Determination of parameters affecting the calculation time of the image average colour

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Abstract. Results of pilot studies of determination of average color when using the automated program systems provided. Experimental and analytical means revealed the critical parameters influencing the speed of process of determination of average color. As research showed, the most significant parameters are geometrical image sizes. Also the limit of change of image sizes for the TIF, JPG, PNG, BMP formats at which average color began is irreversible to change was set. The BMP format showed the highest resistance among all studied graphic formats to loss of average color depending on change of image sizes. Research of models of RGB and HSL color showed that the HSL model is not suitable for determination of average color of the image, because of the unpredictable sensitivity. The software capable automated computation of the image average color developed.

1. Introduction
Development of information technologies dictates improvement existing and emergence of new approaches to different solution of problems. Analyzing the works connected with software processing operations of images makes possible to draw a conclusion that this direction has been quickly developing from long ago, mentioning the most different areas of human activity, from polygraphy, to problems of medicine, astronomy, cartography and cybernetics. In most cases, articles are devoted to a solution of tasks distinguishing images, to decision-making, determination of zones of risks, search of images at the request of users, to storage systems of images.

The greatest interest among researchers is the organization of images search at the request of users and data storage. These are the big, many-sided questions including not only features of technology of search, but also psychological, philological aspects. Such works include [1] and [2]. However, the simple, special cases directed on the search of optimum solutions or development of recommendations for programmers, designers solving problems of selection of optimum color for design, design of applications or models is not enough. The work, approximate to this subject, in this direction is work on optimization of data storage of images in databases and search to requests with indication of color of images [3-5]. In this article, we solve the problem of reducing the size of the database, by entering the image color parameter not for each object, but by combining graphics into groups of colors. For this purpose, the color parameters H, S were determined based on which further data processing was carried out.

Therefore in our opinion actual problems in the field of application of digital images still are insufficient research of the questions connected with determination of the general image color for example of its average color. It belongs to approaches of a selective assessment of image zones, and to determination of average color, an image saturation.
The matters for polygraphy can significantly facilitate work of designers, to apply in the field of prepress production or program implementation of different slideshows. As the perspective directions, it is possible to determine application of similar technologies for problems of preparation of design of products, for example, creation of the mechanism of sorting images by color and its shades. Besides, approach by determination of mean value of color, can affect results of the works connected with the CBIR technologies, described in works [3], [6] because of expected bigger accuracy. Besides, knowledge of average color of images can be useful to creation of the tools applied in programming on high-level languages and Web-technologies, for example, in the areas connected with showing of graphics to users.

Determination of average color - technology, is simple and exact, but costly on time. Accuracy of determination of image average color directly depends on completeness of poll of the pixels creating the image. Ideal option from the point of view of mathematics is to complete poll of pixels of the image with drawing up a color matrix with which it is possible to execute different actions further. However, this approach has essential minus - time of processing of the image. These costs of time are significantly higher, than at methods of accidental tests, poll of the accidental or fixed image zones. However, in our opinion this shortcoming can be reduced to acceptable values. For this purpose, it is necessary to reveal limit opportunities reduction of the images sizes of popular graphic formats. It will reveal a limit, which will allow reducing significantly time of processing and will show the most adequate graphic formats for this task.

2. Definition of problem
Primal problems, which need to be solved in the work progress, are the maximum reduction of operation time of determination of average color on the image, identification of the parameters influencing the time and quality of process, software development and elaboration of recommendations for determination of reduction of image size at constancy of its average color.

3. Theory
Equation (3)
The main task of assessing the average color is identification of a limit after which irreversible color distortion of the image begins. We suppose that image resolution, type of a graphic format and dominance in the image of one of basic colors of the RGB model can affect this limit. In further experiments, we attempted to set influence of the last two factors. Image permission was permanent and equal 75 DPI, since the majority of the images applied in expected areas of use technology of determination of average color aim at decrease in the general file size, and seldom happens lower. As control of a deviation of the received average color from original, taken for a standa

\[ E_{ab} = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2} \]

By this technique, at a visual assessment by the observer value \( \Delta E_{ab} = 5 \ldots 2 \) it is indiscernible. As the instrument of automation of calculation the third-party calculator - Delta-E Calculator used [7].

