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A Study of the Impact of JPEG Compression on Visual and Digital Image Degradation

ABSTRACT

A key feature of the JPEG standard is the ability to control the degree of compression, and, consequently, the extent of information loss that occurs during image encoding. Modern image-editing environments, including professional software suites such as Adobe Photoshop, allow users to select the desired compression level. However, the software documentation rarely contains a comprehensive analysis of the precise relationship between the intensity of compression and the resulting deterioration in image quality. This study analysed the impact of different JPEG compression levels on perceived image quality and selected digital image characteristics. Following analysis of the results, a set of practical recommendations has been formulated.

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KEY WORDS
JPEG, lossy compression, block artefacts, Adobe Photoshop

1. Introduction

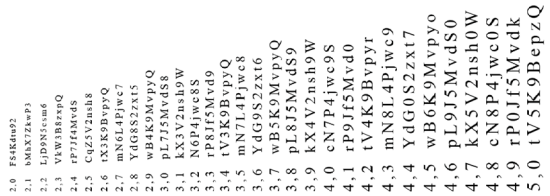
JPEG encoding facilitates high-ratio image compression, with ratios as high as 20:1, though this result in some loss of detail. The compression process takes place in several stages. First, the image stored in the RGB colour space is converted to the YCbCr colour space, where Y represents luminance and Cb and Cr are the chrominance components. As the human eye is less sensitive to changes in colour than to changes in luminance, it is possible to reduce the file size without any noticeable loss of quality. In the process of chroma subsampling, the resolution of the Cb and Cr channels is reduced, usually by half both horizontally and vertically. This means that several neighbouring pixels share colour information, which significantly reduces the amount of data. The image is then divided into 8 × 8 pixels blocks, on which further operations are performed. The algorithm applies a discrete cosine transform (DCT) to each block, which transforms the image data into frequency coefficients. The next stage is the quantisation of the coefficients, which is the main source of quality loss. At this stage, the compression level (image quality) is determined. The stronger the compression, the more coefficients are set to zero. This results in a smaller file size, but characteristic distortions, known as JPEG artefacts, appear. (Karwowski, 2019).

A key benefit of the JPEG algorithm is its capacity to adjust the compression level, enabling users to customise it for specific images to achieve the smallest possible file size while maintaining acceptable quality. The popular image-processing programme Adobe Photoshop also offers such a tool; however, there is no clear information on how it works (Adobe Help Center, 2023). This project was undertaken due to the lack of detailed documentation on the criteria for using this function.

2. Methods

To determine the optimal level of JPEG compression for various source images, a series of visual assessments were conducted. For the purposes of this study, a new test image was created based primarily on a selection of high-quality photographs and graphics, as well as the results of a review of the sensitivity of different tests used in previous studies on JPEG compression artefacts (Markowski & Jeliński, 2011; Żurek, 2021). Fifteen groups of elements were arranged on an A4 sheet (Fig. 2). Each group was used to assess the reproduction of different

aspects: text legibility, microline resolution, tonal continuity, colour uniformity and detail recognisability. The groups, numbered from 1 to 15, comprise: 1) an alphanumeric scale with 31 sizes of randomly generated characters, in positive and negative variants and on backgrounds of varying shade and contrast (Fig. 1); 2) a microline scale with line widths ranging from 0.05 to 0.25 mm; 3) a continuous greyscale range of 0–100%; 4) colour gradients; 5) an ordered colour chart; 6) a randomly arranged colour chart; 7) a map; 8) a woodcut; 9) textures; 10) a steel engraving; 11) an offset print reproduction; 12) a photograph lacking fine detail; 13) a photograph with typical detail; 14) a photograph with high detail; 15) a miniature group photograph. Vector objects were created for text, line art and colour fields. The original reproduction sources were saved in the lossless TIFF format. The entire test was created using Adobe Illustrator and then rasterised to PNG format using the 'optimised composition without interlacing' option and a base resolution of 300 ppi, which is standard in print reproduction. The PNG file was used as the source material for preparing all the test samples in Photoshop, which were saved in JPEG format at the thirteen available quality levels (0–12).



