

Representation and Retrieval of Paintings based on Art History Concepts

Marchenko Yelizaveta, Chua Tat-Seng, Aristarkhova Irina
National University of Singapore
E-mail: {marchenk, chuats}@comp.nus.edu.sg
E-mail: uspia@nus.edu.sg

Ramesh Jain
Georgia Institute of Technology
Email: jain@ece.gatech.edu

Abstract

This paper presents a framework for the retrieval of paintings using concepts defined in the field of art and design. These concepts are organized into meta and application-specific layers in the system. Concepts of the meta-layer take into account the visual attributes of the paintings, and their manipulations, which infer abstract attributes that influence the interpretation of the paintings by the observers. The concepts of the application-specific layer are built above the meta-layer. They represent art categories that are widely used by general users for navigating the collections of paintings. Potentially, the usage of artistic concepts for annotation supports a wider query base making the retrieval much more powerful.

1. Introduction

Effective image retrieval systems are needed in various areas such as e-commerce, Web image searching etc. Early retrieval system which retrieve paintings based on bibliographical annotations [4, 9] are not very flexible, and those utilizing color, texture and other low level features are not able to handle the complexity of paintings. Other systems like ARTISTE [11] retrieve images based on similar color and texture distribution pattern using Color Coherence Vector and Pyramid Wavelet Transform. This type of retrieval does not capture the semantic categories of paintings which are more useful for retrieval. These shortcomings can be addressed to a large extent with the help of well-established concepts in the field of art and design.

Explicit representation of visual attributes, techniques, abstract and specific terms of art will facilitate more flexible querying and retrieval. For example, user will be able to query "paintings in style of impressionism", which will result in images with short brush-work with high jitter, and colors from

primary palette etc. The user can further narrow down his/her search and query to "impressionistic paintings delivering warmth", which would result in images in the style of impressionism with a variety of red-yellow-orange colors. User may specify parameters for object arrangement based on, say, a "golden ratio" rule that represents the proportion of 1:1.618.

This paper explores the retrieval of paintings by semantic art concepts based on an earlier proposed framework [16]. The rest of this paper is organized as follows. Section 2 surveys related work, while Section 3 describes high-level query support and framework design. Section 4 presents the experiment results. Finally, Section 5 concludes the paper.

2. Literature survey

Art and design concepts have been used for various aspects of paintings analysis to support applications such as image annotation, anti-fakery analysis etc. Sablatnig et al. [14] developed streak-detector for brush-stroke identification. Overlap among brush-strokes was analyzed in 3D space, where the intensity value becomes the surface height. This method detected around 80% of brush-strokes on the test set of 44 watercolor images.

Tanaka et al. [15] performed composition analysis of masterpieces based on "golden ratio" rule. Initially, they performed background-foreground segmentation, using contrast measurements of homogeneous regions with their neighborhood in both spectra and spatial domains. Segmentation offers the basis to investigate various proportions of composition defined in art to establish visual balance. Tanaka et al. investigated composition information of the foreground objects, obtained from such segmentation, based on Dynamic Symmetry Principle.

Analysis of colors and their perceptual effect was performed by Corridoni et al [7]. In this work, images are annotated with sensations they convey such as

warmth, harmony, and contrast based on Itten's theory. Itten's color theory proposes the mapping between colors and such sensations as used by artists [6]. Colors in the image are clustered into homogeneous regions and back projected onto Itten sphere consisting of 180 colors. Numerical measurement of high-level terms is based on various properties of color regions such as hue, saturation, luminance, position, size, luminance contrasts etc.

3. Support of high-level queries

Jorgensen [3] developed a comprehensive classification of user's queries in the art domain. Based on this classification we conducted survey of five art-historians and identified that such query categories as visual attributes (color, composition parameters etc), art-historical information (artist, style, historical period etc.), and abstract concepts (warm, expressive etc.) are largely based on the visual means and techniques of depiction. The art-historians suggested that visual attributes, abstract concepts and medium appear to be of interest to the expert users such as art students and art-historians. The general public users, however, rely more on query categories such as artist, style, historical period for navigating the arts domain.

To facilitate flexible retrieval, we define three informational levels in the system as shown in Figure 1.

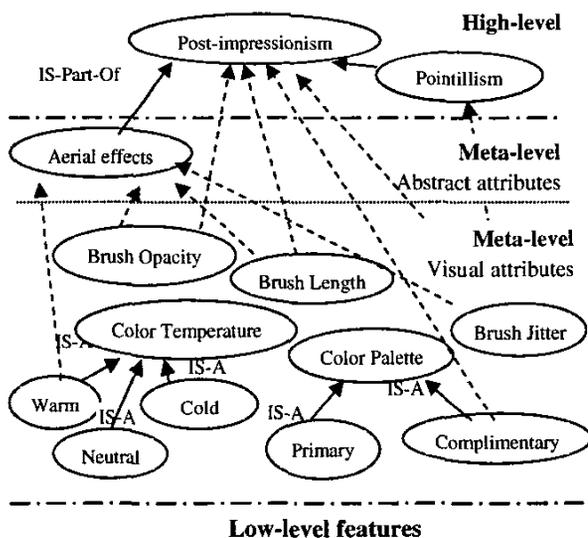


Figure 1. Example of concept organization

The levels are: visual meta-level concepts, abstract meta-level concepts and application-specific high-level concepts. Concepts within each layer are connected as they contribute to each other's definition from bottom to top are shown in Figure 1 (dashed arrows connect

concepts of the lower-level to define concepts of the higher-level; solid arrows correspond to relationships between concepts). Explicit representation of visual, abstract and application-specific concepts offers more flexibility for querying and retrieval

