Bauhaus-Universität Weimar

Fourier Transform

Painting Classification

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Faculty of Media

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Introduction

Problem: $19,000 or $150 million???

"The Beautiful Princess" from **Leonardo da Vinci** because of a fingerprint.
(Source: `https://usatoday30.usatoday.com/news/world/2009-10-14-new-da-vinci-fingerprint_N.htm`)

Problem: How could we distinguish the painting from the specific artist?

Goal

famous artist = **high price + forgeries**

Traditional way: **art expert** (long time training, costly, subjective)

Goal: create a mathematic method to **classify the paintings**

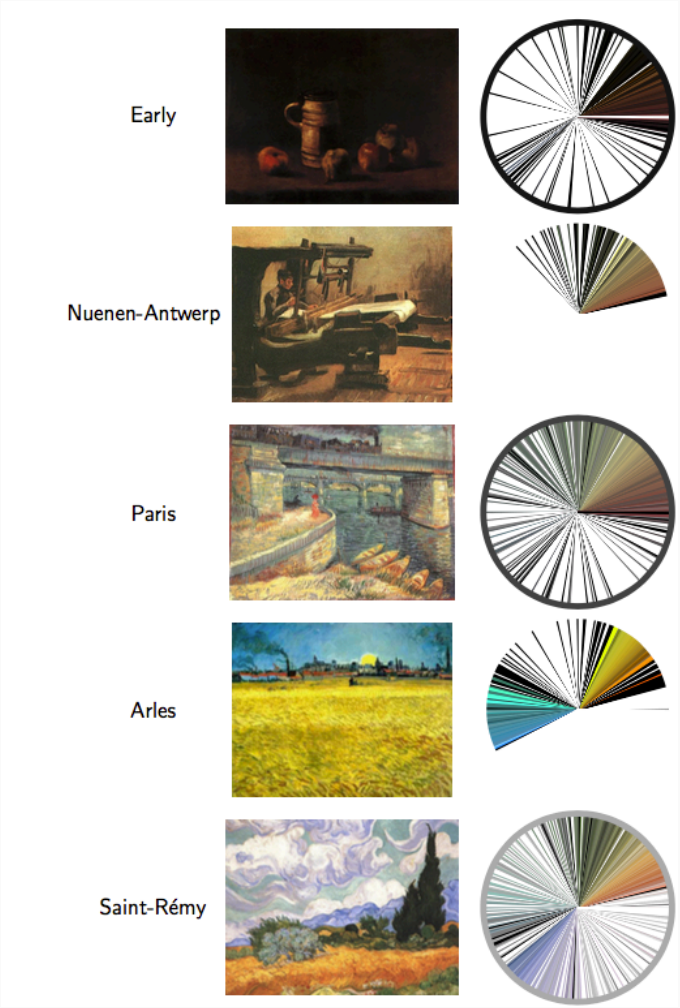
Related Work

Color Analysis

Method 1: Digital Image "Palette"—Lombardi, Thomas (2005) and Rigau, Jaume(2010)

Dataset: Cezanne, Monet, Pissarro, Seurat, Sisley, and Van Gogh (10)

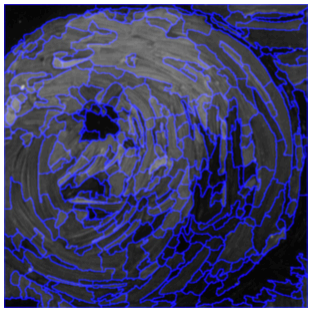
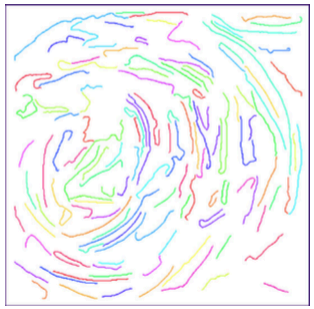
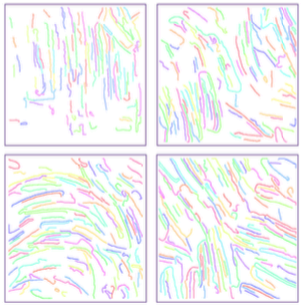
Result: 100%, 20%, 0, 60%, 20%, 0



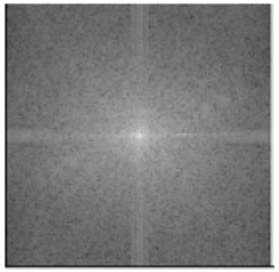
Brushstroke Analysis

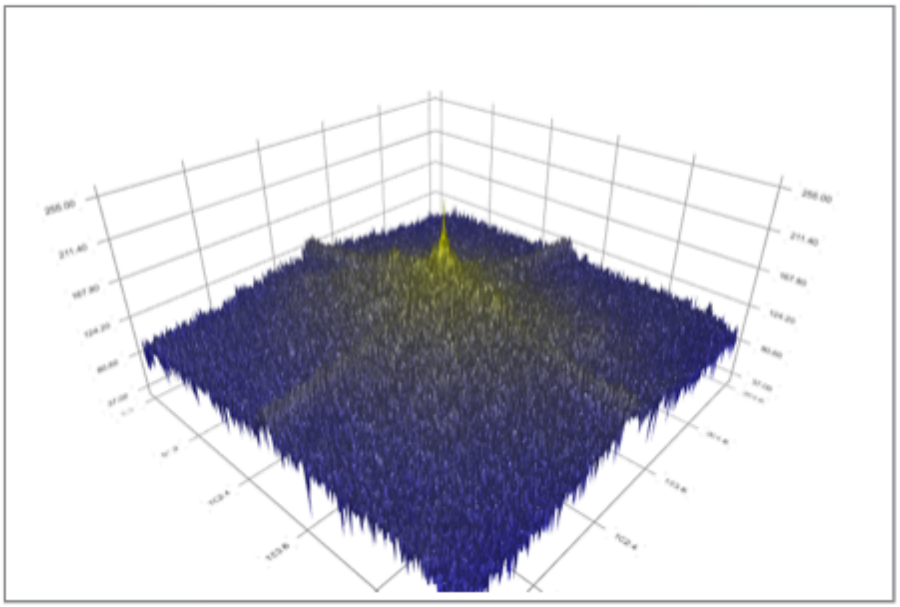
Method 2: Wavelet transform–Johnson, Hendriks and Berezhnoy, 2008

Dataset: 101 paintings with 82 van Gogh, 6 non-van Gogh, others is questioned
Result: 4 out of the 6 non-van Gogh paintings were detected

