 0ms	N5X 0ms	N6 0ms
RF	28.11	34.76	36.38	41.4
DT	28.81	35.58	37.03	42.56
KNN	28.67	34.61	36.36	42.91
GP	53.35	66.83	69.53	79.06
	S3M 33ms	S4 33ms	N5X 33ms	N6 33ms
RF	27.91	34.29	36.05	40.45
DT	28.39	35.1	35.03	41.52
KNN	28.41	34.31	35.92	42.13
GP	52.89	66.82	69.52	79.05
	S3M 66ms	S4 66ms	N5X 66ms	N6 66ms
RF	27.54	33.58	35.24	40.18
DT	27.9	32.74	34.67	39.54
KNN	28.1	33.99	35.93	41.62
GP	44.65	64.83	67.88	76.18

Table 2: Average euclidean distances (mm) for baseline regressors from scikit-learn¹.

Report about your model. No source code!
Report about the validation dataset / validation study.

5 DISCUSSION

Disuses why it is still not awesome and how this could be improved. Why this is still awesome? Think about: Nobody has done this before.

Limitations

In this paper we focused on one specific use task where users touched randomized targets on smart-phones while sitting in on a chair without armrests. The sensor samples generated during our study are specific for this use case and thereby do not cover ordinary smartphone usage and implied phone movement when for example walking or operating the phone in a train.

Limitations of using our machine learning approach

6 CONCLUSION

Two sentences wrap up what you have done. Than report what you achieved.

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