12-17-2010

Nonattribution Properties of JPEG Quantization Tables

Punnya Tuladhar
University of New Orleans

Non-attribution Properties of JPEG Quantization Tables

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Science
in
Computer Science

by

Punnya Tuladhar

B.E. Pulchowk Campus, Nepal, 2004

December, 2010

ACKNOWLEDGMENT

I am grateful to Dr. Vassil Roussev, my thesis advisor, for providing me topic of this thesis and guiding and instructing me through every step of this research. Without his help, this thesis wouldn't be possible. Also, I would like to show my gratitude to Dr. Golden Richard and Dr. Shengru Tu for being members of the thesis committee.

CONTENTS

LIST OF FIGURES

ABSTRACT

In digital forensics, source camera identification of digital images has drawn attention in recent years. An image does contain information of its camera and/or editing software somewhere in it. But the interest of this research is to find manufacturers (henceforth will be called make and model) of a camera using only the header information, such as quantization table and huffman table, of the JPEG encoding.

Having done a research on around 110, 000 images, we reached to state that *"For all practical purposes, using quantization and huffman tables alone to predict a camera make and model isn't a viable approach"*. We found no correlation between quantization and huffman tables of images and makes of camera. Rather, quantization or huffman table is determined by the quality factors like resolution, RGB values, intensity etc. of an image and standard settings of the camera.

KEYWORDS:
identification of camera, huffman table, quantization table, jpeg exif data, correlation of camera and quantization

CHAPTER 1:
INTRODUCTION

Attribution is a critical component of forensic analysis both in the physical and the digital world. One particular attribution problem, source camera identification for digital images, has received quite a bit of attention in recent years. Indeed, a number of research results point rather unambiguously that it is possible to reliably identify the source camera based on artifacts that are a function of the inherent sensor imperfections of each camera.

A related problem is that of source camera *model* identification: given an image, identify the model and/or manufacturer of the source camera. It is increasingly becoming accepted wisdom that a camera *model* fingerprint could be derived using only the header information, such as the quantization and Huffman tables, of the JPEG encoding. The underlying assumption is that camera manufacturers produce unique implementations for each camera model (or at least each line of camera models) and that such uniqueness can be readily observed from the basic parameters of the image. The idea is conceptually similar to an approach routinely used by network security tools to map out network services.

Farid's original study of images from 204 cameras that started this line of work. This was followed up by a large-scale statistical study which concluded that *"while the JPEG quantization table is clearly not unique, it (paired with the image resolution) is reasonably effective at narrowing the source of an image to a single camera make and model or to a*

small set of possible cameras”. Some tools, such as JPEGSnoop maintain a collection of “camera fingerprints”.

Our own experience in attempting to apply a similar methodology on a real-world sample ran into serious problems. In our work, we present an empirical study of ~110,000 JPEG qunatization tables (Q-tables) that contradicts the conclusions by previous work. Our inquisition was- Given a set of JPEG, what is the likelihood that we can correctly identify make/model based on Q-tables?

CHAPTER 2:
DESIGN OF THE STUDY

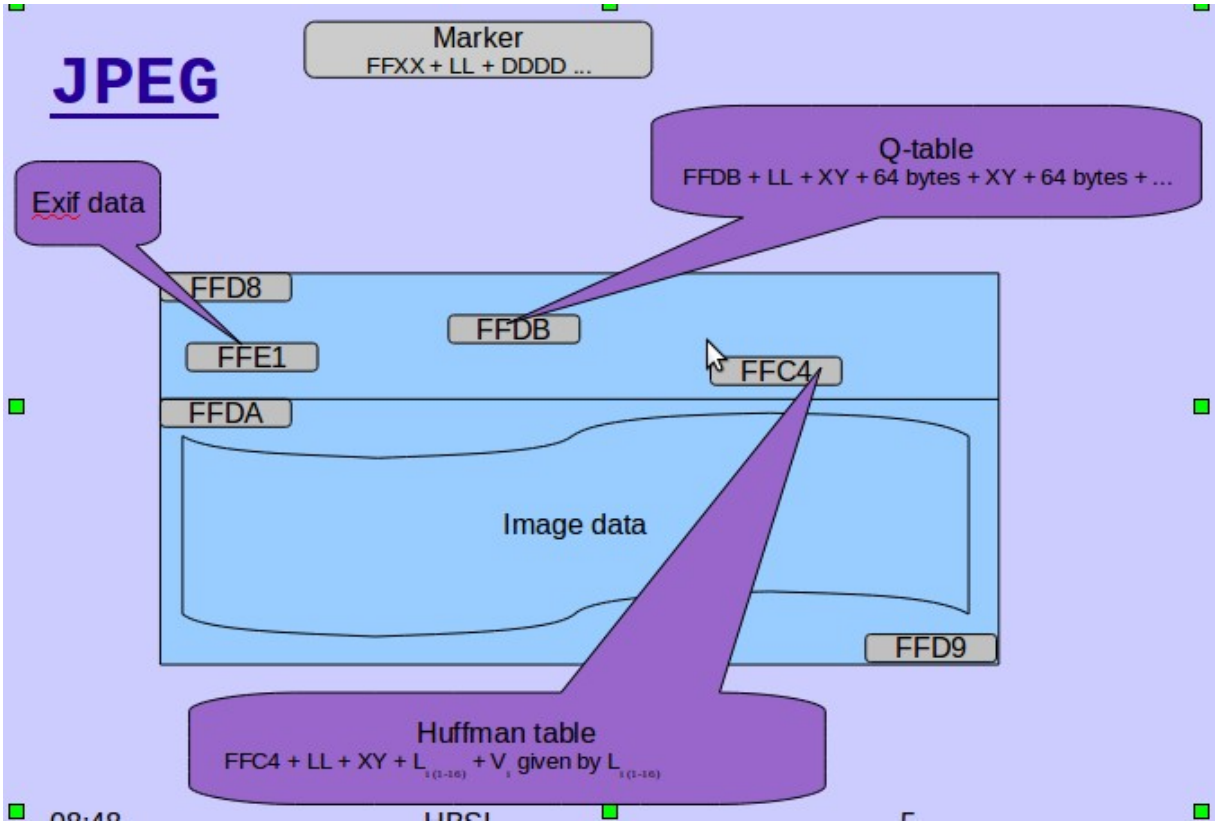
Our research comprised of 4 different phases-

1. Extraction of quantization and huffman tables.
2. Hash Generation
3. Extraction of Exif data.
4. Statistical Analysis

In the first phase, we extracted quantization and huffman tables from 109,774 images downloaded from http://domex.nps.edu/corp/files/govdocs1/. The resulted quantization tables were ~204,000 in number whose hash values were generated using md5sum in second phase. Then exif information of images and source camera or software were extracted; which were combined with the hash values and resulted data set was used for statistical analysis.