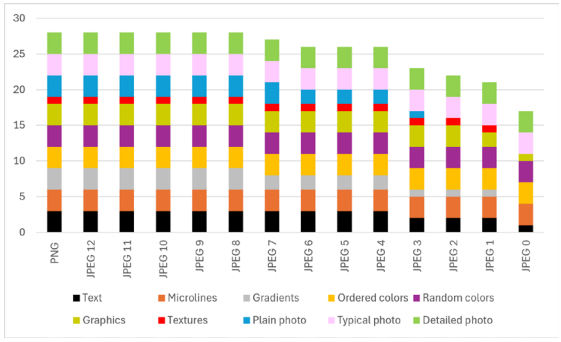
» **Figure 1:** *A test for assessing the recognisability of alphanumeric characters, shown at a magnification of 2:1. Each of the 31 size levels features a random combination of 10 characters; successive levels differ by 0.1 points. The characters are set in Times New Roman*

The visual assessment of the test images was carried out under diffused lighting, using the method of alternating comparison of samples displayed in the same position on the monitor screen. The samples were analysed from 25 cm, which is considered the standard minimum distance for good vision. The study utilised an Eizo ColorEdge CS2740 monitor with an IPS panel and a resolution of 3840 × 2160 pixels (164 ppi). The images were viewed at actual size (A4 format) and at a 2:1 magnification factor to assess fine details more accurately. All JPEG samples were compared with the original in PNG format. The following rating scale was used: 0 – poor quality, 1 – adequate, 2 – good, 3 – identical to the original.

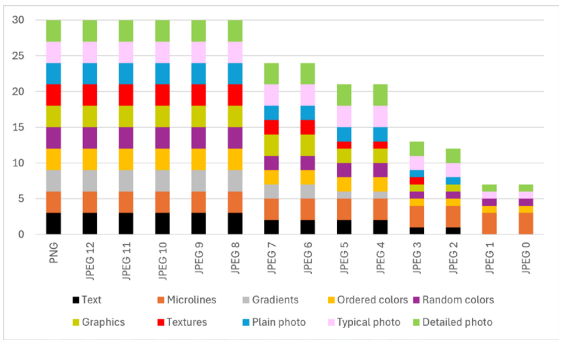
3. Results

3.1. Visual evaluation of test images

The ten most representative elements were selected for evaluation. Figures 3 and 4 present the results of the visual analysis of test elements subjected to lossy compression. At a 1:1 magnification, the first drop in quality is observed at level 7, and subsequent drops occur gradually at levels 3–0. The most significant adverse changes affect gradients, text, graphic reproduction, and photographs with large areas of similar tonality, such as clouds against the sky. The textures used are so fine that they cannot be distinguished at a 1:1 scale. At a 2:1 magnification, compression artifacts are more visible, which is why the overall ratings are lower than when viewed at a 1:1 scale. The first decline in the quality of alphanumeric characters, gradients, and textures occurs at level 7, with subsequent declines—gradually—at levels 5, 3, and 1. At levels 1–0, half of the test elements were completely degraded.



» **Figure 3:** *Cumulative results of visual evaluations of test images viewed at 1:1 magnification after JPEG compression at levels 12–0. The first drop in quality occurs at level 7, and subsequent drops occur gradually at levels 3–0*



» **Figure 4:** *Cumulative results of visual evaluations of test images viewed at a 2:1 magnification after JPEG compression at levels 12–0. As in Fig. 3, the first noticeable drop in quality occurs at level 7, followed by gradual declines at levels 5, 3, and 1. At levels 1–0, half of the test elements were completely degraded*



