Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
*Young Researches and Scientist Paper / * Supervisor, Mentor*

RELATION OF STATISTICAL INFORMATION AND VISUAL QUALITY IN HALFTONE IMAGES.

SECKAR, J[an] & POKORNY, P[avel]*

Abstract: *It is hard to choose the most suitable halftone algorithm for the image processing among the large number of existing algorithms. This article describes results of the research that try to find the connection of the visual halftone image quality and the statistical data obtained from the processed image. It describes two possible methods that can be used for evaluation of the algorithm quality in specific image application. These findings should make process of choosing the proper halftone algorithm easier.*
Key words: *halftone, statistical evaluation, visual quality*

1. INTRODUCTION

Halftone is a process that replaces the color palette of image by significantly lower resolution color palette with effort to sustain the highest possible amount of the information in the final image. Sustainment of the information is achieved by arrangement of pixels in patterns, which in a certain distance of observer from the image creates the illusion of colors that are not inherited in the processed image. This phenomenon is caused by the imperfect resolution capability of the eye, which does not recognize the individual dots but instead it percept them as the average color value. The usage of color depth reduction allows printing and displaying images with high color resolution on low resolution devices with an acceptable quality loss. Due the color depth reduction the size of the picture is reduced, because for one pixel is stored less information than for the original one. These features of halftoning can be also used for the reduction of the data flow of the images streamed in networks.

As Sharma (Sharma, 2003) stated that halftone originally established as a photographic method. In 1833 William Henry Fox Talbot experimented with the light capturing and developed the first photographic "negative-positive" process along with the first Halftone method.

Digital Halftone originated in the 60th with the need to reproduce images for binary displays. Therefore need to find a method that obtained the image with a binary color from the higher resolution image appeared. Nowadays, with the true color possibility, this method seems pointless, but as previously mentioned, not all devices are able to represent such a high color resolution, and therefore the reduction of color resolution with minimal loss of visual quality is required.

Halftone algorithms can be essentially divided into two basic groups. The first group is the AM halftone, which received its name from the amplitude modulation. Algorithms in this group create halftone images by changing the size (amplitude) of uniformly distributed points.

The algorithm Clustered-dot ordered Dither represent points by a matrix of pixels, which differs in size by desired color resolution. The size of used matrix can not be fully used, because only some arrangements of pixels are visually different. Different setup of the matrix can determine the shape of the resulting points and hence the resulting image appearance.

Another possibility to alter characteristics of the processed image is changing angle of points. According to Campbell (Campbell et al., 1966) it is recommended to use a rational angle, because of uneven thresholds matrix. Study suggests the rotation angle around 45 degrees, because the human visual system does not recognize linear artifacts around this point as easily as when they are aligned linearly or horizontally.

Since the AM halftone methods generate items which are easily noticeable because of their size, the alternative methods were proposed. These methods try to minimize the visibility of individual points. Because they do not work with the point size, but whit their density (frequency), this group of algorithms is called FM halftone. In this case points can have the smallest possible size, which is the screen or printer able to display.

The first applications from this group used similar principles as AM halftone algorithms. They used matrix of thresholds. High rated thresholds are distributed as much as possible in the matrix. The problem with these methods was formation of periodic structures in the result image, because the evaluations were calculated on relatively small field of thresholds. These methods include method Dispersed dot. This method works on the same principle as the above-mentioned method Clustered-dot, only uses a different threshold matrix in which individual pixels are more distributed in the matrix.

More sophisticated methods (Floyd & Steinberg, 1975) using thresholds and scatter errors between neighbor pixels, thereby reducing the loss of information in the image. These methods were further optimized (Jarvis et al., 1976) for a lower computational complexity by simplifying the division, using a bit shift of the previous result.

Lately there are still a new methods appearing. User controlled dot size and shape using block quantization called quantization and feedback process block error diffusion (Damera-Venkata & Evans, 2001). Algorithms try to reduce artifacts and error appearance in halftone images. Tone-dependent error diffusion method (Monga et al., 2007) reduces artifacts by controlling the diffusion of quantization errors based on the input graylevel. Also some methods are specialized for color images (Baqai et al., 2005).

All these algorithms generate different final images and there are no elementary methods that allow comparison of them and their quality on selected image. The main aim of this study was to determine whether it is possible to find a connection between the visual image quality and basic statistical data obtained from the original and the processed image.

2. USED STATISTICAL METHODS AND HALFTONE ALGORITHMS

Original images have been reduced to the grayscale and processed images to binary color resolution for the purpose of statistical information and visual quality dependence examination. It is supposed that results will be equivalent for the color images and images with higher final color resolution.

Halftone algorithms chosen for purposes of examination were from both mentioned groups. Chosen algorithms achieve significantly different visual result, so visual quality can be compared easily.

Chosen images contain large areas, smooth and sharp transitions, shades and variations, both horizontally and vertically oriented, and thus test the ability of the algorithms.

Statistical methods used for evaluation and comparison of image quality were average error of pixel and average variance of new pixels.

For purpose of examination have ben chosen 8 halftone algorithms and 3 specific images. On selected images were applied the halftone methods and subsequently the error rate based on earlier mentioned methods were calculated.

This sample should be sufficient for proving or disproving any theoretical dependencies of statistical data and visual quality of image.

