On the Efficiency of the Wavelet Based Compression Techniques

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Abstract

In this paper we address the problem of the correlation between the objective quality measures, like mean squared error or signal to noise ratio and the subjective quality perceived by human viewers. Using both the objective and subjective quality measures we aimed to compare the efficiency of the wavelet based lossy codecs *DJVU* and *LWF* with the DCT based standard *JPEG* compression method.

For the experiments a set of 3 gray-scale and 3 color test images was used. The images were encoded at the same compression levels and standard objective quality measures were calculated for all images. For the visual assessment of the quality of the compressed images, a group of 100 male students evaluated them using a linear rating scale. The results have shown that there is no significant correlation between the objective and subjective quality measures. Although the wavelet based *LWF* codec outperformed significantly *DJVU* in terms of MSE and SNR, no significant differences in human visual perception of those images were observed. It was also observed that the histogram of the viewers preferences regarding the image compression ratio is bimodal and no optimal compression level could be established.

1. Performed tests

The image quality assessment remains an active area of research as the evaluation of picture quality is indispensable in modern image coding [1-6].

In this paper we present the results of the evaluation of the efficiency of two wavelet based compression techniques - *DJVU* and *LWF* in comparison with the standard *JPEG* method.

In our view the simple distorsion scales are good estimators of random errors, but do not describe correctly the structured correlated errors typical to *JPEG* and wavelet based compression methods (Fig. 1, Tab. 1, Fig. 4). To assess the efficiency of the three losssy compression methods a joint subjective and objective study was undertaken.

For the experiments a set of 3 gray-scale and 3 color test images was used (Fig. 2). The images were compressed at nearly the same compression ratios and the standard quality measures like RMS, MSE, SNR and PSNR were calculated for all images at different compression levels.

For the visual assessment of the quality of the compressed images, a group of 100 male students, which obtained a short introductory training was asked to perform three tests.

Figure 1: *Image disturbancies resulting from the application of a specific compression method :* **left***) blocking artifacts typical to* JPEG*,* **right***) ringing effects typical to wavelet based codecs.*

The aim of the first test was to establish an optimal compression ratio in terms of image quality and its size in kB. So the subjects were asked to choose an image from

a set of about 20 images compressed at different compression levels, which in their view represents the best compromise between the image quality and the image file size.

The results of the first test, in which we wanted to determine the optimal compression ratios with respect to the visual quality perception, showed that the histogram of the subjective quality measures and the image size in kB is bimodal (Fig. 5), which indicates that the subjects consisted of two groups with different preferences regarding image quality. This effect was observed for **all** test images and compressors used in our study with high statistical significance. This result indicates that there is no one optimal compression ratio for the codecs used in this study, however two optimal levels of compression can be established for the quality demanding group and the group for which the compression induced artifacts are of not so high importance.

During the second test, images compressed at different levels were evaluated by the subjects using a 1 (very bad) to 10 (excellent) psychometric scale. In our tests we made use of the NIIRS scale (National Imagery Interpretability Scale).

For each image we have a chosen a compression level which lies between the peaks of the histograms calculated from the data obtained from the first test. The compression levels taken for the second test are shown in Tab. 2.

At the end the subjects selected the best and worst compression method for each of the test images at a compression level used for the second test. The purpose of this test was to check if the subjects were performing the test according to the guidelines. The results of these tests are summarized in Tab. 3.

The results showed again that the correlation between the standard quality measures and the human judgment is very low, if any, for the compressors evaluated in this study. Although the *LWF* compression technique was significantly better in terms of the mean squared error MSE and the signal to noise ratio SNR, there was not a a significant difference between the subjective quality assessment performed by the the observers.

What is interesting the experiments indicated that there is no evidence that the wavelet based compression techniques outperforms the *JPEG* standard (Tab. 3).

2. Conclusions

The results of the experiments show that there is no clear correlation between the subjective and objective quality measures for the three tested compression methods. Although the *DJVU* was outperformed significantly by *JPEG* and *LWF* in terms of objective quality measures, like RMS, SNR, (Tab. 1, Fig. 4), the subjects did not perceive this effect and in their opinion *DJVU* compressed images were more pleasing and were rated as better than those compressed with *LWF* in case of the OPERA image and better than *JPEG* in case of the TIFFANY image. However this cannot be generalized, as in the case of the PATTERN image, *DJVU* was outperformed significantly by *JPEG*. So, the results are image dependent (see Fig. 3) and no clear statement about the subjective efficiency of the compressors can be made using 6 images only.

Figure 2: *Set of test images, left column : gray scale 8 Bit images* - BRIDGE, PATTERN, TIFFANY*, right column : 24 Bit color images* - LOCOMOTIVE, PARROT, OPERA.

It was expected that the histogram of the human viewers preferences regarding the compromise between the image quality and image file size will be of Gaussian shape. However in all cases (6 images) it was clearly bimodal, which indicates that no optimal compression ratio could be found.

