Evaluation of Minutiae Reproducibility for Seasonal Variation

Evaluation of Interoperability between Touch and Sweep Fingerprint Sensors

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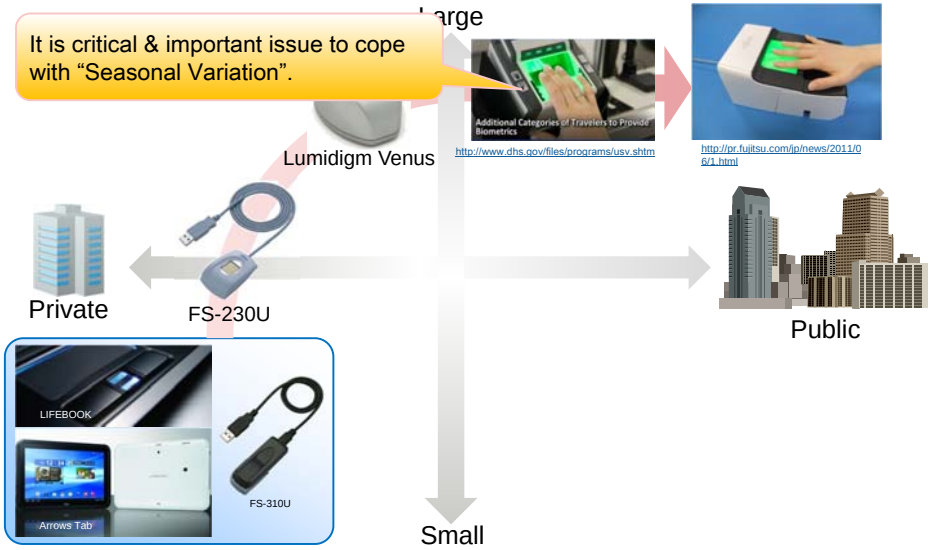
Overview

- Introduction
- Fingerprint minutiae reproducibility
  - Evaluation
    - Data collection and evaluation method
    - Result
  - Discussion
    - Consideration of the result
    - How about countermeasures?
- Interoperability between touch and sweep sensors
  - Evaluation
    - Data collection and evaluation method
    - Result
  - Discussion
    - What are the causes?
    - How about countermeasures?
- Conclusion

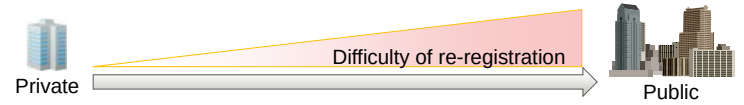
Introduction

- Fingerprint verification is widely spread in many fields



Objective

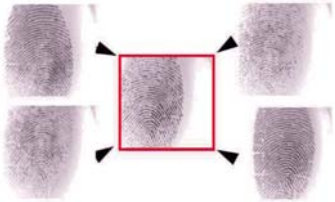
- The finger surface condition changes depending on factors such as:
  - Climate conditions
    - Temperature
    - Humidity
    - Weather
  - Physical conditions
- “Re-registration” is a very simple and effective way.
  - The bigger the scale of the system is, the more difficult it is to re-register
    - The number of users is also big / collection is difficult in National ID, etc…



What influences does seasonal variation have?

Related Work: Seasonal Variation

- Evaluation
  - Fingerprint
    - Statistical inference [Michael et al. 4]
    - Analysis of effect of fingerprint sample quality [Jieun Ryu et al. 5]
  - Iris [P. Tome-Gonzalez et al. 6]
- Solution
  - Biometric template selection and update: a case study in fingerprints [Umut et al. 3]



[Umut et al. 3]

How reproducible are the extracted minutiae?
Reproducibility means how accurately the position of minutiae is extracted when comparing extractions performed on the same day and on different days

Evaluation Method

Data Collection

- Sensors
  - Gardian F, made by CROSSMATCH
  - PalmSecure
- Period
  - 1st collection: December 2010 to March 2011
  - 2nd collection: July 2011 to October 2011
- Database information

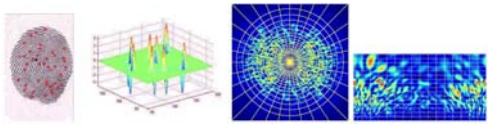
- Notes
  - Technical staff support
    - How to input their biometric information in order to mitigate the affect that the way information is input may have on the results

Evaluation Method

Method of Calculating Reproducibility

- Minutiae extraction
  - NEUROtechnology's Verifinger 6.0
- Compare minutiae
  - Most fingerprint verification engines use features such as:
    - Position of minutiae
    - Relation among minutiae
  - Spectral minutiae representation based on location (SML)

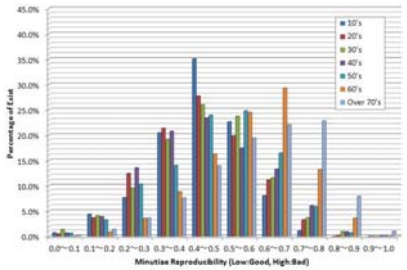
$$\left|M_L(\omega_x,\omega_y;\sigma_L^{\ 2})\right| = \exp\left(-\frac{\omega_x^{\ 2}+\omega_y^{\ 2}}{2\sigma_L^{\ -2}}\right)\sum_{i=1}^{Z}\exp(-j(\omega_x x_i+\omega_y y_i))$$



Haiyun et al., 2008.