For implementation of program part, it is necessary to study means, which the selected programming language possess. As the main language, we selected C#. In it is possible to implement reading of colors by two built-in methods, and also own algorithm based on processing of binary data. These are the most popular options of color processing. GetHue() belong to the built-in methods, GetSaturation(), GetBrightness(), and also pixelColor.A, pixelColor.R, pixelColor.G, pixelColor.B. The first three can read out indications in the HSL-models, which remained obtain data on the channel an alpha, red, green and blue in the RGB-model. The appeal to the RGB-model is performed through Color.FromArgb. It is possible to receive data on color of pixel through myBitmap.GetPixel(x, y), where x, y - point coordinates.
Since the Microsoft company does not open a technique of modules operation, we can only guess, and in our opinion, it is quite logical that methods on poll of the HSL model originally obtain data on RGB channels, then perform their recalculation in LAB, and then in HSL. Therefore, extra time is spent on this operation and this operation is slightly spent, but occurs longer, than simple poll of RGB.

In addition to the above-described method, also there is an option of use of poll of a byte structure of the image. In this case poll of pixels with entering of data in a binary type in random access memory usually passes, thus we have opportunity along with this process to transform data to colors canals, because of properties of random access memory. It is possible to consider that multitasking in random access memory executed, therefore it is possible to do at the same time some processes. Also random access memory is well structured, i.e. we always know in what cell this or that color channel is written.

The main reason for the emergence of such method is a reduction of time of operation because of the absence of the intermediary in the form of a method of poll, the GetPixel type since we directly address to random access memory. Besides, this device gives the high speed of operation of application that has to reduce operation time, but there is a risk of emergence errors of reading indicators of color, therefore we took as a basis the ready similar function most often used and fulfilled.

4. Results of experiments

We conducted researches using the developed software based on the C# language, and Adobe Photoshop Version 13.0.1x32. Computer had the following configuration: Windows 10, Intel CPU Family:6, Model:10, Stepping:9 with MMX, SSE Integer, SSE FP, SSE2, SSE3, SSE4.1, SSE4.2, HyperThreading. Other parameters were: Physical processor count: 4, Logical processor count: 8, Processor speed: 3410 MHz, Built-in memory: 16338 MB, OpenGL Drawing: Enabled, Video Card Renderer: GeForce GTX 1060 6GB/PCIe/SSE2, Video Card: NVIDIA GeForce GTX 1060 6GB, Driver Version: 23.21.13.9135.

The experimental software in the C# language with the standard interface, which works by the principle of poll of pixels in the image, developed and determines by them average color.

For testing of the software created by us and detecting of possible inaccuracies in determination of color pixels, the test object was created in the Photoshop program, with which we carried out comparisons afterwards. Appearance of test object is shown in Figure 1.

![Figure 1. View of test object](image)

Then experiments for determination of calculation time for different methods of pixels poll were made. Results of research are provided to table 1.

As during the work with the HSL model originally obtain data on RGB channels, and then perform recalculation in LAB, and then in HSL, for this operation excess time is spent, accordingly operation slightly, but occurs longer, than simple poll of RGB.
This circumstance are shown in table 2, where the method of poll of RGB goes on some seconds quicker, than HSL. Designations hereinafter accepted: CPU - the central processor, RAM - random access memory.

| Format | Original RGB | Result RGB | Result HSL | Average RGB color | Recalculation of average color from HSL to RGB |
|--------|--------------|------------|------------|------------------|-----------------------------------------------|
| BMP    | 1. 0.0.0     | 1. 0.0.0   | 1. 0.0.0   | 105.141.123      | HSL 102.63.48 RGB 92.200.45                  |
|        | 2. 0.173.78  | 2. 147.100.34 | 2. 147.100.34 | 105.141.123    |                                               |
|        | 3. 240.73.35 | 3. 11.87.54  | 3. 11.87.54 | 105.141.123      |                                               |
|        | 4. 250.243.153 | 4. 56.91.79  | 4. 56.91.79 | 105.141.123      |                                               |
|        | 5. 0.173.232 | 5. 195.100.45 | 5. 195.100.45 | 105.141.123    |                                               |
| JPG    | 6. 138.182.63 | 6. 82.49.48  | 6. 82.49.48 | 105.141.123      | RGB 32.213.38                                 |
|        | 7. 65.76.160 | 7. 233.42.44 | 7. 233.42.44 | 105.141.123    |                                               |
| PNG    | 8. 255.255.255 | 8. 0.100.0  | 8. 0.100.0  | 105.141.123      | HSL 102.63.48 RGB 92.200.45                  |
|        | 9. 0.92.128  | 9. 197.100.25 | 9. 197.100.25 | 105.141.123    |                                               |

