
# A generalized Benford's law for JPEG coefficients and its applications in image forensics: Summary

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Professor Matthew Stamm

# Publication Details

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|---|---|
| Title | A generalized Benford's law for JPEG coefficients and its applications in image forensics |
| Authors | Dongdong Fu, Yun Q. Shi, Wei Su |
| Hosting Institute | New Jersey Institute of Technology |
| Published Year | 2007 |
| Objective | Demonstrate effectiveness of proposed Benford-like model for the probability distribution of the most significant digit of the DCT coefficients used in JPEG compression |

# What is Benford's Law?

- "First Digit Law" or "Significant Digit Law"
- Empirical Law
- Discovered by Frank Benford in 1938

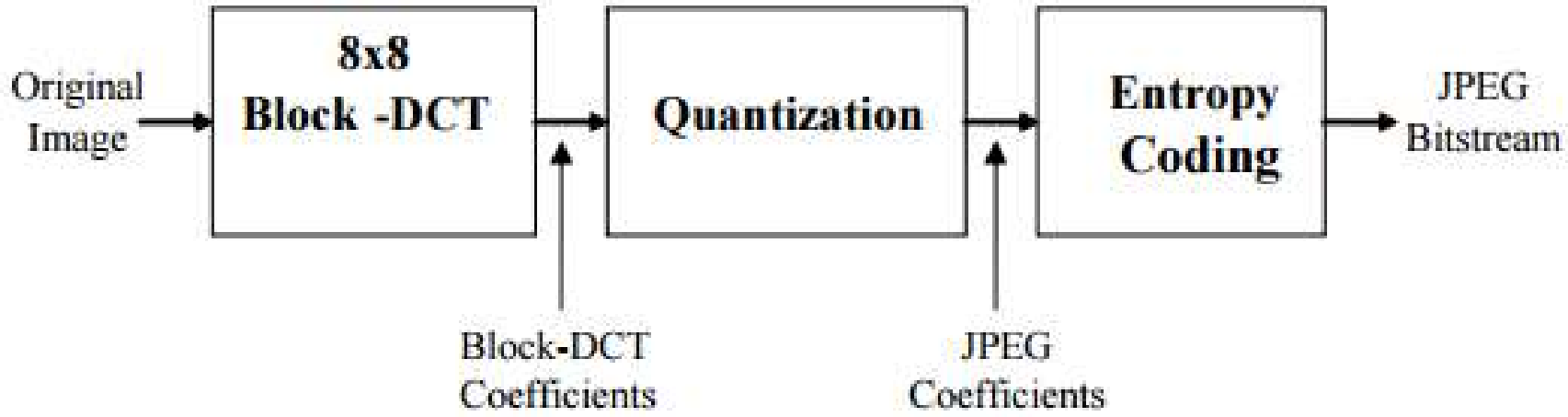
Probability distribution of the first digits in a set of natural numbers $(x \in 1, 2, 3, \ldots 9)$ is logarithmic—

$$p(x) = \log_{10}\left(1 + \frac{1}{x}\right)$$

Image Forensics

- Light intensities in natural images obey Benford's Law
- Random guess and modified data does not

# JPEG Compression Overview



# Benford's Law in Block-DCT Coefficients

1) Block-DCT coefficients were calculated for each image
   - 8 x 8 DCT blocks
   - 1,338 Images
2) Histogram of first digit was computed for each image
3) Average of histograms shown

Most significant digit in block-DCT coefficient follows Benford's Law.

