A Monitor Gamut Description Model Based on BP Neural Network

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Abstract

In the printing industry, monitor gamut is one of the most important indices of the preprocess system. Usually, under some condition, monitor gamut is described as triangle by three vertex, all of them come from three monitor drive extreme values, in the channels such as red, green and blue one. In spite of the simplicity of the description method in manipulation, the triangle can't describe the monitor gamut exactly, because the number of the samples are too small too indicate the feature of the monitor gamut perfectly and the monitor gamut is related to its surround and configuration. In the research, based on mapping relation of digital image pixel value and its corresponding monitoring color, data pairs of digital image pixel values and its corresponding monitoring color blocks chroma values are sampled to establish a mapping model, which is based on BP neural network with exactitude to a perfect certainty. Then, more digital image pixel values are sampled at thicker intervals, their corresponding printing color chroma values are calculated by the mapping model, so the monitor gamut is covered by thicker chroma data not only in the gamut but also on the gamut polygon contour and vertexes, that leads to the best of its ability, much more vertexes are acquired in far much more color hue angel ranges to form the gamut polygon, and the gamut is described much more fully. The experiment shows that the gamut polygon drawn by the mapping model describes the monitor gamut much more objectively and reflects the monitor gamut factually.

Introduction

Monitor gamut is the most important factor in the performances, and it plays a vital role in color management system. Monitor gamut chart usually expresses on its screen under certain condition [1]. Maxim red, green and blue drive value in their respective channel and their secondary colors' chroma values are measured by spectrometer, and the data is drawn on the color circle to present the monitor gamut. This method with high efficiency is easily to operate, and its experimental data is much less, but its accuracy is not enough, thereby the hexagon drawn could not reflect the monitor gamut fully. In addition, there is no consideration of the secondary colors formed by the drive values in three channels of different percentages, as well as with black condition [2]. In the study, the color is recorded and shown in CIE 1976 $L^*a^*b^*$ uniform color system [3].

In the study, for its good linear characteristics, self-learning and adaptive capacity[4], a color monitor characterization model based on BP neural networks is established, with the model, a considerable number of color samples is calculated by limited experimental data, in order to describe the monitor gamut through software to calculate more fully.

Determination of the BP Neural Network

By neural network theory, BP neural network capacity and the number of hidden layer and hidden layer neurons is closely related. In general, the more the number of hidden layer and the hidden layer neurons are, the stronger the capability of the neural network is [4]. The to-be-setup neural network input data (RGB format digital image pixel values) and output data (monitor printed $L^*a^*b^*$ values) distribute in [0, 255] and [-100,100] dispersedly. To complete the nonlinear transformation between the data with such features, it is necessary to increase the network hidden layers and the number of hidden layer neurons, i.e. to use stronger neural networks of approximation capability [5].

In the further study, it found that simply relying on single-hidden layer network to increase the number of neurons can not make the capacity of neural networks to certain requirements, but also training time increases considerably, even long time training leads to slow convergence and can not end the training [6], thus not only the number of hidden layer neurons increases, but also does the level of the neural network, a three layer hidden layer BP neural network is adopted [7] [8].

In addition, the experimental data which is used to setup the model is of 1000 sets. By BP neural network theory, a neural network with stronger capability is needed to process so much data [9]. After repeated experiments, the network approximation capability of training time and other factors considered, the BP neural network is determined, and its structure from the input layer to output layer neurons of each layer is 3-30-20-30-3 [2], input layer and output layer neurons is both 3, which correspond to the RGB format digital image pixel values and the $L^*a^*b^*$ color values. The BP network structure is shown in Figure1. Hidden layer neuron activation functions are all Sigmoid () functions, the output layer neuron activation function are all pure linear purelin() functions [10].

