Metrics for Enhancement of Latent Fingerprint Images

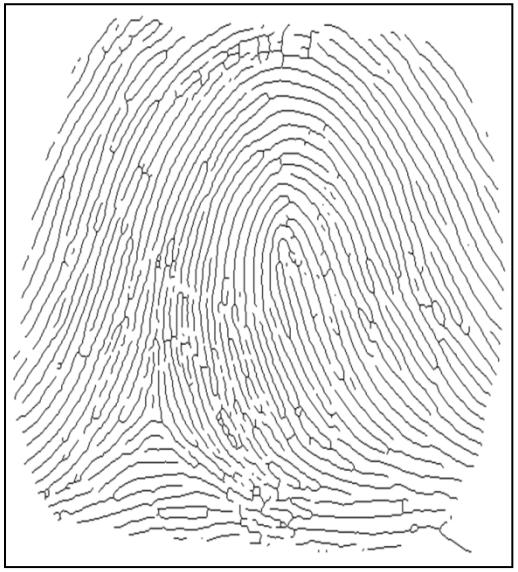
Mary Theofanos
Andrew Dienstfrey

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

The Value of Image Enhancements

Image from crime scene

Image after enhancement.



What AFIS sees

Goals

- To characterize the effect of image processing and enhancement that occur between obtaining the latent fingerprint image from the crime scene and identifying features of the print for data matching against the database

- Adoption of uniform and enforceable best practices

Analysis of Latent Fingerprint Image Enhancement

What is the image enhancement decision making process?

- Image enhancement workflow

What are these enhancements? What do they look like?

- New database of triples: latent images, enhanced images, metadata

What are these enhancements really? Are they reproducible?

- Mine the metadata for most common enhancement commands
- Universal (i.e. mathematical) description the underlying algorithm

Where are the metrics?

- Modifications to SIVV to customize for latent image characteristics
- Investigate application independent image metrics

2012-05-25T22:07:53-05:00 File NIST Study Images 057 - V700.tif opened
Open C:\Users\matt\Desktop\2012 NIST Image Study\NIST Image Scans - Both copies\NIST Study Images 057 - V700.tif
Rectangular Marquee
Set Selection To: rectangle
Top: 0.347 inches
Left: 0.124 inches
Bottom: 1.477 inches
Right: 1.167 inches

Crop
Crop
2012-05-25T22:08:06-05:00 File C:\Users\matt\Desktop\2012 NIST Image Study\NIST Image Scans - Both copies\NIST Study Images 057 - V700.tif saved
2012-10-26T08:32:32-05:00 File NIST Study Images 057 - V700.tif opened
Open C:\Users\dlwitzke.FORAY\Desktop\NIST Developed\NIST Study Images 057 - V700.tif

Select blue channel
Select RGB channel
Select blue channel
Extract Channel
Convert Mode To: grayscale mode

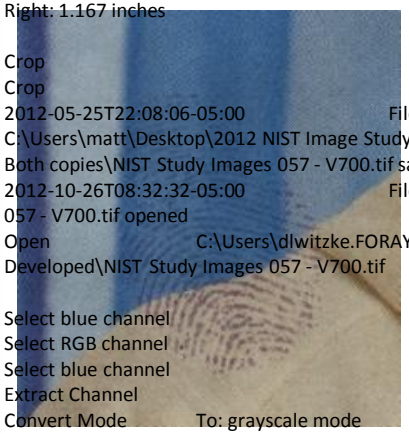
Chromatic FFT
Filter Using: “Chromatic FFT…”

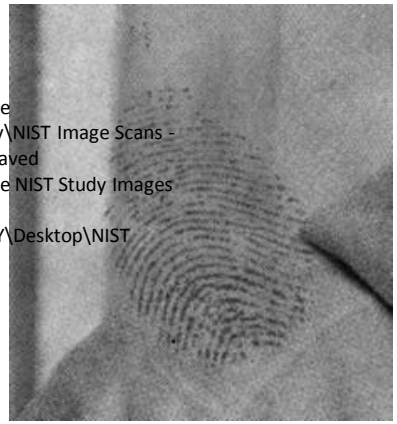
Shadows/Highlights
Shadow/Highlight Shadow: Parameters
Amount: 35%
Tone Width: 50%
Radius: 30
Highlight: Parameters
Amount: 68%
Tone Width: 67%
Radius: 30
Black Clip: 0.01
White Clip: 0.01
Contrast: 36
Brightness: -24

