ON THE ATTRIBUTION OF A NUDE-MAN DRAWING: ANALYSIS OF STROKE CHARACTERISTICS

ARTRENDEX INC
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This study was commissioned to determine whether Pablo Picasso is the author of a Painting of a bearded nude man (referred to here as the "Painting", or "Subject Work"), as illustrated in Figure 1.

1. Introduction

Description of the Subject Work:

The subject work is in dimension 53 cm × 38 cm and is an ink drawing with few watercolor strokes. The work depicts a bearded nude male sitting under what seems to be grapevine. The work can be seen in Figure 1. The work is in the neoclassical style. The style of the work has apparent similarity to Picasso neoclassical style drawings, painting, and prints from the 1920's and 1930's, in particular figures from the sculptor studio collection of the Vollard suite prints, which was executed in 1933. This apparent and intriguing similarity motivated this study.

Prior Studies:

The subject work has been investigated using Raman Spectroscopy technique at the Polytechnic University of Catalonia [12]. The report of this investigation was presented by the Trust to Pervasight. The report concluded that the pigments used in the work are dated from 1910 to 1940. The study also concluded that the paper has watermarking dating prior to 1950. These findings are consistent with the hypothesis that this work might be done by Picasso around the same time he executed the Vollard suite, the report concluded. The report also pointed out several stylistic similarities between the subject work and the figures in Picasso's Vollard suite and other paintings from the same period. The report pointed to striking similarity between the watercolor brush strokes and the silhouette profile of Marie-Thérèse Walter.

Visual Inspection Observations:

There is one notable very long and curved stroke at the right side that makes compositional balance in the drawing. This stroke appears to be executed before executing the left foot in the drawing, and emphasized by a watercolor stroke. The stroke is further emphasized by horizontal, sparse, almost equidistance, hatching marks perpendicular to the contour of that stroke. These hatching marks at the periphery of the work are similar to those that can be found in some of Picasso's work such as Vollard suite plate numbers 39, 42,43, 48, 49, 50, see Figure 2 . These hatching marks appear also in a painting called

FIGURE 1. Subject Work

"Homme au masque, femme et enfant dans ses bras (Marie-Thérèse et Maya)", 1936, at the Picasso Museum in Paris [11].

FIGURE 2. Five examples from the Vollard Suite with hatching lines similar to the subject work. Plates 39,42,43,48,49

The watercolor strokes are in warm colors (red, brown). The marking seems to serve as a framing or suggest other composition. We can count about 15 wide strokes that enclose the foreground figure in a way that frames it. Almost all the brush strokes are not closely tight to the drawing strokes, except at the right curved stroke, which closely follow the watercolor stroke. This tight relation, along with the hatching marks, emphasize the intentionality of that stroke. This long curved stroke holds striking visual similarity in its curvature and position at right side of the canvas to the silhouette profile of Marie-Thérèse Walter.

The watercolor strokes in the subject work seem very unique compared to other Picasso drawings. Picasso used some loose watercolor brush strokes in the illustrated book "Divers Poèmes du Livre Ouvert" in 1941[1]. There are some works of Picasso in neoclassical style, executed in 1933 (the same year he executed most of the Sculptor collection of the Vollard suite), which combine ink drawings with other techniques, such as ink wash, watercolor, and gouache. Several of these works have dimensions very similar to the subject work ($\approx 50 \times 40cm$). Six of these works [9, 6, 7, 8, 10, 5] are shown in Figure 3.

[1]Text with double page decoration from the illustrated book Divers Poèmes du Livre Ouvert 1941 - MoMA Collection.

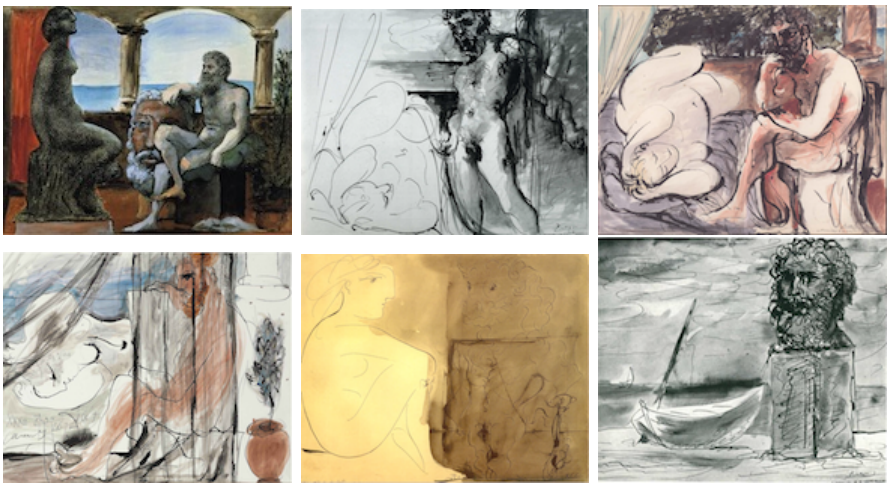

FIGURE 3. Six paintings by Picasso from 1933, with similar dimensions to the subject work, using ink drawing combined with watercolor and other techniques

