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TwistIn: Tangible Authentication of Smart Devices via Motion Co-analysis with a Smartwatch

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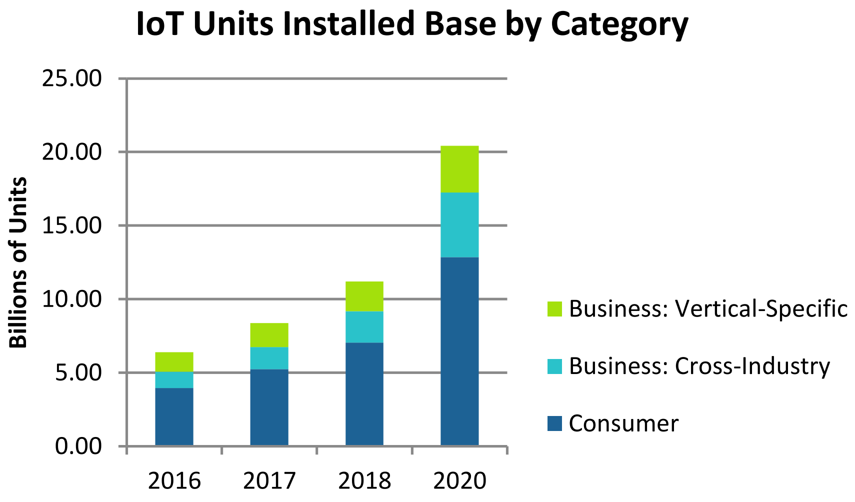
Introduction

- More connected devices in the future (20.4 billions by 2020 [1])
- Devices are getting smaller with limited interface



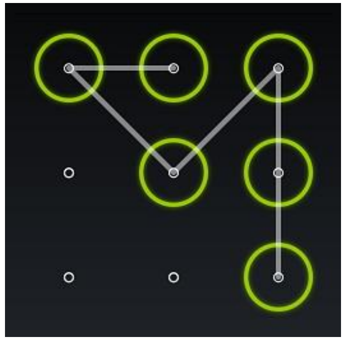
Source: Gartner (January 2017) [1]

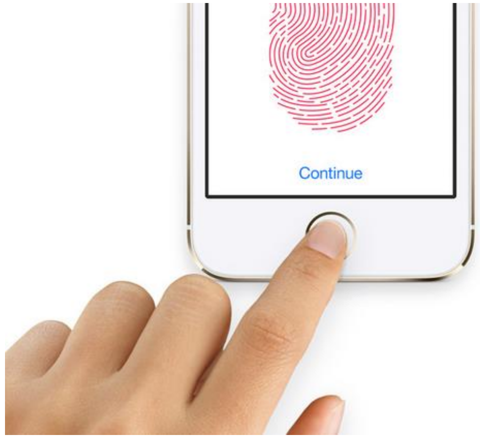
Bluetooth Tracker, Smart Glasses, Bluetooth Toy, Speaker, 360 Camera

[1] Gartner, I. Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016, 2017. *[Online; accessed 26-Sept-2018]*.

Introduction

- Existing methods are not effective
  - PIN, Passcode, Swipe Patterns
  - Biometrics
    (e.g. Fingerprint, Face, Touch Behavior)
  - Via Mobile Applications
  - Physical Proximity
  - Virtual Assistant





Android Swipe Pattern, Apple's TouchID, BB-8 Toy, Apple Watch Unlocking, Amazon Alexa