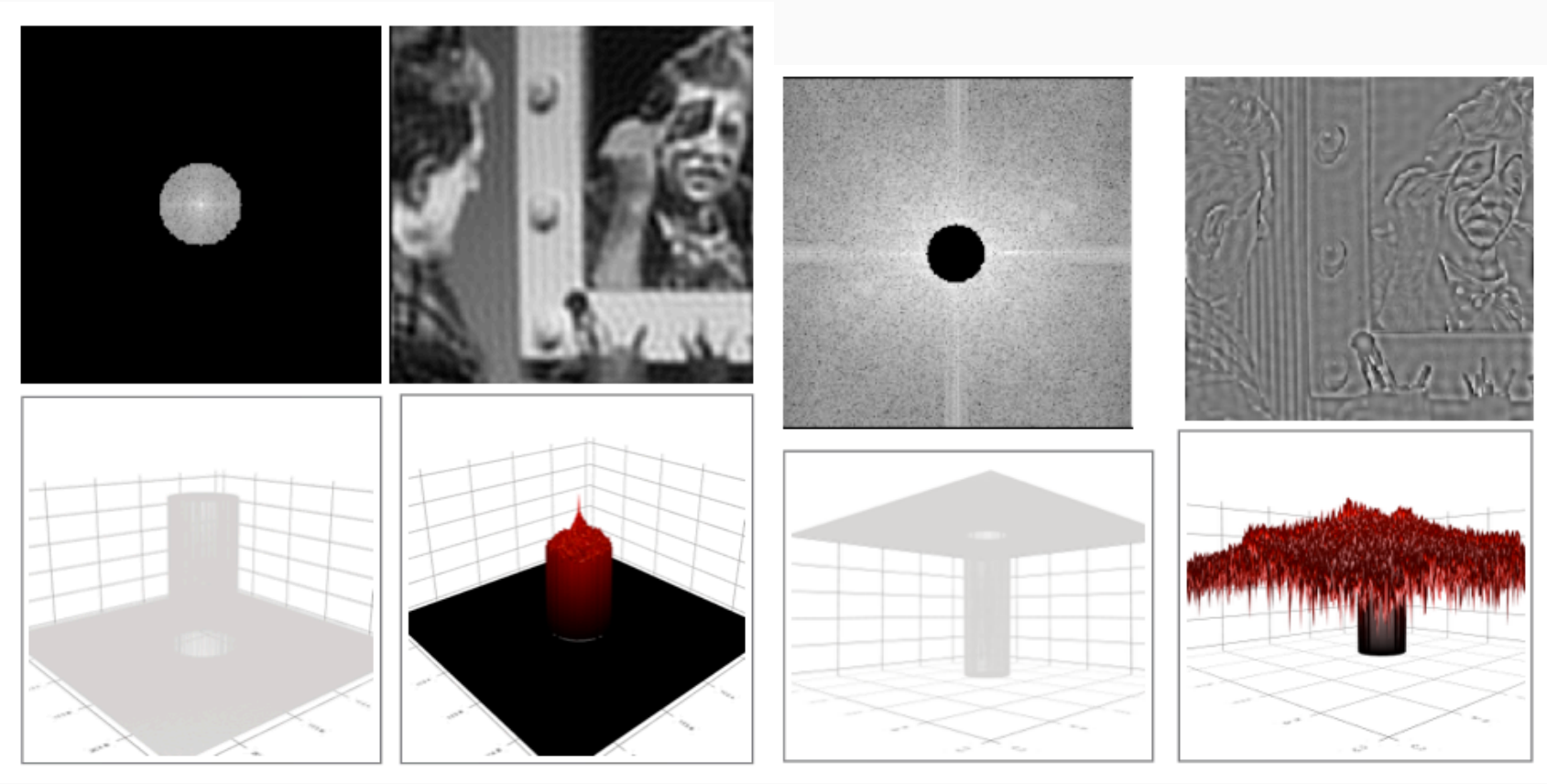




Fourier Transform

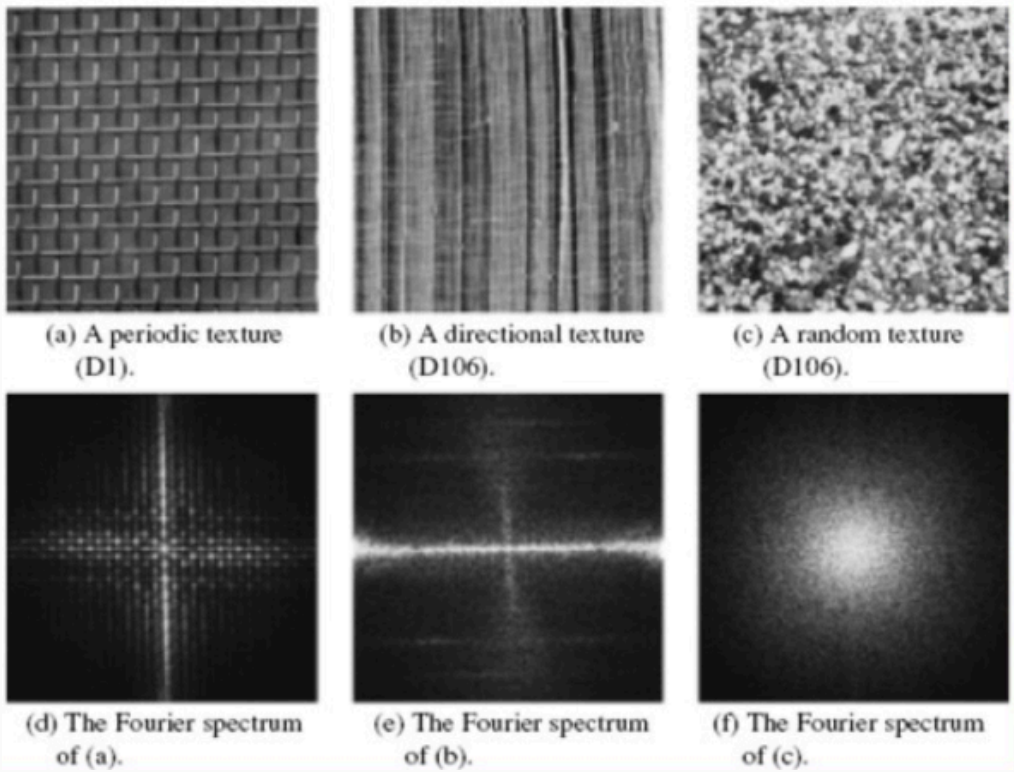




Filtering in Frequency Domain



Texture Recognition

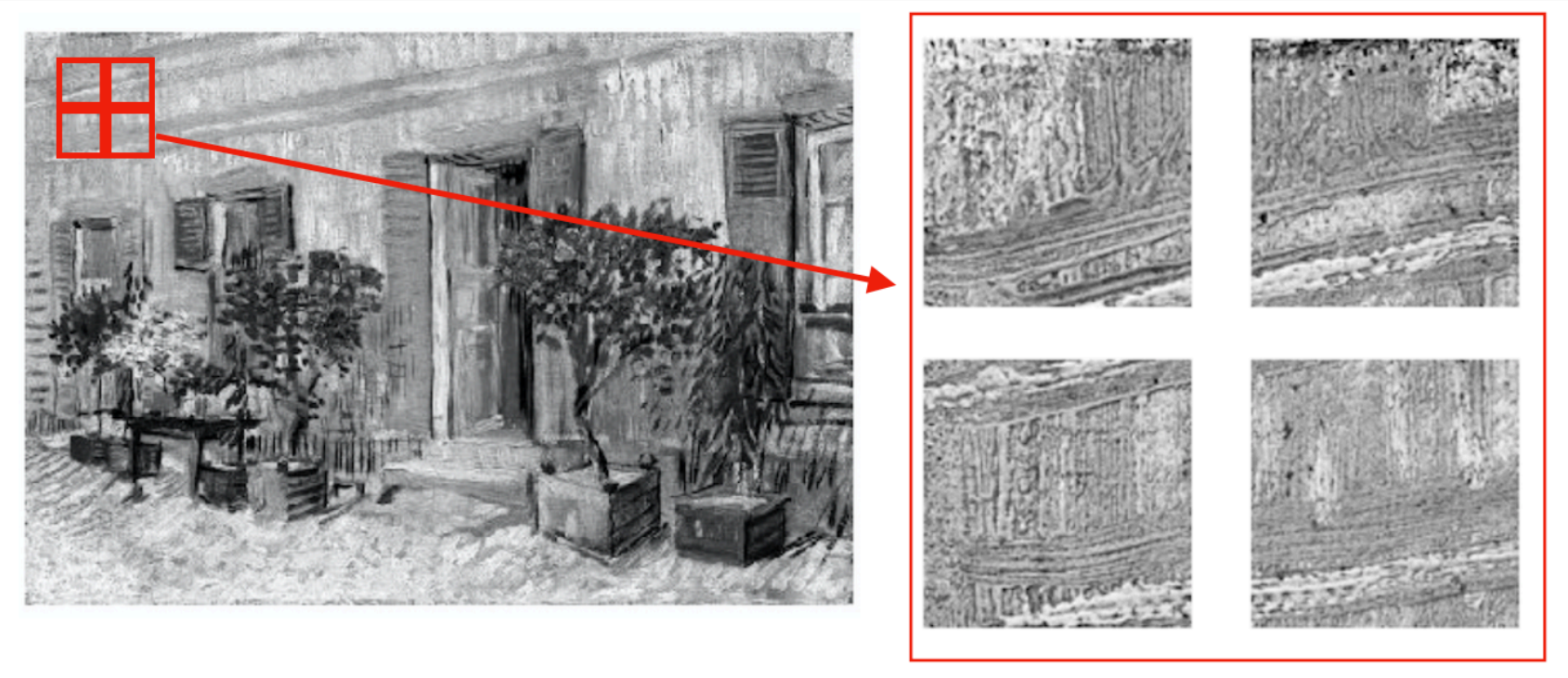


(a) A periodic texture (D1). (b) A directional texture (D106). (c) A random texture (D106).

(d) The Fourier spectrum of (a). (e) The Fourier spectrum of (b). (f) The Fourier spectrum of (c).

Source: `http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.331.4952&rep=rep1&type=pdf`

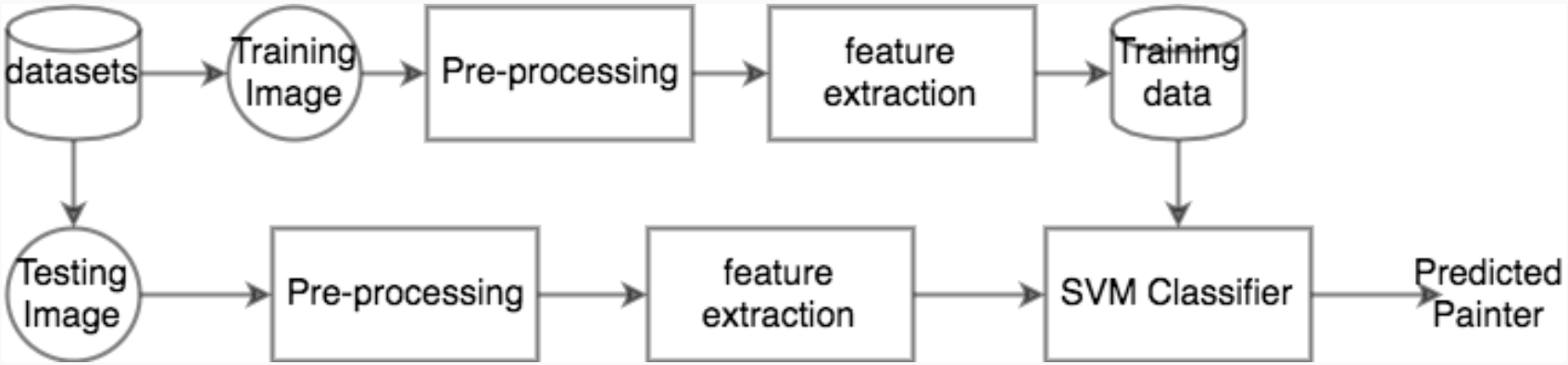
Brushstroke Texture



Van Gogh–"Exterior of a Restaurant in Asnieres"

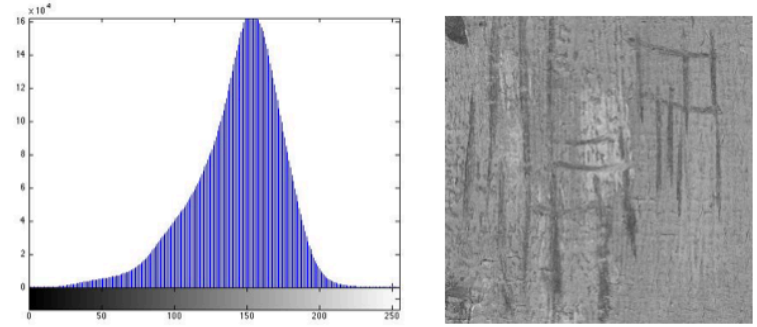
Proposed Approach

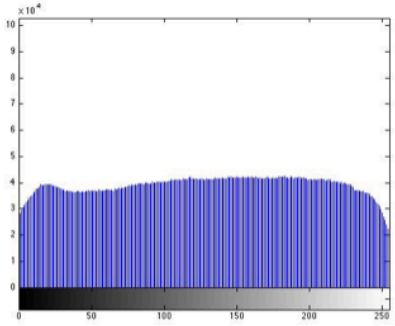
Workflow


datasets
Training Image
Pre-processing
feature extraction
Training data
Testing Image
Pre-processing
feature extraction
SVM Classifier
Predicted Painter

