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A Study on Fingerprint Interoperability: Image Quality and Minutiae Count Across Sensors

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Abstract

This study investigated whether nine different fingerprint sensors were interoperable. Seven of these sensors were optical and two were capacitive. 165 fingerprint images (all right index fingers) from 55 subjects were recorded. The study showed that there was a significant difference between sensors in both fingerprint image quality $F(8, 1475) = 5.05$, $p = 0.000$, and minutiae count $F(8, 1475) = 34.434$, $p = 0.000$.

Introduction

Do image quality and minutiae count differ between sensors? Does price have an impact? Is there interoperability between sensors? With regards to biometric technology, interoperability is very important. “Sensor interoperability refers to the ability of a biometric system to adapt to the raw data obtained from a variety of sensors” (Jain, 2004). Ideally, sensors from different manufacturers and differing systems should be able to communicate with each other successfully. However, it is possible that there could be a significant difference in image quality and minutiae count between different sensors, sensor technology types, manufacturers, and price ranges. This study was conducted in order to determine and evaluate the impact of differing sensors and sensor technologies on image quality and minutiae count.

Hypothesis (for image quality and minutiae count):
Null: s1=s2=s3=s4=s5=s6=s7=s8=s9
Alternative: s1≠s2≠s3≠s4≠s5≠s6≠s7≠s8≠s9

Figure 1. Depiction of All Sensors

Analysis of Variance

A one-way ANOVA was conducted to determine if image quality and minutiae count changed across sensors. The measurements of 165 subjects (55 separate right index fingers, 3 times each) were taken over a 3-day period. At $\alpha = 0.05$, there was a significant difference between sensors for fingerprint image quality $F(8, 1475) = 5.05$, $p = 0.000$, and minutiae count $F(8, 1475) = 34.434$,
$p = 0.000$. The Tukey HSD post-hoc test revealed that the Digital Persona U.are.U 4500, Eikon Touch 710, Futronic FS10, Futronic FS88H, and the Integrated Biometrics Curve exhibited the most significant differences.

TABLE 2. One-Way ANOVA Results for Image Quality

ANOVA

Quality

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3153.796	8	394.225	5.050	.000
Within Groups	115151.300	1475	78.069		
Total	118305.096	1483			

TABLE 3. One-Way ANOVA Results for Minutiae Count

ANOVA

Minutiae Count

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16355.833	8	2044.479	34.434	.000
Within Groups	87575.770	1475	59.373		
Total	103931.603	1483			

Methods

- The fingerprint images were captured over a three-day period.

TABLE 1. Data Collection Summary

Start Date	End Date	Days	Subjects
10/3/18	10/5/18	3	55

- The sensors were placed in a line and labeled from 1 to 9 (Digital Persona U.are.U 4500, Eikon Touch 510, Eikon Touch 710, Futronic FS10, Futronic FS80H, Futronic FS88, Integrated Biometrics Curve, SecuGen Hamster IV, and SecuGen Hamster Pro 20).
- All test subjects presented their right index finger.
- Each subject presented their right index to each sensor until three successful captures or five total attempts had occurred.
- Each unsuccessful attempt was recorded as a failure to acquire (FTA).
- The order of sensors was randomized in order to reduce bias effects. Each subject would start and end at the sensor after the previous subject.
- A one-way ANOVA was conducted to determine if there was a significant difference in image quality and minutiae count between fingerprint sensors.

