AUTHENTIC: COMPUTERIZED BRUSHSTROKE ANALYSIS

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ABSTRACT

The paper provides insights into our efforts to develop techniques for the analysis of visual art. The AUTHENTIC project aims at creating a collection of software tools to support art experts in their assessments of the authenticity of paintings. We describe our progress on the automatic analysis of the visual texture of the paintings of Vincent van Gogh. The texture-analysis technique reveals two main clusters of brushstroke shapes used in the paintings by Van Gogh. These qualifying results lead us to conclude that the use of advanced digital analysis techniques will change the way in which the authentication of visual art is performed.

1. INTRODUCTION

The assessment of paintings is largely performed by human art experts. Connoisseurship has played an important role throughout the history of art. Undoubtedly, the assessments of skilled experts are of great value to the visual arts. However, inevitably human judgements are highly subjective and prone to error. Occasionally, experts judging the authenticity of paintings made mistakes and were more then once forced to revise their opinions in the light of objective evidence. So far, objective evidence bearing on the issue of authenticity came from chemical analysis, infrared reflectography, and other examinations of the physical properties of the painting such as dendrology. In the context of the AUTHENTIC project, we attempt to develop digital techniques for an objective examination of the visual properties of paintings. The aim of the AUTHENTIC project is to develop a set of digital tools for the art expert. Using modern image-analysis and machine-learning techniques, the visual structure of (digital reproductions of) paintings can be quantified and incorporated into the overall judgement of the expert.

In this paper we focus on the analysis of the visual feature of texture. The analysis of texture proceeds using a tailor-made brushstroke-extraction technique to quantify the shape of brushstrokes. We applied the technique to digitized paintings of Vincent van Gogh. The outline of the paper is as follows. Section 2 presents our qualifying results on the brushstroke analysis applied to the same collection of paintings. Then, in section 3 we discuss how our analysis techniques will change the way authentication and art analysis will be performed in the near future. Finally, in section 4 we draw conclusions.

2. THE AUTOMATIC ANALYSIS OF BRUSHSTROKE TEXTURE

Texture is the second visual feature for which we developed an analysis technique. This feature reflects the statistical properties of small image regions. The statistical properties are dominated by visual contours, i.e., transitions in intensity along a contour. In Van Gogh's paintings the local texture is determined by the way he applied brushstrokes on the canvas.

2.1 Van Gogh's brushstroke alphabet

Art experts agree on the observation that the nature and distribution of brushstrokes is highly characteristic for a painter. This applies especially to Van Gogh whose brushstrokes are clearly visible due to his painting style. The brushstrokes of Van Gogh constitute a kind of alphabet, the elements of which are repeatedly used in his paintings. Examples of elements of Van Gogh's brushstroke alphabet are curved strokes, repetitive parallel strokes, and circular strokes. In an attempt to detect and quantify the occurrence of the elements of the alphabet, we started with the extraction of the shape of brushstrokes in a single painting.

2.2 Brushstroke extraction

The digital extraction of brushstrokes proceeds in two steps: (I) contour enhancement, and (II) quantification of brushstroke shape. Below, we provide a brief outline of both steps.

I. Contour enhancement. Although the brushstrokes are visually obvious for human observers, their automatic extraction is far from trivial. In order to enhance the

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brushstroke contours and suppress any other visual structure, we apply a circular filter to the painting. This filter enhances the parallel contours, characteristic of brushstrokes, irrespective of their orientation. Figure 1 illustrates the circular filter. The vertical axis represents the filter response; the two planar axes represent the image plane. The main parameter of the filter is the diameter of the circle which is optimised to match the average separation of the parallel contours of the brushstroke. Figure 2 shows the result of applying the (optimised) circular filter to Van Gogh's Korenveld met kraaien (JH 2117). The brushstroke contours are clearly visible.

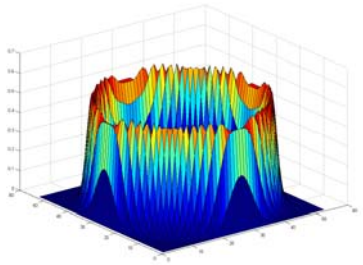

Figure 1. Illustration of the circular filter.