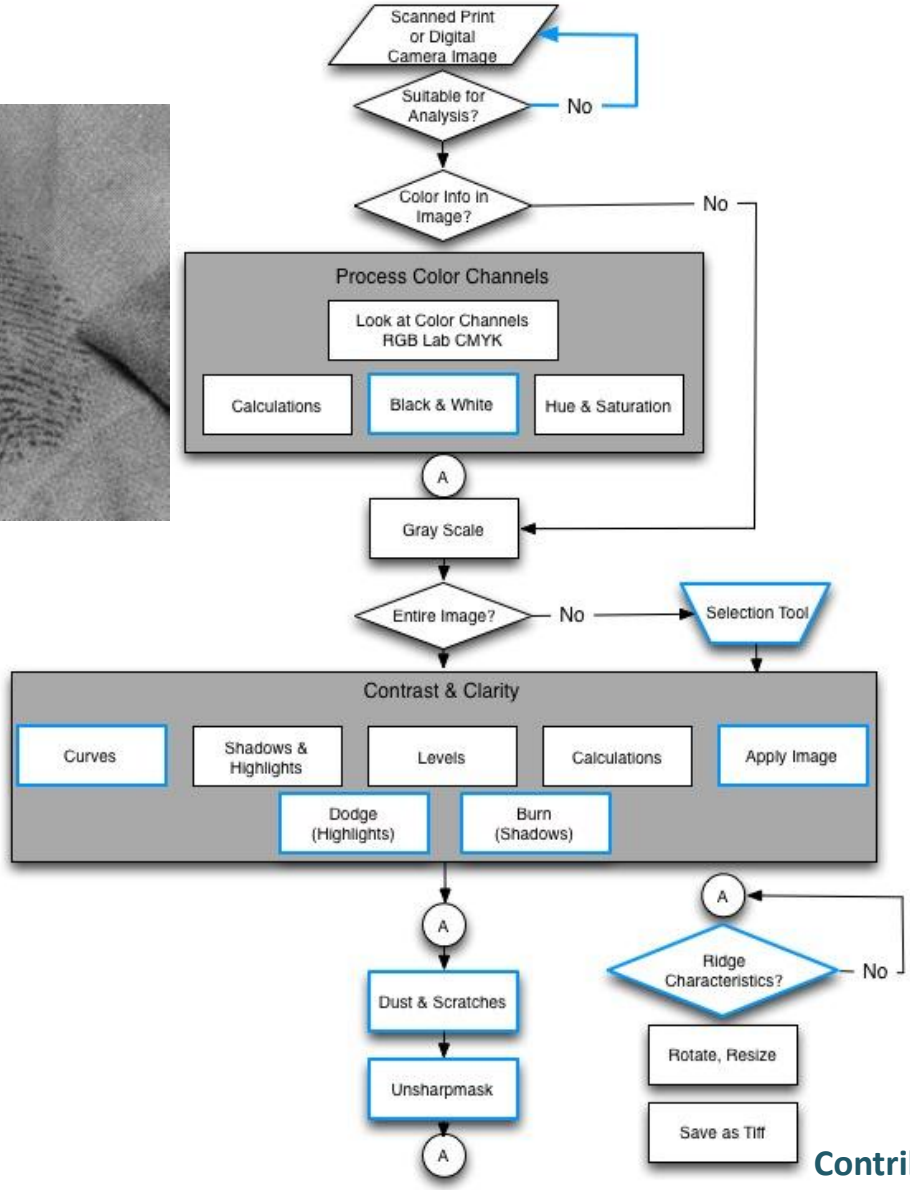
Apply Image
Apply Image With: calculation
Source: current channel
Calculation: overlay
With Preserve Transparency

Apply Image
Apply Image With: calculation
Source: current channel
Calculation: screen

There is a consistent process





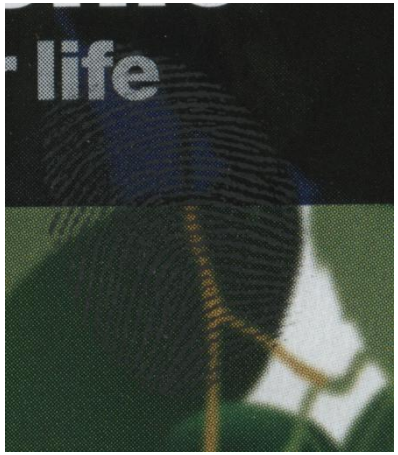


Contribution of:

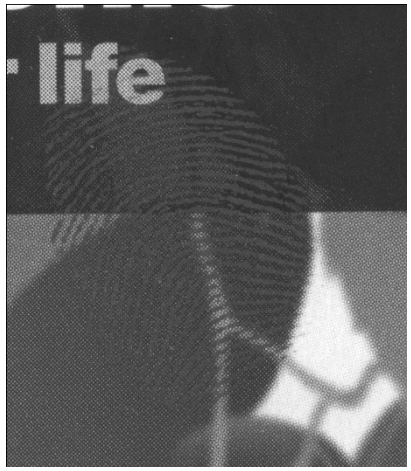
- Brian Stanton— NIST

The process needs a trained examiner

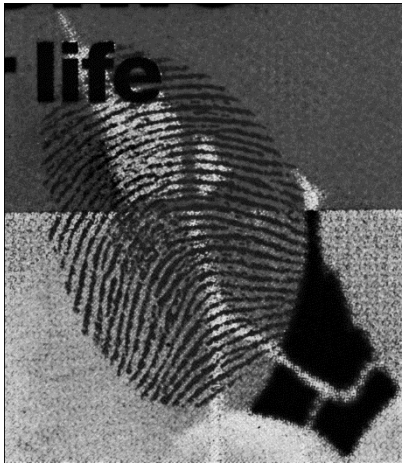
- Contrast and Consistency are critical across image
- Clarity is crucial
- Decision points– must have more than sufficient number of ridge characteristics for individualization
- Enough information for confidence
- All about tracing points to get from one place to another



