A Proposed Method for Detecting Fake Art by Using B-Spline Curves

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ABSTRACT

This paper presents proposed method for detecting fake art by using B-Spline curves. In this paper B-Spline curve is used with special technique helps to determine the difference between the excellent copy and the real McCoy image. In the proposed method B-Spline curves are created for the McCoy and the image in question as *digital print* for these images. The number of defined control points, generated curves, and the order of the polynomial segments of the generated B-spline curvesare an important factors which determine the accuracy of detecting fake art.In order to determine if the image in question is McCoy or not the detection process is executed by comparing the function values of generated B-Spline curves of the excellent copy (its digital print) with the function values of generated B-Spline curves of the McCoy (its digital print).

Keywords: Fake art, B-Spline, McCoy, digital print.

طريقة مقترحة لاكتشاف اللوحات الفنية المزورة باستخدام منحنيات الB-Spline

الخلاصة

هذا البحث يقدم طريقة مقترحة لاكتشاف الفن المزور باستخدام منحنيات B-spline. في هذا البحث منحنى B-spline يستخدم مع تقنية خاصة تساعد على تحديد الاختلاف بين النسخة الممتازة والصورة الحقيقية. في الطريقة المقترحة يتم توليد منحنيات B-spline لكل من الصورة الاصلية والنسخة الممتازة التي تحت الفحص كبصمة رقمية لهتين الصورتين. عدد نقاط السيطرة المعرفة، المنحنيات المولدة، وترتيب قطع متعددة الحدود لمنحنياتB-spline المولدة هي عوامل مهمة تحدد الدقة في اكتشاف الفن المزور. ولتحديد فيما اذا كانت الصورة قيد الفحص هي اصلية او لا. عملية الاكتشاف تنفذ عن طريق المقارنة بين قيم الدالة للمنحنيات المولدة للنسخة الممتازة (بصمتها الرقمية) مع قيم الدالة للمنحنيات المولدة للصورة الاصلية (بصمتها الرقمية).

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INTRODUCTION

In fake art scam artists will print a photograph on a canvas or paper. They apply paints or graphite (in the case of a graphite drawing) to the image. This is done to create textures, to make each image look and feel like a real painting or drawing (as well as to conceal the dots). Nowadays, large-format inkjet printers can be bought at a reasonable price, enabling scam artists to easily produce large prints, such as 18 x 24 inches.

Determining what is real and what is fake has long been a problem for art curators. It is estimated that 20 percent of the worldwide art market is made up of forgeries. With the advancement in technology, detecting fake art has become possible to a large extent. Non-destructive techniques that use microscope, radiography and chemical analysis and dating techniques are used to detect an artwork.Even a ten thousand year old art work can be detected for fake art using what is known as the radio carbon dating to measure the age of the painting. Infrared and x-ray photography can detect signatures that cannot be seen by the naked eye. X-ray diffraction is also used to analyze components that make up the artist’s paints. X-ray fluorescence can reveal the artist’s finger prints and the metals present in a sculpture or in the composition of the paints that are used in the painting or the sculpture.

Another technique known as digital authentication: This technique breaks down a picture into collection of more basic images called as sub-bands. These are analyzed to determine the texture by assigning a frequency to each sub-band.

In the world of art, the authenticity of a work can make millions of dollars worth of difference. Although it's possible to detect recent frauds based on objective measures like chemicals in the paints, it often requires subjective judgments to determine the difference between the work of a true master having an off week and the product of one of that master's students.

A few researches talk about methods for detecting fake art by using mathematics. Dartmouth College mathematics department Chairman Daniel Rockmore and others developed a technique helps to determine the difference between excellent copy and the real McCoy [1]. They describe a computational technique for authenticating works of art, specifically paintings and drawings, from high-resolution digital scans of the original works. This approach builds a statistical model of an artist from the scans of a set of authenticated works against which new works then are compared. The statistical model consists of first- and higher-order wavelet statistics.

The study of artwork through math and statistics is known as "stylometry," and is a relatively recent development—similar methods have been used to analyze literature for much longer. There is an article written by Casey Johnston [2]. Johnston talk about new research will appear in PNAS, the new paper uses a technique called sparse coding, in which analysts break down works of art into tiny patches and represent them as a series mathematical functions. By comparing the functions produced with authentic artwork to those from possible imitators, they can produce an objective measure of whether the piece in question is real or fake.

