Construction Feature of Intrinsic Color Vector Span Space on Appearance of Tibetan Traditional Architecture from Digital Images

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Abstract. This article is focused on the qualitative analysis in the color art analysis of Tibetan traditional architecture(TTA) while lack of quantitative analysis, the definitions of visual distinguishable function, color vector distinguishable level and intrinsic color vector span distinguishable space(ICVSS) are introduced firstly, method for ICVSS is put forward by these definitions and simple set operation about TTA, which is used as the main manifestation of the color features of the TTA. Finally, numerical tests are implemented with the digital images and color point cloud data set is inputted by Matlab programming. The experiments are proved that the method is simple, accurate and effective, and agree with the works of the existing qualitative analysis.

Introduction

The distinctive decorative appearance of Tibetan architecture is the architectural culture formed by the people who live in Tibetan areas during a long history. It is the aesthetic art formed by the Tibetan people in their cultural atmosphere based on their religious beliefs. The research and analysis of the appearance’s color of Tibet architecture are mainly based on religious culture at present. From the perspective of research methods, at present, it is still at the stage of basic visual observation and artificial subjective analysis. From the point of view of the use of research data, it is basically an analysis and study of a class of buildings or their local appearance’s colors. The existing research results are basically qualitative results and conclusions [1-6]. With the continuous development and progress of multidimensional data analysis theory and methods, it is possible for using multidimensional digital analysis technology to analyze the color of appearance on Tibet buildings. The basis of multidimensional data analysis is based on the extracted features, which often rely on data mining, knowledge discovery and other related algorithms. However, works on the construction feature of intrinsic color vector span space(ICVSS) are lack which is the base for multidimensional data analysis. This work is aimed to preliminary exploration on ICVSS of Tibetan traditional architecture.

The color models include RGB for general electric devices, CMY for color printing, HIS, HSV and HSB for visual perception and they can be transformed to each other by multiplied a special matrix [7]. The quantitative analysis of the external color of Tibetan buildings is less reported in previous research works; on the other hand, from a human perspective, the color information that can be distinguished and accepted is difficult to describe and analyze through the current RGB color model for human visual perception system, especially for some monochromatic analysis, which is often subjective. Based on collecting images of Tibetan traditional architecture by camera and color point cloud by 3D laser scanner, method of ICVSS is proposed by introducing definitions of visual discriminatory function and color discriminative gray level with RGB model which can also be transformed into other color models.
Related Definitions and Assumptions

Definition 1. Visual distinguishable function: let \( f(x,y) \) be a bivariate vector function defined on \( n \)-dimension and such that value of the function is invariable for two linearly dependent vectors, that is, for any constant \( k(k \neq 0) \), there will be \( f(x, kx) = f(x, x) \).

Actually, the most common function is the two vector inner product defined in Cartesian space with being normalized and satisfied definition 1. Therefore, any compound function which one variable function defined on the value of inner product function can be discriminatory function.

Definition 2. Color distinguishable gray level: let \( C_1, C_2 \) be two quantized color vectors from an image, given visual discriminatory function \( f(x,y) \) and \( L > 0 \), if

\[
f(C_1, C_2) < L. 
\]

the two color vectors \( C_1, C_2 \) are called indiscernible for the discriminatory function \( f(x,y) \). If function

\[
f(C_1, C_2) \geq L. 
\]

the two color vectors \( C_1, C_2 \) can be recognized by the discriminatory function \( f(x,y) \).

According to the above definition, it is obvious that the color divisibility depends strictly on the separable index and the visual divisibility function. From the definition of the function, it basically accords with the cognitive process of color in the human visual system.

Definition 3. Intrinsic color vector span space: let \( C_1, C_2, \ldots, C_n \) be the quantized color value which formed a set \( V \) from the given images, and call the \( P \) which formed by \( C_1, C_2, \ldots, C_n \) as color vector span space related to the discriminatory function \( f(\cdot, \cdot) \) with level \( L \) if \( \forall C \in V, \exists k, i \) such that:

\[
C = kC_i, 
\]

where \( k > 0 \), \( C_i = \max \{ \|C_i\| \mid f(C_i, C_j) < L, C_j \in V \} \),

\[
\|\cdot\| \text{ is matrix norm}[8] \text{ and elements of } P \text{ is minimal.}
\]

In terms of the definition of intrinsic color vector span space (ICVSS), it is different from linear space in general mathematical sense for when \( C \) is a vector with three components must be a three-dimensional linear space according to the definition obviously with three standard bases. However, according to the previous definition 3, the color vector span space usually exceeds the three-primary colors. From the point of view of the appearance decoration color of Tibetan architecture and architectural art, it is of great significance to discovery the color features of Tibetan traditional architecture, architectural style, art system and so on by using the existing quantitative data, according to the above relevant definition. At the same time, it is important to guide for the Tibetan traditional architecture artificial color restoration as well as the digital restoration.