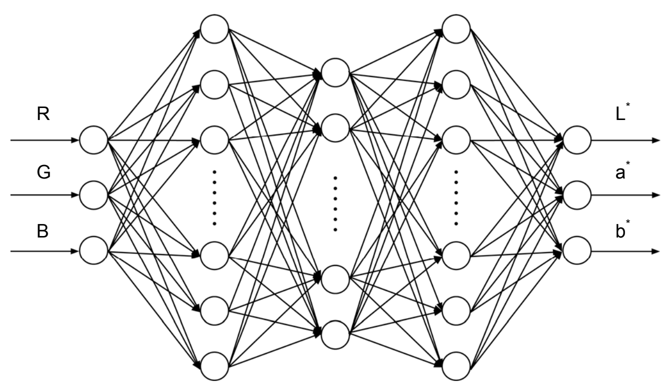

***Figure 1**. BP neural network structure*

Samples Data Acquiring for Neural Network Training of Monitor Characterization Model

Color blocks are generated in MatLab 7.0 software and the BP neural network is setup by using Neural Network toolbox included in MatLab. Color blocks are generated based on 24-bit color RGB format digital image pixel values. RGB values are selected as the interval of 10 values namely 0, 26, 52, 78, 104, 130, 156, 182, 208, 234 and 255, 3 RGB digital image pixel values are in each combination of values, 10^3 = 1000 pixel digital image value and its corresponding print color blocks and its $L^*a^*b^*$ color values are gotten as the BP neural network training data.

24-bit color BMP format image files containing 1000 blocks of color is displayed on *CTX EX700F* CRT monitor, with Photoshop CS software without its color management function module activation. The monitor color temperature is set to custom mode. The drive values of red, green and blue electron guns are 75, 70 and 80 respectively. The brightness and contrast are set to the intermediate values 50. When the monitor is turned on and warm-uped for half hour to be stable, the measure process began. The color blocks are displayed and measured with X-Rite Monitor Optimizer one by one, the experimental data is recorded as Excel 2000 file via its supporting software Color Shop and the computer COM2 interface by data cable.

Establishing Monitor Characterization Model

Monitor characterization model describes the transformation between the monitor input data and the color chroma value the monitor displays. In steady state, the monitor could be regarded as a black box, and black-box theory is used to describe the correspondence relation between the input digital image pixel values and output RGB color L*a*b* values. In the study, BP neural network is setup to describe the transformation.

After experimental data acquiring and the determination of the BP neural network structure, in MatLab 7.0 software, its neural network module is used to establish a BP neural network, and data is normalized to range of [-1,1] or [0,1], and then the neural network is trained to achieve the target in a relatively short period of time [9].

Monitor Gamut Samples Data Acquiring by Monitor Characterization Model

As mentioned above, the monitor as a black box, its function is to enter the image pixel to the corresponding print color, and performs different color values. Therefore, in order to obtain more data within the monitor gamut, the number of pixel values is increased to get more color samples of the monitor gamut.

Color monitor gamut sampled are selected in 24-bit color RGB format RGB digital image of the pixel value, RGB values are 0, 5, 10, 15, ……, 250 and 255, the number of value of digital image RGB data sets is 52^3=140608, which is used to input the BP network monitor characterization model to get the corresponding printed color chroma value to describe the monitor gamut more fully and exactly.

Experimental Results and Analysis

The purpose of this study is get more gamut samples through calculation methods in the monitor by software within the wider gamut to facilitate the evaluation of the monitor gamut, the printing quality control and color management for printing.

Monitor and Its Characterization Model Evaluation

Monitor Repeatability and Stability Testing

Representative colors such as black, white, R, G, B, C, M, Y, 20% gray, 40% gray, 50% gray, 60% gray, 80% gray are used to form color block to print, their corresponding RGB digital image pixel values are (0,0,0), (255,255,255), (255,0,0), (0,255,0), (0,0,255), (0,255,255), (255,0,255), (255,255,0), (51,51,51), (102,102,102), (128,128,128), (153,153,153), (204,204,204), color blocks with pixel value as above are displayed for three times in three color blocks. Each kind of the three color blocks is measured and calculated. The average color error of all color blocks as 0.7189, which indicates the monitor has a higher repeatability and stability.

Evaluation of the Monitor Characterization Model

1000 sets of monitor experimental digital image color values are input into the BP neural network, 1000 sets of chroma values are calculated.

The color error between the two kinds of data are as the following respectively. The mean color error is 2.088, the maximum color error is 9.452, and the minimum color error is 0.1691. The number of color with its color error greater than 6 is 8. It shows that the monitor characterization model achieves high accuracy, and it can be used to calculate a wider color gamut of monitor gamut chroma values.

Comparison between Experimental Data and Data Calculated by Monitor Characterization Model

Gamut Drawing Based on Experimental Data

1000 sets of discrete experimental data distribution are shown in Figure 2.

R, G and B with maximum drives values and their secondary colors' chroma values are drawn on to describe the monitor gamut in Figure 3, i.e. traditional method.