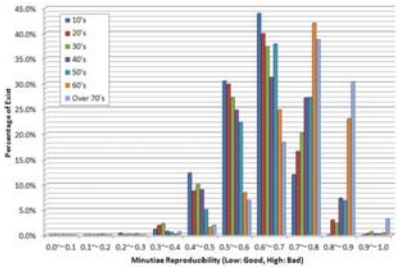
  - Score fusion algorithm
    - One captured image has three fingerprints (index, middle, and ring fingers)
    - Simple **sum** rule (Hand = Index + Middle + Ring)

Calculation Result



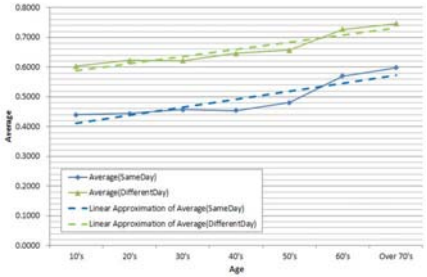
Same day

Good ⟵ ⟶ Bad



Different day

- Information
  - The number of calculated combinations is 7,725
  - The figures show a histogram of the score
- As the person's age rises…
  - Less reproducibility



Average

Are There Any Countermeasures?

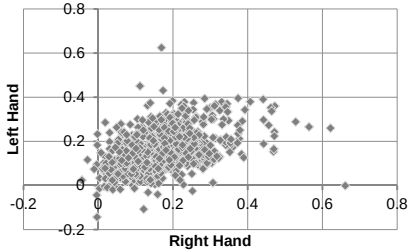
- What we learned
  - Fingerprint quality is affected by seasonal variation
  - The current quality is NOT important, BUT the difference in quality is important
  - We have to take care the way to input as well

- Countermeasures
  - Try another finger or the other hand
  - Image enhancement
  - Template update
  - Prediction methods?

Any Countermeasures?

Try the Other Hand

- Measuring one hand is difficult, so try the other hand!
  - It is a very natural countermeasure to try the other hand
- The difficulty of measuring one hand may be related to the other hand
- Correlation coefficient of the different scores obtained on the same day and on different days



Correlation coefficient
0.41 ($p<0.01$)

Even if a user changes to the other hand, it may be difficult to verify

Any Countermeasures?

Others

- Image enhancement
  - Image enhancement [1,2,7]
    - Filter base [8,9,10,11,12,13]
    - Others [14,15]
  - Evaluation [16]

We have to take care not to over-enhance

- Template update
  - System updates updated to the latest fingerprint data
  - System can keep up with changes in the finger surface

- Cannot keep up with drastic changes
- Difficult to collect fingerprints constantly (e.g., at border control)

- Prediction method
  - What kind of quality is related to seasonal variation?
    - Traditional quality measures represent the quality when captured
    - It may be impossible to predict the future input's quality:
      - Next input / Six months later
  - It may be necessary to use time-series quality

We do not have any solution so far

Minutiae Reproducibility for Seasonal Variation

Conclusion & Summary

- Result
  - Data from younger people have better reproducibility than data from older people
  - Seasonal variation influences data from people of all ages
  - As the age rises, the reproducibility gets worse
- Countermeasures
  - Try the other hand?
    - Even if a user changes to the other hand, it may be difficult to verify
  - Image enhancement
    - Enhancement may be effective, but we have to take care not to over-enhance
  - Template update
    - Updating may be effective, but it is difficult to collect images constantly
  - Predict method?
    - Future work