Construction Feature of ICVSS Method

From the definition given in this paper, the determination of ICVSS mainly depends on the color discriminative level \( L \) and the color discriminative function \( f(x,y) \). The discriminative level \( L \) is inversely proportional to the number of primary colors forming the color divisible space under the same conditions with the discriminative function \( f(x,y) \). The choice of discriminative function \( f(x,y) \) will affect the construct features of ICVSS and the process can complete by the set operation with the discriminative function \( f(x,y) \). Thus, the construction process can be described as follows:

Step 1: Give the color vector set \( S \), discriminative function \( f(x,y) \) with corresponding discriminative gray level \( L \);

Step 2: Let ICVSS be \( P = \{ C \}, C \in S \)

Step 3: Set \( S' = S - P \), and do the following:
If \( S' \neq \Phi \),
Do the following:
For every $C \in S'$,
To calculate (1)
If it’s satisfied,
let $S' = S' - \{C\}$;
Repeat step 3;
Otherwise,
according to (4)
select the $C_i$
$P = P \cup \{C_i\}$;
Repeat step 3;
If $S' = \Phi$, turn to Step 4;
Step 4: Output $P$.

In the execution of the above algorithm, the calculation efficiency is very low for the process is calculated strictly according to the definition. In the improvement and optimization of the algorithm, there are two kinds of strategy which can be applied. The one is to research a new method to change images color level to one color vector set whose element is unique; the other is to find a simple discriminative function $f(x,y)$ which can be calculated with more accurate simulation of human visual system. According to the definition 2, it shows that the discriminative function $f(x,y)$ are invariant for two color vectors whose intensity are linear. Furthermore, the discriminative function $f(x,y)$ can be selected by its specific application.

Data Collection and Numerical Implement

The collection of the appearance’s color data of traditional Tibet architecture is a basic starting point of the algorithm in this paper. From the existing data collection devices, they can be divided into two categories. One is based on photography, which includes manual photography of general digital cameras, small unmanned aerial vehicle systems with photographic equipment, etc. Their final forms of date are often series of digital images or videos with being uniform sampled and quantified. In fact, video can also be decomposed into several limited frames of images. The other is scanning data based on laser and radar integrated photography technology. These devices include color laser scanner, vehicular laser scanner, radar scanner and airborne radar scanner. This kind of acquisition equipment often obtains batches of color point cloud data while cost of this data is relatively high and its application is limited at present. In our numerical tests, two kinds of different data acquisition devices are used to get the ICVSS respectively.

The test data is comprised of more than 5,000 digital images of Tibetan traditional architectures manually taken by general digital single lens reflex camera and dji drone with camera by fixed-focus lens and a set of point cloud data. Numerical tests are implemented by programming Matlab2013b, which is running on the ThinkStation T500 with CPU being E1605 and 32GB RAM. The final results are as follows: color discriminative gray level: $L = 0.005$, visual discriminatory function $f(x,y)$ is The inner product of two color vectors with being normalized. Figure 1, Figure 2 and Figure3 showed the results of the data which the left side of each Figure is the original digital image, the right side is its ICVSS. Figure 4 is the result of color point cloud data set with 2,026,116 points by the color laser scanner 3 stations of TrimbleX5 color laser scanner. Figure 5 is the intersection of ICVSS of the Figure 3 and Figure 4.
Summary

This article put forward ICVSS from color vector sets by introducing visual discriminatory function and color discriminative gray level. Every ICVSS of single image, multiple digital images data sets and color point cloud data is achieved by using Matlab 2013 programming and all the results also proved the correctness and validity of the method. Meanwhile, the intersection of two kinds sets, which experimentally proved Tibetan red, golden, white and other colors are the distinctive features of Tibetan traditional architecture and consistent with the existing qualitative works[9-10]. From the software implementation of the process, it is one of the effective ways to reduce the operation time by improving the power of parallel computing and the capability of RAM in the future. At the same time, it is the fundamental way to improve the accuracy of the algorithm by minimizing the impact of the environment illumination on the data collection. In the experiments, the ICVSS of the performance of environmental light and its surface reflection effect on the object is required to be further analyzed theoretically.

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References


