https://doi.org/10.2352/ISSN.2169-4451.2018.34.95

Research on Several Models of Computer Color Matching for Flexographic Printing Based on Improved BP Neural Network

Xiaozhou Li[1,2], Jingqiang Jia[2], Mingming Cui[2], Yu Liu[2];

[1] State Key Laboratory of Pulp and Paper Engineering , South China University of Technology , Guangzhou, Guangdong/China;
[2] Key Laboratory of Pulp and Paper Science & Technology of Ministry of Education/Shandong Province, Qilu University of Technology(Shandong Academy of Sciences); Jinan, Shandong/China.

Abstract

The requirements on flexographic spot-color matching model is put forward due to the rapid development of flexography printing and the wide use of environmentally friendly aqueous ink and corrugated paper. In this paper, the flexographic spot-color matching model was designed using BP neural network algorithm for flexography printing where the aqueous ink and corrugated were used. The training and testing samples were obtained by using IGT, and the data was trained based on several mathematics models to find a suitable weighting factor. The matching models' performance and prediction error were analyzed, and the improved algorithm was put forward according to the BP neural network. It showed that the improved BP algorithm was better than the other algorithms in the area of convergence speed and training accuracy.

Introduction

Flexographic printing have many advantages which includes wide adaptive abilities, environmental friendship, wide range of product applications[1]. Color matching system is used more often in flexographic printing process for there are so many spot colors to be used. However, many enterprises in China still use artificial color matching methods which not only affects the accuracy and speed but also results in wasting ink. The computer color matching technology is replacing artificial color matching methods with its advantages of fast calculation speed and cost saving[2-3]. Neural network is one of the most important color matching models with powerful abilities of data processing, nonlinear mapping broad application prospect. Neural network matching algorithm can reduce the workload of repeatedly creating basic data and can avoid the complex mathematical operations to improve the fault tolerance. In the last few years, there are many researches on the color matching methods based on neural network[4-5]. Improved BP neural network algorithm for color matching method was used and compared with other mathematical methods in this paper.

Improved BP neural network algorithms

In recent years, many researchers have done research works and many improved methods are put forward. LM(Levenberg Marquardt) algorithm, Bayesian regularization algorithm, conjugate gradient algorithm, BFGS quasi Newton algorithm and tangent quasi Newton algorithm were obtained for color matching in flexographic printing. In this paper, these four methods were used to improve BP neural network. The neural network algorithm based on LM algorithm is actually the combination of gradient descent method and quasi Newton method. The advantage of LM algorithm is that it converges very quickly when the number of network weight is less [4]. Bayesian Networks is proposed in order to solve the problem of the uncertainty and the incompleteness, which is widely used in many fields. Conjugate gradient's convergent speed is faster than most conventional gradient descent method, and only require increase a little of storage capacity and computing capacity, and therefore, conjugate gradient method would be a better choice for a network that have a lot of weights in theory [5]. BFGS quasi Newton algorithm requires storing the approximate Hessian matrix. And the calculation is more complex when the network has many parameters and great storage capacity. Tangent quasi Newton algorithm is a compromise between BFGS quasi Newton algorithm and Conjugate gradient algorithm [6].

Experiments

The instruments used for the experiment including IGT printability tester and X-rite spectrophotometer. The experimental materials included Qingdao Tianlong aqueous inks (cyan, magenta, yellow, green and white) and varnish and linerboard. The printing speed was 0.3m/s, and the pressure between printing cylinder and substrate was 200N. The pressure between printing cylinder and anilox roller was 300N. The ruling numbers of anilox roller was 80l/cm.

Cyan, magenta, yellow, green and white were mixed according to different mass ratio until the naked eye can't see the difference. Then print them on IGT printability tester, and then use the spectrophotometer to measure the L^*, a^*, b^* values. And 250 printed samples were obtained using these five inks and were set as the training samples.

Three network layers which include input layer, the output layer and the hidden layer were chosen to ensure rapid training. According to the theory of BP, the number of input layer node is 3, i.e., L^*, a^*, b^* of samples. And the number of output layer node is 5, i.e., the mass ratio of each ink. The number of hidden layer node is critical to network performance. If the node number is less, the network is simple and training time is short. And the ability of fault tolerance is poor. However the node number is more, the network may appear excessive training, the training time is long and the network is complex. Therefore, in order to ensure the efficiency of network training, it is necessary to find a suitable number of nodes. In this experiment, the tests of each algorithm were made with hidden layer's nodes from 5-23.The number of hidden layer node based on comprehensive analysis of training time, errors, number of steps and the fitting degree was determined. The best states of four algorithms tests were shown in Table 1:

Table.1 The best states of four algorithms tests

algorithm	Hidden layer nodes	MSE1	MSE2	R	time	epoch
LM	7	0.00518	0.01	0.95078	137s	5000
Bayesian regularization	10	0.0048	0.0069	0.95498	79s	2393
BFGS quasi Newton	15	0.0075	0.01	0.072491	181s	5000
tangent quasi Newton	17	0.0069	0.0148	0.06971	75s	5000

Where, MSE represents mean squared error, MSE1 represents the fitting degree of the algorithm, $0<R<1$. If R value is closer to 1, it indicates the fitting degree is better. If it is closer to 0, it indicates the fitting degree is worse. For the range of the ink mass ratio is between 0 and 1, logsig function was chosen as the transfer function.

