A Security System Using Curve Fitting

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ABSTRACT

Recently, information hiding has become the main focus of the researchers in the last two decades because of its benefits in document security and image protection versus copyright. In fact, this research paper proposed a modified authentication method based on the curve fitting technique with curves hiding in the images in the way that is sturdy for printing and scanning. Apparently, the introduced method proceeds by inserting a secure imprint designed by curves interpolated using cubic spline interpolation technique within the printed imagpe. Mainly, by using the proposed modified methods, several secures imprints can be embedded into images with a perfect recovery against the print-scan operation. In conclusion, the proposed models have been tested by producing samples with some image samples; the samples were printed on the traditional papers using traditional inks and printers.

INTRODUCTION

Recently, the printed documents are broadly employed in formal documents verification, i.e., communicating sensitive military information, driving licenses, nation ID, Diploma, and official papers of court of law. Along several applications, taking actions should be carried out after verify the image authenticity because the outcomes may be crucial and harmful. However, this paper proposed a modified authentication method based on the curve fitting technique with curves hiding in an image in a way that is hardy for printing and scanning. [1]. In fact, the conventional methods for verifying and identification the integrity of document will be based on some principles such as specialty Kaule and Stenzel [2], security paper, inks customization, [3] special optical, [4] and the reproduction procedures of printing[5]. Fundamentally, these methods afford immunity or reproduction, and their protection comes from the fact the not all the users can have the special materials and high precision reproduction devices and procedures. Basically, some of these methods [6] have also been extended for printed text authentication; this is can be achieved by using a barcode within the printed that represent cipher of the text. Obviously, the image content authentication and verification along printed document received as an interested area for research [7]. Recently, in [8] the image content was formed while retaining the print substrate and further highlights the need for such authentication.

In this research paper, a new method has been manifested for hiding information in images using cubic spline curve fitting technique in a way that is strong to printing and scanning with possible using the traditional papers, inkjet, and laser printers. The achievement is depending on the designed process, [1] basically, the modified technique changes the curve shape without changing the control points which is based on the guide points [1].

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Background

Cubic Spline

The interpolation spline considered as a single curve which is represented by a set of parts which is continuous functions $R_i(x)$ for $i = 1, \dots, n-1$ which is the achievement of the interpolation over the points (x_i, y_i) for i = 0, 1, . . . ,n. [1],[9], [10].

The following equation demonstrates the cubic spline [1].

$$R_i(X) = A_i(X - x_i)^3 + B_i(X - x_i)^2 + C_i(X - x_i) + E_i \quad \text{....(1)}$$

Where $R_i(x)$ is the spline function. A_i, B_i, C_i and E_i are variables, and R(x) is the interpolating function, x is the x-axis coordinate and y is the y-axis coordinate.

The cubic spline characteristics illustrated as below [1], [9]:

1. The spline is continuous in $x_0 \le x \le x_n$, or $R_1(x_0) = y_0$ and $R_i(x_i) = y_i$ for $i = 1, 2, \dots, n$.
2. $R_i(x_{i+1}) = R_{i+1}(x_{i+1})$ for $i = 1, 2 \dots N-1$.
3. $R_i'(x_{i+1}) = R_{i+1}'(x_{i+1})$ for $i = 1, 2 \dots N-1$.
4. $R_i''(x_{i+1}) = R_{i+1}''(x_{i+1})$.
5. $R(x_0) = R(x_n)$.

