Understanding the Impact of the Human-Biometric Sensor Interaction & System Design on Biometric Image Quality

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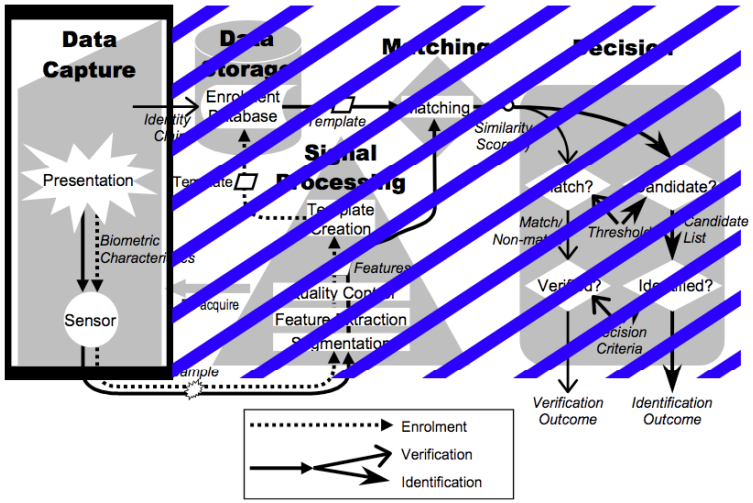
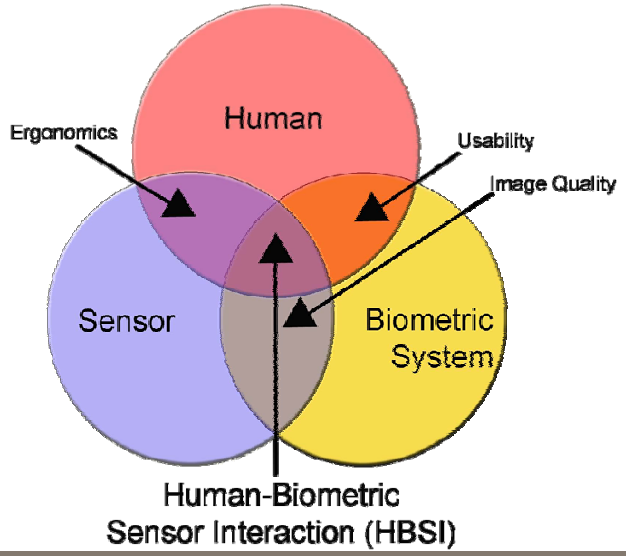
Agenda

- The HBSI
- Potential Influencing Factors for Fingerprint Recognition
- Research Motivation
- Experimental Setup
- Data Analysis
- Conclusions
- Future Work
- Questions

The Human-Biometric Sensor Interaction (HBSI)

- What impacts the performance of a biometric system?
  - Is the algorithm the cause of matching errors?
  - Is the application/environment the problem?
  - Is the design of the sensor the problem?
  - Are the users the problem?
    - Cannot do what the system/sensor is asking for.
    - Do not understand how to use the system/sensor.
    - Cannot produce repeatable images.





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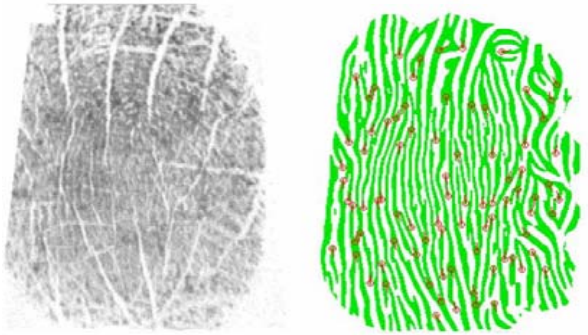
Potential Influencing Factors for Fingerprint Recognition

- Environmental factors
  - Time, illumination, distortion
- Social/Behavioral factors
  - Occupation
  - Habituation
- Physical factors
  - Age
  - Moisture
  - Contact

22 Year Old

81 Year Old



Inconsistent Contact / Dry Fingerprint Image

Good Quality Fingerprint Image

From: *ANSI Technical Report - Information technology - Biometric Performance Testing and Reporting - Part 7: Framework for Testing Methodologies for Specific Biometric Modalities*

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Fingerprints from Sickler and Elliott, 2002

Research Motivation

- The motivation for this research was to determine if the force (pressure) an individual applies to an optical fingerprint sensor can be correlated with the resulting image quality [matching].
  - Applications
    - US VISIT and RT programs
  - Positive correlation between image quality and performance
    - Effect of pressure on image quality has not been measured quantitatively

Research Motivation (continued)

- Kang et al. (2003) examined finger force and indicated force does impact quality, but did not specify quantitative measures, rather classified force as low (softly pressing), middle (normally pressing), and high (strongly pressing)

