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Chronological classification of ancient paintings using appearance and shape features ☆

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ABSTRACT

Ancient paintings are valuable for historians and archeologists to study the humanities, customs and economy of the corresponding eras. For this purpose, it is important to first determine the era in which a painting was drawn. This problem can be very challenging when the paintings from different eras present a same topic and only show subtle difference in terms of the painting styles. In this paper, we propose a novel computational approach to address this problem by using the appearance and shape features extracted from the paintings. In this approach, we first extract the appearance and shape features using the SIFT and *k*AS descriptors, respectively. We then encode these features with deep learning in an unsupervised way. Finally, we combine all the features in the form of bag-of-visual-words and train a classifier in a supervised fashion. In the experiments, we collect 660 *Flying-Apsaras* paintings from Mogao Grottoes in Dunhuang, China and classify them into three different eras, with very promising results.

1. Introduction

Ancient paintings have provided valuable sources for historians and archeologist to study the history and humanity at the corresponding eras. Fig. 1 displays four painting images collected from Mogao Grottoes in Dunhuang, China. These four paintings were created in different eras of China, namely the Wudai dynasty, the Sui dynasty, and the peak Tang dynasty, respectively. From these paintings, we can find a lot of important information in the corresponding eras, e.g., the architecture style in the Wudai dynasty from Fig. 1(a), the musical instruments in the Sui dynasty from Fig. 1(b), the plowing manner of farmers in the peak Tang dynasty from Fig. 1(c), and the costumes in the peak Tang dynasty from Fig. 1(d).

Obviously, a very important problem is to correctly determine the era in which a painting was created. Usually it is unreliable to determine the painting era based only on the specific content of the painting, since one same topic may be presented in the paintings in different eras. As widely adopted in art appraisal, people usually determine the era of a painting by examining its painting style, which usually varies with time and shows subtle differences from one era to another. It is usually difficult, if no impossible, for the general people without special training on painting and painting history to identify such subtle variation of the painting style for correctly determining the era of a painting. In this paper, our goal is to develop an automatic, computational approach to address this problem by using both appearance and shape features. Together with a supervised learning, we expect that the proposed approach can implicitly capture the specific painting style in different eras for painting-image classification.

To better capture the painting style implied in the paintings, we focus on the paintings created in different eras, but presenting the same topic. An example is shown in Fig. 2, where all 12 painting images present the *Flying Apsaras*, an important theme of the paintings of Mogao Grottoes in Dunhuang, China. These 12 paintings were created in different periods of Dunhuang Art: the infancy period (Row 1), the creative period (Row 2), and the mature period (Row 3). From these sample images, we can see that the painting-style difference in these three periods are subtle and only experts on Chinese classic art may be able to distinguish them. In this paper, we develop our automatic approach to localize such subtle difference and correctly determine the eras for such paintings.

Besides the appearance features, one interesting observation is that, each flying fairy in the *Flying-Apsaras* painting wears scarves, and it seems that the shape of the scarves varies from one period to another. An example is shown in Fig. 3. In the infancy period of the

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Fig. 1. Sample paintings from different eras. (a) A painting in Wudai dynasty (907–960) from Mogao Grottoes 61, (b) a painting in Sui dynasty (581–618) from Mogao Grottoes 285, (c) a painting in peak Tang dynasty (712–762) from Mogao Grottoes 23, (d) a painting in peak Tang dynasty (712–762) from Mogao Grottoes 45.

Fig. 2. Sample paintings with the same topic but created in different eras. Row 1: four paintings created at the infancy period of the *Flying-Apsaras* art (421–556), Row 2: four paintings created at the creative period of the *Flying-Apsaras* art (557–618), Row 3: four paintings created at the mature period of the *Flying-Apsaras* art (619–959).

Flying-Apsaras art, line and curve strokes sketching the scarves are relatively simple and flat, as shown in Fig. 3left). In the creative period, scarves are sketched with small waves, as shown in Fig. 3middle). While in the mature period, scarves as well as clouds are more wavy than in the early periods, as shown in Fig. 3right). In this work, the main hypothesis is that the painting style can be described by the local appearance and shape features extracted from the painting images. This way, the difference of painting styles in different eras can be captured by learning from a set of training image samples. Based on this hypothesis, the proposed approach consists of the following steps: (1) appearance and shape features are extracted using the Scale-Invariant Feature Transform (SIFT) [21] and *k*AS shape description [7], (2) appearance features are further encoded by a deep-learning algorithm to enhance the representation abstraction ability, (3) visual codebooks are constructed based on the encoded appearance features and shape features, (4) feature histograms are produced for each painting as the input of the classifier, (5) training a classifier in a supervised fashion to determine the era of a painting based on the above feature histogram. In the experiments, we collect 660 *Flying-Apsaras* paintings from Mogao Grottoes in Dunhuang, China and classify them into either the infancy period, the creative period, or the mature period as shown in Fig. 2.

There are two major contributions in this paper. First, we developed a feature detection/combination method that can distinguish the subtle difference of the Dunhuang *Flying-Apsaras* paintings from different eras. We found that both appearance features and shape features are important for this classification task, which is consistent with the opinions of the art experts on Dunhuang paintings. Second, we proposed to use, in an original way, the combination of a typical set of image features (SIFT, an image-gradient based feature that are scale and rotation invariant) with one of the most effective feature refinement algorithms (deep learning, a specific type of Boltzmann machines). In the experiments, we compared the proposed method to a recent state-of-the-art painting classification method, with a clearly better performance.

The remainder of this paper is organized as follows. Section 2 introduces the related work. Section 3 presents our approach for extracting the appearance and shape features. Section 4 reports our experiment results on 660 *Flying-Apsaras* paintings and Section 5 concludes the paper.

2. Related work

As a branch of the image classification/retrieval research, painting classification has attracted more and more attention in the past two decades [26,17,28,29,15,8]. Existing painting-classification researches are usually focused on two applications, classifying