One other notable feature of the subject work is that the eyes of the nude man directly gaze at the viewer. This is quite rare in Picasso drawings and can be noticed only in Vollard suite plate 81 and to some degree in plate 63.

2. Methodology

The methodology used in this study is based on quantifying the characteristics of individual strokes in the drawing and comparing these characteristics to a large number of strokes by different artists using statistical inference and machine learning techniques. This process is inspired by the Pictology methodology developed by M. M. Van Dantzig [3]. Van Dantzig suggested several characteristics to distinguish the strokes of an artist, and suggested that such characteristics capture the spontaneity of how original art is being created, in contrast to the inhibitory nature of imitated art. The details of the methodology was validated and published in a peer-reviewed paper published in the AAAI 2018 conference, the flagship AI conference [4]. The methodology is patented under under US Patent number 11,087,164

Among the characteristics suggested by van Dantzig to distinguish the strokes of an artist are the shape, tone, and relative length of the beginning, middle and end of each stroke. The characteristics include also the length of the stroke relative to the depiction, direction, pressure, and several others, see figure 9. The list of characteristics suggested by van Danzig is comprehensive and includes, in some cases, over one hundred aspects that are designed for inspection by the human eye. The main motivation is to characterize spontaneous strokes characterizing a certain artist from inhibited strokes, which are copied from original strokes to imitate the artist style.

We excluded using comparisons based on compositional and subject-matter-related patterns and elements. There are several reasons behind adapting this methodology for this

study. Using compositional and subject-matter-related patterns and features might obviously connect the subject work to figures and composition in the Picasso classical period since not many artists executed line drawings in that style in that period. Comparisons using subject-matter-related elements to other drawings by other artists who did not draw in neoclassical style would obviously conclude, by human or by the machine, that the subject work resembles Picasso style. In other words that might constitute the "begging the question" fallacy.

On the other hand, to rule out the possibility of the subject work being executed by another artist imitating Picasso's neoclassical style, i.e., a pastiche, we need to compare features and visual elements that are not easily copied by such an artist. Most forged art works are based on copying certain compositional and subject-matter-related elements and patterns. In contrast to subject matter and compositional elements, the characteristics of individual strokes carry the artist's unique, unintentional signature, which is hard to imitate or forge, even if the forger intends to do.

Given the above two reasons, the methodology used in this study is based on quantification of individual stroke characteristics and would result in a reliable framework that allows comparing the subject work to a collection of works by different artists to infer the attribution based on these characteristics. This also facilitates combining evidence from a massive number of analyzed strokes and using statistical inference and machine learning techniques to come up with quantifiable measures of attribution.

3. Preprocessing

The subject work was digitized by the Friend Trust at 2870×2091 pixel resolution in uncompressed png RGB format. In all the experiments two versions of the work were examined: 1) the full-resolution version as received from the Trust, 2) a half-resolution version ($1373 \times 1000 pixels$). The purpose of this is to insure that any results obtained are not sensitive to change of digitization resolution.

The work shows a drawing using black ink of a nude male subject as well as watercolor brush marks. In this report we refer to the drawing in black ink as the "drawing field", while we refer to the watercolor brush marks as "the painting field". The first stage of preprocessing involved separation between the drawing and painting fields in the subject work. To achieve this separation, several patches (small polygonal regions) of the digitized work were manually selected from water-color areas and other patches were selected from the purely drawing areas (containing areas of both ink strokes and background). The selected patches are shown in Figure 4.

The selected patches were analyzed in the HSV (Hue, Saturation, Value) color space. Figure 5 shows the histograms for the hue, saturation, and value channels for both the drawing and painting patches. The hue histogram shows no separation between the drawing and paint patches. The hue histogram for painting patches clearly shows two peaks, which corresponds to the two (red and yellow) pigments identified in the spectroscopy analysis report [12]. The saturation and value histograms show clear difference between the distributions for the painting and drawing pixels. However no separation is observed between the painting/drawing distributions in these one-dimensional HSV histograms.