1 Address Color



2 Address Contrast



3 Fine Tune Image

Some Actions Create Artifacts

1. Resampling
2. Interpolation
3. Rotation

4. Levels
5. Curves
6. Dodge and Burn

Outline

What is the image enhancement decision making process?

- Image enhancement workflow

What are these enhancements? What do they look like?

- New database of triples: latent images, enhanced images, metadata

What are these enhancements really? Are they reproducible?

- Mine the metadata for most common enhancement commands
- Universal (i.e. mathematical) description the underlying algorithm

Where are the metrics?

- Modifications to SIVV to customize for latent image characteristics
- Investigate application independent image metrics

What are Latent Fingerprint Enhancements?

New database of > 150 latent fingerprint images

- Different fingerprint development techniques
  - —Bichromatic Powder
  - —Black Ink
  - —Silver Mag Powder
  - —Bichromatic Mag Powder
  - —Ninhydrin
  - —White Powder
- Each image has enhanced counterpart
- PS utility logs metadata describing enhancement process

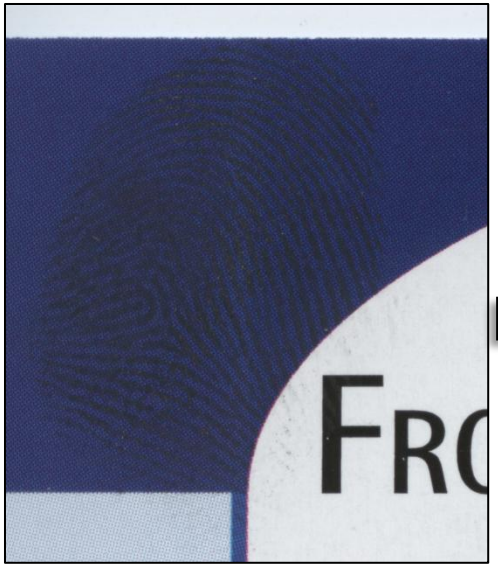
Create a controlled workspace.

Let's have a look…

Enhancement Triple: Original, Enhancement, Metadata

Bi-Chromatic Mag Powder

Original



Enhanced

Metadata

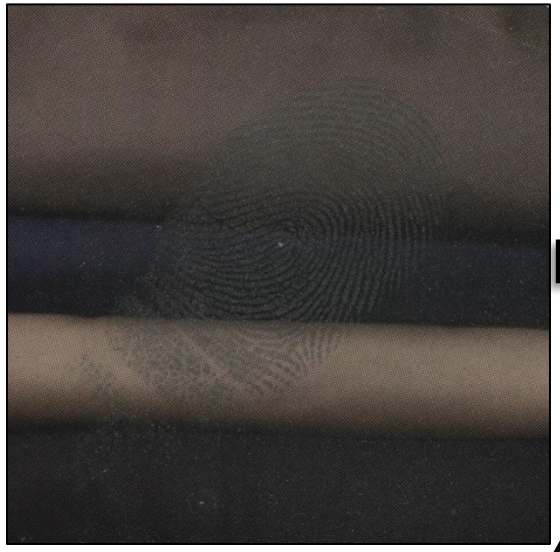
2012-05-26T16:13:11-05:00
File NIST Study Images 158 - V700.tif opened

Black & White
Black & White Preset Kind: Custom
red: -12
yellow: -68
green: 300
Invert
Burn

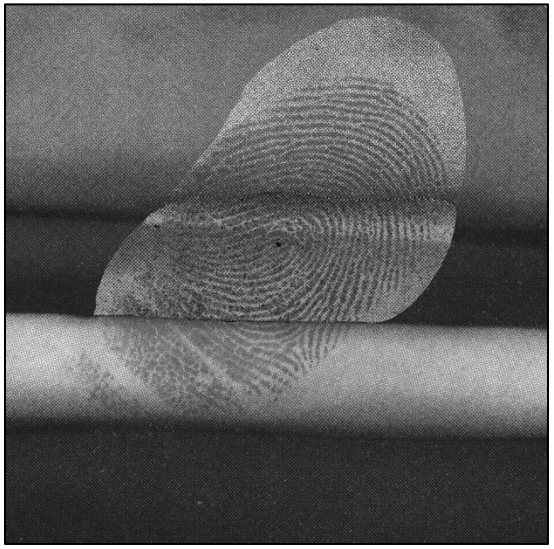
Enhancement Triple: Original, Enhancement, Metadata

