Smartwatch Input from the Resting Wrist

Decoding the direction and length of same-hand finger strokes with the watch's built-in motion sensors

MSc Thesis Research · Computer Science

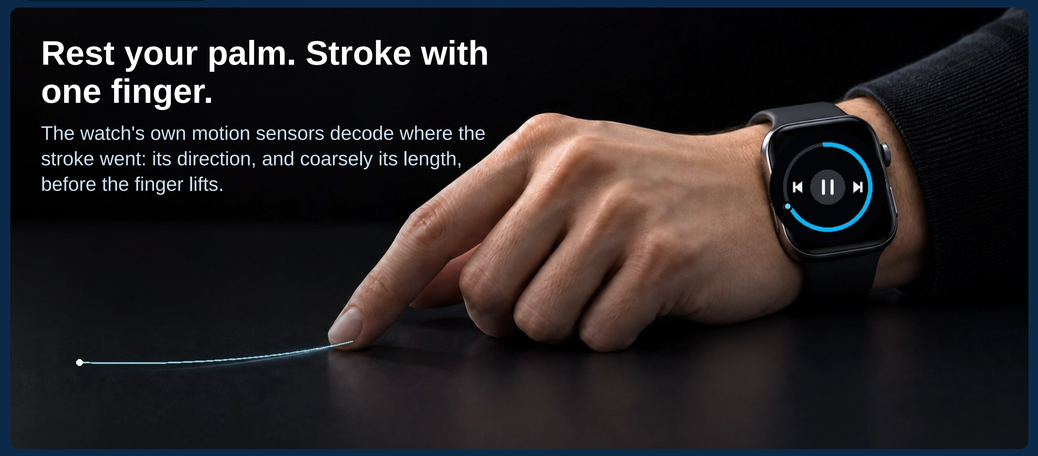
Mohammed Nasif Zawad · Supervisor: Dr. Ali Neshati

User Experience and Interaction Design (UXID) Lab · Ontario Tech University, Oshawa, Canada

uxid.ca

Rest your palm. Stroke with one finger.

The watch's own motion sensors decode where the stroke went: its direction, and coarsely its length, before the finger lifts.



Main finding

The motion sensors of an unmodified smartwatch carry the direction, and coarsely the length, of finger strokes made by the watch-wearing hand while the palm rests on a surface.

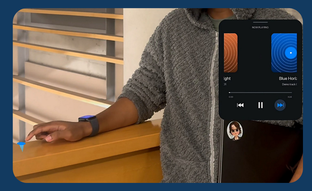
- **18.6°** median direction error, with the wearer's other sessions in training
- **18.8 mm** median endpoint error, for strokes averaging 42 mm
- **54% → 74%** eight-way accuracy for a new wearer with online adaptation
- **182 ms** median lead before finger lift at which direction was recoverable

Envisioned applications



Keep swiping to scroll

Repeated strokes move through the app list.



Swipe sideways to change the song

A left or right stroke skips to the next or previous track.



Swipe down to answer a call

A stroke toward the wrist accepts the call.

Illustrative scenarios; the study evaluated decoding on a tablet surface, not these interfaces.

Motivation

Continuous smartwatch input, such as scrubbing audio or adjusting a level, often occupies the other hand, which in many seated situations already holds a mouse, a pen, or a cup.

Existing one-handed techniques add sensing hardware[1], use wrist tilt, which moves the display[2], or return discrete gesture labels[3, 4]. This thesis examines the continuous information available from the watch's own inertial sensors when the palm rests on a surface.

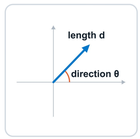
How it works



1 Finger stroke →



2 Wrist rotation →



3 Decoded value

A finger stroke rocks the hand about the palm heel; the gyroscope's pitch and roll encode the stroke's direction and length.

Decoding pipeline

Watch IMU	Representations	Decoders	Outputs
6 channels, 100 Hz	• 237 features • 10 × 128 sequence	• random forests • convolutional network	• direction, endpoint • eight-way class

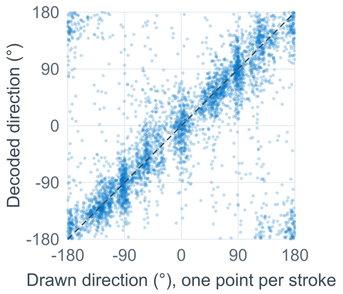
Decoders use only the stroke so far; the tablet is never a decoder input.

No added hardware · **Surface not instrumented** · **Watch screen stays still**

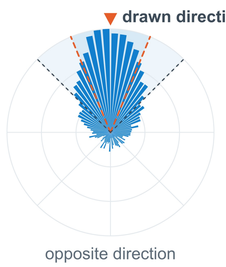
RQ1 How accurately can direction and length be decoded from the watch alone?