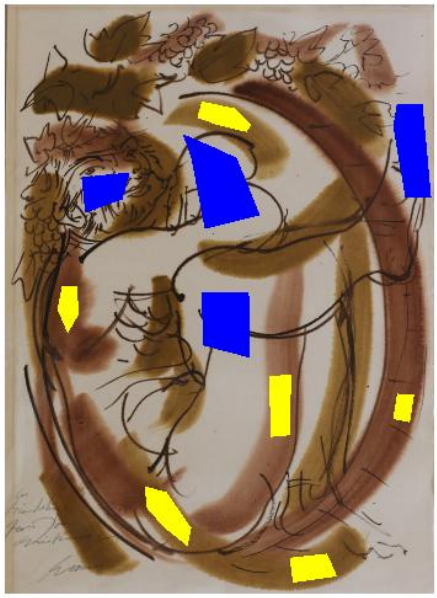

FIGURE 4. Illustrations of patches selected to separate drawing and painting fields. Painting patches are showing in yellow. Drawing patches are shown in blue

To separate the drawing and painting fields a support vector machine (SVM) classifier was trained based on the selected patches in the HSV color space. The pixels in the patches were split into an 80% training sample and a 20% test sample. Radial basis function kernel was used for the classifier. The classifier achieves an accuracy of 99.99% for both the training and testing samples, which clearly show the separation between the drawing/background and water-colored pixels in the HSV space. The classifier was then applied to the whole image to obtain a separation of the drawing and painting fields, as shown in Figure 6-top. All pixel are classified to either drawing/background or water-color painting. Pixels that contain ink drawings painted over with water color are classified as part of the drawing field since the completeness of the drawing field is essential for the following steps of the analysis.

The drawing field is binarized using thresholding to separate the ink strokes from the background. Figure 7 shows the the intensity histogram of the draw field image, which shows clear separation between the ink and background distributions. Figure 6-bottom left shows the extracted foreground ink drawing after thresholding.

The strokes are then segmented into individual strokes using a segmentation algorithm introduced in [4]. The result of stroke segmentation is shown in Figure 6-Bottom Right. The stroke segmentation exhibits in some cases over segmentation, however this should not affect the analysis since such over segmentation should be uniform over all training and validation data.

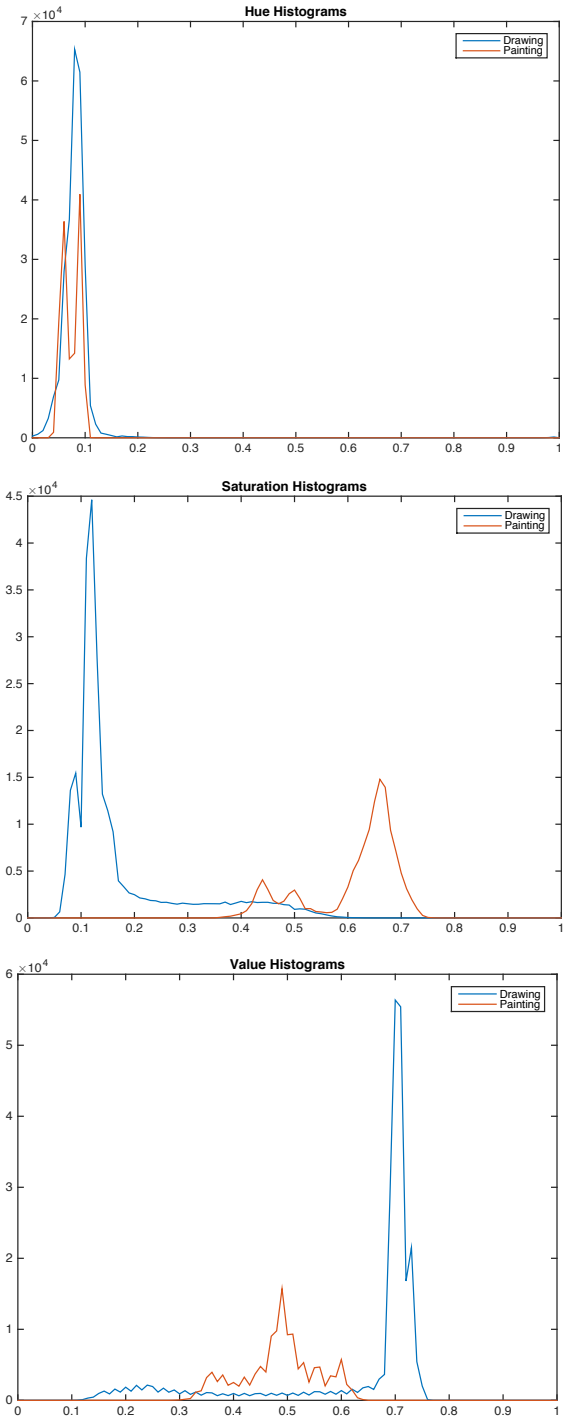

FIGURE 5. Histograms of hue, saturations and value channels of the drawing and painting patches in Figure 4. The horizontal access is the range (0-1) and the vertical axis is the pixel count.