In the suggested method high-resolution digital scans of the original works must be stored or archived. B-Spline curves correspond to that stored digital image must be created and archived as *digital print*to be used in the comparing process with the generated B-Spline curves (*digital print)* of excellent copy (imitator).

B-Spline curve

A B-spline curve P(t) is defined by [3,4,5,6]:

$$P(t) = \sum_{i=0}^{n} P_i N_{i,k}(t) \qquad \ldots (1)$$

Where $\{P_i$: i=0,1,2,…., n) are the control points (*de Boor points*),
K is the order of the polynomial segments of the B-spline curve. Order *k* means that the curve is made up of piecewise polynomial segments of degree *k-1*.

The $N_{i,k}(t)$ are the "normalize B-spline blending functions". They are described by the order *k* and by a non-decreasing real-valued numbers $\{t_i$: $i=0\ldots n+k\}$. Normally called the "knot sequence". The $N_{i,k}$functions are described as follows:

$$N_{i,k}(t)= \begin{cases} 1 \text{ if } u \quad [t_i, t_{i+1}) \\ 0 \text{ Otherwise.} \end{cases} \qquad \ldots. (2)$$

And if $k>1$,

$$N_{i,k}(t)= \frac{t-t_i}{t_{i+k-1}-t_i} N_{i,k-1}(t)+\frac{t_{i+k}-t}{t_{i+k}-t_{i+1}}N_{i+1,k-1}(t) \qquad \ldots.. (3)$$

And $t \quad [t_{k-1},t_{n+1})$.

Suppose that a *degree n* and a knot sequence (in which no knot has multiplicity greater than *n+1*) are chosen. The design of the B-spline curve is complete by choosing a sequence of control points, which are called *de Boor points* or *B-spline control points*. Each de Boor point is labeled by a block of adjacent knots from the knot sequence, and successive de Boor points are labeled by blocks that are shifted by one step with respect to each other. There are important cases of choosing the knots to draw the spline:

a) The affine case: suppose n=1, and the knot sequence {…, 1, 2, 4, 5, 5, 6, 8,} is chosen. Since n=1, each de Boor point will be labeled by single knot, whit adjacent de Boor points labeled by adjacent knots. So among the control points of spline f the points p_1,p_2, p_4,p_5, p_5,p_6, and p_8. Note that there are two de Boor points labeled p_5, since 5 is a double knot.

The resulting affine spline f is quite straightforward. Over the time interval [1...2], the spline *f* moves from p_1 to p_2 at a constant rate of speed. Over time interval [2...4], it moves from p_2 to p_4. Over [4...5], it moves from p_4 to the first of the two points labeled p_5. Over [5..6], it moves from the second point labeled p_5 to the point labeled p_6. And so on.

b) The quadratic case: suppose n=2, and the knot sequence {.., 0, 1, 2, 3, 5, 6, 7, 7, 8, 9, 9, 9...} is chosen. Since n=2, each de Boor point is now labeled by a pair of adjacent knots. So reasonable names for the de Boor points are:

P_{01}, P_{12}, P_{23}, P_{35}, P_{56}, P_{67}, P_{77}, P_{78}, P_{89}, P_{99}, and P_{99}.

c) The cubic case: in this case n=4 and knot sequence will be {1,2,3,4,5,6,7}.

THE PROPOSED METHOD FOR DETECTING FAKE ART

In the suggested method B-spline is used to determine whether the image in question is fake or real.B-spline curves are created for the real image as print to that image.*P(t)* is computed for the image by using its pixels values as control pints for the generated curves (i.e. each generated B-spline curves has different control points from the other corresponding to the pixels values of the image). The B-spline curves are drawn as straight horizontal lines in new digital image or over the image in question and those created lines are drawn corresponding to the image details.

The shape of B-spline curves can be controlled by the control points and knots which are related to those curves. The control points in the suggested method are chosen carefully in a way to force the curve to take the line shape (i.e. B-spline curves pass through all control points which are arranged in a straight line). The straight horizontal lines are optional choice but there is wisdom behind it and it will explain in the next sections. Also uniform B-spline curves can be created with predefined control points and knots values.