3.1. Visual meta-level concepts

Meta-level of visual concepts serves as the basis for the definition of subsequent concept levels. Visual attributes represent visual characteristics of paintings (eg., color palette, brush-work, composition). Visual attributes have been largely discussed in art [5, 12, 13] and computer science literature [1] and can be roughly categorized into attributes pertaining to imagery in general (eg, color, composition, balance) and attributes pertaining to specific type of imagery (eg, brush-work in paintings).

Color properties are represented as color temperature (warm, cold, neutral), color palette used (primary, complimentary or mixed), and degree of contrast. We investigate properties of color on the basis of Itten's sphere as is done in [7]. Warm color temperature is defined as the set of yellow-red-purple, and cold color temperature is the set of green-blue colors on the Itten's sphere. Contrast is defined with the help of palette used and geometrical relationships among colors on color sphere.

Brushwork is represented using the length of brush-strokes, opacity of brush-strokes (how "thick" the paint looks) and jitter of brush-strokes (color variety in brush-stroke). We use regions extracted by segmentation algorithm [4] as the basis to analyze the contrast among brush-strokes. Brush-strokes detection in color miniatures based on the brush-stroke model has been discussed in [14].

Composition is defined as plan for arranging objects in the picture [15]. Such rules as "rule of fifth", "rule of thirds", "golden ratio" etc. are used to extract compositional information [12, 15]. Rules of composition are known to achieve various perceptual effects: "golden ratio" produces more harmonious effects, "rules of fifth" or "rule of thirds" are used for relatively more dynamic compositions, while "rule of half" and "rule of fourth" add stability [1, 13].

Balance in image is analyzed with the help of Perceptual Balance Map [12], which defines stable positions for objects in the composition and measures the balance of overall composition. Composition in general is a complex part of analysis because it requires foreground-background segmentation. Tanaka et al [15] performed segmentation for paintings based on color and texture contrast.

3.2. Abstract meta-level concepts

In the field of art and design, various manipulations with visual attributes and their combinations are associated with specific abstract feelings of human spectator. Terms referring to such abstract feelings form the abstract meta-level concepts.

Currently vocabulary of the abstract attributes includes: warmth, cold, expressive, aerial effect, dynamics, balance [12, 13]. Heuristics representing abstract attributes and high-level concepts are defined by art-historian. Abstract attributes used for our experiments are shown in Table 1. They are expressed as weighted combination of visual attributes.

Table 1 Abstract concepts at meta-level

Abstract concepts	Heuristics
Warmth/cold	Warm/cold color temperature of colors
Dynamics	Positions of the large color regions in diagonal directions, usage of "rule of fifth" and/or "rule of thirds",
Balance	Usage of "rule of half" and/or "rule of fourth" and high degree of balance detected via Perceptual Balance Map
Expressive	High degree of color contrast and brush-work contrast, high brush-stroke opacity
Aerial effects	Short brush-work of high or medium jitter and high level of color contrast among brush-strokes, warm color temperature.

3.3. High-level application-specific concepts

At present we consider styles and movements in fine art [8] as high-level concepts. We use the collection of modern art, and thus the current vocabulary of application-specific concepts consists of painting styles of modern era: impressionism, post-impressionism, pointillism, expressionism, and fauvism [5]. Table 2 shows heuristics for the style of impressionism. Other styles mentioned above have also been formalized similarly. The visual attributes used to describe impressionism in Table 2 are listed in descending order of importance.

Table 2 Heuristics for style "impressionism"

Application-specific concepts	Heuristics
Impressionism	Medium brush length Low/medium opacity; High color jitter; High color contrast of brush; Primary palette; Medium/low color contrast; Medium/high perceptual balance

In our system heuristics that define meta-level abstract concepts and high-level application-specific concepts are represented with the help of frames [10].

3.4. User interaction

The system consists of six major components: raw images of paintings, concept base, reasoning block, retrieval interface, annotation interface, and modification interface. It supports three modes of user interaction: retrieval, re-annotation of paintings, and modification of meta-level and high-level concepts. The user interaction scheme is discussed in detail in [16].

4. Experimental results

We evaluated the performance of the system with respect to the abstract attributes and application-specific attributes on the dataset of 340 paintings of modern art. Meta-level visual attributes for each painting were manually assigned by the art-experts. Table 3 shows examples of user queries based on the abstract attributes. Ground truth for the experiments was defined by the art-experts.

Table 3 List of queries with abstract terms

1.	Images with dynamic composition
2.	Images with expressive color and brush-work
3.	Depiction of aerial effects
4.	Images with balance in composition
5.	Images containing warm colors

Performance of the system based on the queries from Table 3 is measured in terms of recall and precision as shown in Table 4.

