Currency Recognition System Using Image Processing

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***Abstract*—In this paper, we propose a system for automated currency recognition using image processing techniques. The proposed method can be used for recognizing both the country or origin as well as the denomination or value of a given banknote. Only paper currencies have been considered. This method works by first identifying the country of origin using certain predefined areas of interest, and then extracting the denomination value using characteristics such as size, color, or text on the note, depending on how much the notes within the same country differ. We have considered 20 of the most traded currencies, as well as their denominations. Our system is able to accurately and quickly identify test notes.**

***Keywords*—Image Processing, Feature extraction, Aspect ratio, Denomination, Binary image, Currency recognition**

I. INTRODUCTION

According to the survey conducted by the CIA [7], there are around 180+ currencies presently circulating in the world. Each of these currencies differs greatly in features such as size, color and texture. Unlike the olden times, the trade and commerce between countries has increased in all sorts of levels. The need for acquiring knowledge about all the currencies by the banks has been extremely important. However for any human teller to recognize each note correctly is something that is not feasible. Thus the need for an efficient automated system that helps in recognizing notes is pivotal for the future.

In this paper, we propose an automated system for currency recognition using Image processing techniques. Our system works for 20 of the most commonly used currencies. These currencies are listed in Table I.

The method being used is shown as a block diagram in Fig. 1. The nature of each image is firstly refined to convert it into a usable input to extract various pictorial information in the pre-processing phase. The system then extracts the region of interest (ROI) based on features such as size, color and text. Using these regions of interest, the system first determines the country of origin of the currency note. After this phase, the denomination of the currency note would be identified using the differentiating characteristics of each note within the same currency. As mentioned earlier, these characteristics would be size, color or text, based on the country of origin of the currency note.

TABLE I. LIST OF CHOSEN COUNTRIES

S No	*Country*
1	Australian Dollars
2	Canadian Dollars
3	Chinese Renminbi
4	American Dollars
5	Danish Krone
6	Euro
7	Hong Kong Dollar
8	Indian Rupee
9	Indonesian Rupiah
10	Kuwaiti Dinar
11	Mexican Peso
12	Norwegian Kroner
13	New Zealand Dollar
14	Philippine Peso
15	Japanese Yen
16	Russian Rubles
17	Saudi Riyal
18	Singapore Dollar
19	Swiss Franc
20	UAE Dirhams

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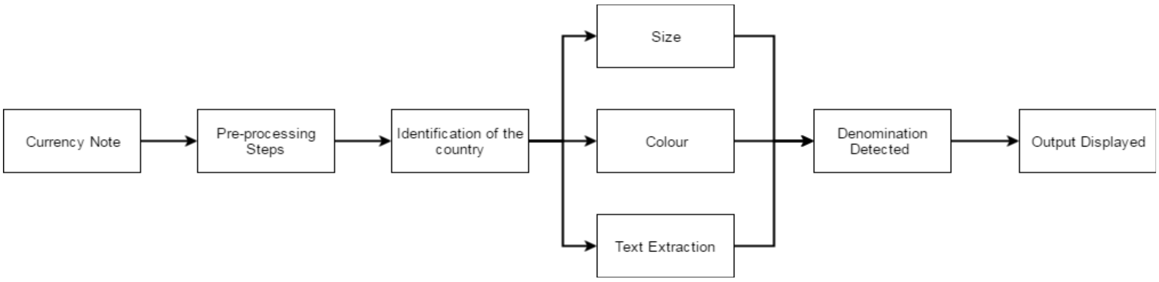

Figure 1: Block diagram of proposed system

This paper is organized as follows. Section II deals with the previous works done in the field of currency recognition. Sections III and IV outline the proposed method by explaining the various techniques and parameters in detail. Section V presents the results obtained by the implementation of the model. Finally, Section VI concludes the paper.

II. BACKGROUND MOTIVATION

Around 180+ currencies are available around the world and the need for an automated system related to currencies has been increasing exponentially recently. The need for developing systems that process notes without human intervention for various different uses has been pivotal for the development of systems that help in detecting and recognizing currency notes. However the varying features in each notes and the security aspects involved in different currencies make this task extremely difficult. Various systems have been proposed in the past that take into account different features such as aspect ratio and HSV values [7]. Methods such as pattern matching have been proposed to develop a system that uses a single algorithm for all the currencies. However not a single method has proven to be efficient enough for actual development thereby making this problem statement an interesting area of research.

