Application of Hyperspectral Imaging Technology in the Analysis of Jingdezhen Blue and White Porcelain Dynasty

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Abstract: Jingdezhen blue and white porcelain is one of the most representative ceramic in China, which is a meaningful project that has high value in both academic and social economy. At present, to identify the production time of porcelains merely relying on experience is very difficult. Under such circumstances, with the development of modern technology, non-destructive spectroscopy, by virtue of its nondestructive characteristic, speediness and convenience, has been introduced into the field of cultural relics protection by more and more researchers. Though better than traditional techniques in terms of information content and band number, some problems such as information redundancy, Slowest of processing and impact on model accuracy that Hyperspectral technology has been brought alongside can't be neglected.it is a necessary step to extract and screen out the characteristic band. To improve the accuracy of the model, the information of the original spectral reflectance, the first derivative spectrum, the principal components and the effective characteristic parameters are found out, and the sensitive information of the waveband characteristics is used for analysis, and so as to further achieve the goal of the cohort study of blue and white porcelains. In this research, the Reflectance Spectra of Jingdezhen's Blue and White Glaze and Cobalt Blue Silver of different ages were achieved by using Portable high spectrometer, the spectral characteristics were analyzed by spectral curves, the first derivative curves and the principal component analysis method; through experimental verification, the highest identification accuracy can reach up to 93%. Compared with the traditional methods, the on-line analysis of blue and white porcelain by hyperspectral technique can improve the efficiency greatly and guarantees no damage to the samples. Therefore, the technique of hyperspectral qualitative analysis has a promising application prospect in the cohort study of blue and white porcelain.

Introduction

Since the Ming Dynasty, Jingdezhen has gradually become the center of porcelain industry in China. Jingdezhen has made remarkable innovation and reform in the development and selection of raw materials, improvement of glaze formula, forming technology, glaze application method, firing and decoration, etc. Because of its special status and influence, the study of blue and white porcelain, especially the study of the jingdezhen blue and white porcelain in the past dynasties, has a high value in academic and social economy, and has a good prospect of application and practical value.

At present, the age of blue and white porcelain has been identified only by experience, and both the ocular method and the traditional chemical instrument analysis method have their own weaknesses. The visual appraisal method requires the appraiser not only to have a comprehensive understanding of the history of blue and white porcelain, but also to have rich experience in the appraisal of blue and white porcelain. However, the traditional chemical instrument analysis method has some damage to the internal structure of the tested samples. However, blue and white porcelain research samples are rare and precious. At the same time, the previous studies mainly depend on the changes of the elemental composition in the porcelain or glaze, but the studies on the blue and white material are relatively few[1].

Hyperspectral technology has been applied to the information extraction and virtual restoration of murals and ancient calligraphy and paintings, and has a broad prospect in the field of cultural relic analysis [2-4] :Fischer[5], Brauns [6], Kubik [7] Padoan, [8] And Kim [9] have used hyperspectral technology for the study of painted cultural relics, Liang [10] discussed the research progress of multispectral and hyperspectral techniques in Archaeology and art preservation from aspects of instrument design, data processing, combination with other technologies and application prospects. Chinese scholar Wu [11] used visible and infrared hyperspectral technology to image the spectra of ancient painting pigments, and then matched and identified them based on spectral feature fitting (SFF) method, and analyzed the main pigment components; Gong [12] used spectral angle (SAM) mapping method to classify and identify pigments from hyperspectral images of ancient Chinese paintings;.Jin[13] processed the spectral data of textiles with first derivative, and established a partial least squares discriminant analysis (PLS-DA) identification model for textile components with MATLAB, which accurately identified textiles with different processing technologies.

The main purpose of this paper is to measure the reflectance spectra of embryo glaze and blue and white porcelain fragments samples from Jingdezhen in past dynasties by using a imaging spectrometer, and to set up the blue and white porcelain spectral database of Jingdezhen in groups. Using first derivative curve and principal component analysis to analyze the spectral features of different types and ages of blue and white glaze. The spectral features are parameterized by continuum removal (the parameters include the center wavelength position, depth and width of the absorption valley after continuum removal), SPSS and other software were used to carry out multi factor analysis of variance and correlation analysis to find out the sensitive principal components and characteristic parameters of blue and white materials. The linear discriminant analysis model (LDA) was established by inputting the whole spectrum, derivative spectrum, principal component and effective spectral feature parameters to classify the blue and white porcelain, test the accuracy and find the best model and matching algorithm.

