Automatic System to Improve Quality of 2D Images Based on Kohonen Classifier

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***Abstract*—In this paper, the idea of creating a system to analyze and improve quality of 2D images is presented. Proposed model operates on self-organizing Kohonen network. For this purpose, the method of image processing and preparation of vectors representing the components of the image are described. Tests on various images were made and presented.**

I. Introduction

2D image processing is not only a very important part of today's science but ubiquitous technology. Mobile phones, police speed cameras, or analysis of images in different factories are just a few basic applications of processing of 2D graphics. This is the main motivator for creating new and improving existing methods of detection and analysis of shapes, or improve quality of graphics.

For the image analysis, it is important to prepare the image, in a certain way. For this purpose, a number of filters are used to minimize the amount of information contained in the image leaving only the essential information or delete a plurality of noise and distortion. An example of a filter is a filter for removing noise with using the theory of fuzzy sets, and other methods of artificial intelligence [1]. In [2] a guided filter which acts as a smoothing operator was proposed. Another example is the design of recursive algorithms eg.: the bilateral filter [3].

An important aspect of the image processing is their compression. File compression increases possibility of easy transfer and processing of files. Compression algorithms should not only reduce the weight of the file, but keep the best image quality. One example of the newer compression algorithms that use rbfnn and discrete wavelet decomposition is shown in [4]. Another idea for image compression is the use of artificial neural networks. In the paper, the authors used and compared the different architecture of this structure for the purpose of compression [5]. Again in [6] was presented an idea of a physics-based transform that enables compression. In case of medical research, created image files are usually high resolution and thus the image files have large weight. This problem did not pass indifferently, and in [7] was shown an efficient compression algorithm dedicated to the medical files.

One of the most popular applications of image processing is medicine - the detection of various diseases in the early stages can save lives. In [8], the authors proposed the detection of various types of smog and stains on the X-rays through the use of modern methods of artificial intelligence - heuristic algorithms - in search of key-points. Moreover, in [8]–[11] was shown the analysis and comparison of different methods of heuristic search using important areas of 2D images is paramount for efficiency. Not only X-ray images were subjected to computer analysis, but magnetic resonance of brain section images were too [12]. The authors presented three different ideas for visual representations of the original data. Again, in [13] was presented the analysis of infrared thermal imaging of the skin.

An interesting topic in the field of image processing are neural networks, which are often used in the classification of different objects or even the entire image. In [14] was shown the use of neural networks as classifiers in clinical diagnosis. Again [15] proposed a model of multi-column deep neural networks for the classic problem of recognition of numbers from 0 to 9. The authors of [16] presented an analysis of the accuracy of recognition large-scale image by the use of very deep convolutional networks. An interesting idea is learning neural classifiers to determine the contents of the graphic objects [17]–[19]. In the case of use of artificial neural networks it requires a very large number of samples. Samples often are stored in databases, and thus algorithms for fast searching and sorting of data are important. Algorithm for fast data sorting in large datasets is shown in [20], and [21] presented possibility of the organization of NoSQL database systems. Another known problem with neural networks is insufficient number of samples to perform correct learning process. The most common solution is to use the theory of fuzzy sets and other methods of artificial intelligence to increase the number of samples on the basis of existing ones [22]–[25].

Quick and effective methods have numerous applications in factories, wineries and orchards eg.: in [26] was shown the algorithm for detecting defects of fruit based on pictures using radial basis probabilistic neural networks.

In this work, I would like to introduce an idea of a system to improve image quality. For this purpose, an innovative way to extract data about the image quality from image file is discussed. In addition, implementing self-organizing Kohonen network to indicate what needs to be improved in order to get the best quality picture is presented.

II. HSL

HSL next to RGB and CMYK is one of the most famous models of color space. It was first presented in [27] as a model associated with the perception of color by the human eye. Each color is perceived as a light coming from a certain point (lightning), what is more, each color is derived from white light. The name comes from the proposed model of the three characteristics of color **H**ue, **S**aturation and **L**ightness.