Figure 2. The result obtained after applying the circular filter to Van Gogh's "Korenveld met kraaien", Auvers-sur-Oise, 1890 (JH 2117).

II. Quantification of a brushstroke shape. The quantification of a brushstroke shape proceeds in three steps. Firstly, the closed contours are filled. Figure 3A illustrates a filled closed contour corresponding to a single brushstroke (or brushstroke fragment). Secondly, the closed contour is skeletonized yielding a thinned line-like representation of the brushstroke (figure 3B). Thirdly, the thinned brushstroke is fitted to an Nth order polynomial. The value of N is proportional to the complexity of the fitted curve. Figure 3C shows the result for N=3. Small irregularities are removed in this step. With these three steps, the brushstroke contours are transformed into a compact quantitative representation, i.e., into N polynomial coefficients.

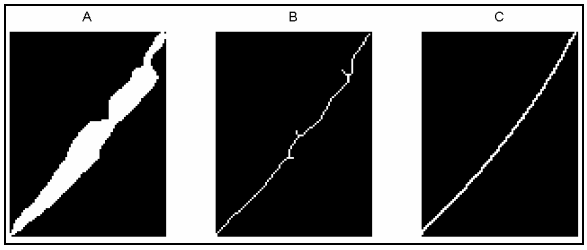

Figure 3. Brushstroke quantification in three steps: (A) filling closed curves, (B) skeletonizing the filled curve, and (C) fitting an Nth order polynomial.

2.3 Texture-analysis results

The quantitative representation of brushstrokes enables the application of statistical analysis and learning techniques to discover painter-specific regularities. We have applied our brushstroke-extraction technique to 169 paintings of Van Gogh which resulted in over 60 thousand separable brushstrokes (and brushstroke fragments). Each of these brushstrokes is transformed into three coefficients. Figure 4 shows a plot of the distribution of the two relevant coefficients (i.e., the polynomial equals: $coef1\ x + coef2\ x^2$). The figure reveals a clear structure; the coefficients are grouped into two largely overlapping clusters. In terms of brushstroke shapes, the distribution of points represent brushstrokes ranging from slightly curved leftwards to slightly curved rightwards. Such brushstrokes correspond to letters of Van Gogh's alphabet. Currently, we are undertaking a detailed analysis of sub-clusters within the displayed distribution and within other distributions to find additional letters of the brushstroke alphabet.

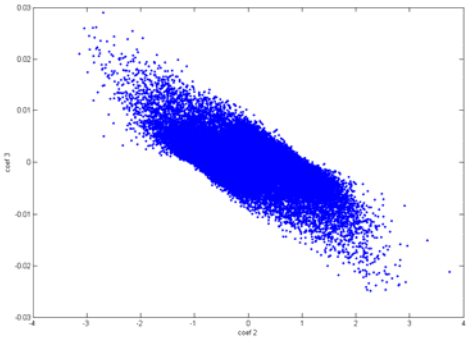

Figure 4. Illustrative results of the brushstroke-analysis technique. The plot shows the distribution of the second and third coefficient of a third-order polynomial fit to the brushstrokes in 169 paintings of Van Gogh.

3. DISCUSSION

Our analysis technique is only the start of a promising development to explore the possibilities of automatic visual examination of Van Gogh's paintings. The qualifying results on the analysis of texture reveal a glimpse of the potential of digital image-analysis and machine-learning techniques. In the coming years, we will extend our techniques and results in order to obtain a full-fledged toolbox to support the art expert in his judgement.

4. CONCLUSIONS

At present, the cultural heritage benefits insufficiently from innovations in computer science. In this contribution we provided some insights into our progress in the AUTHENTIC project. For the first time, objective visual analysis techniques are applied to the paintings of Vincent van Gogh. From the results given above and published elsewhere [1,2] we may conclude that the use of advanced digital analysis techniques will change the way in which the authentication of visual art is currently performed.

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