The NIST Fingerprint Image Compression Study

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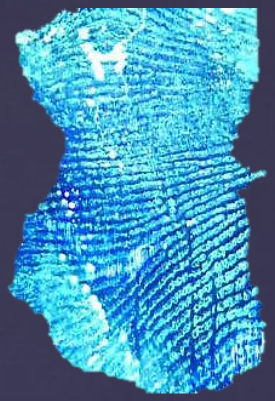


Key team activities:

- Simulation modeling
- Standards & conformance work
- Algorithm R&D

Primary focus for the past year has been the ***Fingerprint Compression Study***, which ties together all the above competencies.

Before we talk about the study, What is compression? →

Background info... What is **compression**?

- A method of encoding information in a way that it uses fewer bits than the original representation, and thereby becomes smaller in size.

- Two approaches to compression:
  1. Lossless
  2. Lossy

Examples of each... →

Lossless Compression:
Compressed image is as good as the original… Nothing is lost.

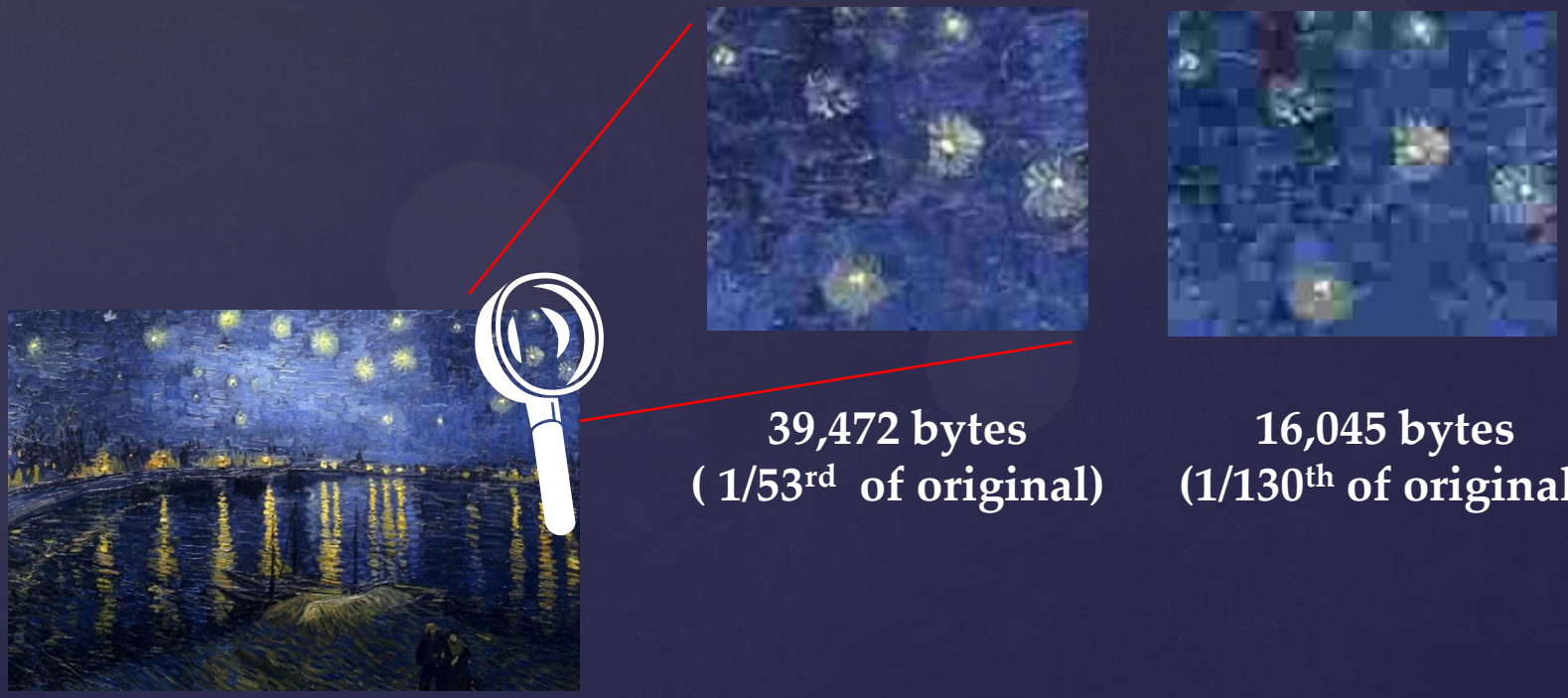
Original uncompressed size: 2,095,104 bytes
Compressed size: 251,171 bytes (1/8th of original)

