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Fake Currency Detection using Image Processing (Case Study Libyan Currency)

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Abstract Deferent methods have been developed to reduce use of money paper currency, among those methods saving money currency in magnetic card, in smart card or electronically. But still people uses money paper currency in vary places and this will encourage others to fake them. Fake currency detection is a process of finding the forgery currency and its in attention of all countries over the word. This paper presents an algorithm to detect fake currency among true one based on use of image processing. In the presented algorithm the currency image features are extracted using hu moments and used with two parameters (MSE and RMSE) to detect forgery from original currency.

Keywords: Image processing, fake detection, Hu moments, MSE, RMSE.

اكتشاف التزوير في العملة باستخدام معالجة الصورة (العملة الليبية كنموذج)

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الملخص طرق عديدة طورت بغرض تقليص الاعتماد على العملة الورقية كاعتماد البطاقات البلاستيكية المغنطيسية او البطاقة الذكية الا الناس لاتزال تستعمل النقود الورقية في مساحات واسعة من العالم وهذا ما يشجع على تزويرها. فاكتشاف تزوير العملة يعني معالجة لكشف المزورة من تلك العملة وهذا الامر يشكل هاجزا للعديد من الدول حول العالم. الورقة تقدم خوارزمية لاكتشاف المزورة من العملة باستخدام معالجة الصورة. الخوارزمية تستند على استخراج سمات والعزم هيومومنت ثم استخدام المعيارين (MSE,RMSE) لكشف المزور من الاصلية الصحيحة.

الكلمات المفتاحية: معالجة الصورة، اكتشاف التزوير، العزم هيومومنت، المعيار ام اس اي، المعيار ار ام اس اي.

Introduction

Digital image can be processed using computer algorithms to perform a subcategory or field of digital processing. Noise and distortion are first removed from the digital image to come out with its data contents [1]. Image segmentation means the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels) to simplify and /or change the representation of an image into something that is more meaningful and easier to analyse. Segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images [2]. Image restoration is used to emphasize features of the image that make the image more pleasing to the observer [3]. Image enhancement techniques are used to contrast stretching or de-blurring by a nearest neighbour procedure helps in noise removal [4]. More advanced image processing techniques must be used to recover the object and discover paper currency counterfeit to avoid using it. This action is considered as a form of fraud or forgery among all governments. Counterfeiting is almost as old as money itself. A counterfeit is performed use of legitimate printers in response to fraudulent instructions [5]. The counterfeit is difficult to be discovered in very begging, it causes government economic losses. In following paragraph will present an algorithm which will help governments to avoid currency counterfeit and reduce economic losses earlier.

Methodology

Sequences of the proposed fake currency detection algorithm as shown in Fig 1 are given in the following lines:-

- Data collection
- Image pre-processing
- Image segmentation
- Features extraction

- Features comparisons and fake detection

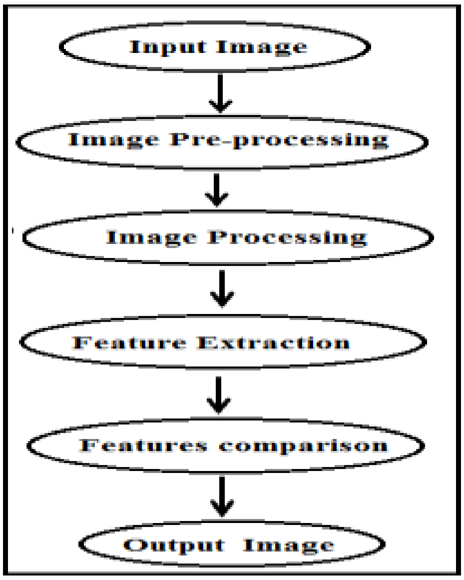

Fig: 1. Sequences of proposed algorithm

Data collection
Few currency papers of Libyan currency are acquired by simple scanner and digital camera. Acquisition as first stage of any vision system is performed to retain all image features. Fig. 2., shows sample of acquired image of ten dinars of the Libyan currency,

Fig. 2. Scanned Ten Libyan Dinars image

Image pre-processing
The main goal of this stage is to enhance the visual appearance of images and to improve the manipulation of datasets. The process is also called image restoration, it is involves the correction of distortion, degradation. Several filter operations was used to reduce intensify of an image details to be easier or faster evaluation. The interpolation as technique is used for zooming, rotating, shrinking, and for geometric corrections. A noise is removed from the given image otherwise it may affect segmentation process and give bad pattern matching. The neighbour of the pixel is used to do some transforming as smoothing process. Fig. 3., shows smoothed ten dinars image.

