Adjusted JPEG Quantization Tables in Support of GPS Maps

Yair Wiseman

Computer Science Department, Bar-Ilan University, Ramat-Gan 52900, Israel, wiseman@cs.biu.ac.il

Abstract.

Image quality manipulating in JPEG is done by quantization tables. JPEG has two quantization tables – one table for the luminance information and one table for the chrominance information. These quantization tables have been designed in support of images with few sharp changes; however, typically most GPS image maps have many sharp changes and as a result, the images are not optimally compressed. The designers of the quantization tables have presumed that sharp changes in the colors will rarely occur. Therefore, they divide the values that represent sharp changes in the frequency space by large numbers and divide other values by smaller numbers. As a result, when there are sharp changes in an image, the proportional allocation for each kind of data in the compressed image is inappropriate and results in an inefficient compression. In this paper the standard quantization tables have been modified as to handle the different kinds of GPS image map data appropriately. Consequently, the experimental results show that images with sharp changes are compressed more efficiently when making use of the new quantization tables.

Keywords. Image Compression, JPEG, GPS, Quantization Tables.

1. INTRODUCTION

JPEG is a longstanding image compression format. JPEG stands for "Joint Photographic Experts Group", which is the working group name which was established in 1986 by the CCITT and ISO Standards organizations with the intention of generating a standard for image compression. The group completed the design of the standard by early 1991 and after that the standard was accepted by the International Standards Organization (ISO) [1].

The first versions of JPEG had only an average compression ratio of 15:1; however, in recent years, JPEG have been succeeding to obtain much better compression ratios. These better compression ratios have been enabling real-time, full-motion and video applications to employ JPEG [2,3]. Also the feature of automatic error correction of JPEG promoted the format popularity [4,5].

GPS systems [6,7] usually make use of maps divided into small squares [8]. These small squares are commonly compressed by the JPEG algorithm so as to make the size of the data smaller [9,10].

The algorithm of the JPEG compression standard is explained briefly herein below:

JPEG makes use of the Chroma subsampling method of image encoding. This method supports lower resolution for chrominance data; whereas luminance data have a better resolution. This subsampling method takes advantage of the lower sensitiveness of usual human eyes to chrominance data.

Initially, JPEG converts the original image color into a suitable color space. Usually JPEG converts the image into YUV components [11]. The YUV components are interleaved together within the compressed data; however, the ratio between the Y components, the U components and the V components will typically not be one to one. The Y components will typically appear four times more than the U components and the V components. The Y components represent the luminance data of the block, whereas the U components and the V components represent the chrominance information of the block. For the reason that usual human eyes are more sensitive to the data of the Y components [12], more data is stored for the Y components in JPEG compressed file [13]. Specifically, the arrangement of the blocks in a JPEG compressed file is four Y components, one U component and one V component. Thereafter repeatedly, four Y components, one U component and one V component are stored; whereas each component represents the data of 8X8 pixels block.

This technique of quartered resolution of the U components and the V components is called 4:1:1 chroma subsampling, which denotes the luminance data and the chrominance data are in quantity of four for the luminance data, one for the U chrominance data and one for the V chrominance data. Specifically, for each sampled block of 16X16 divided to four blocks of 8X8 as in Figure 1, there are four Y components of luminance and only one U component of chrominance and one V component of chrominance [14].

.

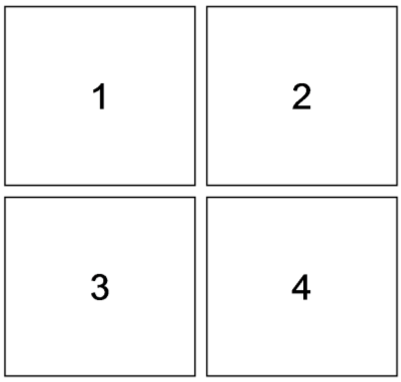

Figure 1: JPEG sampled block of 16X16

However, there is another chroma subsampling technique of JPEG which is named 4:2:0. In this subsampling technique, the horizontal sampling of the U components and the V components is doubled compared to 4:1:1 chroma subsampling, but the vertical sampling of the U components and the V components is equal to 4:1:1 chroma subsampling and the U components and the V components are sampled only on each alternate line.

JPEG supports values of 8 bits or 12 bits, which results in a range of 0-255 for 8 bits and 0-4095 for 12 bits. 8 bits are more common in use. These values are modified from unsigned integers in the range of [0,2p-1] to signed integers in the range of [-2p-1,2p-1-1], by reducing 2p-1 from their original values, where p is the precision (8 or 12) [15]. Next, these modified values are the input of the FDCT function.

JPEG gathers all the 8X8 values to one block. The blocks are arranged in lines from left to right from the top line of the image to the bottom line of the image. After that, JPEG converts each block to a frequency space using the Forward Discrete Cosine Transform (FDCT) [16]. This conversion keeps lower frequency data which human eyes are more sensitive to [17].

Next, the quantization is performed. For each block, each of its 64 values is divided by a predefined quantization coefficient and rounded to an integer value. Therefore, dividing by a large quantization coefficient will cause more information loss, so the quantization coefficients are decided according to the preferred balance between the compressed file size and the image quality.

