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Stylometry of paintings using hidden Markov modelling of contourlet transforms ☆

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ABSTRACT

Visual stylometry is the task of quantifying artistic style in the visual arts. In this paper we present a method for visual stylometry of paintings from digital reproductions.

Our method is framed around modelling contourlet transforms of the digital reproductions with hidden Markov models. Using the contourlet transform in the field of classification is a new approach motivated by the contourlets' efficiency in representing piecewise smooth contours such as brushstrokes.

To test our method we have used paintings related to the Danish painter Asger Jorn and drawings related to the Flemish artist Pieter Bruegel the Elder. The paintings related to Asger Jorn are recorded in multiple digital images and by two different cameras. With multiple sources we are able to get insight into the robustness of our method against different means of acquisition.

Through a cross-validation of the Jorn images by one of the cameras we are able to correctly classify 39 out of 44 images; based on this classifier we can correctly classify 28 out of 36 images in the other data set.

A cross-validation of the Bruegel images correctly classifies 11 out of 13 images.

1. Introduction

The aim of visual stylometry of paintings is to quantify the artistic style of a painter and thus get an insight into the development of his style throughout his career. In the present paper we study quantification for the purpose of authenticating paintings based on digital reproductions: Is it possible to determine the authenticity of a painting based on digital photos?

Traditionally the task of authenticating paintings has been performed by art experts and connoisseurs with a profound and detailed knowledge of the artist and his contemporaries. However, this method will always involve some subjectivity and therefore the experts do not always agree. So assisting the authentication by more unbiased automatic methods may – besides being a topic of mathematical interest – also be valuable for the art community.

All automatic authentication methods work on digital reproductions of the paintings and the fundamental idea is to extract a number of features from the digitized paintings that are sufficiently expressive to distinguish the styles of different artists. Previous attempts have been made to perform automatic authentication of paintings by training models to separate paintings that are known to be authentic (i.e., painted by the claimed painter) from known forgeries.

The authentication task has been tried most thoroughly on paintings by Vincent van Gogh [3,4,22,26], Pieter Bruegel the Elder [20,24] and Jackson Pollock [1,21,31,32]. But authentication from digital reproductions have also been tested on Chinese ink paintings by multiple artists [23] and unknown painters portraying the Austrian royal family [29].

Our work in this area is motivated by the theory that a forger can reveal himself by having brushstrokes that are different in style [22]. With this assumption it seems attractive to explore the fine details in paintings for the authentication purpose.

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Several of the above-mentioned methods employ multiresolution analysis to extract relevant features from the paintings. Both wavelets [22–24,26] and curvelets [20] have been applied for this task. The reason for applying these signal processing tools is that they are (hopefully) able to detect subtle differences in the details between authentic paintings and forgeries at different scales in the paintings.

In this paper, we work with the contourlet transform [10] of the digital photographs. The reason for this choice of multiresolution analysis is that the atoms of the contourlet transform resemble contours well, making it likely to also represent the brushstrokes well and thereby the (subtle) differences between paintings made by different artists.

The contourlet transform of the paintings is modelled by a hidden Markov model [25] and by exploiting the differences between the hidden Markov models of different artists, we are able to predict the affiliation of new images. Our method is inspired by the Princeton approach in [22], where complex wavelets are modelled by hidden Markov models instead of contourlets.

Modelling contourlet transforms is a new contribution to the field of visual stylometry, as well as the subsequent processing of the fitted models. The main contribution of this paper is our experiments indicating that multiresolution transforms are not too sensitive to different means of obtaining the digital reproductions.

The rest of the paper is organized as follows: In Section 2 we present the data used in the experiments. Section 3 describes the tools we utilize for our classification task. This includes the contourlet transform and how we model these with hidden Markov models to distinguish between paintings by different artists. In Section 4 we present the most important results of our experiments. Section 5 discusses the interpretation of the presented results and Section 6 contains our conclusions.

2. Artists used in our experiments

We have worked with paintings related to three different artists, as described in the subsections. The acquisition of the digital reproductions have varied depending on the origin of the data.

Each color image with Red, Green and Blue (RGB) components was converted to grayscale (gray = 0.2989 R + 0.5870 G + 0.1140 B) as in [20,24]; this preserves the brushstrokes (lines) in the image and we do not have to worry about how to combine edges from the color channels.

Each image was furthermore divided into square patches with a side length of 1024 pixels. We choose a fixed number of pixels that neighboring patches are allowed to overlap and the patches are chosen such that they span the largest possible area of the image while not overlapping more than allowed.

2.1. Asger Jorn

Our primary data set is related to the Danish painter Asger Jorn (1914–1973) and consists of paintings by Asger Jorn and his collaborators/apprentices. The images were provided courtesy of Museum Jorn, Silkeborg, Denmark.

We photographed the paintings with two cameras with very different technical specifications: A Canon Powershot G2 and a Nikon D90 with an AF-S Nikkor 50 mm f/1.4G lens. We used two different cameras to test the robustness of our classification procedure to the means of acquisition and digital format. The Canon camera recorded images in JPEG format and the Nikon camera in raw format which we then exported to a lossless TIFF image.

The distance between the Canon camera and the paintings was consistent for all photos, however, this was not the case as to the Nikon camera. The photos taken by the Nikon camera were digitally corrected afterwards for the inconsistency in distance, i.e., for the inhomogeneous number of pixels per physical area – this was possible since the camera recorded the distance to its focus point.

The paintings were photographed in their display positions on the walls in the museum where the lighting was homogeneous.

The paintings photographed are listed in Table 1. Not all paintings could be captured in a single photograph of

Table 1
The paintings related to Asger Jorn used in our experiments. The first column is the name of the artist, the second column is the original name of the painting, the third column is the year(s) of production and the fourth column is the catalogue number of the paintings at Museum Jorn. Additional information can be found at Art Index Denmark, https://www.kulturarv.dk/kid/. The painting "Portræt. Bodil" is displayed at Museum Jorn, but belongs to a private collector and therefore it has no catalog number.

Artist	Title	Year	Catalog no.
Asger Jorn	Automolok	1948	1986/0001
Asger Jorn	Euphorisme	1970	1971/0274
Asger Jorn	Hoved	1935	1958/0043
Asger Jorn	Henning. Figurstudie	1933	1972/0205
Asger Jorn	Portræt. Bodil	1961	–
Asger Jorn	Grand ventre – incendie	1953	1958/0210
Asger Jorn	Digteren Jens August Schade	1937–1944	2008/0001
Asger Jorn	Prete Alla Spiaggia	1957–1959	1977/0001
Asger Jorn	Trolden og fuglene	1944	1962/0183
Asger Jorn	Le Vent Nous Emporte	1970	1988/0001
Asger Jorn	Uden Titel	1946	1961/0116
Asger Jorn	Uden Titel	1956–1957	1961/0115
Jacqueline de Jong	Admiration de la reine de vert	1961	1961/0119
Asger Jorn/Enrico Baj	Uden titel	1958	1958/0290
Helmut Sturm	Uden titel	1961	1961/0114