Hierarchical Classification of Paintings Using Face- and Brush Stroke Models *

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Abstract

It is often difficult to attribute works of art to a certain artist. In the case of paintings, radiological methods like X-ray and infra-red diagnosis, digital radiography, computer-tomography, etc. and color analyzes are employed to authenticate works of art. But all these methods do not relate certain characteristics of an art work to a specific artist - the artist's personal style. In order to study this personal style, we examine the "structural signature" based on brush strokes in particular in portrait miniatures. A computer-aided classification and recognition system for portrait miniatures is developed, which enables a semi-automatic classification based on brush strokes. A hierarchically structured classification scheme is introduced which separates the classification into three different levels of information: color, shape of region, and structure of brush strokes.

1 Introduction

The members of the Austrian royal family who lived in Vienna were connected with their relatives in foreign countries through a collection of nearly 600 portrait miniatures (small format pictures approximately 8cm x 6cm in size of a person which has the same character as a photograph, see Figure 1). The characteristics of the art works in the collection cannot lead to an affiliation with certain artists, especially because of the lack of signatures on the portrait miniatures.

In the case of portrait miniatures painted in an aquarell style using point and line strokes, one can recognize certain mechanical trademarks. Because the subject is produced in a small format and the application of multiple strokes is used to create the face, one can observe that the artist has relied on his/her own unconscious rhythm [2, 7]. This term describes not only the "handwriting" of an artist which follows a certain pattern of stroke length and angle, but also the system of lines and the relation of lines to one another. In portrait miniatures, this basic pattern is that of the face, which consists of different recurrent parts (basic oval form, eyes, nose, mouth, etc.). The artist applies an individual line system of strokes and colors to this basic pattern, thereby not only adding his artistic signature but also giving the portrait an individual physiognomy.

Figure 1. Portrait miniature.

To overcome this identification problem we present a portrait classification model in Section 2, which describes artist-specific and artist-independent characteristics of a painted portrait miniature. We claim that these characteristics are expressed in the way the artist placed the brush strokes and the constraints he had to work within to create a realistic reproduction of a human face. In Section 3 the classification model and a brush stroke model used to detect brush strokes in intensity images (see [10]) are integrated into a classification scheme that allows the identification of an artist. Experimental results and an outlook on future work conclude the paper.

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2 Portrait Classification Model

To relate the characteristics to a specific artist, a so-called artist-model is developed. The model is based on a reference model of a human face, which assigns local artist-dependent characteristics to facial regions. A closer look at portrait miniatures and their corresponding painting technique reveals that there are a number of brush strokes and brush stroke arrangements that are not only specific to a certain artist but are also influenced by the shape of the painting ground and the object to be painted. To achieve a realistic impression of a face the artist must consider the influence of physical illumination on the appearance of the face.

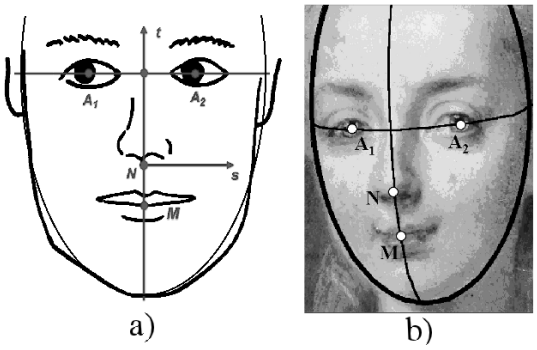

Figure 2. a) face model, b) model reference points.

A connection between the three-dimensional world coordinate system $(x, y, z) \in R^3$ of a human face and a parameter space $(s, t)S \times T$ can be defined as follows (see Figure 2 a): $N : nose = (0, 0)$; $M : mouth = (0, -1)$; $A1 : left_eye = (-1, 2)$; $A2 : right_eye = (1, 2)$. The geometrical connection between arbitrary points in the parameter space (s, t) and the corresponding points in the world coordinate system can be defined via a homomorph transformation: $(s, t) = (x(s, t), y(s, t), z(s, t))$.

The definition of the individual reference points and distances is inspired by face recognition methods [3, 5, 11] which also use reference models to represent a human face and can be transformed.

Using the mathematical model, we can select a certain elliptic region within the parameter space of the reference model and transform it to the appropriate image (see Figure 2 b). The reference model is the basis for the artist-specific model. Artist-characteristic features are represented in a set of parameters (like set of colors, eye shape, face shape, average stroke length, width, and curvature) of the mathematical model. We use similarity measures of artist-specific parameter sets to compare different artists. The verification of the model within an image results in a measurement, which makes it possible to distinguish paintings of artists.