2.1 Structure of JPEG

Figure below shows the file organization of JPEG format. JPEG [Joint Photographic Experts Group] or jpg refers to a standard organization, a method of file compression, and sometimes file format. The JPEG File Interchange Format [JFIF] is designed to allow files containing JPEG-encoded data streams to be exchanged between otherwise incompatible systems and applications. A JFIF file is basically a JPEG data stream with a few restrictions and identifying marker. Both JPEG and JFIF data are byte streams, always storing 16-bit word values in big endian format. JPEG data in general is stored as stream of blocks, and each block is identified by a marker value.



Fig#1: JPEG File Organization

Every JPEG file starts with binary value 'FFD8', ends with binary value 'FFD9'. There are several binary FFXX data in JPEG data, they are called "Marker", and it means the period of JPEG information data. FFD8 means SOI(Start of image), FFD9 means EOI(End of image). Basic format of Marker is below.

FFXX + Length + Data

Details of each marker can be found at itu-t81.pdf documentation.

If there is a marker like this-

FF C1 00 0C XX XX XX …

It means this marker(FFC1) has 000C(equal 12)bytes of data including the length [2 bytes] of this length specifier too. It follows only 10 bytes of data after 000C.

In JPEG format, some of markers describe data, then SOS(Start of stream) marker placed. After the SOS marker, JPEG image stream starts and terminates with EOI marker. Real data starts with the marker FFDA.

Exif:

Basically, Exif file format is the same as JPEG file format. Exif inserts some of image/digicam information data and thumbnail image to JPEG in conformity to JPEG specification. Exif data starts with the marker FFE1 and contains information like make, model of camera, resolution, size, dates, software etc.

Quantization Table:

Quantization table is an 8*8 table which controls the quantization quality in a jpeg image. Typically, an image has 2 (or 3) such tables. It is generated by cameras or photo editing softwares for each image which differ depending on both the quality settings of cameras and on the standards which cameras or softwares follow.

In image header, this table starts with the marker FFDB in the format as shown below:

FFDB + LL + 00 + 64 byte data + 01 + 64 byte data + 02 + …

where the sequence 00, 01, 02 appears like incremented table counters but in fact they are combination of element precision

of data (0 or 1) and destination identifier (0 to 3) at the decoder. LL is total length including length of LL.

Huffman Table:

Huffman coding is used in jpeg compression. Huffman tables generated by cameras and photo editing softwares. This table starts with marker FFC4 in the format as below:

FFC4 + LL + XY + $L_{i\,(1\text{-}16)}$ + V_i given by $L_{i\,(1\text{-}16)}$
LL is total length of all huffman tables, length of length specifier inclusive,
X is 0 or 1 indicating DC table or AC table respectively,
Y is destination identifier (0 to 3) at the decoder,
Each Li gives number of huffman codes for each of the 16 possible lengths,
Vi is Vi bytes of codes given by each Li.
This can be more clear by the formula:
LL = 2 + sum of $(17 + m_t)$, t= 1 to n.
and
m_t = sum of Li , i = 1-16

2.2 Source Data

The original data set "ffdb_hash" required to perform statistical analysis was obtained by running hash_calc.sh on quantization tables which were obtained by running FFDBExtractor.java (see appendix). This was then reformatted to "ffdb_hash_formatted" file using Format.java. Using freq.sh, frequency of the hashes from ffdb_hash was computed and saved to "ffdb_hash_freq". Certain number of exif data extracted from all ~110K images, using ExifExtractor.java, were first normalized so that it contained only meaningful words and then saved to "data_set_final".

```
########### ffdb_hash #############
0656ffc785f02947576c3b671c50db9b  000107.00.ff-db
54e464a3c6056f015f7da1e86a0086f8  000107.01.ff-db
c30a1cdefc2d7ef4914b2bfdbf33743c  000108.00.ff-db
6307cac23d9b65d1c95cd695a22d1f26  000108.01.ff-db
0656ffc785f02947576c3b671c50db9b  000109.00.ff-db
54e464a3c6056f015f7da1e86a0086f8  000109.01.ff-db
0656ffc785f02947576c3b671c50db9b  000110.00.ff-db
54e464a3c6056f015f7da1e86a0086f8  000110.01.ff-db
```

Fig#2: ffdb_hash

```
########## ffdb_hash_formatted #########
000107.jpg  00  0656ffc785f02947576c3b671c50db9b
000107.jpg  01  54e464a3c6056f015f7da1e86a0086f8
000108.jpg  00  c30a1cdefc2d7ef4914b2bfdbf33743c
000108.jpg  01  6307cac23d9b65d1c95cd695a22d1f26
000109.jpg  00  0656ffc785f02947576c3b671c50db9b
000109.jpg  01  54e464a3c6056f015f7da1e86a0086f8
000110.jpg  00  0656ffc785f02947576c3b671c50db9b
000110.jpg  01  54e464a3c6056f015f7da1e86a0086f8
```

Fig#3: ffdb_hash_formatted

```
########## ffdb_hash_freq ###########
21784    197abd2b5741a96ff5b83121f760ed52
19561    5524f5067b8475f1e7a29fd90c1d98ef
12505    c714773c7a90b0f95a0a714f3e18729e
12331    8a7c44033e511bbf00563b8beea563a6
8717     784d68ba9112308689114a6816c628ce
5588     0e4362ba11351c4808b4e46aeaf94170
5541     3fee0917e01167d5795ed5e4f283e3ad
5539     2417671783bf9c3261707fb94f7b6cc3
```