FIGURE 6. Top Left: separated drawing field. Top Right: separated painting field (water color). Bottom Left: Segmentation of ink drawing. Bottom Right: Segmentation of individual strokes.

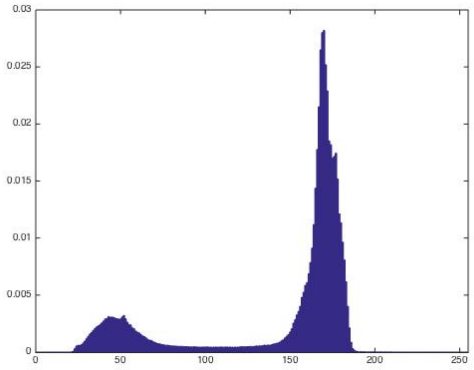

FIGURE 7. Intensity histogram of the draw field. The horizontal access is the range of the intensity values (0-255) and the vertical axis is the pixel count.

4. Data collection

A collection of 297 drawings were gathered from different sources to train, optimize, validate, and test the various classification methodologies used in this study. The drawings selected are restricted to line drawings. The collection included drawings and prints by Picasso (130), Henry Matisse (77), Egon Schiele (36), Amedeo Modigliani (18), and a small representative works of other artists (36), ranging from 1910-1950AD. These artists were chosen since they were prolific in producing line drawings during the first half of the Twentieth century, which is the period identified by the spectroscopy analysis report[12].

The collection included a variety of techniques including: pen and ink, pencil, crayon, and graphite drawings as well as etching and lithograph prints. Table 1 shows the number of drawings for each artist and technique. In the domain of drawing analysis it is very hard to obtain a dataset that is uniformly sampling artists and techniques. The collection is biased towards ink drawings, executed mostly with pen, or using brush in a few cases. There is a total of 145 ink drawings in the collection. The collection contains more works by Picasso than other artists. In all the validation and test experiments an equal number of strokes were sampled from each artist to eliminate data bias.

The Picasso collection included works from his classical period (1920's - 1930's) including 23 plates from the Vollard suite, in particular from the Sculptor Studio collection, mainly produced in 1933. However, the collection also included 104 works from sources other than the Vollard suite because almost all works in this suite are etching, which makes the characteristics of the strokes quite different from pen and ink drawing. The Picasso collection included works not only in neoclassical style, but in a variety of styles, to insure that the classification will not be mainly based on the difference in style between the neoclassical Picasso and non-neoclassical Matisse/Schiele.

The collection included digitized works from books, downloaded digitized images from different sources, and screen captured images for cases where downloading was not permitted. The resolution of the collected images varies depending on the sources. The effective resolution varies from 10 to 173 pixel per cm depending on the actual drawing size and the digitized image resolution. Figure 8 shows the distribution of the digitized images resolution. Given this wide range of resolutions, the algorithms and features used were designed to be invariant to the digitization resolution.

Table 1. Dataset collection: technique distribution

Technique	Pen/brush (ink)	Etching	Pencil	Drypoint	Lithograph	Crayon	Charcoal	Unknown	Total
Picasso	80	38	8	2	2	0	0	0	130
Matisse	45	10	5	2	14	1	0	0	77
Schiele	0	0	10	0	0	5	4	17	36
Modigliani	0	0	9	0	0	8	1	0	18
Others	20	0	0	0	9	4	1	2	36
Total	145	48	32	4	25	18	6	19	297
Strokes	36,533	19,645	9,300	914	6,180	4,648	666	2,204	80,090
Others: Georges Braque, Antoine Bourdelle, Massimo Campigli, Marc Chagall, Marcel Gimond, Alexej Jawlensky, Henri Laurens, Andre Marchand, Albert Marquet, Andre Masson, Andre Dunoyer Dr Segonzac, Louis Toughague									

