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O. Paladiiev, O. Lisovychenko

INFLUENCE OF THE OPPONENT COLOR MODEL ON THE GENERALIZATION CAPACITY OF NEURAL NETWORKS

Annotation: This article deals with the problem of transferring an ordinary three-channel color vector of data into a fully connected neural network. The process of preprocessing input data is proposed, which is based on the study of color-sensitive cells and opponent cells in the structure of the human eye. The advantages and disadvantages of various color schemes are described and illustrated.

Keywords: artificial neural networks, opponent cells, color models, data vectors, signal processing, RGB, Lab.

Introduction

Nowadays, many different tasks in programming are solved with the help of neural networks, from classification to predictions. The main principle of operation of most networks is training with a teacher, during which the tested system is forced to learn with the help of "stimulus-response" examples. There may be some relationship between the inputs and the reference outputs, but it is unknown. Only a finite set of precedents is known - a stimulus-response pair called the training sample. On the basis of these data, it is necessary to restore the dependence, that is, to build an algorithm capable of giving a fairly accurate answer for any object [2]. Such precedents or stimulus-reaction pairs are formed by people and are humanly understandable, but the machine processes this data in its own way, therefore, in the training of neural networks, processing of such data is used to transform the values into such a form with which the algorithm being developed will be "more convenient" to work with.

Depending on the tasks to be solved, different network training data are used (images, video, sound, text, numbers). For each of these types of data, their own pre-training methods are used, this article considers the adversarial color model as a method of pre-preparing data for transmission to the input layers of the network, as well as its impact on generalization abilities in solving the problem of image classification.

Pre-processing of images

After analyzing the most common image processing methods for neural network classification tasks, the following can be identified.

1. *Linear averaging and Gaussian filter.* Their main idea is to take the arithmetic mean value of the points in some neighborhood as the new value of the point. Physically, such filtering is implemented by bypassing image pixels with a convolution matrix [3].

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2. *Otsu's method.* This is an algorithm for calculating the binarization threshold for a halftone image, which is used in the field of computer pattern recognition and image processing to obtain black and white images [4].

3. *Data normalization.* A process in which each input parameter receives the same distribution of data. This allows the neural network to converge faster during training. Data standardization is performed by subtracting the mean value of each pixel and then dividing the result by the standard deviation. The distribution of this data is similar to a Gaussian curve centered at zero. The input image requires the number of pixels to be positive, so normalized data can be scaled in the range [0,1] or [0,255] [5].

From these methods, we can see that the first method actually creates a smoothing of the image, which helps to fight noise, but does not affect the reception of data by the network. The second method is used to highlight object boundaries in the image, but works only with monochrome data. Data normalization already works with colors, and we can consider this method, but, like the previous ones, it does not affect color perception in any way. Even after normalization, all data will still be transmitted in separate colors in a three-channel form. The approach described in this article can be used with all methods, even at the same time, because it is not a way to improve the quality of the image, but only changes the perception of the neural network of the usual three-channel paradigm.

Usually, you don't resort to using different color models when training neural networks. Color is transmitted in RGB format in three channels (each transmitted separately). There are also such models as CMYK, PAL, YUV, etc., but they also transmit one color per channel. The disadvantage of this approach is the reduction of the value of data for a specific channel and the presence of empty values, values at the input of the network that are equal to zero, which leads to a decrease in the speed of convergence of the neural network.

Formulation of the problem

To improve the generalization abilities of neural networks for color image classification problems, a method of preliminary data preparation by changing the color model (scheme) is proposed to eliminate the shortcomings of monochrome data transmission.

Opponent Process Theory of color perception

Consider the RGB color wheel. Let's convert all its colors to 3 channels. That is, we will highlight 3 colors (Red, Green, Blue).

You can see large black segments (Fig. 2). This is the area where the meaning of each color is absent. Black is coded as zero and therefore will have no effect on the activation function of subsequent network layers. What is the reason for the periodic decrease in the significance of individual color channels and the decrease in the convergence of the model.