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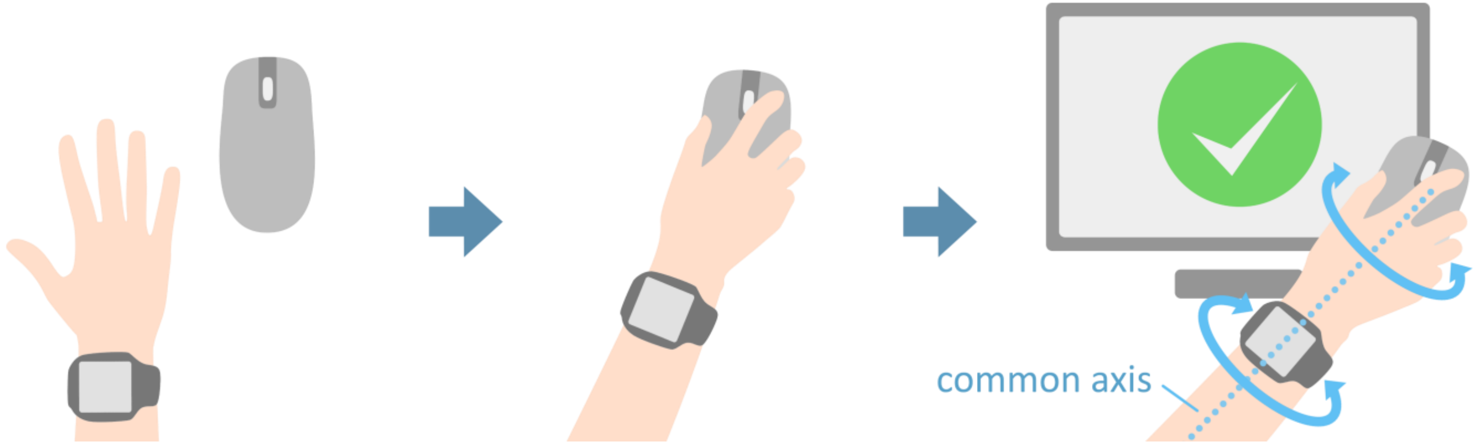
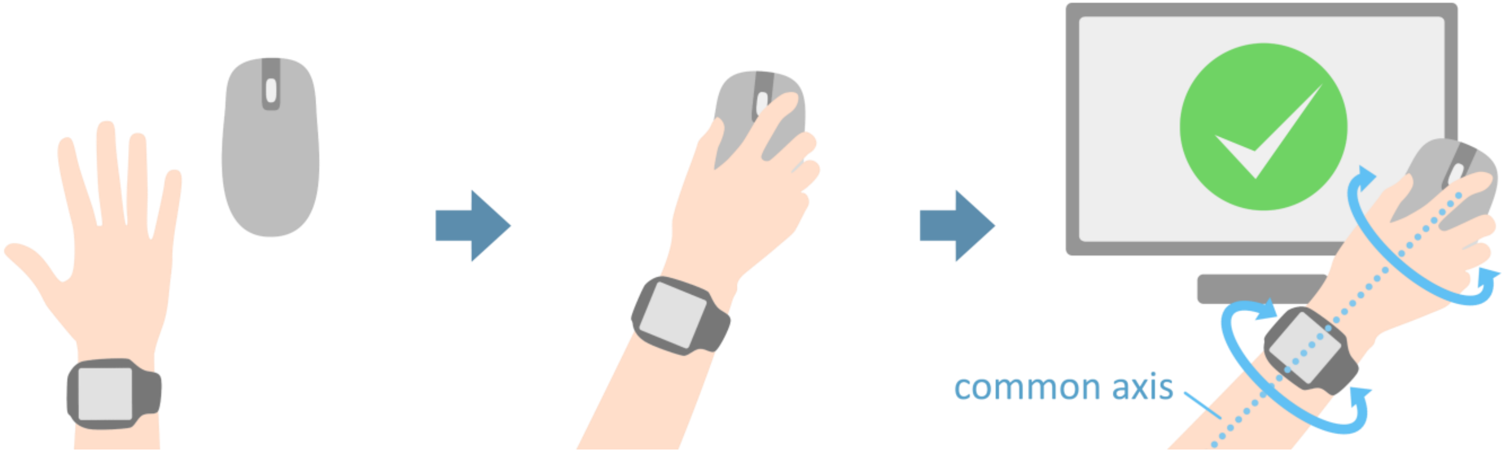
Our method

1. The user is wearing an already-authenticated smartwatch
2. A smart device is picked up by the user
3. The user performs the TwistIn gesture simultaneously on both devices
4. The motions of the devices are co-analyzed
5. The smart device is authenticated



Potential Applications

1. A smart mouse that can log into a computer without typing the username and password
2. A game controller (e.g., a Xbox controller) that allows a player to join in a game immediately with the player's profile and preference loaded automatically.