Table 2. Comparison of time of process of determination of average color for images of the formats BMP, TIF, JPG, PNG received by the built-in methods during the work with a color in C# language for color models of HSL and RGB

| Format   | Loading | File size | Process time, min |
|----------|---------|-----------|-------------------|
| BMP/HSL  | ~17.4   | 1 Mb 966 Kb 136 b | 20.38 |
| BMP/RGB  | ~16.5   | 1 Mb 966 Kb 136 b | 20.17 |
| TIF/HSL  | ~16.4   | 1 Mb 990 Kb 016 b | 20.53 |
| TIF/RGB  | ~16.4   | 1 Mb 990 Kb 016 b | 20.38 |
| JPG/HSL  | ~16.4   | 422 Kb 827 b | 20.38 |
| JPG/RGB  | ~16.4   | 422 Kb 827 b | 20.35 |
| PNG/HSL  | ~16.3   | 839 Kb 944 b | 20.30 |
| PNG/RGB  | ~16.4   | 839 Kb 944 b | 20.22 |

Results of the experiments made by means of external function on processing of image colors pixels are given in table 3.

Table 3. Process time of determination of average color for images of formats BMP, TIF, JPG, PNG received by the image translation function in RAM in C# language for the color model of RGB

| Format | Loading | File size | Process time, min |
|--------|---------|-----------|-------------------|
| Static | 21      | 33        | -                 |
| BMP    | ~17.5   | 1.8       | 1 Mb 966 Kb 136 b | 13.25 |
| TIF    | ~17.4   | 1.8       | 1 Mb 990 Kb 016 b | 13.20 |
| JPG    | ~17.4   | 1.8       | 422 Kb 872 b    | 13.43 |
| PNG    | ~17.4   | 1.8       | 839 Kb 944 b    | 12.93 |
For a solution of the main task - decreasing time for process of determination of average color it is necessary to reveal a threshold of reduction of the image at which irreversible changes of this parameter of rather original image will begin.

For experiment, we selected on one sample with dominance of red, green and blue shades. The formats we used - bitmap images of the JPG, TIF, PNG, BMP format with the resolution of 75 DPI and the geometrical sizes 1024×768 pix. Test objects for this experiment given in Figure 2.

Figure 2. Test objects for experiment on establishment of a limit of change of the sizes of images without essential distortion of average color.

During experiment the original file – «the parent» consistently and in proportion decreased by 10%, up to 10% of the original. Reduction of image sizes were executed by means of the Photoshop program, when preserving files the parameter of the highest quality selected. All formats remained without application of compression and with standard settings of Photoshop.

Since in most cases as the most critical of parameters in prototyping of Web-products and other software solutions drawing height usually acts, reduction of images is made in this parameter.

Results of experiments given in table 4…6: calculations of image average color and parameter of quality $\Delta E_{ab}^*$. 

Table 4. Influence of graphic format type on limit of image reduction there is a many RED channel for image

| Percent of reduction, % | Image size, pix | Average image color in RGB-model | Analysis time, min. | $\Delta E_{ab}^*$ |
|------------------------|----------------|---------------------------------|---------------------|------------------|
|                        | Format BMP     |                                 |                     |                  |
| 100 (original)         | 1024 × 768     | 199.94.15                       | 15.77               | 0                |
| 90                     | 922 × 691      | 199.94.15                       | 12.32               | 0                |
| 80                     | 819 × 614      | 199.94.15                       | 9.5                 | 0                |
| 70                     | 717 × 538      | 199.94.16                       | 7.37                | 0.2582           |
| 60                     | 614 × 461      | 199.94.16                       | 5.15                | 0.2582           |
| 50                     | 512 × 384      | 199.94.16                       | 3.52                | 0.2582           |
| 40                     | 410 × 307      | 199.94.16                       | 2.23                | 0.2582           |
| 30                     | 307 × 230      | 199.94.16                       | 1.27                | 0.2582           |
| 20                     | 205 × 154      | 199.94.16                       | 0.55                | 0.2582           |
| 10                     | 102 × 77       | 201.98.17                       | 0.13                | 1.697            |