Factor			State
Environment	Temp (°C)	Below 0	Winter
		0~10	Beginning of the spring or End of the fall
		10~20	Spring or fall
		20~30	Room Temperature
		Above 30	Summer
	Humidity		0 ~ 100%
User	Pressure	Low	Softly pressing
		Middle	Normally pressing
		High	Strongly pressing
	Skin Humidity	Low	0 ~ 35%
		Middle	36 ~ 70%
		High	71 ~ 100%

Purdue's Research

Experiment 1	Experiment 2
3N	3N
9N	5N
15N	7N
21N	9N
	11N

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Experimental Setup

- Equipment
  - CrossMatch Verifier™ 300 LC optical fingerprint device
  - Vernier Dual-Range Force Sensor
    - Range of ±50N and error of ±0.05N.
- Participants
  - 18-25 years old, mostly male
  - Right index finger**
- Experiments
  - One
    - 4 Force Levels → 3, 9, 15, 21 newtons
    - Capture tolerance → f ± 0.50N
  - Two
    - 5 Force Levels → 3, 5, 7, 9, 11 newtons
    - Capture tolerance → f ± 0.25N

= 3.95N on the Vernier Dual-Range Sensor

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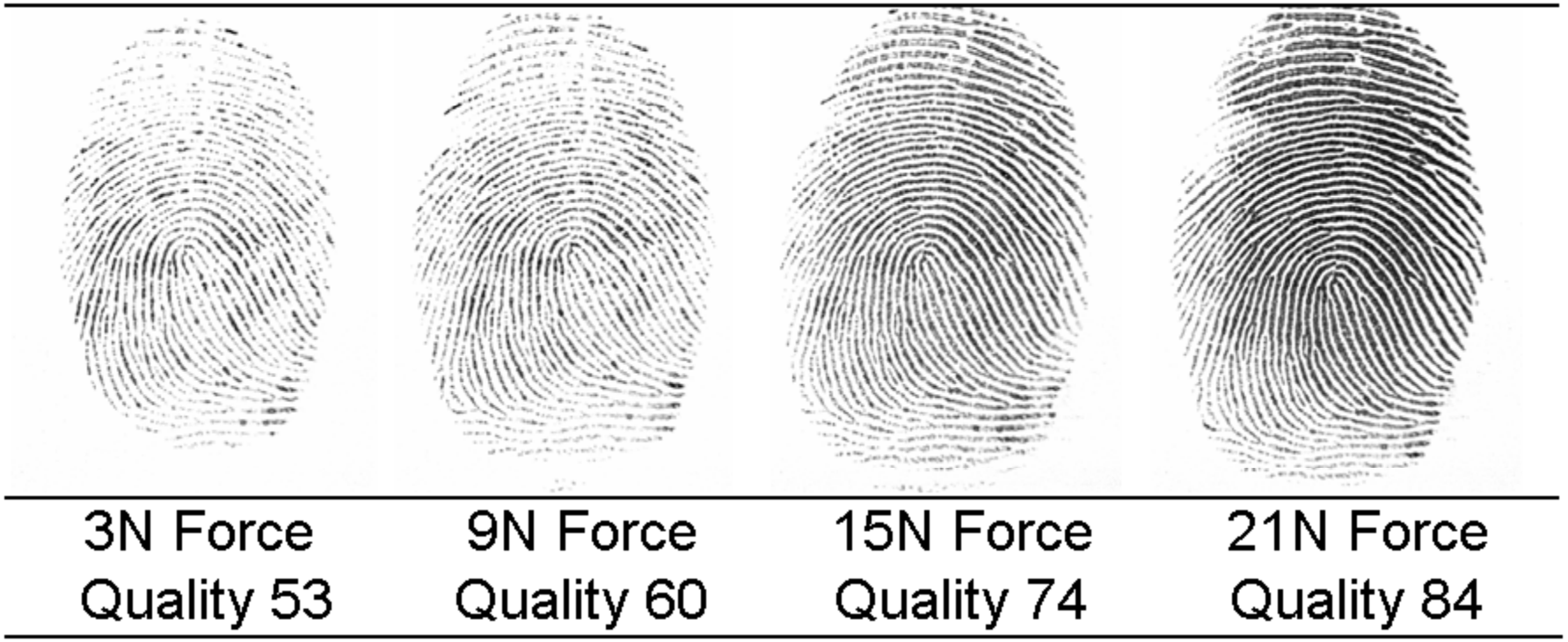
Experiment Analysis Protocol

- Between Experiment Analysis
  - Overlapping force levels across experiments
- Within Experiment Analysis
  - Commercially available image quality software
    - Utility Image quality score
    - Number of detected minutiae
  - User Input