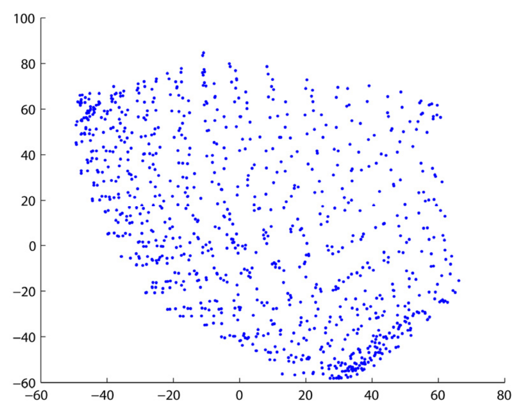

***Figure 2**. Discrete experimental data distributions*

From Figure 3, the monitor gamut drawn by traditional method with hexagon does not contain all the experimental data, because this method does not consider chroma value of secondary color of different percentage process inks. For the experimental data is of great quantity, which is of 1000 sets, based on the CIE 1976 $L^*a^*b^*$ color range and its a^*b^* plane, take the origin (0,0) as the center and hue angle range, the plane is divided into ranges, range in each hue angle range obtained from the origin point of the

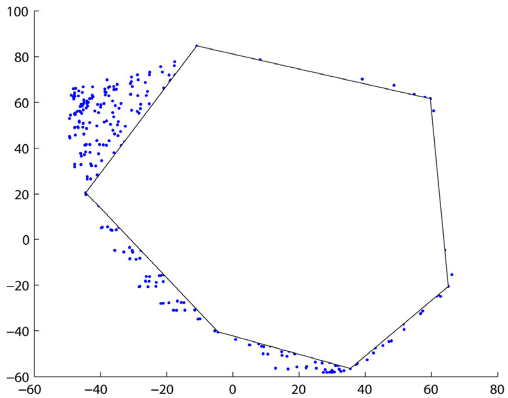

***Figure 3**. Gamut polygons drawn with three channel full drive value and secondary colors chroma values*

furthest color samples, and hue angle for each color range samples are recorded as color gamut polygon vertices. By this way, a^*b^* plane is divided into 20, 40, 60, 80, 100, 120, 140, 160, 180, 200 slices, and gamut polygons are obtained and shown in Figure 4, with hue angel of 20, 40, 100 and 200.

From Figure 4, the arrange of color gamut polygons covering the range of experimental data points expands with the a^*b^* plane division of the shares increases, when the slice number reaches 20, the maximum coverage achieves, and it reaches to 100, the polygons coverage shrinks and the shape also became apparently irregular. This shows that if the experimental data is limited, only by increasing hue angle monitor gamut can not be completely described.

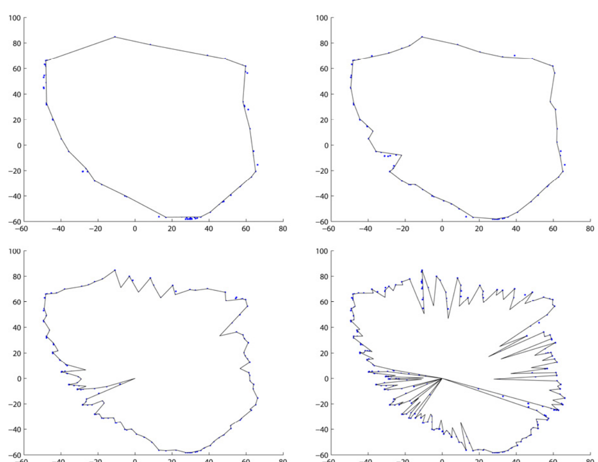

***Figure 4**. Gamut polygons with hue angel number of 20, 40, 100 and 200 with experimental data*

Gamut Drawing Based on Data Calculated By Monitor Characterization Model

140608 sets of monitor data calculated by monitor characterization model are shown in Figure 5.

Solid cyan, magenta and yellow and their secondary color chroma values are drawn on to describe monitor gamut in Figure 6.

