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Image-Based Processing of Paper Currency Recognition and Fake Identification: A Review

Sabat Salih Muhamad

sabat.muhamad@soran.edu.iq
Computer Science Department, Faculty of Science, Soran University, Soran,
Erbil, Kurdistan Region, Iraq

Twana Nasih Ahmed

Twana.nasih@spu.edu.iq
Horticulture and Landscape design Department, Bakrajo Technical institute, Sulaimani
Polytechnic University

Abstract There are over 180 different currencies on the globe. Each currency is distinct in terms of scale, paper, colors, patterns, text, etc. It is tough to keep track of all of the different currencies. Often, determining whether a currency is genuine or counterfeit is challenging. Many methods investigate currency recognition. In this review, the following techniques are widely used in image processing for currency recognition tools, including acquisition, image enhancement, segmentation, and object detection and recognition. This review shows the ability of image processing techniques, including pre-processing, edge detection, feature extraction, and thresholding, to recognize paper currency have been used. Thus, the outcome of this review indicates that for currency recognition the techniques that used for feature extraction are (LBP, SIFT, SURF and ROI) and choosing the best technique depends on the application.

Keywords: Image processing, Currencies, Real and fake authentication, Classifier, Feature extraction.

1. Introduction

Computer vision is the hottest research area right now. It is applicable to a variety of academic fields, including computer science, mathematics, engineering, biology, and psychology. The term "computer vision" refers to a general understanding of visual environments. Many scientists agree that the area opens the way for Artificial General Intelligence (AGI) because of its cross-domain mastery [1].

Governments are becoming increasingly concerned about the use of bank notes as a primary source of currency [2]. Individuals are unable to quickly distinguish between different currencies from various countries. Automatic currency recognition systems have become a main source of concern for researchers and developers due to the currency's importance in facilitating the overall management of countries' economies [3].

To trade off goods and services, currencies are used all over the world. Since coins are difficult to pass, paper currency is increasingly becoming more common. People are enticed to copy original currencies as a result of this. Since there was no mechanism in place to recognize fake currency notes in the beginning, the supply of counterfeit currency notes grew day by day. Every country has its own currency. Size, form, color, and pattern are all different. It is tough to count various denominations and distinguish fake notes as all notes are subjected to mandatory testing. To overcome this issue, a currency recognition system is required in banking and other money transaction services. Automated teller machines, automatic good selling machines, and other similar machines are now commonly used in stores and bank counters [4].

Currency recognition technology essentially seeks to recognize and extract visible and invisible features of currency banknotes. Several methods for identifying currency notes have been suggested up to this stage. However, the most effective method is to make use of the note's obvious features [5].

Almost every currency in use around the world has a different appearance and, as a result, different characteristics, for instance, the paper's size, identification marks, color, pattern, and so on. It is not an easy task to differentiate between different currencies, particularly for those who work in places like money exchange offices [6]. Remembering the symbols for each currency is a challenging job that can lead to incorrect recognition. Furthermore, due to advances in imaging technology for scanning and printing, fake banknote processing has become very easy and more difficult to detect (Rahman, Sargano, and Bajwa, 2017).

The main objective of a currency recognition model is to assist humans in identifying counterfeit banknotes while also reducing human energy. Moreover, Digital image processing is a broad field that offers a precise solution to this issue [4]. So, having a quick and straightforward way to recognize banknotes is essential. The system needs Scanners, machines, and booklets by using image processing approaches and methods (Mitsukura, Fukumi, and Akamatsu, 2000).

This review aims to introduce the impact of image processing techniques and their roles in paper currency recognition. Moreover, this review article is structured as follows: part 2 summarizing previous literature in the field and outlines some of the techniques utilized, part 3 information on background, the findings are discussed in part 4, and the last part concludes this review article.

2. Related Works

A lot of researchers have contributed to the development of currency-recognition techniques in various ways. Researchers approach the identification task differently for each because of the differences in properties between coins and bills. The previous work in currency recognition techniques is reviewed in this section and showed the main points in Tabel.1.

In [9] described an approach for recognizing paper currency that depended on Hidden-Marko- Model (HMM). HMM was utilized to model the banknote texture as a random operation. The pre-processing stage was necessary to solve the problem of identifying dirty banknotes. The attribute vectors for various banknotes were stored in a database for paper currency identification. The following steps were followed to identify a query banknote: (a) The banknote's size was calibrated to ensure that it falls within the appropriate limit. (b) The Wiener filter was used to pre-process the banknote image. (c) The image of the ban-knote was converted to a 64-gray-scale image. (d) The transformation matrix's main diagonal value was determined and compared to database values. The query banknote was allocated to a class in which the difference between the main diagonal values was less than a predetermined value. According to their tests, setting the threshold value to 0.02 results in decent detection efficiency overall. The method was tested on 150 banknotes from 23 countries, with 101 different denominations. 98 percent accuracy is claimed for the technique.