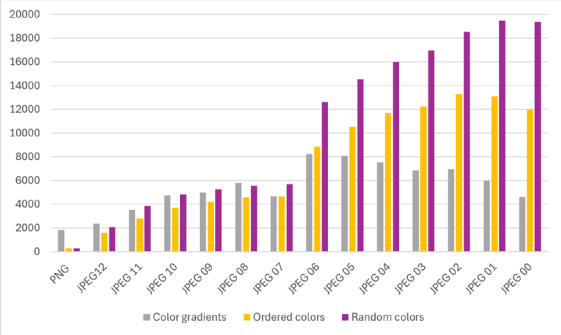
» **Figure 2:** *Test image developed for the visual assessment of image degradation after JPEG compression (scale 1:2)*
Sources of originals: 7 – Butler, S., The Atlas of Ancient and Classical Geography. E-book: 21.11.2005;
8 – Digital National Museum. Women carrying a jug, vertical woodcut;
10 – stamp for the Iceland Post designed by Czesław Słania (steel engraving based on a drawing by August Mayer);
11 – stamp for the Polish Post designed by Jan Rutka; stamp for the Lithuanian Post designed by Balakauskaite;
12, 13, 14 – photographs by Leszek Markowski;
15 – photomontage created by AI

3.2. The effect of JPEG compression on the number of colors

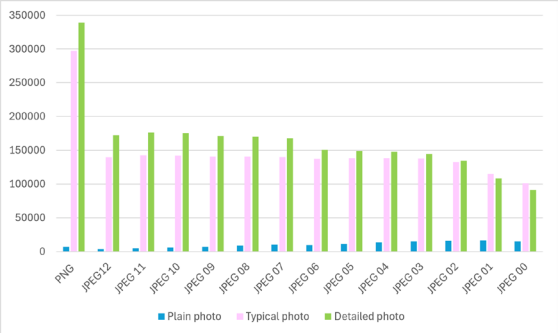
One of the key factors in determining the effectiveness of the JPEG algorithm is the change in the number of unique colours in an image. To investigate this effect at various compression levels, the Image Color Counter tool available on the Novaboard platform (Image Color Counter, 2026) was used. The results are presented in Figures 6 and 7. Figure 6 shows changes in the number of colours in gradients (Test 4) and colour charts (Tests 5 and 6), while Figure 7 shows changes in photographic images (Tests 12, 13, and 14). In images containing vectorgenerated gradients and test patterns, an unexpected relationship was observed: at successive compression levels, the number of colours increases rather than decreases. This effect is the result of the operation of the JPEG algorithm and the recalculation of pixel values in 8 × 8 blocks. As a result of the conversion process from PNG to JPEG 12, the number of unique colours is reduced by 50%. At higher compression levels, there is only a minimal reduction in the number of unique colours. However, there is an exception to this rule, which applies to photographs of clouds with a limited tonal range. In this case, the number of colours increases at subsequent quantisation levels (see Fig. 5). Color changes in compressed images are visible as tonal jumps and local discolouration. These changes only become apparent at compression levels lower than 5. It was determined that desaturation effects were not evident at any compression level.



» **Figure:** *5: A magnified section of a PNG image (left) and the same image after lossy JPEG compression at level 0 (right). The PNG image shows only pixelation. In the JPEG image, in addition to pixelation, there is a blocky effect caused by lossy compression. Within individual blocks, many pixels appear discoloured, and colours not present in the original — navy blue, purple, turquoise, and yellow — are visible*



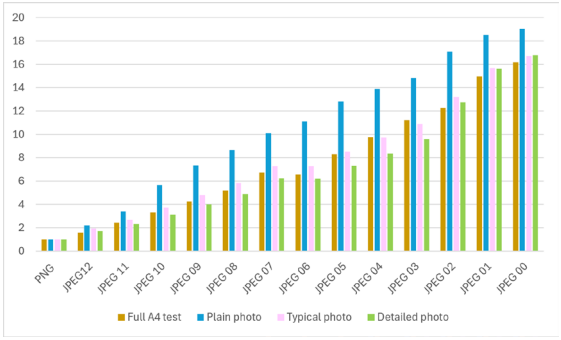
» **Figure 6:** *Number of unique colours before and after JPEG compression (levels 12–0) in selected images containing colour gradients, ordered colour arrays and randomly arranged colour arrays. Tests with solid-colours fields do not fully demonstrate the specific characteristics of JPEG compression — after stronger compression, the number of colours increases rather than decreases*