The image maker decides about a number from 1 to 100 which denotes the image quality. The value 1 is the poorest image quality and the best compression ratio, whereas the value 100 is the best image quality and the poorest compression ratio. Actually, value 100 denotes a quantization table full of 1s which results in a smaller loss, because there is no loss in the dividing step, only the rounding causes a minor loss.

It is important to note that there is no standard practice for building the quantization table from the selected image quality, so the entire quantization table is stored in the compressed image file. This feature can be helpful for watermarking algorithms [18].

The last step of JPEG is reducing the file size by a version of Canonical Huffman compression [19]. JPEG also supports Arithmetic coding [20], but the default is the Canonical Huffman compression [21,22]. Since most of the image makers prefer to use the default, the use of Arithmetic code is very limited. Additional compression algorithms have been suggested for JPEG [23], but the official standard does not specify them as supported algorithms and most of the conventional applications does not support them [24].

This paper suggests improved quantization tables for JPEG images of GPS maps with the intention of generating a small information size.

2. CURRENT QUANTIZATION TABLES

There have been suggestions for improvement of JPEG quantization tables for specific uses [25]. The standard quantization tables are designed for general purpose; however, these tables are not suitable for every application. As a matter of fact, these standard quantization tables appear to be more suitable for images containing no sharp changes in the colors [26]. Images of maps usually contain many sharp changes in the colors.

Therefore, assuming that many changes in color do occur, the standard quantization tables can be adjusted with the purpose of producing better compression ratio.

The standard quantization tables of 90% which is commonly used in GPSes [27] are presented in Table 1a and Table 1b.

3	2	2	3	5	8	10	12
2	2	3	4	5	12	12	11
3	3	3	5	8	11	14	11
3	3	4	6	10	17	16	12
4	4	7	11	14	22	21	15
5	7	11	13	16	21	23	18
10	13	16	17	21	24	24	20
14	18	19	20	22	20	21	20

Table 1a: JPEG luminance quantization table of 90%

3	4	5	9	20	20	20	20
4	4	5	13	20	20	20	20
5	5	11	20	20	20	20	20
9	13	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20

Table 1b: JPEG Chrominance quantization table of 90%

The designers of these quantization tables have assumed that the chances for sharp changes in the colors are quite slight. Therefore, they put larger numbers in the right lower part of the quantization tables, so when the values in the right lower part of the block will be divided by these numbers, a significant amount of data will be gone. If indeed not much data is stored in the right lower part of the blocks, such quantization tables can be very effective. However, in blocks of images with sharp changes in the colors, the difference between the left upper part and the lower right part of the quantization tables will be smaller.

In the standard quantization tables of 90%, the difference between the highest value and the smallest value is about 7 times. In standard quantization tables of less than 90% the difference becomes even more substantial and can be easily even more than 10 times. When there are sharp changes in the pictures, these differences are not suitable and must be reduced.

The sharp changes in the images of maps do not have an effect only on the AC values in the blocks, but also on the DC values. The most upper left value of each 8X8 block is called "DC" [28]. DC is the sum of the sampling values in the block divided by eight; however, since the algorithm of JPEG presumes that sharp changes in the color do not often occur, the difference between the DCs of adjacent blocks is expected to be small [29], so it is better to store the difference between the previous DC value and the current DC value which is anticipated to be smaller than the DC value itself and therefore can be compressed better [30,31].

In images of GPS maps, sharp changes are more likely to occur, so the DC differences might be higher and even if a DC difference is divided by a larger number, it will not be zeroing.

3. ADJUSTED QUANTIZATION TABLES FOR GPS MAPS

There have been several works about identifying sharp changes in JPEG images, so as to utilize these sharp changes for a number of applications such as detection of a cancerous lesion [32,33], finding damages in tires [34,35,36], locating damages in fuselages [37,38], observing of traffic congestions [39,40,41], an alert system for worn out pipes in autonomous vehicles [42], safety mechanism for SkyTran tracks [43] and adjustable flush toilet [44].

We suggest adjusting the quantization tables for images with sharp changes. The sharp changes in the colors give rise to a smaller difference between the left upper part and the lower right part of the JPEG blocks. Therefore, an adjustment of the quantization tables can provide a better compression ratio.

Usually, there is still difference between the left upper part and the lower right part of the JPEG blocks of GPS maps, but the difference is smaller, so we suggest for the luminance component this formula:

$$f(x) = \frac{8 * \tan^{-1}\left(\frac{x}{16}\right)}{\pi} + 8 * \mathrm{DOTTIE}$$

Where:

$$x = X^2 + Y^2$$

X is the index of the coefficient in the X-axis.

Y is the index of the coefficient in the Y-axis.

f(x) is the value of the coefficient in the quantization table.

DOTTIE is the Dottie number [45].

The graph of the formula is depicted in Figure 2.