Preprocessing

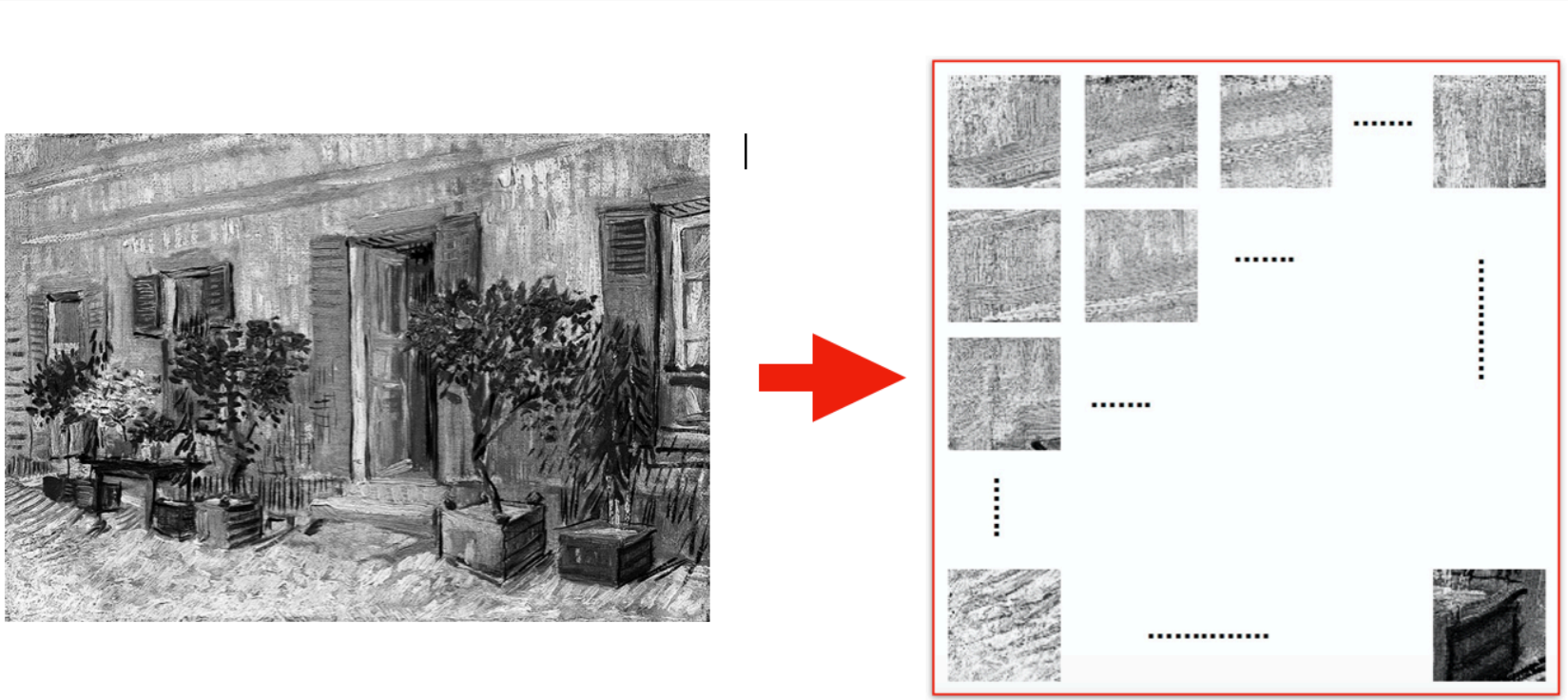
Histogram Equalization





Feature extraction

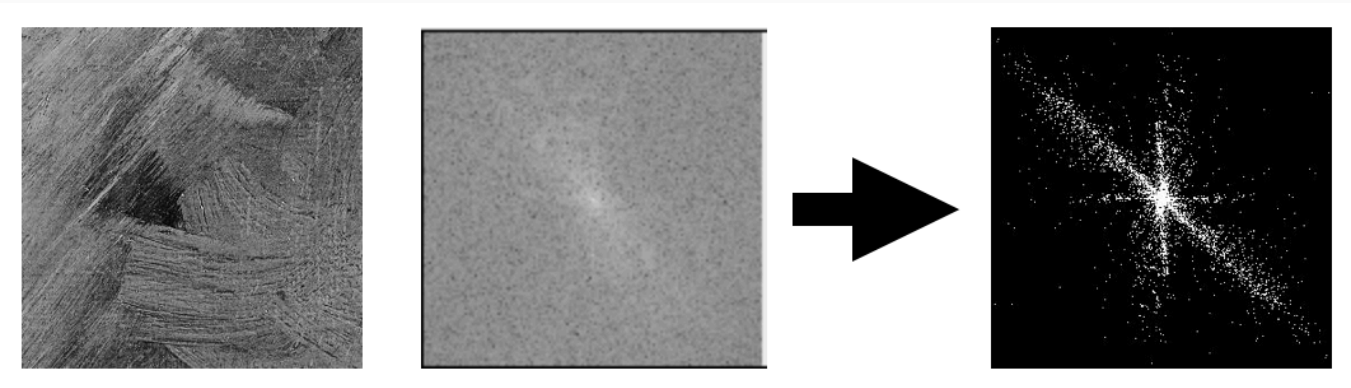
1. Cropping



Parameters:

- Patch size: the size of patch.

Fourier Transform of Brushstroke

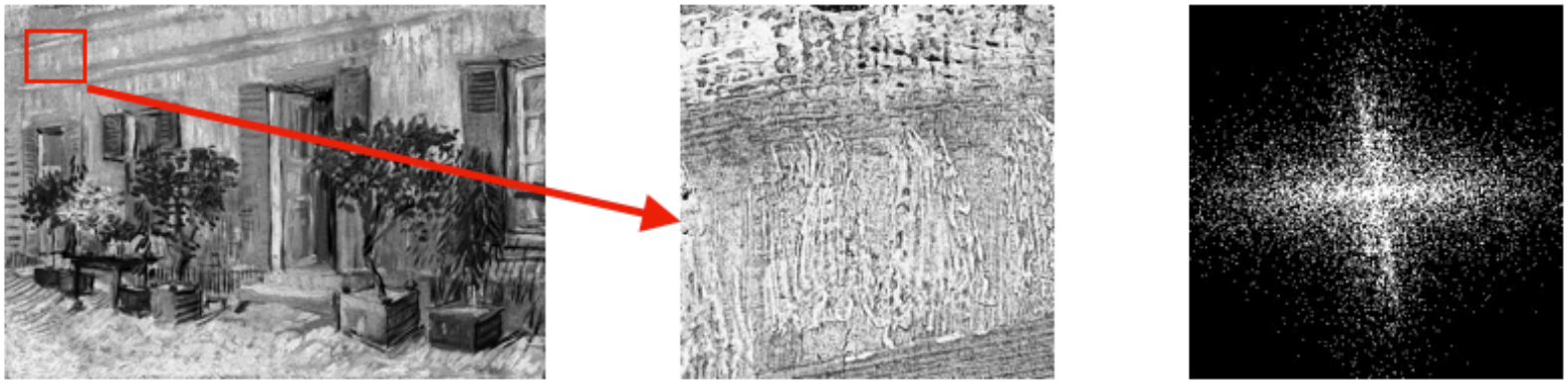


Parameters:

- Threshold: use to remove the low value of the frequency.

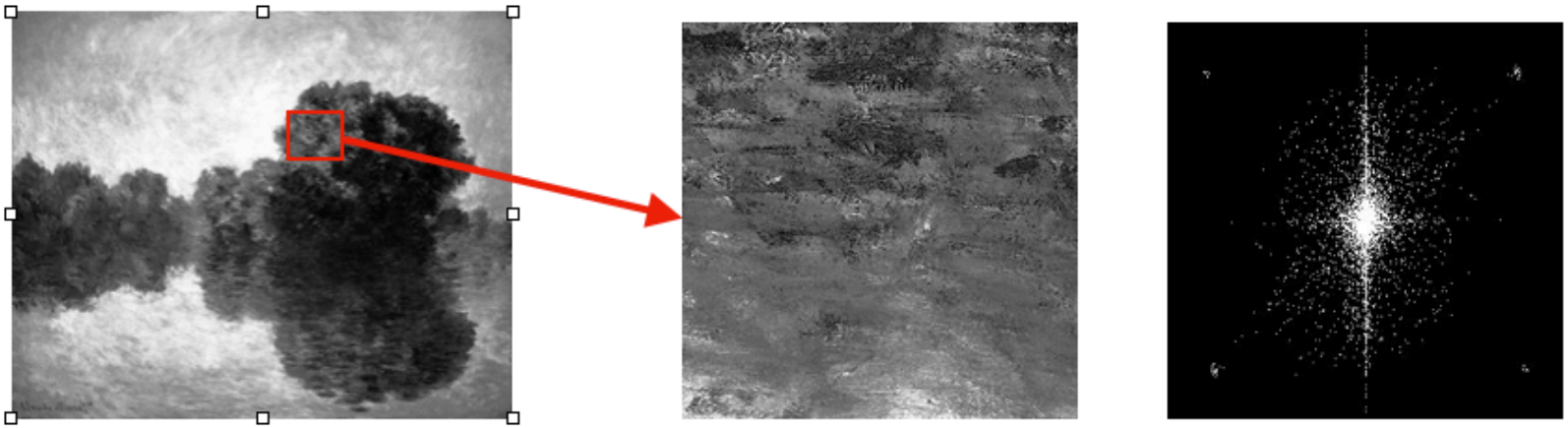
Fourier Transform of Brushstroke

Van Gogh–"Exterior of a Restaurant in Asnieres"