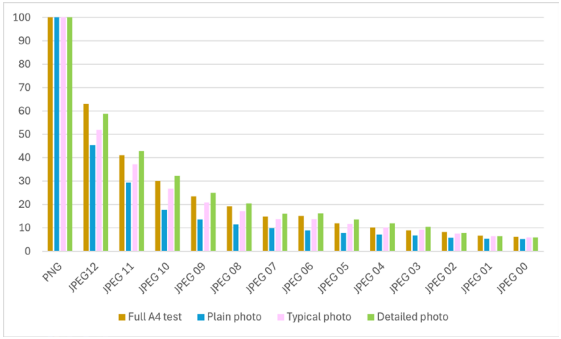
» **Figure 7:** *The number of unique colours in selected photographs before and after JPEG compression (levels 12–0): plain photo with large areas of similar tone, typical photo with a moderate amount of detail, and detailed photo with a high amount of detail*

3.3. JPEG compression levels in adobe photoshop and compression ratio

To compare the effectiveness of compression at different JPEG settings, the degree of compression was calculated. This is defined as the ratio of the data size before compression to the size after compression. This calculation was performed on selected original photographs. Figure 8 shows that the compression ratio depends on the image content. Images with little tonal variation and few details (plain photo) are most susceptible to compression. Each successive compression level reduces the file size, but this relationship is not linear. The diagrams in Figure 9 illustrate this phenomenon more clearly, showing the JPEG file size as a percentage of the original PNG size. At level 8, for examle, files range from 12% to 20% of the original size, depending on the image content. At level 4, it is approximately 7–12%. This means that at level 8, files are 5 to 8 times smaller. However, increasing the compression to level 4 only reduces their size by about half, which causes a significantly higher risk of artefacts appearing.



» **Figure 8:** *A comparison of the ratio compression for selected image files at each JPEG level from 12 to 0 (PNG/JPEG)*



» **Figure 9:** *A comparison of the compression efficiency of selected image files at JPEG levels 12–0, expressed as a percentage of the original file size. (JPEG × 100) / PNG*

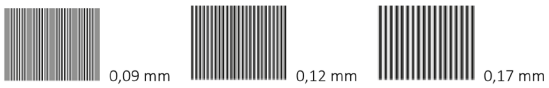
3.4. Sensitivity of test images



» **Figure 10:** *Examples of alphanumeric test patterns in PNG (left) and JPEG 0 (right) formats, with two contrast variants: ΔL = 60 and ΔL = 40. Artifacts along the edges blur the shapes of the characters; this degradation is more pronounced for objects with lower contrast. Magnification: 2:1*

Alphanumeric test (Fig. 10): Alphanumeric characters are among the most objective elements of a visual assessment, as they provide a relatively unambiguous evaluation criterion in the form of a recognition threshold. For the test to be sufficiently sensitive, it must include very small characters, which are difficult to read. In this study, evaluation at a magnification of 2:1 was found to be more reliable than evaluation at a scale of 1:1.

Line test (Fig. 11): Rasterisation of the line test converts a vector line into a pixel image at a specified resolution (300 ppi). The pixels making up the image take on intermediate values and merge with one another, which prevents the lines from being reproduced correctly. The resolution of the input file (300 ppi) and the monitor resolution (164 ppi) set a practical limit on the reproduction of lines with a width of approximately 0.17 mm. An additional issue with similar line tests (e.g. Siemens Star) is the occurrence of interference phenomena, which makes reliable assessment difficult. This limits the effectiveness of such tests for evaluating images on a monitor.



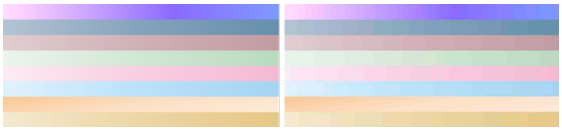
» **Figure 11:** *Enlarged images of test lines, displayed on a monitor with a resolution of 164 ppi, after rasterisation to a resolution of 300 ppi and saving in PNG format. The original line widths are shown below the examples. Lines narrower than 0.17 mm become blurred because of rasterisation. This effect is so pronounced that it masks the artefacts caused by lossy compression. Magnification: 3:1*

Textures: Test image containing textures enables an objective assessment of quality based on the recognisability of the material's texture. Some textures are so fine that they must be analysed under magnification.