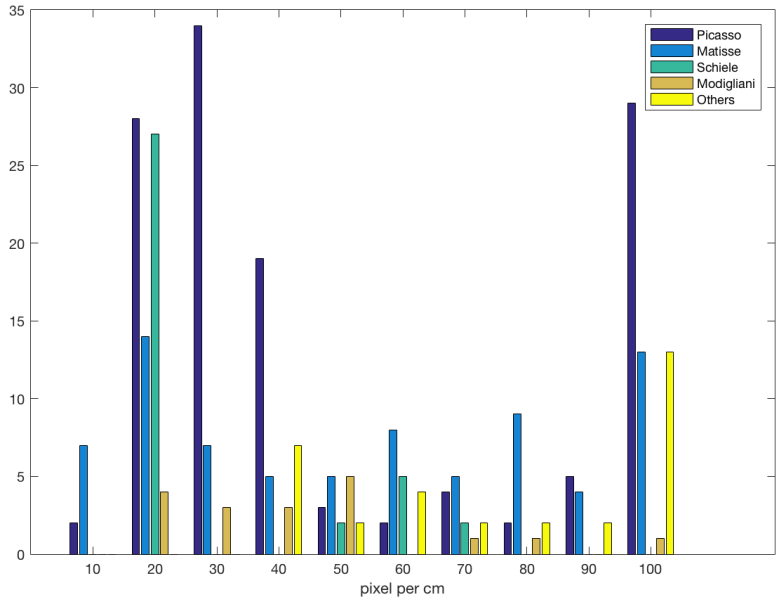

FIGURE 8. Distribution of digitization resolution (in Pixel per cm units)

5. Stroke Analysis Methodology and Validation

5.1. **Quantifying Stroke Characteristics.** This section explains the process of quantifying the characteristics of individual strokes and the extracted features used to represent each stroke. This process is inspired by the Pictology methodology developed by M. M. Van Dantzig [3]. Van Dantzig suggested several characteristics to distinguish the strokes of an artist. Among them are the shape, tone, and relative length of the beginning, middle and end of each stroke. The characteristics include also the length of the stroke relative to the depiction, direction, pressure, and several others. The main motivation is to characterize spontaneous strokes characterizing a certain artist from inhibited strokes, which are copied from original strokes to imitate the artist style, see figure 9

The list of characteristics suggested by van Danzig is comprehensive and includes, in some cases, over one hundred aspects that are designed for inspection by the human eye. In this study we do not implement the exact list of characteristics suggested by van Dantzig; instead we developed methods for quantification of strokes that are inspired by his methodology, trying to capture the same concepts in a way that is suitable to be quantified by the machine, is relevant to the digital domain, and facilitates statistical analysis of a large number of strokes by the machine rather than by human eye.

In our study, we developed techniques to quantify and characterize: 1) stroke contour shape and 2) stroke tone variations. The overall methodology is illustrated in Figure 10.

5.1.1. **Stroke Contour Shape Features:** Each stroke is represented by its skeleton, its boundary, and the rib length around the skeleton. The following descriptors are extracted to

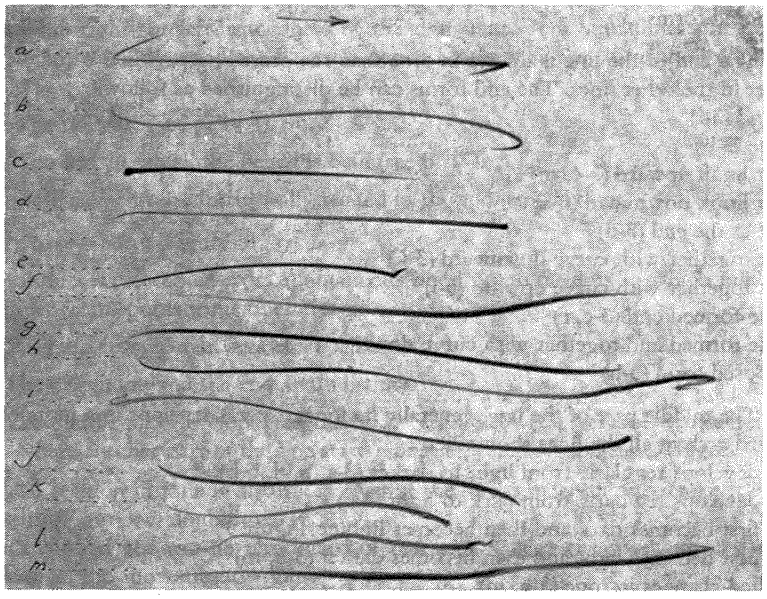

FIGURE 9. Illustration of van Dantzig methodology on simple strokes. Spontaneous strokes differ in their shape and tone at their beginning, middle and end. Figure from [3]

