CONF-9606169--1

LA-UR- 96-0352

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE: **WAVELET/SCALAR QUANTIZATION COMPRESSION STANDARD FOR FINGERPRINT IMAGES**

AUTHOR(S): Christopher M. Brislawn

SUBMITTED TO: Proceeding Conference on Signal Image Processing and Applications
Annecy, France
June 12-14, 1996

Los Alamos

Los Alamos National Laboratory
Los Alamos New Mexico 87545

Wavelet/Scalar Quantization Compression Standard for Fingerprint Images

Christopher M. Brislawn

Computer Research/Applications Group (CIC–3)

Los Alamos National Laboratory, Mail Stop K987

Los Alamos, New Mexico 87545–1663, USA

phone: (505) 665–1165, FAX: (505) 665–5638, e-mail: brislawn@lanl.gov

Abstract

The US Federal Bureau of Investigation has recently formulated a national standard for digitization and compression of gray-scale fingerprint images. Fingerprints are scanned at a spatial resolution of 500 dots per inch, with 8 bits of gray-scale resolution. The compression algorithm for the resulting digital images is based on adaptive uniform scalar quantization of a discrete wavelet transform subband decomposition, a technique referred to as the wavelet/scalar quantization method. The FBI standard produces archival-quality images at compression ratios of around 15 to 1 and will allow the current database of paper fingerprint cards to be replaced by digital imagery. The compression standard specifies a class of potential encoders and a universal decoder with sufficient generality to reconstruct compressed images produced by any compliant encoder, allowing flexibility for future improvements in encoder technology. A compliance testing program is also being implemented to ensure high standards of image quality and interchangeability of data between different implementations.

Keywords

wavelets, image compression, fingerprints, Federal Bureau of Investigation

I. Introduction.

The United States Federal Bureau of Investigation (FBI) retains in its criminal archives some 200 million criminal fingerprint cards. Cards in active use correspond to over 29 million individual suspects. Local police agencies from all over the country submit on the order of 30,000 new fingerprint cards *per day* for background checks. In response to rapidly growing demand within the criminal justice community for faster turn-around time on background checks, the FBI is converting this database from paper to a digital electronic format. One goal for the FBI's Integrated Automated Fingerprint Identification System (IAFIS) is to respond to requests from police agencies for background checks on criminal suspects in under 24 hours, a feat that is not possible at present.

Through the use of computers, it is possible to make print comparisons against the entire active card set once the prints have been reduced to digital classification data. Automatic recognition of fingerprint "minutiae" (ridge endings and bifurcations) has been performed on digitized cards for two decades, but complete fingerprint classification [1], which includes global pattern characteristics, has proven much harder to automate. Current computerized pattern classification techniques [2], [3] show considerable promise—at some computational cost—for automating the first level of fingerprint classification into five principal classes: Arch, Tented Arch, Left Loop, Right Loop, and Whorl. Providing such a fingerprint classification capability in under 24 hours will allow police to run background checks using nation-wide FBI data and receive a response before suspects are released from police custody. A major obstacle to automating fingerprint analysis, though, is the problem of converting the current, paper-based archive to a digital format.

To achieve this goal, maintain consistently high standards of image quality, and ensure interchangeability of data amongst different jurisdictions, the FBI's Criminal Justice Information Services Division, in collaboration with the National Institute of Standards and Technology and Los Alamos National Laboratory, has developed national standards for fingerprint digitization [4] and compression [5]. Fingerprint images are digitized at a resolution of 500 pixels/inch with 256 levels (8 bits) of gray-scale information; gray-scale images have a more natural appearance to human viewers than do bit-mapped (black/white) images and allow a higher level of subjective discrimination by fingerprint examiners.

The data storage and transmission requirements imposed by this level of resolution are considerable: a single 1.5×1.6 inch rolled fingerprint produces around 600 kilobytes of digital information; an entire card (10 rolled impressions, plain impressions of the thumbs and simultaneous impressions of both hands) produces about 10 megabytes of data. At this rate, digitizing the FBI's current holdings would result in some 2,000 terabytes of archival data. Accordingly, the FBI has made data compression part of the digitization process.