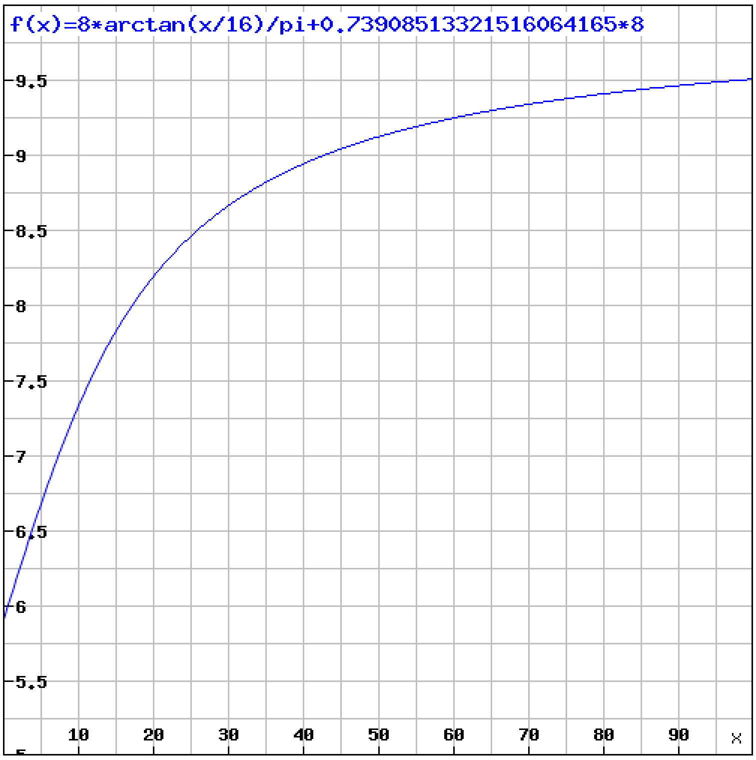

Figure 2. Graph of the luminance quantization table values.

For the chrominance quantization table we suggest this formula:

$$f(x) = \pi * \tan^{-1}\left(\frac{x}{16}\right) + 8 * \mathrm{DOTTIE}$$

Where:

$x = X^2 + Y^2$

X is the index of the coefficient in the X-axis.

Y is the index of the coefficient in the Y-axis.

f(x) is the value of the coefficient in the quantization table.

DOTTIE is the Dottie number.

The graph of the formula is depicted in Figure 3.

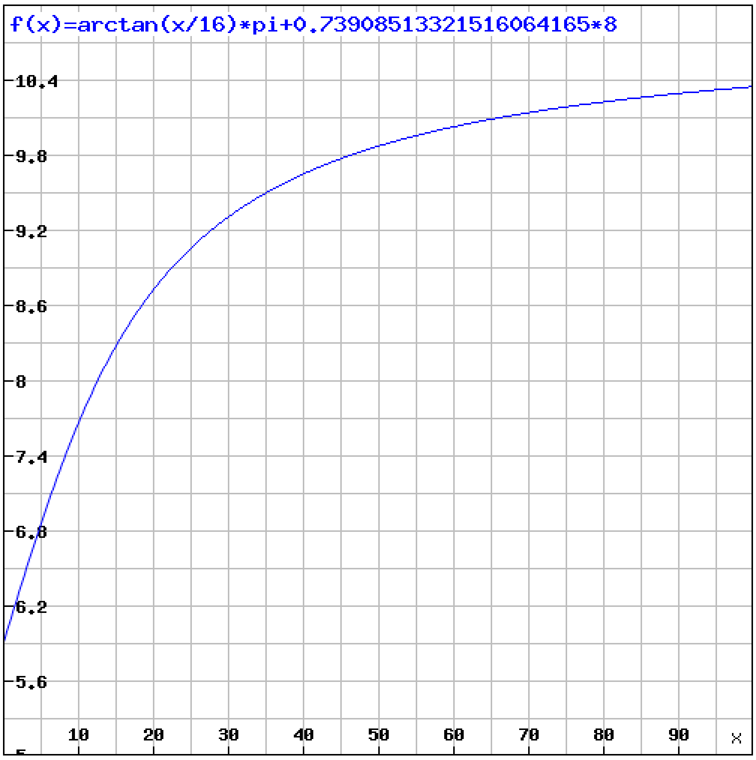

Figure 3. Graph of the chrominance quantization table values.

Accordingly, the new quantization tables are shown in Tables 2a and 2b.

6	6	6	6	8	8	9	9
6	6	6	6	8	8	9	9
6	6	6	6	8	8	9	9
6	6	6	8	8	9	9	9
8	8	8	8	9	9	9	9
8	8	8	9	9	9	9	9
9	9	9	9	9	9	9	9
9	9	9	9	9	9	9	9

Table 2a: New JPEG luminance quantization table.

6	6	6	6	8	8	9	10
6	6	6	6	8	8	9	10
6	6	6	6	8	8	9	10
6	6	6	8	8	9	9	10
8	8	8	8	9	9	10	10
8	8	8	9	9	10	10	10
9	9	9	9	10	10	10	10
10	10	10	10	10	10	10	10

Table 2b: New JPEG Chrominance quantization table.

In both of the luminance quantization table and the chrominance quantization table the values of the lower right part have been reduced and the values of upper left part have been increased in order to make smaller differences between the coefficients produced by the DCT algorithm.

4. EXPERIMENTAL RESULTS

Figure 4a contains an image of a GPS map [46] of a region in Jerusalem, Israel compressed by JPEG with standard quantization tables. The image contains many sharp changes. Therefore, the standard quantization tables are not so suitable for a proper compression.