1. Experimental Part

1.1 Experimental Samples

In order to make Jingdezhen blue and white porcelain fragment samples have better representativeness, seven different blue and white materials, including Zheliao, Pingdengqing, Zhumingliao, Huiqing, Shiqing, Suliao and Yangblue, and 28 pieces of Jingdezhen blue and white porcelain fragments from different historical periods, such as yuan, Ming and Qing Dynasties, were selected from the blue and white porcelain samples. The samples were roughly divided into 9 representative categories (Table 1), and the portable high spectrometer was used to measure and record the reflectance spectrum of the glaze and blue and white parts of the sample.

Table 1 Information of blue and white porcelain samples

No	Sample ID	validation group	Cobalt blue material	Dynasty
1	A1	A1 '	Suliao	Yuan
	A2	A2 '	Suliao	Yuan
	A3	A3 '	Suliao	Yuan
	A4	A4 '	Suliao	Yuan
2	B1	B1 '	Suliao	Ming Hongwu ()
3	C1	C1 '	Suliao	Ming (Yongle to Xuande)
	C2	C2 '	Suliao	Ming (Yongle to Xuande)
	C3	C3 '	Suliao	Ming (Yongle to Xuande)
4	D1	D1 '	Pingdengqing	Ming (Chenghua to Zhengde)
	D2	D2 '	Pingdengqing	Ming (Chenghua to Zhengde)
	D3	D3 '	Pingdengqing	Ming (Chenghua to Zhengde)
	D4	D4 '	Pingdengqing	Ming (Chenghua to Zhengde)
	D5	D5 '	Pingdengqing	Ming (Chenghua to Zhengde)
	D6	D6 '	Pingdengqing	Ming (Chenghua to Zhengde)
	D7	D7 '	Pingdengqing	Ming (Chenghua to Zhengde)
	D8	D8 '	Pingdengqing	Ming (Chenghua to Zhengde)
5	E1	E1 '	Huiqing	Ming (Jiajing to Wanli)
6	F1	F1'	Shiziqing	Ming (Jiajing to Wanli)
	F2	F2'	Shiziqing	Ming (Jiajing to Wanli)
	F3	F3 '	Shiziqing	Ming (Jiajing to Wanli)
7	G1	G1 '	Zheliao	Since the late Ming
	G2	G2 '	Zheliao	Since the late Ming
	G3	G3 '	Zheliao	Since the late Ming
	G4	G4 '	Zheliao	Since the late Ming
	G5	G5 '	Zheliao	Since the late Ming
8	H1	H1 '	Zhumingliao	Qing(Kangxi)
	H2	H2 '	Zhumingliao	Qing(Kangxi)
9	I1	I1'	Yanlan	Qing(Guangxu)

1.2 Experimental acquisition and pretreatment

American SVC HR-1024I portable ground-object spectrometer was used to measure and record the reflectance spectra of the glaze and blue-and-white material parts of the samples. In SVC hr-1024i software, the original spectra collected by SVC were processed by sig file overlap / matching and SIG file merge, and the ENVI spectral library was established. The reflectance spectral curves of 28 samples of different types of blue and white porcelain after pretreatment (Fig. 1) and the reflectance spectral curves of blue and white materials (Fig. 2) were obtained.

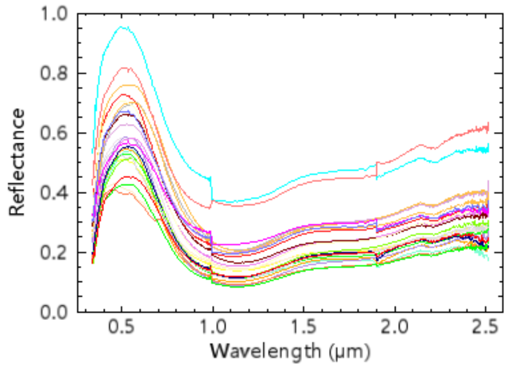

Fig 1 Reflectance spectra of different blue and white porcelain categories(body and glaze)

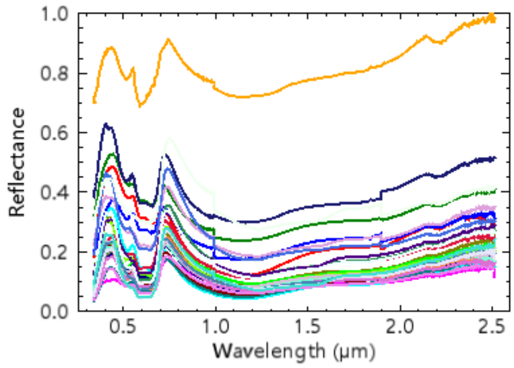

Fig 2 Reflectance spectra of different blue and white porcelain categories(cobalt and material)

