Research on the Analysis and Identification Model of Ancient Glass Composition Based on SVM Algorithm

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Abstract. In this paper, for the problem of classification and identification of ancient glass objects, a prediction model based on mean processing of monitoring point data, a classification model of cultural relics, and a chemical composition analysis and identification model are established by means of chi-square test and spectral clustering, and the SVM algorithm is used to study the classification and identification methods of cultural relics.

Keywords: SVM, glass composition, classification study.

1. Introduction

The Silk Road is an ancient commercial route that began in ancient China and connected Asia, Africa, and Europe [1-2]. The Silk Road was a major route of economic, political, and cultural exchange between the East and the West [3]. Ancient glass, silk and metal products are important physical materials for exploring the economic, technological, and cultural exchanges between China and foreign countries along the Silk Road [4]. The glassware introduced to China through the Silk Road has obvious characteristics of the times in terms of shape, production process, chemical composition, and distribution area [5]. A batch of data related to ancient glass objects in China is available, and archaeologists have classified them into two types, high potassium glass and lead-barium glass, based on the chemical composition of these artifact samples and other testing methods [6-7]. The original data give information on the classification of these artifacts, as well as the corresponding percentages of the main components. Therefore, the study of the origin and evolution of ancient glass on the Silk Road is of great importance for understanding the development of cultural and technological exchanges between China and abroad [8].

2. The fundamental of data analysis

Step1 Eliminate invalid data:

In this paper, the data with the proportion of components accumulated and between 85% and 105% are considered as valid data. Therefore, in this paper, the chemical composition content of each group of artifacts in the data sample was cumulated. The artifacts with invalid experimental data were counted and the results are shown in Table 1.

From Table 1, the sum of the contents of each chemical component of the high potassium glass of artifact group number 15, 17 does not meet the requirements of the topic, so these two groups of data are eliminated in this paper, and the relevant data of artifact groups 15 and 17 are ignored in the subsequent research process.

Table 1. Statistical table of artifacts with invalid data

Heritage Category	Total chemical composition content	Artifact Number
High Potassium	Less than 85% or more than 105%	15, 17
Lead Barium	Less than 85% or more than 105%	/

Step2 Improve the missing information:

Observation of the data can be seen: the color of the artifacts in groups 20,41,49,59 is missing, this paper based on the relevant chemical principles, consult the relevant literature can be seen: BaO after weathering and Cu^{2+} to form a compound, showing a blue-green color, while referring to the original data in the color of the 23rd artifact, resulting in form 1 lead barium artifacts related to missing information is shown in Table 2.

Table 2. Some of the cultural relics missing information processing table

Artifact Number	Artifact Color
20	Pale Blue
41	Dark Green
49	Pale Blue
59	Blue-Green

Step3 Grouping of similar experiments:

When artifacts are weathered, the chemical content of their weathered areas is altered. The second sub-question of Question 1 asks for the type of combined glass and analyzes the statistical pattern of the chemical content of the artifact samples with and without weathering on the surface. Analysis of the data shows that the content of PbO and in the high potassium glass is nearly zero, and the content of $BaO\ K_2O$ in the lead-barium glass is also nearly zero [9]. Therefore, the chemical composition data of high potassium glass and lead-barium glass were processed separately in this paper. The specific classification results are shown in Table 3.

Table 3. Heritage classification table

Heritage Category	Heritage Group
High Potassium	Original form 1 for the rest of the high potassium groups except groups 15, 17
Lead Barium	The original form 1 of the lead and barium group of artifacts

Step4 Difference processing:

To analyze the statistical pattern of the content of chemical components on the surface of artifact samples with and without weathering and to predict the content of their chemical components before weathering. In order to visually reflect the trend of the content of each chemical component before and after weathering of artifacts when the category of artifacts, color is the same, this paper through the change in the content of each chemical component.

$$\Delta f_i = f_i - f_i' \tag{1}$$

Where Δf represents the change in the content of each chemical component before and after weathering of the artifacts when the artifacts are of the same category and color, and f_i, f_i' represents the content of each chemical component before and after weathering of the artifacts of the i group when the artifacts are of the same category and color, respectively. Since there are multiple chemical content of artifacts, Δf is the set of changes in each component, so that

$$\Delta f = \{\Delta f_{i1}, \Delta f_{i2}, \Delta f_{i3} \cdots\cdots \Delta f_{i14}\} \tag{2}$$

Where $\Delta f_{i1}, \Delta f_{i2}, \Delta f_{i3} \cdots\cdots \Delta f_{i14}$ indicates the change in content before and after weathering of SiO_2, NaO, K_2O ..... SO_2 in Form 2, respectively, with the same color as Group i artifact category [10].

3. Results

3.1. The establishment of simulation model

In this paper, we analyze the classification laws of high potassium glass and lead-barium glass based on the attached data, and then choose the appropriate chemical composition for each category to classify them into subclasses, so this paper uses SVM algorithm to classify them; Q-type clustering method is used to classify them into subclasses, and finally sensitivity analysis is performed by changing their related data.