Figure 4b contains the same image, but compressed with the suggested adjusted quantization tables. The differences between the images are unnoticeable; however, the standard quantization tables produced a file size of 130,991 bytes, whereas the suggested adjusted quantization tables produced a file size of 120,303 bytes. That is to say a save of 8.16%.

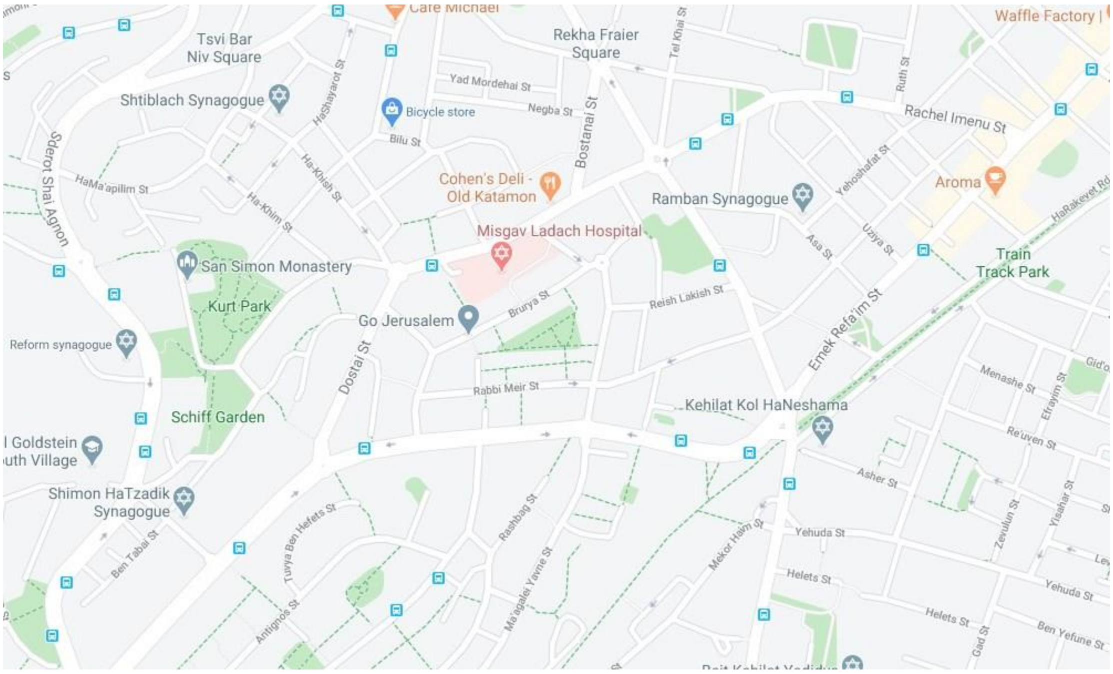

Figure 4a: GPS map of a region in Jerusalem compressed by the standard quantization tables.

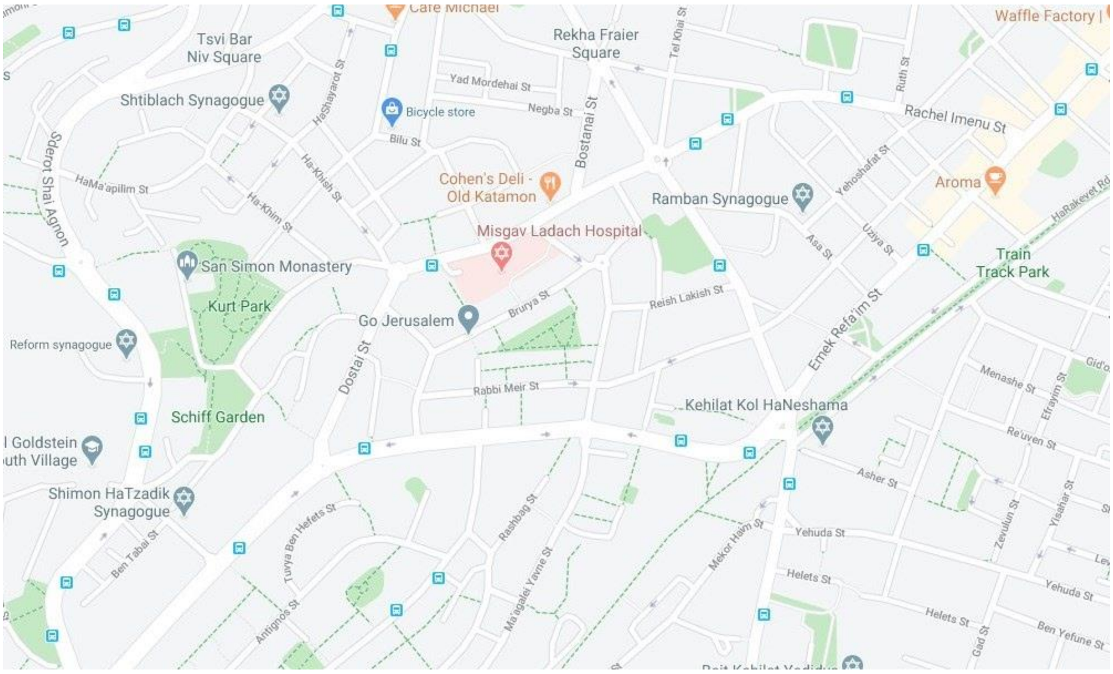

Figure 4b: GPS map of a region in Jerusalem compressed by the suggested adjusted quantization tables.