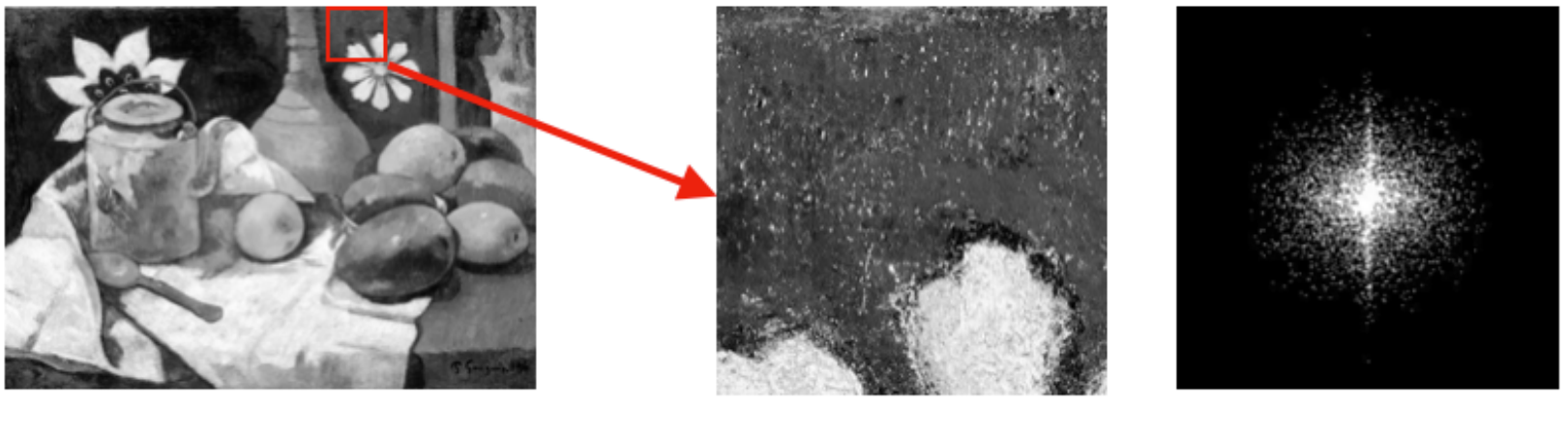
Fourier Transform of Brushstroke

Monet–"The Seine at Giverny"



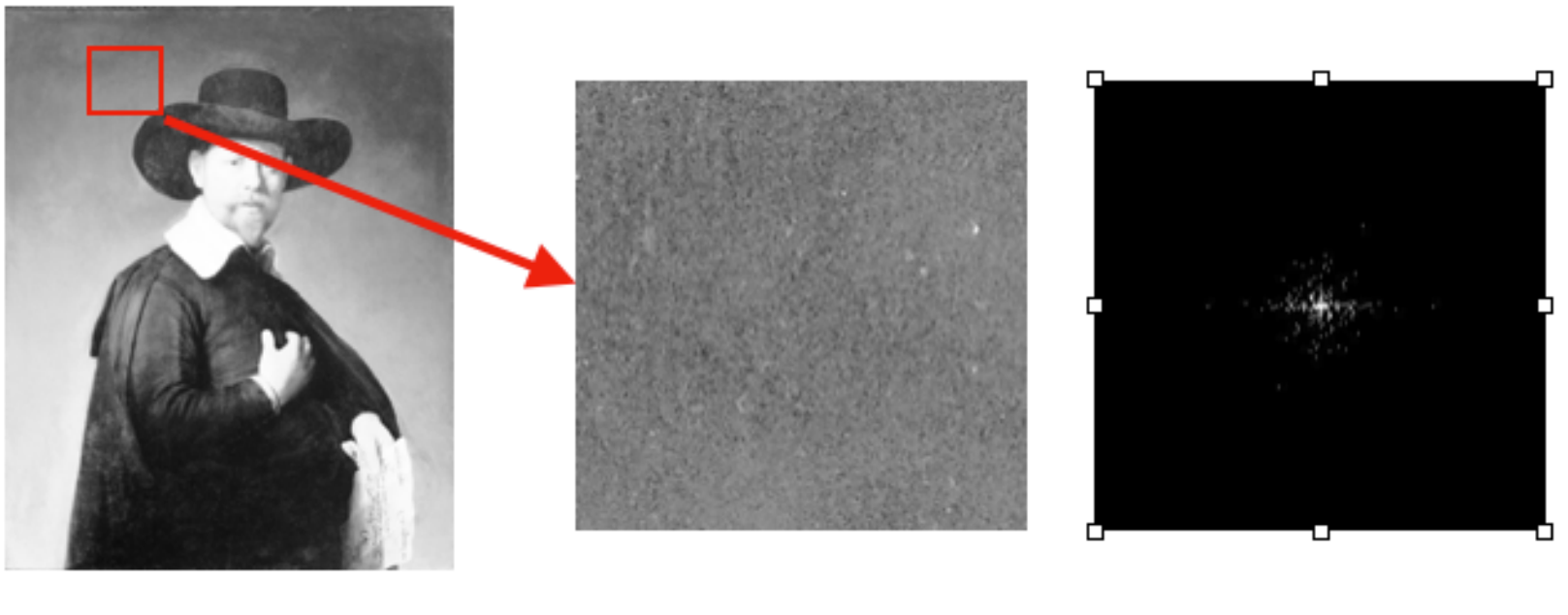
Fourier Transform of Brushstroke

Gauguin–"Still Life with Teapot and Fruit"

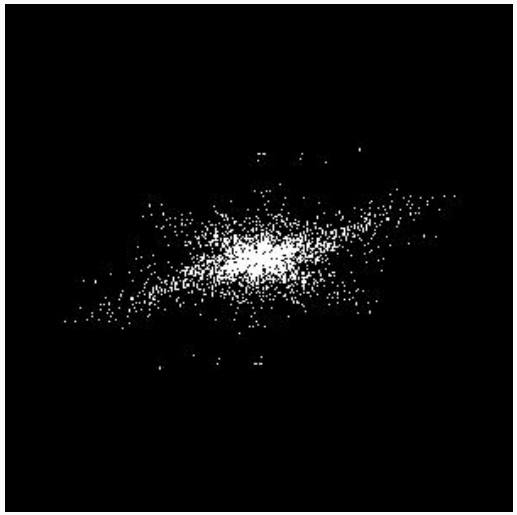


Fourier Transform of Brushstroke

Rembrandt–"Portrait of Marten Looten"



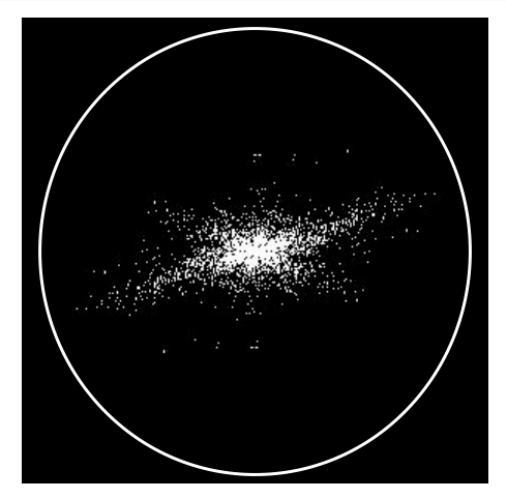
FT Spectrum Size



Parameters:

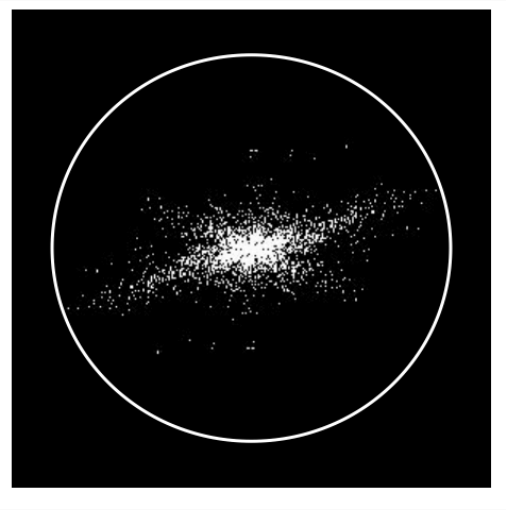
- Max Level: the number of the cycles we used.