Experiment 1 Force levels and sample images

- 29 participants
- Testing in October 2006



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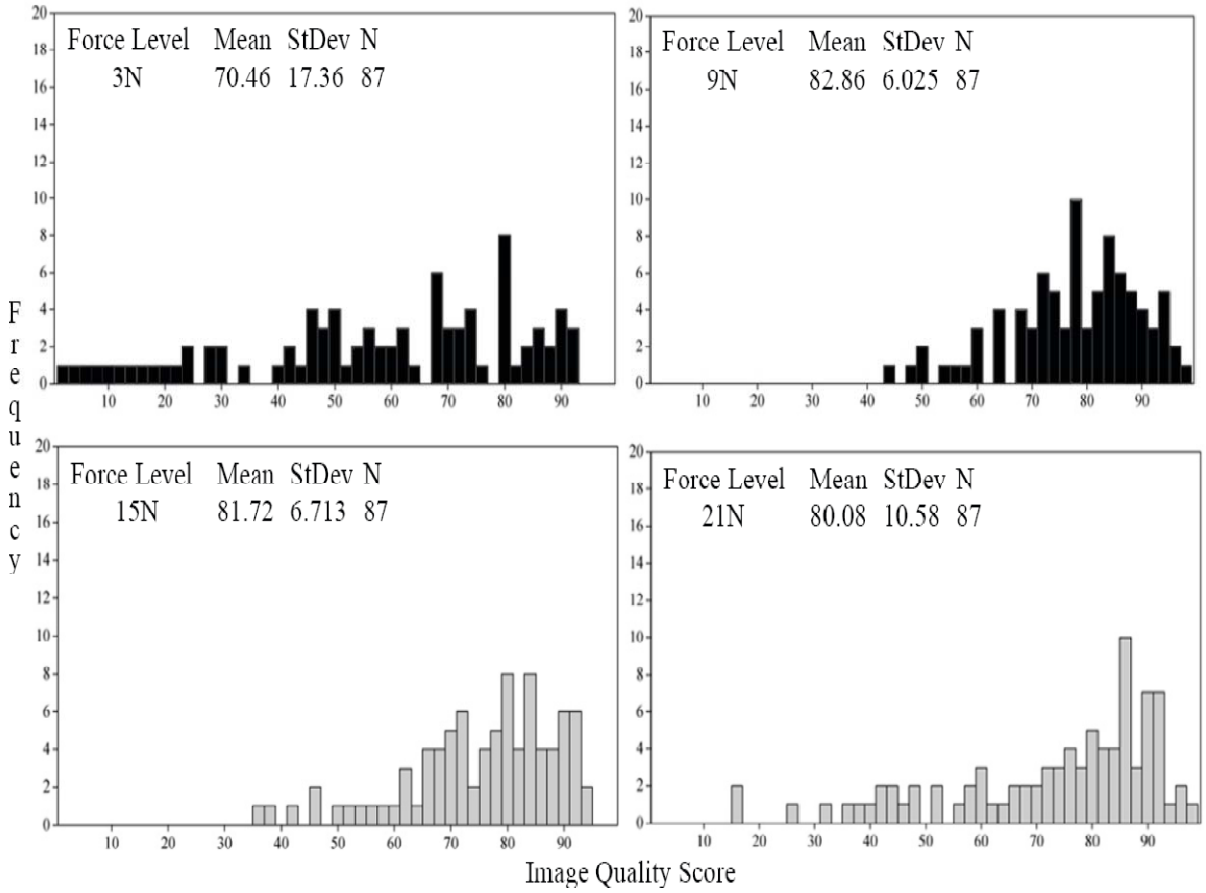
Experiment 1 Quality score results

- Analysis of Variance statistical test
  - Response Variable – image quality score
  - Factor – applied force on the sensor
  - $F(.95, 3, 344) = 22.56$, $p = 0.000$
- Tukey Pairwise Comparison
  - Level 1 different than other 3