Introduction

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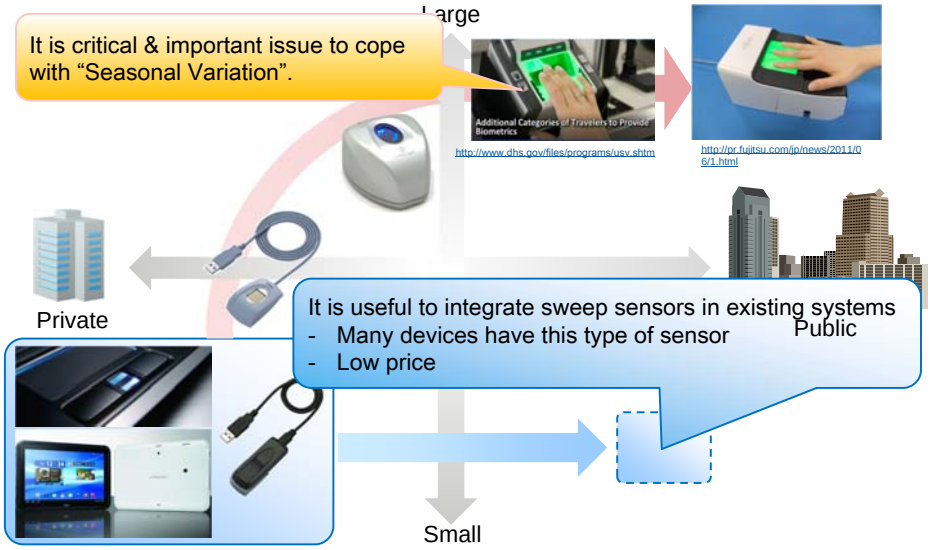
- Fingerprint verification is widely spread in many fields



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Evaluation of Interoperability between Touch and Sweep Fingerprint Sensors

Objective

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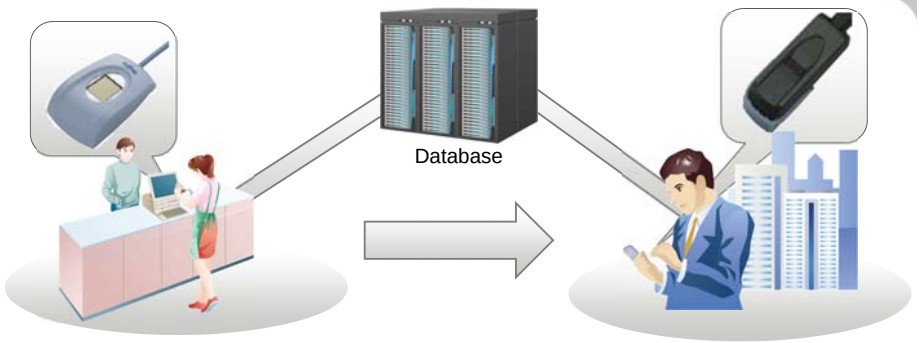

- Go from using a console and touch sensor to a mobile device and sweep sensor
  - We want to use the existing system with a sweep sensor
  - Templates in the existing system were created with a touch sensor

How about interoperability?

Related Work: Interoperability

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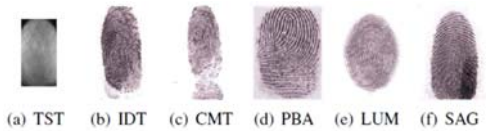
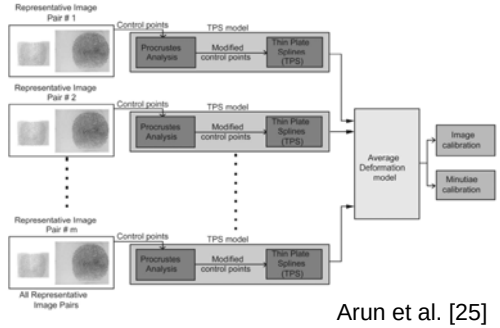
- Evaluation
  - Fingerprint [17, 18, 22]
  - Signature [21]



Davrondzhon et al. [18]

- Solution
  - Segmentation [19]
  - Feature selection [20]
  - Calibration [23, 25]
  - Fusion [24]



Arun et al. [25]

How about interoperability **between touch and sweep**?

Evaluation Method

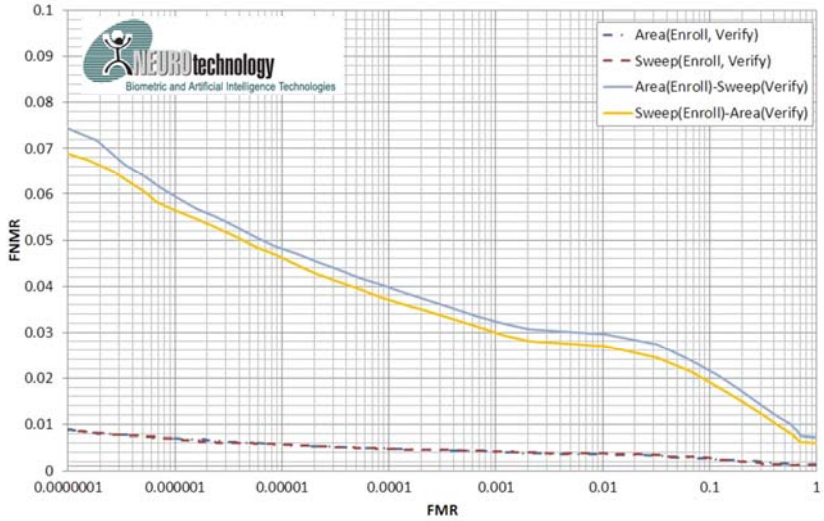
- Data collection
  - Environment
    - Sensor
      - FS-230U (by FUJITSU)
      - AES2501 (by AuthenTec)
  - Database information