[10], in their article, block-LBP algorithm, was proposed for feature extraction based on the standard local-binary-pattern (LBP) process. Their proposed technique contained the following steps: step1 Segment the whole picture into M* N blocks. Ensure the picture's width and height could be divided precisely by M and N by normalizing it. M = N = 30, PW = PH = 300, m = n = 10, where PW and PH were width and height. Step2 Calculate the LBP histogram for each block, which has 256 different patterns. The amount of patterns in the histogram is reduced to 32—step3 Normalization of the Block-LBP histogram. Every histogram score means the probability of each pattern appearing in the block. Step 4: Build a multi-dimensional vector for identification by connecting all of the LBP-block-histograms. They examined 545 RMB sheets (87 1yuan, 135 5yuan, 84 10 yuan, 66 20 yuan, 36 50 yuan, 137 100 yuan). Matlab 7.1 was used to do all of the transformations. The findings of the experiments revealed that this enhanced approach has a high identification rate to paper currency recognition as well as robustness to noise and changes in illumination.

In [11], they identified a method for distinguishing fake from genuine banknotes applied to Indian banknotes. In their experiment used 1000 samples (500 genuine and 500 fake). The identification of notes is modeled as a two-class class label: distinguishing between genuine (marked by G) and false (marked by F). Support-vector-machines (SVM) and artificial-neural-networks (ANN) were used to classify the data. The data set was split into a 2:1:1 ratio to create training, validation, and test datasets. Their findings revealed that the relative performance of the features could provide crucial details to note designers, such as which feature performed better and which was more vulnerable to counterfeiting attacks.

In [12] suggested using image processing methods to create an automatic method for currency recognition. Their model is compatible with 20 of the most widely used currencies. In the pre-processing step, each image's essence is refined first in order to turn it into a functional input for extracting several pictorial details. After that, the system extracts the region of interests (ROI) based on scales, colors, and text features. The method first decides the country of origin of the currency banknote using these regions of interest. Following this step, the denomination of the currency note will be determined by comparing the distinguishing features of each note within the same currency. Their system correctly identified the majority of countries and denominations (93.3 percent accuracy). Compared with the crude algorithm of pixel by pixel, their algorithm is more accurate and takes less time (an average of 5.3 seconds).

An automatic recognition system used smartphone used scale invariant feature transform (SIFT) algorithm was proposed by [13].The authors used a database of 400 Jordanian-banknotes, which included 10 different types of banknotes (50 JD, 20 JD, 10 JD, 5 JD, 1 JD, 50 piasters, 25 piasters, 10 piasters, 5 piasters, 1 piaster). The number of detected features in color SIFT is clearly higher than in the gray SIFT, as shown by the findings. When comparing color SIFT descriptors to gray SIFT descriptors, the assessment results revealed that color SIFT descriptors outperformed gray SIFT descriptors in processing time and accuracy rates.

[2] proposed a cost-effective and automated counterfeit currency identification method that could be used in mobile apps based on image processing methods. To build the training dataset, a total of 40 actual and 20 fake notes were used. All of the photographs were taken with a smartphone camera. This dataset was used to train the SVM classifier and evaluate the threshold value by converting the RGB image to YCrCb, LUV, and HSV color spaces. In the case of actual notes, two colors, one for the backdrop and another for the security thread, predominated in each image plane. In the fake notes, these colors were not visible. K-means was used for classification. They split the images into two groups. To decide whether the note was true or false, the Euclidean distance between the centroids of the two clusters was measured and compared to a fixed threshold value. The output was determined using a research dataset that included 20 actual and 10 fake notes. The technique, as mentioned above, was tested and found to be 90 percent correct.

In [4] research, the use of digital image processing in a novel model for currency recognition has been mentioned. The input was a picture. The input image is pre-processed to eliminate noise, improve, and adjust the output to a norm. The edge-detection technique was used to extract the boundaries of objects in an image. This was also used to analyze and detect brightness discontinuity to extract features of paper currency by used Sobel-operator, Prewitt operator, wavelet transform function, and so on. The characteristics were extracted from the currency. For edge detection, the Scale-invariant function transform could be utilized to extract features. Image segmentation was used to divide an image into different segments for making the analysis simpler. Grayscale conversion methods were utilized to extract the patterns. When compared to SURF, the

ORB function extraction technique was quicker. SURF, on the other hand, provides accurate data. Accuracy is more critical than a millionth of a second in this process.