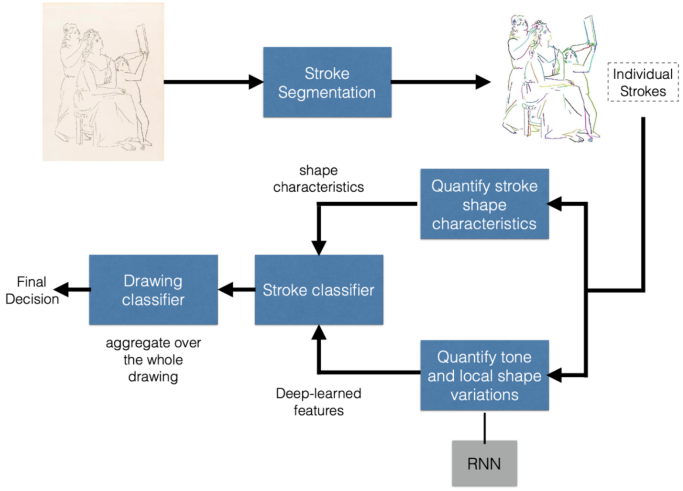

FIGURE 10. Overview of the process of stroke analysis

quantify the characteristics of each stroke. All the descriptors are designed to be invariant to translation, rotation, scaling (change in digitization resolution).

- *Shape of the boundary:* The shape of the stroke boundary is quantified by Fourier descriptors [2]. Fourier descriptors are widely used shape features for a variety of computer vision applications such as character recognition and shape matching. Fourier descriptors provide shape features that are proven to be invariant to translation, scaling, rotation, sampling, and contour starting points [2]. We used 40 amplitude coefficients (first 20 harmonics in each direction) to represent the shape of the boundary of the stroke.
- *Reconstruction error profile:* The mean reconstruction error as a function of the number of harmonics used to approximate the shape of the strokes is used as a descriptor of the smoothness of the contour and the negative space associated with the stroke. In particular, we compute the mean reconstruction error at each step while incrementally adding more harmonics to approximate the shape of the stroke. The reconstruction error profile is normalized by dividing by the stroke mean width in pixels to obtain a descriptor invariant to digitization resolution.
- *Contour Curvature descriptor:* To quantify the curvature of the stroke contours, we use the first and second derivatives of the angular contour representation. The distributions of these derivatives are represented by their histograms.
- *Stroke thickness profile:* To quantify the thickness of the stroke, we compute the mean and standard deviation of the rib length around the skeleton of the stroke, as well as a histogram of the rib length. All rib length measurements are mapped to mm units to avoid variations in digitization resolution.
- *Stroke Length:* The length of the stroke is quantified as the ratio between the stroke skeleton length to the canvas diagonal length. This measure is invariant to digitization resolution.

5.1.2. **Stroke Tone Variations:** Variations of tone and shape along the stroke is characterized using a Recurrent Neural Network (RNN) [**?**]. RNN is a type of deep neural network that is used to learn and classify sequential data. To characterize the variation of tone and shape along the stroke, patches of fixed size are taken along the skeleton of each stroke and sequentially fed to a RNN. In particular we used Gated Recurrent Unit (GRU, [1]), which is an advanced RNN variation that use gated memory mechanism to avoid the typical problem of vanishing gradient during training RNN. Figure GRU illustrates the concept of using GRU for stroke analysis. The details of the method can be seen in [4].

5.2. **Validation Experiments.** This section describes the experiments conducted to test and validate the performance of the stroke classifiers and the drawing classifiers on the collected dataset. In particular, the experiments are designed to test the ability of the stroke classifier to predict Picasso vs. non-Picasso strokes.

In all experiments the stroke data set was split into 80% training and 20% test splits. In all splits the same number of strokes are sampled from each artist class to eliminate dataset bias.

Stroke Classification Validation - Technique Specific:

We evaluated individual stroke classifiers on two settings: 1) across all techniques and 2) Pen/ink specific. In the two cases we evaluate Picasso vs. all other artist classifiers

applied on each individual stroke. In each case, the experiments were executed five times with random sampling of train/test splits. Table 2 shows the mean and standard deviation for each validation experiment.

The results shows the ability of the developed algorithms to classify the individual strokes of Picasso vs. non-Picasso with high accuracy when the strokes are compared to works executed with the same technique and across different techniques.

Table 2. Validation of Individual Stroke Classifiers -

Across-Techniques - Mean (std) of five folds							
		Stroke Contour Shape		Stroke Tone - RNN		Combined	
Classifier	technique	train	test	train	test	train	test
Picasso vs. all	All	72.59% (1.19 %)	67.26% (8.37 %)	81.92% (2.59 %)	75.09% (5.09%)	86.05% (1.08 %)	78.54% (4.36 %)
Technique-specific - Mean (std) of five folds							
		Stroke Contour Shape		Stroke Tone - RNN		Combined	
Classifier	Technique	train	test	train	test	train	test
Picasso vs. all	Pen/Ink	73.20% (2.21%)	68.93% (7.04%)	84.08% (2.20%)	72.24% (1.87 %)	88.40% (1.19%)	75.92% (4.22%)

Drawing Classification Validation:

We evaluated the drawing classification accuracy using four aggregation strategies on two settings, as before: 1) across all techniques and 2) Pen/ink specific. A leave-one-out evaluation methodology is used for these experiments, i.e., one drawing is left out for testing and the classifier is trained using all other drawings, and then this process is repeated for all drawings in the studied subset. Table 3 shows the accuracy of the drawing classifier for each aggregating strategy for each setting.