This is an example of **lossless** compression.

What if we're willing to lose a bit of fidelity, to gain even more compression? →

Lossy compression (magnified):

We can specify how much effective compression we're willing to gain at the price of how much information we're willing to lose. The price is fidelity loss.



39,472 bytes
(1/53rd of original)

16,045 bytes
(1/130th of original)

Same is true with fingerprints →

Example of fingerprints with lossy compression:

Lossless

1/100th of original (100:1)

1/200th of original (200:1)

1/400th of original (400:1)

1/800th of original (800:1)

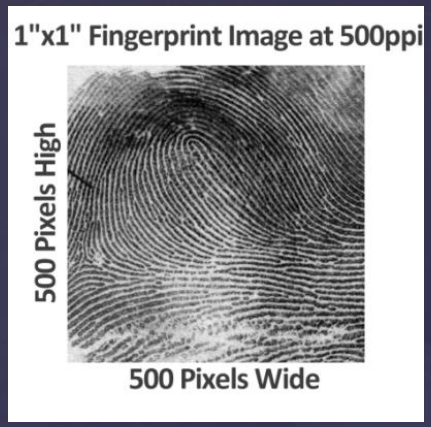
So why lossy compression for fingerprints? →

So why go Lossy?

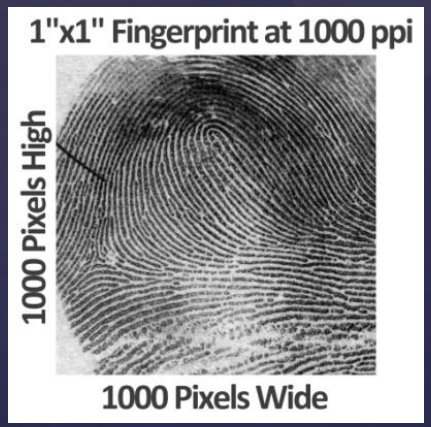
Lossy compression will be a critical part of modern biometric systems processes to help make the most out of our existing resources, as well as keep up with an ever increase load.

Speaking of ever increasing load... →

Changes coming…



- Currently, bulk of legacy biometric systems operation is based on 500ppi fingerprint processing with lossy compression.



- NGI as well as other modern systems will support higher resolution (1000ppi).

1000ppi will quadruple the load →

Twice as much data in each direction means four times the data total.

1	**2**
3	4

1	**2**	**3**	**4**
5	6	7	8
9	10	11	12
13	14	15	16

This quadrupling of data reinforces why we will have to continue to rely on lossy compression to keep data footprint managable.

Not all bad news… 1000ppi yields much better images? →

Actual Specimen Images: 500ppi vs. 1000ppi

500ppi

1000ppi

So how do we get there? →

So how do we get there?

Lossless is easy: You don't do anything special, the algorithm ensures what goes in will be the same as what comes out later.

Lossy is tougher: You need a 'recipe' to provide your algorithm on how much its allowed to filter out when compressing your data.

For 500ppi (legacy) the IAI conducted a study in 1994 to establish the basis of what became the recipe on lossy fingerprint compression using the WSQ algorithm.

In the NIST compression study we tried to replicate the IAI study at 1000ppi .