Calculation: Max Level: 10



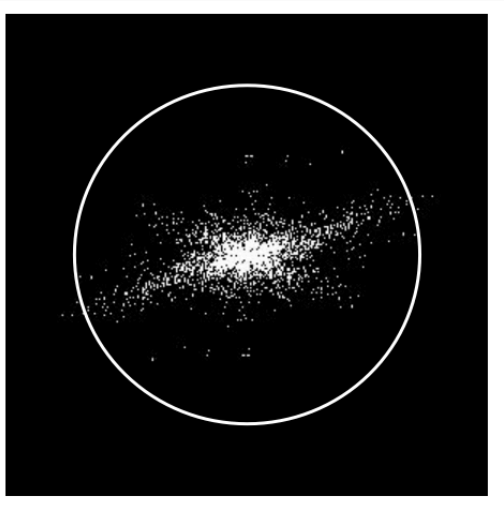
Level 10, continue

Calculation: Max Level: 10



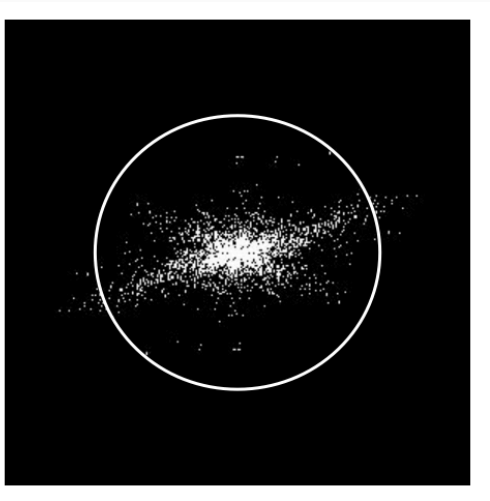
Level 9, continue

Calculation: Max Level: 10



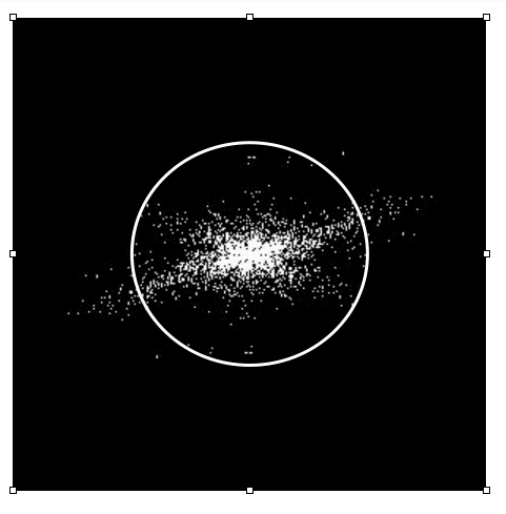
Level 8, continue

Calculation: Max Level: 10



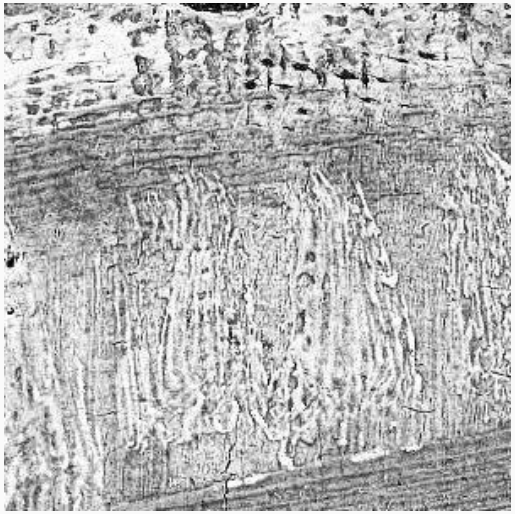
Level 7, continue

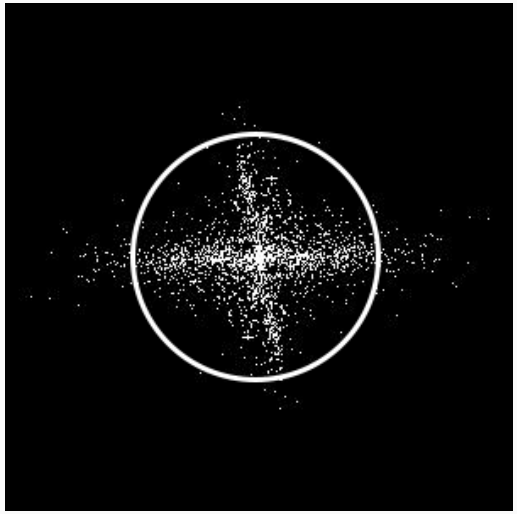
Calculation: Max Level: 10



Level 6, return

FT Spectrum size



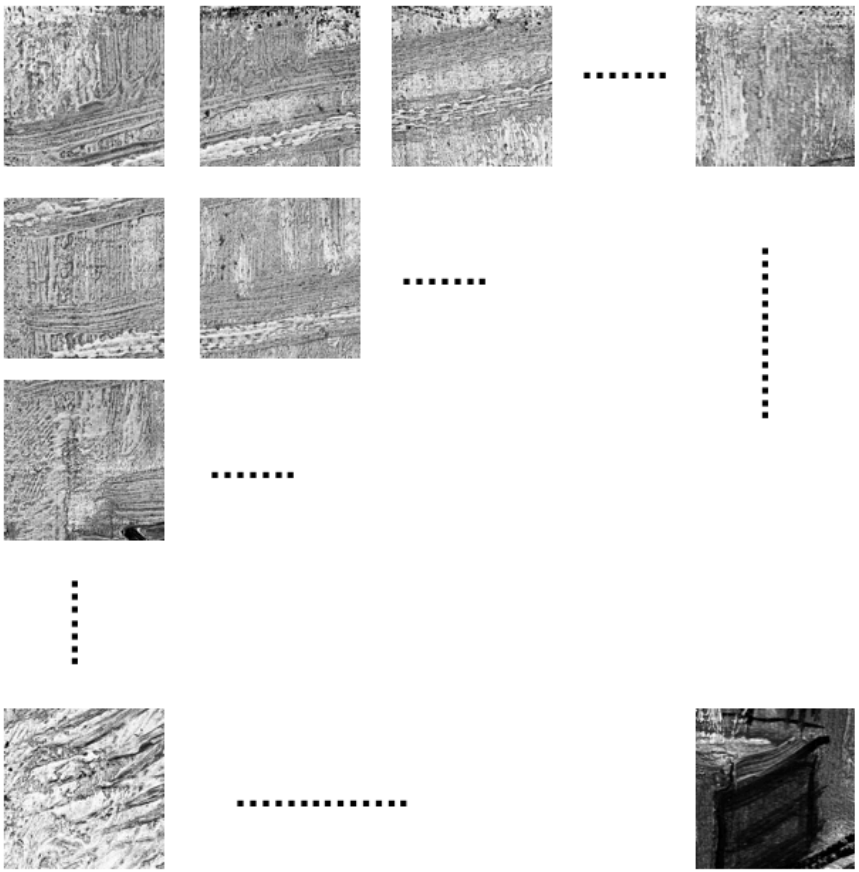


Parameters: Max Level: 10; Threshold: 0.6

Result: level 6

Feature extraction

2. Calculate the FT Spectrum size of each patch.



8	9	8	8	8	9	9	9	9	8	8	9
9	8	8	9	9	9	9	9	10	9	8	10
9	9	9	10	9	9	10	10	10	9	9	10
9	10	10	10	10	10	10	10	10	10	10	10
9	10	9	10	10	10	9	10	10	10	10	10
9	10	10	10	10	10	10	10	10	10	10	10
9	9	10	10	10	10	8	9	10	10	10	10
7	8	6	7	8	9	9	9	9	10	9	10

FT Matrix example

Bokeh Photo example

1	1	1	2	2	2	2	2	1	1	3	1	2	2	3	1	2	1
1	1	1	1	5	3	2	3	2	1	2	3	3	1	2	3	3	1
1	1	1	1	7	8	2	2	1	2	1	2	4	3	3	3	4	2
1	2	4	4	7	5	6	6	2	1	2	1	3	2	1	2	1	1
4	2	2	3	5	7	7	5	3	3	1	1	1	2	1	1	3	4
5	7	9	4	5	7	3	5	3	2	3	1	3	2	1	1	6	4
7	4	6	3	5	6	5	4	3	1	1	4	4	3	1	3	2	2
8	4	7	4	3	4	6	3	8	5	2	3	2	5	1	3	1	1
3	2	6	2	4	4	4	5	5	9	3	4	1	3	3	1	4	3
3	3	5	3	5	4	5	3	1	2	2	2	1	2	4	2	1	2
2	7	4	5	5	5	5	5	7	2	2	2	2	1	4	3	2	5
2	5	5	4	4	5	5	4	7	4	2	4	2	2	1	3	1	3

Source: https://www.flickr.com/photos/79786806@N07/page3 (common use allowed)

FT Matrix example

Painting example

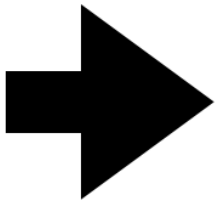
11	10	10	9	9	10	10	10
10	10	11	10	11	10	9	9
9	10	11	10	10	10	10	8
10	10	11	9	6	7	9	8
10	10	9	4	4	6	9	6
10	9	6	3	4	7	9	7
7	5	2	3	6	7	7	8
4	2	2	2	4	7	9	9
4	4	2	3	2	5	9	6
4	4	4	5	4	2	8	8

Van Gogh — "Portrait of a prostitute"

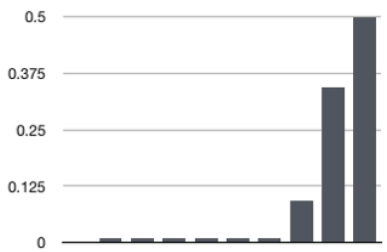
Feature extraction

3. Calculate FT Spectrum size histogram.

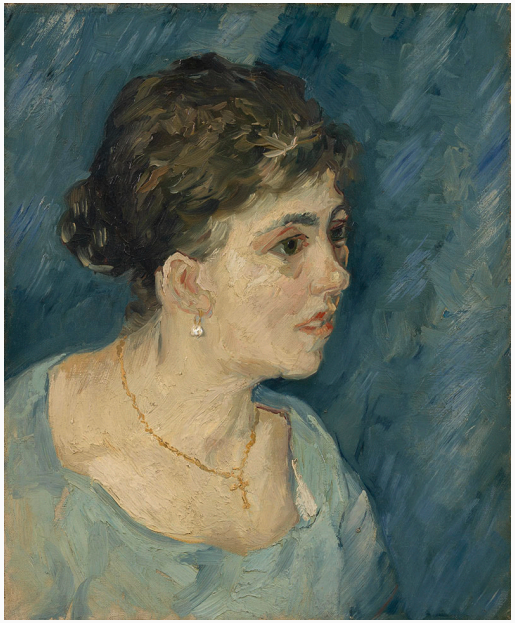
8	9	8	8	8	9	9	9	9	8	8	9
9	8	8	9	9	9	9	9	10	9	8	10
9	9	9	10	9	9	10	10	10	9	9	10
9	10	10	10	10	10	10	10	10	10	10	10
9	10	9	10	10	10	9	10	10	10	10	10
9	10	10	10	10	10	10	10	10	10	10	10
9	9	10	10	10	10	8	9	10	10	10	10
7	8	6	7	8	9	9	9	9	10	9	10