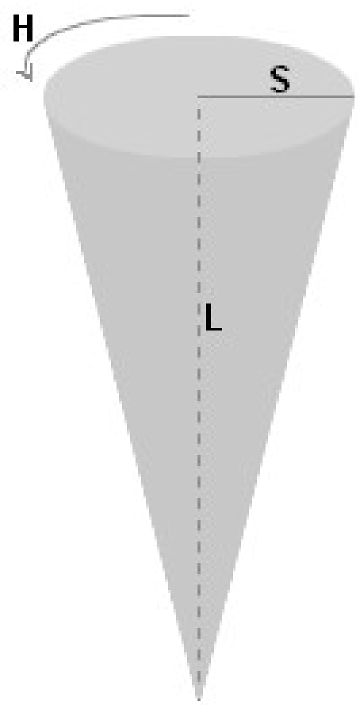

Fig. 1: The HSL color model mapped to two color cone.

Color model HSL is understood as a cone in which the color wheel is the base of the cone (see Fig. 1). Each color can be represented as a three-element vector of the following form

$$[h, s, l]\,, \tag{1}$$

where all values describe one component of the cone.

The hue h is understood as the angle on the color wheel which takes a value between $\langle 0^\circ, 360^\circ\rangle$. The color wheel begins with the red color and subsequently at 120° moves to a different color (120° is green and 240° is blue). Formally, the hue is a property that the human eye can classify as one of three primary colors (red, green, blue). Determination of the hue occurs according to

$$h = \begin{cases} 60^\circ \left[\dfrac{G-B}{\delta-\eta}\,(\mathrm{mod} 6)\right] & \text{if } \delta = R \\ 60^\circ \dfrac{B-R}{\delta-\eta} + 2 & \text{if } \delta = G \\ 60^\circ \dfrac{R-G}{\delta-\eta} + 4 & \text{if } \delta = B \end{cases}, \tag{2}$$

where $\delta = \max(R, G, B)$ and $\eta = \min(R, G, B)$. In the case where $\delta - \eta = 0$, it is considered that the value is indeterminate.

The second value describing the HSL model is a saturation that is described as the radius of the base that takes values of $\langle 0, 1\rangle$. The formula describing this attribute is

$$s = \frac{\delta - \eta}{1 - |\delta + \eta - 1|}, \tag{3}$$

where $\delta = \eta$ then $s = 0$.

The third and the last variable of the model is lightness l. It is interpreted as the height of the cone. Lightness as well as saturation takes values in the range $\langle 0, 1\rangle$. It is defined as the average value of the largest and smallest components of color what can be represented as the following formula

$$l = \frac{\delta + \eta}{2}. \tag{4}$$

III. Kohonen's self-organizing map

The first models of artificial neural networks have already appeared in the 40s of the twentieth century [28]. More than 30 years later, a Finnish scientist Teuvo Kohonen has developed a model of neural networks that learning does not require supervision [29], [30]. Applied learning is called competitive learning or learning with the competition. After entering patterns on the network, winning neuron is determined only this one neuron and its neighborhood have updated weight. In the case of this type of network, an important element is the choice of distance measure. With this measure, the network creates image of topological space of the input signals.

Euclidean metric is the most common metric. The mathematical formula between two points x_1 and x_2 is defined as

$$d(x_1, x_2) = ||x_1 - x_2|| = \sqrt{\sum_{i=0}^{n} (x_{1i} - x_{2i})^2}, \tag{5}$$

where n is the number of point coordinates.

Learning operates by selection of the winning neuron which the weights are similar to the input vector. It can be represented by

$$d(x, w_n) = \min_{i=1,2,,n} (d(x, w_i)). \tag{6}$$

Using the selected metric, the size of the neighborhood is chosen. The radius of the neighborhood is reduced with successive epochs. In the next step, the weight of the selected neurons are updated by the following equation

$$w_i(t) = w_i(t-1) + \eta f(i, x)(x - w_i(t-1)), \tag{7}$$

where η is a learning parameter, t is the number of epoch and $f(i, x)$ is a function of the neighborhood defined as a Gaussian function as follows

$$g(i, x) = e^{\dfrac{-(d(i, w))^2}{2\lambda^2}}, \tag{8}$$

where λ is a parameter. Calibration step is the last step of learning the teacher introduces the input vectors and describes a neurons which represents the specific class. Model of such network is presented in Fig. 2.