What happened in the IAI study?→

The 1994 IAI Study in a nutshell:

- 100 fingerprints cards selected from Illinois State Police
- 4 rolled prints selected from each card yielding 400 prints. Selection was representative by pattern class (65%L/29%W/6%A), 86%M / %14F
- Each of the 400 prints compressed randomly at 5:1, 10:1, 15:1 or 20:1... Yielding about 100 prints at each of the four ratios
- Two professional examiners independently compared the 400 compressed images to the original, and rated the degradation (1-3 scale)
- If the two examiners were deadlocked, a third examiner would break the deadlock

Compression Level	Result Code			Total
	1 : no noticeable degradation	2: degradation of non-Galton	3: degradation of Galton details	
5:1	202	0	0	202
10:1	200	0	0	200
15:1	**195**	**7 (3.4%)**	**0**	**202**
20:1	37	159	0	196
Total	634	166	0	800

Goals of the NIST study... →

The strategic goals of the NIST compression study:

- Replicate the best practices of the IAI study, for 1000ppi this time, and improve where we can.
- Large scale test of MITRE guidance (MTR-04B0000022)
- Test wider range of compression ratios (from 2:1 to 38:1) than the original IAI study
- Utilize more image sets, test wider range of impression types. rolled, flat, slaps, both card scan and live scan to more

Details of the study... →

2010 Compression Study Details:

- Utilized 3 examiners at the same time
- Utilized 84000 image pairs
- Each pair was guaranteed to be observed by exactly 3 unique examiners.
- Examiners were shown an image pair, one lossy-compressed and one original.
- First, examiners asked to make an ident decision on the pair of images.
- Next, examiners asked for a subjective evaluation of compression fidelity loss between the two images.
- Examiners were not told which image was compressed.
- Examiners were provided equal and identical calibrated stations.

Investigative goals... →

The NIST compression study is very large in scope so it has been partitioned into several reports.

First is NISTIR-7778 which is the topic of this presentation, was released on May 25, 2011.

Four investigative goals for NISTIR-7778:

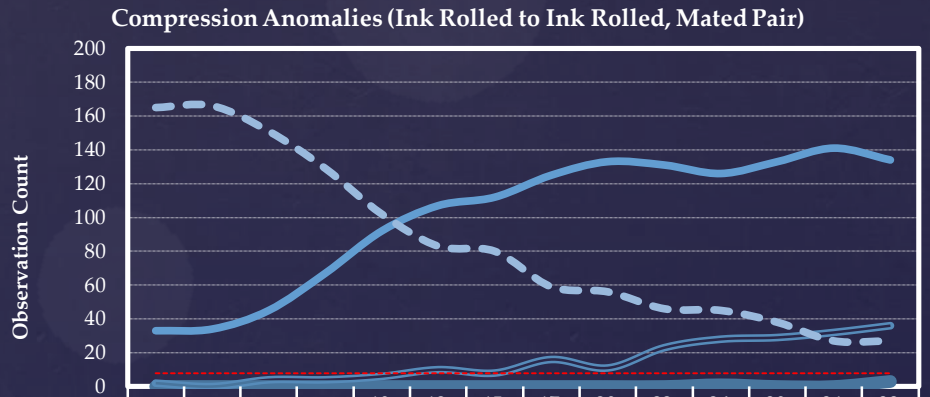
1: Validate 15:1 target compression ratio
2: Examine image degradation relative to compression ratio
3: Assess impact of compression on identification error rates
4: Examine compression anomalies relative to impression type

So what did we find? Results... →

Investigative Goal 1: Validate 15:1 target compression ratio

Finding: Study shows that 15:1 compression of rolled-to-rolled ink card scan imagery at 1000ppi falls just a bit outside of the quality criteria the IAI used to establish guidance at 500ppi (4% mark).

Going Forward: **15:1 is a viable compression goal, but a lower compression ratio may offer benefits. A final** recommendation will be made after other segments of compression study complete.

