Iris Image Compression Using the FBI Algorithm

Aaron Ortega, Student. Department of Mathematical Sciences, The University of Texas at El Paso
Melissa Martinez, Student. Department of Psychology, The University of Texas at El Paso
Ariel González, Student. Department of Mathematical Sciences, The University of Texas at El Paso
Helmut Knaust, Ph. D., Mentor. Department of Mathematical Sciences, The University of Texas at El Paso

MATHEMATICAL ASSOCIATION OF AMERICA

Introduction

During the 20th century, the Federal Bureau of Investigation (FBI) established an Integrated Automated Fingerprint Identification System (IAFIS) composed of human fingerprints. The FBI had around 200 million inked fingerprint cards that were in need of digitization (Brislawn et. al, 344). In order to achieve this task, the FBI developed the Wavelet Scalar Quantization (WSQ) algorithm. The algorithm facilitated storage requirements and procedural information exchange between agencies. With technological advances in the recent years, various groups have sought to expand with new biometric identifiers, such as the human iris, palm print, voice, signature, and gait (Kaucher).

Figure 1

Our focus on the iris

The iris' texture and complex pattern on its interior surface offers an extremely valid biometric cue for human recognition (Ross, 30).The iris has great variation among individuals, even among monozygotic twins. Random events during gestation influence an individual's iris pattern (Ross, 31).The pattern of the iris is not easily altered by environmental factors, such as lacerations or infections, so the form remains consistent over time (Cho, Caytiles, and Kim, 586). There is a growing number of entities that are focusing on iris recognition for security and Identification purposes, and they are going to need a large database to compile the iris images as well as a compression algorithm.

Methodology

For this research, we used the Wolfram Mathematica (versions 8 and 9) software to produce a modified version of the FBI WSQ algorithm and to implement a quantization method to iris images.

The image of an iris was first imported into the Mathematica software, where a command called the NTSC was applied to the image to obtain a greyscale image.
After obtaining the Greyscale image, we need to apply the normalization formula:
$\tilde{A}_{i,j} = (A_{i,j} - \mu)/R$, $\tilde{A}$ = normalized image/matrix, A = original image/matrix and where $R = (1/128) \max\{M_1-\mu, \mu-m_1\}$,
and M_1 = maximum value of A, and m_1 = minimum value of A.
Normalization of an image/matrix_changes the range of pixel values in order to increase the compression factor.

We then used the JPEG2000 lossy wavelet transform, employing the (9,7) Cohen-Daubechies-Feauveau Filter Pair (CDF97), as described by Van Fleet (469) to create the CDFBI wavelet transform. Lossy compression reduces an image by discarding some of the data in order to lower the storage capacity of the image.

To obtain the FBI fingerprint compression standard, we performed n = 1 iteration to each assigned section of the image previously transformed, beginning with the entire normalized image. Each iteration transforms the designated image into four sections, a blur, the vertical edges, the horizontal edges, and the diagonal edges, in which all the edges are extracted from the chosen image to generate the blur.
The quantization process allows for a wavelet transform values to be mapped from a large set to a small set of integers. The image is divided into 64 sub bands, where each undergoes a separate and unique quantization provided by a function f. The function allocates each bit into two conditioned bin widths where they will be subject to either an integer or zero quantization. This process incorporates the majority of the compression and allows the user to issue a desired bit rate, r. However, unlike the WSQ algorithm, this procedure does not have the benefit to guarantee an entropy level lower than r. However, In the end, a lossy compression is achieved de to the inability of being able to return quantize values to their original state.
The dequantization procedure initiates the image decompression process. This process returns some but not all values to the original matrix.

The dequantized image needs to be run through an inverse wavelet transform to retrieve the original image. The inverse wavelet transform (InvCDFBI) we fabricated has the same general process as our CDFBI wavelet transform, except we reversed the order of the commands. At the end of our InvCDFBI transform, we obtained the normalized image once again. We then denormalize the resulting image with the formula: $N_{i,j} = R\tilde{N}_{i,j} + \mu$, $\tilde{N}$

For μ the mean of A, with N = denormalized image where $R = (1/128) \max\{M_1-\mu, \mu-m_1\}$ and M_1 = maximum value of A, and m_1 to obtain the original image, with slight differences in image quality.