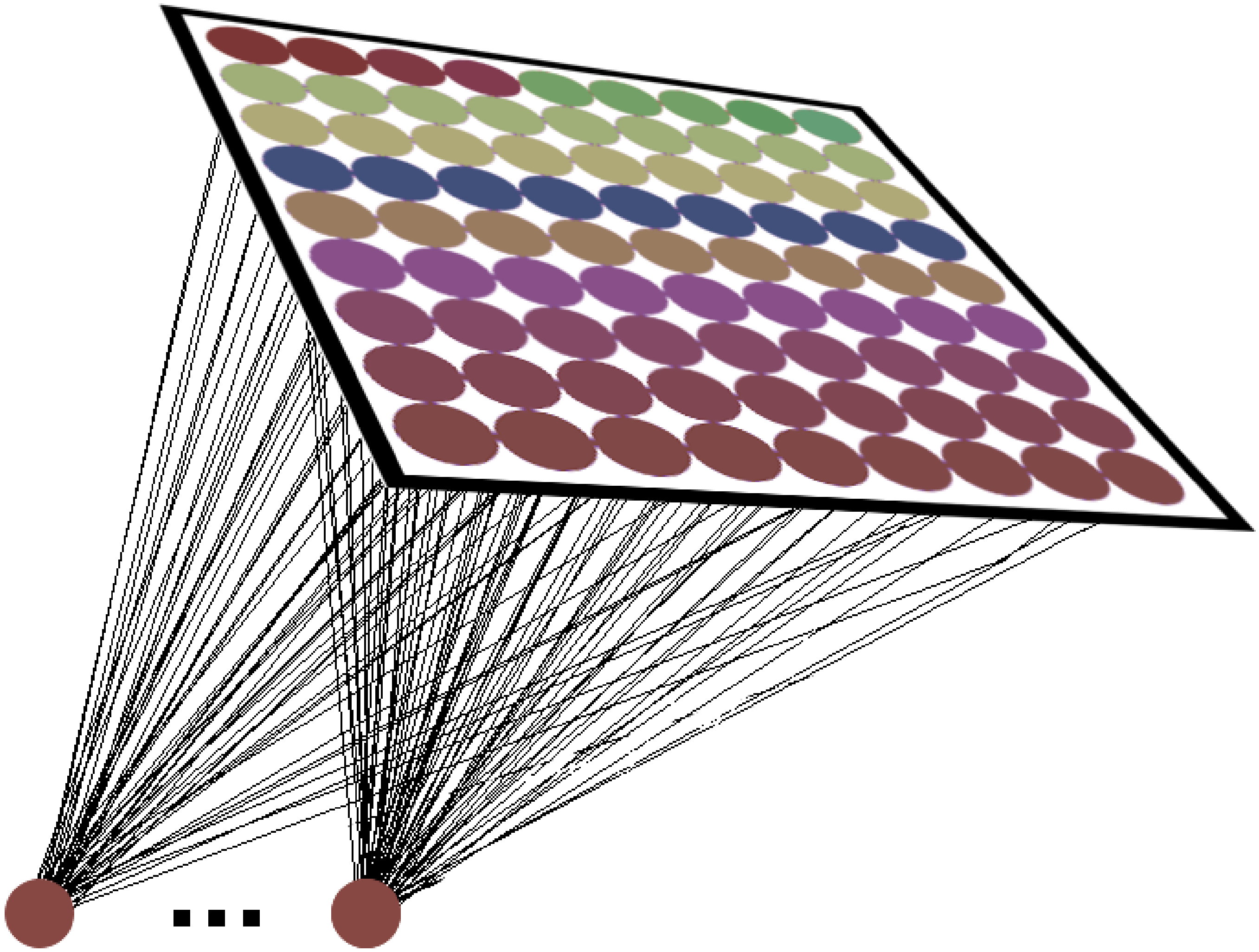

Fig. 2: Kohonen self organizing map also known as Kohonen classifier.