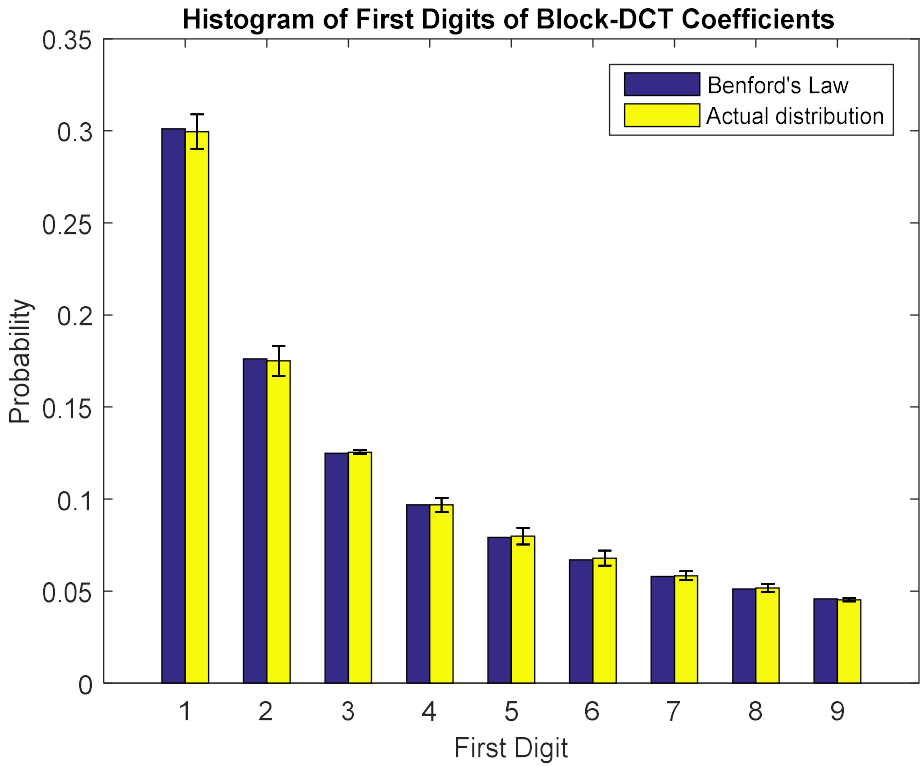



Figure 1. First digit probability distribution of the Block-DCT coefficients.

# Benford's Law in Quantized JPEG Coefficients

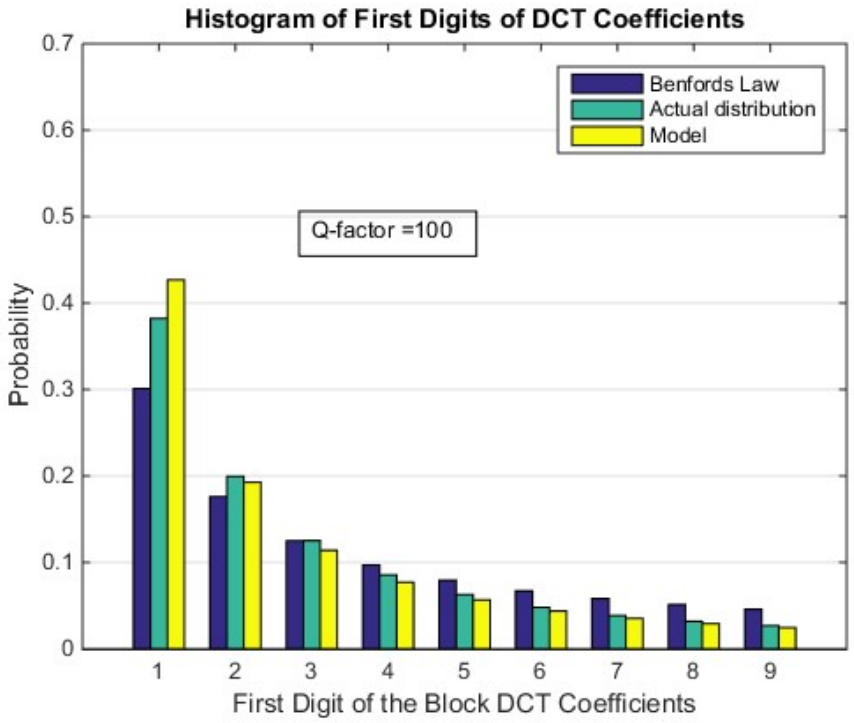



Figure 2. Averaged first digit probability distribution of JPEG coefficients. Includes all images in UCID. Proposed model is generalized Benford's law.

