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Assessment model for perceived visual complexity of painting images

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ABSTRACT

In the construction of the knowledge system, visual perception is the primary means of acquiring knowledge. Thus, it is very essential to solve the problems related to visual perception. Visual complexity, as a basic aspect of visual perception, is extremely important for human being to understand and perceive the visual stimuli. This leads to an interesting question: what factors affect visual complexity of images and how to evaluate the visual complexity objectively. In order to address this issue, we take digital painting images as the visual stimuli. We firstly conduct an experiment to collect the subjective complexity labels of painting images and then identify the factors that affect visual complexity perception. Three main factors that affect human visual complexity perception are identified, namely, distribution of compositions, colors, and contents. Secondly, we study theoretical and empirical concepts from psychology and art theory to design 29 global, local, and salient region features which represent the above three factors. Moreover, we provide two ways to estimate the visual complexity of painting images. One is to evaluate the visual complexity level of painting images by classifying the complexity level into three levels (low, middle and high complexity). Another one is to predict a complexity value for painting images by a regression model. The experimental results indicate that the proposed classification method (by Random Forest classifiers) can predict the visual complexity perception of paintings with an accuracy of 86.78%. By the comparisons, the proposed method outperforms other measurements of image complexity with a higher correlation coefficient between subjective complexity and objective measures of complexity. Furthermore, we apply the regression model of visual complexity to predict the other features of painting images. The results show that the regression model has a good ability of measuring aesthetic quality, beauty, and liking of color of the painting images involved in JenAesthetics dataset.

1. Introduction

For humans, 80% of the information and knowledge are acquired from human vision system. This makes the importance of visual perception is for more than other perceptions in the construction of the knowledge system. Moreover, with the development of Artificial Intelligence, it is increasingly necessary to endow a computer the ability of visual perception like a person. Visual complexity, as a basic aspect of visual perception, is extremely important for human being to understand and perceive the visual stimuli. Therefore, how to evaluate visual complexity objectively becomes a timely topic in the fields of psychology and computer science.

Visual complexity is regarded as a primary cue on judgments of visual appeal [1]. Nowadays, people can easily enjoy the paintings on the Internet without going to the museums [2]. If they select images only by visual feeling (e.g., visual appeal or pleasure) instead of specific keywords (e.g., rose), then visual complexity plays several central roles in composing the said feeling [3]. Hence, presenting an objective measure of complexity which is similar to human perception is exceedingly useful. In practice, objectively measuring visual complexity has a wide range of applications. From a psychological sense, measures of visual complexity are helpful for human viewers to analyze the effects of visual complexity on aesthetic judgments, and thus are useful for neuroscientists and psychologists who are interested in the mechanism of object perception and the process of learning and memory. From an applied sense, measures of visual complexity can be utilized by computer engineers to construct information systems and tools for the analysis, estimation, visualization and recognition of images, and could allow designers to anticipate consumers' and users' aesthetic and affective responses to the complexity of the products from wallpapers to

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webpages.

Previous research [3–15] has proposed a number of measures of image complexity such as information theory, pattern measure, fractal dimension, quad tree method and region of interest method. These methods can provide a computable and objective means to measure the image complexity. However, they merely consider the distribution of spatial frequencies of visual stimuli and disregard the mechanism of human visual perception.

Considering the nature of visual perception (i.e., assessing visual complexity is a constructive process of perception), we assume that visual complexity perception is significantly affected by visual features in the images, such as the features of colors, distribution of objects, and contents. Therefore, in this paper, we hope to achieve a model to estimate the visual complexity of painting images based on image features. In order to achieve this purpose, three steps are conducted: (1) Experiment of subjective complexity: labeling subjective complexity of paintings and identifying the factors that affect human visual complexity through a questionnaire survey;(2) Feature extraction: extracting a group of global, local, and salient features depending on the results of the questionnaire in step (1); and (3) Mapping stage: employing classification and regression methods to build the relationship between the visual complexity perceived by humans and the features extracted from the paintings.

In conclusion, our research identifies the main factors that affect visual complexity perception of visual stimuli, and provides computational methods to estimate visual complexity of painting images. Our research contributes to the “computational visual complexity” by:

- Identifying three main factors (distribution of compositions, colors, and contents) that affect visual complexity perception of painting images.
- Providing quantified methods to compute visual features that represent three factors and distinguishing influential visual features of perceived complexity.
- Validating the effectiveness of the proposed complexity assessment methods (visual complexity level classification and visual complexity score prediction) and applying it to predict other visual emotions (aesthetic, beauty, etc.).

