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Chinese Painting Algorithm: A Study of Scene Characterization by Chromatographic Multiple Analysis and Handwriting Co-construction

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***Abstract*—The understanding of scene representation is a deep knowledge service structure strategy arising from the increasing scale of data and the need for complex logic solving. This study proposes a modeling improvement method based on the fusion of complex feature data and exploration behavior trajectory extremes, which effectively utilizes the artistic feature study of the interplay between the unique colorant mixture attachment features of Chinese painting and complex handwriting features as the orientation region, realizes the classification constraint of colorant data through multispectral detection, and characterizes the handwriting as the behavior law, realizes the parametric extraction and then couples the solution encoding to complete the improvement of the algorithm. Since all scenes in Chinese painting are recorded in the bearer medium with handwriting characteristics after mixing Chinese brushes and colorants, the computational model of Chinese painting algorithm proposed in this paper starts from the processing of representation hierarchical structure and painting behavior of various scenes deposited to realize the principle of describing their material deposition goals and information exchange functions. The experimental analysis shows that i. deep knowledge understanding achieves the derivation of sparse feature validity, ii. the coverage calculation obtained by drawing on technological means can vividly describe the implicit characteristics of handwriting behavior, and iii. the improved modeling process has more humanized perceptual habits and enhances the accuracy and robustness of service domain requirements.**

***Keywords*—drawing; multispectral reflectography; Imaging spectroscopy; Non-invasive diagnostics**

I. INTRODUCTION

Hyperspectral visualization has become an important part of the study of artworks, and the analysis of painting techniques with the help of spectral imaging is actively studied. In the last decades, spectral imaging treatments have been successfully combined with location-specific chemical methods such as Raman spectroscopy [1], X-ray fluorescence (XRF) [2], fiber-optic reflectance spectroscopy (FORS) [3], and particle-induced X-ray emission (PIXE) [4], mainly for identifying and mapping pigments in painted manuscripts and coloring books [5]. Infrared thermography (IRT) [6] and XRF [7] were also used for stratigraphic analysis of miniatures and antique books to highlight the presence of structural defects, such as peeling of gilding. Past art historical studies on Leonardo da Vinci's paintings have integrated analytical measurements to identify compositional materials and depict the evolution of art-making techniques and materials.

The properties of sensitive colorants can help analyze the preservation efficacy of Chinese painting collections. In this paper, we used the painting "The Great Green Wall" (created in 1973) by Mr. Guan Shanyue, a master of modern Chinese landscape painting, to collect different versions with multispectral analysis data based on digital paintings to develop a characterization acquisition scheme. As a model of landscape painting in the new era, "The Great Green Wall" depicts the coastal ranger belt in western Guangdong. The technique draws on the color technique of Western oil painting, and the whole work shows a change in hue of warm yellow near and cold blue far away. From the subject matter to the content, it has a strong representative meaning. Since there are some visual similarities and significant differences between the colorants and handwriting in the different versions of the data, the study used non-invasive techniques to compare the sample colorants with control chromatograms, using XRF and Raman spectroscopy for additional analysis.

The goal of this study was to determine the correlation between color palette and handwriting marks in different works. This study compared colorants in Chinese painting works with reference samples using non-invasive techniques focusing on multimodal imaging and reflectance spectroscopy. XRF and Raman spectroscopy were used for complementary analysis. The samples were selected as paintings of the same subject by the same author, from a similar period, which are visually similar and have subtle visual differences in color. The colors in The Great Green Wall #1 (hereafter referred to as "JP1") appear slightly less saturated than the highly saturated colors in The Great Green Wall #2 (hereafter referred to as "JP1"). This difference in saturation makes it difficult to distinguish whether different colorants were used or whether similar coloring products were used, and the differences reveal differences in the authors' behavioral traces.

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The study has two objectives: (1) to clearly identify correlations in the colorant palette of the associated works (2) to develop an analytical scheme for the behavioral characterization of handwriting.