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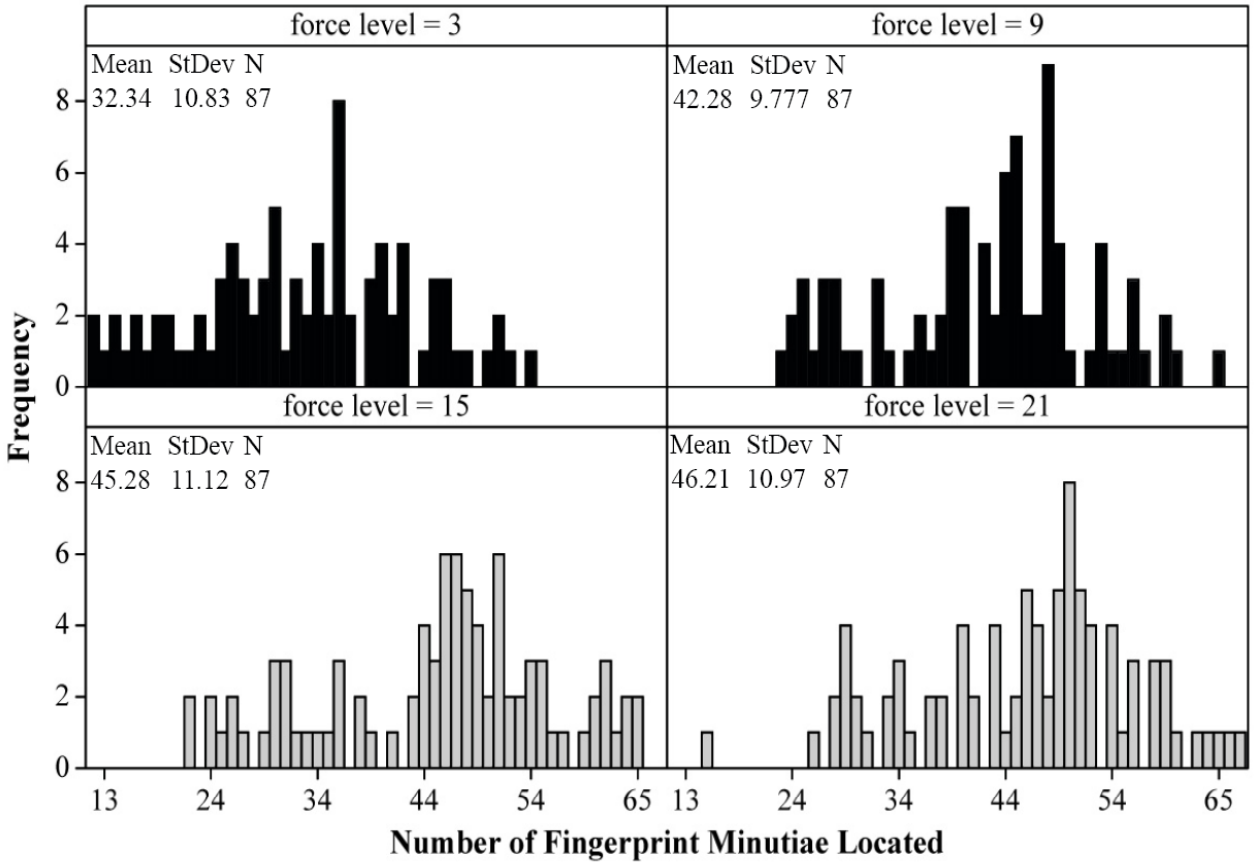
Experiment 1 Results – Number of Detected Minutiae

- Analysis of Variance statistical test
  - Response Variable – Number of detected minutiae
  - Factor – applied force on the sensor
  - $F(.95, 3, 344) = 30.69$, $p = 0.000$
- Tukey Pairwise Comparison
  - Level 1 different than other 3