Figure 2

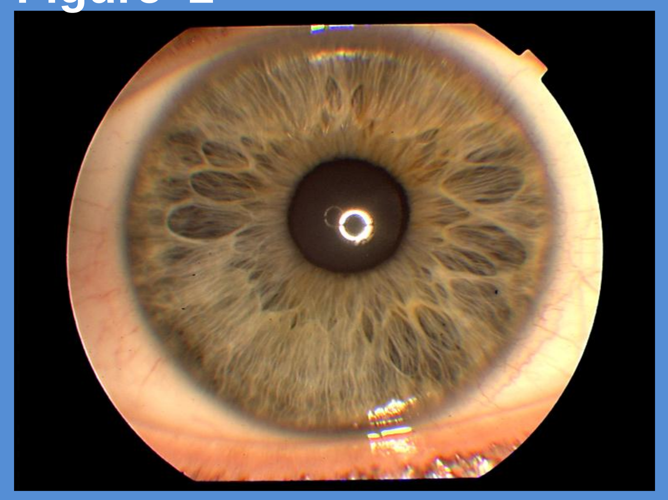


Figure 3

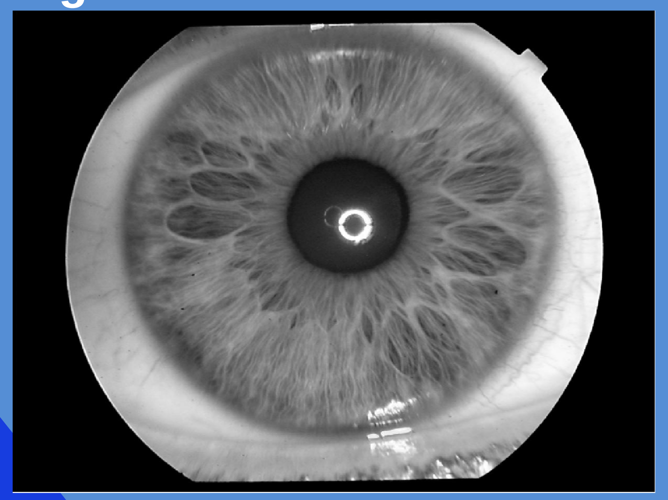


Figure 4

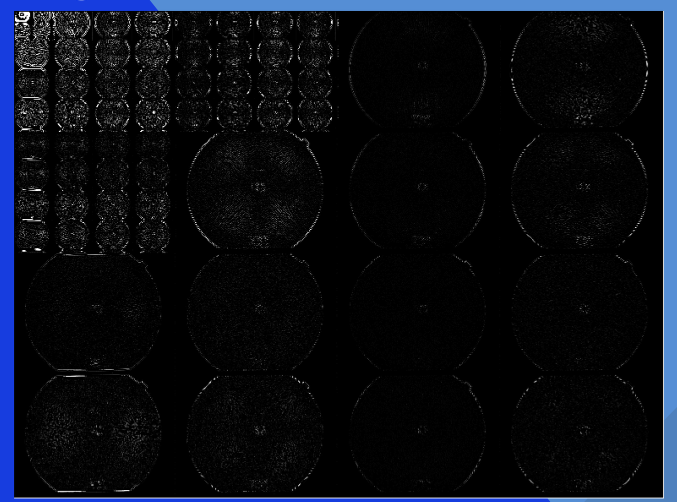


Figure 5

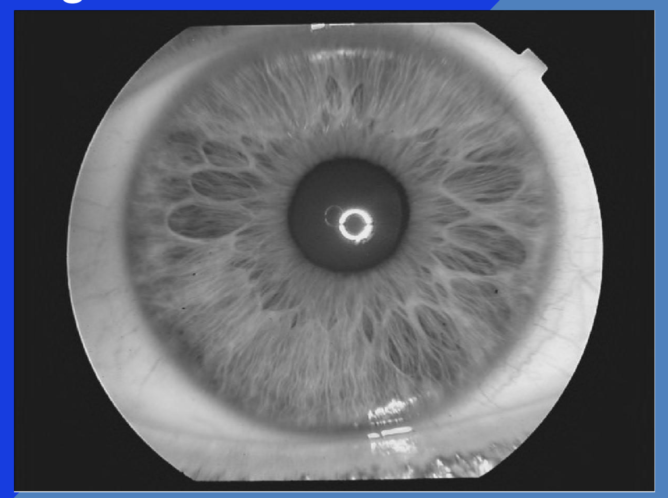
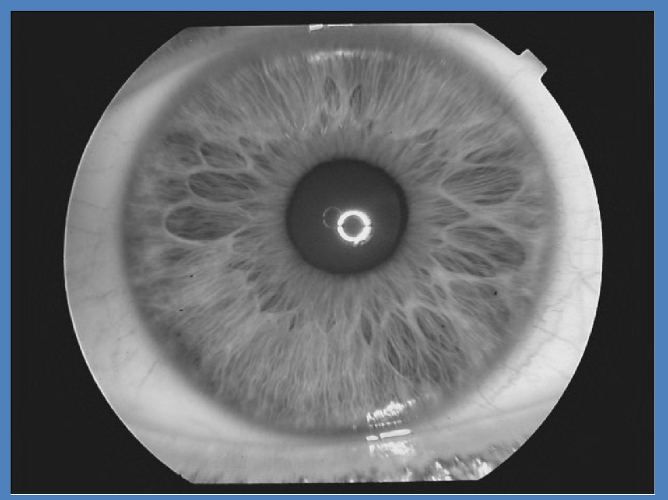


Figure 6



Results

For the sake of comparing, we decided to use the Haar, Daubechies-6, and JPEG2000 wavelets with the quantize function from the Mathematica software for the Haar and Daubechies-6 wavelets and a step-quantize process for the JPEG 2000 in order to find the efficiency of the IWQ algorithm.

The Peak-Signal-to-Noise Ratio (PSNR), takes the matrix of the original greyscale image against the matrix of the denormalized image. The PSNR measure for image compression determines the quality of reconstruction of lossy compression.

As you can see in Table 1, the IWQ algorithm, with the same compression, has a lower PSNR than the JPEG 2000. On the other hand, in Table 2, the IWQ, with the same compression factor has a higher PSNR than the other three algorithms used. This proves that the IWQ algorithm retains more details with a higher compression of the images, which gives high efficiency to the image processing of irises. While modifying the quantization, we found that at a compression factor of 20.10 the PSNR is at 34.97, which is a good amount of details retained. At this point, our standards of the details that have to be retained are only preliminary and they are only based on the definition of the PSNR of good quality.

Table 1: Fingerprint Image

Algorithm	Compression Factor	Peak to Noise Ration
CDFBI	9.00	28.5240
JPEG 2000	9.00	30.1596
Haar	8.90	26.8740
Daubechies-6	9.00	29.6029