Since the piecewise function *R(x)* interpolates all of the data points, it can be conclude that

$$y_i = R_i(x_i) = E_i \text{ for each } i = 1, 2, .., n \quad \text{....(4)}$$

$$R_i'(x_i) = c_i \quad \text{.... (3)}$$

The above equations can be replaced $R_i''(x_i)$ by D_i, this replacement made determining the weights for A_i, B_i, C_i and E_i as sample task. In fact, the B_i has been demonstrated by [1], [9], [10].

$$R_i''(x_i) = 2B_i, D_i = 2B_i,$$

$$B_i = \frac{D_i}{2}, \quad \text{....(5)}$$

$$A_i = \frac{D_{i+1} - D_i}{6h_i}, \quad \text{....... (6)}$$

$$C_i = \left(\frac{y_{i+1} - y_i}{h_i}\right) - \left(\frac{D_{i+1} + 2D_i}{6}\right) h_i \quad \text{....... (7)}$$

These systems can be handled more conveniently by putting them as follows [1], [9].

$$C_{i+1} = 3A_i h_i^2 + 2B_i h_i + C_i .$$

Where $h_{i+1} = x_{i+1} - x_i$.

$$(D_i + 4D_{i+1} + D_{i+2}) = 6\left(\frac{y_i - 2y_{i+1} + y_{i+2}}{h_i^2}\right) \quad \text{....... (8)}$$

For $i = 1, 2, 3, \dots, n-1$.

This leads to the matrix equation

$$\begin{bmatrix} 1 & 4 & 1 & 0 & & 0 & 0 & 0 & 0 \\ 0 & 1 & 4 & 1 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 4 & & 0 & 0 & 0 & 0 \\ & & \vdots & & \ddots & & \vdots & & \\ 0 & 0 & 0 & 0 & & 1 & 4 & 1 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 0 & 1 & 4 & 1 \\ 0 & 0 & 0 & 0 & & 0 & 0 & 1 & 4 \end{bmatrix} . \begin{bmatrix} D_1 \\ D_2 \\ D_3 \\ D_4 \\ \vdots \\ D_{n-3} \\ D_{n-2} \\ D_{n-1} \\ D_n \end{bmatrix} = \frac{6}{h_i^2} . \begin{bmatrix} y_1 - 2y_2 + y_3 \\ y_2 - 2y_3 + y_4 \\ y_3 - 2y_4 + y_5 \\ \square \\ \vdots \\ \square \\ y_{n-4} - 2y_{n-3} + y_{n-2} \\ y_{n-3} - 2y_{n-2} + y_{n-1} \\ y_{n-2} - 2y_{n-1} + y_n \end{bmatrix} \quad \ldots(9)$$

Note that this system has n-2 rows and n columns, and is therefore underdetermined. In order to generate a unique cubic spline, two other conditions have to be imposed upon the system. The curves generated in this paper are Natural cubic splines with the condition

$$(D_1 = D_n = 0) \quad \ldots\ldots (10)$$

Test Tools

The result images shown in this work and other images have been tested passing through measure test. In order to determine the similarities between the original image and the secured image, the measurements used to achieve this test are, [1], [11]: -

$$MSE = \frac{1}{H*W}\sum_{y=0}^{H-1}\sum_{x=0}^{W-1}\left(f(x,y) - f'(x,y)^2\right), \qquad RMSE = \left[\frac{1}{H*W}\sum_{y=0}^{H-1}\sum_{x=0}^{W-1}\left(f(x,y) - f'(x,y)\right)^2\right]^{1/2}$$

$$SNR = \frac{\sum_{y=0}^{H-1}\sum_{x=0}^{W-1}(f(x,y))^2}{\sum_{y=0}^{H-1}\sum_{x=0}^{W-1}(f(x,y) - f'(x,y))^2}, \qquad PSNR = 10\log_{10}\left(\frac{(255)^2}{MSE}\right)$$

$$Similarity(A_{ij}, B_{ij}) = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} a_{ij} b_{ij}}{\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N} a_{ij}^2}\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N} b_{ij}^2}}.$$

Where *f(x,y)* represent the pixel value of the original image with row(y) and column (x), *f* '(x,y) represent the pixel value of the new image, H represent the height of the image, W represent the width of the image and lastly A_{ij} ,B_{ij} resent two images matrixes with size equal to (N × N).
Another characteristic which characterizes the light of an image can be used as measurement test for the picture before and after applying the proposed method which they are intensity, luminance and brightness.[1], [11].