In [6] a system for identifying paper currency was proposed that takes into account the identification marks on the currency. They used seven major amounts of Pakistani paper money (PKR-10, PKR-20, PKR-50, PKR-100, PKR500, PKR-1000, and PKR-5000). Their proposed algorithm contained the following steps: Step:1: Read/capture the picture of any denomination of currency. Step:2: Binarizing the input of images through the use of Otsu's threshold. Step:3: Extraction of the Region of Interest (ROI). Step:4: Calculate the ROI's circulatory matrix. Step 5: Show the currency denomination that has been found. The image is scanned or captured by a digital camera. Basic image processing methods may also be used to eliminate noise during the pre-processing stage. Easy mean and median filtering, for example, can be utilized to filter noise. Otsu's thresholding, the most well-known form of global thresholding, was used for binarization. After pre-processed the Region on Interest (ROI) extracted. Bounding boxes, which reflected the specific identification mark, displayed the ROIs for each currency note. The proposed technique had been employed in MATLAB. According to the experiments ' results, the proposed approach effectively and accurately recognizes Pakistani currency in each of the seven denominations.

A template-matching-based coin recognition method has been proposed by [14], six different South-African coins (R5, R2, R1, 50c, 20c, 10c) were used. The Circular Hough Transform CHT, average color K-Means clusters, Local Binary Patterns LBP with Spatial Histograms, and rotationally invariant lengthened Polar Transform were all used to extract radius, color, and texture features from coin images for use in automatic identification. A sensitivity and specificity test was used to evaluate the findings. The success of the technique was shown by a 91.7 percent recognition rate.

Ultraviolet lighting was used as an identification feature in Iraqi currency[15]; there are five stages in their currency recognition process. stage1:read both the template and target image. Stage2: Used the detectSURFFeatures tool, find the feature point in both images. Stage3:used SURF function to extract the interest point descriptor. Stage4:Used the match features tool to find potential point matches. Stage5:The software looks for similarities between the goal and one of the templates, and the picture with the most match points was called a success. A set of 2400 banknotes was used, 300 banknotes pre (50Dinars, 250Dinars, 500Dinars, 1000Dinars, 5000Dinars, 10000Dinars, 25000Dinars, 50000Dinars) class. The MATLAB, too, was used. Their findings were 100 percent correct, implying that this method could be used in industrial bill acceptors with great success.

Table.1.summarizing the main points of the literature review.

Researchers	year	Type of money	algorithm	Used dataset	Accuracy recognition	Limitation
[9]	2009	Paper	Hidden Markov Model	150 banknotes from 23 countries, with 101 different denominations	98%	The suggested system's accuracy is lower.
[10]	2010	Paper	block-LBP algorithm based on traditional LBP	545 RMB sheets (87 1yuan, 135 5yuan, 84 10 yuan, 66 20 yuan, 36 50 yuan, 137 100 yuan).	100%	their approach does well when dealing with pepper noise but not so well when dealing with Gaussian noise.
[11]	2015	Banknote	The system for distinguishing fake notes from genuine notes is built using image processing and pattern recognition techniques. SVM and ANN were used to classify the data.	1000 Indian samples (500 genuine and 500 fake).	Depends on the features they chose from 0 – 100%	the crucial security feature (watermark feature) of the currency notes is not considered.
[12]	2017	Paper currency	Automatic system for currency recognition by using an image processing method	20 of the most widely used currencies.	93.3%	Fake or counterfeiting cannot be detected.

[13]	2017	Coin and paper	An automatic-mobile-recognition-system through the use of smartphone on the dataset using scale-invariant feature transform (SIFT) algorithm.	10 different types of Jordanian-banknotes (50 JD, 20 JD, 10 JD, 5 JD, 1 JD, 50 piaster, 25 piaster, 10 piaster, 5 piaster, 1 piaster).	Color SIFT has 71% accuracy rate in compared with gray scale SIFT	their system has some drawbacks when they have some cases as (too wrinkled, folded several times, image taken from a near distance, image taken from a distance that is too great) for paper banknotes and some cases as (Images with high illumination, image taken from a near distance, image taken from a distance that is too great) for coin banknotes.
[2]	2018	Paper	cost-effective and automated counterfeit currency identification method that could be used in mobile apps based on image processing methods and k-means cluster for classification.	Rs 500 -rupee note. a total of 40 actual and 20 fake notes for training and 20 actual and 10 fake notes for testing.	90%	The amount of Indian currency that can be used is limited to the Rs 500 note.
[4]	2018	Paper	digital image processing in a novel model for currency	Indian currency	Not mentioned	Review limited articles.