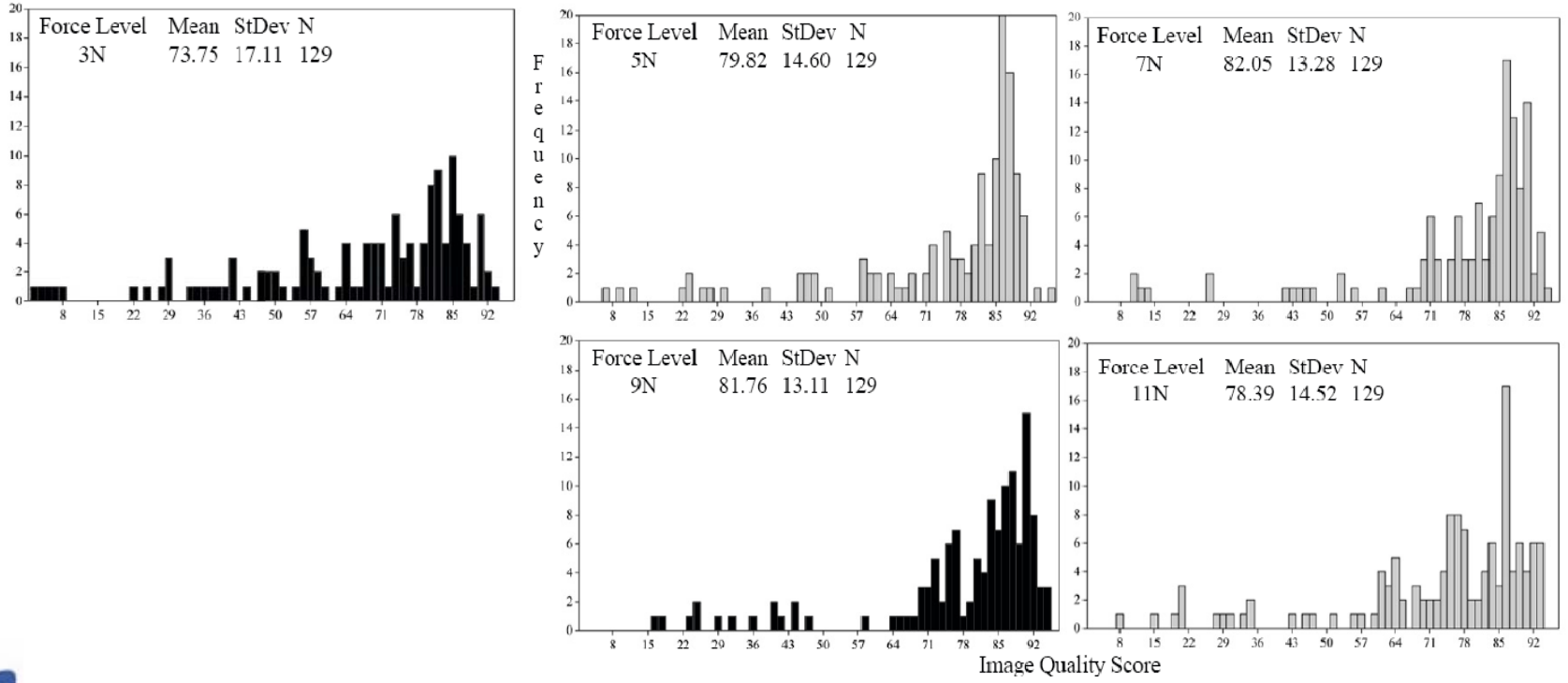
Experiment 2 Force levels and sample images

- 43 participants
- Testing in January 2007

3N Force Quality 3	5N Force Quality 87	7N Force Quality 91	9N Force Quality 88	11N Force Quality 90

Experiment 2 - Quality score results

- Analysis of Variance statistical test
  - Response Variable – image quality score
  - Factor – applied force on the sensor
  - $F(.95, 4, 640) = 6.88$, $p = 0.000$
- Tukey Pairwise Comparison
  - Level 1 different than other 4



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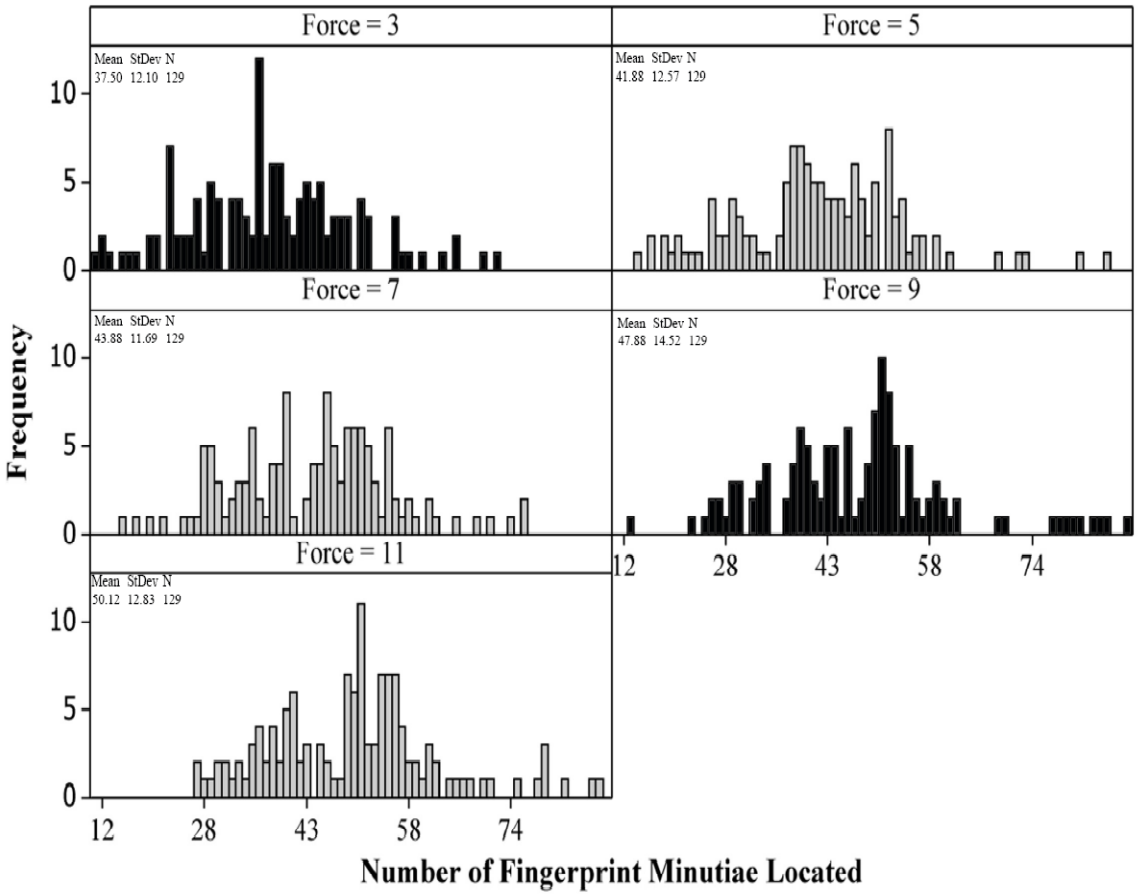
Experiment 2 Results - Minutiae