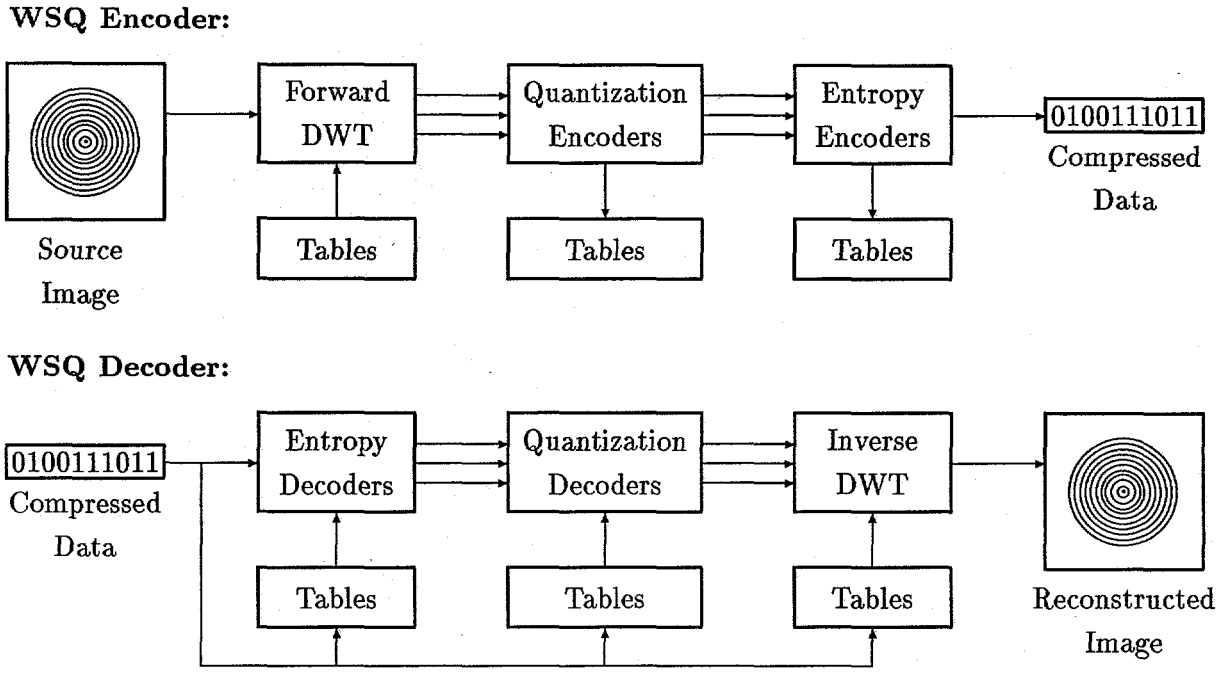

Fig. 1. High-level overview of FBI WSQ fingerprint image compression codec.

II. Overview of the FBI Compression Algorithm.

After considering a number of different digital image compression methods [6], including the ISO JPEG still image compression standard [7], the FBI selected a customized algorithm based on adaptive uniform scalar quantization of a discrete wavelet transform (DWT) spatial frequency decomposition. We refer to this technique as the *wavelet/scalar quantization* (WSQ) method. A high-level overview of the WSQ method is shown in Figure 1.

This particular approach was chosen on the basis of follow-up studies to the investigations reported in [6], [8], and the algorithm's suitability for fingerprint image data has been verified in tests performed by FBI fingerprint examiners. Testing has shown that the compressed image quality produced by the first-generation WSQ encoder is high enough to be acceptable for archival purposes at compression ratios of around 15 to 1.

The fingerprint image shown in Figure 3 has been compressed to a target bit rate of 0.6 bpp (13:1 compression in the absence of additional lossless coding gain) and reconstructed in Figure 4. For comparison, the same image has been compressed to the same compressed file size (including tables) by the ISO JPEG standard and reconstructed in Figure 5. The pronounced blocking artifacts were a major objection to the use of the JPEG standard for fingerprints.

The discrete wavelet transform (DWT) in the FBI standard is implemented using a two-channel linear phase

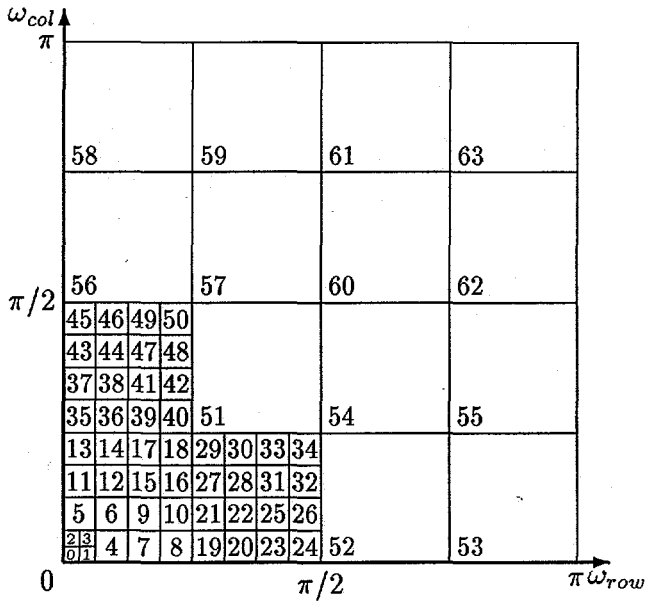

Fig. 2. Frequency support of fingerprint DWT subbands.