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			recognition. Sobel operator, Prewitt operator, wavelet transform function was used to extract the boundaries.			
[6]	2018	Paper currency	Used Otsu's thresholding tool, image processing techniques were used to distinguish the main denominations.	7 major amounts of Pakistani paper money (PKR-10, PKR-20, PKR-50, PKR-100, PKR500, PKR-1000, and PKR-5000).	Above 51%	It may lose efficiency if the picture is heavily rotated and the backdrop is crowded.
[14]	2018	Coin	Automatic coin recognition by using image processing methods for extracting radius, color, texture features.	six different South African coins (R5, R2, R1, 50c, 20c, 10c) .	91.7%	It only worked on 300DPI images.
[15]	2019	banknote	Ultraviolet lighting was used as an identification feat ure in Iraqi currency and used SURF function for detect and extract feature	2400 banknotes was used, 300 banknotes pre (50Dinars, 250Dinars, 500Dinars, 1000Dinars, 5000Dinars, 10000Dinars, 25000Dinars, 50000Dinars) class	100%	It only worked for Iraqi currency recognition.

3. Background

Image processing and machine learning have both been linked to computer vision. The field of computer vision, which encompasses a wide range of disciplines, has long been related to the subject of image processing. Image processing has benefited several fields of technology, particularly in the analysis of pictures to extract the essential information. Computer vision has been extended to various technical domains such as geographical-remote-sensing, robotics, computer and human-communication, healthcare, and satellite-communication as a technological area to be developed with it. Researchers interested in computer vision can utilize their newfound knowledge to predict specific occurrences by studying and extracting characteristics from pictures and videos. Because computer vision advances are intimately linked to image processing and machine learning, it may be applied to a wider range of studies to anticipate or identify object behavior and features, such as human activities and natural phenomena [16]. Using image processing methods for paper currency identification has become the hottest topic in the research area to decrease the problems that the economy of almost all countries faces with counterfeit money.

3.1 Computer vision

The science of giving computers or other devices eyes, or the ability to see, is known as computer vision [17]. The aim of computer vision is twofold. Computer vision attempts to develop digital models of the human visual system from the standpoint of biological science. From an engineering perspective, computer vision seeks to create intelligent devices that can handle some of the functions that the human visual system could (and even surpass it in several cases). Many vision activities include extracting 3D and temporal detail from time-varying 2D data collected by one or more television cameras and recognizing such complex scenes in general[18].

It is a multidisciplinary discipline that could be categorized as a subfield of artificial intelligence and machine learning, and it may use advanced methods as well as general learning algorithms [19]. The relationship between AI and computer vision shows in figure.1.

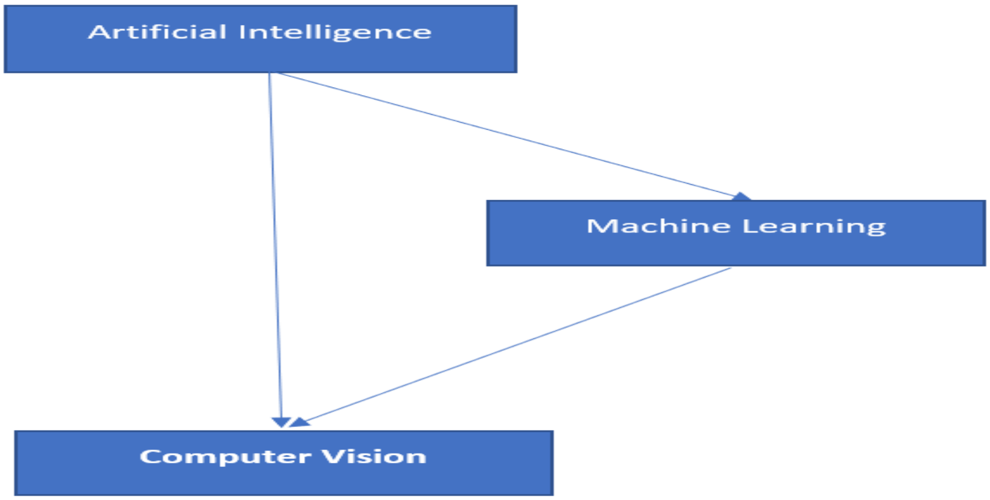

Fig.1: Relationship between AI and computer vision.

3.2 Computer Vision and image processing:

Computer vision is not the same as image processing.