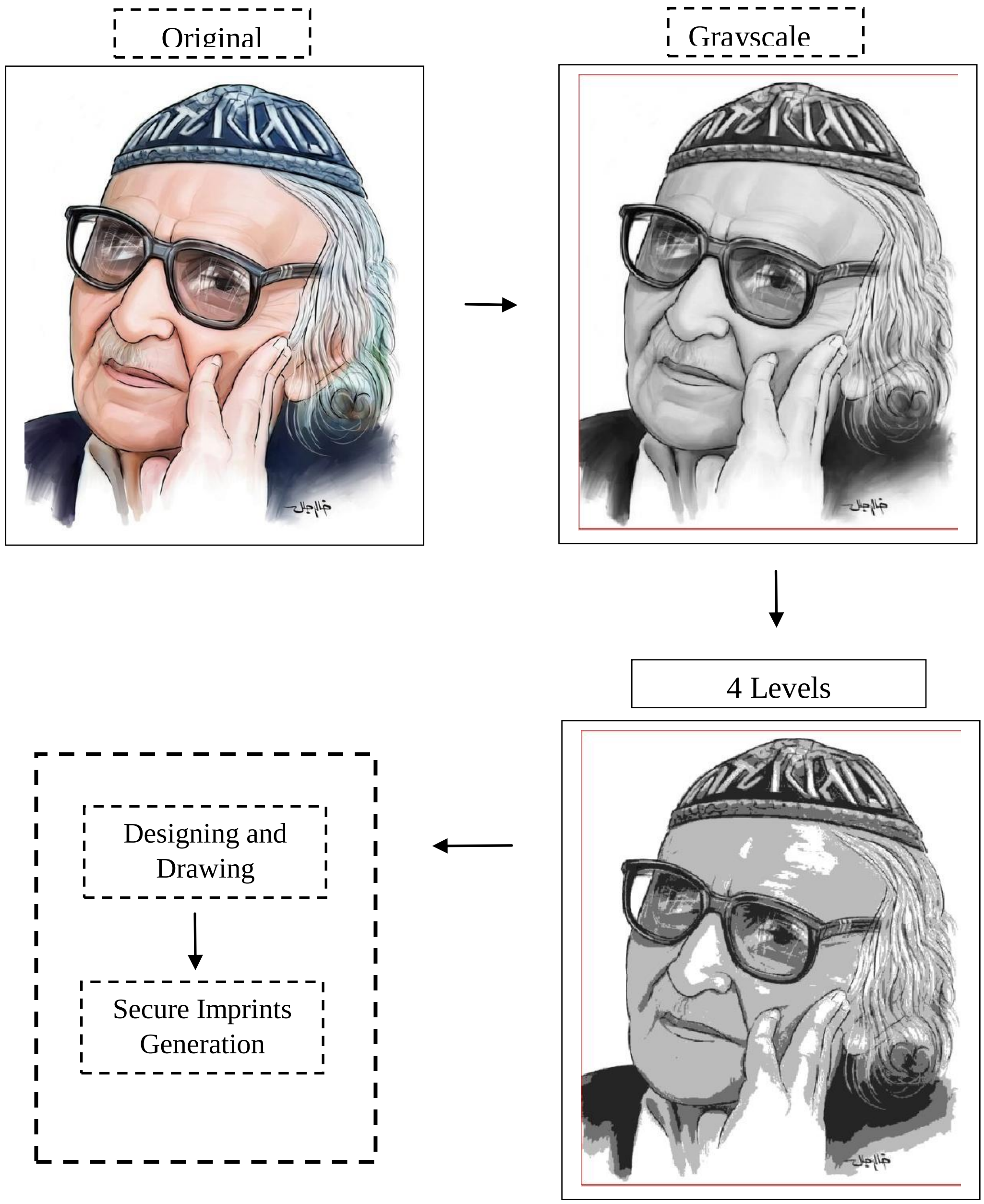
Intensity = $\sum (X(m,n).red + X(m,n).green + X(m,n).blue)$

Luminance = $0.299 \times$ red $+ 0.587 \times$ green $+ 0.114 \times$ blue.