	Value	Note
Number of fingers measured	6,000	There were 1,500 subjects.
Male : Female ratio	1:1	-
Age	10 to 89	-

  - Notes
    - Technological staff gave instructions and helped the subjects to input their biometric information, in order to mitigate the affect that the way information is input may have on the results
- Extractor & verification engine
  - NEURO technology's Verifinger 6.0 in order to be able to test again.

Simulation Result

DET Curve



Cross-verification result is about 7 to 8 times worse than the same sensor

Simulation Result

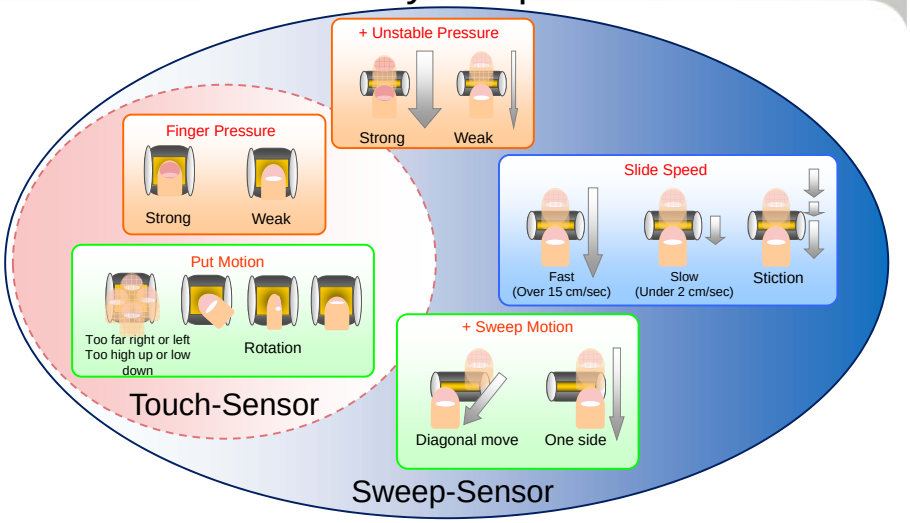
Verification Success Rate by Finger

- Rate of difficult-to-measure fingers
  - Fingers with a verification success rate of under 50%
- Rate of fingers that could not be verified
  - Fingers with a verification success rate of 0% when conducting cross-verification

(Enroll) (Verify)		(Touch) (Touch)	(Sweep) (Sweep)	(Touch) (Sweep)	(Sweep) (Touch)
FMR 0.1%	Difficult	0.3%	0.3%	3.0%	2.8%
	Impossible	-	-	1.2%	1.4%
FMR 0.01%	Difficult	0.4%	0.3%	3.6%	3.6%
	Impossible	-	-	1.9%	1.8%
FMR 0.001%	Difficult	0.5%	0.4%	4.2%	4.2%
	Impossible	-	-	2.2%	2.1%
FMR 0.0001%	Difficult	0.6%	0.5%	5.0%	5.0%
	Impossible	-	-	2.7%	2.7%

What Kind of Differences Are There?

Differences of The Way to Input



It is more difficult to **sweep** a finger than to **touch** it

Are There Any Countermeasures?

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① Deforming captured image

- There are many algorithms:
  - Fingerprint deformation [29, 27, 33]
  - Fingerprint mosaicking [28, 31, 32, 34]
  - Matching [30]

It is important to consider variation input

② Stabilizing input motion with sweep sensor

- Design an appropriate guide and apparatus
- Users have to learn the right way to swipe

Conclusion & Summary

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- Evaluation
  - We evaluated the interoperability between area and sweep sensors
  - FNMR increases 7 - 8 times, and about 1 - 3% of fingers cannot be verified
- What are the causes?
  - Difference characteristics of touch and sweep sensors
  - More variation in how people input a fingerprint than touch sensors
- Countermeasures
  - Teaching users how to input is very effective
  - Deforming fingerprints may be effective

Conclusion & Summary

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- Minutiae reproducibility for seasonal variation
  - Seasonal variation influences data from people of all ages
  - Countermeasures
    - ① Try the other hand
    - ② Image enhancement or template update (if possible)
    - ③ Predict method (future work)
- Interoperability between touch and sweep sensors
  - About 1 - 3% of fingers cannot be verified
  - Countermeasures
    - How much FAR you set
    - Teaching users how to input is very effective

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