In this paper B-spline curves are created as straight lines from defining control points which are arranged in lines. The first B-spline curve is generated by choosing number of neighbor control points distributed to cover most detail of one line of the image (i.e. all control points in one line have same raw co-ordinates but different column). The next B-spline curve is generated by re-arranging the previous control points co-ordinates to take different raw, and so on for all other B-spline curves. the knot values which are defined for the first curve and all other B-spline curves can take the same values. More details are explained in the next sections.

B-spline curve generation

In the proposed method very large number of B-spline curves can be generated to fit the real image size and describe all image details. The first aim of creating those curves is to determine the *P(t)*values *(t means time)*for each curve in the digital image which is created for the real image (McCoy). Each generated B-spline curve has its own values of control points which represent the pixels values of the image (i.e. each generated curve has its own *P(t)* values depending on pixels values of the image) .The blending function values multiplied with the corresponding control points plays an important role in determining the shape of B-spline curves and as result *P(t)* values. In the suggested method each generated B-spline curve is forced to cross all defined related control points which are located at the same horizontal line. Fig1 illustrates this idea. The second aim of generating B-spline curves is for giving the real image a *print* which describes the image detailsas unique *p(t)* values. The horizontal uniform lines help the detection process to be flexible such that any difference between the origin and the excellent copy can be seen by the naked eye on the print of the image in question (where the print of generated B-spline curves must be created for that image in question).

The horizontal style of the B-spline curves makes the detecting process of image in question easy. More control points, more generated B-spline curves means more accuracy in detecting fake.Each curve can be drawn with it's a predefined control points and knots to give the McCoy image more complex *digital print*. EachB-spline curve is generated with different values of control points –and same knots- in different coordination. The spaces between the generated curves are defined by the user. The number of control points with their coordinates is also defined by the user. Each control point takes its values corresponding to the pixel values of the same defined coordinates of the control point.

FAKE ART DETECTION PROCESS

As explained in the previous sections McCoy (real image) must be scanned with high resolution and then should be archived for using it in generation process of digital print and then compare it with any excellent copy in question. That print is digital image of generating B-spline curves of horizontal lines style but with keeping of*P(t), polynomial order k, control points, and knots* values corresponding to each pixel in the real image.

To test the image if it is real image (McCoy), the print of that image must be created in the same way of creation the print of McCoy. This print represents digital image of generated B-Spline curves. The number of generated B-Spline curves is determined according to the size of excellent copy (image in question). The shifting distance between generated curves is determined by user, minimum distance between each line of control points means more accuracy to detect any fraudulence in any part of the image in question.

The number of control points and their coordinates with polynomial order *k* must be determined by the user. And then the B-spline curves will generated automatically by the algorithm using some defined values and functions.

THE SUGGESTED ALGORITHM

INPUT: High-resolution digital scans of the original works must be stored or archived.High-resolution digital scan to the excellent copy (the image in question) must be taken.

Number of control points of B-spline curves *n*.

Coordinates of control points of the first B-spline curve must be read. The other control points of other B-spline curves can be generated automatically depending on the first curve with different coordinates and pixel values. Note that the control points coordinates of the first B-spline curve should be chosen carefully to cover most details of the image along one line.

Order of the polynomial segments of the B-spline curves K

Shifting distance between each neighbors group (line) of control points. Shifting distance must be uniform between each generated B-spline curve to give high accuracy in detection process.

Knots sequence for all groups. This values should be given depending on *k*and *n*value. Where *the number of knots= n+k*

OUTPUT: Digital print of generated B-spline curves for the imagein question and digital print of generated B-spline curves for the McCoy. The differences with red color which covers parts of the image in question. These differences can be seen by the naked eye (if there is exist). And output text message shows the image in question is fake or McCoy.

Step 1: B-spline curves must be generated for the excellent copy to make *digitalprint* of B-spline curves for it. The *digital print* of McCoy can be generated and stored previously.

Step 1.1: Generate the control points of the first curve from the given coordinates values for the image in question.

Step 1.2: Generate the knots values depending on the order which is given as input. Such that number of *knots=n+k*

Step 1.3: Set variable B=1, // B as counter to the number of B-spline curves want to be generated.

Step 1.4: While the number of generated B-spline curves B<=m, // m is the number of B-spline curves want to be generated.