Table 2: Iris Image

Algorithm	Compression Factor	Peak to Noise Ration
CDFBI	7.00	40.9632
JPEG 2000	7.00	39.7877
Haar	7.00	37.2152
Daubechies-6	7.00	38.7083

Conclusion

The ISQ algorithm was more efficient when applied to iris images rather than on fingerprints. The reason found was due to the cloudiness of some areas in the irises, as opposed to the many edges found in the fingerprint images. A few tweaks are needed in the quantization process of the IWQ to generalize the algorithm since some of the iris images were not able to go through the process.

Future Research

Future research should concentrate on the quantization method of our constructed wavelet transform in order to compress the iris images further.
As seen in the transformed iris image, we are able to set ¾ of the entire transformation to zero in the quantization since the last ¾ of the transformation do not hold much important iris pattern texture. Also, future research should put forth effort in extracting the pupil in the quantization, since the pupil has unnecessary information needed for optimal iris image compression. Research should also aim at finding a measure in place of the PSNR for better evaluation of detail retention in the final inverse image when compared to the original.

Acknowledgements

This work was supported in part by The National Research Experience for Undergraduates Program (NREUP) which is a program of the *Mathematical Association of America*, funded by the *National Security Agency* (H98230-13-1-0270) and the *National Science Foundation* (DMS-1156582. The authors also express appreciation to Dr. Helmut Knaust for his mentorship and guidance through this project.