In this experiment, 200 color samples was chosen as training samples to train networks using four different algorithms. Then 50 samples were selected for network verification. Among 50 validation samples, L^*, a^*, b^* of the color samples were known and the mass ratio of five inks were obtained through neural network, then the validation error trough comparing with primary inks mass ratio were obtained. 20 samples were selected randomly from 50 samples to test the algorithm again. Among the 20 samples, the mass ratio of five inks and the L^*, a^*, b^* values were known, and inks based on the mass ratio were deployed. Then it was printed using IGT printability tester. According to controlling variables method, the factors including ink, paper, and printing conditions may affect the results which should be set the same.

Results and Analysis

250 color bars based on mass ratio using IGT printability tester were printed and L^*, a^*, b^* were measured using a spectrophotometer. 200 color samples were selected as training samples and 50 color samples were selected as the validation samples. Then 20 sets of data were selected from the validation samples to do test the results. In the process, the mass ratio of inks can be obtained based on network, and target samples were printed in accordance with the given mass ratio. Finally the color difference was calculated between standard samples and target samples. Four algorithms results were shown in Table 2 to Table 5.

***Table 2** color difference based on LM algorithm*

No.	L1	a1	b1	L2	a2	b2	ΔE
1	42.87	-28.99	2.22	40.49	-23.92	3.79	5.8245
2	42.8	-28.2	2.58	41.38	-21.55	5.08	7.2460
3	41.28	-27.71	2.65	39.61	-21.80	4.16	6.3231
4	42.08	-22.88	8.49	39.32	-18.94	12.41	6.2013
5	35.45	1.31	-13.83	34.57	2.60	-9.49	4.6077
6	40.05	-0.56	-15.67	39.37	1.48	-10.89	5.2375
7	39.85	-23.75	7.89	38.77	-19.35	10.17	5.0721
8	37.975	-21.92	7.535	36.97	-18.67	9.67	4.0177
9	37.13	-20.94	7.63	36.46	-18.12	9.60	3.5036
10	36.53	-20.43	7.58	37.14	-16.58	9.86	4.5129
11	41.03	-1.52	9.51	34.41	1.735	9.96	7.3913
12	26.87	6.71	-2.26	28.42	2.91	-1.76	4.1343
13	31.90	-13.66	7.05	33.58	-14.51	8.45	2.3504
14	30.24	14.22	12.85	34.17	16.49	15.52	5.2689
15	29.09	9.32	9.75	30.75	11.66	12.36	3.8761
16	31.67	-4.29	10.1	31.94	-5.13	10.04	0.8875
17	29.61	4.46	8.11	29.68	5.69	8.71	1.3684
18	28.94	4.09	7.22	29.58	4.01	7.43	0.6811

Where, *L1, a1, b1* represents values of standard samples, where *L2, a2, b2* represents colorimetric values of target samples. From Table 2, it found that the maximum color difference between standard samples and target samples was 7.39 and the minimum color difference was 0.68, and the average color difference was 4.35. And its color difference δE was shown as follows.