Table 3. Validation of Drawing Classifiers - - Picasso-vs-All

Picasso-vs-All						
	Across-Techniques			Pen/Ink		
Aggregation	Stroke Contour Shape	Stroke tone variation	Combined	Stroke Contour Shape	Stroke tone variation	Combined
Majority	66.67%	76.77%	82.49%	72.41%	82.76%	81.38%
Posterior	67.68%	77.44%	81.48%	72.41%	82.76%	81.38%
85%-certain	73.06%	79.80%	82.83%	72.41%	82.76%	82.76%
Certainty-weighted	67.34%	79.80%	82.83%	71.72%	82.76%	82.07%

The conclusion from these experiments is that the developed algorithms have the ability to successfully predict, with high accuracy, the authorship of a drawing based only on the characteristics of the strokes without involving any encoding of subject matter or compositional visual elements. The accuracy is around 82% for the case of ink drawings, which is the most relevant case to the subject work. The accuracy is similar for the case of using all techniques. The accuracy does not significantly change across different aggregation strategy. Therefore, for the subject evaluation in the next section, we will mainly focus on the majority voting aggregation strategy.

6. Analysis Results on Subject Work

The subject work was tested using classifiers trained on relevant subsets of the data collection. We conducted tests based on two comparative subsets: 1) the subset of Ink

drawings, which is the most relevant subset, and hence would yield the most important results; 2) a subset that combines all techniques. As explained in Section 5, the methods used focused on quantifying the characteristics of strokes and ignored subject matter and compositional features to avoid obvious determination that the subject work belongs to Picasso just because it appears to be in neoclassical style. In fact, a large portion of Picasso's ink drawings used in the comparisons are not from a neoclassical style.

In each test we used two digitized versions of the subject work, one in full resolution and one in a reduced resolution (50% reduced resolution) to test whether the results are sensitive to the digitization resolution.

In all tests we used majority voting strategy to aggregate the evidence from the stroke level to the drawing level to determine whether the strokes in the subject work belong to the class of Picasso strokes or class of non-Picasso strokes.

Comparative Set I: Ink drawings:

In this experiment the subject work was tested using a classifier trained on ink drawings by Picasso and all other artists in the dataset. The classifier was trained by sampling an equal number of strokes from each class of strokes to avoid data bias. The performance of the stroke classifier on that dataset was shown in Table 2, which showed correct prediction with accuracy of 75.92% on the test data. The performance of the classifier at the drawing level was shown in Table 3 -first row, which showed accuracy in the range 81-82%.

Three drawing-level classifiers we used for testing, using 1) Stroke contour shape features, 2) Stroke tone variations features using deep neural network (RNNs), 3) combined contour shape and stroke tone variation features.

Table 4 shows the results of the three classifiers applied to the subject work. The three different classifiers predicted that the strokes of the subject drawing is probably coming from the same distribution of Picasso ink-drawings strokes with very high certainty. This prediction persists using both full resolution and reduced resolution versions of the work, with around 4% drop in accuracy.

TABLE 4. Comparative Set: Pen/Ink drawings

		Pen / Ink			All Techniques		
		Hand-Crafted	RNN	Combined	Hand-Crafted	RNN	Combined
Full resolution	Class: Certainty:	Picasso 96.61%	Picasso 92.45 %	Picasso 97.13 %	Picasso 83.06%	Picasso 82.23%	Picasso 85.33%
reduced Resolution	Class: Certainty:	Picasso 94.63 %	Picasso 88.76 %	Picasso 93.55%	Picasso 81.53 %	Picasso 80.44%	Picasso 82.34 %

Comparative Set II: All Techniques:

In this set of experiments, the subject work is tested against classifiers trained on all the techniques in the dataset shown in Table 1 with 297 images including 80,090 strokes. As in the previous experiments, three classifiers were used: 1) Stroke contour shape features, 2) Stroke tone variations features using deep neural network (RNNs), 3) combined contour shape and stroke tone variation features.