Fig#4: ffdb_hash_freq

```
################ data_set_final ####################
795043.jpg,0.056,,NIKON,d1x,CS2Mac
875003.jpg,0.3072,, ,,3.0
983694.jpg,0.4456,,KODAK,z740,CSWin
800534.jpg,3.24,, ,,
417505.jpg,1.6875,, ,,CSWin
542256.jpg,0.0702,60%, ,,
```

Fig#5: data_set_final

Then joining 3 data sets – ffdb_hash_formatted, ffdb_hash_freq and data_set_final, a master data set for statistical analysis was created.

```
############# ffdb_data_freq ####################
000ac84aa6fc3ae3c76872e55dc50c1d 164933.jpg 0.1 null null null null 01 388
000ac84aa6fc3ae3c76872e55dc50c1d 164935.jpg 0.1 null null null null 01 388
000ac84aa6fc3ae3c76872e55dc50c1d 173364.jpg 0.0 null null null null 01 388
000ac84aa6fc3ae3c76872e55dc50c1d 195389.jpg 0.3 null null null null 01 388
000ac84aa6fc3ae3c76872e55dc50c1d 251934.jpg 0.0 null olympus ud600 null 01 388
000ac84aa6fc3ae3c76872e55dc50c1d 253354.jpg 8.0 null sony dsc-h9 null 01 388
000ac84aa6fc3ae3c76872e55dc50c1d 255338.jpg 0.2 null panasonic dmc-lz2 null 01 388
```

Fig#6: ffdb_data_freq

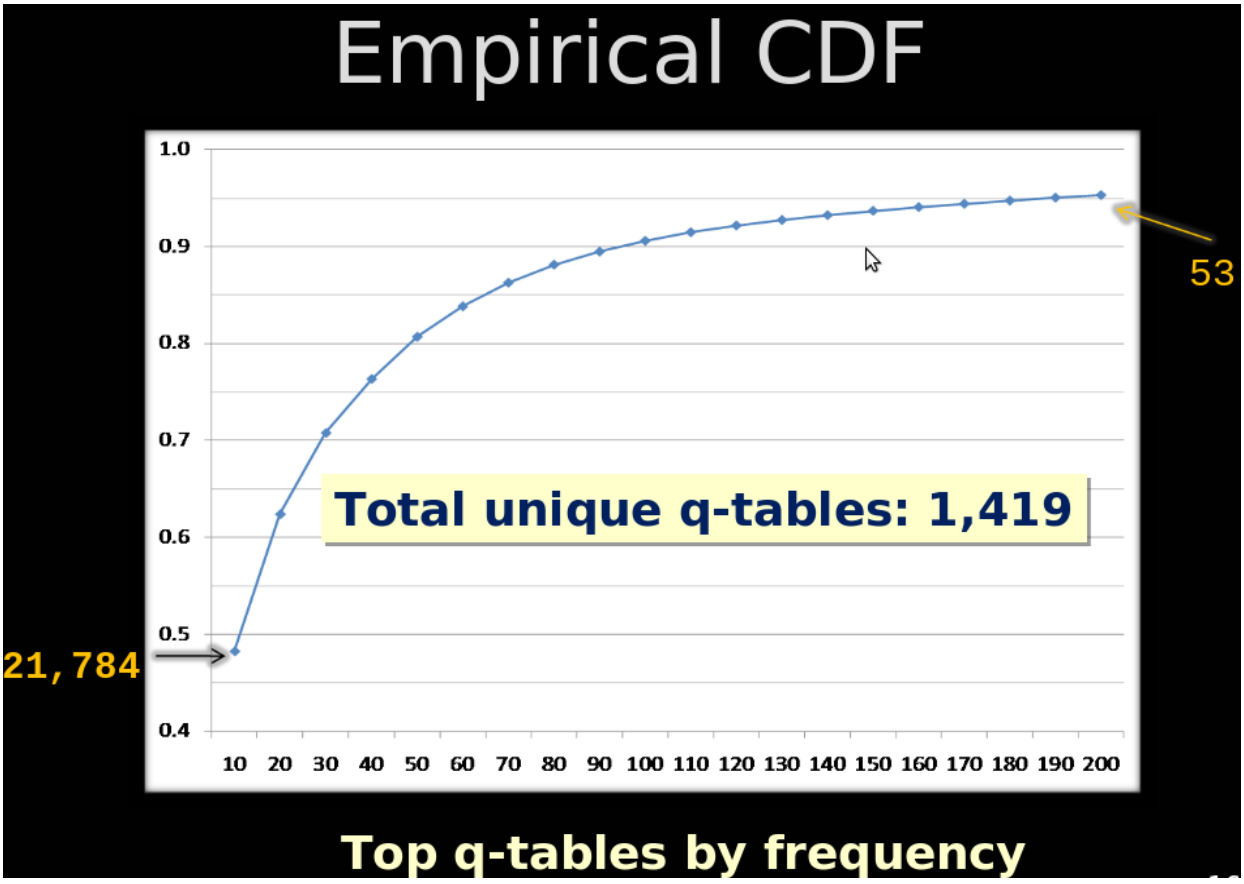
Similarly, ffc4_hash, ffc4_hash_formatted and ffc4_hash_freq were also generated.