Brightness = $\frac{\sum (X(m,n).red + X(m,n).green + X(m,n).blue)/3}{Size\ of\ image\ (m*n)}$

Research Method

This study was conducted to create a technique that can be used to validate reliably for an important document as a reference to ensure that the document was issued by the issuing party. Hiding curves in the images is technique used as a problem-solving to create a document in which integrated a sign embedded either logo or other image owned by the owner. After successfully embedded the document, the document will be validated with scanning on the documents in the extraction process, when the embedded image is detected, it shows that the document is valid. Fig.1. Demonstrates the flowchart of the suggested modified method that shows the generating of cubic spline curves and inserting these curves in the image



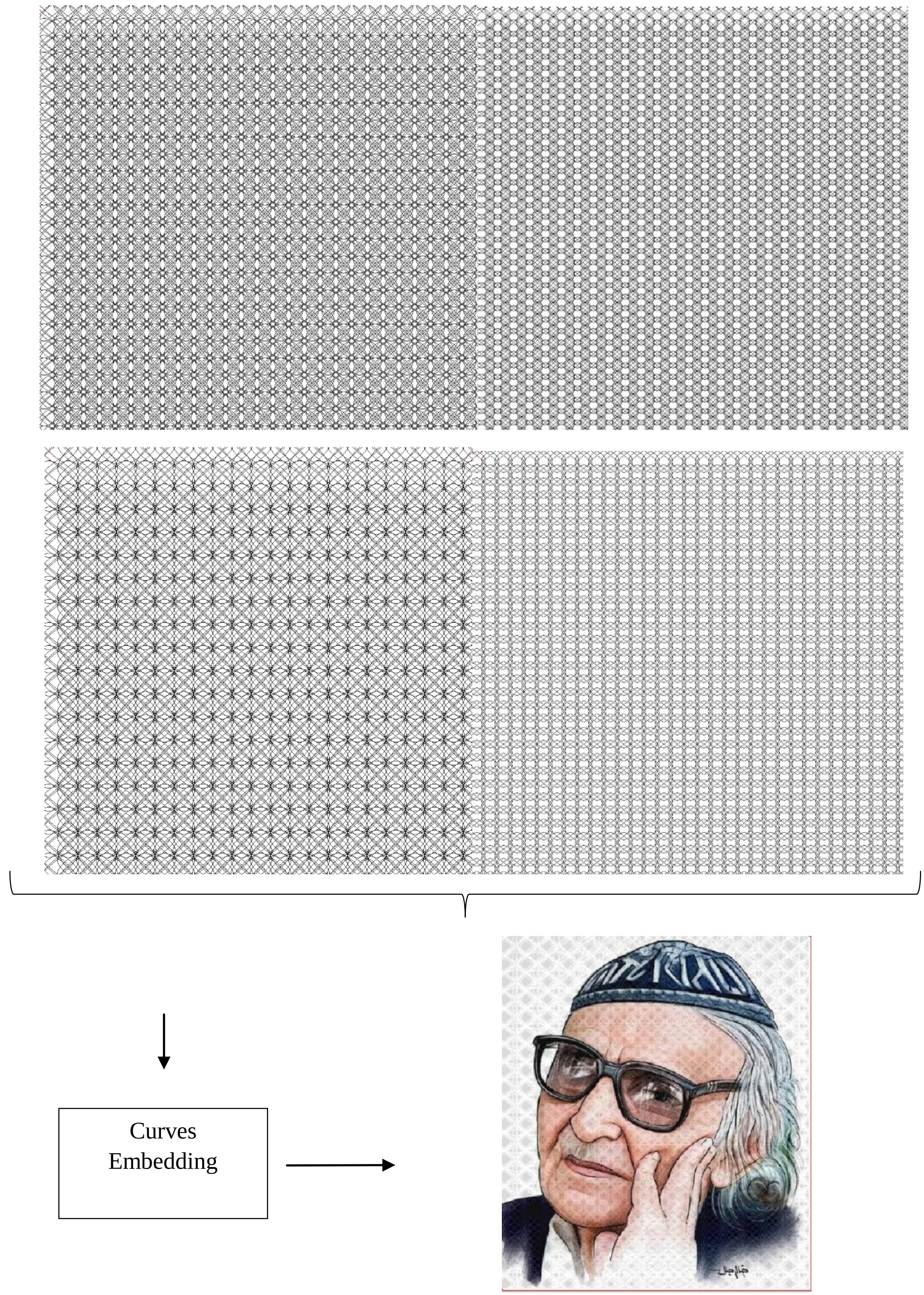


Figure.1. the proposed method based on cubic spline prototype.

The proposed methods and algorithms is described as follows:

Image pre-processing

In the first stage, the process of preparing the image is start by converting the image into gray scale from using one of the known methods (Averaging method, luminance method or Desideration method), then