Fig. 3. A smoothed ten dinars image

Image processing
The obtained images as RGB images then are converted into grey scale images. As result a grey scale is obtained as shown in Fig. 4.

Fig. 4. A ten dinars grey scale image

Image segmentation
The goal of segmentation is to simplify and/or change the representation of an image to make it more meaningful and easier to analyse. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. Edge detection is performed for grey scale image by applying Sobel operator to perform a 2-D spatial gradient measurement on an image. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image. The Sobel edge detector uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows). Fig. 5 shows an image after performing an edge detection using Sobel operator algorithm.

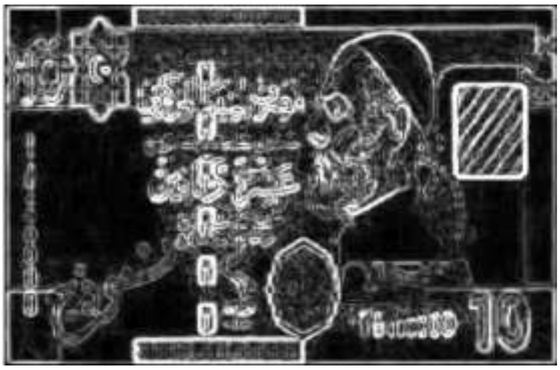

Fig. 5. Image edge detection using Sobel operator

A convolution mask is usually much smaller than the actual image. As a result, the mask is slid over the image, manipulating a square of pixels at a time. The actual Sobel masks are shown in Fig 6.

Gx

-1	0	+1
-2	0	+2
-1	0	+1

Gy

+1	+2	+1
0	0	0
-1	-2	-1

Fig. 6. Used Sobel masks

The magnitude of the gradient is then calculated using the equation (1)

$$|G| = \sqrt{Gx^2 + Gy^2} \quad (1)$$

An approximate magnitude can be calculated using equation (2).

$$|G| = |Gx| + |Gy| \quad (2)$$

Once the process of image segmentation is performed, portion of a grey scale image contains information is selected and cropped to be used in farther process. Fig. 7 shows a segmented grey scale ten dinars currency image.

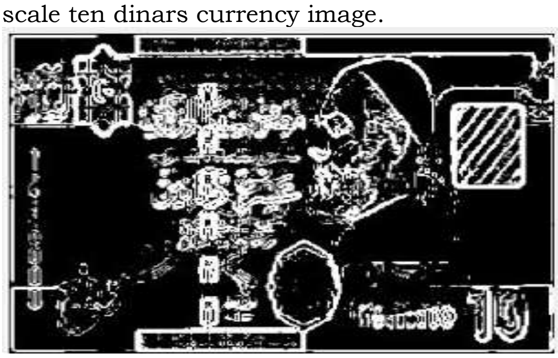

Fig. 7. Segmented ten Libyan dinars image

In Fig. 8 shows four sets of grey sale currency image. The used currency sets from top ten dinars, one dinar, fifty dinars and five dinars. Sets are grouped and then a segmentation process is performed.

Fig. 8. Segmented four sets of different Libyan currency image

Feature extraction

In this process features of the segmented image will be extracted, that is a process to come out features from segmented cropped images. To extract features different parameters and functions are used. The extracted features will be use later to distinguish one image from another by use of Hu moments algorithm to detect fake currency.

Hu moments algorithm is used to calculate features form segmented cropped images as will be shown in the following paragraphs.

Invariant Moment

1. Select the input image I.
2. Transform the image into two dimensional, real valued and numeric forms.
3. Calculate the value of raw moment's m_{pq} using equation (3).

$$\mu_{pq} = \sum_x \sum_y (x)^p (y)^q f(x,y) \quad (3)$$

4. Calculate the central moment μ_{pq} using equation (4).

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y) \quad (4)$$

$$\text{where } \bar{x} = \frac{m_{10}}{m_{00}} \text{ and } \bar{y} = \frac{m_{01}}{m_{00}}$$

5. Find the normalized central moment pq using equation (5).

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\gamma}} \quad (5)$$

$$\text{where } \gamma = \frac{p+q}{2} + 1 \quad \text{for } p+q = 2,3,....$$

For a 2-D continuous function *f*(*x*,*y*), the moment of order (*p*+*q*) is defined as in equation (6).