Silver Mag Powder

Original



Enhanced



Metadata

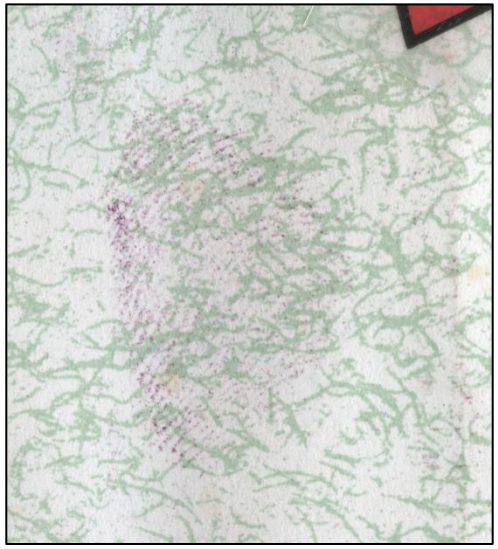
2012-05-25T22:43:54-05:00
File NIST Study Images 095 - V700.tif opened

Levels Preset Kind: Custom
Adjustment: levels adjustment list
levels adjustment
Channel: composite channel
Input: 0, 240
Gamma: 0.16
Deselect

Enhancement Triple: Original, Enhancement, Metadata

Ninhydrin

Original



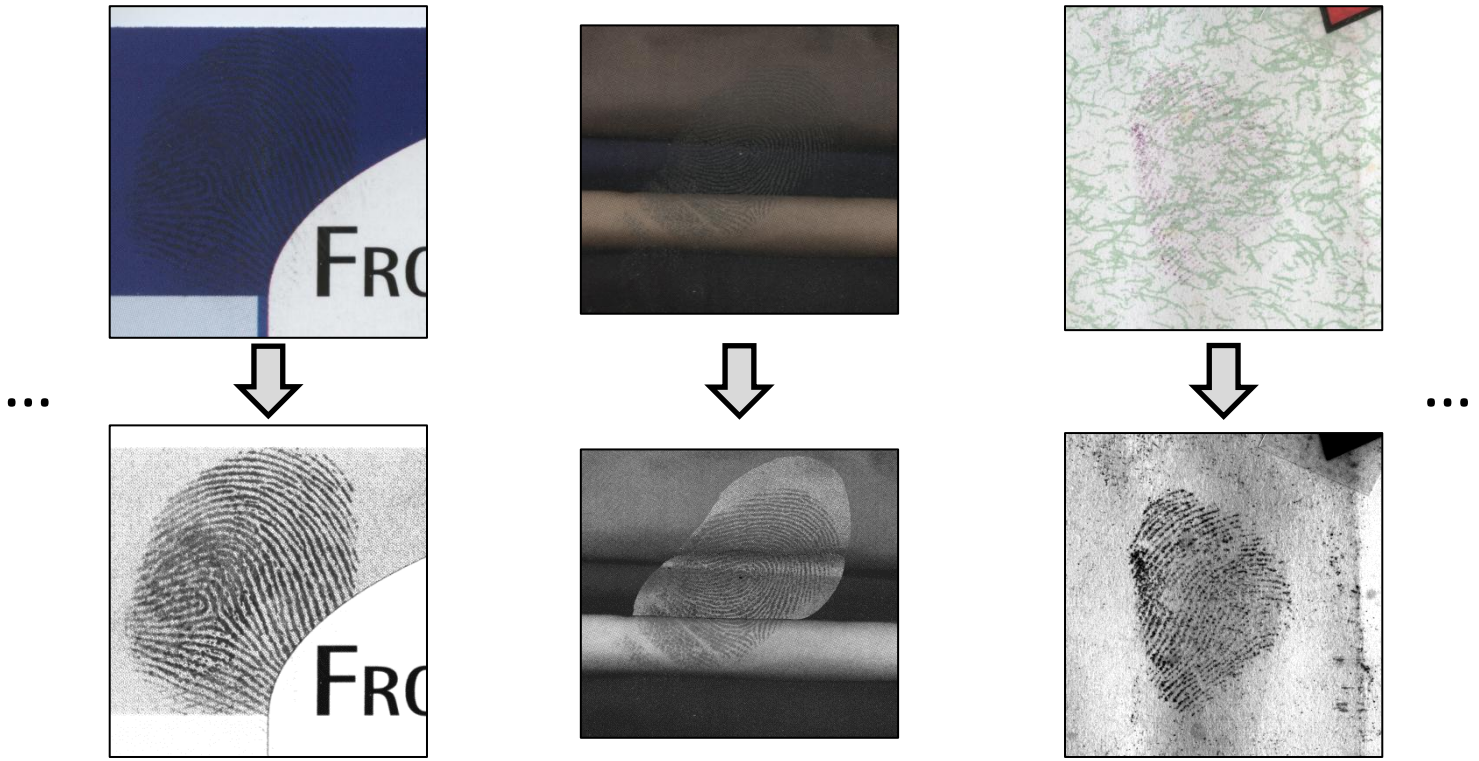
Enhanced

Metadata

2012-05-25T22:37:31-05:00
File NIST Study Images 080 - V700.tif opened

Calculations
MakeNew: channel
Using: calculation
Source: current channel
Calculation: multiply
Opacity: 50%
Source2: current channel
Calculations
Extract Channel

What are Latent Fingerprint Image Enhancements?