For each B-spline curve want to be generated do the following

Step 1.4.1: While t [0,1] do the following steps

Step 1.4.1.1: Compute p(t) for all values of control points p_i related to B-spline want to be generated, $P(t)=\sum P_i N_{i,k}(t)$, To be continued..
Step 1.4.1.2: Compute the normalize B-spline blending functions for a given *t* value according to thedefined conditions given in functions 2 and 3.
Step 1.4.1.3: Draw the B-spline pixel[x,y] corresponding to the *t* as *x* and *p(t)* as *y*.
Step 1.4.1.4: Store each p(t) value as element of array corresponding to the serial number of B-spline curve want to be generated, such that each curve has p(t) values of interval [0,1].
At the same time of storing check the differences between the image in question and the print of McCoy by do the following:

Each computed value of p(t) corresponding to one curve must be compare with the corresponding stored p(t) value of curve (curve with the same serial number) of the McCoy. If the value of p(t)(of image in question) does not equal the corresponding value p(t) of the same curve of McCoy then set flag to (1) to register the first difference and draw the pixel with coordinate (t,p(t)) as one different point of generated B-spline curve over the image in question. If the two values are equal then set the flag to different value (0) and draw the pixel (t, p(t)) with different color. For each generated B-spline curve there is an array of flags. Flag1[1][t]=flag2[1][t] means the flag1of the first generated B-spline curve [1] equals the flag2 of that B-spline curve [1] for the same value of *t* in McCoy print.
Step 1.4.2: Check the value of t, if t =1 then goto step 1.4 else modify t value by adding small shift value to it and goto step1.4.1 to read the next value oft.
Step 1.4: Check the number of generated curves. if all curves is generated then go to 1.5 otherwise goto step 1.4 to generated the next curve.
Step 2: Save the print (B-spline curves) of the tested image and compare it with the print of McCoy to see the difference between each other, if there is a difference then it can be seen clearly by the naked eye, if there is not then the image in question is a McCoy. The comparison is executed as follows:
Step 3: End.

ALGORITHM IMPLEMENTATION

The algorithm is implemented by using Delphi.7 programming language. The algorithm is executed by comparing *p(t)* values of each generated B-spline curve of image in question with corresponding *p(t)* values of the B-spline of McCoy. The output of the algorithm is digital print of McCoy and digital print of excellent copy of that McCoy or may be the McCoy itself. If there is difference between two images then the user can see that differenceclearlyby the naked eye. Some images are drawn with many details which makes the comparison by the naked eye is very difficult to see the differences. In the suggested method B-spline curves are generated with comparison with McCoy over the image in question to see the differences in details between each other with different color.

EXPERIMENTAL RESULTS

The suggested algorithm is applied on many examples of images, some of them are chosen. Appendix A shows the samples and the results. According to the results very small differences are detected clearly by B-spline curves.

CONCLUSIONS AND FUTURE WORK

Depending on the results mathematics is considered very effective way to detect the fake art. B-spline curve is very sensitive in drawing the image details by its control points and knots. In the proposed method the generated B-spline curves of corresponding image are forced to be as horizontal lines and this represents the optimal case in which the B-spline curve passes through all control points. To make the created digital print of the image more complex the *cubic B-spline* can be used for that purpose. Changing the shape of the curve by changing the control points and knots sequence is play an important role in creation of the image print, that is more complex information about the McCoy or any document can be stored for that image or document. More complex information about the image more security and obtain the integrity for that image.

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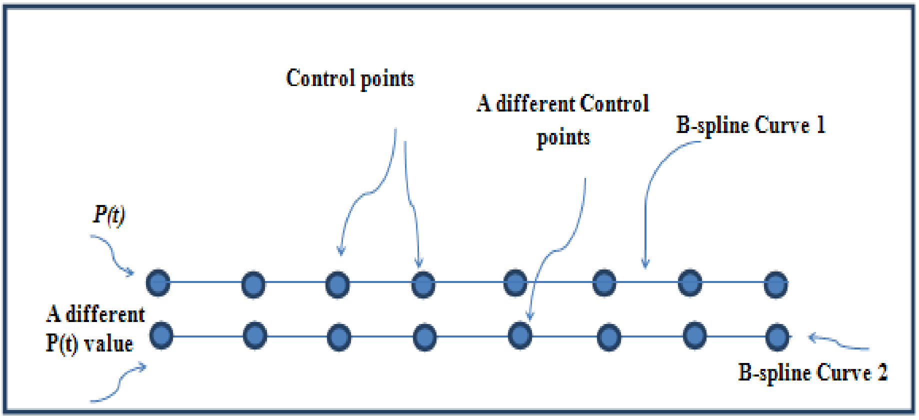

Figure (1) B-Spline curve cross all related control points.