- Analysis of Variance statistical test
  - Response Variable – Number of detected minutiae
  - Factor – applied force on the sensor
- *F*(.95, 4, 640) = 19.52, *p* = 0.000



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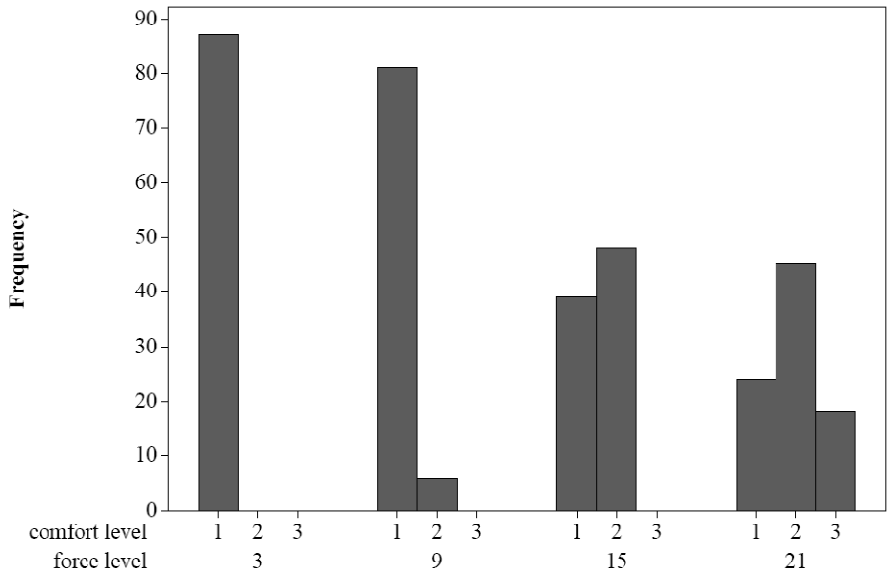
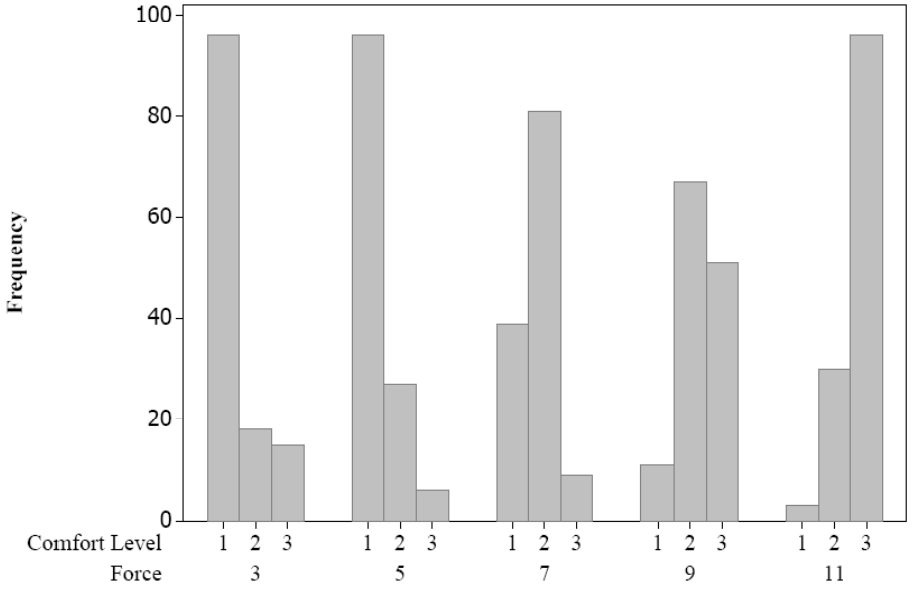
User Input Results