|                        | Format JPG     |                                 |                     |                  |
| 100 (original)         | 1024 × 768     | 199.94.15                       | 15.42               | 0                |
| 90                     | 922 × 691      | 199.94.16                       | 12.77               | 0.2582           |
| 80                     | 819 × 614      | 199.94.16                       | 9.93                | 0.2582           |
| 70                     | 717 × 538      | 199.94.16                       | 8.65                | 0.2582           |
| 60                     | 614 × 461      | 199.94.16                       | 5.27                | 0.2582           |
| 50                     | 512 × 384      | 199.94.16                       | 3.62                | 0.2582           |
| 40                     | 410 × 307      | 199.94.16                       | 2.3                 | 0.2582           |
| 30                     | 307 × 230      | 199.94.16                       | 1.28                | 0.2582           |
| 20                     | 205 × 154      | 200.96.16                       | 0.58                | 1.9535           |
Table 5. Influence of graphic format type on limit of image reduction there is a many GREEN channel for image

| Percent of reduction, % | Image size, pix | Average image color in RGB-model | Analysis time, min. | \( \Delta E^*_{ab} \) |
|------------------------|-----------------|----------------------------------|---------------------|-----------------|
|                        | Format BMP      |                                  |                     |                 |
| 100 (original)         | 1024 x 768      | 129.187.19                       | 15.52               | 0               |
| 90                     | 922 x 691       | 129.187.19                       | 12.22               | 0               |
| 80                     | 819 x 614       | 129.187.19                       | 9.88                | 0               |
| 70                     | 717 x 538       | 129.187.19                       | 7.22                | 0               |
| 60                     | 614 x 461       | 129.187.19                       | 5.13                | 0               |
| 50                     | 512 x 384       | 129.187.19                       | 3.52                | 0.5837          |
| 40                     | 410 x 307       | 129.187.19                       | 2.22                | 0.5837          |
| 30                     | 307 x 230       | 129.187.19                       | 1.25                | 0.5837          |
| 20                     | 205 x 154       | 129.187.19                       | 0.55                | 0.5837          |
| 10                     | 102 x 77        | 129.187.19                       | 0.13                | 2.2412          |
|                        | Format JPG      |                                  |                     |                 |
| 100 (original)         | 1024 x 768      | 129.187.19                       | 15.42               | 0               |
| 90                     | 922 x 691       | 129.187.19                       | 12.17               | 0               |
| 80                     | 819 x 614       | 129.187.19                       | 9.38                | 0               |
| 70                     | 717 x 538       | 129.187.19                       | 7.22                | 0               |
| 60                     | 614 x 461       | 129.187.19                       | 5.13                | 0               |
| 50                     | 512 x 384       | 129.187.19                       | 3.52                | 0.5837          |
| 40                     | 410 x 307       | 129.187.19                       | 2.22                | 0.5837          |
| 30                     | 307 x 230       | 129.187.19                       | 1.23                | 0.5837          |
| 20                     | 205 x 154       | 129.187.19                       | 0.55                | 0.48            |
| 10                     | 102 x 77        | 129.187.19                       | 0.13                | 0.9954          |
|                        | Format PNG      |                                  |                     |                 |
| 100 (original)         | 1024 x 768      | 129.187.19                       | 15.42               | 0               |
| 90                     | 922 x 691       | 129.187.19                       | 12.17               | 0               |
| 80                     | 819 x 614       | 129.187.19                       | 9.38                | 0               |
| 70                     | 717 x 538       | 129.187.19                       | 7.22                | 0               |
| 60                     | 614 x 461       | 129.187.19                       | 5.13                | 0               |
| 50                     | 512 x 384       | 129.187.19                       | 3.52                | 0.5837          |
| 40                     | 410 x 307       | 129.187.19                       | 2.22                | 0.5837          |
| 30                     | 307 x 230       | 129.187.19                       | 1.23                | 0.5837          |
| 20                     | 205 x 154       | 129.187.19                       | 0.55                | 0.48            |
| 10                     | 102 x 77        | 129.187.19                       | 0.13                | 0.48            |