In this study, the colorant characteristics in the collected data were compared to a reference sample of unused colorants left by Mr. Guan Shanyue during his lifetime. The reference colorants used in making the samples included blue (dayflower, indigo, Prussian blue), red (safflower, sumac, celandine, cochineal, kermes, purple gum, red ochre, cinnabar, red lead) and yellow (rice, acacia, hickory, toringo begonia, amur cork, gardenia, licorice, turmeric, yellow ochre, estradiol). Other obtainable colorants were included in this study for reference comparison. Since it is common to use a mixture of colorants in painting, a 1:1 colorant mixture of blue and red to make purple and blue and yellow to make green were also included for reference comparison. To make samples, colorants or colorant mixtures were used to make paper samples.

Fig. 1 describes the technical process of obtaining the information on painting and calligraphy colorants, behavior traces and base materials based on multispectral imaging technology, in which the corresponding data sets will be produced for the experimental behaviors at each stage. The effective management of data sets is in the form of metadata forms, which can manage the location of image data and detection data collected by multiple times and multiple devices, and can realize the effective utilization of multiple heterogeneous data.

China's painting and calligraphy resources are enormous, with the National Palace Museum alone having 130,000 pieces of painting and calligraphy artifacts. Currently, painting and calligraphy artifacts are more fragile and difficult to sample. To conduct scientific analysis of painting and calligraphy artifacts, it is necessary to use nondestructive analysis methods as well as to ensure the efficiency of the analysis methods. Because painting and calligraphy artifacts are generally large in size, important information may be missed if only local points are analyzed, so the best analysis method is to analyze the painting and calligraphy artifacts as a whole, so it is important to ensure that the analysis method is sufficiently efficient.

Hyperspectral imaging is one of the safest new NDT techniques in terms of obtaining colorants and behavioral traces, and is not easily restricted by the inspection target and inspection environment. Hyperspectral imaging is capable of acquiring image data in many very narrow wavelengths in the ultraviolet, visible, and infrared electromagnetic bands, i.e., providing tens to hundreds of wavelengths of spectral information per image element to form a complete and continuous spectral curve that can be used to quantify the properties of the observed object. Hyperspectroscopy has higher efficiency compared to nondestructive analysis methods such as portable X-ray fluorescence spectroscopy and Raman spectroscopy. This is because hyperspectral imaging technology can acquire images and reflectance spectra simultaneously in large format and at high speed. For painting and calligraphy, hyperspectral image information can be used to investigate the damage of painted artifacts, and can be used to identify hidden damage, restoration marks, and some faded and blurred contents of paintings and calligraphy; hyperspectral reflectance spectroscopy can be used to identify the composition of pigments and adhesives, and the combination of reflectance spectroscopy and images can also be used to analyze the surface distribution of pigments and adhesives.

II. METHOD

Multimodal imaging maps data from each pixel in an image to the entire painting surface, aiding in attribution and interpretation of painting analysis. Fiber-optic reflectance spectroscopy, on the other hand, is a non-invasive technique that allows measurement of completely immobile objects, helping to identify pigments as well as analyze color changes in paintings. In this paper, reference samples are characterized using multimode imaging and fiber-optic reflectance spectroscopy (FORS) to characterize identification needs, and Raman spectroscopy and X-ray fluorescence spectroscopy (XRF) can be used to complement these primary analytical methods.

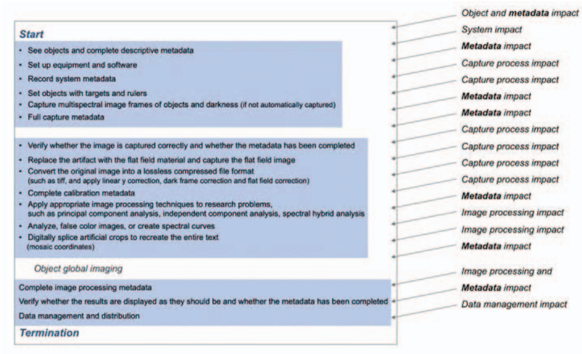

Fig. 1. A meta learning approach to image interpretation considering cartography

A. Multimodal Imaging

The samples were first characterized using various imaging modalities (including photographic and processing techniques) over a broad band of the UV-Vis-IR spectrum. The imaging modes used in the study were: visible reflection, infrared reflection, visible light induced infrared luminescence, near ultraviolet (UVA) induced visible luminescence, near ultraviolet (UVA), infrared reflection pseudocolor, and ultraviolet reflection pseudocolor. Photographing and processing of the stroke behavior identified areas of interest for further analysis based on the multimodal imaging results, which identified the presence of discrete colors [8].