the image is converted into four regions of gray scale making fourth reshold fields (black, white and two gray levels). The whole image pix leaser compared with these thresholds as shown in Algorithm (1), andFig.2, Fig.3, andFig.4. A copy of the original image should be kept to be reused later to recover the original colors. Fig.2, Fig.3, andFig.4, illustrate the image pre-processing states.

Algorithm (1) Image Pre-processing

Input: Color BMP image.

Output: Four levels grey scale BMP image.

Step1: Define parameters:

1.1 Define the image's width (Im.width).

1.2 Define the image's height (Im.height).

1.3 Define the image's pixels color (p.clr).

Step2: convert color image to gray image:

2.1 For x=0 to Im.width - 1.

2.2 For y=0 to Im.height - 1.

2.3 z = (p.clr.G + p.clr.B + p.clr.R) / 3.

2.4 Set p.clr = z, 2.5 Next 2.6 Next

Step3: Convert grey image to four levels (black, white and two gray levels):

3.1 For x=0 to Im. Width - 1.

3.2 For y=0 to Im.height - 1.

3.3 If p.clr = 0 then p.clr = 0.

3.4 If p.clr>= 1 and p.clr =< 75 then p.clr = 37.

3.5 If p.clr>= 76 and p.clr =< 150 then p.clr = 112.

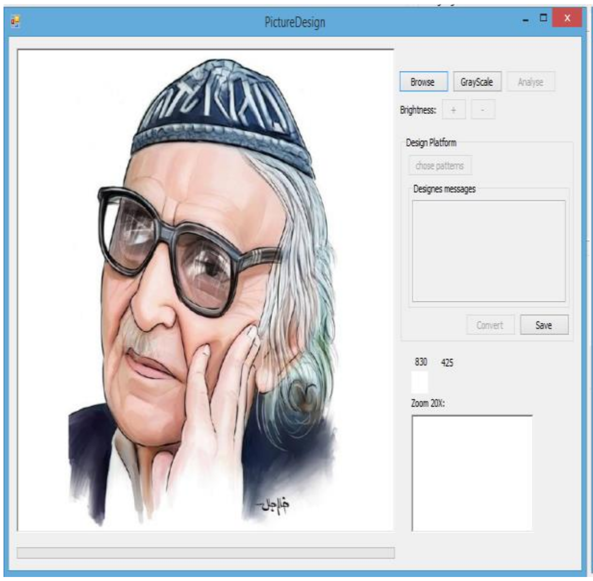
3.6 If p.clr>= 151 and p.clr =< 225 then p.clr = 187.