It should be noted that sometimes images of GPS maps can be with almost no sharp changes like a road in an uninhabited region. Figure 5a contains an image of a GPS map of an uninhabited region in the Negev district, Israel. This image has been compressed using the standard quantization tables.

Figure 5b contains the same image as Figure 5a; however, In Figure 5b the image has been compressed by the suggested adjusted quantization tables. The dimensions of the images are exactly the same size of Figures 4a and 4b; however, because there are very few sharp changes in Figures 5a and 5b, the images' sizes are smaller.

The size of the image in Figure 5a is 14,015 bytes; whereas the size of Figure 5b is 14,203 bytes. In other words, the size of the image compressed by the suggested adjusted quantization tables is larger than the size of the image compressed by the standard quantization tables. The addition is not large, only 1.34%, but since the suggested adjusted quantization tables have been designed for images with many sharp changes, there will be a small increase in the file sizes if the image contains very few sharp changes.

Figure 5a: GPS map of an uninhabited region compressed by the standard quantization tables.

Figure 5b: GPS map of an uninhabited region compressed by the suggested adjusted quantization tables.

Figures 4a,4b and 5a,5b show extreme cases – many changes and no changes. A case in the middle is shown in Figures 6a and 6b. The left part of image contains a sea which has no changes, whereas the right part contains a part of the city of Tel-Aviv which has many changes.

Figure 6a has been compressed with the standard quantization tables of 90% whereas Figure 6b the image has been compressed by the suggested adjusted quantization tables. The dimensions of the images are exactly the same size of Figures 4a, 4b, 5a and 5b; however, because it is a middle case, the results are worse than Figure 4a and 4b and better than Figures 5a and 5b.

The size of the image in Figure 6a is 103,726 bytes; whereas the size of Figure 6b is 99,919 bytes, i.e. 3.67% has been saved by using the suggested adjusted quantization tables which is less than the 8.16% obtained in the image with the many sharp changes and more than the -1.34% obtained in the image with almost no sharp changes.

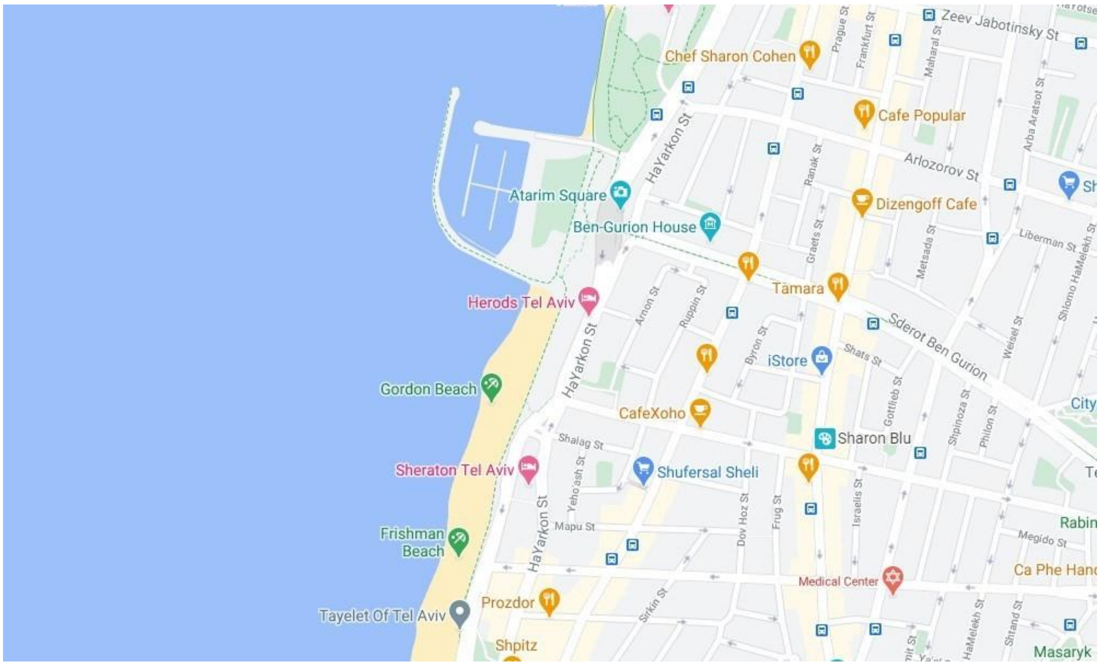

Figure 6a: GPS map of Tel-aviv seashore compressed by the standard quantization tables