1) Block-DCT coefficients were quantized to get JPEG coefficients
   - Standard JPEG quantization table used
2) Average histogram of first digit was computed

Most significant digit in JPEG coefficient follows Benford-like logarithmic Law.

# Generalized Benford's Law

- JPEG Coefficients follow parametric logarithmic function
- Fu et. al. adapted generalized Benford's law to fit different images and different compression quality factors

$$p(x) = N\ log_{10}\left(1 + \frac{1}{s + x^q}\right), \qquad x \in 1, 2, 3, \ldots 9$$

$$N: Normalization\ factor$$
$$s, q: Model\ parameters$$

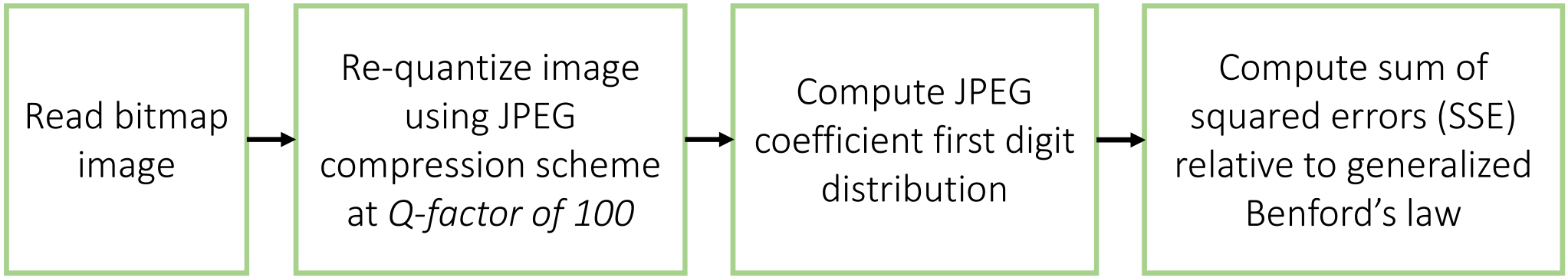
# Applications

Detection of JPEG compression for bitmap images

Estimation of Q-factor for JPEG compressed bitmap images