Median direction error is 18.6°; length is coarse

(a) Decoded vs. drawn direction



(b) Where the decoded direction lands



29% within ±10°

57% within ±22.5° half an eight-way sector

82% within ±45°

Median error

Wearer's other sessions in training		Unseen participant		Pivot geometry only, no learned model	
18.6° direction	**18.8 mm** endpoint	**24.2°** direction	**21.5 mm** endpoint	**25.4°** direction	**22.7 mm** endpoint

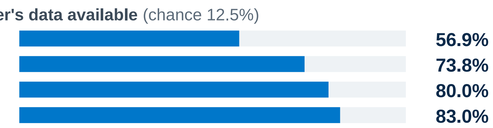
Length is coarse (within-direction r = 0.55) and insufficient for cursor positioning.

RQ3 Does the mapping differ across people, and can the decoder adapt?

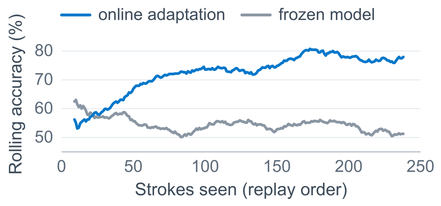
The decoder adapts to a new wearer during use

With the correct label after every stroke, a new wearer's eight-way accuracy rose from 54.0% to 73.8%, and all 16 participants improved.

Eight-way accuracy by the wearer's data available (chance 12.5%)

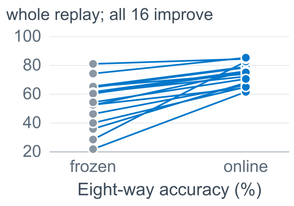


(a) Accuracy during use



(b) Each participant

whole replay; all 16 improve

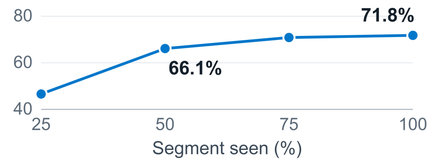


Each stroke is scored before its label is used. The online start is a single-seed network (54.0%); 56.9% averages five seeds. Own-stroke values use folds grouped by stroke.

RQ2 How early in a stroke does its direction become available?

Direction is recoverable before the finger lifts

Eight-way accuracy (%) by share of the stroke seen

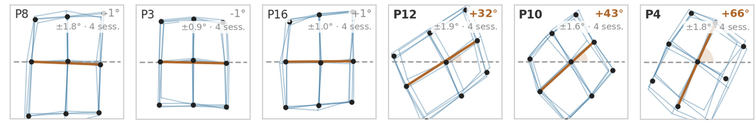


182 ms

median lead before finger lift, for correctly classified strokes (57.2% of two-stroke trials)

Retrospective, not system latency. Chart: within-participant model, all strokes.

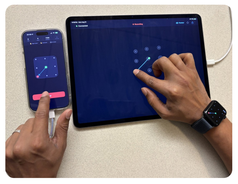
Each wearer adopts a personal spatial frame



Calibration grids of six of the 16 participants, with sessions overlaid.

Six of 16 participants rotated their grid by 32° to 66°. Rotation changed by 1.8° across a participant's sessions, compared with 25° between participants.

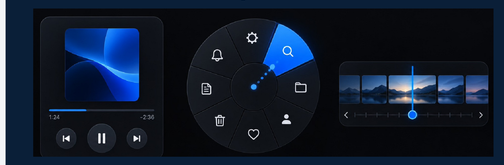
Study



- **16** participants
- **67** sessions
- **4,130** strokes analyzed
- **100 Hz** motion data

Apple Watch Series 9 on the dominant wrist; 72 cued strokes per session. An iPad recorded the touch path as ground truth. Results are for held-out sessions or participants unless noted.

Interface concepts



Media controls · **Radial menu selection** · **Timeline scrubbing**

- **Direction** selects an item or a control.
- **Coarse length** sets a small or large step.
- Concepts from the thesis demo; not yet evaluated.

Design implications

- **Prefer a coarse vocabulary.** 94.7% of eight-way errors fell in an adjacent sector.
- **Adapt to each wearer** during use, where reliable feedback is available.
- **Keep motion data on the watch.** One stroke identified its wearer with 86.9% accuracy (chance 6.25%).

Limitations and next steps

- A tablet supplied every stroke boundary; on-watch detection was not evaluated.
- Seated, dominant hand, one glass surface, no decoded feedback.

Next: on-watch stroke detection and closed-loop evaluation.

1. J. Gong, X.-D. Yang, and P. Irani. 2016. WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures. UIST '16.
2. A. Guo and T. Paek. 2016. Exploring Tilt for No-Touch, Wrist-Only Interactions on Smartwatches. MobileHCI '16.
3. X. Lin, Y. Chen, X.-W. Chang, X. Liu, and X. Wang. 2018. SHOW: Smart Handwriting on Watches. Proc. ACM IMWUT 1, 4.
4. P. Knierim, J. Höck, and T. Kosch. 2025. Wrist-Powered Touch: Evaluating Smartwatch-Based Touch Gesture Recognition for Interaction in Extended Reality. MuC '25.

Research ethics. Approved by the Ontario Tech University Research Ethics Board (file 20360).