Since one of the purposes of this study was to compare colorant characteristics, the same picture notation regions were selected and the full region was analyzed traversing the whole region. At least two regions of each different color or mixture were analyzed using FORS, Raman spectroscopy, and/or XRF spectroscopy.

B. Fiber optic reflectance spectroscopy

In this study, reflection spectra were obtained using an ASD FieldSpec 4 high-resolution spectroradiometer (Malvern Analyti-cal). The spectral resolution was 3 nm at 700 nm and 8 nm at 1400 and 2100 nm. light from a halogen bulb (ASD contact probe) was used at a height of about 20 cm from the surface (set at an angle of 45° to avoid specular reflection. The fibers were kept at a distance of about 1 cm from the surface with a sampling size of 3 mm. 10 spectra were averaged with a total acquisition time of <5 s. The spectra were normalized to the Spectralon white reference standard. The system was controlled via ASD's proprietary software RS3. Reflectance spectra were viewed and processed using ViewSpec Pro; the first order derivative was calculated using the built-in ViewSpec Pro software function with a derivative gap of 9 to highlight the rate of change of reflectance with respect to wavelength.

C. Raman microspectroscopy

A Renishaw InVia Raman microscope was used for this study, using a 785 nm laser, 1200 l/mm grating and a 50x follow-on air objective for measurement. The laser power at the sample was typically close to 2 mW. 10 scans were performed for an average of 10 s each. Raman spectroscopy can be obtained for a spectrum of about 1200 cm-1 spectral window, where the central wavelength is selected by the user. The spectral resolution is approximately 3-5 cm-1. The system is controlled via the Renishaw software Wire 4.0.

D. X-ray fluorescence spectroscopy

X-ray fluorescence spectroscopy was performed using Bruker tracer 5i. The spectrometer had a 4-watt Rh tube, an 8 m beryllium detector window and a proprietary silicon drift detector. A current of 50 kV in air with a 20 μ-beam diameter of 3 mm and colorant properties and methods. Radiation/light sources: Northlight High Intensity Discharge (HID) replication light (2) Northlight High Density Discharge (HIT) replication light (2) PowerSmith LED work light with 2 BG38 filters connected to UV system, Tri-light II LW370 (2) UV system, Tri-light II LV370 (3) Channel replacement, GtoB; RtoG; IRRtoR Global TC; BtoG; UVRtoB integration time of 30 seconds. The instrument is controlled via Bruker software.

III. Results

The combination of non-invasive optical and spectroscopic techniques (multimodal imaging, FORS, Raman and XRF spectroscopy) shows that the two pieces have an approximate color palette [9].

Multimodal imaging shows seven different colors in the image, using pure colorants, colorant mixtures: blue-gray (sky), blue (clothing), pink/red (roofs, flowers, and flags), yellow (mixed), green (mixed), and varying degrees of Chinese ink. The seven colors responded similarly, indicating that the impressions had a similar palette. The color responses were compared with those of the reference samples to help characterize them. The most useful imaging modes used for pigment characterization in this study were visible light-induced infrared luminescence, UVA-induced visible luminescence, and infrared reflection pseudocolor.

The analysis was complicated by the presence of acrylic traces in some areas of JP2. The brushstroke traces can be clearly seen by UVA-reflected light imaging. This imaging mode captures the absorption of UVA radiation by the surface coating, making the coating appear darker. The brushstroke layer as a whole is applied to the full area of the image front, with varying temporal coverage evident in the mid-tree area and the root zone of the tree, which is relatively uneven with the overall colorant use characteristics. This may indicate that the painter's line brush was applied to the area multiple times and occurred sufficiently.