Detection of JPEG double-compression image

# Detection of JPEG Compression (.bmp)




***Decision Rule:**
Re-quantize image follows generalized Benford's model if no JPEG compression occurred

# Detection of JPEG Compression (.bmp)

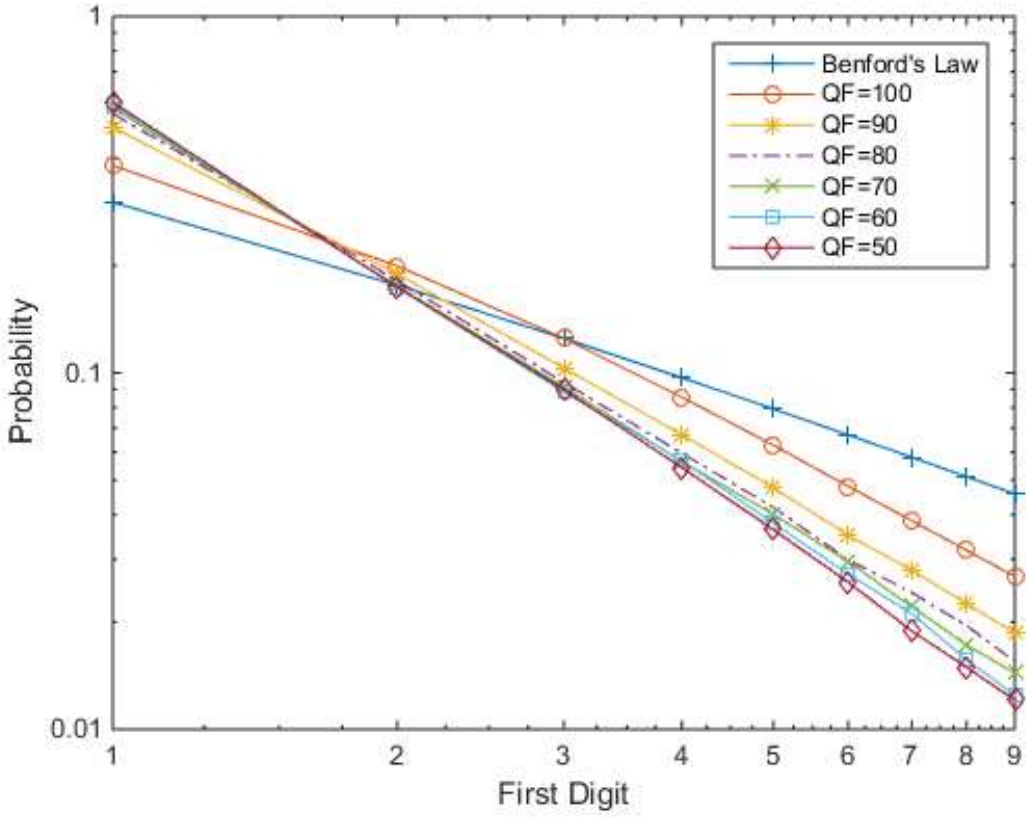



Figure 3. Mean distribution of first digit of JPEG coefficients of uncompressed (Benford's law) and compressed images at a given quality factors

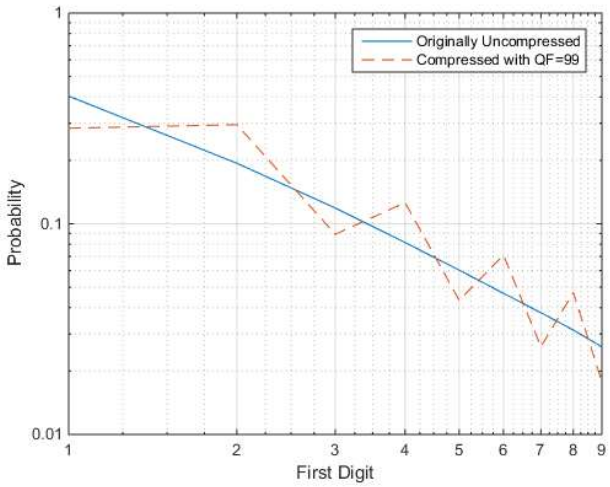
Detection using same QF as respective compressed image follows Generalized Benford's Law

Note:

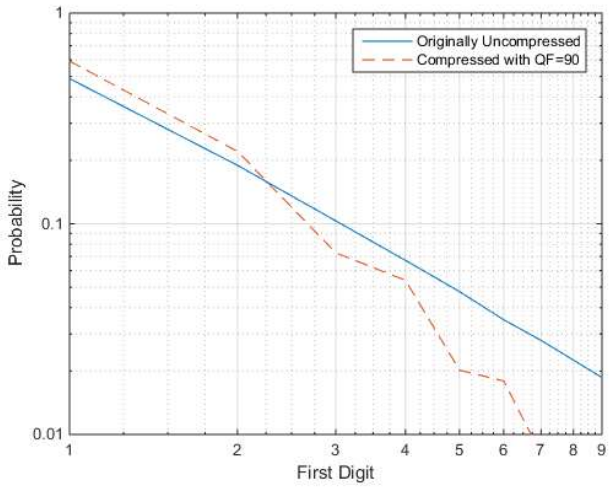
Benford's Law case is achieved by parameters
s = 0 and q = 1
substituted in generalized Benford's law model

# JPEG compression Detection using QF=100

(a)




(b)




(c)