Potential Applications

3. Controlling robot swarms

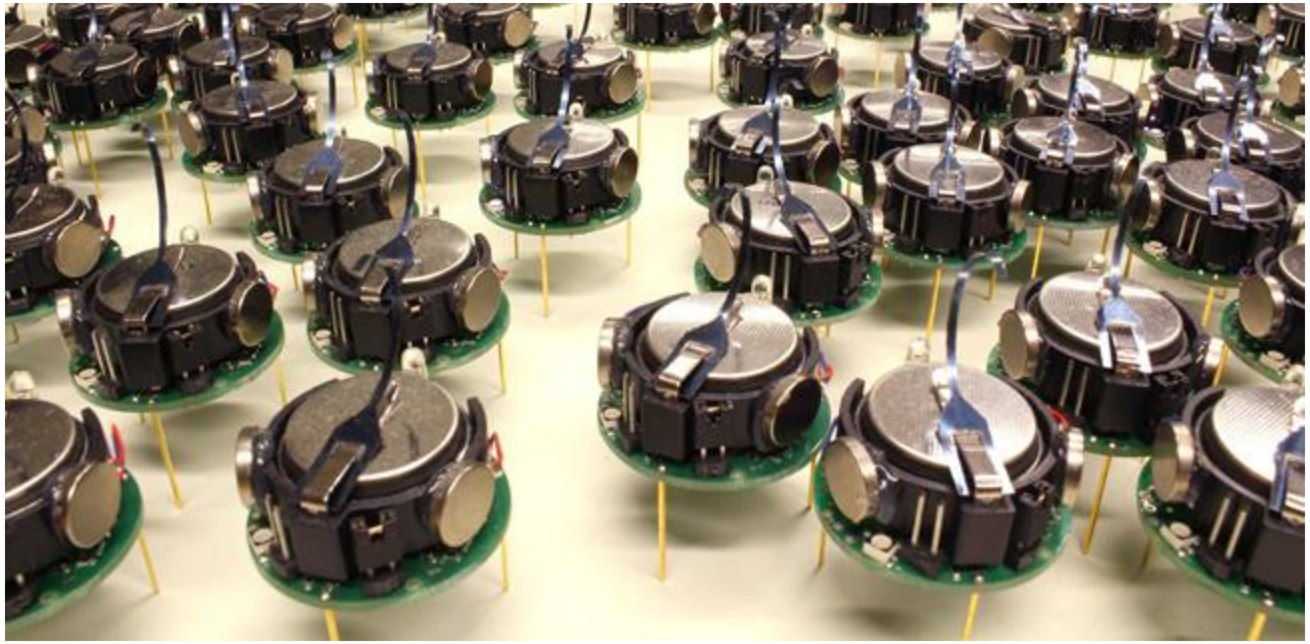
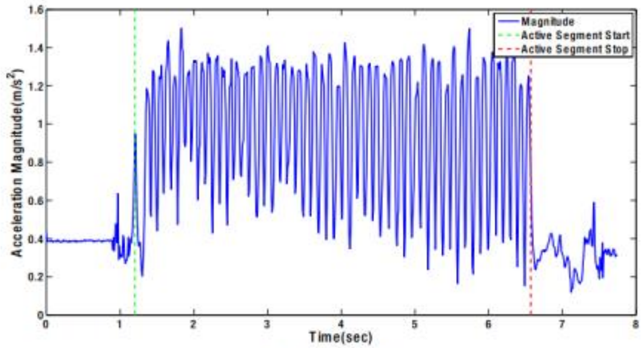


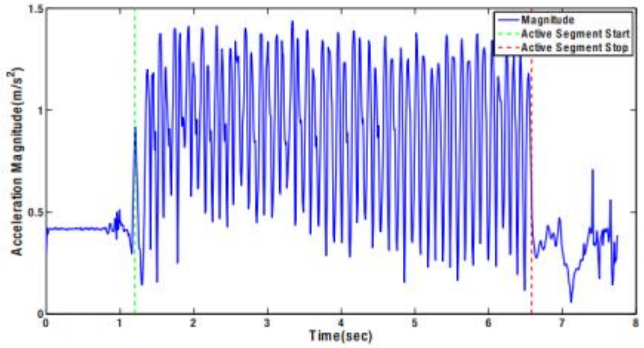
Photo: Kilobots Mike Rubenstein/Harvard University

Related Work

- ShakeUnlock [2]
  - Devices are held and shaken together vigorously (~8Hz)
  - Correlate the devices’ shaking frequency and magnitude.
  - True match rate of 84.6% after shaking for 5 seconds, and 63.7% for 1.2s.