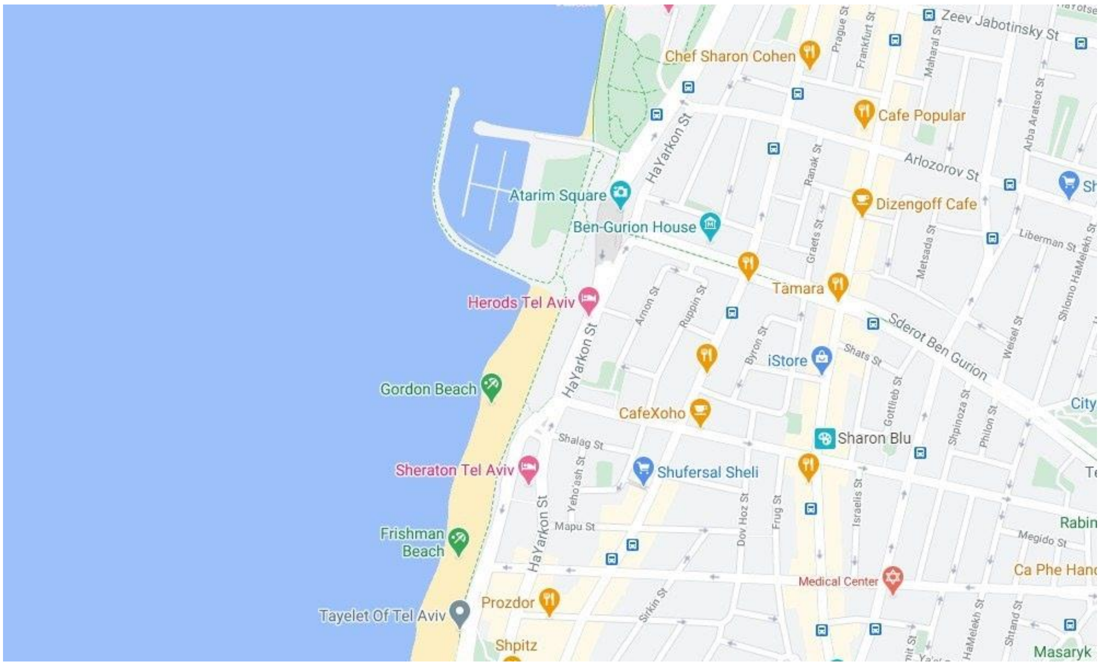

Figure 6b: GPS map of Tel-aviv seashore compressed by the suggested adjusted quantization tables.

The experiment results are summarized in Table 3.

Image type	Image file size when compressed by the standard quantization tables	Image file size when compressed by the suggested adjusted quantization tables	Percent saved by using the suggested adjusted quantization tables
Image with many sharp changes	130,991	120,303	8.16
Image with almost no sharp changes	14,015	14,203	-1.34
A middle case of sharp changes	103,726	99,919	3.67

Table 3: summary of experimental results

Usually GPS image maps contain a sufficient amount of sharp changes that make the use of the suggested adjusted quantization tables worthwhile. Yet, it should be noted that there is no change in the clarity of the maps when using the suggested adjusted quantization tables regardless of the image content. I. e. Many sharp changes or few sharp changes do not change the quality of the image.

5. CONCLUSIONS

GPS stores many map images in its memory [47,48]. To accommodate these memory needs, compression is applied [49,50]. We suggest a technique to obtain a lower compressed file size of GPS image compressed by JPEG algorithm without changing the algorithm itself. We just modify the quantization tables that are stored within the JPEG images.

The proper quantization tables for images with many sharp changes are different from quantization tables for images with few sharp changes. The sharp changes in the colors generate a smaller difference between the left upper part and the lower right part of the JPEG blocks. In order to adjust both the luminance quantization table and the chrominance quantization table so they will meet the attributes of GPS image maps, the values of the lower right part have been reduced and the values of upper left part have been increased with the aim of making smaller differences between the coefficients produced by the DCT algorithm. As we have shown in this paper, such an adjustment of the JPEG quantization tables can provide a better compression ratio in images containing GPS maps.

6. REFERENCES

[1] J. Guo and X. Lv, "Comparison and analysis of the compression algorithm based on DCT and DWT warehousing image", In Proceedings of 2015 International Symposium on Computers & Informatics. Atlantis Press, (2015).

[2] P. Holub, M. Šrom, M. Pulec, J. Matela and M. Jirman. "GPU-accelerated DXT and JPEG compression schemes for low-latency network transmissions of HD, 2K, and 4K video", Future Generation Computer Systems, Vol. 29, No. 8, (2013).

[3] H. Sohn, W. De Neve and Y. M. Ro, "Privacy protection in video surveillance systems: Analysis of subband-adaptive scrambling in JPEG XR", IEEE Transactions on Circuits and Systems for Video Technology, Vol. 21, No. 2, pp. 170-177, (2011).

[4] Y. Wiseman, "Diminution of JPEG Error Effects", The Seventh International Conference on Future Generation Information Technology, Vol. 117, pp. 6-9, (2015).

[5] Y. Wiseman, "Alleviation of JPEG Inaccuracy Appearance", International Journal of Multimedia and Ubiquitous Engineering, Vol. 11(3), pp. 133-142, (2016).

[6] Y. Zhang and K. T. Chong, "A GPS/DR data fusion method based on the GPS characteristics for mobile robot navigation", International Journal of Control and Automation, Vol. 7, No. 10, pp. 119-132, (2014).

[7] A. M. Hasan, K. Samsudin and A. R. Ramli, "GPS/INS Integration Based on Dynamic ANFIS Network", International Journal of Control and Automation, Vol. 5, No. 3, pp. 1-21, (2012).