CHAPTER 3:
ANALYSIS

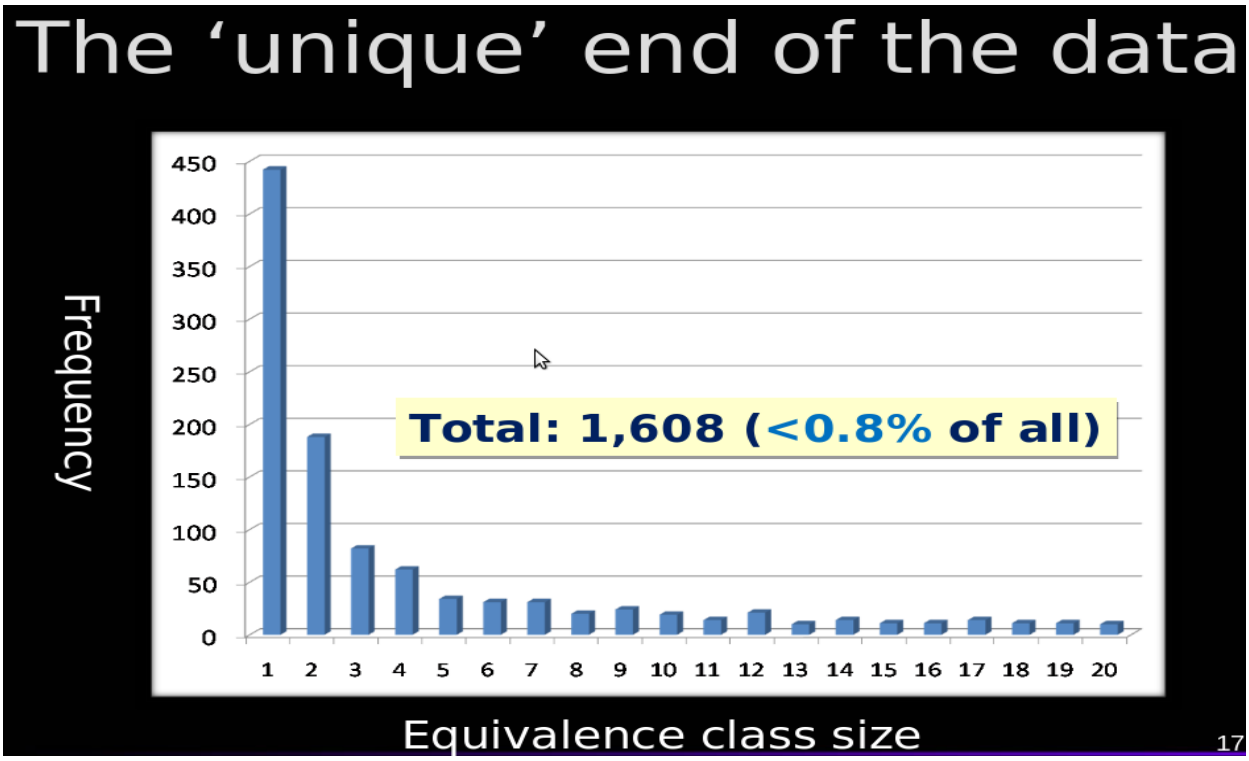
The file "ffdb_hash_formatted" contains ~204K quantization tables whose distribution looks like -

- 9% one table/image
- 89% two tables/image
- 2% three tables/image

Cumulative Distribution Function graph and class size vs frequency graph drawn for obtained results are given below.

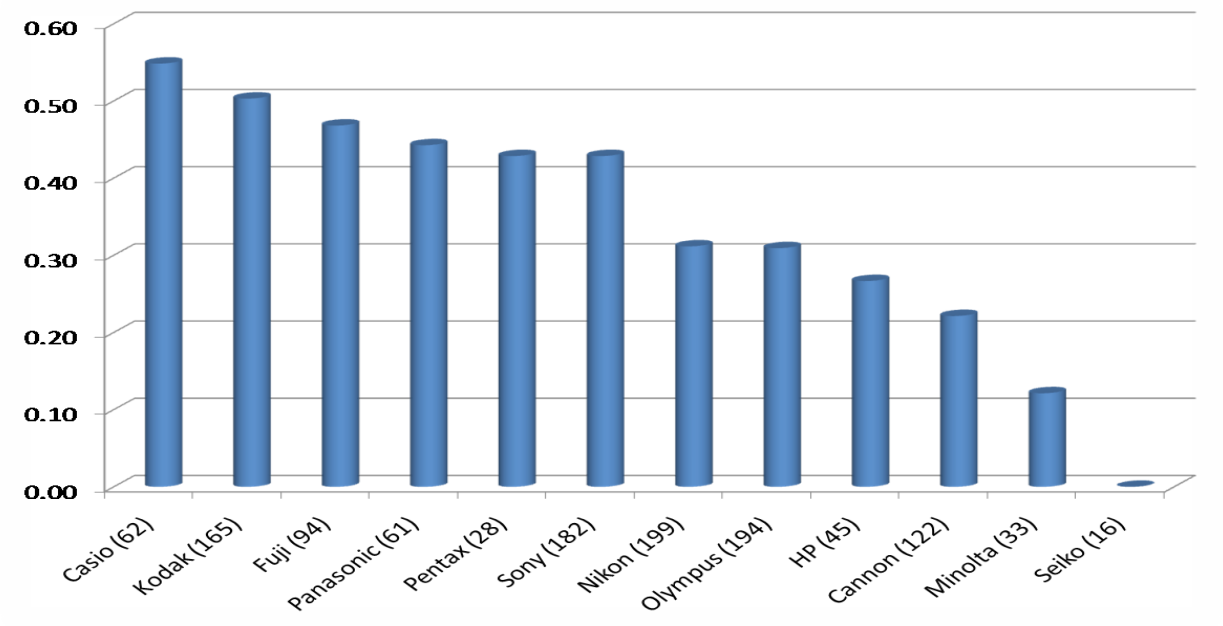


Fig#7: empirical_cdf



Fig#8: freq_vs_class

There were 1,419 unique ones whose distribution chart is



Fig#9: distribution_unique

Our preliminary findings are:

- The most frequent table accounted for over 10% of all occurences.
- The top 10 most frequent tables accounted for almost 50% of all occurrences.
- The top 200 accounted for over 95%.
- The 200^{th} ranked table occurred 53 times (with several different makes).
- There were less than 450 unique and less than 200 duplicate tables.
- There were a total of 1,060 tables(0.5% of total) that occurred 20 times or less (and had any hope as identifying features).

- Considering table uniqueness by make (fraction of tables observed only from the specific make):
  - 1 make (Seiko) had no make-specific table.
  - 5 had only 10-30% of their tables as make-specific.
  - 6 had 40-55%.

For both quantization and huffman tables, statistics based on make, model and photoshop version were calculated (see appendix) with the help of our generated files – ffdb_data_freq and ffc4_data_freq.

Observing these statistics, we can say that high frequency hash values (representing quantization or huffman tables) are associated with different makes, models and software versions.