Figure (2): On the left, the fraud image, the image in question. On the right, the McCoy image. *Abstraction, White Rose II*, 1927 by Georgia O'Keeffe [8]. The result of test is on the next page...

Figure (3): On the left the image in question with the B-spline curves as print for that image. The difference between the image on the left and the McCoy on the right is seen by the naked eye with redparts of B-spline Curves, the yellow parts means no difference on that area for both images. The number of control points=6, polynomial order k=1, the knots sequence= {1, 1, 2, 2, 3, 4, 5, 6}. Number of generated B-spline curves=200. The distance between each generated B-spline curve=3.

The (x,y) coordinates of the first line of control points which are chosen for the image in question are:

Cp_1=(10,21), cp_2=(10,28),cp_3=(10,272), cp_4=(10,413), cp_5=(10,434), cp_6=(10,435),

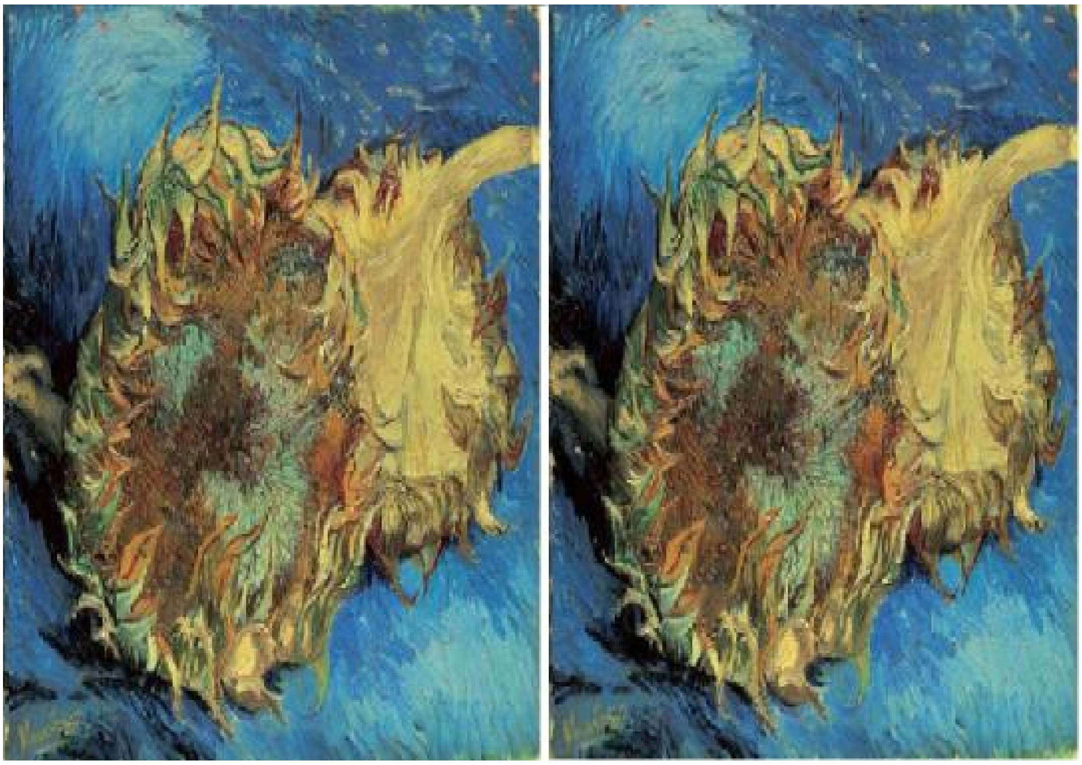

Figure (4): On the left, the fraud image (the image in question). On the right, the McCoy image byVincent van Gogh, *Sunflowers*, 1887 [8]. The result of the test is in the next page…