[8] J. Wang, X. Rui, X. Song, X. Tan, C. Wang and V. Raghavan, "A novel approach for generating routable road maps from vehicle GPS traces", International Journal of Geographical Information Science, Vol. 29, No. 1, pp. 69-91, (2015).

[9] Y. Wiseman, "Enhancement of JPEG compression for GPS images", International Journal of Multimedia and Ubiquitous Engineering, Vol. 10, No. 7, pp. 255-264, (2015).

[10] Y. Wiseman, "Improved JPEG Based GPS Picture Compression", Advanced Science and Technology Letters, (2015).

[11] Y. Yalman and İ. ERTÜRK, "A new color image quality measure based on YUV transformation and PSNR for human vision system", Turkish Journal of Electrical Engineering & Computer Sciences, Vol. 21, No. 2, pp. 603-612, (2013).

[12] M. Dreyfuss, and Y. Giat, "Decision support information system for urban lighting", Issues in Informing Science & Information Technology, Vol. 15, pp. 109-124, (2018).

[13] H. Chen, X. He, C. An and T. Q. Nguyen, "Deep wide-activated residual network based joint blocking and color bleeding artifacts reduction for 4: 2: 0 JPEG-compressed images", IEEE Signal Processing Letters, Vol. 26, No. 1, pp. 79-83, (2018).

[14] F. X. Coudoux, M. Gazalet and P. Corlay, "Reduction of color bleeding for 4: 1: 1 compressed video", IEEE transactions on broadcasting, Vol. 51, No. 4, pp. 538-542, (2005).

[15] T. Richter, A. Artusi and T. Ebrahimi, "JPEG XT: A new family of JPEG backward-compatible standards", IEEE Multimedia, Vol. 23, No. 3, pp. 80-88, (2016).

[16] Y. Wiseman, "The still image lossy compression standard – JPEG", Encyclopedia of Information and Science Technology, Third Edition, Vol. 1, Chapter 28, (2014).

[17] D. J. Fleet and D. J. Heeger, "Embedding Invisible Information in Color Images", In Proceedings of IEEE International Conference on Image Processing, vol. 1, Santa Barbara, CA, USA, pp. 532-535, (1997).

[18] R. M. Ahmad, X. Yao, S. A. Nawaz, U. A. Bhatti, A. Mehmood, M. A. Bhatti and M. U. Shaukat, "Robust Image Watermarking Method in Wavelet Domain Based on SIFT Features", In Proceedings of the 3rd International Conference on Artificial Intelligence and Pattern Recognition, pp. 180-185, (2020).

[19] S. R. Khaitu and S. P. Panday. "Canonical Huffman Coding for Image Compression", In 2018 IEEE 3rd International Conference on Computing, Communication and Security (ICCCS), pp. 184-190, (2018).

[20] Y. Wiseman, "A Pipeline Chip for Quasi Arithmetic Coding", IEICE Journal - Trans. Fundamentals, Tokyo, Japan, Vol. E84-A No.4, pp. 1034-1041, (2001).

[21] S. T. Klein and Y. Wiseman, "Parallel Huffman Decoding with Applications to JPEG Files", The Computer Journal, Oxford University Press, Swindon, UK, Vol. 46(5), pp. 487-497, (2003).

[22] S. T. Klein and Y. Wiseman, "Parallel Huffman Decoding", In Proceedings of Data Compression Conference DCC-2000, Snowbird, Utah, USA, pp. 383-392, (2000).

[23] X. Yuan and R. Haimi-Cohen, "Image Compression Based on Compressive Sensing: End-to-End Comparison with JPEG", IEEE Transactions on Multimedia, Vol. 22, No. 11, pp. 2889-2904, (2020).

[24] Y. Wiseman, "Burrows-Wheeler Based JPEG", Data Science Journal, Vol. 6, pp. 19-27, (2007).

[25] L. Y. Duan, X. Liu, J. Chen, T. Huang and W. Gao, "Optimizing JPEG Quantization Table for Low Bit Rate Mobile Visual Search" In Proceedings of 2012 IEEE Visual Communications and Image Processing Conference, pp. 1-6, (2012).

[26] Y. Wiseman, "Efficient Embedded Images in Portable Document Format (PDF)", International Journal of Advanced Science and Technology, Vol. 124, pp. 129-138, (2019).

[27] P. Drahoš, D. Manura, J. Barbero, "Independent JPEG Group's JPEG software", (2015), available online at: https://github.com/LuaDist/libjpeg

[28] H. Qiu, Q. Zheng, M. Qiu and G. Memmi, "DC Coefficients Recovery from AC Coefficients in the JPEG Compression Scenario", In Proceedings of International Conference on Smart Computing and Communication, pp. 266-276, Springer, (2019).

[29] H. Qiu, G. Memmi, X. Chen and J. Xiong, "DC Coefficient Recovery for JPEG Images in Ubiquitous Communication Systems", Future Generation Computer Systems, Vol. 96, pp. 23-31, (2019).

[30] K. Iida and H. Kiya, "Robust Image Identification with DC Coefficients for Double-Compressed JPEG Images", IEICE Transactions on Information and Systems, Vol. 102, No. 1, pp. 2-10, (2019).

[31] S. Kim, F. Huang and H. J. Kim, "Reversible Data Hiding in JPEG Images Using Quantized DC", Entropy, Vol. 21, No. 835, pp. 1-14, (2019).