$$m_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^p y^q f(x,y)dxdy \quad \text{for } p,q = 1,2,3,... \tag{6}$$

The central moments are defined as in equation (7):

$$\mu_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q f(x,y)dxdy \tag{7}$$

$$\text{where } \bar{x} = \frac{m_{10}}{m_{00}} \text{ and } \bar{y} = \frac{m_{01}}{m_{00}}$$

If $f(x,y)$ is a digital image, then use equation (8)

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y) \tag{8}$$

The central moments of order up to 3 are calculated using equation (9)

$$\mu_{00} = \sum_x \sum_y (x-\bar{x})^0 (y-\bar{y})^0 f(x,y) = \sum_x \sum_y f(x,y) = m_{00}$$

$$\mu_{11} = \sum_x \sum_y (x-\bar{x})^1 (y-\bar{y})^1 f(x,y) = m_{11} - \frac{m_{10}m_{01}}{m_{00}}$$

$$= m_{11} - \bar{x}m_{01} = m_{11} - \bar{y}m_{10}$$

$$\mu_{10} = \sum_x \sum_y (x-\bar{x})^1 (y-\bar{y})^0 f(x,y) = m_{10} - \frac{m_{10}}{m_{00}}(m_{00}) = 0$$

$$\mu_{01} = \sum_x \sum_y (x-\bar{x})^0 (y-\bar{y})^1 f(x,y) = m_{01} - \frac{m_{01}}{m_{00}}(m_{00}) = 0 \tag{9}$$

The central moments of order up to 3 are calculated using equation (10).

$$\mu_{20} = \sum_x \sum_y (x-\bar{x})^2 (y-\bar{y})^0 f(x,y) = m_{20} - \bar{x}m_{10}$$

$$\mu_{02} = \sum_x \sum_y (x-\bar{x})^0 (y-\bar{y})^2 f(x,y) = m_{02} - \bar{y}m_{01}$$

$$\mu_{21} = \sum_x \sum_y (x-\bar{x})^2 (y-\bar{y})^1 f(x,y) = m_{21} - 2\bar{x}m_{11} - \bar{y}m_{20} + 2\bar{x}m_{01}$$

$$\mu_{12} = \sum_x \sum_y (x-\bar{x})^1 (y-\bar{y})^2 f(x,y) = m_{12} - 2\bar{y}m_{11} - \bar{x}m_{02} + 2\bar{y}m_{10}$$

$$\mu_{30} = \sum_x \sum_y (x-\bar{x})^3 (y-\bar{y})^0 f(x,y) = m_{30} - 3\bar{x}m_{20} + 2\bar{x}^2 m_{10}$$

$$\mu_{03} = \sum_x \sum_y (x-\bar{x})^0 (y-\bar{y})^3 f(x,y) = m_{03} - 3\bar{y}m_{02} + 2\bar{y}^2 m_{01} \tag{10}$$

The normalized central moments are defined as in equation (11).

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\gamma}} \quad \text{where } \gamma = \frac{p+q}{2} + 1 \quad \text{for } p+q = 2,3,.... \tag{11}$$

A seven invariant moments can be derived from the second and third moments using equation (12).

$$\phi_1 = \eta_{20} + \eta_{02}$$

$$\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2$$

$$\phi_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2$$

$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2$$

$$\phi_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})\left[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right] + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})\left[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right]$$

$$\phi_6 = (\eta_{20} - \eta_{02})\left[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03})$$

$$\phi_7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})\left[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right] + (3\eta_{12} - \eta_{30})(\eta_{21} + \eta_{03})\left[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] \tag{12}$$

To extract features a Hu moments equations (2) to (12) are used. The calculated values will be saved in database to be used later in comparison process and for fake currency detection. Table 1 shows calculated values of an image used as features of an image. Column name ID represents image number where M1 to M7 represent Hu moment calculated values.

Table 1. calculated features

ID	M1	M2	M3	M4	M5	M6	M7
1	2.035513	6. 417259	8.298347	8.005038	16.284094	-11.360782	16.333165
2	2.031900	6. 117154	6.830815	7.629875	14.887468	11.374117	-15.324413
3	2.006231	6.050556	8.379262	8.032045	-16.268179	-11.106741	16.679122
4	1.906431	4.049746	7.295030	7.286615	14.581799	9.315965	15.428230

Feature comparison

For any new unknown currency image, it is first will be processed, segmented as show previously then features are extracted using equations (2) to (12) as shown in Table 2. Calculated features will be compared with the original pre-stored image in the system. An image is considered as genuine if it matches otherwise the currency is counterfeit.