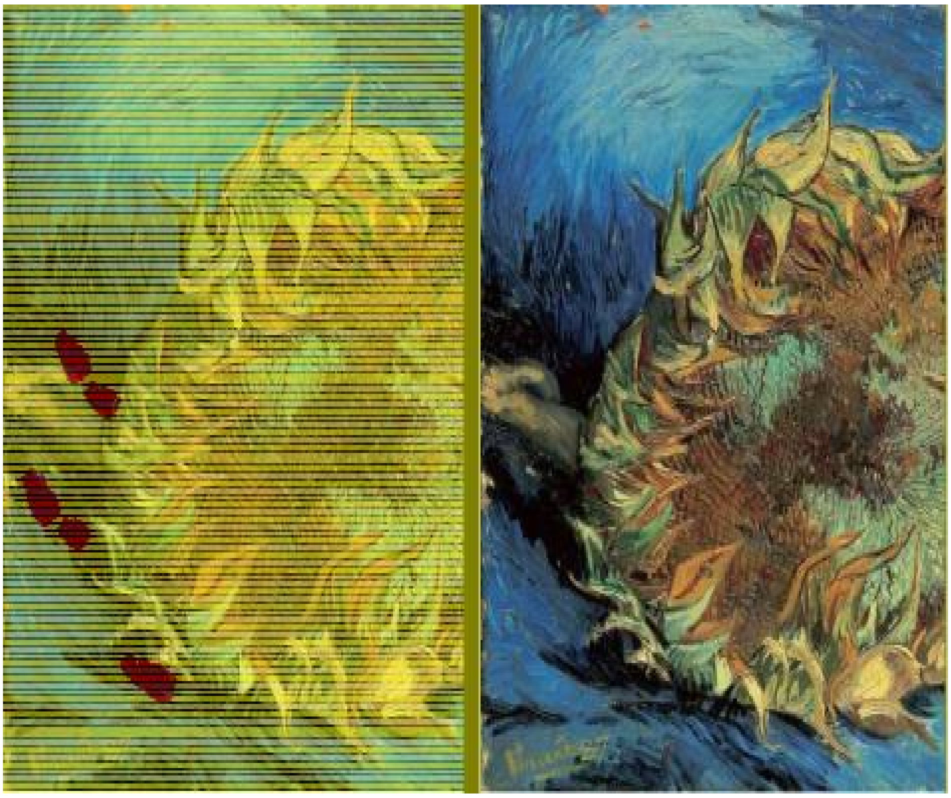

Figure (5): Here the algorithm is executed on a part of the image in fig.4 (optional case).On the left the image in question with the B-spline curves as print for that image. The difference between the image on the left and the McCoy on the right is seen by the naked eye with red parts of B-spline Curves. The number of control points=6, polynomial order k=1, the knots sequence= {1, 1, 2, 2, 3, 4, 6}. Number of generated B-spline curves=200. The distance between each generated B-spline curve=3.
The (x,y) coordinates of the first line of control points which are chosen for the image in question are:
Cp_1=(57,61), cp_2=(57,92), cp_3=(57,141), cp_4=(57,206), cp_5=(57,668), cp_6=(57,675).

Figure (6): On the left, the image in question. On the right, the McCoy image. Caspar David Friedrich, *Wanderer above the Sea of, Fog*, *c*.1818 [8]. The result of the test is in the next page...

Figure (7): On the left the image in question with the B-spline curves as print for that image. The difference between the image on the left and the McCoy on the right is seen by the naked eye with red parts of B-spline Curves. Number of control points=5, polynomial order k=1, the knots sequence= {1, 2, 3, 4, 4, 5}. Number of generated B-spline curves=200. The distance between each generated B-spline curve=3.

The coordinates of the first line of control points (cp) are chosen as following:

Cp_1=(73,43), cp_2=(73,137),cp_3=(73,270), cp_4=(73,389), cp_5=(73,434).

Figure (8): Cat image [7].on the left, the fraud (the image in question). On the right the McCoy image.
The result is in the next page…

Figure (9): Cat image [7].On the left the image in question with the B-spline curves as print for that image. The difference between the image on the left and the McCoy on the right is seen by the naked eye with red parts of B-spline Curves. Yellow color in an area means no difference in that area. Number of control points=10, polynomial order k=1, the knots sequence= {1, 2, 3, 3, 4, 5, 6, 7, 8, 9, 10}. Number of generated B-spline curves=200. The distance between each generated B-spline curve=3.