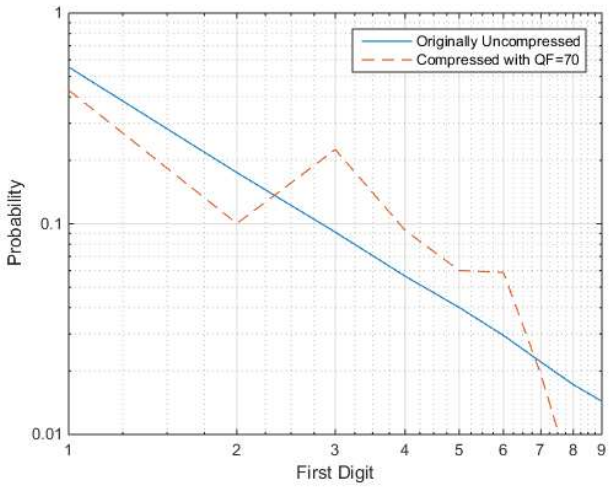
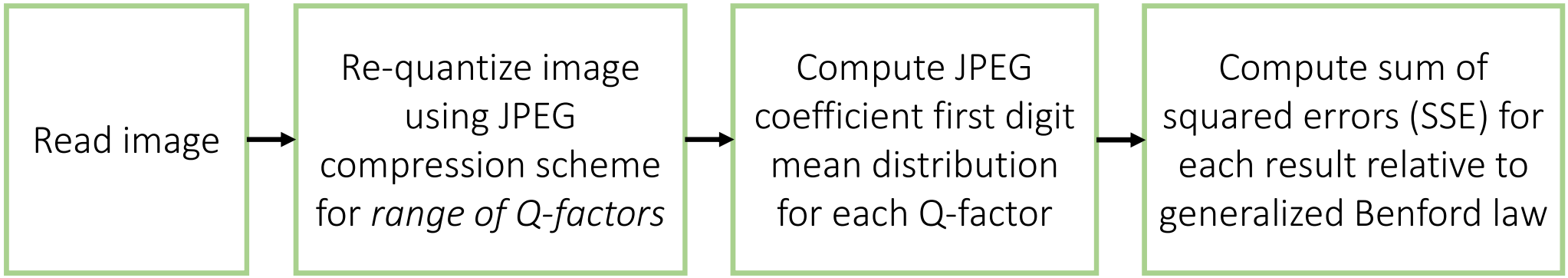



Figure 4, a-c. Effects of re-quantizing JPEG compressed images with different Q-factors. Generalized Benford's Law violated (a) Q-factor = 99. (b) Q-factor = 90. (c) Q-factor = 70

Re-quantizing of JPEG compressed with different QF reveals artifacts in the first digit distribution of JPEG coefficients.