Table 2. New unknown image features

ID	M1	M2	M3	M4	M5	M6	M7
1	2.035513	6. 417259	8.298347	8.005038	16.284094	-11.360782	16.333165

Mean Square error (MSE)

The mean square error or MSE of an estimator is one of many ways to quantify the difference between an estimator and the true value of the quantity being estimated. The MSE was calculated using equation (13).

$$MSE = (1/MxN)\sum_{i=1}^{M}\sum_{m=1}^{N}(a_{ij} - b_{ij})^2 \tag{13}$$

Root Mean Squared Error (RMSE)

The RMSE is frequently used to measure the difference between values predicted by a model or an estimator and the values actually observed. It the square root of the mean squared root error value was calculated using equation (14).

$$RMSE = \sqrt{MSE} \quad (14)$$

Testing of proposed system using MSE, and RMSE

A currency image is first to be processed by the proposed system. The process is performed by smoothing the given image, noise removing and edge detection. Fig. 9 shows processed currency image by the proposed algorithm.

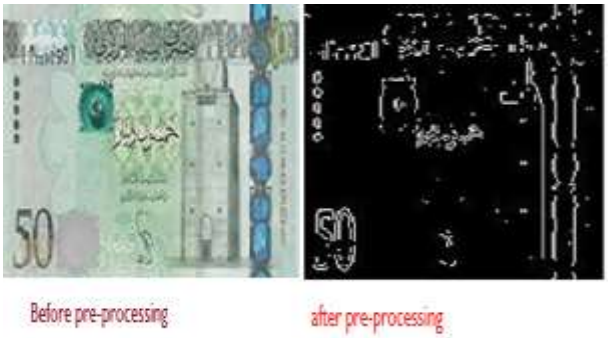

Fig.9. processed currency image

Then image features are extracted using equations (2) to (12) as shown in Table 2.

Table 2. Extracted features for the given Libyan currency using Hu moments

M1	M2	M3	M4	M5	M6	M7
2.006231	6.050556	8.379262	8.032045	-16.268179	-11.106741	16.679122

A comparison of obtained features with stored one in databases are performed using two parameters MSE and RMSE as in equations (13) and equation (14), results of comparison are shown in Table 3. As shown only an ID 3 is genuine where other images are counterfeit.

Table 3. Comparison of extracted features to detect fake currency

ID	MSE	RMSE	Decision
1	0.059040821780367	0.2930939818192	NO
2	0.0323169914168925	0.1797692727173	NO
3	0	0	OK
4	0.175572579827306	0.4190138181818	NO

Related work

The survey on fraud detection techniques was presented in paper [6] it presents techniques using performance metrics. Various fraud detections like credit card fraud, computer intrusion and telecommunication fraud are surveyed. The main methods behind the credit card fraud detections and computer intrusion are neural networks and model based reasoning, some with data mining. In telecommunication fraud detection, the visualization methods are used. This paper presents a summary on Next-Generation Intrusion Detection Expert [7] System (NIDES) by using the real-time and batch techniques. The real-time is used to analyze data and report the suspicious activity. The batch operation is a mode of operation that allows the user to run the tests and specify the maliciousness. A paper [8] presents a fake currency detection using image processing and other standard methods by using various methods like watermarking, optically variable ink, florescence, security thread, intaglio printing, latent image, micro lettering and identification mark. By combining two various components of two images then, the variation will be decreased. But by using layman method the fake note is detected. A paper [9] presents the design and implementation of Indian paper currency authentication system based on feature extraction by edge based segmentation using sable operator. To do this, the features are extracted from the original image and the edges are identified. Then, the edges are segmented and it is compared with the dataset and finds out the fake detection. A paper [10] it presents paper currency verification system which is based on classification extraction using image processing but uses machine vector where in the proposed system the extraction is performed by getting the image and converts it to gray scale and then edge is detected. Then the image is segmented and the characteristics are extracted and it is compared and the output is shown.

Conclusion

This paper proposed fake Libya currency detection using image processing. In image pre-processing the image converted into grey scale. After conversion the edges are detected. In edge detection used the Sobel operator. Next the image segmentation is applied. After segmentation the features are extracted. Finally compared and find the currency original or fake.

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