IV. System to improve the quality of 2D images

The proposed system consists of two parts – preparation of the vector representing the image and Kohonen classifier.

The system accepts a 2D image, which is divided into four parts. Then, the six points of (x, y) are selected at random. Points must be within a smaller area of the image. For each image, the selected points are found. Then, the neighborhood of 12 points is determined for each point. The arithmetic average of each value (hue, saturation, lightness) is calculated for all areas defined by the neighborhood. As a result, four vectors are created. All of the vectors are combined in a single thirteen-element vector representing the quality of the input image. Created vector takes the following form

$$[h_1, h_2, h_3, h_4, s_1, s_2, s_3, s_4, l_1, l_2, l_3, l_4, c], \tag{9}$$

where c is the value of 1 when the image is correct, and 0 in other cases, individual values are calculated by

$$\begin{cases} h_i = \frac{1}{6}\sum_{j=0}^{5}\left(\frac{1}{13}\sum_{k=0}^{12} h_{ijk}\right) \\ s_i = \frac{1}{6}\sum_{j=0}^{5}\left(\frac{1}{13}\sum_{k=0}^{12} s_{ijk}\right) \\ l_i = \frac{1}{6}\sum_{j=0}^{5}\left(\frac{1}{13}\sum_{k=0}^{12} l_{ijk}\right) \end{cases}, \tag{10}$$

where i means the number of the image, j is the number of neighborhoods and k is the total number of points in the neighborhood.

The resulting vector can be added to the database or be assessed by Kohonen classifier. The system classifies the 2D image in terms of its quality. In the case where any of the components of the HSL model differ from the norm, this component should be improved by increasing/decreasing