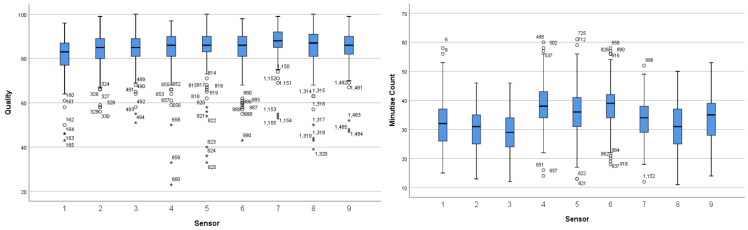

Figure 2. Boxplots of Image Quality and Minutiae Count Across Sensors

Summary and Conclusions

- The hypothesis was that there would be no statistically significant difference in image quality or minutiae count between sensors, since the environment was controlled and the sensors were similar in price ($60 - $110).
- The test results showed that there was a significant difference in image quality and minutiae count between sensors.
- The differences in platen size was likely a contributing factor in the significant difference in minutiae count between sensors.
- The one-way ANOVA revealed that at $\alpha = 0.05$, the difference in image quality ($p = 0.000$) and minutiae count ($p = 0.000$) between sensors were statistically significant.
- The Tukey HSD post-hoc analysis showed that the Digital Persona U.are.U 4500 and the Integrated Biometrics Curve appeared to exhibit the most significant differences in image quality.
- The Tukey HSD post-hoc analysis also showed that the Eikon Touch 710, Futronic FS10, Futronic FS88H, and the Integrated Biometrics Curve appeared to exhibit the most significant differences in minutiae count.

Future Directions

- For further research, investigating overall performance between sensors would be interesting.
- Some sensors took longer to capture the fingerprint. Researching whether this difference in time lapse had an impact on image quality or minutiae count would also be worth investigating.
- Including other types of fingerprint sensor technologies (in addition to optical and capacitive) and determining whether they differ in image quality or minutiae count would be good to research.
- Increasing the price range of fingerprint sensors could also provide insight into eliminating or confirming price as a significant factor.

PURDUE UNIVERSITY Discovery Park

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A Study on Fingerprint Interoperability: Sensor and Individual Performance

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Introduction

Previous research resulted in data that indicated there was indeed a significant difference in image quality and minutiae count across sensors. By conducting a one-way ANOVA test, the difference between sensors for fingerprint image quality $F(8, 1475) = 5.05$, $p = 0.000$, and minutiae count $F(8, 1475) = 34.434$, $p = 0.000$ were shown to be statistically significant. This study was intended to determine if there was a difference in fingerprint performance between sensors, as a population and on the individual level.

Results: Detection Error Trade-off and FRR performance at 0.01% FAR

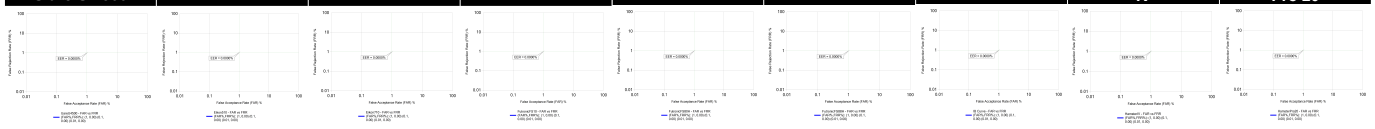
The performance of each of each sensor was computed. Each sensor performed at the same FRR (false rejection rate) for each of the respective FARs (false acceptance rates), as shown by table 1 below and by the respective DET curves below in Figure 1. Subsequently, zoo properties were examined in order to evaluate individual performance for each sensor. The results showed there was no difference in fingerprint performance across sensors. Each sensor produced identical effective error rates (EER's), as shown in the DET curves below. An ideal 0% EER means that no false acceptance or false rejections occur. It was also discovered that individuals' zoo properties changed across visits. Match score matrices (genuine and imposter) were calculated below in Tables 2 and 3. A genuine match score here, would be the score generated when one sensor was compared to itself (should be a higher score). An imposter match score here, would be the score generated when a sensor is compared to a different sensor (should be a lower score). All sensors had higher genuine and imposter match scores when compared to themselves, as expected. The SecuGen Hamster Pro 20 appeared to be the most interoperable sensor since it produced higher match scores against other sensors than any other sensor did. The Futronic FS10, Futronic FS80H, and Futronic FS88H (same manufacturer) were interoperable with each other. The IB Curve had relatively high imposter match scores compared to the other sensors, but in terms of genuine match score, did not perform well against other sensors.