- The short answer is, “Indispensable”.
- Of course this is not enough…

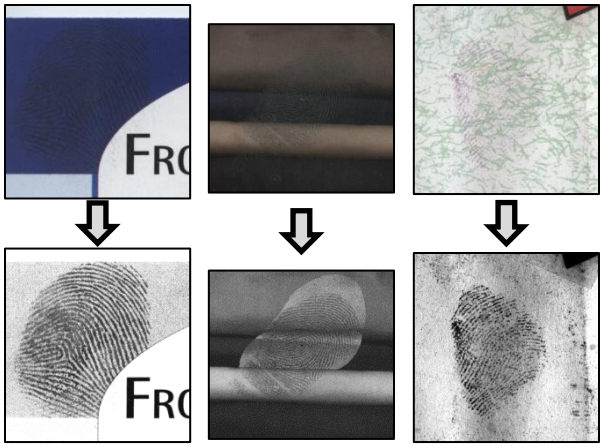
Latent Fingerprint Image Enhancement Database

Can one provide a basis for rules of evidence?*:

- “Nothing material or essential has been added to the original image.”
- “Nothing material or essential has been removed from the original image.”

New latent fingerprint database records

- Representative mappings: latents to enhancements
- Representative usage of Adobe Photoshop



Contribution provided by:

- David “Ski” Witzke, Foray Technologies
- Matt Schwarz, Schwarz Forensics

*Robinson, *Crime Scene Photography* 2nd Edition, (2010) pg. 549

Outline

What are these enhancements? What do they look like?

- New database of triples: latent images, enhanced images, metadata

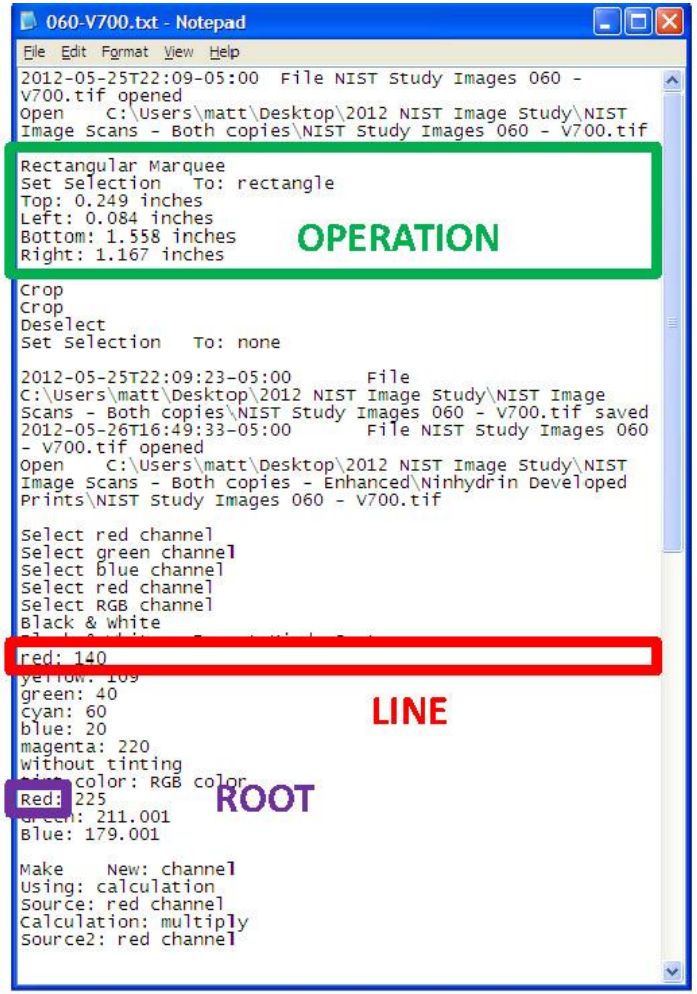
What are these enhancements really? Are they reproducible?