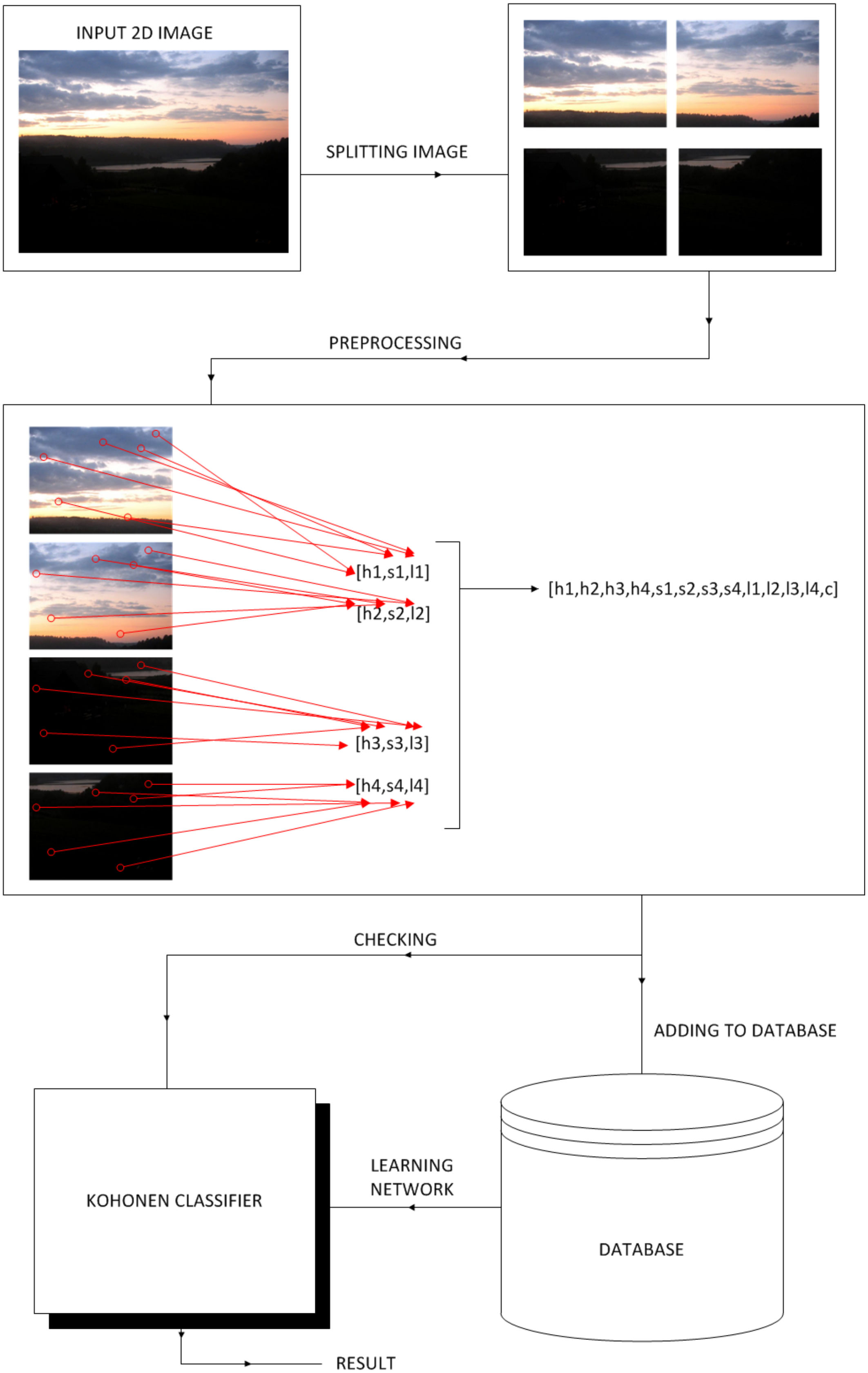

Fig. 3: The model of the proposed system.

according to mathematical formulas in Sec. II. In the case of learning, vectors stored in database are used. A model of such system is illustrated in Fig. 3.

V. Experiments

In order to test the proposed system, 100 pictures were taken – 80 pictures with a digital camera with a resolution of 15 Mpx and 20 images capture with the camera in a mobile phone with a resolution of 8 Mpx. Among the samples of photos taken with a digital camera, 50 of them were made in good quality. All images taken with the camera in a mobile phone were made in the best quality.

For each photo, the vector was created according to the notation in (9). Then, the vectors were added to the database with corresponding markings c. Kohonen classifier has been made of two layers: an input (13 neurons) and output (9×9 grid of neurons). Learning on the network is performed using all samples from the database to achieve 10000 epochs. In order to know the percentage of correctness of the network we check the results for all samples in the database. The obtained result was 71% correctly classified images.

The results of the network considered and applied the appropriate corrections by increasing or decreasing eg.: saturation. Sample images before and after improvement are shown in Fig. 4 and 5.

Algorithm 1 Kohonen Network Algorithm

```
Start
Initiate a learning parameter η, Gaussian function parameter λ, the number of epochs
Set weights at random
while t < epochs do
  for each input vector x do
    for each output neuron k do
      Calculate the distance according to (5)
      Find the winning neuron using (6)
      Find the neighborhood of the winning neuron
      for each neuron in the neighborhood do
        Update the weight using (7)
      end for
      Reduce the radius of the neighborhood
    end for
  end for
end while
Stop
```

VI. Conclusions

The presented model not only allows to determine whether a particular 2D image is correct in terms of quality, but it shows what needs to be improved. Implementation of algorithms to improve the quality of basic HSL attributes is performed by specific equations shown in Sec. II for each pixel of the image.

Result correctness of the analyzed samples were obtained at the level of 71%, which is a good result due to the small number of photos taken in the learning process. The system is unable to cope with the correct classification of the images in the most complex color (eg.: partially obscured), which is its disadvantage.

In the future research work is planned to consider a more complex system in terms of execution time, learning time and more parameters than the HSL model.

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Fig. 4: Sample images made by a digital camera with a resolution of 15 Mpx before (on the left) and after (on the right) the improvement of quality.