| Percent of reduction, % | Image size, pix | Average image color in RGB-model | Analysis time, min. | $\Delta E_{ab}^*$ |
|------------------------|----------------|----------------------------------|---------------------|-------------------|
| 100 (original)         | 1024 x 768     | 129.187.19                       | 15.73               | 0                 |
| 90                     | 922 x 691      | 129.187.19                       | 12.37               | 0                 |
| 80                     | 819 x 614      | 129.187.19                       | 9.6                 | 0                 |
| 70                     | 717 x 538      | 129.187.19                       | 7.18                | 0                 |
| 60                     | 614 x 461      | 129.187.19                       | 5.28                | 0                 |
| 50                     | 512 x 384      | 129.187.19                       | 3.57                | 0.5837            |
| 40                     | 410 x 307      | 129.187.19                       | 2.25                | 0                 |
| 30                     | 307 x 230      | 129.187.19                       | 1.25                | 0.5837            |
| 20                     | 205 x 154      | 130.187.19                       | 0.55                | 0.48              |
| 10                     | 102 x 77       | 131.187.19                       | 0.13                | 0.9594            |
| **Format TIF**         |                |                                  |                     |                   |
| 100 (original)         | 1024 x 768     | 129.187.19                       | 15.73               | 0                 |
| 90                     | 922 x 691      | 129.187.19                       | 12.37               | 0                 |
| 80                     | 819 x 614      | 129.187.19                       | 9.6                 | 0                 |
| 70                     | 717 x 538      | 129.187.19                       | 7.18                | 0                 |
| 60                     | 614 x 461      | 129.187.19                       | 5.28                | 0                 |
| 50                     | 512 x 384      | 129.187.19                       | 3.57                | 0.5837            |
| 40                     | 410 x 307      | 129.187.19                       | 2.25                | 0                 |
| 30                     | 307 x 230      | 129.187.19                       | 1.25                | 0.5837            |
| 20                     | 205 x 154      | 130.187.19                       | 0.55                | 0.48              |
| 10                     | 102 x 77       | 131.187.19                       | 0.13                | 0.9594            |
| **Format JPG**         |                |                                  |                     |                   |
| 100 (original)         | 1024 x 768     | 129.187.19                       | 15.67               | 0                 |
| 90                     | 922 x 691      | 129.187.19                       | 12.37               | 0                 |
| 80                     | 819 x 614      | 129.187.19                       | 9.6                 | 0                 |
| 70                     | 717 x 538      | 129.187.19                       | 7.2                 | 0                 |
| 60                     | 614 x 461      | 129.187.19                       | 5.28                | 0                 |
| 50                     | 512 x 384      | 129.187.230                      | 3.58                | 0.5714            |
| 40                     | 410 x 307      | 129.187.230                      | 2.27                | 0.5714            |
| 30                     | 307 x 230      | 129.187.230                      | 1.25                | 0.5714            |
| 20                     | 205 x 154      | 130.187.230                      | 0.57                | 1.2747            |
| 10                     | 102 x 77       | 131.187.229                      | 0.13                | 1.765             |
| **Format PNG**         |                |                                  |                     |                   |
| 100 (original)         | 1024 x 768     | 105.174.231                      | 15.67               | 0                 |
| 90                     | 922 x 691      | 105.174.231                      | 12.37               | 0                 |
| 80                     | 819 x 614      | 105.174.231                      | 9.53                | 0                 |
| 70                     | 717 x 538      | 105.174.231                      | 7.2                 | 0                 |
| 60                     | 614 x 461      | 105.174.231                      | 5.18                | 0                 |
| 50                     | 512 x 384      | 105.174.230                      | 3.55                | 0.5714            |
| 40                     | 410 x 307      | 105.174.230                      | 2.27                | 0.5714            |
| 30                     | 307 x 230      | 105.174.230                      | 1.27                | 0.5714            |
| 20                     | 205 x 154      | 105.174.230                      | 0.55                | 0.5714            |
| 10                     | 102 x 77       | 107.176.228                      | 0.13                | 2.9708            |