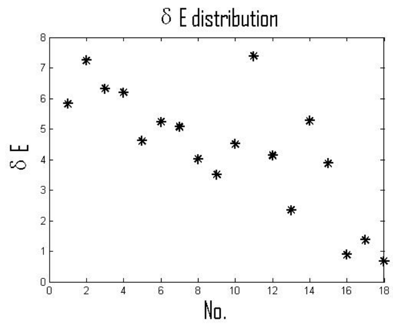

***Figure 1**. color difference distribution for LM algorithms*

***Table 3** color difference based on Bayesian regularization algorithm*

No.	L1	a1	b1	L2	a2	b2	ΔE
1	42.87	-28.99	2.22	39.88	-24.05	6.13	6.9843
2	42.83	-28.20	2.58	39.66	-24.68	7.02	6.4969
3	41.28	-27.71	2.66	39.12	-22.68	6.13	6.4818
4	39.85	-23.75	7.88	35.35	-17.83	9.17	7.5464
5	37.97	-21.92	7.53	34.02	-16.36	8.01	6.8426
6	37.13	-20.94	7.63	34.89	-18.04	10.86	4.8791
7	36.53	-20.43	7.58	35.35	-18.12	10.96	4.2578
8	41.03	-1.52	9.51	33.35	-2.40	8.08	7.8663
9	26.87	6.71	-2.26	26.84	4.16	-0.82	2.9286
10	31.90	-13.66	7.05	32.99	-15.47	10.10	3.7169
11	30.24	14.22	12.85	30.48	12.95	12.76	1.2922
12	27.97	6.74	6.93	28.35	6.03	6.86	0.8079
13	27.31	4.71	0.21	27.52	3.13	0.77	1.6910
14	31.66	-4.29	10.10	31.88	-4.45	10.31	0.3444
15	29.61	4.46	8.11	29.32	4.82	8.74	0.7877
16	28.94	4.09	7.22	28.82	3.98	7.33	0.1995
17	28.54	3.97	4.88	29.02	5.11	6.88	2.3558
18	31.67	2.25	11.2	32.06	6.25	12.84	4.3356

From Table 3, it found that the maximum color difference between standard samples and target samples was 7.86, the minimum color difference was 0.34, and the average color difference was 3.75. And its color difference δE was shown as follows.

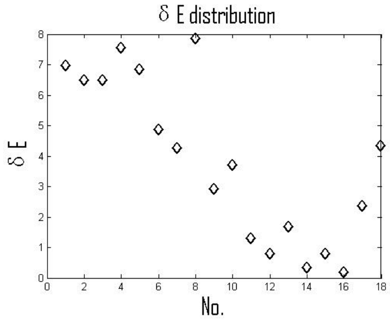

Figure 2. *color difference distribution for Bayesian regularization algorithm*

Table 4 color difference based on BFGS quasi Newton algorithm

No.	L1	a1	b1	L2	a2	b2	ΔE
1	42.87	-28.99	2.22	42.09	-26.65	3.01	2.5870
2	42.83	-28.20	2.57	42.00	-26.20	2.95	2.1920
3	41.28	-27.71	2.65	40.97	-25.53	3.29	2.2978
4	54.02	-25.55	5.95	49.78	-23.9	8.89	5.4158
5	39.85	-23.75	7.88	38.62	-23.59	11.72	4.0256
6	37.97	-21.92	7.54	37.29	-22.46	12.00	4.5499
7	37.13	-20.94	7.63	37.28	-22.06	12.83	5.3225
8	36.52	-20.43	7.58	36.84	-21.86	12.53	5.1586
9	34.03	-8.65	13.71	35.09	-7.97	16.04	2.6548
10	26.87	6.71	-2.25	27.39	2.80	-0.30	4.4029
11	29.09	9.32	9.75	30.65	12.96	11.85	4.4825
12	27.97	6.73	6.92	29.07	7.27	8.28	1.8254
13	27.31	4.70	0.20	27.51	2.23	1.39	2.7468
14	31.66	-4.29	10.1	32.05	-2.99	11.35	1.8476
15	29.61	4.46	8.11	29.88	7.345	9.59	3.2537
16	28.94	4.09	7.22	29.18	5.65	8.32	1.9192
17	28.54	3.97	4.88	28.46	4.27	6.18	1.3417
18	31.67	2.25	11.2	31.32	7.9	12.17	5.7387

From Table 4 it found that the maximum color difference between standard samples and target samples was 5.74, the minimum color difference was 1.34, and the average color difference was 3.34. And its color difference δE was shown as follows.

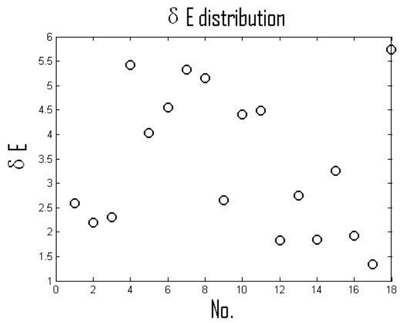

Figure 3. *color difference distribution for BFGS quasi Newton algorithm*

Table 5 *color difference based on tangent quasi Newton algorithm*

No.	L1	a1	b1	L2	a2	b2	ΔE
1	42.87	-28.99	2.22	42.06	-26.12	4.10	3.5290
2	42.83	-28.20	2.57	42.29	-26.26	4.29	2.6393
3	41.28	-27.71	2.65	40.69	-25.05	4.59	3.3369
4	35.45	1.31	-13.83	32.33	2.63	-10.70	4.6123
5	49.16	-2.05	8.86	45.59	-5.69	3.55	7.3603
6	51.28	-1.89	8.41	48.55	-4.32	2.16	7.2323
7	53.03	-1.23	9.05	51.20	-2.94	2.92	6.6173
8	26.87	6.71	-2.26	26.78	4.71	-2.02	2.0209
9	31.90	-13.66	7.04	32.61	-14.77	5.15	2.3080
10	30.23	14.21	12.85	30.77	14.64	12.50	0.7717
11	29.09	9.32	9.75	30.23	12.31	10.61	3.3122
12	27.97	6.73	6.92	28.98	9.15	7.46	2.6718
13	27.31	4.71	0.21	27.48	3.72	0.31	1.0054
14	31.66	-4.29	10.10	32.06	-2.07	8.87	2.5736
15	29.61	4.46	8.11	29.88	7.78	7.76	3.3546
16	28.95	4.09	7.22	29.23	6.91	6.80	2.8653
17	28.54	3.97	4.88	28.82	5.75	4.92	1.8014
18	31.67	2.25	11.2	31.82	6.03	10.03	3.9500