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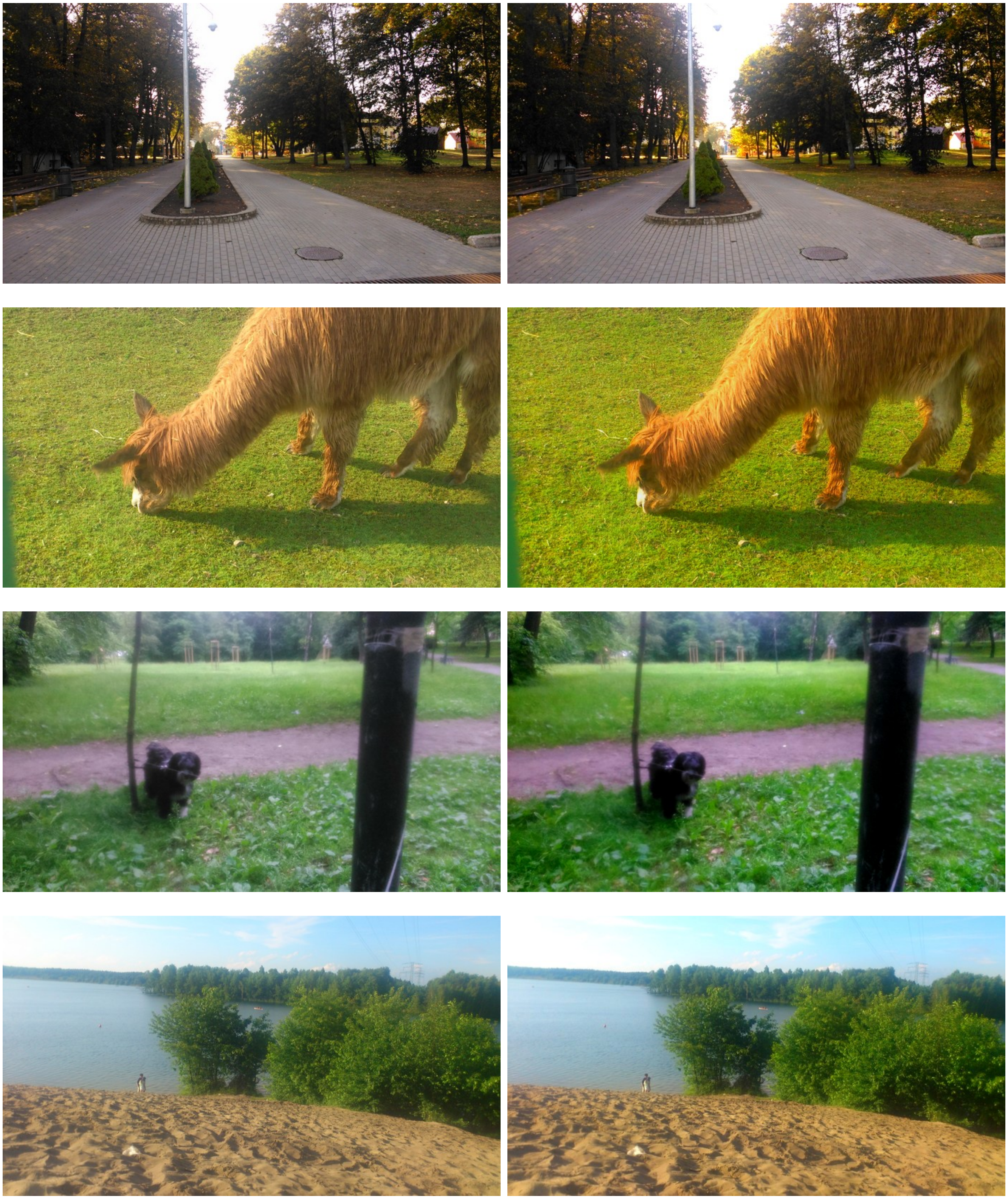

Fig. 5: Sample images made by the camera on the mobile phone with a resolution of 8 Mpx before (on the left) and after (on the right) the improvement of quality.

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