# Detection of Q-factor of JPEG compression




*Decision Rule:
Correct Q-factor will follow generalized Benford law

# Estimation of Q-factor for JPEG Compressed Bitmap Image

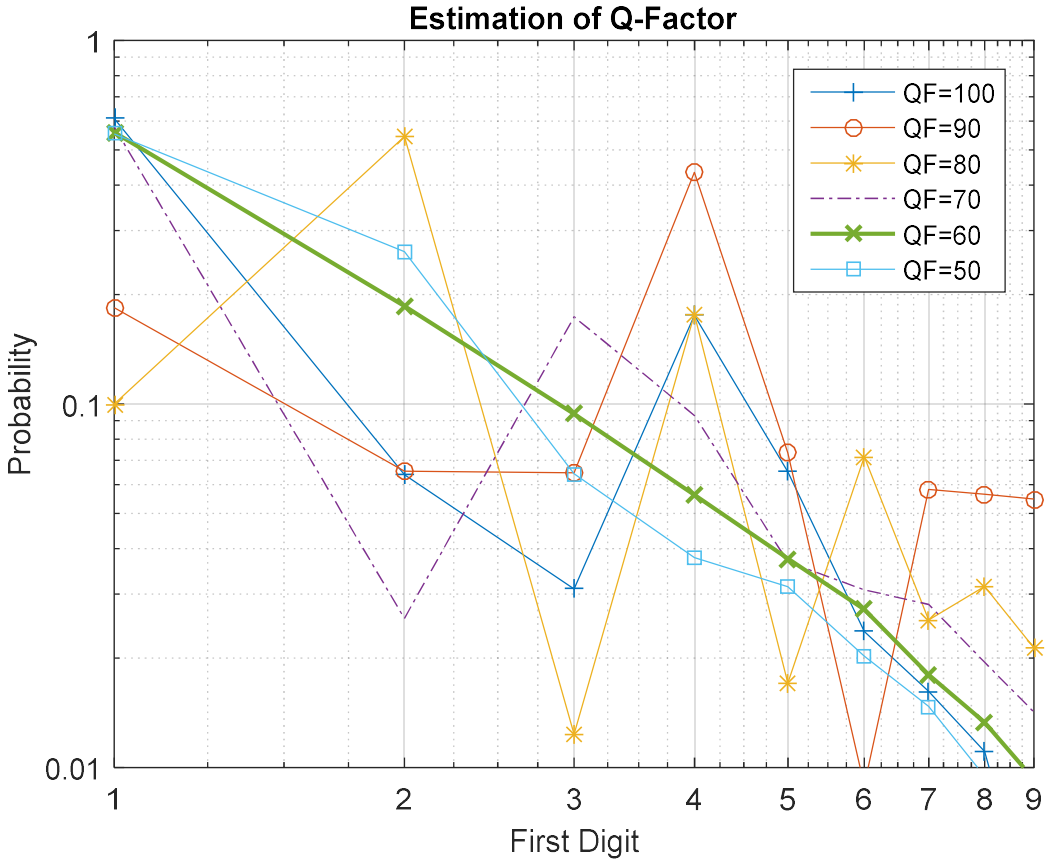



Figure 5. Estimation of JPEG compression Q-factor for bitmap image

1) Original image compressed with Q-factor of 60
2) Re-quantize with different Q-factors to determine best fit to Benford's Law

Re-quantizing with QF-factor of 60 yields first-digit distribution that follows Generalize Benford's Law.

# Double JPEG compression

- Re-quantizing double-compressed image yields first-digit distribution that does not follow Generalize Benford's Law

- Machine-learning and non-machine learning classifier can be used to detect double-compressed images