Since the absorption of light by the colorant coating is limited to the surface, other imaging methods are unaffected by the coating. The UVA-induced visible luminescence of some colorants is much stronger than the visible fluorescence of the coating and can therefore still be used to characterize the colorant. The coating transmits IR radiation and therefore does not affect the characterization of colorants using IR imaging modalities.

A. Blue-Gray

Sky is a mixture of two colorants: blue and white. It is noteworthy that the blue coloring is more pronounced in JP2, which is larger in size and was created later, compared to JP1. The blue coloring in JP1 is clearly lost, faded, and/or altered, resulting in a light blue or gray coloring.

B. Red

In the center of the image, the red response of the roof glows strongly in the visible light-induced infrared luminescence and UVA-induced visible light luminescence imaging modes.

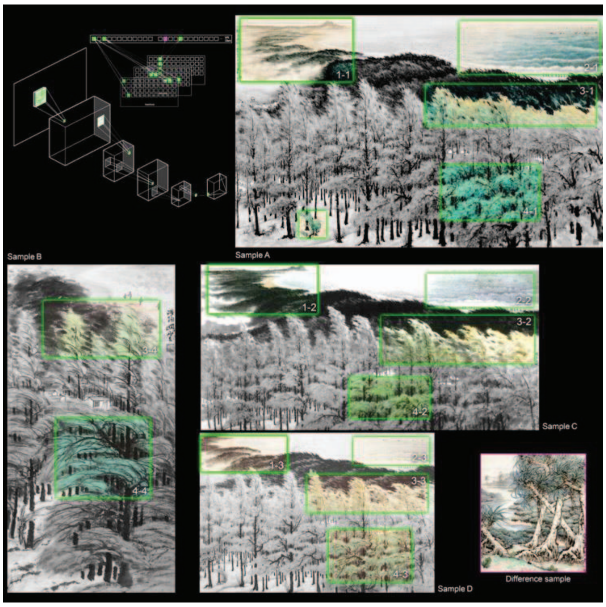

Fig. 2. A meta learning approach to image interpretation considering cartography

C. Green

The green color in the picture is a mixture of blue and yellow colorants. Interpreting the colorants in the mixture and the response from only multimodal imaging is difficult because the colorant responses may enhance each other or interact with each other; likewise, sometimes the response of one colorant may overwhelm the response of another colorant. Further complicating the issue are the different ratios of colorants used in the mixture and the different colorant coloring intensities used in the overprint.

In JP1, almost no blue colorant remains, causing the green areas to look more yellow than green. For multimodality in imaging, the green mixture does not glow in visible light-induced infrared luminescence or UVA-induced visible luminescence. These preliminary indications were confirmed by a combination of FORS and Raman spectroscopy.

Scientific analysis using hyperspectral imaging techniques not only revealed some hidden information and modification traces, but also provided an effective analysis of the distribution of some of the pigments.