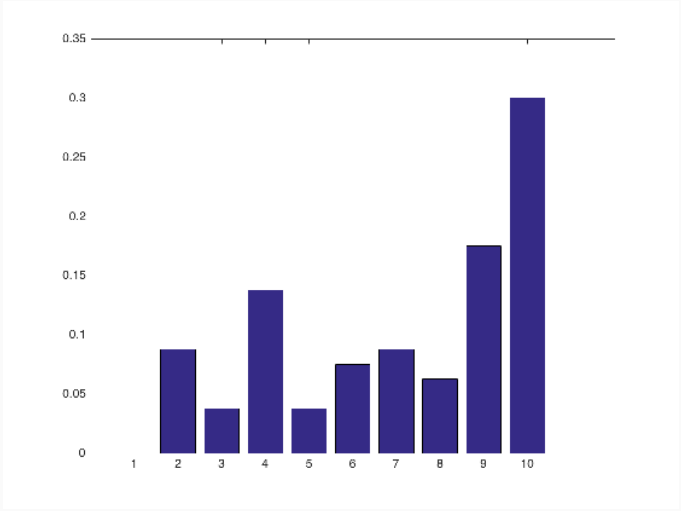


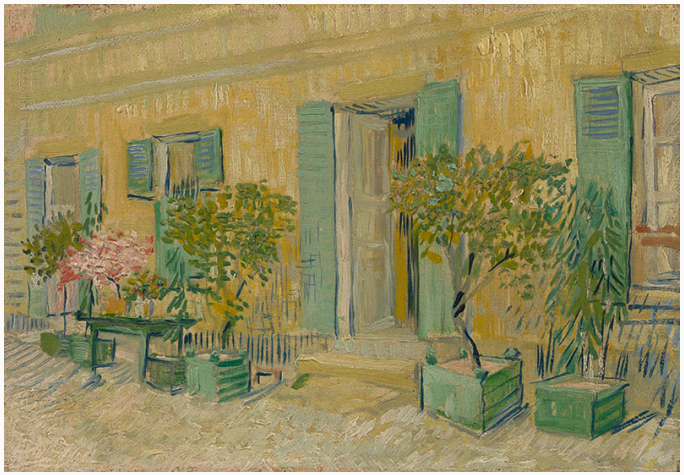
0	0.010416667	0.010416667	0.010416667	0.010416667	0.010416667	0.010416667	0.09375	0.34375	0.5

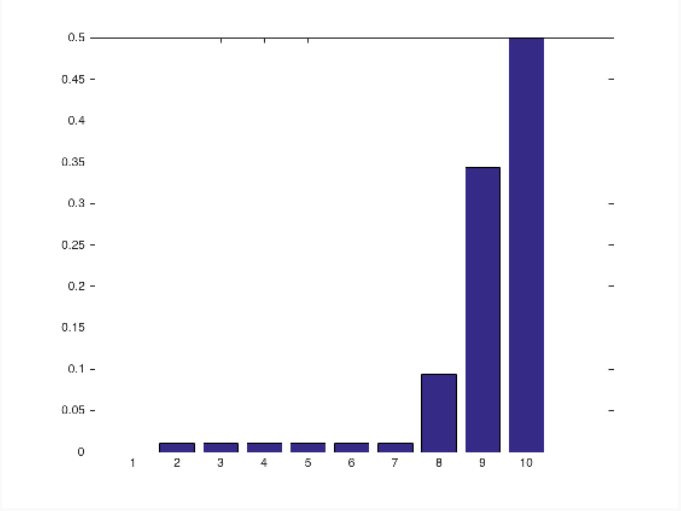


Feature example of van Gogh

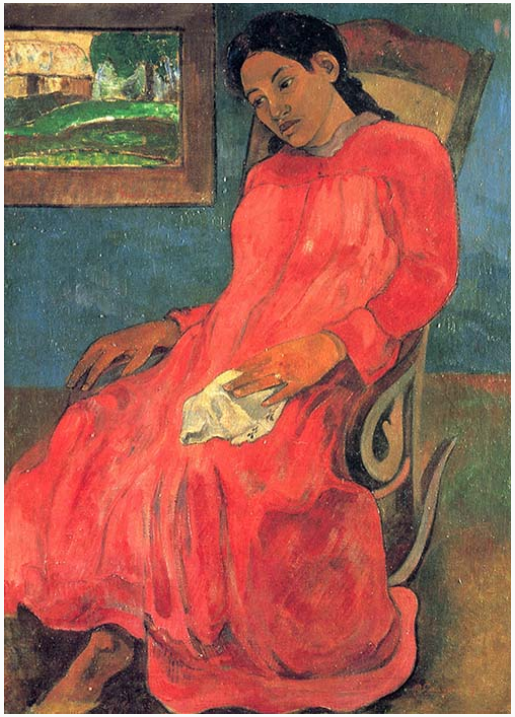


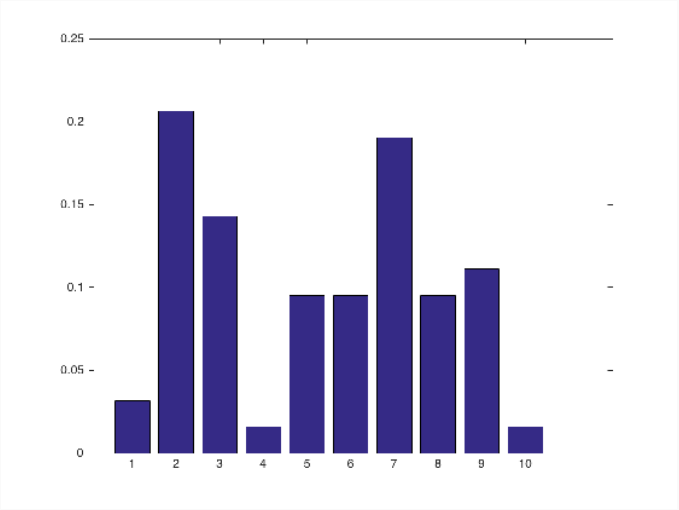


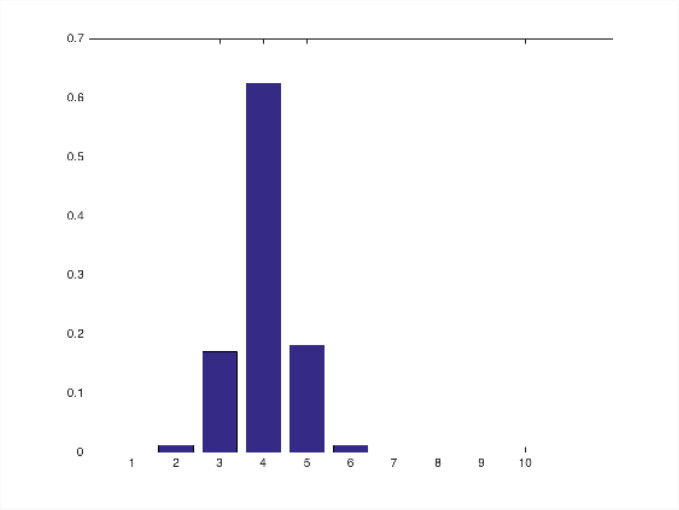




Feature example of Monet and Gauguin

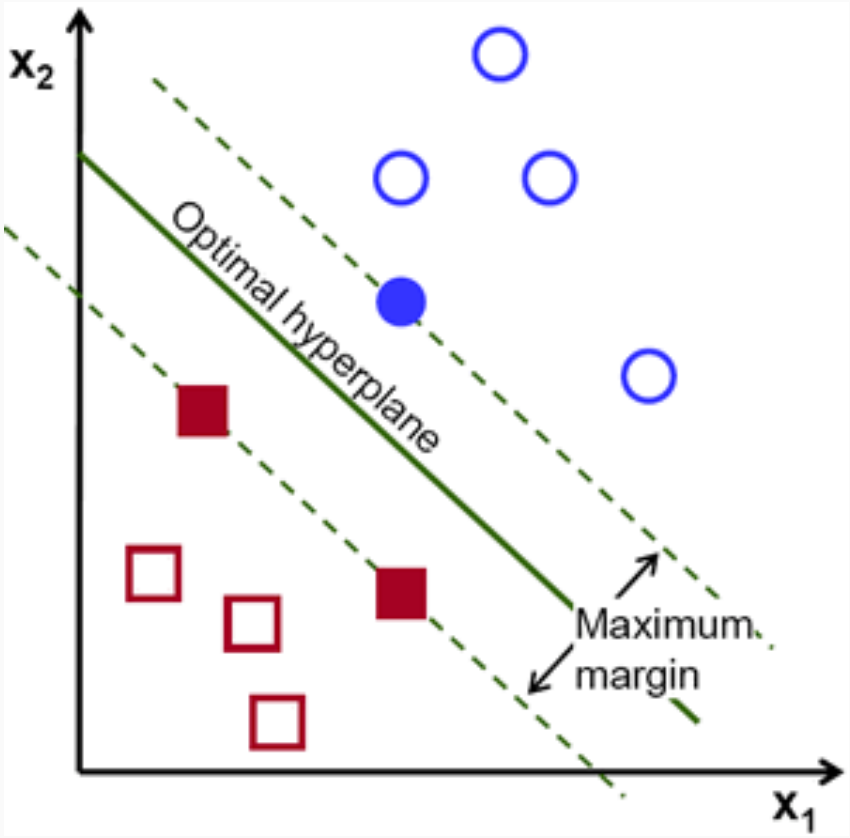






Support vector machine

The SVM algorithm is a discriminative classifier that is formally defined by a separating hyperplane.



Source: `http://docs.opencv.org/2.4/doc/tutorials/ml/introduction_to_svm/introduction_to_svm.html`

Experiments and Results

Datasets and Configuration

Datasets:

- 6 painters: Gauguin, Monet, Rembrandt, Rubens, Toulouse Lautrec and van Gogh
- high-resolution digital images($>$ 3 MP).
- 30 paintings for each painter, half as training data, the rest as test data.