(a) Sensor 1



[2] Findling, R. D., Muaaz, M., Hintze, D., & Mayrhofer, R. (2014, December). Shakeunlock: Securely unlock mobile devices by shaking them together. *In Proceedings of the 12th International Conference on Advances in Mobile Computing and Multimedia (pp. 165-174). ACM.*

Contributions

- Optimize a transformation matrix to align two devices' motion data

Apple Watch

$$\max_{r} \sum_{t \in T_{\text{basis}}} \langle \Delta q_A^t, r\, \Delta q_B^t\, r^{-1} \rangle$$

$$\text{subject to} \quad ||r|| = 1\ .$$

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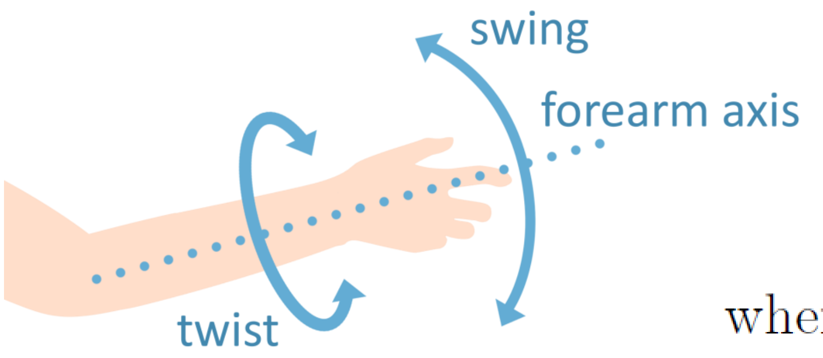
Contributions

- Filter out the unwanted motion by extracting the forearm rotation using rotation decomposition



$$\max_{\vec{a_A}, \vec{a_B}, r} \sum_{t \in T_{\text{basis}}} \langle p_A^t, r\ p_B^t\ r^{-1} \rangle$$

$$\text{subject to} \quad ||\vec{a_A}|| = 1, ||\vec{a_B}|| = 1, \text{ and } ||r|| = 1,$$

$$\text{where } p_A^t = \frac{[w_A^t, (\vec{a_A} \cdot \vec{q_A^t})\vec{a_A}]}{\sqrt{(w_A^t)^2 + (\vec{a_A} \cdot \vec{q_A^t})^2}} \text{ and } p_B^t = \frac{[w_B^t, (\vec{a_B} \cdot \vec{q_B^t})\vec{a_B}]}{\sqrt{(w_B^t)^2 + (\vec{a_B} \cdot \vec{q_B^t})^2}}.$$

Contributions

- We consider two conditions to see if the motions are in sync:

i. The weighted mean squared prediction error, which describes how r fits the data

ii. The weighted variance of r, which describes the stability of the estimated transformation over time

$$\sqrt{\frac{\sum h^t (1 - (\Delta q_A^t \cdot \bar{r} \Delta q_B^t \bar{r}^{-1})^2)^2}{\sum h^t}} < \beta_{\text{err}} \quad \text{and} \quad \sqrt{\frac{\sum h^t (1 - (r^t \cdot \bar{r})^2)^2}{\sum h^t}} < \beta_{\text{var}}$$

Experiment 1: Determining the Number of Twists for a TwistIn Gesture

- Having more twists could yield a longer time series with more rotations, thereby enhancing the gesture detection accuracy.
- The user may feel more tired and uncomfortable when performing the gesture for too long.
- ➢ Minimize the number of twists required in a TwistIn gesture, while maintaining the performance at an acceptable level.
- ➢ We decided to use two twists as the minimum requirement in the TwistIn gesture.

Experiment 2: Evaluate Performance

- 12 Participants: 9 males and 3 females aged from 19 - 31 (Mean = 24.75, SD = 3.415)
- We collected 1,200 motion samples (12 participants × 2 devices × 10 times × 5 scenarios)
  - 480 positive cases (scenario 1, 2, 3, and 5)
  - 120 negative cases (scenario 4)

	Scenario	TPR	FPR	FNR	TNR
(i)	Sitting (w/ preferred hand)	0.9833	—	0.0167	—
(ii)	Sitting (w/ non-preferred hand)	0.9750	—	0.0250	—
(iii)	Standing (w/ preferred hand)	0.9833	—	0.0167	—
(vi)	Attacking (w/ preferred hand)	—	0.0583	—	0.9417
(v)	Sitting (w/ preferred hand)	0.9917	—	0.0083	—
	Overall	0.9833	0.0583	0.0167	0.9417

User Study

- A user study is conducted right after experiment 2, where the same batch of participants were asked eight questions concerning their subjective ratings on our method.
- Users enjoyed using TwistIn to log in and access devices.
- Our method is preferred over many other existing methods
- Provide an alternative method that can complement each other

Summary

- Reviewed the existing methods
- Presented a new method to access and control smart devices
- Discussed the potential applications
- Correlated the transformation between devices in addition to the frequency and magnitude
- Formulated a rotation decomposition technique to filter out the unwanted rotation
- Evaluated our method through experiments and a user study

Q&A

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