2 Results and discussion

2.1 First derivative curve analysis

The first derivative of blue and white porcelain spectrum was programmed by Matlab, and the first derivative spectrum curve of blue and white porcelain was obtained after processing. The spectral curves of the 28 samples processed by the first derivative are very concentrated, which almost completely eliminates the baseline drift phenomenon and amplifies the characteristic differences of the spectral curves. Without E1, which has a large fluctuation, the remaining 27 spectral curves (8 classes in total) all show reflection peaks in the near-infrared band (around 0.71 m), and the peak values were different.

In spectral curve 8 classes were selected representative eight spectrum, and analysis of the first derivative spectra of partial enlargement (fig 3), the peak order from large to small is I1>H2>G1>D1>F3>C2>B1>A4, respectively corresponding toYanglan>zhumingliao> Zheliao > pingdengqing > shiziqing > Suliao. , so you can through the 0.71 mu m the reflection peak near the size relations to roughly speculate that the kinds of blue and white material, achieve the goal of qualitative identification.

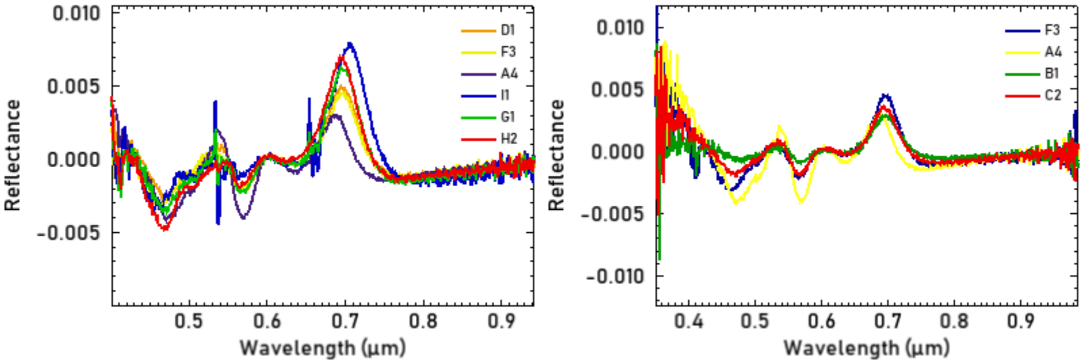

Fig 3 Partial enlarged view of the first derivative spectrum

2.2 Principal component analysis

By calculating and retaining three principal components, the contribution rate can reach 99.5% and above, and the principal component table (Table 2) can be obtained.

Table 2 Principal component table

species	FAC1_1	FAC2_1	FAC3_1	species	FAC1_1	FAC2_1	FAC3_1
A1	0.3012	2.8702	0.6753	D7	0.1280	1.3525	0.0533
A2	0.8975	1.8605	0.2125	D8	1.3335	1.1014	0.2872
A3	0.3726	1.0253	0.5203	E1	4.1942	0.7692	1.9537
A4	0.5796	1.9537	0.5929	F1	0.5295	0.1422	0.6961
B1	0.7063	0.5969	1.4432	F2	0.5859	0.2865	0.4735
C1	0.3457	0.2661	0.0486	F3	0.4854	0.0542	0.5134
C2	0.7456	0.1099	1.3846	G1	0.4347	0.3024	0.8152
C3	0.6182	0.4478	0.7178	G2	0.0543	0.3928	0.3095
D1	0.3423	0.2450	0.0716	G3	0.4226	0.4554	2.8926
D2	0.5407	0.1942	0.6836	G4	0.5054	0.2033	0.1553
D3	0.5495	0.4496	0.1707	G5	0.5215	1.0075	0.1968
D4	0.3617	0.3211	0.6324	H1	0.1321	0.7027	0.8167
D5	0.7302	0.4211	1.0398	H2	0.4733	0.8830	0.5310
D6	0.1562	0.0259	0.3064	I1	1.1351	1.6401	2.0661

2.3 Spectral feature parameters

2.3.1Continuum removal curve

When the spectral curves are similar, it is not convenient to directly extract the spectral features. By the continuum removal , the absorption and reflection characteristics of the spectra can be effectively highlighted and normalized to the same spectral background, so as to compare the values with other spectral curves and extract the characteristic parameters. The reflectance spectral curve of the blue and white material after the continuum removal can be obtained through ENVI (Fig 4).