Parameters:

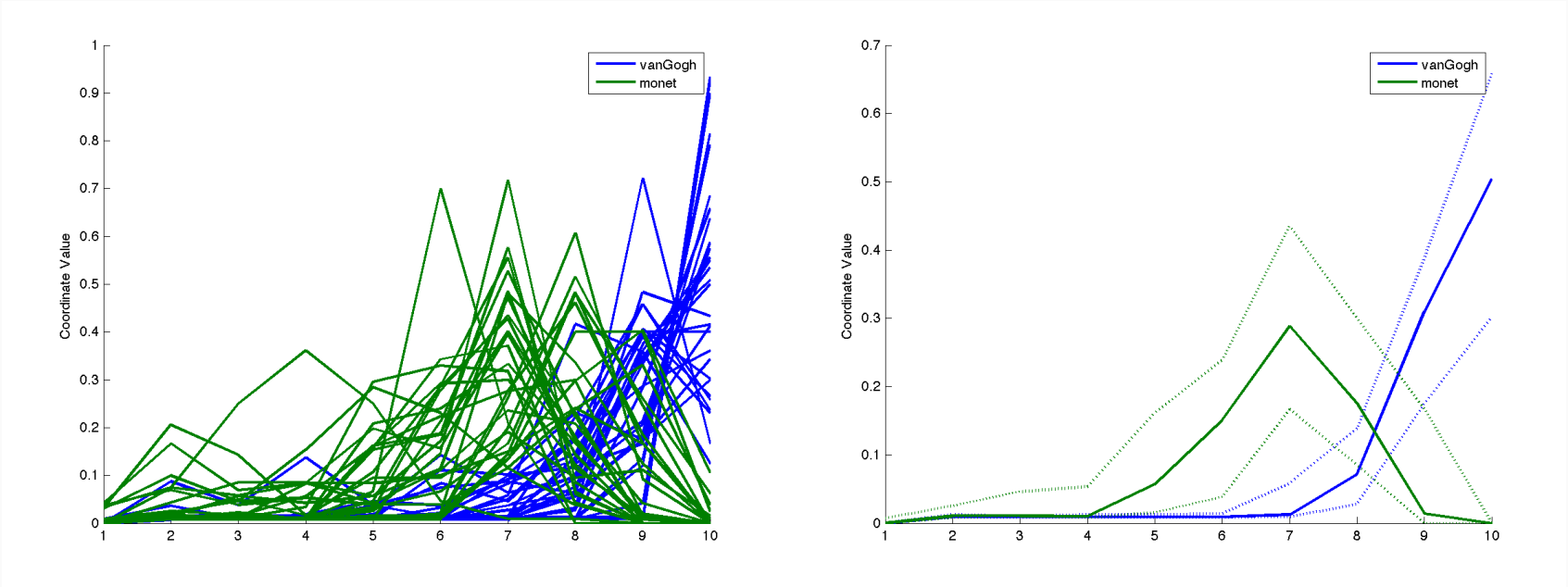
- Patch size: 300px * 300px
- Max Level: 10
- Threshold: 0.6

2-class Experiment Result

Authors	Accuracy
Van Gogh / Monet	96.6667
Van Gogh / Toulouse Lautrec	100
Van Gogh / Gauguin	96.6667
Van Gogh / Rembrandt	100
Van Gogh / Rubens	100
Monet / Toulouse Lautrec	100
Monet / Gauguin	93.3333
Monet / Rembrandt	90
Monet / Rubens	90
Toulouse Lautrec / Gauguin	60
Toulouse Lautrec / Rembrandt	86.6667
Toulouse Lautrec / Rubens	83.3333
Gauguin / Rembrandt	80
Gauguin / Rubens	60
Rembrandt / Rubens	73.3333