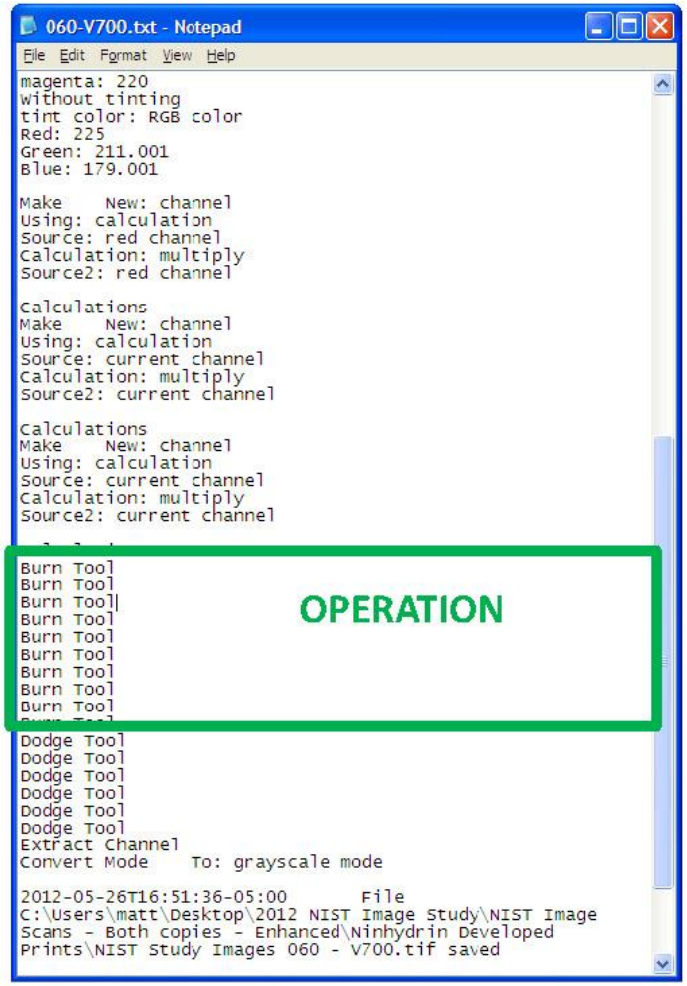
- Mine the metadata for most common enhancement commands
- Universal (i.e. mathematical) description the underlying algorithm

Where are the metrics?

- Modifications to SIVV to customize for latent image characteristics
- Investigate application independent image metrics