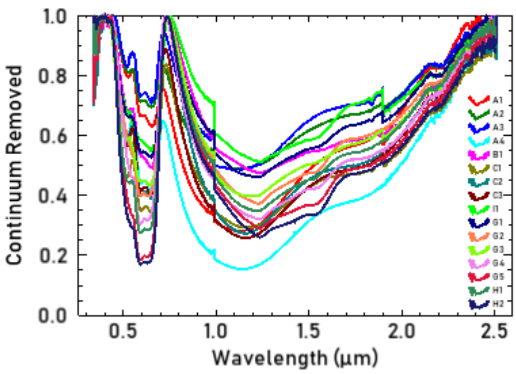

Fig 4 Blue and white material reflectance spectrum curve removed by envelope

2.3.2 Spectra Feature Extraction

The features of hyperspectral curve can be expressed by several characteristic parameters, on which feature vectors are formed to serve as the basis for the recognition of blue and white porcelain. Spectral feature parameters are quantified through the continuum removal curve, including the position, depth and width of the absorption peak.

1) Absorption valley center wavelength position P(the position with the lowest ratio reflectivity);

2) Absorption depth H(the ratio of reflectivity at the position of the absorption peak to 1);

3) Absorption width W(the absolute value of the difference between two wavelengths corresponding to half of the absorption depth).These serve as the basis for the classification and recognition of blue and white porcelain hyperspectral.

2.4 Statistical Analysis

SPSS and other software were used for multi-factor analysis of variance and correlation analysis to find out typical spectral feature parameters sensitive to color, type and age information of blue and white materials, and extract effective spectral features and input them into the subsequent classification and recognition model.

Single-factor variance analysis was used to analyze whether each principal component and spectral feature parameter had significant influence on the types of blue-and-white porcelain ($P < 0.05$). From the analysis results, it was found that the first, second and third principal components, as well as P1, H1, P2 and H2, had significant influence on the types of blue-and-white porcelain.

Correlation analysis was used to analyze whether there was significant correlation between principal component, spectral feature parameters and blue and white porcelain ($P < 0.05$) and the correlation between spectral feature parameters. The results showed that the second and third principal components and P1, H1, P2, W2 were significantly correlated with blue and white porcelain species, P2 was significantly correlated with P1 and H1, H2 was significantly correlated with H1, W2 was significantly correlated with H2.Finally, the first, second, and third principal components (X1, X2, X3) and P1, H1, P2, H2 and W2 are selected to input the model.

2.5 Classification matching model

With 28 samples as the modeling group, the whole spectrum, derivative spectrum, principal component and effective spectral feature parameters input were respectively used to establish a linear discriminant analysis model (LDA) to classify blue and white porcelain, compare the accuracy of classification results, and find out the best model and matching algorithm.

2.5.1 Input the entire spectrum

The category of blue and white porcelain (corresponding to 1-9) was selected as the dependent variable, and the reflectance of the entire spectral curve was the dependent variable. A linear discriminant analysis model was established and the confusion matrix of the classification results was observed(Table 2). VX represented the corresponding bands respectively, and 6 samples were classified wrongly in the returned classification results, with a calculation accuracy of 79%.

2.5.2 Input derivative spectrum

The category of blue and white porcelain (corresponding to 1-9) was selected as the dependent variable, and the reflectance of the whole derivative spectrum was the dependent variable. A linear discriminant analysis model was established and the confusion matrix of the classification results was observed(Table 3). VX represented the corresponding band respectively, and there were 0 samples in the classification results, and the calculation accuracy was 100%.