The method of generating a new image from an existing image, usually by simplifying or improving the content in any way, is known as image processing. It is a form of digital signal processing that is unconcerned with image material comprehension[19].

Many well-known machine vision applications include attempting to recognize objects in images, such as; Classification of Objects, Identifying an Object, Verification of the Picture, Object detection, Object Landmark Detection, Item Segmentation, Item Recognition [19].

3.3 Image processing:

Image processing is used in a wide range of industries, but it is mostly used for two purposes:

1. enhancing the visual quality of photographs for human observers, including printing and transmission, and
2. arranging images for measurement and study of the characteristics and objects shown by them [20].

3.3.1 Image Processing Stages:

Image processing stages, including; Acquisition, Image Enhancement, Image Restoration, Color Image Processing, Wavelets and Multi-Resolution Processing, Image Compression, Morphological Processing, Segmentation Procedure, Representation & Description, and Object Detection and Recognition [21] , are implemented in numerous applications. Some of the stages are utilized in the currency recognition applications, such as (Acquisition, Image Enhancement, Segmentation Procedure, Object Detection and Recognition), which will discuss briefly in the below subsections.

3.4 The identification system's general structure:

The identification system's general structure is shown in figure.2.

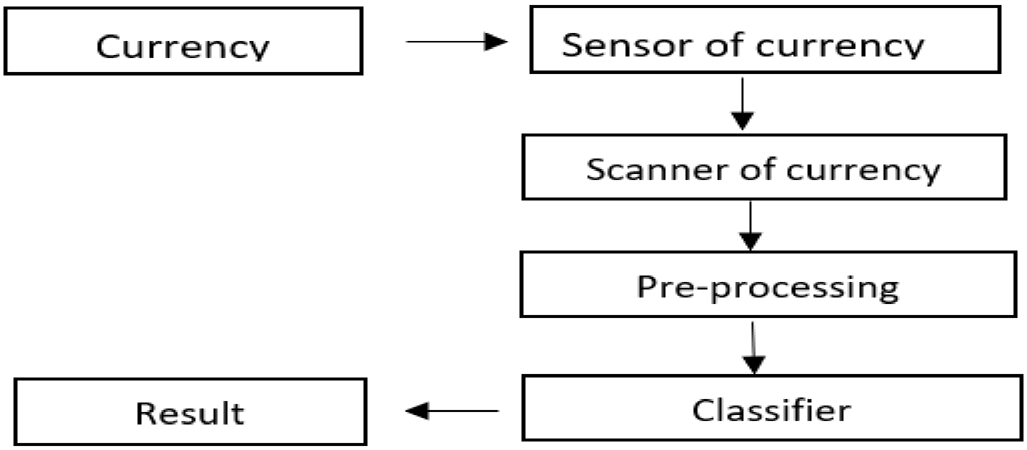

Fig.2 General structure of the recognition system.

3.5 A Paper Currency Recognition System in Its Most Popular Form:

The picture captured by the input system must be of excellent quality. The archive stores identical images (in terms of size and quality). Image collection, pre-processing, including noise reduction, attribute extraction, detection, and identification, are also part of the system [3]. The construction of the money recognition system is shown in figure.3.