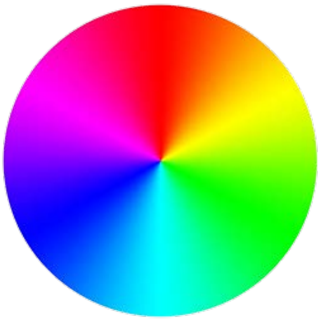

Figure 1. Spectrum of RGB colors

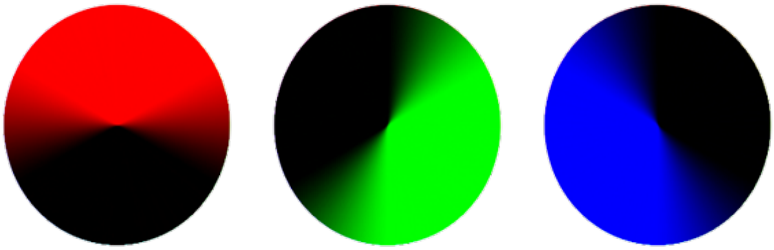

Figure 2. Individual channels of the RGB spectrum

Opponent theory is a theory of color that states that the human visual system interprets information about color by processing signals from bulbs and rods in an antagonistic (competitive) manner. The opponent theory of color suggests that there are three opponent channels through which the photoreceptors are combined to form three pairs of opposite colors: red vs. green, yellow vs. blue, and black vs. white (the latter is achromatic and determines dark-light changes, or luminance). [1].

The opposing theory suggests a color scheme close to the Lab scheme. After converting the color circle to the Lab model, we see the following changes (Fig. 3).

Figure 3. Individual channels Lab

The black spots from the previous segments are now in the first achromatic circle and are "competing" with white shades, determining the degree of brightness. In the second circle, we see the opposite of green in the form of purple instead of red, because the Lab is slightly different from the human perception system. And in the third, blue against yellow.

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Such results were obtained according to the following color mixing scheme (Fig. 4).

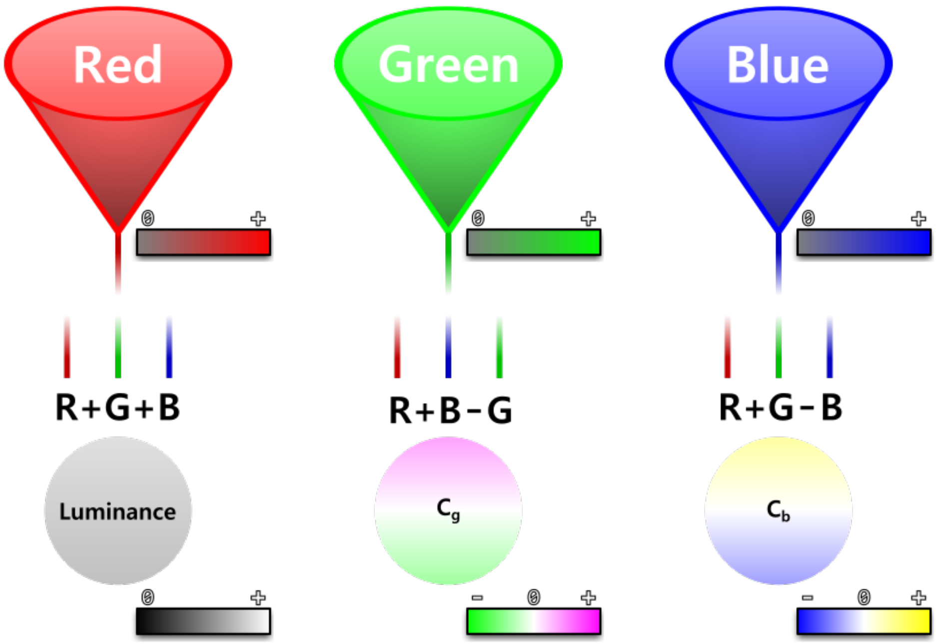

Figure 4. Scheme of color mixing [1]

We see the same color ranges in Fig. 3.

Advantages of using the opponent model

If we consider the reasons for which the opponent's model is better, the following points can be distinguished.

First, there are no zones with zero values (black areas in Fig. 1), which in turn indicates a significant reduction of zero components in the transmitted data, and this will increase the influence of each channel on the result and generalizing abilities in general.