TABLE 1. Error Trade-off and FRR Performance at 0.01% FAR

Digital Persona FAR 0.01%	Eikon Touch 510 FAR 0.01%	Eikon Touch 710 FAR 0.01%	Futronic FS10 FAR 0.01%	Futronic FS80H FAR 0.01%	Futronic FS88H FAR 0.01%	IB Curve FAR 0.01%	SecuGen Hamster IV FAR 0.01%	SG Hamster Pro 20 FAR 0.01%
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 1. DET Curves For Each Sensor

Digital Persona U.are.U 4500	Eikon Touch 510	Eikon Touch 710	Futronic FS10	Futronic FS80H	Futronic FS88H	IB Curve	SecuGen Hamster IV	SecuGen Hamster Pro 20



Zoo Characteristics: The Case of Individual Movement

Zoo properties associate animals with an individual's performance. "Chameleons" possess high genuine and imposter match scores, "Doves" possess high genuine scores and low imposter scores, "Phantoms" have low genuine and imposter scores, "Worms" have low genuine scores and high imposter scores, and "Normals" are all the rest, that don't fall within one of those 4 quadrants. Zoo characteristics were evaluated in order to determine whether there was a difference in individual performance despite each sensor performing identically overall (0% EER). The change in individual zoo properties across visits is shown below in Figure 2. The right index of subject #51 was tracked across each sensor. The red arrows highlight the jump or shift across sensors. Subject #51's associated animal changed ("Normal" on the Digital Persona U.are.U 4500, Eikon Touch 710, Futronic FS80H, IB Curve, and SecuGen Hamster Pro 20, was a "Worm" on the Eikon Touch 510, Futronic FS10, and SecuGen Hamster IV, and was a "Chameleon" on the Futronic FS88H. This means that an individual's performance is unstable across different sensors.

Figure 2. Individual Zoo Characteristics for Each Sensor

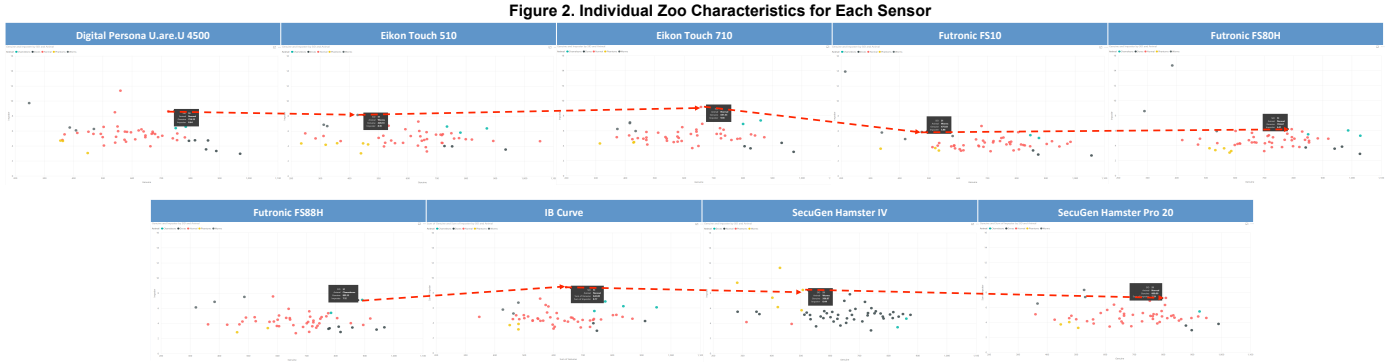


TABLE 4. Zoo Characteristics Across Sensors for Subject #51

Sensor	Genuine Score	Imposter Score	Animal
Digital Persona 4500	724.33	8.64	Normal
Eikon Touch 510	428.33	8.16	Worm
Eikon Touch 710	657.33	9.18	Normal
Futronic FS10	475.83	5.88	Worm
Futronic FS80H	793.67	6.21	Normal
Futronic FS88H	891.33	7.12	Chameleon
IB Curve	643.00	8.77	Normal
SecuGen Hamster IV	506.67	8.44	Worm
SecuGen Hamster Pro 20	809.00	7.29	Normal