REFERENCES

[1] ITU-T81.pdf

[2] http://park2.wakwak.com/~tsuruzoh/Computer/Digicams/exif-e.html

[3] http://www.fileformat.info/format/jpeg/egff.htm

[4] http://impulseadventure.com

[6] H. Farid, "Digital Image Ballistics from JPEG Quantization", Technical Report, TR2006-583, Dartmouth College, Computer Science.

[7] H. Farid, "Digital Image Ballistics from JPEG Quantization: A Followup Study", Technical Report, TR2008-638, Dartmouth College, Computer Science.

[8] Dr. Vassil Roussev, "JPEG Quantization Ballistics Revisited", NeFX 2010.

A: FFDBExtractor.java

```
import java.io.File;
import java.io.FileOutputStream;
import java.io.IOException;
import java.io.RandomAccessFile;
/*
 * version: 3
 * Extracts ff-db (quantization table).
 * QUANT. TABLE FORMAT:
 * ffdb |total-length|00|64bytes-data|01|64bytes-data|02 ...
 */
public class FFDBExtractor {
	private RandomAccessFile jpegSource;

	public static void main(String[] args) throws Exception{
	   File folder = new File("/media/corpora/jpg-set");
	   File[] listOfFiles = folder.listFiles();

	   for (int i = 0; i < listOfFiles.length; i++) {
	      String fullName = listOfFiles[i].getName();
	      System.out.println(i + ". Extracting ... " + fullName);
	      FFDBExtractor parser = new FFDBExtractor("/media/corpora/jpg-set/" + fullName);
	      parser.parse(fullName.substring(0, fullName.lastIndexOf(".")+1)); //include "."
	   }
		System.out.println("Finished");
	}

	public FFDBExtractor(String file) {
		try {
			this.jpegSource = new RandomAccessFile(file, "r");
		} catch (IOException e) {
			e.printStackTrace();
		}
	}

	public void parse(String fileName) throws IOException{
		this.jpegSource.seek(2);
		int c, j=0, k=0;

		while((c = this.jpegSource.read()) != -1){
			//read marker first
			String first = Integer.toHexString(c);
			String sec = Integer.toHexString(this.jpegSource.read());
			String lastName = "." + first + "-" + sec; //eg .ff-db; . for file extension
			//read 2 bytes of length
			String len1 = Integer.toHexString(this.jpegSource.read());
			String len2 = Integer.toHexString(this.jpegSource.read());
			int length = Integer.parseInt(len1 + len2, 16);
```

```
                        //if data stream started , end parsing
                        if(first.equals("ff") && sec.equals("da")){
                                break;
                        } else if(first.equals("ff") && sec.equals("db")){
                                int times = length/64; //size of quantization table = 64 bytes
                                for(int n = 0; n < times; n++){
                                FileOutputStream fosdb = new FileOutputStream("ffdb/" + fileName +
String.format("%02d", j++) + lastName);
                                        //skip 1 byte which is quantization table counter.
                                        this.jpegSource.read();
                                        for(int i = 0; i < 64; i++){
                                                fosdb.write(this.jpegSource.read());
                                        }

                                        fosdb.close();
                                        fosdb = null;
                                }
                        } else {
                                Long current = this.jpegSource.getFilePointer();
                                this.jpegSource.getChannel().position(current + length - 2);
                        }
                }

                this.jpegSource.close();
                this.jpegSource = null;
        }
}
```

B: FFC4Extractor.java

```
import java.io.File;
import java.io.FileOutputStream;
import java.io.IOException;
import java.io.RandomAccessFile;
/*
 * version: 3
 * Extracts ff-c4 (huffman table).
 *  HUFF TABLE FORMAT:
 *  ffc4|total-length|ac-dc|16bytes-length|data-l|ac-dc|16bytes-length|datal-l|... where
 *  16bytes-length: l1, l2, ... l16
 *  data-l: val of l1 + val of l2 + ... + val of l16
 */

public class FFC4Extractor {
        private RandomAccessFile jpegSource;

        public static void main(String[] args) throws Exception{
                File folder = new File("/media/corpora/jpg-set");
           File[] listOfFiles = folder.listFiles();
```

```
            for (int i = 0; i < listOfFiles.length; i++) {
                String fullName = listOfFiles[i].getName();
                System.out.println(i + ". Extracting ... " + fullName);
                FFC4Extractor parser = new FFC4Extractor("/media/corpora/jpg-set/" + fullName);
                        parser.parse(fullName.substring(0, fullName.lastIndexOf(".")+1)); //include "."
            }

                System.out.println("Finished");
        }

        public FFC4Extractor(String file) {
                try {
                        this.jpegSource = new RandomAccessFile(file, "r");
                } catch (IOException e) {
                        e.printStackTrace();
                }
        }

        public void parse(String fileName) throws IOException{
                this.jpegSource.seek(2);
                int c, j=0, k=0;

                while((c = this.jpegSource.read()) != -1){
                        //read 2 bytes marker
                        String first = Integer.toHexString(c);
                        String sec = Integer.toHexString(this.jpegSource.read());
                        String lastName = "." + first + "-" + sec;//eg .ff-c4; . as file extension

                        //read 2 bytes length
                        String len1 = Integer.toHexString(this.jpegSource.read());
                        String len2 = Integer.toHexString(this.jpegSource.read());
                        int length = Integer.parseInt(len1 + len2, 16);

                        //if data stream started , end parsing
                        if(first.equals("ff") && sec.equals("da")){
                                break;
                        } else if (first.equals("ff") && sec.equals("c4")){
                                long total = 2; //2bytes-total-length which is ffc4|total-length
                                do{
                                        FileOutputStream fosc4 = new FileOutputStream("ffc4/" + fileName +
String.format("%02d", k++) + lastName);
                                        //skip 1 byte which is huffman table counter.
                                        this.jpegSource.read();

                                        //read next 16 bytes which give total # of huffman codes
                                        int subTotal = 0;
                                        for(int h = 0; h < 16; h++){
                                                String len = Integer.toHexString(this.jpegSource.read());
                                                subTotal += Integer.parseInt(len, 16);
                                        }
```

```
                                        //extract codes
                                        for(int i = 0; i < subTotal; i++){
                                                fosc4.write(this.jpegSource.read());
                                        }

                                        fosc4.close();
                                        fosc4 = null;

                                        total += 17 + subTotal; // 1byte-counter + 16bytes-length
                                }while(length > total);
                        } else {
                                Long current = this.jpegSource.getFilePointer();
                                this.jpegSource.getChannel().position(current + length - 2);
                        }
                }

                this.jpegSource.close();
                this.jpegSource = null;
        }}
```