3 Classification Scheme

The portrait classification model and the brush stroke model [10] are integrated into a hierarchical classification scheme for portraits. The structural analysis which relates an artwork to an artist can be divided into 3 hierarchical steps: color classification, shape classification, and stroke classification. This top-down classification scheme is extended by a bottom-up strategy within each classification step (see Figure 3). In the following a description of the function of the individual processing steps is given:

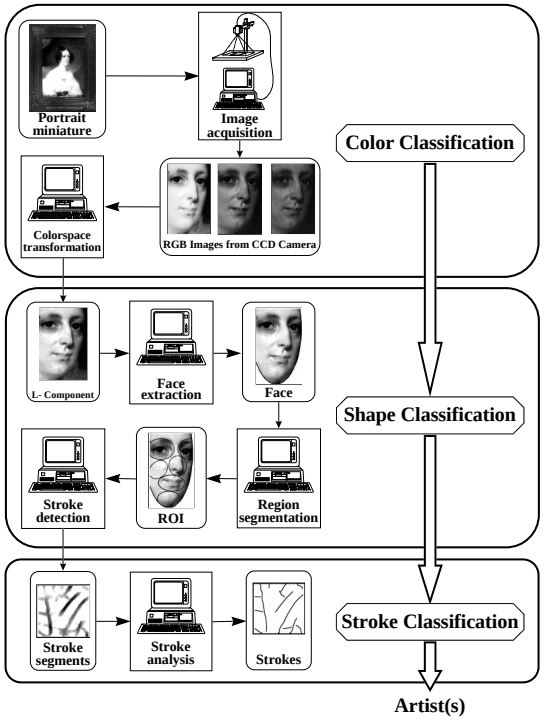

Figure 3. Portrait classification scheme.

Image acquisition: A 3-chip color CCD camera in combination with a specific optical lens system is used. The 24-bit color representation of the face is necessary to carry out color classification. During acquisition the illumination conditions are kept constant.

Color classification: Artist classification by art historians is based on color impression. This term describes the overall color perception of the painted face - its color tone. Based on this fact, portrait miniatures are first grouped by computing the mean RGB value of the image.

Color space transformation: A color space transformation [12] is used since true color image processing is time-consuming and there is a lack of feasible methods of color feature detection [1, 8]. A RGB to HLS transformation [12] was chosen, because the lightness channel of the

HLS-model represents relevant information for brush stroke detection [6].

Face extraction: When dealing with portraits, face extraction is easier than conventional face detection since artists paint a person with a standard "creation model" in mind [2]. Artists use an elliptical scheme, which determines shape and orientation of the head as well as the position of eyes, nose, cheeks etc. (Figure 4 a). Our approach assumes that the head can be described by an ellipsoid whose major axis is parallel to the image plane. The projection of the ellipsoid into the image plane is a *face* ellipse, which is invariant to the rotation of the ellipsoid with respect to the major axis. A second ellipse within the ellipsoid describes the intersection of the facial symmetry plane with the ellipsoid (*symmetry* ellipse). Up to now these ellipses have been adapted manually to the face contours [9]. The second ellipse shares the major axis of the first ellipse and its minor axis is oriented according to the orientation of the face. Figure 4 b shows the result of the ellipse fitting, the face- and symmetry ellipse and the axis of rotation of the ellipsoid.

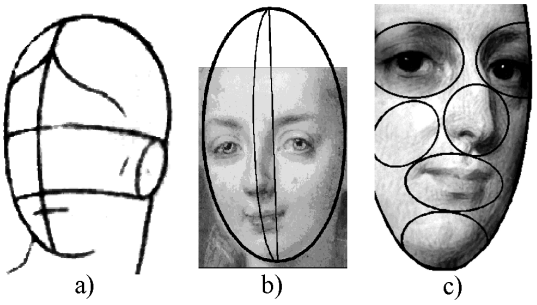

Figure 4. a) schematic head [2], b) fitted ellipses, c) segmented ROI's.

Region segmentation: The face ellipse is segmented into facial regions because stroke arrangements differ within these regions. Face- and symmetry ellipse are used to estimate the position of the head (Figure 4 c), to segment the face into characteristic regions [4], and to support the extraction of facial features.

Shape classification: Portraits are compared on a region by region basis, since artists tend to use a rather schematic than realistic way of modeling face details. The region based matching reduces the complexity of comparison since the search space is reduced to specific ROI's.

Stroke detection and analysis: In order to compare the segmented regions not only by shape but also by the brush strokes used to paint them, the stroke detector is applied in specific regions [10]. The stroke segments are grouped into strokes by matching similar curvatures and orientations of neighboring stroke segments.

Stroke classification: The structure of the detected stroke segments allows a classification of the miniatures since it is similar to the basic elements of art historical classification.

4 Conclusion and Outlook

The hierarchical structure of the classification steps allows a top-down classification; first the color impression is used for a rough classification, within this subset of all possible artists a more detailed classification is performed on the basis of shape features within certain face regions which reduces the set of possible candidates once again. Within the regions of the face under examination the stroke classification introduces a bottom-up approach. These three classification stages allow an economical search space adaptation, having a set of possible artists as classification result.

The experiments which have been conducted up to now are pre-studies for the stroke classification within the artist-specific model, which can describe an individual artist or a group characterized by specific arrangements of strokes based on a stable method to detect them. The final goal is the greatest possible reduction of the number of potential candidate artists.

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