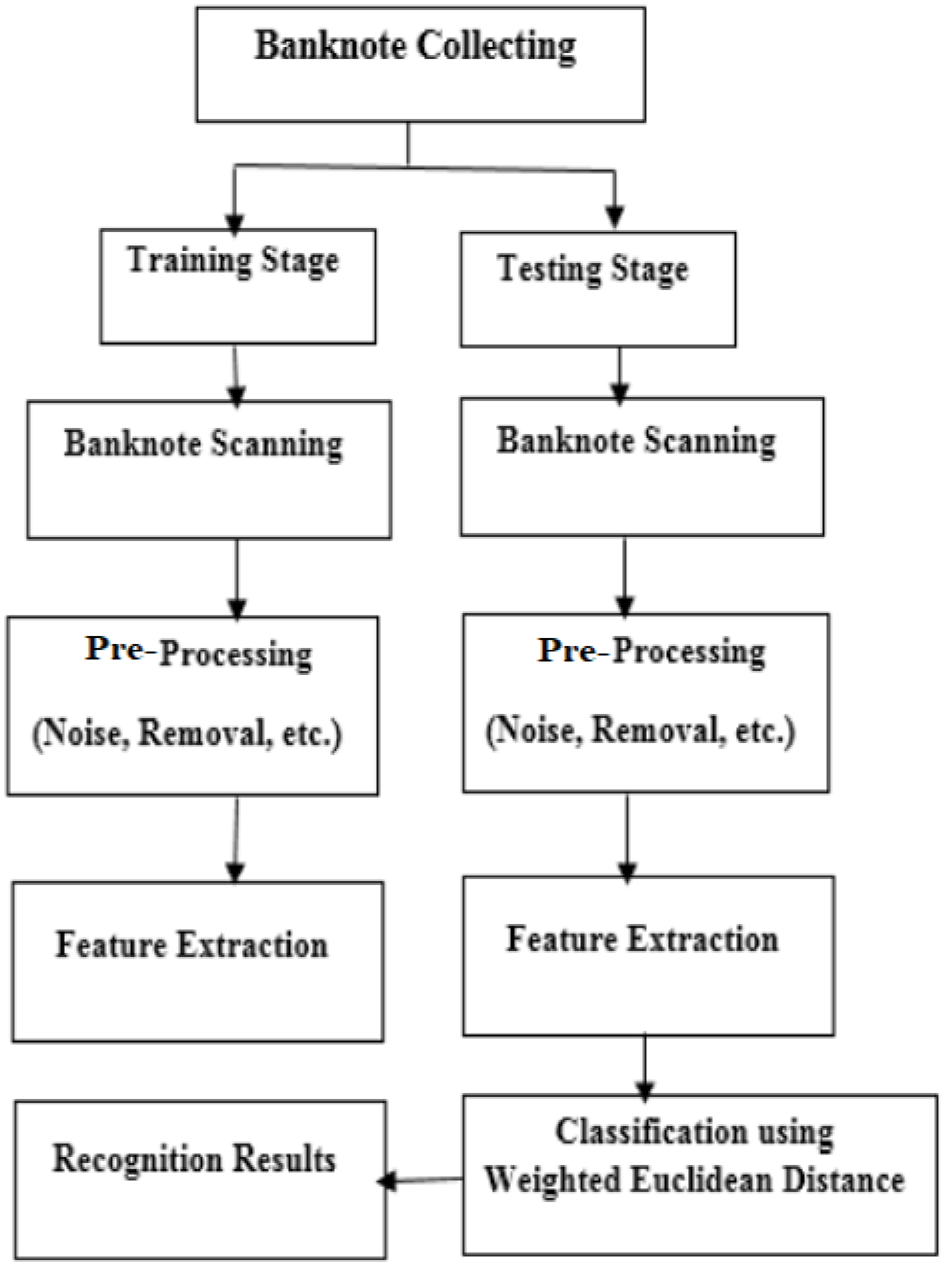

Fig.3: construction of a currency recognition.

3.5.1 Steps for Recognizing Paper Money:

The following procedures are done in every Currency Recognition System:

Stage1-Image Acquisition:

It is the process of creating photographic images with the use of a digital camera. After that, the image is saved in order to be stored [22].

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Stage2Pre-processing:

Unwanted noise must be filtered at this point so that processing can begin. The median filter is used to smooth the images in order to minimize noise. To find the median, a median filter of 3*3 neighbourhoods is used; Figure. (4) gives a sample of a median filter [3].

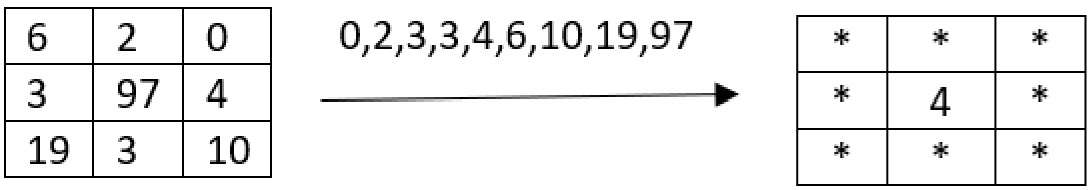

Fig.4: 3x3 of Median Filter (from [3]).

Following that, the image enhancement stage is utilized to upgrade low-contrast photographs. It is a dark picture if the histogram of a grayscale image shows a gray degree clustered toward zero. The gray level would be concentrated more at the upper end, towards 255, in brighter photographs [23].

Stage3-Edge Detection:

The aim of edge detection is to distinguish points in a digital picture where the image brightness differs sharply. To limit the currency banknote that is the region of interest, edge detection is needed [24].

Stage4-Image Segmentation:

This splits the picture into its component parts or ingredients. The majority of dull image segmentation algorithms are based on two properties:(a. Discontinuity. b. Similarity.). The bwlabel operation has been used in image segmentation to identify the connected components in an image or part of an image. Each group of pixels must be linked [23]. Figure (5) depicts a binary image with three linked elements.