perfect reconstruction filter bank [9]. Symmetric extension methods are used to apply the filters near the image boundaries, an approach that allows transforming images with arbitrary (e.g., odd) dimensions; see [10] for details on symmetric extension techniques for filter bank implementation. This two-channel splitting is applied to both the image rows and columns, resulting in a four-channel, 2-dimensional decomposition. The analysis filter bank is cascaded several times to generate the 64-subband spatial frequency decomposition shown in Figure 2. This unconventional-looking frequency decomposition was designed specifically for 500 dpi fingerprint images; it is *not* a general-purpose image decomposition!

The 64 DWT subbands (indicated by parallel arrows in Figure 1) are quantized by a family of uniform scalar quantizers designed to meet the target compression ratio in a manner that ensures uniformly high reconstructed image quality. The optimal bit allocation used in the first-generation encoder is given by the solution to a nonlinear optimization problem that seeks to minimize overall distortion in the compressed image subject to a constraint on the target bit rate. Discussions of the adaptive bit allocation and scalar quantizer design methods can be found in [11], [12]. The integer indices output by the quantization encoders are entropy-encoded by run-length coding of zeros and image-specific Huffman coding, a lossless coding technique also employed in the JPEG standard [13].

The compressed data is written out using a syntax similar to that employed by the JPEG standard. This compressed data contains a table of wavelet transform specifications and tables for the scalar quantizers and Huffman coders. The WSQ decoder parses the compressed data and extracts the tables needed in the decoding

process. To produce the reconstructed image, the decoded, quantized wavelet coefficients are run through an inverse DWT.

The standard specifies a class of encoders and a single decoder with sufficient generality to decode compressed image data produced by any compliant encoder; in particular, we anticipate future refinements in the areas of filter bank and scalar quantizer design. Parameter settings for the first FBI-approved encoder, including filters, quantizer parameters, and Huffman coding specifications, are given in [5]. The FBI specification also includes compliance tests for commercial implementations. These compliance tests are currently being conducted by NIST; to date, several vendors have successfully passed the compliance tests with commercial implementations of the FBI WSQ standard.

References

[1] *The Science of Fingerprints*, Federal Bureau of Investigation, Washington, DC, Dec. 1984.

[2] C. Wilson, G. Candela, P. Grother, C. Watson, and R. Wilkinson, "Massively parallel neural network fingerprint classification system," Tech. Rep. NISTIR 4880, Nat'l. Inst. Standards Tech., Gaithersburg, MD, July 1992.

[3] G. Candela and R. Chellappa, "Comparative performance of classification methods for fingerprints," Tech. Rep. NISTIR 5163, Nat'l. Inst. Standards Tech., Gaithersburg, MD, Apr. 1993.

[4] *American National Standard—Data Format for the Interchange of Fingerprint Information*, ANSI/NIST-CSL 1-1993, Amer. Nat'l. Standards Inst., Nov. 1993.

[5] Federal Bureau of Investigation, *WSQ Gray-Scale Fingerprint Image Compression Specification*, IAFIS-IC-0110v2, Feb. 1993. Drafted by T. Hopper, C. Brislawn, and J. Bradley.

[6] T. Hopper and F. Preston, "Compression of grey-scale fingerprint images," in *Proc. Data Compress. Conf.*, (Snowbird, UT), pp. 309–318, IEEE Computer Soc., Mar. 1992.

[7] *Digital Compression and Coding of Continuous-Tone Still Images, Part 1, Requirements and Guidelines*, ISO Draft Int'l. Standard 10918-1, (a.k.a. "the JPEG Standard"), Amer. Nat'l. Standards Inst., Feb. 1991.

[8] J. N. Bradley and C. M. Brislawn, "Compression of fingerprint data using the wavelet vector quantization image compression algorithm," Tech. Rep. LA-UR-92-1507, Los Alamos Nat'l. Lab, Apr. 1992. FBI report.

[9] P. P. Vaidyanathan, *Multirate Systems and Filter Banks*. Englewood Cliffs, NJ: Prentice Hall, 1993.

[10] C. M. Brislawn, "Classification of nonexpansive symmetric extension transforms for multirate filter banks," Tech. Rep. LA-UR-94-1747, Los Alamos Nat'l. Lab, May 1994. Submitted for publication.