The hidden information extracted from the paintings and calligraphy generally includes traces of alteration and restoration, hidden text patterns, and illegible information. A visible near-infrared hyperspectral imaging system was used to image parts of The Great Green Wall with the aim of extracting the painted parts during the painting process through the algorithm. The extraction of the artist's smear information can further analyze the overall layout of the artist during the painting process and be used for the restoration of local details. Compared to conventional RGB cameras, hyperspectral imaging systems have a wider range of wavelengths, facilitating the use of sophisticated processing algorithms. It is observed that:(1) Sample A is the most critically affirmed version of the painter's creation is a technically comprehensive evolution after fully absorbing the creative insights of Sample 2, Sample 3, and Sample 4; (2) With the continuous observation of 1-1 in Sample A, 1-2 in Sample C, and 1-3 in Sample D, and combined with the hyperspectral analysis data, it can be seen that a multi-layer overlay of Garcinia, earthen yellow and Chinese ink is used in 1-1. The behavioral traces are very light, mostly using water blending; fusion and independent ink painting and mixed color painting features in 1-2 and 1-3, and increased colorant types to form a rich color expression; (3) With the continuous observation of 2-1 in sample A, 2-2 in sample C, and 2-3 in sample D, and combined with hyperspectral analysis data, it can be seen that multiple layers of Green、Garcinia and Chinese ink were used in 2-1 overlay, with complex behavioral traces, using pre-blanking and repeated staining, which is very different from the single painting behavior of 2-2 and 2-3; (4) With the continuous observation of 3-1 in sample A, 3-2 in sample C, 3-3 in sample D, and 3-4 in sample B, and combined with the hyperspectral analysis data, it can be seen that the traces of line strokes appear to change greatly, from the high speed strokes of 3-4 and 3-3 in the early days to the 3 2 of the medium-speed strokes to 3-1 in the composite strokes behavior, and a complex trend from the use of colorants; (5) continuous observation with 4-1 in sample A, 4-2 in sample C, 4-3 in sample D, and 4-4 in sample B shows that the adjustment of colorants, from the early Stone Green to the middle Stone Green and Garcinia, to the late Emerald Green, there is a shift in the overall colorant selection. (6) The single plant drawing with the greatest differentiation from the colorant of the whole picture respectively appears in the lower left corner of sample A. Here the plant uses Shi Qing, which is a special case of single colorant use and is unified with the colorant use behavior of another work of this artist, which can be seen to be an image transplant with encrypted nature.

In the upper part of Sample A, there are complex smear marks at the junction of the mountain peaks and the trees, and the smear marks are different for each wavelength image. Combining the 690nm, 514nm, and 453nm wavelengths, the pseudo-color composite image clearly shows that the artist made several subtle adjustments to the darker areas in order to express the dynamics of the trees blowing in the sea breeze.

IV. Algorithm Description

From the material structure and recording function of Chinese landscape painting, it is clear that the basic function of the painter's behavior is to distinguish himself from the external environment [10], to divide and constitute different functional areas of the scene with brushstroke features, and to have multiple sets of objects in the area, which means that the traces of the image as a whole have multiplicity and are one of the basic features that constitute the calculation. A string or data value can be used to represent a region in the diagram. These traces evolve through "expressivity rules", which are selected in parallel and non-deterministic. The behavior of the handwriting can change its own inertia and can even be alienated and opposed. Then, using these characteristics to define a region of the image, the handwriting in each scene region evolves according to the corresponding rules, resulting in a new representation (record) of the image. In this way, the transformation of a series of handwriting behaviors is called computation. When there are no rules to act in all scene areas, i.e., no more painterly breakthrough behavior occurs, the pattern is said to be a preserved pattern. If the calculation can achieve a preserved pattern, it is called a preserved calculation or a successful calculation. The result of the calculation is the validity of the coupling of the painter's handwriting to the scene performance.

The evaluation system contains 3 main elements: brushstrokes, colorants, and rules. The rules are abstracted from the big data of the painter's handwriting reactions. With the involvement of enough samples, the time series implies the parallel execution of many basic operations and the creation can evolve in many ways from a given initial state. Therefore, evaluation systems tend to be parallel and non-deterministic in nature.

Currently, there are 2 main types of computational models in this study: colorant attachment computational models and stroke trajectory computational models. 2 types of models are distributed parallel computational models based on colorant and stroke behavior in image data, respectively, and can be abstracted structurally as trees and directed graphs, respectively.

In general, a chromophore attachment system of degree m can be represented by a multivariate group $\prod$.

$$\prod = \left(V, T, C, \mu, w_1, \cdots, w_m, \left(R_1, \rho_1\right)\left(R_2, \rho_2\right), \cdots, \left(R_m, \rho_m\right)\right) \quad (1)$$

where v is the input alphabet, whose elements are called objects; $T \subseteq V$ is the output alphabet; $C \subseteq V - T$ is the catalyst, whose elements do not change during the drawing process and are used to control a specific evolutionary reaction; and μ is a hybrid structure containing m colorants, which is used to describe the inclusion hierarchy in colorant attachment. Each colorant and the enclosed region is represented by the set of markers $\hbar$, $H = \{1, 2, \cdots, m\}$,where m is the degree of the colorant system; $w_i \in V^*(1 \leq i \leq m)$ denotes the multiple set of objects contained in the region of the structure μ, and V^* is the set of arbitrary strings composed of characters in the alphabet v.