3. References

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BRIDGE	**R**	**MSE**	**SNR** [dB]
JPEG	0.855	79.187	23.037
LWF	0.837	45.616	25.433
DJVU	0.860	162.416	19.918
PATTERN	**R**	**MSE**	**SNR** [dB]
JPEG	0.946	18.883	30.518
LWF	0.947	47.567	26.506
DJVU	0.949	92.864	23.600
TIFFANY	**R**	**MSE**	**SNR** [dB]
JPEG	0.899	32.051	27.961
LWF	0.895	20.012	30.006
DJVU	0.900	120.556	22.207
LOCOMOTIVE	**R**	**MSE**	**SNR** [dB]
JPEG	0.947	131.387	22.633
LWF	0.952	111.950	23.329
DJVU	0.946	186.480	21.111
PARROT	**R**	**MSE**	**SNR** [dB]
JPEG	0.967	39.593	24.413
LWF	0.966	28.497	25.841
DJVU	0.977	154.512	18.500
OPERA	**R**	**MSE**	**SNR** [dB]
JPEG	0.954	37.401	24.107
LWF	0.951	29.059	25.203
DJVU	0.964	161.733	17.748

Table 1: *Results of the objective quality measures (MSE and SNR) for different codecs and compression ratios R is defined as $1 - compressed/original$.*

IMAGE	**JPEG**	**LWF**	**DJVU**
BRIDGE	0.8031	0.8229	0.8149
PATTERN	0.9316	0.9341	0.9285
TIFFANY	0.8747	0.8952	0.8758
LOCOMOTIVE	0.9272	0.9307	0.9256
PARROT	0.9546	0.9520	0.9557
OPERA	0.9469	0.9508	0.9463

Table 2: *Compression ratios applied for test images. The compressed images were used in the second test, in which the subjects rated the quality of the images encoded with the codecs compared in the paper.*

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BRIDGE	**S**	**worst**	**medium**	**best**
JPEG	7.30_{*}	21	23	56
LWF	6.58_{*}	26	59	15
DJVU	6.94	37	28	35
PATTERN	**S**	**worst**	**medium**	**best**
JPEG	7.81_{*}	18	36	46
LWF	6.87	36	44	20
DJVU	7.21_{*}	27	33	40
TIFFANY	**S**	**worst**	**medium**	**best**
JPEG	7.80_{**}	24	28	48
LWF	7.15_{*}	30	43	27
DJVU	$7.94_{\star}$	19	33	48
LOCOMOTIVE	**S**	**worst**	**medium**	**best**
JPEG	8.16	19	34	47
LWF	7.93	21	50	29
DJVU	8.12	31	27	42
PARROT	**S**	**worst**	**medium**	**best**
JPEG	8.19	18	26	56
LWF	7.87	29	40	31
DJVU	8.33	25	29	46
OPERA	**S**	**worst**	**medium**	**best**
JPEG	7.62	31	22	47
LWF	7.29_{*}	26	55	19
DJVU	7.88_{*}	31	36	33

Table 3: *Results of the second and third test. Left column: subjective mean opinion score results. The subjects were asked for their preference of a particular compression method. The signs $*$ and $\star$, indicate that the differences between the results of visual assessment were statistically significant ($p < 0.01$). Beside the results of the third test, in which the subjects were asked to rate the images as the best and the worst.*

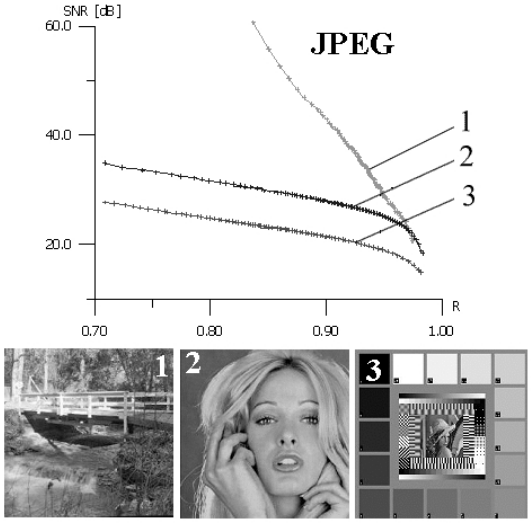

Figure 3: *The objective quality measures are highly dependent on the image structure. As an example the signal to noise ratio versus compression ratio (*JPEG*) for 3 gray scale images are shown.*