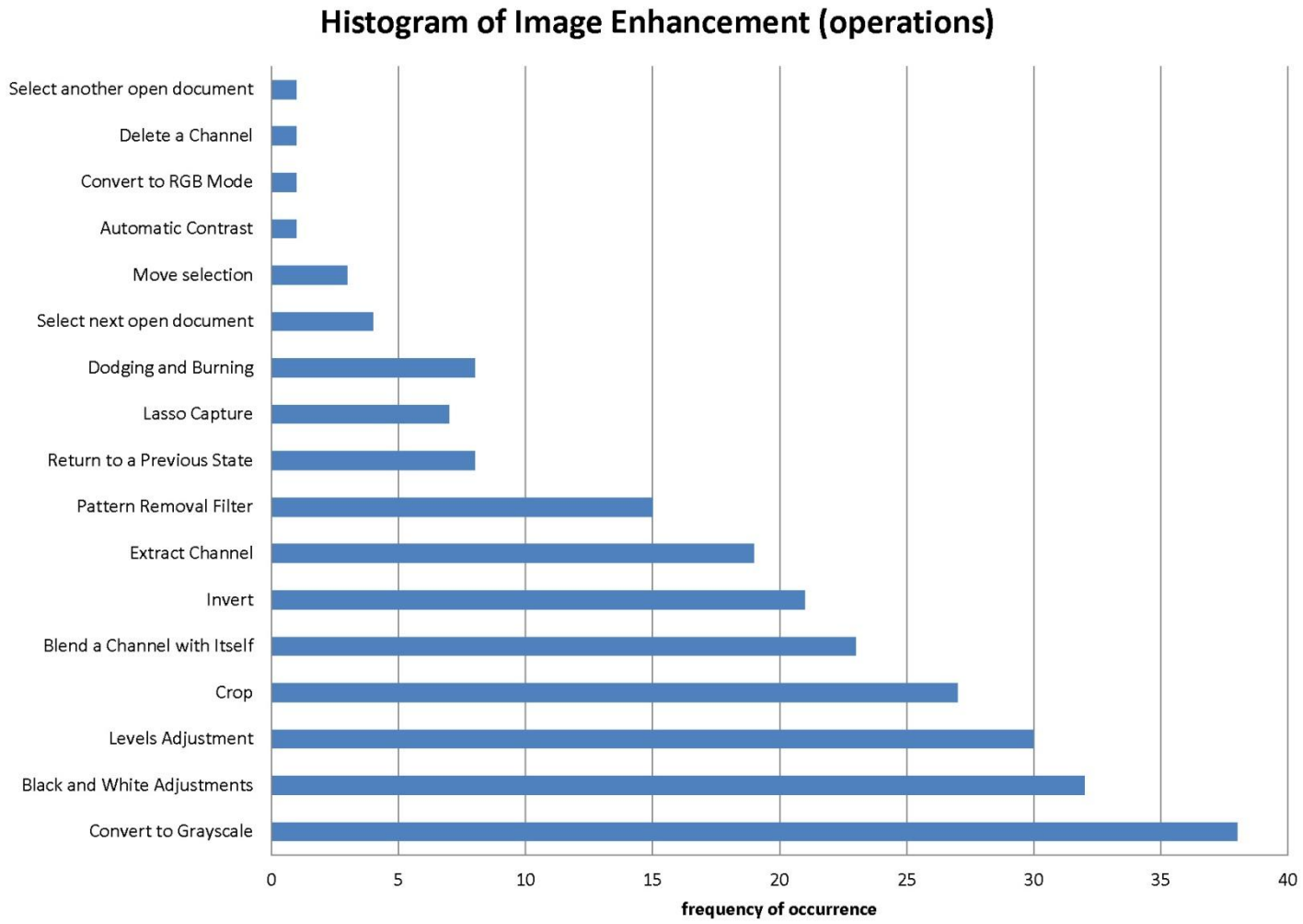
Data Mining the Database





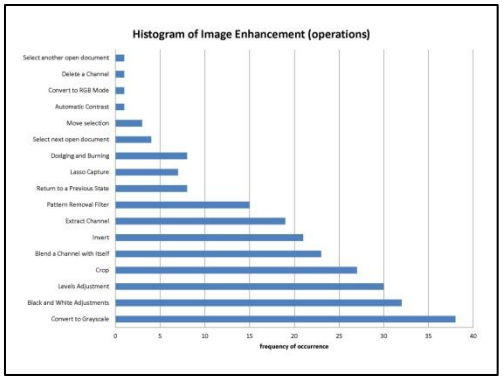
Parsing hierarchy: Line < Root < Operation

Distribution of Enhancement Command Usage



New Data to Inform Answers to Natural Questions

Old Questions



Q: Which PS commands are important?

A: Look at the graph.

Q: Are latent fingerprint enhancements reproducible?

A: Not pixel-for-pixel using the metadata logs

— “Burn and Dodge” are used a total of 130 times in 7 out of the 39 images.

New Questions

What are the PS commands? PS-independent specifications are desired.

RGB-to-Gray is used 39/39 times.

— Different algorithms documented in practice: linear, affine, non-linear

— PS adds a (1-bit) random number to its output! Dither!

Contribution of:

- Peter Bajcsy, Joe Chalfoun, and David Nimorwicz — NIST
- Julian Lee — SURF Student Researcher, University of MD

Part II: Analysis of Image Enhancement

What are these enhancements? What do they look like?

- New database of triples: latent images, enhanced images, metadata

What are these enhancements really? Are they reproducible?

- Mine the metadata for most common enhancement commands
- Universal (i.e. mathematical) description the underlying algorithm

Where are the metrics?

- Modifications to SIVV to customize for latent image characteristics
- Investigate application independent image metrics

What do Latent Fingerprint Image Enhancements do?

SIVV is the angle averaged 2D power spectral density*

$$f(x,y) \underset{\mathcal{F}}{\Leftrightarrow} F(k_x, k_y)$$

$$f_{SIVV}(r) = \int_0^{2\pi} |F(r\cos\theta, r\sin\theta)|\, d\theta$$

Modifications needed for latent fingerprint images

- Dynamic selection of region of interest and windowing (Blackman)
- User selected ridges to fix search region in r
- Define pairwise comparison of SIVV curves.

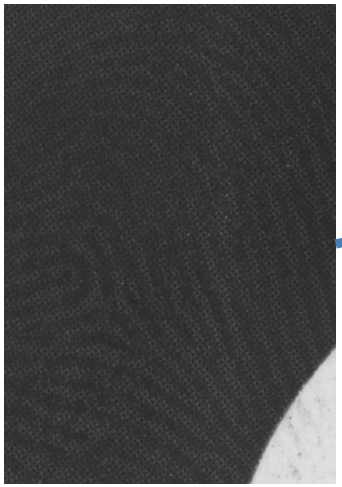
Contribution of:

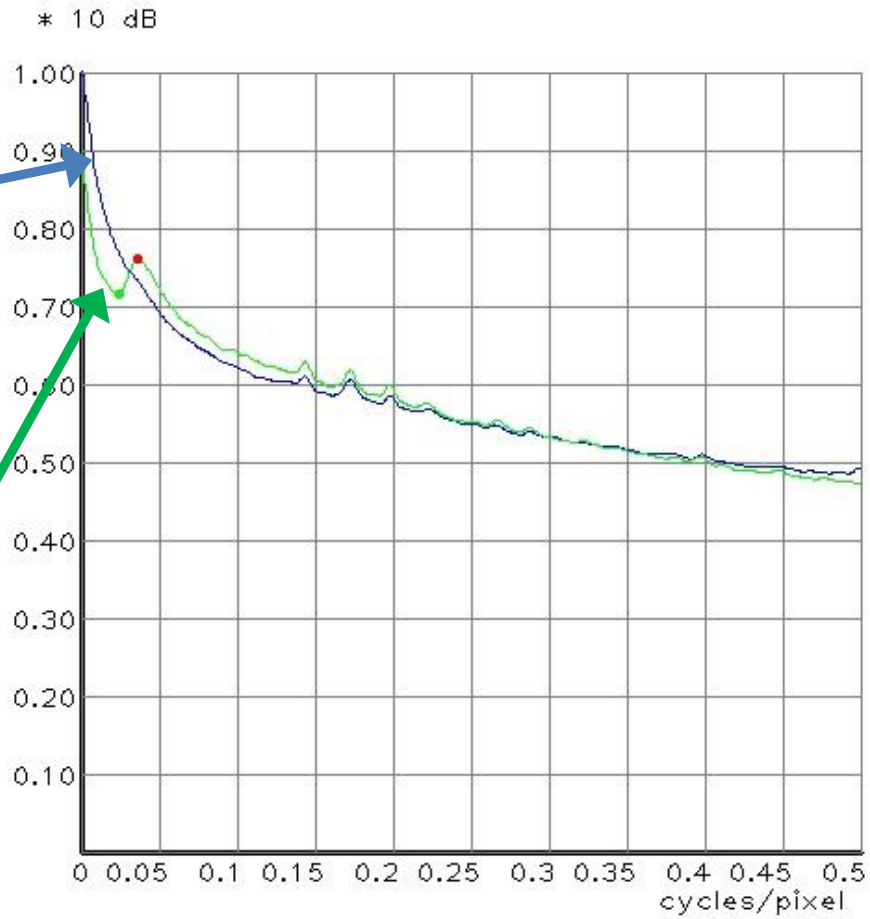
- Haiying Guan — NIST
- Additional thanks to the NIST Image Group.

SIVV = Spectral Image Validation/Verification

*Libert, *et. al.*, "A 1D Spectral Image Validation/Verification Metric for Fingerprints", NISTIR-7599 (2009)

Can SIVV Measure the Value of an Enhancement?





Findings to date (research is ongoing):

- **SIVV feature emerges as result of enhancement**
- **Can we develop a metric out of this?**

Now for Something Completely Different

Adobe Photoshop is a double-edged sword

Pros	Cons
Familiar to latent community	Visually motivated
Ease of use	Algorithmic control is limited
	Reproducibility is questionable

Explore alternative tools: Matlab, Interactive Data Language (IDL)

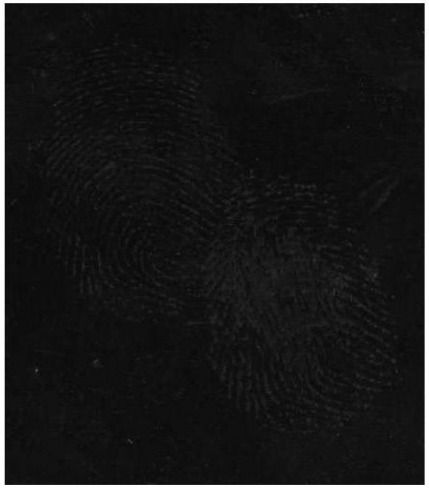
Investigate application independent (i.e. “generic”) image metrics

$$\|f\|_1 = \frac{1}{N_x N_y} \sum_{x,y} |f(x,y)| \qquad \|\nabla f\|_1 = \frac{1}{N_x N_y} \left(\sum_{x,y} \left(\Delta_x f^2 + \Delta_y f^2 \right)^{1/2} \right)$$

$$\|f\|_2 = \frac{1}{N_x N_y} \left(\sum_{x,y} |f(x,y)|^2 \right)^{1/2} \qquad \|\nabla f\|_2 = \frac{1}{N_x N_y} \left(\sum_{x,y} \left(\Delta_x f^2 + \Delta_y f^2 \right) \right)^{1/2}$$

Alternative Tools and Metrics

ORIGINAL LATENT FINGERPRINT



FORENSIC PHOTOSHOP PROCESS

MATLAB CONTRAST ADJUSTMENT

MATLAB HISTOGRAM EQUALIZATION

Image $f(x,y)$	$\| f \|_1$	$\| f \|_2$	$\| \nabla f \|_1$	$\| \nabla f \|_2$
Original Latent Print (A)	16	18	2600	3900
Forensic Photoshop (A)	61	75	25000	36000
Matlab Contrast Adj. (A)	60	80	25000	40000
Matlab Histogram Eq. (A)	112	138	42000	60000

- **Many more details in NISTIR under review.**
- **Contribution of: Al Carasso— NIST**

Conclusions

Accomplishments:

- Defined workflow
- Well characterized database/workspace
- Initiated systematic analysis of enhancement procedures
- Begun metrical analysis

Next Steps

- Refine and document the above

Future Efforts

- Guidelines/Best Practices and Document Standards
- Augment analysis to include matcher technologies

THANK YOU