3.7 If p.clr>= 226 and p.clr =< 255 then p.clr = 255.

3.8 Next.

3.9 Next.

Step4: End



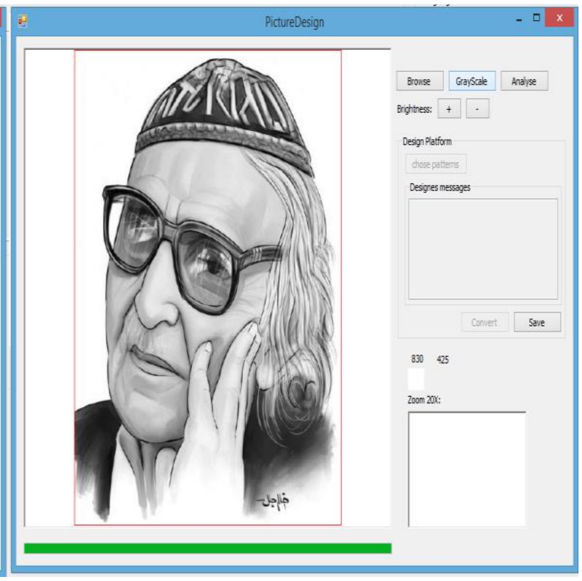


Figure.2. Original image **Figure.3. Gray scale image**

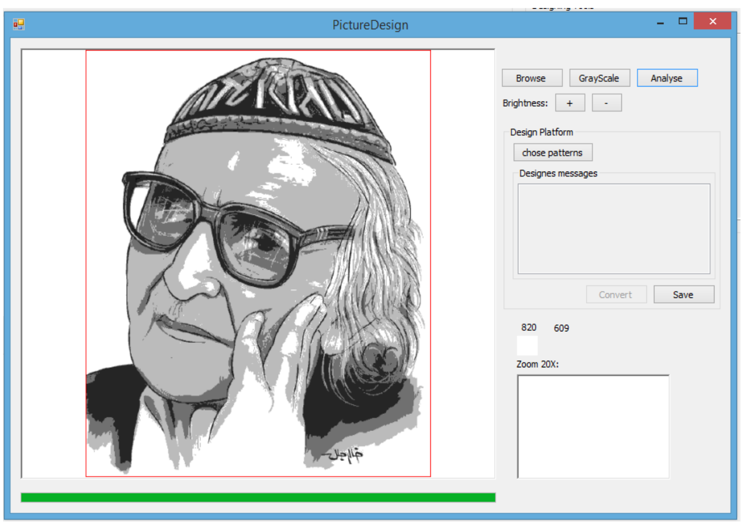


Figure.4. Four threshold fields of image

Curve designing

The design of any curve is totally depends on the main points collection that the interpolation or the approximation among them to create the other curve points. The points are divided into two types (control points and data points) and each type of the them has its special purpose and role in generating the curve design. Cubic spline interpolation is the main method used in the curves generation process, which are illustrated in algorithm (2), [1], [9].

Algorithm (2) Controlling the design of Cubic Spline

Input: N data points $P(x_i, y_i)$, four guide points G1=(G1X,G1Y) , G2= (G2X,G2Y), G_3= (G_3X, G_3Y)and G_4= (G_4X, G_4Y)

Output: t vector that used with $P(x_i, y_i)$ points to control the curve design.

Step 1: Initialize parameters

D_1=0, D_2=0, D_3=0, D_4=0, $\delta_1[0]$=0, $\delta_2[0]$=0, $\delta_3[0]$=0, $\delta_4[0]$=0.

Where:

D_1 represents the overall distance between the first guide point (G_1x, G_1y) and all the N data points P(xi,yi).

D_2 represents the overall distance between the second guide point (G_2x, G_2y) and all the N data points P(xi,yi).

D_3 represents the overall distance between the third guide point (G_3x, G_3y) and all the N data points P(xi,yi).

D_4 represents the overall distance between the fourth guide point (G_4x, G_4y) and all the N data points P(xi,yi).

δ_1i represent the triangular distance between the first guide point (G_1x, G_1y) and the i'th data point P(xi,yi).