Analysis: Parallel Coordinates Plot

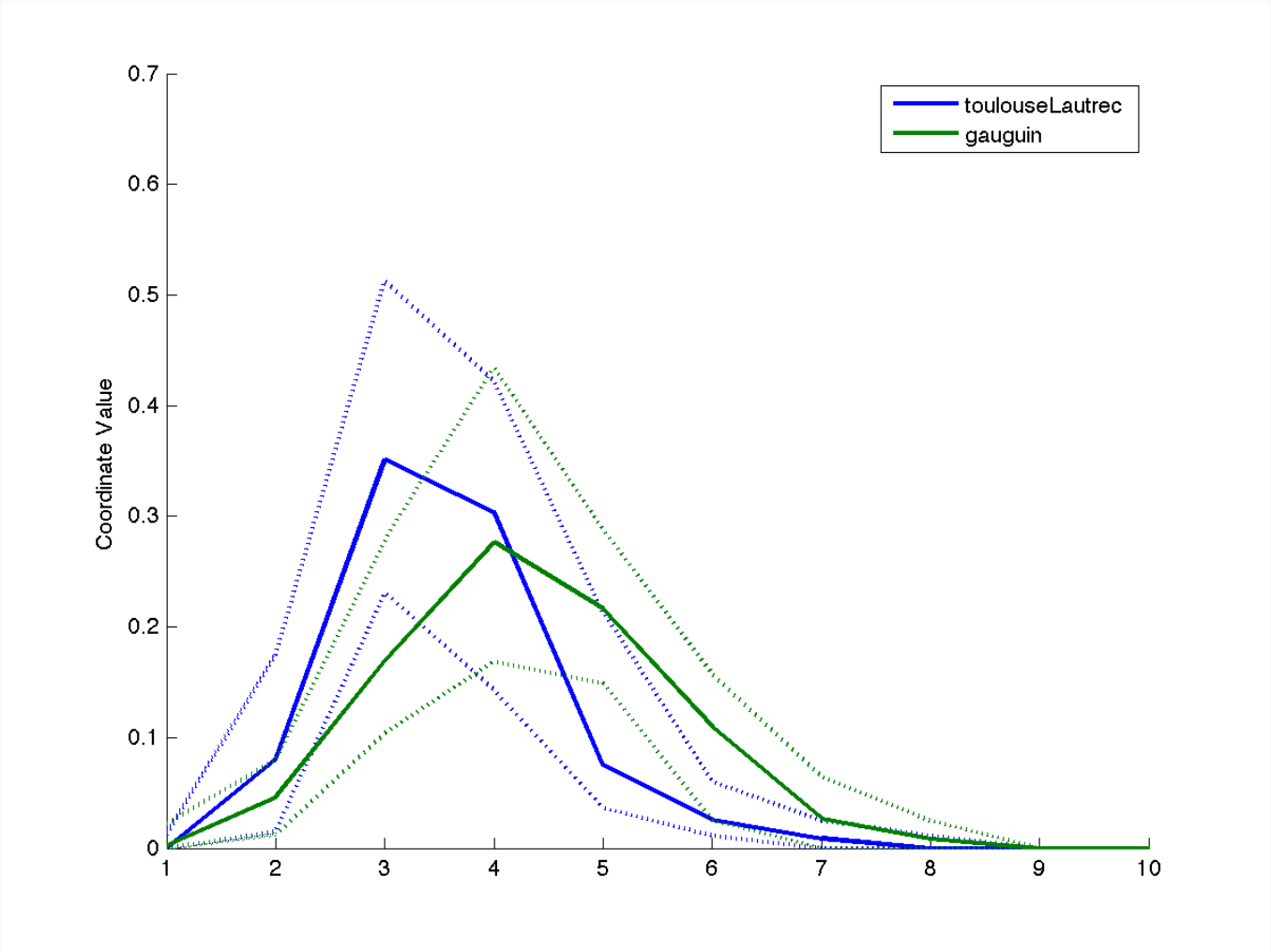
Accuracy: 96.6667



blue: van Gogh; green: Monet

Analysis

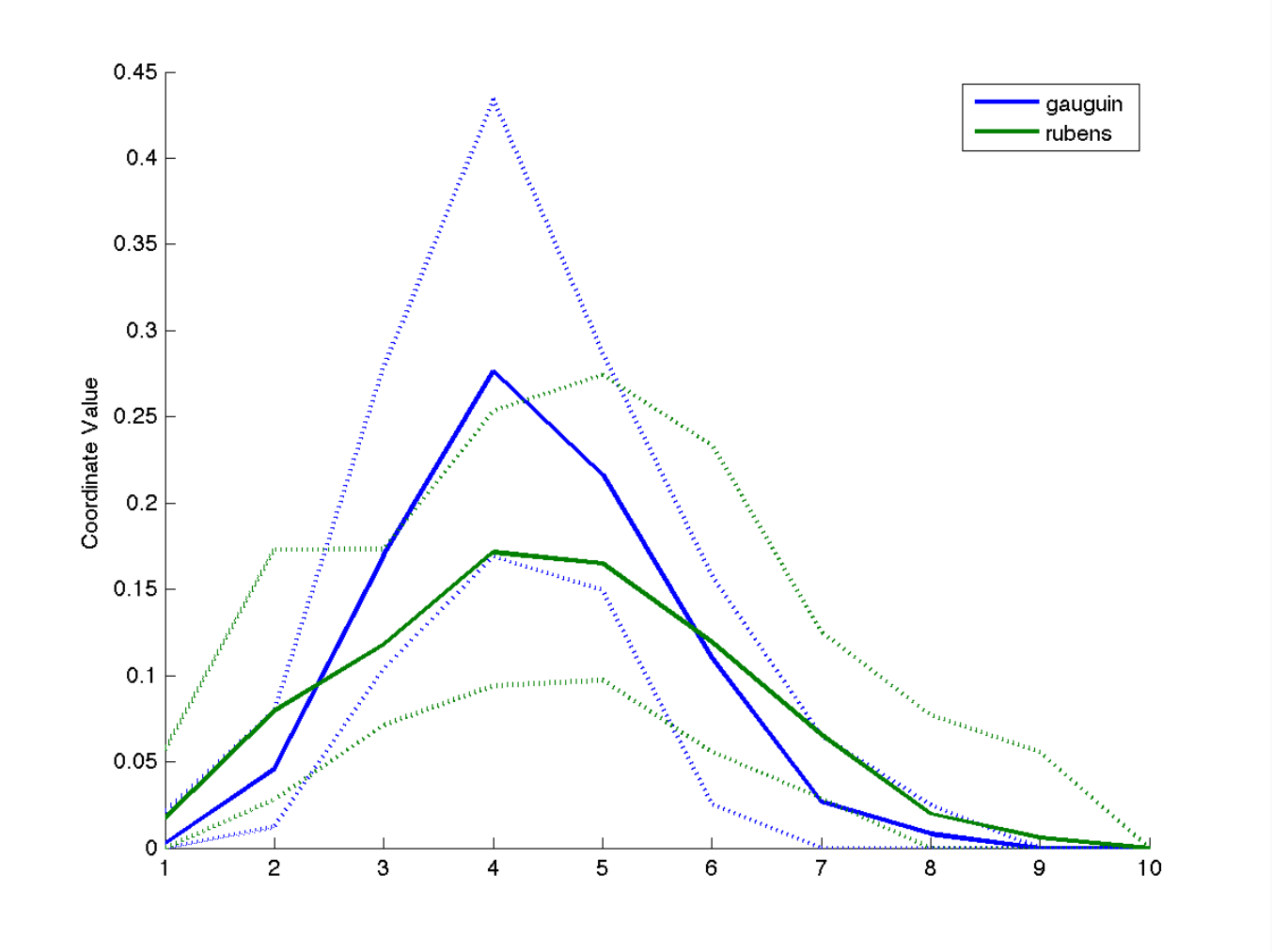
Accuracy: 60



blue: toulouse Laurtrec; green: Gauguin

Analysis

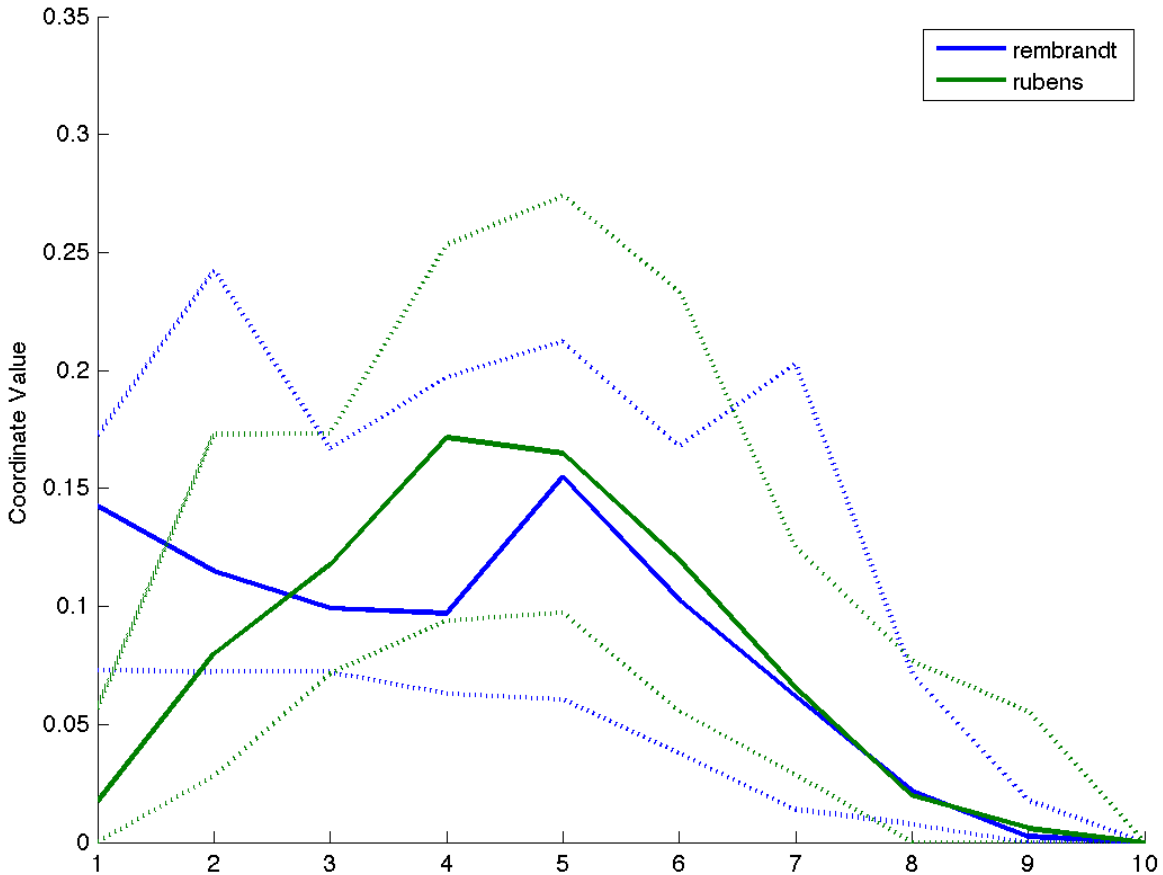
Accuracy: 60



blue: Gauguin; green: Rubens

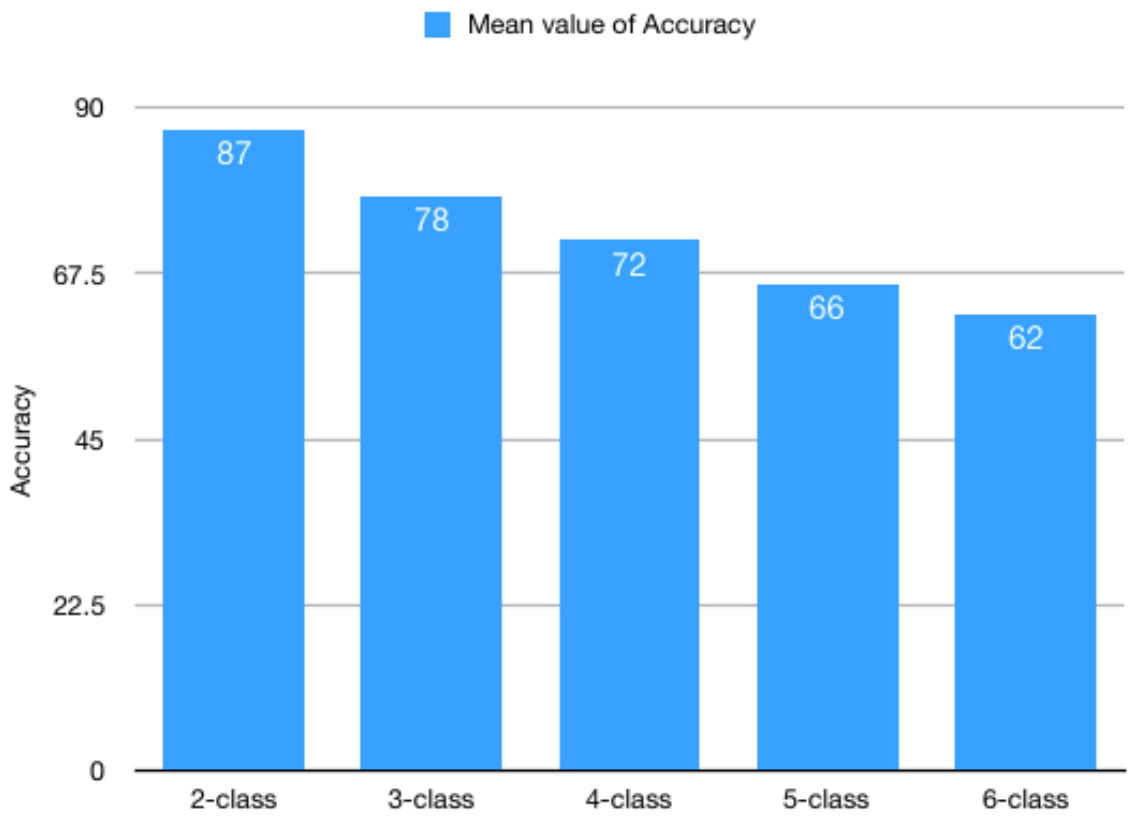
Analysis

Accuracy: 73.3333



blue: Rembrandt; green: Rubens

Multi-class experiments



Discussion and Future work

Discussion

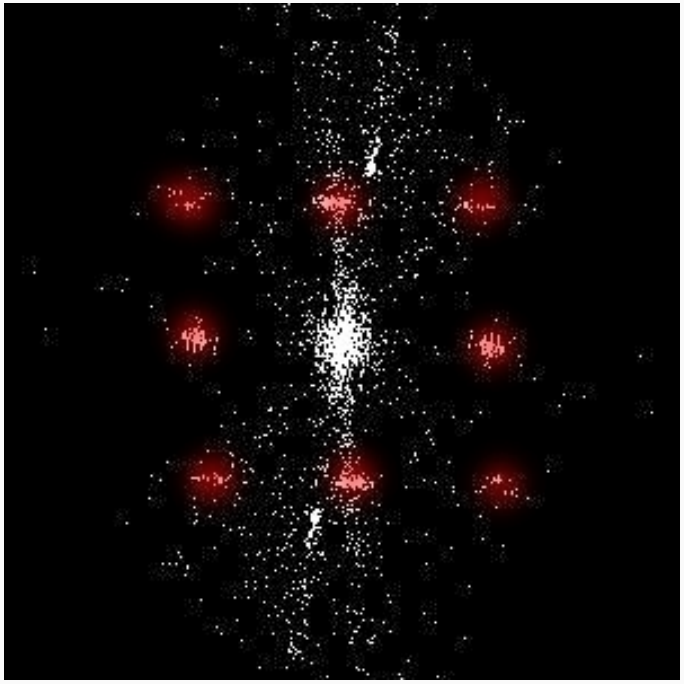
Advantages:

- high classification accuracy, better than methods of color and wavelet transform.
- experiments including different artists, more generic.
- running automatically

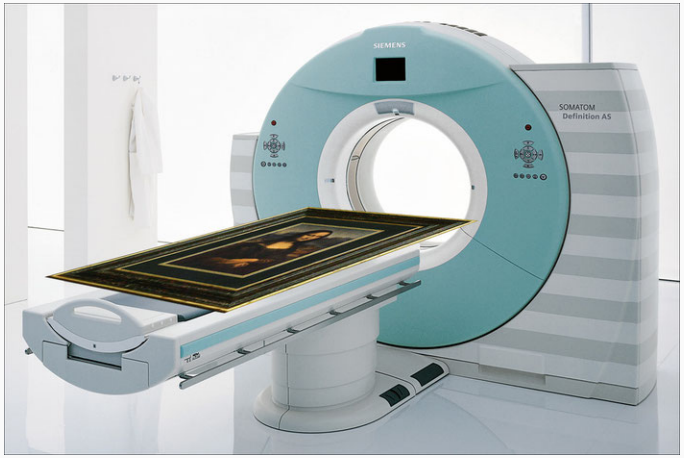
Disadvantages:

- more artists, lower accuracy.
- it could be similar of the brushstroke FT image from different painters.
- Other elements of the texture. (e.g. canvas pattern, digital image input hardware)

Canvas Pattern



Digital Image Input Hardware



Source: `https://www.scantix.com/faq/can-we-scan-a-painting/`

Future Work

- different parameters of features extraction
- combining multiple features (e.g., color)
- different machine learning algorithms (e.g., BoW, KNN)
- larger training set
- higher resolution digital image

Questions?