C: hash_calc.sh

```
          ##########  hash_calc.sh ##########
          #!/bin/sh
          echo "Generating hash ..."
          for f in *.*
          do
            md5sum $f  >> ffdb_hash
          done
          echo "Done."
```

D: Format.java

```
import java.io.FileNotFoundException;
import java.io.FileOutputStream;
import java.io.IOException;
import java.io.RandomAccessFile;

/*
 * cmd: java Format ffdb_hash
 * input : hash *.xx.ff-db
 * output: x.jpg xx hash
 *
 */

public class Format {
        RandomAccessFile jpegSource = null;
        FileOutputStream fosdb = null;

        public Format(String name){
                try {
                        jpegSource = new RandomAccessFile(name, "r");
```

```
                        fosdb = new FileOutputStream(name + "_formatted");
                } catch (FileNotFoundException e) {
                        e.printStackTrace();
                }
        }

        public static void main(String[] args){
                Format hc = new Format(args[0]);
                System.out.println("Re-formatting ...");
                hc.reFormat();
                System.out.println("Done.");
        }

        private void reFormat(){
                try {
                        String line = null;

                        while((line = jpegSource.readLine()) != null){
                                String[] parts = line.split("  ");
                                String[] segs = parts[1].split("\\.");

                                String hash_freq = segs[0] + ".jpg  " + segs[1] + "  " + parts[0] + "\n";
                                fosdb.write(hash_freq.getBytes());
                        }

                        jpegSource.close();
                        jpegSource = null;
                        fosdb.close();
                        fosdb = null;
                } catch (IOException e) {
                        e.printStackTrace();
                }
        }
}
```

E: freq.sh

```
############ freq.sh ################
sort | awk '{print $1}' | awk '{c[$1]++} END{for(i in c){printf "%4d\t%s\n",
c[i], i}}' | sort -rn
```

F: ExifExtractor.java

```
import java.io.BufferedReader;
import java.io.File;
import java.io.FileNotFoundException;
import java.io.FileOutputStream;
import java.io.IOException;
import java.io.InputStreamReader;

/* command:-
```

```
 * exiftool -make -model -xresolution -yresolution -resolutionunit -compressedbitsperpixel
 * -bitspersample -compression -datetimeoriginal -orientation -quality 005408.jpg
 */

public class ExifExtractor {
	public static void main(String args[]) {
		String s = null;
		BufferedReader stdInput;
		Process p = null;
		String cmd;

		File folder = new File("/media/corpora/jpg-set");
		File[] listOfFiles = folder.listFiles();
		FileOutputStream fosdb = null;

		try {
			fosdb = new FileOutputStream("exif_data");
		} catch (FileNotFoundException e1) {
			e1.printStackTrace();
		}

		for (int i = 0; i < listOfFiles.length; i++) {
			String make = " ", model = " ", xres = " ", yres = " ", resunit = " ", bitspp = " ",
			bitsps = " ", comp = " ", date = " ", orient = " ", qly= " ";

			try {
				String fullName = listOfFiles[i].getName();
				cmd = "ExifTool/exiftool -make -model -xresolution -yresolution -resolutionunit
-compressedbitsperpixel" +" -bitspersample -compression -modifydate -quality /media/corpora/jpg-set/" +
fullName;
				p = Runtime.getRuntime().exec(cmd);
				System.out.println(i + ". Extracting ... " + fullName);
				stdInput = new BufferedReader(new InputStreamReader(p.getInputStream()));

				while ((s = stdInput.readLine()) != null) {
					String[] parts = s.split(": ");
					if (parts[0].equals("Make                           ")) {
						if(parts.length > 1)
							make = parts[1];
					} else if (parts[0].equals("Camera Model Name               ")) {
						if(parts.length > 1)
							model = parts[1];
					} else if (parts[0].equals("X Resolution                    ")) {
						if(parts.length > 1)
							xres = parts[1];
					} else if (parts[0].equals("Y Resolution                    ")) {
						if(parts.length > 1)
							yres = parts[1];
					} else if (parts[0].equals("Resolution Unit                 ")) {
						if(parts.length > 1)
							resunit = parts[1];
```

```
                                        } else if (parts[0].equals("Compressed Bits Per Pixel       ")) {
                                                if(parts.length > 1)
                                                        bitspp = parts[1];
                                        } else if (parts[0].equals("Bits Per Sample                ")) {
                                                if(parts.length > 1)
                                                        bitsps = parts[1];
                                        } else if (parts[0].equals("Compression                    ")) {
                                                if(parts.length > 1)
                                                        comp = parts[1];
                                        } else if (parts[0].equals("Modify Date                    ")) {
                                                if(parts.length > 1)
                                                        date = parts[1].split(" ")[0];
                                        } else if (parts[0].equals("Orientation                    ")) {
                                                if(parts.length > 1)
                                                        orient = parts[1];
                                        } else if (parts[0].equals("Quality                        ")) {
                                                if(parts.length > 1)
                                                        qly = parts[1];
                                        }
                                }

                                String exifData = fullName + "|" + make + "|" + model + "|" + xres + "|" + yres +
"|" +
                                resunit + "|" + bitspp + "|" + bitsps + "|" + comp + "|" + date + "|" +
                                orient + "|" + qly + "\n";

                                fosdb.write(exifData.getBytes());

                                if(null != p)
                                        p.destroy();
                        } catch (IOException e) {
                                e.printStackTrace();
                                System.exit(-1);
                        }
                }

                try {
                        fosdb.close();
                        fosdb = null;
                } catch (IOException e) {
                        e.printStackTrace();
                }

                System.exit(0);
        }
}
```