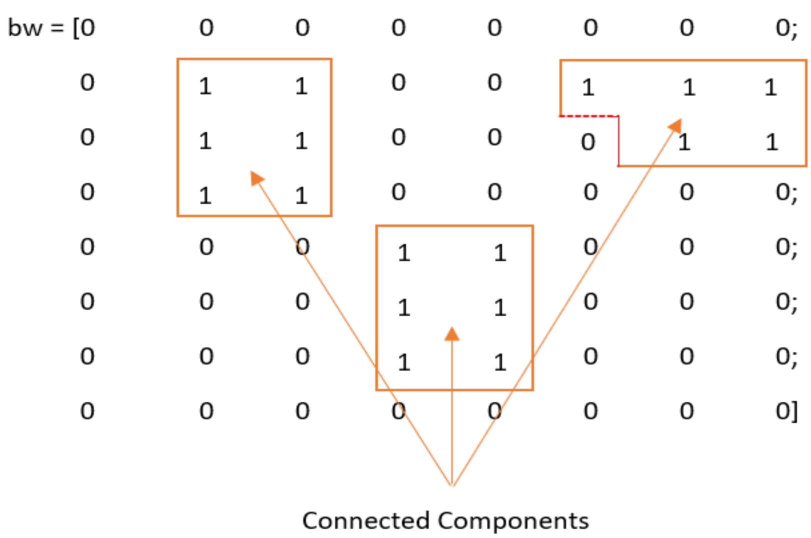

Fig.5: 3 linked components of Binary image (from [3]).

Stage5-Feature Extraction:

This stage is the most complex since it includes a currency gratitude scheme. The aim of this stage is to identify each denomination's single and unique geographies in a variety of challenging circumstances, including old and damaged notes, as well as different lighting and environments [25].

Stage6-Matching Algorithm:

This stage extracts a number of exceptional features that are used to identify or classify currency notes of various denominations [3].

4. Discussion

After reviewing the above articles, we understood that image processing techniques are crucial for recognizing objects in the image, especially for currency recognition.

In the [9] article the authors used HMM for recognizing paper currency of different countries by using image processing techniques like Wiener filter was used to pre-process the banknote and to lessen the computational workload the banknote image was converted to a 64-grayscale image and the transformation matrix's main diagonal value was determined and compared to database values. The accuracy of the results is 98 percent. The drawback of this research might be the suggested system's accuracy is lower.

In the [10] article, the authors used the block-LBP algorithm based on the traditional Local-Binary-Pattern method for feature extraction for six types of RMB recognition, including (1, 5, 10, 20, 50, and 100 yuan). Their proposed approach has the advantages of being fast and straightforward. But the limitation of this paper is their approach does well when dealing with pepper noise, but not so well when dealing with Gaussian noise.

In the (Roy *et al.*, 2015; Singh, Ozarde and Abhiram, 2018) , their system was robust to recognizing fake Indian banknotes from real one by using SVM and ANN to classify the data. But the drawback of their system might be that the crucial security feature (watermark feature) of the currency notes is not considered. But in the[2] article, they used security features and k-means for unsupervised learning (clustering) for recognizing the real and fake currency notes by comparing with fixed threshold value.

In the (Abburu *et al.*, 2018; Ansari and Mahraj, 2018) articles, their system focused on extraction the region of interest (ROI) of the banknotes for currency recognition. The limitation of their system might be Fake or counterfeiting cannot be detected and may lose efficiency if the picture is heavily rotated and the backdrop is crowded.

In (Abu Doush and AL-Btoush, 2017; Rajan *et al.*, 2018; Abbas, 2019) articles, in their system they used SIFT and SURF techniques for extracting the important features of currency banknotes for currency recognition. But in [13], their automatic system highly effective for currency recognition by using color SIFT and gray scale SIFT and when they compared color SIFT descriptors to gray SIFT descriptors, the assessment results revealed that color SIFT descriptors outperformed gray SIFT descriptors in processing time and accuracy rates as shown in figure.6. Their system has the disadvantages as they mentioned in their research because when they have some cases as (too wrinkled, folded several times, image taken from a near distance, image taken

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from a distance that is too great) for paper banknotes and some cases as (Images with high illumination, image taken from a near distance, image taken from a distance that is too great) for coin banknotes.