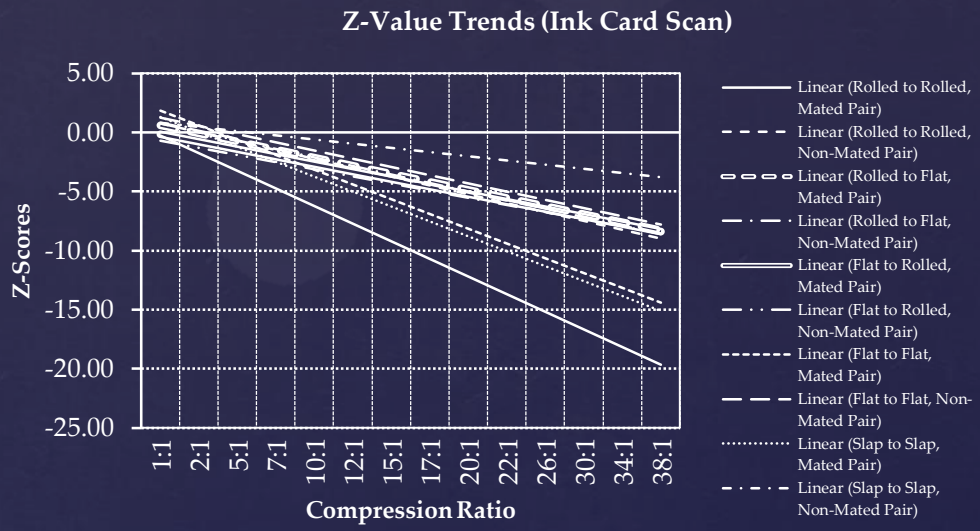


	1:1	2:1	5:1	7:1	10:1	12:1	15:1	17:1	20:1	22:1	26:1	30:1	34:1	38:1
Level 2 and 3 detail degradation	0	0	0	0	0	0	0	0	0	0	1	0	0	3
Level 3 detail degradation	2	0	4	4	6	10	8	16	11	23	28	29	32	36
Some benign degradation	33	34	45	67	92	107	112	125	133	131	126	133	141	134
No visible degradation	165	166	151	129	102	83	80	59	56	46	45	38	27	27
IAI Cutoff (3.4%, adjusted)	8	8	8	8	8	8	8	8	8	8	8	8	8	8

<u>Investigative Goal 2:</u> Examine image degradation trends relative to increasingly higher compression ratios

<u>Finding:</u> Examination of standardized scores demonstrates that perceived image quality trends negatively with increased compression across all image types. Also show that certain impression types degrade more aggressively are than others.

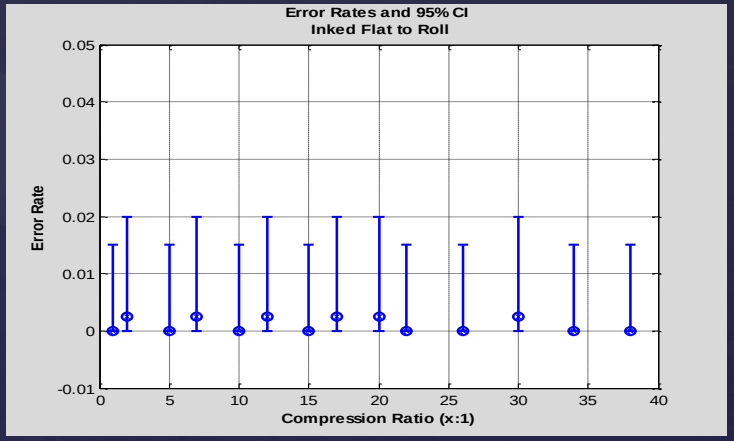
<u>Going forward:</u> Possible exploration of dynamic compression strategy based on image type.



<u>Investigative Goal 3:</u> Assess impact of compression on identification error rates

<u>Finding:</u> Analysis of the observed error rates demonstrates that while expert fingerprint examiners can identify image degradation and feature loss at relatively low compression rates, their ability to make an identification does **<u>not</u>** appear to be measurably impacted.