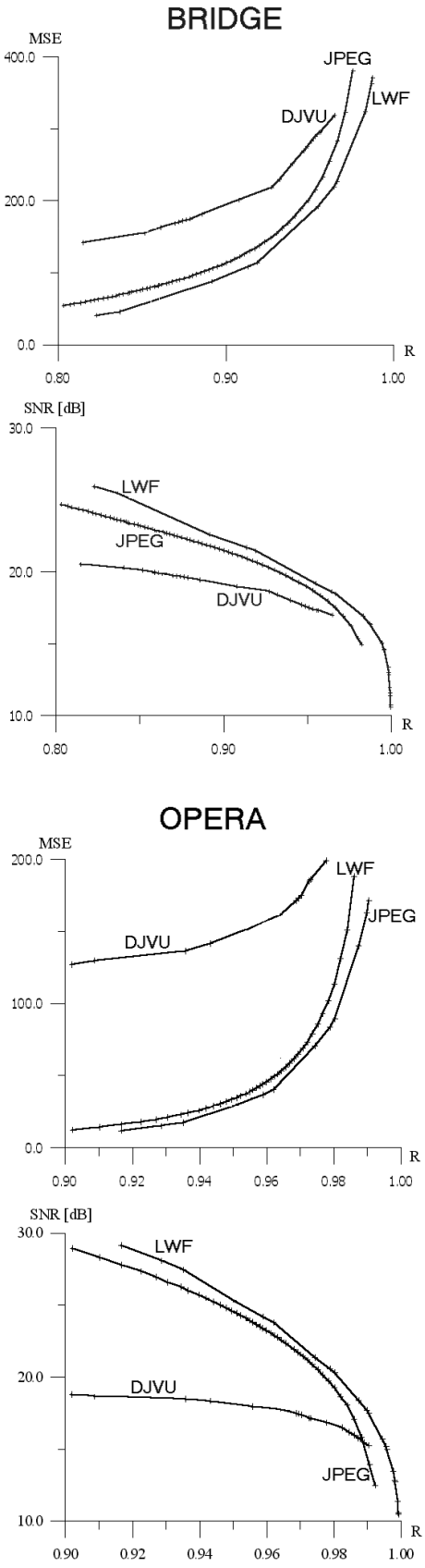

Figure 4: *The dependence of the objective quality measures on the compression ratio for the BRIDGE and OPERA image. As can be seen the* LWF *compression outperformed the other codecs. Similar results were achieved for all test images.*

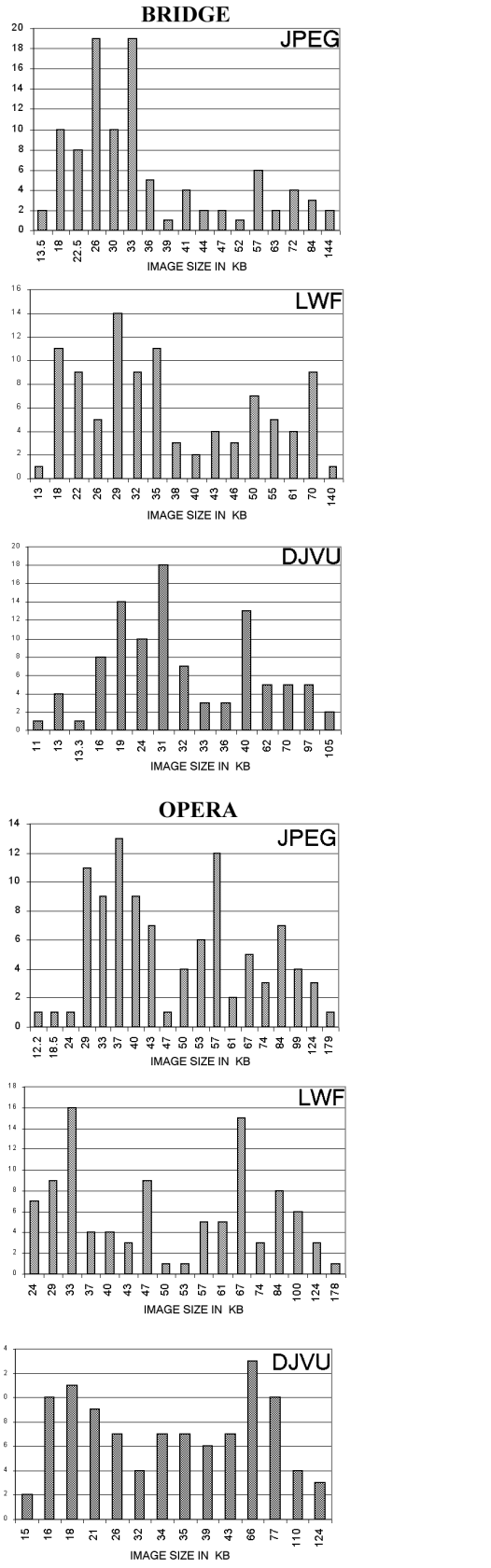

Figure 5: *Results of the first test in which the subjects were asked to indicate an image, which in their view represents the best compromise between the image quality and the image file size in kB. As can be seen the histograms tend to be bimodal.*