From table 5 it found that the maximum color difference between standard samples and target samples was 7.36, the minimum color difference was 0.77, and the average color difference was 3.38. And its color difference δE was shown as follows.

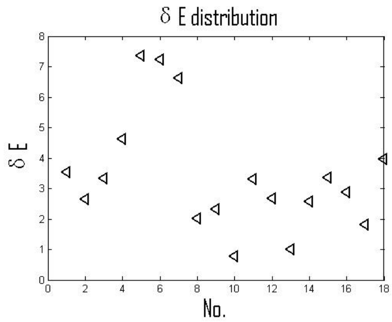

Figure 4. *color difference distribution for tangent quasi Newton algorithm*

The results of comparison for the four algorithms used in this experiment were shown in Figure 5.

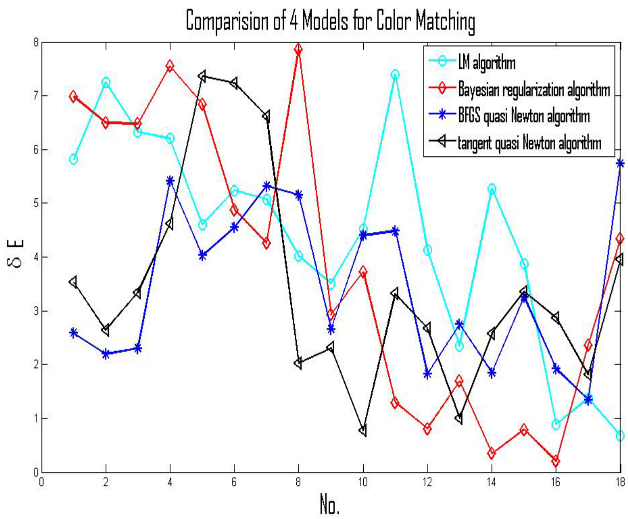

Figure 5 Comparison of four algorithms

In summary, these four algorithms can meet the printing requirement for color matching model, and BFGS quasi Newton algorithm is the best algorithm in four algorithms.

Conclusions

In this paper, four improved BP neural network algorithm were studied and compared using IGT to get printed samples. The number of hidden layer node of each algorithm was determined and each algorithm for color matching was compared to test the BP neural network algorithm properties. It showed that these four algorithms could meet the requirements of rapid color matching for flexographic printing and BFGS quasi Newton algorithm was better in our test. There were also some shortcomings in the experiment e.g., the substrate should have same properties which affects the algorithm's extensive application.

Acknowledgements

This work was supported by State Key Laboratory of Pulp and Paper Engineering (Project Number 201722), the Foundation (No. KF201604) of Key Laboratory of Pulp and Paper Science and Technology of Ministry of Education/Shandong Province of China, Ji'nan City Colleges and Universities Independent Innovation Project (Grant No. 201311032).

References

[1] ZHANG Lin, ZHANG Meiyun, YANG Xu, "Research on Color Difference in Spot Color Printing". Packaging Engineering. 31,19, (2010).
[2] Boyksen F. Automated UV-LED exposure of flexographic printing plates[P]. US Patent, (2018).
[3] J Lipiak. Methodology for Assessing the factors affecting the quality and efficiency of flexographic printing process[J]. Procedia Engineering, 182, 403(2017).
[4] K Hadad, J Mokhtari, H Eidi. Voc level control by ventilation improvement of flexography printing room using CFD modeling[J]. Journal of Applied & computational Mechanics, 3,1, (2017)
[5] Li Anxin, Research and hardware implementation of BP neural network[D]. Shandong university of science and technology. 16. (2010).
[6] Chen Lu, Li Xiaodong, Research of algorithm transforming CMY to XYZ color space based on BP neural network[J]. Packaging Engineering. 28,63. (2007).

Author Biography

Xiaozhou Li received his BS in printing engineering from Shandong Institute of Light Industry (2004) and his PhD in pulp and paper engineering from South China University of Technology (2012). Since then he has worked in the Printing and Packaging Engineering at Qilu University of Technology in Jinan, China. His work has focused on the Color Science and Technology.