2.5.3 Input principal components and characteristic parameters

The types of blue and white porcelain (corresponding to 1-9) were selected as dependent variables, and the principal components and absorption characteristic parameters significantly related to them were selected as independent variables. A linear discriminant analysis model was established and the confusion matrix of the classification results was observed(Table 4). Four samples were identified as classification errors in the classification results, and the calculation accuracy was 86%

Table 3 Linear discriminant analysis results

Confusion matrix	1	2	3	4	5	6	7	8	9	real number
1	4	0	0	0	0	0	0	0	0	4
2	0	1	0	0	0	0	0	0	0	1
3	0	0	3	0	0	0	0	0	0	3
4	0	0	1	5	0	2	0	0	0	8
5	0	0	0	0	1	0	0	0	0	1
6	0	0	0	0	0	3	0	0	0	3
7	0	0	0	0	0	0	4	1	0	5
8	0	0	0	0	0	0	0	2	0	2
9	0	0	0	0	0	0	0	0	1	1
Predicted number	4	1	4	5	1	5	4	3	1	28

Table 4 Linear discriminant analysis results

Confusion matrix	1	2	3	4	5	6	7	8	9	real number
1	4	0	0	0	0	0	0	0	0	4
2	0	1	0	0	0	0	0	0	0	1
3	0	0	3	0	0	0	0	0	0	3
4	0	0	0	8	0	0	0	0	0	8
5	0	0	0	0	1	0	0	0	0	1
6	0	0	0	0	0	3	0	0	0	3
7	0	0	0	0	0	0	5	0	0	5
8	0	0	0	0	0	0	0	2	0	2
9	0	0	0	0	0	0	0	0	1	1
Predicted number	4	1	3	8	1	3	5	2	1	28

Table 5 Linear discriminant analysis results

Confusion matrix	1	2	3	4	5	6	7	8	9	real number
1	4	0	0	0	0	0	0	0	0	4
2	0	1	0	0	0	0	0	0	0	1
3	0	0	3	0	0	0	0	0	0	3

4	0	0	1	5	0	2	0	0	0	8
5	0	0	0	0	1	0	0	0	0	1
6	0	0	0	0	0	3	0	0	0	3
7	0	0	0	0	0	0	4	1	0	5
8	0	0	0	0	0	0	0	2	0	2
9	0	0	0	0	0	0	0	0	1	1
Predicted number	4	1	4	5	1	5	4	3	1	28

2.5.4 Validation group

Taking one of the original spectra of 28 types of blue and white porcelain samples as the verification group, the principal component of its spectral curve and the average value of effective spectral feature parameters were input into the linear discriminant analysis model for verification and calculation accuracy.

The data of the experimental group were substituted into the three linear discriminant analysis models established by the whole spectrum, derivative spectrum, principal component and effective spectral feature parameters respectively for testing, and the confusion matrix of the three models was obtained. Among the classification results, 2, 2 and 10 samples were classified incorrectly, and the calculation accuracy was 93%, 93% and 65%.

2.6 Model results and accuracy

In the established linear discriminant analysis model, the accuracy of the whole spectral curve was 79% and that of the validation group was 93%; the accuracy of the derivative spectrum was 100% and that of the validation group was 93%; the accuracy of the principal component and characteristic parameters was 86% and that of the validation group was 65%. Among them, the accuracy of the linear discriminant analysis model established by derivative spectrum was the most accurate High.

3. Conclusion and Prospect

In view of the demand for non-destructive analysis of blue and white porcelain and the insufficient research of hyperspectral porcelain, A complete technical route for the qualitative identification of blue and white porcelain with a hyperspectral system is proposed, which provides reference and application for the development and application of hyperspectral technology in the field of identification of blue and white porcelain. The conclusions of this study are as follows:

1) Through the first derivative spectrum in the near infrared band (0.71 m or so) the peak size of the reflection peak (I1>H2> D1>F3>C2>B1>A4) can roughly predict the type of blue and white material corresponding to the blue and white material (ocean blue > bead Ming material >, the material > equal blue >0 gravel blue >1 sous material), to achieve the purpose of qualitative identification;

2)Through the whole spectrum, derivative spectrum analysis and principal component analysis and continuum removal spectrum feature parameter extraction can be linear discriminant analysis model is established to identify, effect of comparative analysis, the results show that the established by discriminant analysis model of different kinds of blue and white porcelain are can get identification, and sentenced to up to 100% accuracy, validation group identification accuracy up to 93%, prove high spectrum detection technology was adopted to realize online classification for the type of blue and white porcelain is feasible in theory.

The purpose of qualitative analysis of the types of standard blue and white porcelain can be achieved by treating the spectrum from the above different means and angles. From the classification results and the accuracy of inversion, the analysis model based on hyperspectral analysis greatly improves the accuracy and efficiency of blue and white porcelain analysis and has high adaptability. Hyperspectral technology has the advantages of fast, nondestructive and online classification in large quantities. It has great potential in the research of blue and white porcelain and other cultural relics, and provides new methods and ideas for the qualitative analysis and research of blue and white porcelain in Jingdezhen.

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