Fig. 3. Original fingerprint image.

[11] J. N. Bradley and C. M. Brislawn, "Proposed first-generation WSQ bit allocation procedure," in *Proc. Symp. Criminal Justice Info. Services Tech.*, (Gaithersburg, MD), pp. C11–C17, Federal Bureau of Investigation, Sept. 1993.

[12] J. N. Bradley and C. M. Brislawn, "The wavelet/scalar quantization compression standard for digital fingerprint images," in *Proc. Int'l. Symp. Circuits Systems*, vol. 3, (London), pp. 205–208, IEEE Circuits Systems Soc., June 1994.

[13] W. B. Pennebaker and J. L. Mitchell, *JPEG Still Image Data Compression Standard.* New York, NY: Van Nostrand Reinhold, 1992.

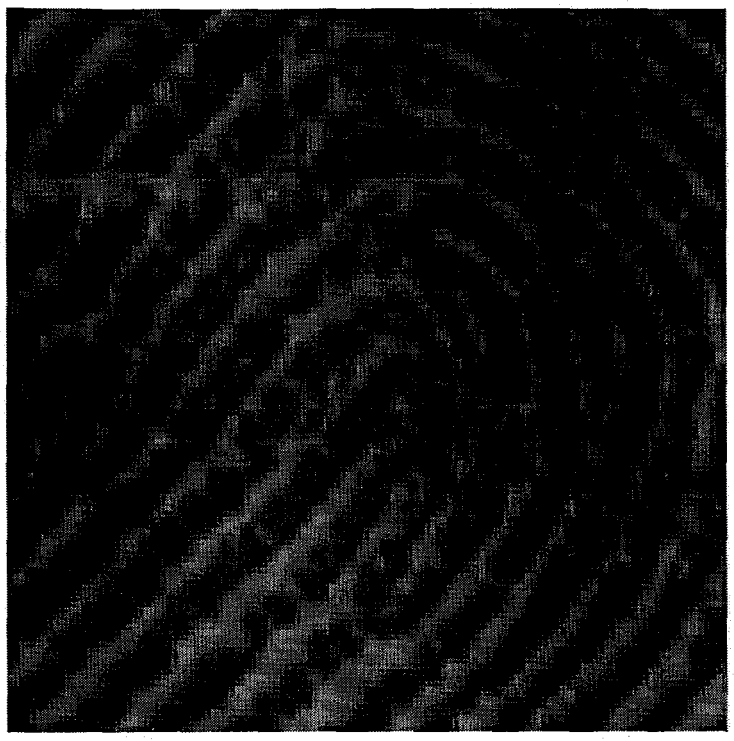

Fig. 4. Fingerprint image compressed via WSQ algorithm.

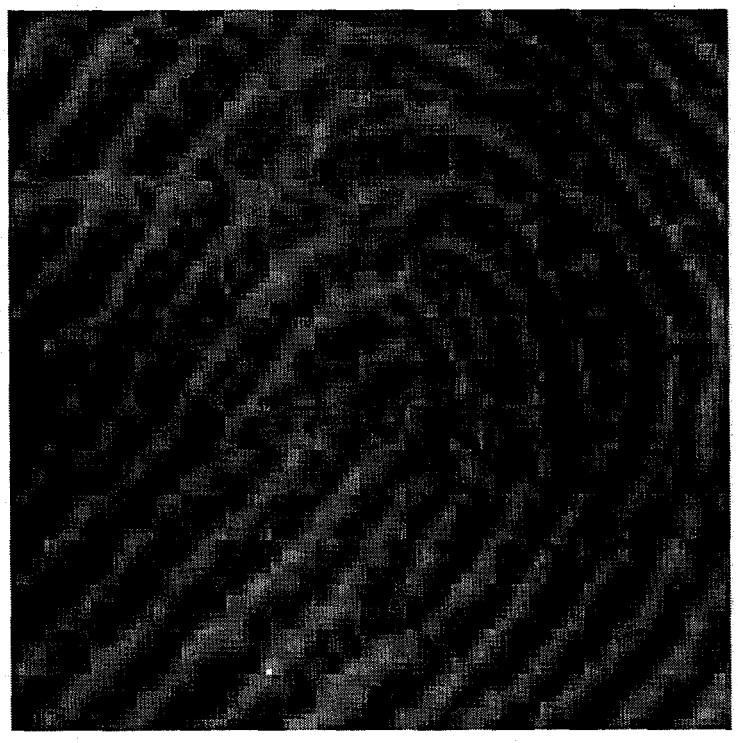

Fig. 5. Fingerprint image compressed via JPEG algorithm.