Secondly, this color model allows you to also use other types of reprocessing of primary data and use mutually contradictory approaches in reprocessing. For example, the Otsu Method works with a monochrome image, it can be applied for the black and white range (the first circle in Fig. 3). And, for example, apply normalization or linear averaging to color channels (second and third circles in Fig. 3).

It is also worth noting that in this processing paradigm, the colors do not complement each other, adding information to the hidden layers, which will then be cut off by the activation functions, but on the contrary, the colors fight for the right to get into the inner layers in order to pass the information on. So the data is not lost in an attempt to adjust their value by constantly compressing them with the help of the selected activation function and subsampling layers, but allows them to manifest themselves in the neural network, to look for patterns in their location and intensity.

Software implementation

The tensorflow machine learning library was used to implement the software part of this solution. A small, fully connected model of simple image recognition was created. For the correctness of the experiment, after creating all the initial connections, the model was copied. In this way, we got 2 models with the same initial weights. Each model was trained on the same dataset, in which the images were presented in the same order. The number of epochs also did not differ, only the type of data preprocessing for the network changed.

Analysis of results

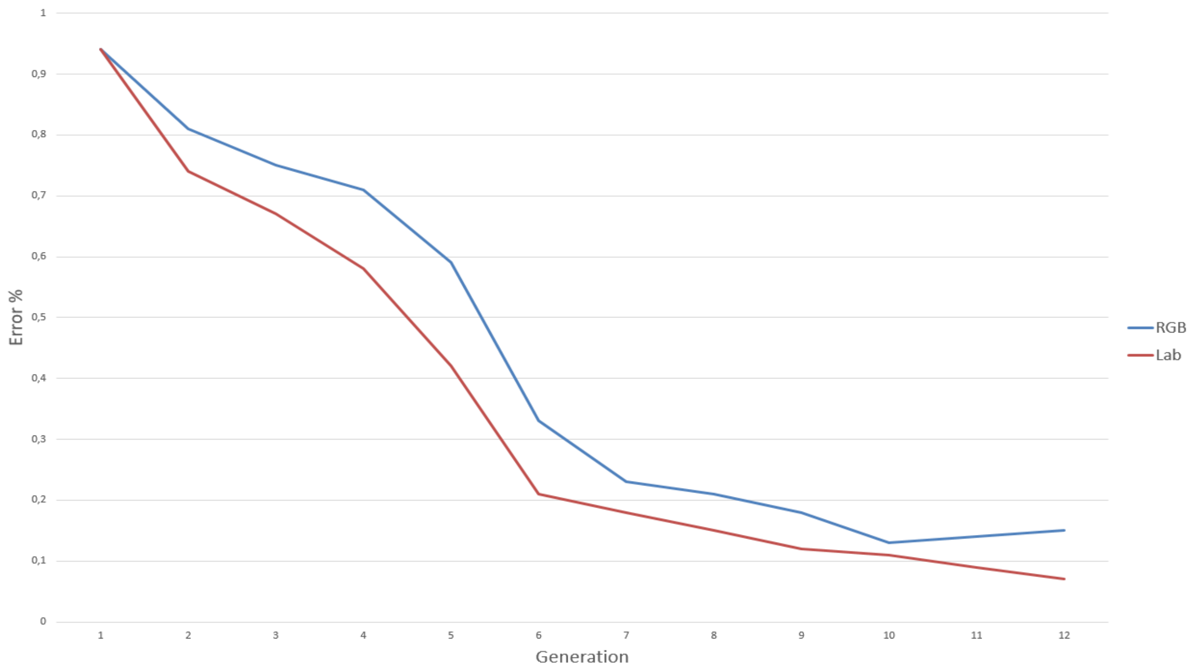

Figure 5. Learning results

From the experiment, we can state the fact that this neural network with pre-processing of data using the opponent's theory of color perception showed better learning results, as well as acceleration in the same learning. Thus, this processing shows good results on fully connected neural networks. It is also planned to conduct an experiment with a convolutional neural network in the future, in which the results will probably be more significant.

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