δ_2i represent the triangular distance between the second guide point (G_1x, G_1y) and the i'th data point P(xi,yi).

δ_3i represent the triangular distance between the third guide point (G_3x, G_3y) and the i'th data point P(xi,yi).

δ_4i represent the triangular distance between the fourth guide point (G_4x, G_4y) and the i'th data point P(xi,yi).

N represents the number of the data points

This stage in interpolation is among the points that are designed in the previous stage to draw a curve that is used in the next stage to generate security imprint. Cubic spline interpolation is the main method used in the curves generation process.

Secure imprints generation

Secure imprint is a set of vertical or horizontal cubic splines that form a high secure design. It can be generated to create different designs by changing the generation parameters. After the curve fitting, regenerate the curve for fixed times with a fixed change factors for the X and Y sides using a special way, a secure imprints will be generated. By changing one of the parameters or all of them at the same time, different secure imprints design can be produced depending on the selected parameters, as illustrated in algorithm (3).

Algorithm (3) Secure Imprints Generation

Step1: Apply Algorithm (1) and (2) to generate the cubic spline interpolation curve.

Step2: Start drawing again after shifting the same curve to the right, consuming the x value for a specific number of shifts.
Step3: Start from beginning and drawing again but shifting to the bottom, consuming the y value for a specific number of shifts.

A. Processing

The four different secure imprints are embedded to the image, which embedded to one of four image regions. After that the real colors are returned to the image to make the result as shown in Fig.5. Algorithm (4) shows the steps of this process.

Algorithm (4) Image Processing
Step 1: Save the colors of the image in an intermediate variable image to return it to the main image later.
Step 2: Start embedding the imprint to the image by changing the value of the pixel that founded at the path of the curve (increasing or decreasing) by a specific fixed number.
Step 3: Apply step two for each color region by using the four different secure imprints.
Step 4: Return the colors of the picture from the intermediate variable that saved in it.

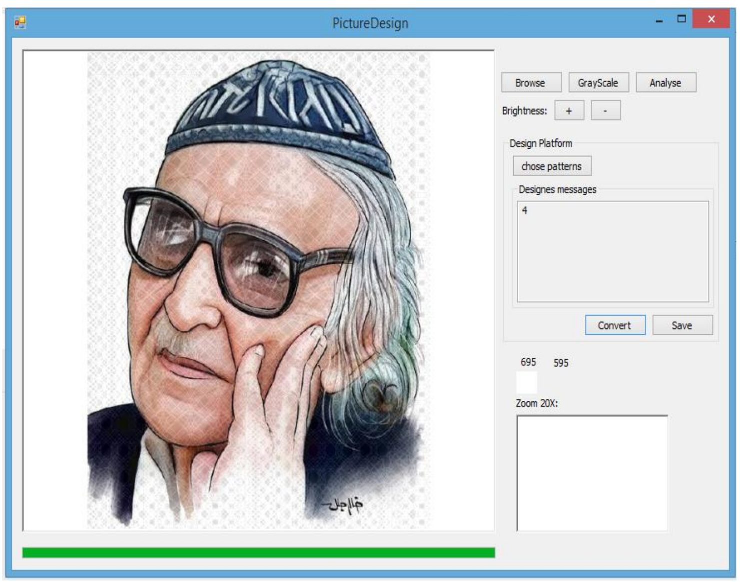


Figure.5. the secured image

RESULTS

The enforcement of system implementation was assessed through utilizing an experiment setup consisting of two parts; the similarity degree between the original image and the secured image and the human recognition of the original documents from legal photocopies, and from the fake ones. The method tested using two images with different gradient these images and the security stages are displayed in Fig.7. The secure signatures created by employing 5 point cubic spline curves which are utilized in formation hiding of printed images provides high secure images against counterfeiting and forgery, which can be used to design any vital documents.