- Self reported after completion of each level

Experiment 1 vs. Experiment 2





☺=1 😐=2 ☹=3

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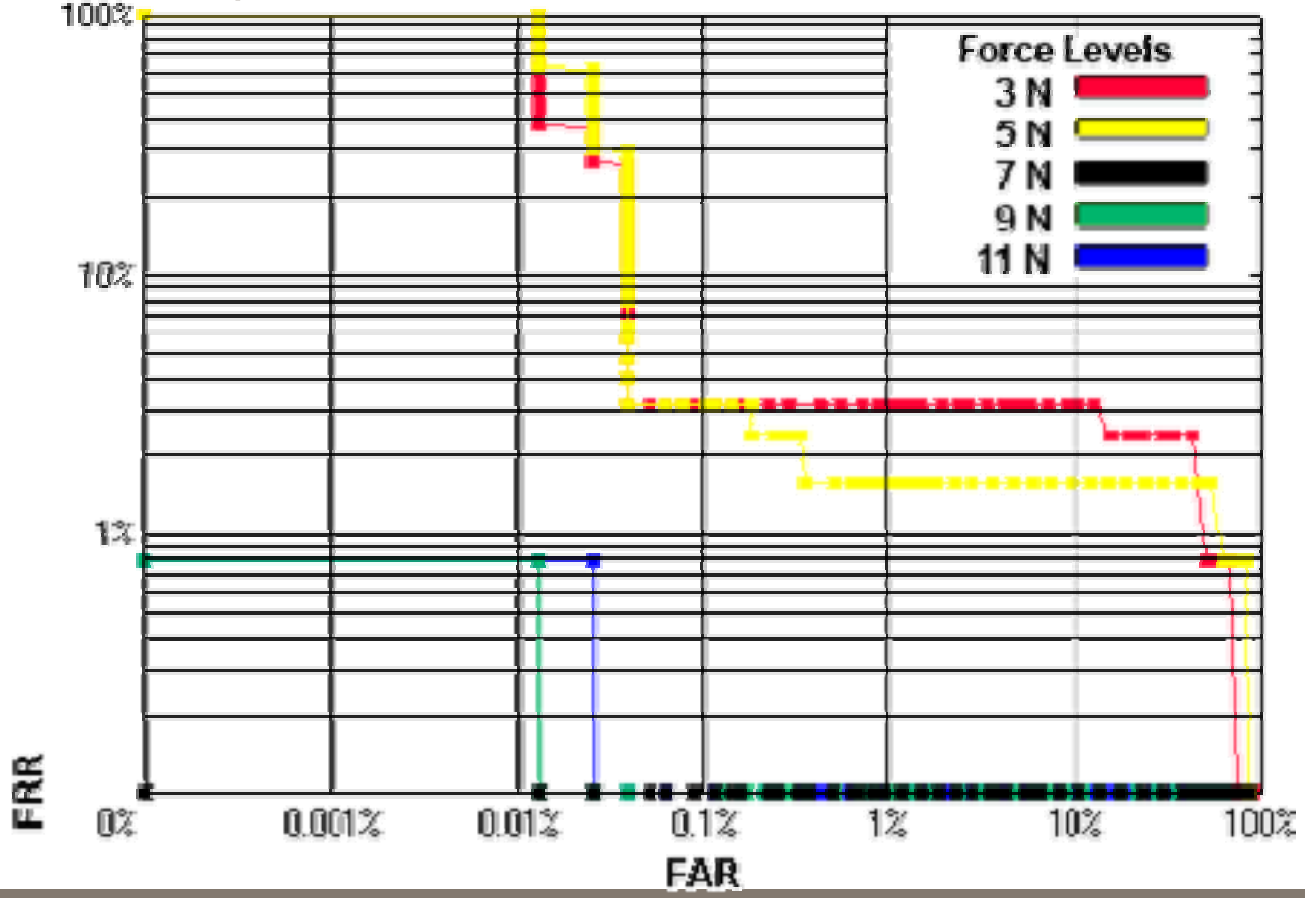
Experiment 2: Force and Matching Performance

- Neurotechnologija Verifinger 4.2 Algorithm
- 126 x 126 comparisons at each force level