G: q-table statistics by make

```
        21784 197abd2b5741a96ff5b83121f760ed52 sony
        21784 197abd2b5741a96ff5b83121f760ed52 seiko
```

```
21784 197abd2b5741a96ff5b83121f760ed52 panasonic
21784 197abd2b5741a96ff5b83121f760ed52 olympus
21784 197abd2b5741a96ff5b83121f760ed52 null
21784 197abd2b5741a96ff5b83121f760ed52 nikon
21784 197abd2b5741a96ff5b83121f760ed52 minolta
21784 197abd2b5741a96ff5b83121f760ed52 kodak
21784 197abd2b5741a96ff5b83121f760ed52 hewlett-packard
21784 197abd2b5741a96ff5b83121f760ed52 fujifilm
21784 197abd2b5741a96ff5b83121f760ed52 casio
21784 197abd2b5741a96ff5b83121f760ed52 canon
19561 5524f5067b8475f1e7a29fd90c1d98ef sony
19561 5524f5067b8475f1e7a29fd90c1d98ef seiko
19561 5524f5067b8475f1e7a29fd90c1d98ef panasonic
19561 5524f5067b8475f1e7a29fd90c1d98ef olympus
19561 5524f5067b8475f1e7a29fd90c1d98ef null
19561 5524f5067b8475f1e7a29fd90c1d98ef nikon
19561 5524f5067b8475f1e7a29fd90c1d98ef minolta
19561 5524f5067b8475f1e7a29fd90c1d98ef kodak
19561 5524f5067b8475f1e7a29fd90c1d98ef hewlett-packard
19561 5524f5067b8475f1e7a29fd90c1d98ef fujifilm
19561 5524f5067b8475f1e7a29fd90c1d98ef casio
```

H: q-table statistics by model

```
21784 197abd2b5741a96ff5b83121f760ed52 sony dsc-w7
21784 197abd2b5741a96ff5b83121f760ed52 sony dsc-t100
21784 197abd2b5741a96ff5b83121f760ed52 sony dsc-p92
21784 197abd2b5741a96ff5b83121f760ed52 sony dsc-p100
21784 197abd2b5741a96ff5b83121f760ed52 sony dsc-m1
21784 197abd2b5741a96ff5b83121f760ed52 sony dsc-h9
21784 197abd2b5741a96ff5b83121f760ed52 sony cybershot
21784 197abd2b5741a96ff5b83121f760ed52 sony cd-mavica
21784 197abd2b5741a96ff5b83121f760ed52 seiko photopc-850z
21784 197abd2b5741a96ff5b83121f760ed52 panasonic dmc-lc50
21784 197abd2b5741a96ff5b83121f760ed52 panasonic dmc-fz20
21784 197abd2b5741a96ff5b83121f760ed52 olympus x550
21784 197abd2b5741a96ff5b83121f760ed52 olympus u10d
21784 197abd2b5741a96ff5b83121f760ed52 olympus e-10
21784 197abd2b5741a96ff5b83121f760ed52 olympus c960z
21784 197abd2b5741a96ff5b83121f760ed52 olympus c900z
21784 197abd2b5741a96ff5b83121f760ed52 olympus c5060wz
21784 197abd2b5741a96ff5b83121f760ed52 olympus c5050z
21784 197abd2b5741a96ff5b83121f760ed52 olympus c3040z
21784 197abd2b5741a96ff5b83121f760ed52 null null
21784 197abd2b5741a96ff5b83121f760ed52 nikon e995
21784 197abd2b5741a96ff5b83121f760ed52 nikon e950
21784 197abd2b5741a96ff5b83121f760ed52 nikon e8700
21784 197abd2b5741a96ff5b83121f760ed52 nikon e5700
21784 197abd2b5741a96ff5b83121f760ed52 nikon e4600
21784 197abd2b5741a96ff5b83121f760ed52 nikon e3100
21784 197abd2b5741a96ff5b83121f760ed52 nikon e2000
```

```
21784 197abd2b5741a96ff5b83121f760ed52 nikon d50
21784 197abd2b5741a96ff5b83121f760ed52 nikon d200
21784 197abd2b5741a96ff5b83121f760ed52 nikon d1x
21784 197abd2b5741a96ff5b83121f760ed52 nikon d1h
21784 197abd2b5741a96ff5b83121f760ed52 nikon d100
21784 197abd2b5741a96ff5b83121f760ed52 nikon d1
```

I: q-table statistics by photoshop version

```
21784 197abd2b5741a96ff5b83121f760ed52 null
21784 197abd2b5741a96ff5b83121f760ed52 doc
21784 197abd2b5741a96ff5b83121f760ed52 cswin
21784 197abd2b5741a96ff5b83121f760ed52 7.0
21784 197abd2b5741a96ff5b83121f760ed52 5.2
21784 197abd2b5741a96ff5b83121f760ed52 5.0
21784 197abd2b5741a96ff5b83121f760ed52 4.0
21784 197abd2b5741a96ff5b83121f760ed52 3.0
19561 5524f5067b8475f1e7a29fd90c1d98ef null
19561 5524f5067b8475f1e7a29fd90c1d98ef doc
19561 5524f5067b8475f1e7a29fd90c1d98ef cswin
19561 5524f5067b8475f1e7a29fd90c1d98ef 7.0
19561 5524f5067b8475f1e7a29fd90c1d98ef 5.2
19561 5524f5067b8475f1e7a29fd90c1d98ef 5.0
19561 5524f5067b8475f1e7a29fd90c1d98ef 4.0
19561 5524f5067b8475f1e7a29fd90c1d98ef 3.0
```