The evolutionary rule is a binary (u, v), usually written as $u \rightarrow v$, u is the string in $V^*$and v is the character output in T, where v is the string in the set $\{a_{here}, a_{out}, a_{in} \mid a \in V, 1 \leq j \leq m\}$ and δ is a special character that does not belong to V. When a rule contains δ, the color material is effectively mixed when the rule is executed. The length of u is called the radius of the rule $u \rightarrow v$. $R_i(1 \leq i \leq m)$ is a finite set of evolutionary rules, each $R_i$is associated with a region in the chromophore structure μ and ρ_i is a partial order relationship in R_i , called the priority relationship for rule R_i execution.

For example, for evolutionary rules

$$ca \to cb_{in}d_{out}\delta \quad (2)$$

In this case, the substance c does not change before and after the evolution and is called catalyst (water blending in Chinese painting); the subscript out indicates that the material element is transported to the area outside the color material ("halo" in Chinese painting); the subscript in indicates that the material is transported to the deep attachment area ("dyeing " in Chinese painting); δ means that the current color is disappeared after the execution of the rule, and the handwriting does not occur ("flying white" in Chinese painting).

A coordinate system is set up for the overall image, and the coordinate system is used to identify the definite information of each region. Each region has a multiple set of objects and a set of evolutionary rules. Each region has a unique rule prioritization relationship of its own. That is, a rule may work only if there is no rule with higher priority than it in this region.

Every colorant has the possibility to be disappeared (dissolved, covered or washed). When a chromatic material is hourly, the objects contained in it will enter the region containing the deep attachment, and the rules in the original region disappear with it.

The structure of the computational system constructed by the Chinese painting algorithm is hierarchical and regional; the basic elements of the computation, one by one objects, are multiple; the selection of objects and rules has maximum parallelism and uncertainty. In essence, the scene representation of colorant attachment characteristics and handwriting records is a process of adaptive transformation, evolution and optimization under the goal of seeking newness and change.

In Fig. 3, A lists the three captured images of the famous work "Autumn Rowing in the Stream" by the painter (Guan Shanyue), which correspond to the true color environment, pseudo-color environment and black-and-white environment, where the true color environment image is a valid capture under a fixed light environment and meets the demand as an ordinary painting and calligraphy image study; the pseudo-color environment image is a hyperspectral image subjected to principal component transformation (Principal Component Analysis (PCA) of the second and third principal component variables of the hyperspectral images. The second principal component variable (PCA2) can highlight the traces of colorant (vermilion) (cooked brown) use, and the third principal component variable (PCA3) can highlight the traces of colorant (garcinia) use; black and white baseline extraction short-wave infrared can penetrate the colorant pigment, and has a strong absorption effect for ink, so using hyperspectral short-wave infrared can extract the material base of this image to study the painter's brushwork process, focusing on B is the knowledge map for research management, which guides the preparation and filling of metadata forms, C is the extracted short-wave infrared imaging spectral data categories, 1000 ~ 2500nm and every 400nm. 400nm Separate images are acquired for each band. The density segmentation method can be used to represent the lower image element values with dedicated colors to derive the line drawing extraction results. It is worth to propose that short-wave infrared data has very good results for the extraction of line drawing features such as starting lines.

V. Conclusion

In most scene representation modeling, data of different phenotypes are often highly coupled. However, usually because it is difficult for researchers to think beyond the limitations of single domain knowledge, it is rarely found that neglected clustering features can be searched for in heterogeneous structures. So far, our discussion of algorithmic improvements with Chinese painting modalities has been limited to the richness of colorants and the identifiable handwriting data therein, without focusing on the connections between the energy efficiency in constituting image space or propagation perception. This level of simple generalization is far from the height of thought-governed behavior after the accumulation of creator experience, and at this stage it does not allow for the simulation of the instantaneous nature of the underlying geometric reasoning ability and emotional perception.