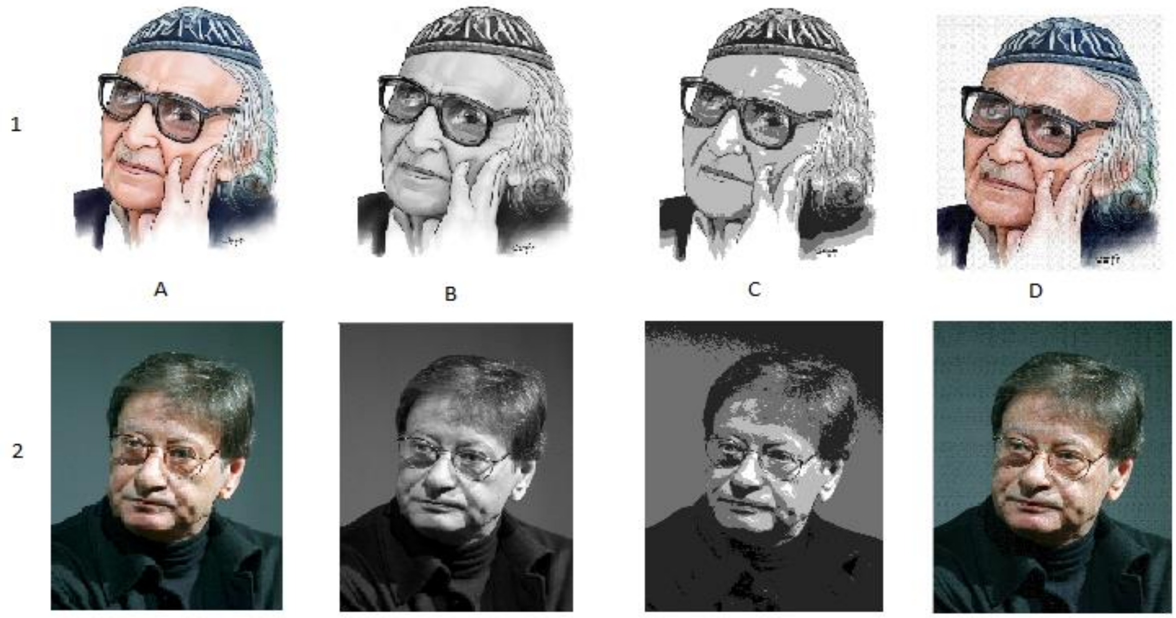


Figure 6 Two different images with the security stages

From the tested images, the Mean, MSE and RMSE for the two images and six more, between the original images pixels and the secure images pixels are calculated. The results are shown in Table 1.

Table1. Image test result

Image Name	***Mean***			***MSE***			***RMSE***		
	R	***G***	***B***	***R***	***G***	***B***	***R***	***G***	***B***
Img1	35.01	11.37	-7.46	2.01	1.22	5.79	1.41	0.75	3.01
Img2	- 32.33	-24.27	- 21.76	0.67	6.45	2.27	0.12	3.58	1.05
Img3	34.20	18.12	30.01	3.75	5.23	2.83	0.90	0.42	2.37
Img4	37.24	12.61	-3.00	2.40	4.14	5.65	0.20	0.93	3.10
Img5	- 12.00	-4.14	-1.20	5.30	2.75	2.89	0.85	0.63	2.10
Img6	29.00	7.35	20.40	1.15	1.92	2.89	1.03	2.82	1.04
Img7	8.93	6.00	6.20	3.55	2.70	3.70	0.32	0.39	1.05
Img8	21.21	17.18	17.86	1.18	1.40	2.04	0.29	0.43	1.99

Conclusion and Discussion

This paper discussed the following points:

1- Using mathematical modeling which were used to design secure non-reproducible documents that not easy to counter fit of forged by scanning the image.

2- The images are designed based on generation of complex curve from mathematical models that are not possible for unauthorized people to know.

3- The modified technique to change the curve shape without changing the control points by depending on the guide points.

4- Using secure imprints technology in the design of complex background of the image.

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