The coordinates of the first line of control points (cp) are chosen as following:

Cp_1=(10,12), cp_2=(10,30), cp_3=(10,54), cp_4=(10,166), cp_5=(10,170), cp_6=(10,189), cp_7=(10,190), cp_8=(10,198), cp_9=(10,200), cp_{10}=(10,271).

Note: the same result is given when the polynomial order k=2, number of control points=5, and the first line of control points : cp_1:=(20,31), cp_2=(20,71), cp_3=(20,163), cp_4=(20,203), cp_5=(20,240). Knots sequence={1,1,2,2,3,3,4}. With the same number of generated B-spline curves and same shift distance.

Figure (10): On the left, the fraud image. On the right the McCoy image. The Tungus (Evenki),(St. Petersburg, n.p., 1774), plate ''Tungus Hunter.'[9]. The result is in the next page…

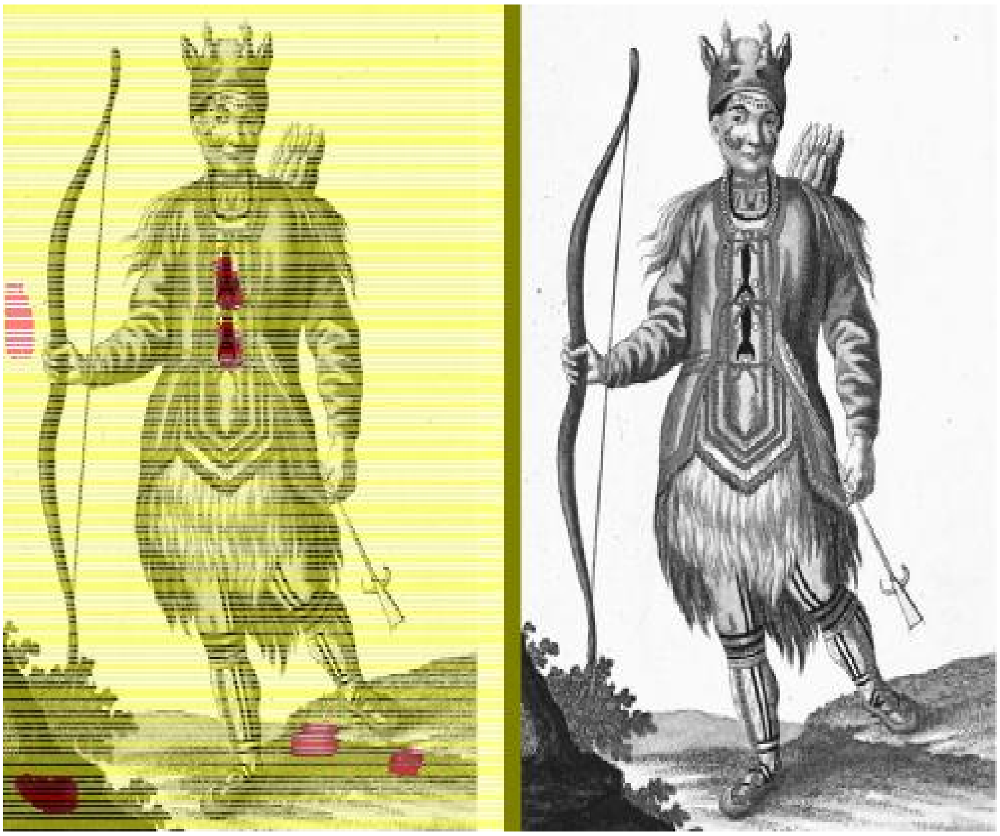

Figure (11): On the left the image in question with the B-spline curves as print for that image. The difference between the image on the left and the McCoy on the right is seen by the naked eye with red parts of B-spline Curves. Number of control points=6, polynomial order`k=1, the knots sequence= {1, 2, 3, 4, 5, 6, 6}. Number of generated B-spline curves=200. The distance between each generated B-spline curve=3.
The coordinates of the first line of control points (cp) are chosen as following:
Cp_1:=(50,30), cp_2=(50,40), cp_3=(50,136), cp_4=(50,199), cp_5=(50,277), cp_6=(50,357).