Table 6. Influence of graphic format type on limit of image reduction there is a many BLUE channel for image
After processing of tabular data the graphic dependences presented on Figure 3…7.

| Percent of image reduction, % | Calculation time of average color from percent of image reduction for different formats |
|-----------------------------|-------------------------------------------------------------------------------------|
| 100 (original)              | 0.55 TIF 1.8257                                                                     |
| 90                          | 1.25 TIF 0.5714                                                                     |
| 80                          | 1.25 TIF 0.5714                                                                     |
| 70                          | 3.58 TIF 0.5714                                                                     |
| 60                          | 5.15 TIF 0.5714                                                                     |
| 50                          | 9.52 TIF 0.5714                                                                     |
| 40                          | 12.28 TIF 0.5714                                                                    |
| 30                          | 15.58 TIF 0.5714                                                                    |
| 20                          | 0.13 TIF 2.4221                                                                     |
| 10                          | 0.13 TIF 2.4221                                                                     |

**Figure 3.** Calculation time of average color from percent of image reduction for different formats.
5. Discussion of results
After data analysis of table 2, 3 it was revealed that average color for test object in the JPG format differs from the others. Therefore there were repeated measurements of color in a JPG format through Photoshop CS 6, and they showed complete data fit, software received with measurements for the RGB-model in the Photoshop CS 6 program. I.e. at the time of the test-object creation, the all colors were fixed and standard, but when saved, they were distorted. It means that there are strongest distortions and noises in this format.
It is also possible to determine the fact that average color of the image on the RGB-model remains invariable, despite distortions of the JPG format. HSL for the JPG format showed the sensitivity to distortions.
It is worth explaining that the Photoshop CS 6 program in the standard type does not give the chance to analyze data in the form of HSL. Therefore, after measurements of colors in our software converting in the RGB format to the HSL-model applied with using online-converter that then to compare to RGB-model.
After similar experiment, it is possible to draw a conclusion that for a number of reasons the color model of HSL does not approach because of hyper sensibility changes, and the JPG format creates
many essential color distortions. Also because of excess recalculation in LAB-model, the HSL-model works slowly than RGB that table 2 shows.
Average color is not shown in table 2 and 3 since it completely matches from what it is possible to draw a conclusion that our method is actual and right, thus less time for execution demands. Supervision over processes shown that at version of the images analysis with use of RAM the CPU is overloaded on average for 1% whereas RAM was loaded less. The analysis of graphic dependences showed that process speed directly depends on image size and on number of pixels in it. Also by diagrams of Figure 4...7 on change of parameter $\Delta E_{ab}^*$ it was determined that graphic formats behave on a miscellaneous and all have aberrations depending on the prevailing channel of color of drawing. The BMP format appeared the most stable.

6. Conclusions
1. As show graphic dependences greatest limit at determination of image average color the BMP format is, its parameter $\Delta E_{ab}^*$ does not exceed 2 units irrespective of parameters of reduction of images.
2. The BMP format gives the chance to define average color of the image even at 90% reduction of image size that gives the chance to reduce time of their analysis on average until 13 seconds, i.e. more than by 100 times.
3. In high-level languages, the analysis of images directly through RAM gives reduction of time of poll of color pixels on average for 5 minutes, in comparison with the methods, which built in them.
4. The HSL-model showed high sensitivity at determination of average color therefore this method is not suitable for these tasks.
5. The graphic JPG and TIF formats showed essential distortion of average color at 80% of reduction of initial image size.
6. The image with the prevailing blue color did not pass test of an average in the parameter $\Delta E_{ab}^*$ for the JPG, TIF and PNG formats.
7. The PNG format did not pass test of an average in the parameter $\Delta E_{ab}^*$ only for images with the prevailing blue color.
8. Time of process of receipt of image average color practically does not depend on a type of the selected graphic format.
9. Based on the experiments made the software by determination of image average color created and tested.

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