Table 4 Performance with abstract attributes: T – total, R – retrieved, C – correct

QN	T	R	C	Recall	Precision
1	116	118	88	75.86%	74.57%
2	70	66	56	80%	84.84%
3	82	76	66	80.48%	86.84%
4	70	68	58	82.52%	85.29%
5	86	84	78	90.69%	92.85%

The top six returned images for the query "images with dynamic composition" are shown in Figure 2. As discussed in Table 1, the major means employed to achieve dynamic composition in paintings are: distribution of large color regions in diagonal directions, usage of "rule of fifth" and "rule of thirds". The top four images from Figure 2 contain large color regions distributed along the diagonals, and, thus, exhibit high degree of "dynamics" in composition. The "rule of thirds" is used in the fourth and fifth image of Figure 3 in vertical direction and horizontal direction respectively. The usage of this rule introduces "dynamics" to the image, though the degree of "dynamics" is lower as compared to the top four ranked images as can be seen in Figure 2.

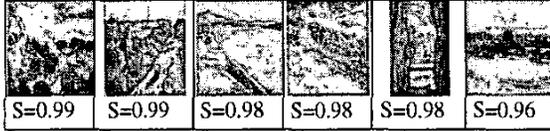


Figure 2 High-ranked images retrieved by query "images with dynamic composition"

The results of retrieval by painting styles in terms of recall and precision are shown in Table 5. Figure 3 shows top six images retrieved by the system with query "Images in the style of impressionism". All images from Figure 3 are classified into the style of "impressionism" in art-history field. These images exhibit medium or short brush-work with high degree of jitter and medium opacity and high degree of color contrast among brush-strokes. According to Table 2, these attributes are found to be the most important in the detection of the style of impressionism.

Table 5 Performance with application-specific attributes

Style	T	R	C	Recall	Precision
Fauvism	70	68	57	81.42%	83.82%
Impress.	72	77	54	75%	70.12%
P/impress	75	74	59	78.67%	79.72%
Express.	70	69	53	75.71%	76.81%
Pointill.	53	57	45	84.9%	78.94%

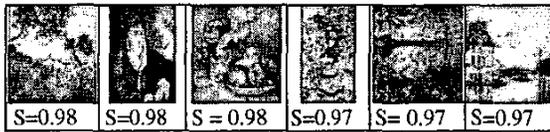


Figure 3 Images retrieved by query "impressionism"

5. Conclusions

In this paper we propose a framework for paintings retrieval based on artistic concepts defined in the field of art. The results of the experiments show that analysis of visual attributes is important for annotation and retrieval of paintings with high-level art concepts, which are desirable for navigation by various user groups. Explicit representation of concepts facilitates flexible querying and the entry of short summaries for the paintings. Future work shall focus on the automatic mapping of low-level features to meta-level concepts, and the extension of vocabulary for novice users with concepts referring to artist names and historical periods.

6. Acknowledgments

The authors would like to thank LASALLE-SIA Singaporean College of Arts, Gunalan Nadarajan and

Milenko Prvacki for the support and valuable guidance in the art aspects of the current research project.

7. References

- [1] B. Gooch et al. "Artistic Composition for Image Creation", Eurographics Workshop on Rendering, 2001.
- [2] C. Carson et al., "Blobworld - Image segmentation using expectation maximization", PAMI24(8): 1026--1038, 2002.
- [3] C. Jorgensen, "Attributes of images in describing tasks", IP&M 34(2), 161-174.
- [4] Getty Research Institute. Getty Vocabulary Program. AAT. (February 2000).
- [5] J. Canaday, "Mainstreams of Modern Art", Saunders College Publishing, 1981.
- [6] J. Itten, "The Art of Color", Reinhold Pub. Corp., New York, 1961.
- [7] J. M. Corridoni et al., "Retrieval of Paintings Using Effects Induced by Color Features", CAIVD'98, pp. 2-11, 1998.
- [8] K. Walton, "Style and the Products and Processes of Art", The Concept of Style, pp. 45-66.
- [9] Library of Congress. "Thesaurus for Graphic Materials I: Subject Terms".
- [10] M. Minsky, "A Framework for Representing Knowledge", The Psychology of Computer Vision, McGraw-Hill, 1975.
- [11] P. Allen et al., "Artiste: An integrated Art Analysis and Navigation Environment", Cultivate Interactive(1), 2000.
- [12] R. Arnheim. "Art and visual perception: A psychology of the creative eye". University of California Press, 1954.
- [13] R. Pumphrey, "Elements of Art", Prentice Hall.
- [14] R. Sablatnig et al., "Structural Analysis of paintings based on brush strokes". Scientific Detection of Fakery in Art, pp. 87-98, USA, 1998.
- [15] S. Tanaka et al, "Composition analyzer: computer supported composition analysis of masterpieces", ACM Creativity & Cognition, pp. 68 - 75, 1999.
- [16] Y. Marchenko, T. S. Chua, I. Aristrakhova. 2004. Retrieval of Paintings Based on Art History Concepts, IWAIT 2004, pp. 85-89.