[32] Y. Wiseman and E. Fredj, "Contour Extraction of Compressed JPEG Images", ACM - Journal of Graphic Tools, Vol. 6, No. 3, pp. 37-43, (2001).

[33] E. Fredj and Y. Wiseman, "An O(n) Algorithm for Edge Detection in Photos Compressed by JPEG Format", Proc. International Conference on Signal and Image Processing SIP-2001, Honolulu, Hawaii, pp. 304-308, (2001).

[34] Y. Wiseman, "Take a Picture of Your Tire!", Proc. IEEE Conference on Vehicular Electronics and Safety (IEEE ICVES-2010) Qingdao, ShanDong, China, pp. 151-156, (2010).

[35] Y. Wiseman, "The Effectiveness of JPEG Images Produced By a Standard Digital Camera to Detect Damaged Tyres", World Review of Intermodal Transportation Research, Vol. 4, No. 1, pp. 23-36, (2013).

[36] Y. Wiseman, "Camera That Takes Pictures of Aircraft and Ground Vehicle Tires Can Save Lives", Journal of Electronic Imaging, Vol. 22, No. 4, 041104, (2013).

[37] Y. Wiseman, "Fuselage Damage Locator System", Advanced Science and Technology Letters, Vol. 37, pp. 1-4, (2013).

[38] Y. Wiseman, "Device for Detection of Fuselage Defective Parts", Information Journal, Tokyo, Japan, Vol. 17, no. 9(A), pp. 4189-4194, (2014).

[39] Y. Wiseman, "Real-Time Monitoring of Traffic Congestions", IEEE International Conference on Electro Information Technology (EIT 2017), Lincoln, Nebraska, USA, pp. 501-505, (2017).

[40] Y. Wiseman, "Tool for Online Observing of Traffic Congestions", International Journal of Control and Automation, Vol. 10, No. 6, pp. 27-34, (2017).

[41] Y. Wiseman, "Computerized Traffic Congestion Detection System", International Journal of Transportation and Logistics Management, Vol. 1, No. 1, pp. 1-8, (2017).

[42] Y. Wiseman, "Automatic Alert System for Worn Out Pipes in Autonomous Vehicles", International Journal of Advanced Science and Technology, Vol. 107, pp. 73-84, (2017).

[43] Y. Wiseman, "Safety Mechanism for SkyTran Tracks", International Journal of Control and Automation, Vol. 10, No. 7, pp. 51-60, (2017).

[44] Y. Wiseman, "Adjustable and Automatic Flush Toilet", International Journal of Control and Automation, Vol. 13, No. 4, pp. 1-10, (2020).

[45] T. H. Miller, "On the numerical values of the roots of the equation cosx= x", Proceedings of the Edinburgh Mathematical Society, Vol. 9, pp. 80-83, (1890).

[46] R. Gibson and E. Schuyler, "Google Maps Hacks", First Edition, O'Reilly Media Inc., Sebastopol, CA, USA, (2006).

[47] D. Livshits and Y. Wiseman, "Cache Based Dynamic Memory Management for GPS", Proceedings of IEEE Conference on Industrial Electronics (IEEE ICIT-2011), Auburn, Alabama, pp. 441-446, (2011).

[48] D. Livshits and Y. Wiseman, "The Next Generation GPS Memory Management", International Journal of Vehicle Information and Communication Systems, Vol. 3(1), pp. 58-70, (2013).

[49] X. Xu, X. Gao, X. Zhao, Z. Xu and H. Chang, "A Novel Algorithm for Urban Traffic Congestion Detection Based on GPS Data Compression", In proceedings of 2016 IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI-2016), Beijing, China, pp. 107-112, (2016).

[50] S. C. Han, J. Sauber and F. Pollitz, "Coseismic compression/dilatation and viscoelastic uplift/subsidence following the 2012 Indian Ocean earthquakes

quantified from satellite gravity observations", Geophysical Research Letters, American Geophysical Union, Vol. 42, No. 10, pp. 3764-3772, (2015).

Biographies

Photograph

Yair Wiseman received the M.Sc. (summa cum laude) and Ph.D. degrees from Bar-Ilan University. He carried out his first Post-Doc research at the Hebrew University of Jerusalem, and the second Post-Doc research at the Georgia Institute of Technology, Atlanta, USA.

His research interests include autonomous vehicles, intelligent transportation systems, embedded systems, real-time systems, computational transportation science, operating systems, process scheduling, and data compression.

Dr. Wiseman has authored two books. He is on the editorial board of several journals, a member of dozens of conference committees and a reviewer of many scholarly journals.

Dr. Wiseman has been teaching in many institutes including Bar-Ilan University, The Hebrew University of Jerusalem and Israel Aircraft Industry and has been supervising many graduate students.

Dr. Wiseman has collaborated with other partners and received research grants to run an active laboratory from inter alia Sun Microsystems, Intel, and Polak Foundation.

Dr. Wiseman is an international expert who has reviewed and evaluated several large projects of the European Union, Israel Science Foundation, Marie Skłodowska-Curie actions in Ireland and the Ministry of Education and Science of Kazakhstan. His more than 50 journal papers have been published in many venues around the world.