» **Figure 12:** *Images of the textures of various fabrics at 2:1 magnification: the original PNG on the left and the image after JPEG compression at level 0 on the right. Compression causes degradation of the actual fabric structure*

Gradients: Continuous tonal scales proved to be the most sensitive element of the entire test. Artifacts in the form of tonal jumps appear at compression level 7 and are visible on the screen without magnification.

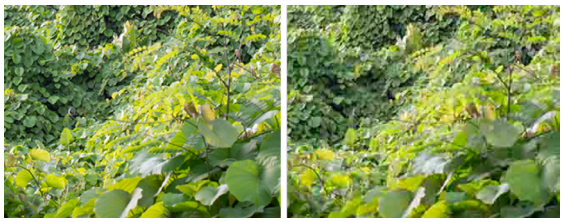


» **Figure 13:** *Colour gradients on a 1:1 scale: the PNG image on the left and JPEG-compressed at level 0 on the right*

Original photographs: A photograph of clouds against a plain sky (plain photo), characterised by little tonal variation, proved to be the most susceptible to lossy compression artefacts. A photograph of a butterfly with typical levels of detail (typical photo) and a photograph of ivy with a high level of detail (detailed photo) showed significantly greater resistance to artefacts. Distortions in these images only became visible at a 2:1 magnification, when saved as JPEGs at compression levels lower than 4.



» **Figure 14:** *A section of the PNG image on the left and the image after JPEG compression at level 0 on the right. Undesirable posterisation and colour distortion are visible*



» **Figure 15:** *A magnified section of a PNG image (left) and a JPEG image compressed at level 0 (right). Although the compressed image is less sharp and blurred in places, the high level of detail largely masks artefacts such as posterisation, colour shifts and block artefacts*

4. Conclusions

Based on a visual assessment of the test images, practical conclusions were drawn regarding the compression of image files in Adobe Photoshop.

- Evaluating test samples at a magnification of 2:1 enables more accurate and the detection of more rendering errors. Consequently, the overall ratings of the test images at various compression levels were more varied at a 2:1 magnification (range 30–7) than at a 1:1 scale (range 28–17).
- As the compression level increases, adverse changes appear most rapidly in gradients and photographs containing large, tonally uniform areas. Minor tonal discontinuities begin to become visible from quality level 7. At level 3, very distinct tonal jumps appear in gradients.

- Images without plain, uniform colours or gradients that are intended for viewing on a screen at a scale of 1:1 can be safely compressed in Photoshop, even at level 4–6. A significant loss of quality in text and photographs containing large uniform areas was observed at compression levels 3–0.
- For highly detailed photographs that are often viewed at high magnification, a compression level of 8–10 is optimal, in line with professional photography recommendations (Mansurov, 2018). Below level 8, artefacts appear in text, gradients and textures. This makes characters difficult to read, causes tonal jumps and blurring of textures, which may prevent them from being correctly identified.
- When comparing the quality of the output images with the size of the compressed files, a compression level of 8 can be considered optimal. For a typical photograph, a file saved at this level was approximately six times smaller than the original. Using a compression level of 4 can reduce the file size by a further twofold, but there is a high risk of artefacts occurring.
- In typical photographic images, the JPEG format always reduces the number of unique colours, regardless of the selected compression level. At higher compression levels, this reduction in the number of colours is only slightly greater and depends on the nature of the image. Visually, this does not manifest as desaturation. Local colour shifts resulting from the division of the image into blocks and the averaging of pixel values within them have a greater impact on colour reproduction. JPEG encoding can generate additional colours in images with little tonal variation, which may cause colour shifts.
- Reducing the resolution of a PNG image from 300 ppi to 250 ppi results in a loss of detail comparable to that caused by compression JPEG at level 4. Reducing it to 200 ppi results in a loss comparable to compression level 2. Therefore, high resolution is the most important factor in preserving image quality. Even reducing the resolution by as little as 20 per cent can result in a greater loss of image information than heavy JPEG compression.

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