From Figure 6, the monitor gamut hexagon drawn by traditional method can not contain all calculated data either. Similarly, the CIE 1976 $L^*a^*b^*$ color range a^*b^* plane is divided into more hue angle range, and monitor gamut polygons could be

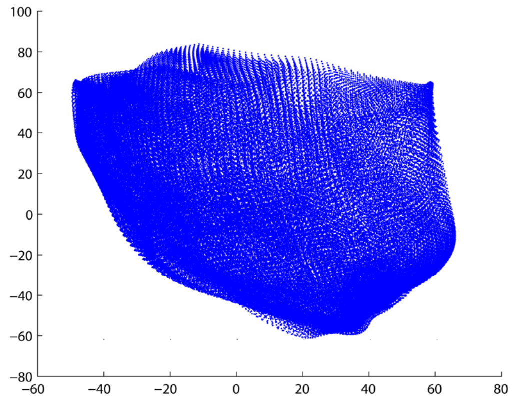

***Figure 5**. Discrete calculated data distributions*

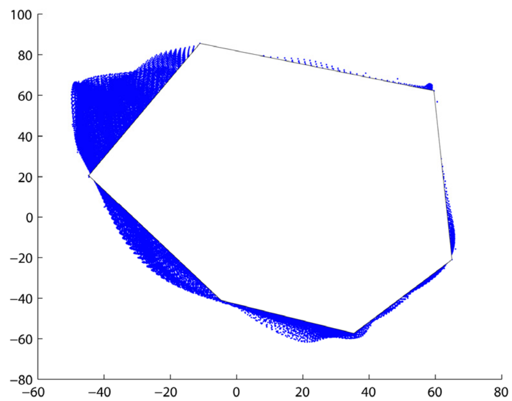

***Figure 6**. Gamut polygon drawn with process ink and its secondary colors chroma values with calculated data*

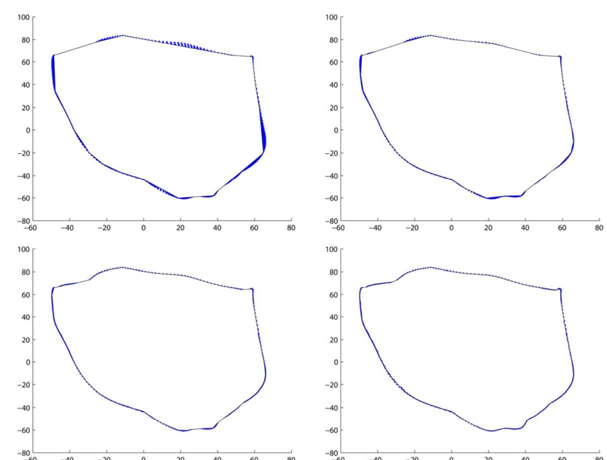

***Figure 7**. Gamut polygons with hue angel number of 20, 40, 100 and 200 with calculated data*

drawn. Parameters with the former ones, monitor gamut polygons are shown in Figure 7, with hue angel number of 20, 40, 100 and 200.

From Figure 7, coverage of gamut polygon calculated data expands with the a^*b^* plane hue angle ranges increases from 6 to 20, but when the division of the shares increases continually, although more and more close to the contour discrete data of the edge of the coverage has increased but has been nearly imperceptible different. When the shares are more than 100, the gamut polygon coverage and its shape is almost not changed. This shows that the calculated data is enough, only if the number of color hue reaches some extent, the monitor gamut could be described fully. The fundamental reason is that sufficiently large number of color samples has a more realistic representation to describe monitor gamut.

Conclusion

In the study, BP neural network with additional variable learning rate and momentum factor and improved training methods, monitor characterization is established based on BP neural network to describe monitor gamut. Because of BP network's good nonlinear approximation properties, characterization model completes the transition of the digital image pixel value and the printing color value. Based on experimental data, more gamut samples are calculated. And on this basis, the CIE 1976 $L^*a^*b^*$ color range a^*b^* plane is divided into more hue angle range by a large number of calculations, and the monitor gamut is drawn. Because the conversion method is based on black box theory and BP neural network, calculated data reflects the monitor gamut more adequately.

Monitor gamut generated by experimental data and monitor characterization model calculated data differs because of the number of the former is more than the later in a great extent, and the CIE 1976 $L^*a^*b^*$ color range a^*b^* plane does not need to be divided into more ranges, the vast majority of color samples could be covered, the monitor gamut could be described fully. But the description capability of monitor gamut polygon based on the former data the graphics, along with the expansion of the number of hue angle, does not increase but decrease. In addition, because of the experimental conditions, in study only a qualitative evaluation method of graphics is conducted.

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