3. DISCUSSION

The data obtained from statistical calculations and the data from the survey are included in the tables Tab. 1. and Tab. 2. In Tab. 1. are the statistical data obtained from the processed images. Lines represent individual halftone algorithms, columns determine used pictures. There are two values for each picture and halftone algorithm. The first is Average error of the pixel (Avr. error) which represents how much in average are new pixels different from the original one. The second statistic is Average variation of new pixels (Avr. var.). This value was calculated as subtraction of the average value of original image pixels and average value of new pixels.

Tab. 2. describes results of survey where 26 respondents were asked to order processed images from best to worse according to similarity to original picture from 1 meter distance.

These data leads to certain behaviors of certain algorithms. For example, the average error criterion can not be used for the average threshold algorithm, since this method sets the threshold according to the average value of pixels in the original image. That is the reason why this algorithm achieves the best results for this criterion. On the other hand the Random dither algorithm ended as the worst by this criterion. However, this algorithm has the best distribution of pixels thanks to his randomness and the final image does not create any patterns. On the other hand, pictures processed with this algorithm contain a high amount of noise. In some cases this can be a big benefit for the final image appearance.

If you examine overall all the results for this criterion, most results end up equally for all pictures and therefore the Average error per pixel does not determine quality of the specific image. However, if we leave aside the extremes, this criterion is an objective for total quality of compared algorithms.

	Lena		Flowers		Vegetable	
	Avr. error	Avr. var.	Avr. error	Avr. var.	Avr. error	Avr. var.
Average treshold	75,59	15,696	73,37	4,515	77,54	12,500
Random dither	96,97	0,925	92,73	0,897	97,79	0,555
Clustered-dot 5x5	96,81	1,355	92,56	1,290	97,30	1,539
Bayer dither 3x3	93,82	0,151	89,39	2,168	94,57	2,111
Floyd-Steinberg	96,27	0,259	91,98	0,230	97,39	0,199
Jarvis, Judice, and Ninke	94,38	0,061	89,84	0,310	96,73	0,550
Sierra2 4A	96,70	0,024	92,31	0,132	97,33	0,504
Bill Atkinson	88,06	2,112	84,36	4,767	91,37	3,582

Tab. 1. Statistical information collected from processed images

	Lena	Flowers	Vegetable
Average treshold	3,48	3,04	3,08
Random dither	2,68	3,28	2,52
Clustered-dot 5x5	3,36	2,72	3,36
Bayer dither 3x3	4,24	4,48	4,76
Floyd-Steinberg	5,36	5,72	5,76
Jarvis, Judice, and Ninke	5,36	5,28	5,52
Sierra2 4A	5,84	5,76	5,6
Bill Atkinson	5,68	5,72	5,4

Tab. 2. Visual quality rating from survey

If we look at the data obtained from visual comparison, all the visually best rated images also achieved the best results for the Average variability criterion. That means that there is some connection in between visual image quality and Average variation of new pixel.

4. CONCLUSION

According to the research, it seems that there are some possible usages of elementary statistical methods in visual quality. Average error of pixel could be used for algorithm comparison. But as you can see from table, in some extreme cases it does not behave properly. Also Average variation of pixels has some connection in visual quality. Because for processed images that receives in survey the best result this criterion achieves mostly the same ranking. To confirm that visual quality of halftone images can be evaluated with this criterion, it is needed to be verified on a larger amount of tested algorithms, with more pictures and respondents.

5. ACKNOWLEDGEMENTS

The work reported in this paper was supported by Grant IGA/51/FAI/10/D (SV30100051020) from the IGA (Internal Grant Agency) of Thomas Bata University in Zlin.

6. REFERENCES

Baqai, F.A.; Lee, J.-H.; Agar, A.U. & Allebach, J.P. (2005). Digital color halftoning. *Signal Processing Magazine, IEEE*, Vol. 22, No. 1, (Jan. 2005), 87-96, ISSN 1053-5888

Damera-Venkata, N. & Evans, B.L. (2001). FM halftoning via block error diffusion, *Image Processing, 2001. Proceedings. 2001 International Conference on*, pp. 1081 - 1084, ISBN 0-7803-6725-1, Thessaloniki , Greece, Oct. 2001

Campbell, F.W.; Kulikowski, J.J. & Levinson, J. (1966). The effect of orientation on the visual resolution of gratings, *Available from:* http://jp.physoc.org/content/187/2/427.full.pdf+html *Accessed:* 2010-08-15

Floyd, R.W. & Steinberg, L. (1976). An adaptive algorithm for spatial grey scale. *Proc. Soc. Inf. Display*, Vol. 17, 75-77

Jarvis, J.F.; Judice, C.N.; & W.H. Ninke, (1976). A Survey of Techniques for the Display of Continuous Tone Pictures on Bi-Level Displays. *Comput. Graph. Image Process.*, Vol. 5, 13-40

Monga, M.; Damera-Venkata, N. & Evans, B.L. (2007). Design of Tone-Dependent Color-Error Diffusion Halftoning Systems. *Image Processing, IEEE Transactions on*, Vol. 16, No. 1, (Jan. 2007), 198 – 211, ISSN 1057-7149

Sharma, G., (2003). *Digital Color Imaging Handbook*, CRC Press, ISBN 0-8493-0900-X, New York