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Conclusion

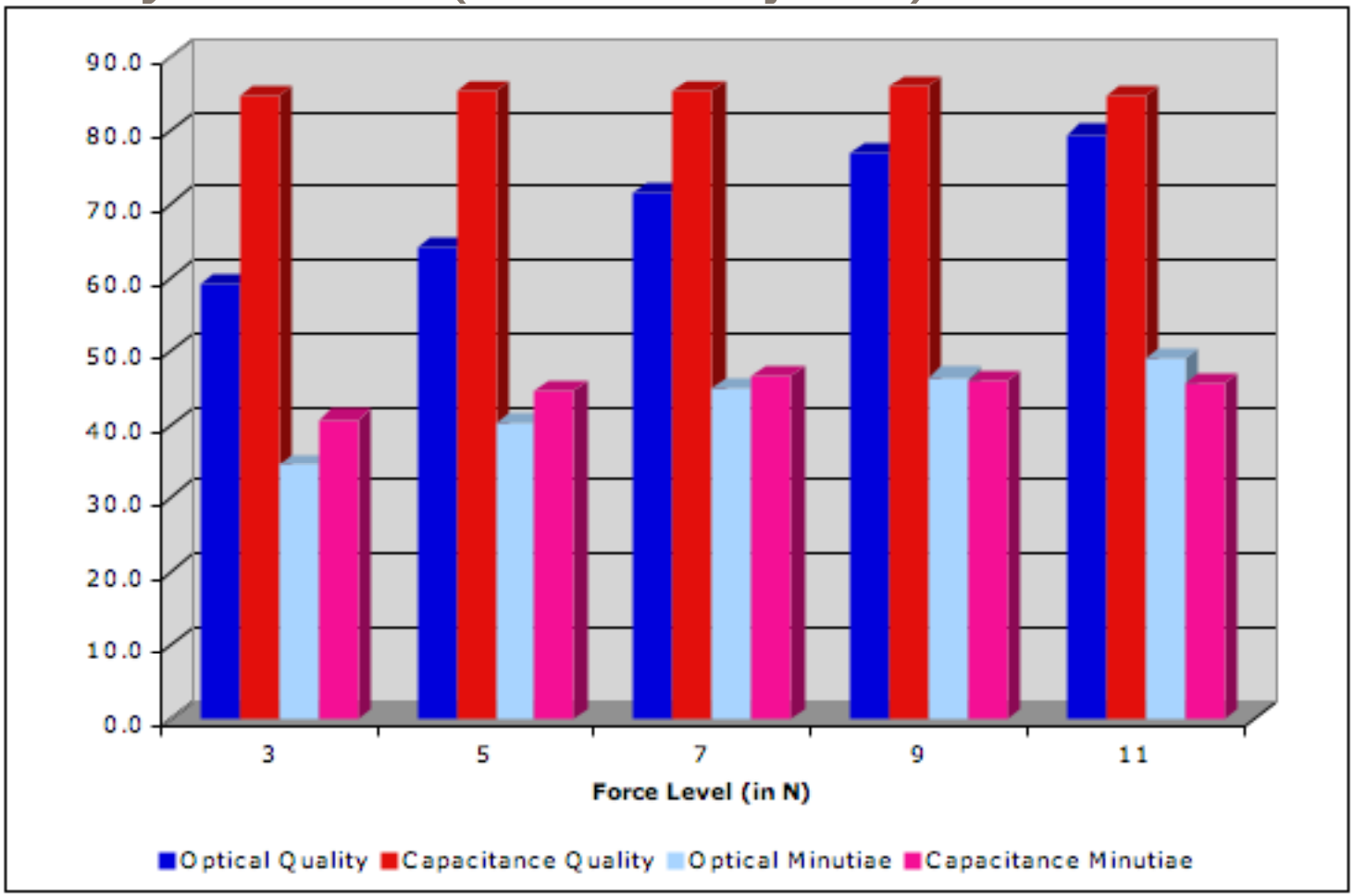
- Image quality scores
  - Significantly increased between the 3N and 5N-7N force level
  - Regressed with more than 11N of force
- Minimal benefit of applying more than 9N of force, as the quality scores did not improve by much
  - Deemed as neutral or unsatisfactory by the users.
- Matching performance best at 7N of force

Future Work

- Do other fingerprint sensor technologies behave similarly to the experiments conducted with optical technologies?
  - 2 Sensors
    - CrossMatch VerifierTM 300 LC Optical device
    - UPEK TouchChip FIPS 201 Capacitance sensor
  - Preliminary Data
    - 8 Subjects
    - 3 images at 3, 5, 7, 9, & 11 newtons of applied force
    - Right Index Finger

Future Work (continued)

- Preliminary Results (8 test subjects)



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Additional Resources & Readings

Kukula, E., Elliott, S., Kim, H., and San Martin, C. (May 17-20, 2007). *The Impact of Fingerprint Force on Image Quality and the Detection of Minutiae.* Proceedings of the 2007 IEEE International Conference on Electro Information Technology (EIT). Chicago, IL. pp. 482-487.

K. Kang, B. Lee, H. Kim, D. Shin, and J. Kim. (2003). *A Study on Performance Evaluation of Fingerprint Sensors*. in Audio- and Video-Based Biometric Person Authentication, Lecture Notes in Computer Science, G. Goos, J. Hartmanis, and J. van Leeuwen, Eds. Berlin / Heidelberg: Springer 2003, pp. 574-583.

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Questions?

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