3.2. Analysis of experimental results

Notation $x_1, x_2, \cdots\cdots, x_{14}$ denotes the 14 chemical components (indicators) of the artifacts SiO_2 , ..., SO_2 , respectively, $i=1,2,\cdots\cdots,67$, and the known observation samples are: $[a_i, y_i]\,(i=1,2,\cdots\cdots 67)$, where: $a_i \epsilon R^{14}$, $y_i=1$ indicates high potassium artifacts, and $y_i=-1$ indicates lead-barium artifacts.

First notational linear classification with optimal classification surface $(w\cdot a_i+b)=0$, where $x=[x_1,x_2,\cdots\cdots x_{14}]^T$, $\omega \varepsilon R^{14}$, $b \epsilon R, \omega, b$ TBD, satisfying the following relations.

$$\begin{cases} (w\cdot a_i)+b \geqslant 1, y_i=1 \\ (w\cdot a_i)+b \leqslant -1, y_i=-1 \end{cases} \tag{3}$$

That is, we have: $y_i[(w\cdot a_i)-b] \geqslant 1, i=1,2,\cdots\cdots 14$,

Where the samples that satisfy the equation $(w\cdot a_i+b)=\pm 1$ are support vectors. To maximize the distance from the two overall classes to the classification plane, we have.

$$\max \frac{2}{||w||} \Longrightarrow \min \frac{1}{2}||w||^2 \tag{4}$$

The SVM algorithm-based heritage classification model established in this paper can be expressed as follows.

$$\begin{aligned} &\max \sum_{i=1}^{n}\alpha_i - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_i\alpha_j y_i y_j K(\alpha_1,\alpha_j) \\ &s.t.\begin{cases} \sum_{i=1}^{n}\alpha_i y_i = 0 \\ 0 \leqslant \alpha_i, i=1,2,\cdots\cdots n. \end{cases} \end{aligned} \tag{5}$$

The expression of the classification function is.

$$g(x)=sign\left[\sum_{i=1}^{n}\alpha_i{}^* y_i K(a_i,x)+b^*\right] \tag{6}$$

The mean vector for the known 67 sample points is calculated as

$$\mu=[\mu_1,\mu_2,\cdots\cdots,\mu_{14}] \tag{7}$$

Vector of standard deviations for 67 sample points.

$$\sigma=[\sigma_1,\sigma_2,\cdots\cdots,\sigma_{14}] \tag{8}$$

Standardization of sample point data with.

$$\widetilde{a_{ij}} = \frac{a_{ij} - \mu_j}{\sigma_j}, i = 1, 2, \cdots\cdots 14; j = 1, 2, \cdots\cdots, 67 \tag{9}$$

Correspondingly, stated.

$$\widetilde{x_j} = \frac{x_j - \mu_j}{s_j}, j = 1, 2, \cdots\cdots 67 \tag{10}$$

Is the indexed standard variable. Denote: $\tilde{x} = \left[\widetilde{x_1}, \widetilde{x_2}, \cdots\cdots, \widetilde{x_{14}}\right]^T$, the normalized 67 sample point data row vectors are $b_i = \left[\widetilde{a_{i1}}, \widetilde{a_{i2}}, \cdots\cdots, \widetilde{a_{i14}}\right]$, $i = 1, 2, \cdots\cdots 14$. The classification is performed using the linear kernel function of the inverse vector machine model with the linear function of

$$c\left(\tilde{x}\right) = \sum_i \beta_i K\left(b_i, \tilde{x}\right) + b \tag{11}$$

Later, Matlab was used to solve it, according to the $c\left(\tilde{x}\right)$'s to classify different groups of artifacts. The Matlab fitcsvm function was used to program the solution. From the previous analysis, it is known that to analyze the classification law of high potassium glass and lead-barium glass, it is only necessary to solve the polynomial classification function $c\left(\tilde{x}\right)$ and to judge the positive and negative of this function.

When $c\left(\tilde{x}\right) \geqslant 0$, $\tilde{x}$ is a lead-barium glass, $c\left(\tilde{x}\right) < 0$, $\tilde{x}$ is a high potassium glass.

4. Conclusion

Glass has been developed in China for more than two thousand years and was an important commodity in the economic and trade exchange between China and abroad along the Silk Road. From the Han Dynasty onwards, glassware produced in the West began to flow into China via the Silk Road, and Chinese glassmaking techniques also drew on foreign technology, so that ancient glass made in China resembles foreign glass in appearance, but due to the different regions, the materials taken are not the same, so the main chemical composition of the two is different.

This paper describes the classification process of ancient glass objects to a certain extent accurately and skillfully, using a classification model based on the SVM algorithm, which avoids the traditional process of induction to deduction, greatly simplifies the difficulty of classifying artifacts, and distinguishes them with high accuracy. In this paper, we firstly clean and classify the data for the original data samples, and then construct an SVM algorithm to classify them only, and innovatively build a classification research model for ancient glass objects. In addition, this model has some implications for the production and planning selection of modern glass products.

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