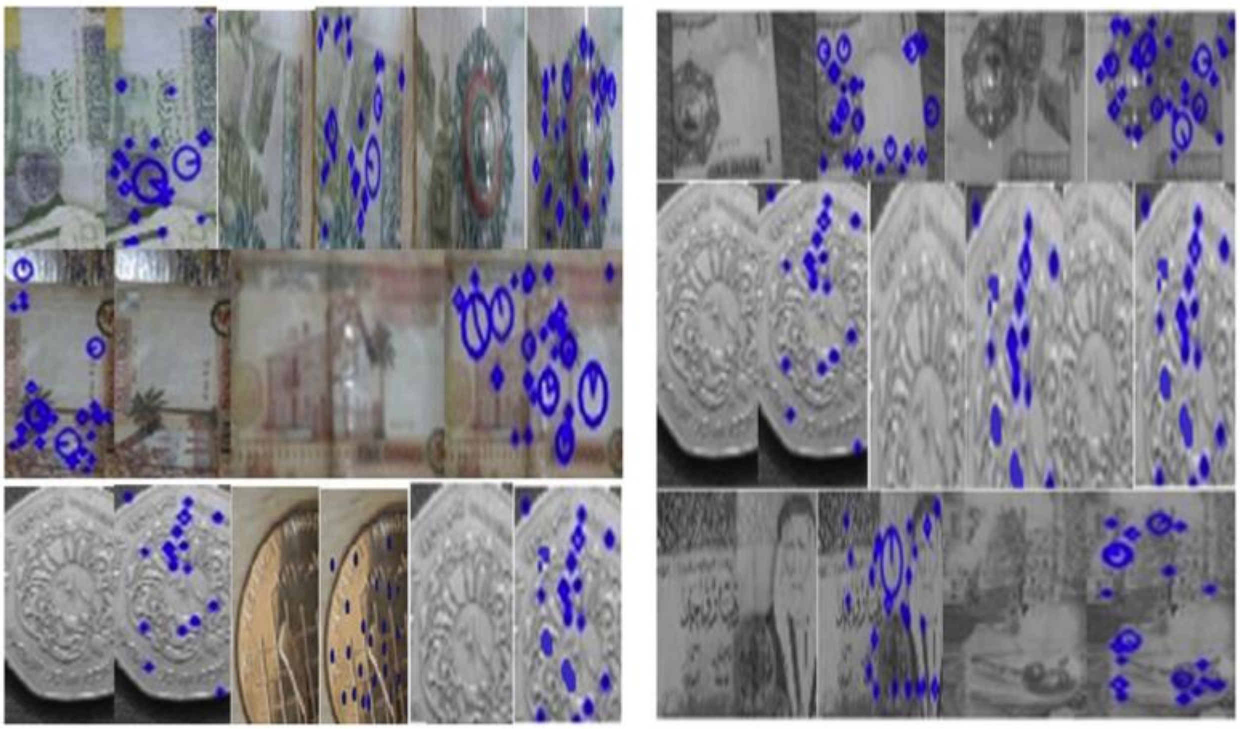

Table 2 Correct recognition average and processing time average for color SIFT approach.

Banknote type	Average correct recognition	Average processing time (s)
Paper Currency	0.71	72.9
Coin Currency	0.25	78.2

Table 3 Correct recognition average and processing time average for gray SIFT approach.

Banknote type	Average correct recognition	Average processing time (s)
Paper Currency	0.53	72.4
Coin Currency	0.20	80

Fig.6.Samples of the tested banknote and the key-points detection from color and gray-scale currency images and table.2 and table.3 shows the comparison results among color SIFT and gray SIFT approaches [13].

In [14]article, their experiments were very effective for recognizing South African coin. The limitation of their research is they only worked on 300DPI images as mentioned in their research.

5. Conclusion

There are too many automatic systems built based on image processing techniques, including pre processing, edge detection, image segmentation, and feature extraction to efficiently identify paper currency recognition and coin recognition.

After reviewing the above articles, we understood that the currencies have different features, and choosing the best techniques to extract those features is crucial. For currency recognition, some of the articles used the LBP technique for extracting the features from currency. Some of them used SIFT and SURF. Some of them are based on characteristics including; scale, color, and text; their system extracts the region of interest (ROI). And some of them utilized color SIFT and gray SIFT after comparing color SIFT descriptors to gray SIFT descriptors. Their assessment results revealed that color SIFT descriptors outperformed gray SIFT descriptors in processing time and accuracy rates.

To conclude this review, several comparisons have been noticed; some features, including (SIFT and SURF), invariant in terms of both rotation and scale by looking for the key points from currencies on the whole scale space and they produced more accurate results. On the other hand, both techniques are complex mathematically and computationally. However, the LBP technique deals with light changes, and it is very simple and fast. Finally, building upon the findings of this review, future researchers for detecting counterfeit notes should focus on extracting the more crucial security feature (watermark feature) of the currency notes.

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