Table 4 shows the results of the three drawing-level classifiers applied on the subject work. The three different classifiers predicted that the strokes of the subject drawing is probably coming from the same distribution of Picasso ink-drawings strokes with very high certainty. This prediction persists using both full resolution and reduced resolution versions of the work, with around 3% drop in accuracy.

7. Conclusion

This study is conducted by Artrendex Inc, to determine whether Pablo Picasso is the author of the Nude Man Painting (referred to here as the "Painting", or "subject work"). The study focused on quantifying the statistical characteristics of the individual strokes of the subject work and comparing it to known Picasso drawings as well as other drawings by artists who draw similar line drawings from the same time frame. The analysis is conducted on a dataset of more than 80 thousands strokes collected from 297 images. The study followed the standard machine learning methodology of splitting the data to training/test splits with five-fold cross validation to evaluate the efficacy of the classifiers. The study is based on methodology that is peer-reviewed and published in a scientific paper published in AAAI 2018 [4] and patented, under US Patent number 11,087,164. The study focused on the characteristics of the individual strokes and excluded subject matter and composition from the analysis since these characteristics are hard to copy by forgers. This approach also rules out the potential that the determination is based mainly on obvious stylistic differences between artists, which are easy to copy by a forger.

In the opinion of Artrendex Inc, the Painting is an authentic original work of Pablo Ruiz Picasso. This opinion is based on scientific testing and a reasonable degree of scientific certainty.

There is enough evidence that the characteristics of the strokes of the subject work are similar to the characteristics of Picasso's strokes in his ink drawings. This opinion is based on the details explained in this report and based on the assumptions laid down in this report. This opinion is based on the comparative data sets studied in this report, which is large enough to support this opinion.

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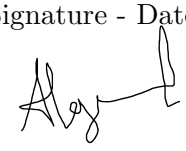

8/26/2023

Dr Ahmed Elgammal, Artrendex Inc.

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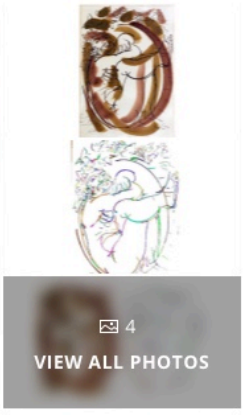
Tech company uses AI program to authenticate forgotten Picasso drawing

by JACKSON SINNENBERG | The National Desk | Thu, July 13th 2023, 9:15 PM EDT



A digital scan image of the drawing "The Naked Man" by Pablo Ruiz Picasso (Courtesy of Artrendex Inc.)

WASHINGTON (TND) — A drawing by famed painter Pablo Picasso, lost to the historical record, was recently confirmed as authentic by AI technology firm.

Artrendex, a New York-based tech company founded in 2018, aimed from its outset to develop artificial intelligence-based solutions for major challenges, such as authentication, in the world of fine art.

Since its founding, the firm has been developing an AI program that analyzes paintings, drawings and prints for the "micro-characteristics" of an artist's true touch – or the work of a copycat – on those works.

> ***It's excellent at detecting patterns in complex data like hatching, brush strokes, and other telltale signs of an artist's method," Ahmed Elgammal, founder of Artrendex and head of the Art & AI Laboratory at Rutgers University, said in a news release.***

Elgammal says Artendex's model utilizes deep learning, a kind of construction of multiple layers of algorithmic processes designed to mirror the process by which neurons in the human brain trade information, to recognize and then analyze the minutia that determine an artist's presence on the page.

> *We cannot just use AI models that recognize cats from dogs and train them to recognize Van Gogh! Such models will be easily fooled by forgeries," he said. "We need to go to the stroke level and learn the spontaneous characteristics of the artist's strokes.*

Artendex's first major test came when the company used its software to help expose a series of paintings purportedly created by the neo-expressionist American painter Jean-Michel Basquiat. The Artendex team compared two exhibits of the artist's work, one in New York and one in Florida, which determined the pieces in the Sunshine State exhibit were forgeries – something the FBI confirmed independently in 2022.

In the case of this Picasso – "The Naked Man," as it has been dubbed – an art collector stumbled upon the piece in Arizona in the early 2000s at the estate sale of an architect and art collector. The collector believed it could be a legitimate Picasso and worked for years with experts to work on authenticating the specimen, including tests on pigment age and other physical attributes. The owner eventually turned to Artendex and requested the AI examine the drawing.

By comparing the brush and pen strokes of “The Naked Man” to other Picasso works from the time period – such as etchings from the “Vollard Suite” – as well as the works of similar contemporaries, like Henry Matisse and Egon Schiele, the study was able to determine the likely authentic nature of the piece.

The firm hopes its technology could be a resources to private collectors, galleries and museums struggling with high-level purchases over similar concerns.