The rest of the paper is organized as follows. Section 2 reviews the measures of visual complexity and its related works. Section 3 introduces the subjective complexity assessment experiment and identifies the main factors affecting visual complexity perception. Section 4 quantifies the visual features that extracted from global, local and salient regions. Section 5 builds the objective measures of complexity: complexity level classification and complexity score regression. Section 6 discusses the influential visual attributes that affect visual complexity of painting images, followed by conclusions in Section 7.

2. Measures of complexity

A variety of methods to measure complexity have been proposed in the fields of psychology and computer science.

In the field of psychology, several researchers mainly investigated the factors that affected human visual complexity perception. According to Oliva et al. [16], visual complexity was defined by the degree of difficulty in providing a verbal description of an image. In their study, 34 participants used the method of hierarchical grouping to classify indoor scenes. The results showed that visual complexity is represented by several dimensions, such as the number of objects, clutter, openness, symmetry, organization, and variety of colors. Pieters et al. [17] investigated the visual complexity of advertising. They distinguished two types of visual complexity (feature complexity and design complexity) in advertising and proposed an objective measure for each. Saleem et al. [18] studied the visual complexity of 3D shapes and introduced an approach based on view similarity to determine the perceived shape complexity. Purchase et al. [19] explored the visual complexity of images. They attempted to investigate whether visual complexity could be quantified to match a human’s perception of complexity. Through an empirical study, they concluded that the subjective notion of complexity was consistent both in an individual and in a group but did not easily relate to the most obvious computational metrics.

From the view of computer science, various methods have been proposed to measure complexity. Andrienko et al. [5] developed a complexity measure based on mean information gain of spatial correlations of 2-D patterns. Rigau et al. [20] proposed a new framework to investigate the complexity of an image by considering the number of partitioned regions and the compositional complexity of partitioned images. The Jensen-Shannon divergence was employed to calculate the compositional complexity of partitioned image. Patel and Holt [21] compared the pattern measure proposed by Klinger and Salingaros [6] with respondents’ perceptions of the complexity of background image scenes; the results showed that a high positive correlation exists between mathematical measures and the subjects’ perceptions. Furthermore, Murguia et al. [7] proposed a novel fuzzy approach to determine the complexity of an image based on the analysis of edge level percentage. Cardaci et al. [8] presented an experiment to obtain the perceived time of paintings. The aim of this experiment was to build the relationship between the objective measure of complexity and the perceived time. The results indicated that there is a strong correlation between psychological and computational results (statistical properties of the paintings). In their another work [9], they proposed a fuzzy mathematical model of visual complexity based on fuzzy measures of entropy. Their proposed method fitted well with the perceived time of images, but neglected the image color and other perceived features. Fractal dimension (FD) has often been applied as a parameter of complexity, related to, for example, surface. The previous research [10] showed that FD accounts for more of the variance in judgments of perceived beauty in visual art than measures of visual complexity alone, particularly in abstract and natural images. Besides, Donderi [11] found a correlation between subjective estimations of visual complexity and the size of compressed digital image files. Rosenholtz et al. [12] proposed two classical methods for image visual complexity measurement: Subband Entroy (SE) and Feature Congestion (FC). Additionally, compression based methods should be the simplest method of measuring the complexity of an image. A larger file size indicates high complexity [22]. However, these methods are abstract and difficulty in explaining why some images look more complex than others. Redies et al. [23] proposed a measure of image complexity (Com) based on the maximum gradient magnitudes of each pixel in the Lab color space. The gradient represents the local changes of lightness in an image. Thus, the higher the mean absolute gradient, the more complex an image is. Sun, Yamasaki and Aizawa [24] designed 114-dimension features to evaluate the image complexity, and then they extended the proposed method to the applications of beauty predication and quality assessment.

3. Experiment: subjective assessment of complexity

Unlike research on photographs, it is very difficult to find a website of paintings with complexity ratings by a large community. Consequently, to implement the first step of the proposed approach, we conduct an experiment to acquire the subjective assessment of the complexity of painting images.

3.1. Stimuli

In the experiment, 500 painting images are utilized, including 50 painting images obtained from the dataset of PaintingDb[1] [25], 150

[1] PaintingDb is a virtual art gallery with thousands of painting images and a