J: h-table statistics by make

```
80402 50a73d7013e9803e3b20888f8fcafb15 vivitar
80402 50a73d7013e9803e3b20888f8fcafb15 sound
80402 50a73d7013e9803e3b20888f8fcafb15 sony
80402 50a73d7013e9803e3b20888f8fcafb15 seiko
80402 50a73d7013e9803e3b20888f8fcafb15 samsung
80402 50a73d7013e9803e3b20888f8fcafb15 research
80402 50a73d7013e9803e3b20888f8fcafb15 pentax
80402 50a73d7013e9803e3b20888f8fcafb15 panasonic
80402 50a73d7013e9803e3b20888f8fcafb15 panaso
80402 50a73d7013e9803e3b20888f8fcafb15 olympus
80402 50a73d7013e9803e3b20888f8fcafb15 null
80402 50a73d7013e9803e3b20888f8fcafb15 nikon
80402 50a73d7013e9803e3b20888f8fcafb15 newsoft
80402 50a73d7013e9803e3b20888f8fcafb15 msm6100
80402 50a73d7013e9803e3b20888f8fcafb15 motorola
80402 50a73d7013e9803e3b20888f8fcafb15 minolta
80402 50a73d7013e9803e3b20888f8fcafb15 logitech
80402 50a73d7013e9803e3b20888f8fcafb15 kyocera
80402 50a73d7013e9803e3b20888f8fcafb15 konica
80402 50a73d7013e9803e3b20888f8fcafb15 kodak
80402 50a73d7013e9803e3b20888f8fcafb15 jvc
80402 50a73d7013e9803e3b20888f8fcafb15 hp
80402 50a73d7013e9803e3b20888f8fcafb15 hewlett-packard
```

```
80402 50a73d7013e9803e3b20888f8fcafb15 fujifilm
80402 50a73d7013e9803e3b20888f8fcafb15 fuji
80402 50a73d7013e9803e3b20888f8fcafb15 casio
80402 50a73d7013e9803e3b20888f8fcafb15 canon
80402 50a73d7013e9803e3b20888f8fcafb15 asahi
42616 1274c9b90c56e7f0e589412cbad79aa2 vivitar
42616 1274c9b90c56e7f0e589412cbad79aa2 sound
42616 1274c9b90c56e7f0e589412cbad79aa2 sony
42616 1274c9b90c56e7f0e589412cbad79aa2 seiko
42616 1274c9b90c56e7f0e589412cbad79aa2 samsung
42616 1274c9b90c56e7f0e589412cbad79aa2 research
42616 1274c9b90c56e7f0e589412cbad79aa2 pentax
42616 1274c9b90c56e7f0e589412cbad79aa2 panasonic
42616 1274c9b90c56e7f0e589412cbad79aa2 panaso
42616 1274c9b90c56e7f0e589412cbad79aa2 olympus
42616 1274c9b90c56e7f0e589412cbad79aa2 null
```

K: h-table statistics by model

```
80402 50a73d7013e9803e3b20888f8fcafb15 canon ixy--50
80402 50a73d7013e9803e3b20888f8fcafb15 canon ixy--200a
80402 50a73d7013e9803e3b20888f8fcafb15 canon ixy
80402 50a73d7013e9803e3b20888f8fcafb15 canon ixus-400
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos--rebel-xt
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos--rebel
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-kiss
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-d60
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-5d
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-40d
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-350d
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-30d
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-20d
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-1d-mark-ii
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-1d
80402 50a73d7013e9803e3b20888f8fcafb15 canon eos-10d
80402 50a73d7013e9803e3b20888f8fcafb15 asahi optio-330
42616 1274c9b90c56e7f0e589412cbad79aa2 vivitar vivicam-3715
42616 1274c9b90c56e7f0e589412cbad79aa2 sound null
42616 1274c9b90c56e7f0e589412cbad79aa2 sound .
42616 1274c9b90c56e7f0e589412cbad79aa2 sony picturegear
42616 1274c9b90c56e7f0e589412cbad79aa2 sony mvc-cd500
42616 1274c9b90c56e7f0e589412cbad79aa2 sony mavica
42616 1274c9b90c56e7f0e589412cbad79aa2 sony fdmavica
42616 1274c9b90c56e7f0e589412cbad79aa2 sony dslr-a100
42616 1274c9b90c56e7f0e589412cbad79aa2 sony dsc-w7
42616 1274c9b90c56e7f0e589412cbad79aa2 sony dsc-w1
42616 1274c9b90c56e7f0e589412cbad79aa2 sony dsc-v3
42616 1274c9b90c56e7f0e589412cbad79aa2 sony dsc-v1
```

L: h-table statistics by photoshop version

```
        80402 50a73d7013e9803e3b20888f8fcafb15 null
        80402 50a73d7013e9803e3b20888f8fcafb15 ele5.0
        80402 50a73d7013e9803e3b20888f8fcafb15 ele2.0
        80402 50a73d7013e9803e3b20888f8fcafb15 doc
        80402 50a73d7013e9803e3b20888f8fcafb15 cswin
        80402 50a73d7013e9803e3b20888f8fcafb15 csmac
        80402 50a73d7013e9803e3b20888f8fcafb15 cs3mac
        80402 50a73d7013e9803e3b20888f8fcafb15 cs2win
        80402 50a73d7013e9803e3b20888f8fcafb15 cs2mac
        80402 50a73d7013e9803e3b20888f8fcafb15 alb2.0
        80402 50a73d7013e9803e3b20888f8fcafb15 7.0
        80402 50a73d7013e9803e3b20888f8fcafb15 5.2
        80402 50a73d7013e9803e3b20888f8fcafb15 5.0
        80402 50a73d7013e9803e3b20888f8fcafb15 4.0
        80402 50a73d7013e9803e3b20888f8fcafb15 3.0
        42616 1274c9b90c56e7f0e589412cbad79aa2 null
        42616 1274c9b90c56e7f0e589412cbad79aa2 ele5.0
        42616 1274c9b90c56e7f0e589412cbad79aa2 ele2.0
        42616 1274c9b90c56e7f0e589412cbad79aa2 doc
        42616 1274c9b90c56e7f0e589412cbad79aa2 cswin
        42616 1274c9b90c56e7f0e589412cbad79aa2 csmac
        42616 1274c9b90c56e7f0e589412cbad79aa2 cs3mac
        42616 1274c9b90c56e7f0e589412cbad79aa2 cs2win
```

VITA

The author was born in Kathmandu, Nepal. He obtained his bachelor's degree in computer engineering from Pulchowk Campus, Nepal in 2004. He joined the University of New Orleans to pursue masters degree in computer science in Spring 2009, and worked for Dr. Vassil Roussev as a research assistant.