Combining the algorithm proposed in this paper to describe the painting and calligraphy experiments against hyperspectral tests, it can be concluded that in a proof-of-concept study we can demonstrate that, with prior access to a calibrated sample set, the algorithm is able to predict the accumulation of the painter's experience prior to the emergence of behavioral iterative behavior, and how that type of accumulation leads to the migration of the painter through the change in usage habits of the thin hazy paint layer and the migration that occurs after the accumulation of experience with behavioral traces. Compared to art researchers' studies through conventional perspectives, the analysis using algorithms on the one hand spawned the achievement of higher predictive accuracy, and on the other hand, the constitutive logic of the algorithm will counteract the hyperspectral experiments and will effectively increase the efficiency of the integration of multiple acquisitions and analysis tools.

The algorithmic logic gains a higher penetration depth compared to traditional research in the case of existing studies. However, the empowerment of the algorithm requires calibration on a dataset of known volume, and a method of positional alignment and management for high-resolution imaging is needed to be able to accurately describe the layer distribution, including local inhomogeneities. On the other hand, experimental analysis of data has so far been limited to physical or functional characterization, while data-driven descriptions of painterly habits are still in their infancy, and the irreversibility of the temporal sequence of painting behavior on Chinese paper, the stability of colorants, and the richness of absorption traces on rice paper can provide additional information and specificity for in-depth research.

Given the broad applicability of the algorithm logic and the potential for further improvements, it is expected that the concept will find many practical applications in a variety of fields including art, archaeology, forensic science, catalytic research, biology and biomedicine. The new offers the ability to complement the analysis of the detection data, especially in the case of hyperspectral acquisition systems obtaining infinitely close microscopic conclusions of the material.

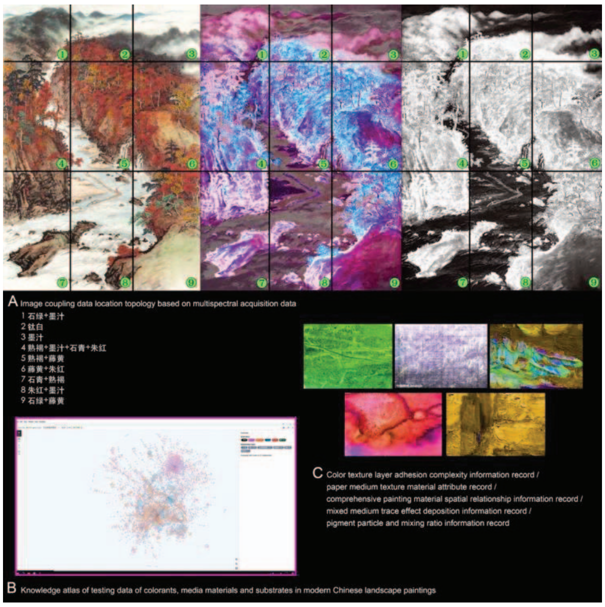

Fig. 3. A meta learning approach to image interpretation considering cartography

However, the model's hypothesis improves our understanding of complex data networks, such as most metrics exhibiting sub-regional frequency characteristics, above average critical density, and preferential attractiveness of image colorant composite structural regions. Subsequent analyses using hierarchical clustering, network and self-organizing map (SOM) analyses can attempt to reveal regional differences or be explored using eye-movement perception evaluation analysis results fusion calculations.

The success of related methods suggests that no single set of laws can completely describe a master-slave study sample. Cross-domain study data are not automatically randomly distributed around the study sample; instead, extensive correlation is performed and a feedback strategy is available to characterize the parameters of the directed target; moreover, both robustness and evolutionary properties can be effectively enhanced with increasing the number of data genes, enriching the complexity level and increasing the sample set size.

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