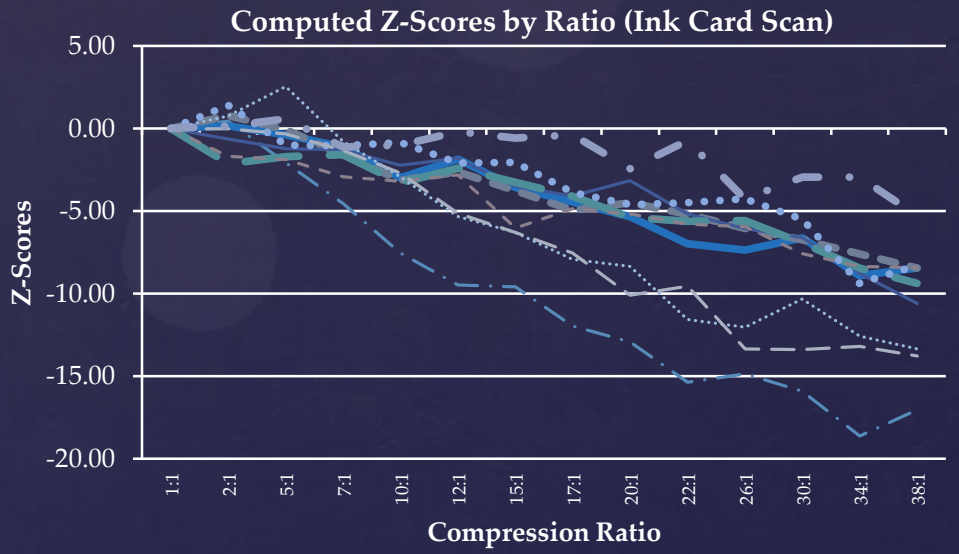
<u>Going forward:</u> This was welcome news. The dirty-windshield analogy lives, even at 38:1!



Investigative Goal 4: **Examine compression anomalies relative to impression type**

Finding: Reinforced some impression types being impacted more than others… Also shows (for the first time?) statistical proof that a little compression can actually help "improve" the image.

Going forward: This Improvement effect is currently being examined further in the scope of latent image analysis.



Where are we on the big NIST Compression Study road map?

(Done) NISTIR 7778- Effects of JPEG 2000 Image Compression on 1000ppi Fingerprint Imagery (Lossy compression)

(En Route) NISTIR 7779- A Survey of Lossless Compression Algorithms for 1000ppi Fingerprint Imagery Data.

(Analysis Started) NISTIR 7780- Effects of JPEG 2000 Image Compression on Latent 1000ppi Fingerprint Imagery

(Analysis Started) NISTIR 7781: Spectral and PSNR Comparison of WSQ and JPEG 2000 Compression of 500ppi Fingerprint Imagery.

(Data collected) NISTIR 7782: Effects of JPEG 2000 Image Compression for 1000ppi Fingerprint Imagery on Legacy 500ppi Processing

(Started) Special Publication 500-289: Compression Guidance for Fingerprint Imagery at 1000ppi. This is a critical item which will bring everything together

Stay tuned… http://fingerprint.nist.gov

Q & A?

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Supplemental Slide

Judgment Criteria for IAI 1994 Study:

1. No noticeable reduction in image quality
2. Slight reduction in image quality which may interfere with an identification based on poroscopy, ridgeology, or other non-Galton details.
3. Noticeable reduction in image quality which may interfere with an identification based on the Galton details.

Judgment Criteria for 2010 Compression Study:

1. No apparent image quality degradation and the quality of Level II(2) and Level III(3) detail in either image should not cause any difficulty in reaching a conclusive decision of identification or exclusion.
2. A noticeable degradation in the quality of Level II(2) or Level III(3) detail in either image, but not enough to have a negative impact on reaching a conclusive decision of identification or exclusion, though the amount of time to reach a decision may increase.
3. Level III(3) detail quality diminished in either image to the extent that a Level III(3) identification is questionable or not possible, and/or is significantly more difficult.
4. Level II(2) detail quality diminished in either image to the extent that a Level II(2) identification becomes questionable or not possible, and/or is significantly more difficult.

2010 Compression Study Test Tool (aka "FIXT") UI