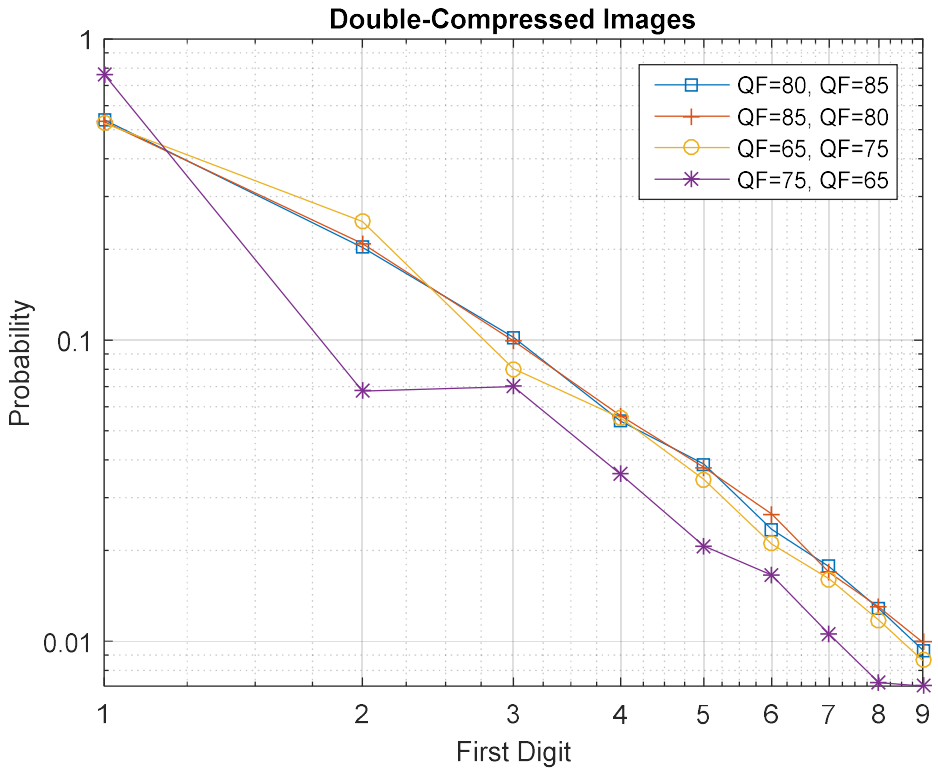



Figure 6. Double JPEG compression artifacts

Double JPEG compression reveals artifacts in the mean first digit distribution of JPEG coefficients.

# Double JPEG compression Detection

- Using Fu et. al. model yields low detection rate even though visual inspection of chart shows high detection
- We used a simple binary classifier using Least Squares
- Yields 100% detection accuracy for both single and double compressed images

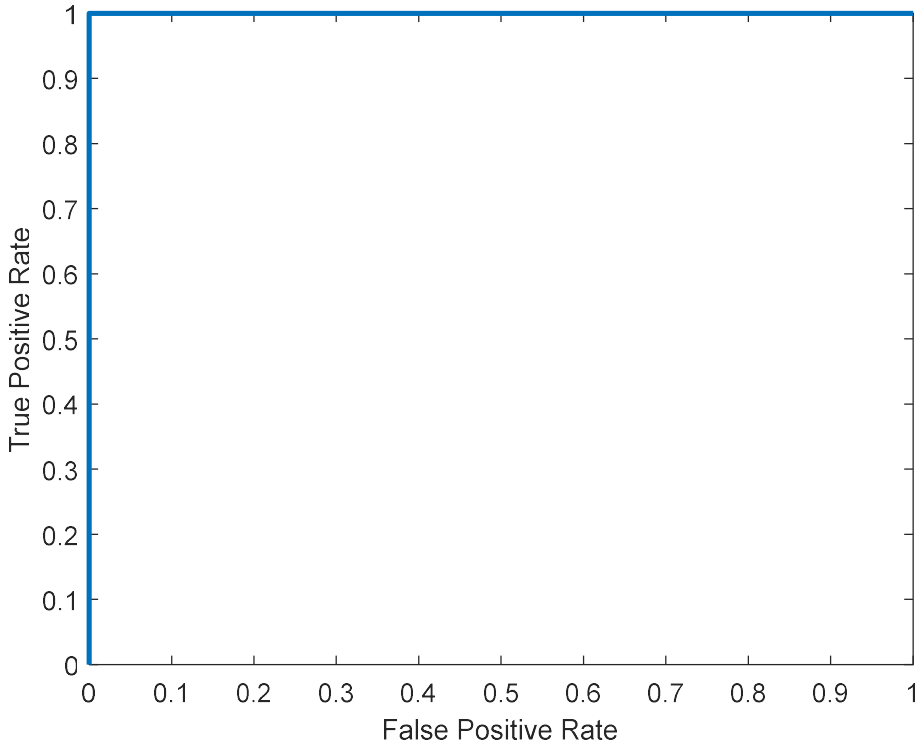



Figure 7. Receiver Operating Characteristic (ROC) of double-compressed least squares classifier

# Conclusion

- Benford's Law can be used to detect
  - Single JPEG compressed images
  - Q-factor for single compressed images
  - Double-compressed images

- Observations
  - Generalized Benford's Law parameters may not be universal or may be too sensitive
  - Was unable to use their model parameters in our detector


# Questions?

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# Appendix

# Experiment Overview

- UCID (Uncompressed Image Database)
  - Consists of 1,338 uncompressed images
  - .tiff format
  - Color images
- Luminance components used
  - Analysis done on 8-bit grayscale images