One of the first methods proposed to identify the currency notes using image processing techniques was in the early 90's. However their algorithm does not take aspects of authentication of the notes into account. Thus it has been assumed that the notes are in good condition and images as desired are obtained. It is noteworthy to mention that the system proposed requires the input images to be taken in a predefined angle and distance. The system proposed then applies a series of pre-processing steps on the input images and then extracts certain features such as hue, saturation and value parameters in order to compute a Euclidean distance using these values and compare them with the values that are used as standards. Though this method tries to propose an overall algorithm for all the currencies, it is not an efficient method to identify the notes as certain notes across countries have similar features.

In the paper [3] a method was discussed have which was similar to the previous method discussed where the system extracts certain features of the currency notes and compares them with the database in order to identify the note. However, this method takes into account a large number of parameters such as height of the note, width of the note and also applies certain techniques such as Prewitt method and Canny Edge Detection to obtain the other parameters that help in calculating the Euclidean distance.

In the paper [2] a method is developed that processes the input image first before extracting features for recognition. The Weiner filter was applied on the input image and the image is then converted gray scale for uniformity. The feature that is focused by this method is the diagonal vector which is then compared with a set of values from the database that helps in identifying the note.

As previously discussed, there have been various systems that have been proposed in various papers [5] [6] [4]. However one can learn from their results that none of the systems proposed is completely efficient and that taking into account a single parameter for this problem statement is not helpful. Hence we propose a system that takes into account various different features understanding the differences in each note. We aim to build our system in a way that it is easily scalable and gives an accurate result.

III. METHOD

In order to differentiate the currency based on two different parameters (country of origin, and denomination), we segment the problem into two steps:

- First, identify the country of origin
- Identify the denomination (value) of the note

The reason we chose this approach is based on the observation that various notes of different value (denomination) from the same country generally can be differentiated based on certain features such as size ratio, color, or in the worst case, a text extraction to obtain the value from the note itself.

The full method has been described briefly below, and a more detailed description can be found in Section IV:

A. Pre-processing

The image of the banknote must first be pre-processed to remove any extraneous noise. This is done by applying a simple de-noising filter. The image is then converted to a binary image using adaptive thresholding. This allows us to identify the empty regions of the banknote as those with all black pixels. Note that these empty regions correspond to regions that are free of any foreground objects in the actual banknote. Although there may be some background patterns, these will be removed by de-noising followed by converting to a binary image. The image is also resized to allow for easier computations.

B. Identify the country of origin

1) *Identifying empty regions:* Once the pre-processing steps have been done, we can identify which regions of the note are relatively empty (black pixels in the binary image). This is done based on certain predefined areas. All the currencies are clustered into groups based on which regions of the note are relatively empty. We have chosen to divide them into 3 groups – left side empty, right side empty, and center empty, although if the number of currencies were larger, we could possibly use a larger set of groups (top empty, bottom empty, etc.). Grouping is done by finding out the ratio of black to white pixels for the required region, and then classifying the note based on this ratio. The values chosen to classify the notes have been found experimentally. Note that some notes have no significant empty space, and therefore don't fall into any of the groups. These notes are classified into another group.

2) *Using template matching to identify country of origin:* Once the banknote has been segregated into one of the predefined groups, we can check the image against templates for each of the countries within that group. Note that this is requires less comparisons than checking the image against all templates of every country in the system, and is the reason we have chosen to segregate the countries into such groups. The templates are chosen such that they are small (thus requiring less computation) but still uniquely identify the country of origin. Thus, the templates are chosen to be uniform symbols such as the country's seal, name of the country itself in stylized font, etc. We can also template match the given banknote in only the region that we know a certain symbol will be, if the location is uniform across all denominations. For example, the maple leaf symbol on the Canadian Dollar can be used as a template, as its location is uniform across all Canadian notes (top left corner). Thus, we can template match for the Canadian maple leaf in only this section of the note. This reduces the amount of computation.

C. Identify the denomination

Once the country has been correctly identified in the previous step, we can try to identify the value of the note. There are three different approaches used for this purpose:

- Size ratio
- Color
- Text extraction

The methods are listed in order of increasing computation time. Some countries have banknotes that can be easily differentiated by the size. If the country of origin has been identified as one of these, then we can simply compare the size of the given banknote with the known sizes of all the denominations.

In some countries, the banknotes are of too similar size to differentiate them based on this feature alone. In that case, we can try using difference in color between the different denominations. For this, the k-means clustering algorithm is run on the given banknote to extract the dominant color. This is done on the image in LAB color space. LAB color space consists of 3 channels: the L channel corresponds to lightness value, and the a* and b* channels represent the color value. LAB color space provides a more accurate perception of color. Once the value of the dominant color is obtained, we compare it with the known color values of all the denominations of that country. The denomination that has the least square distance of the a* and b* channels is the one with the least color difference, and is selected as the actual denomination of the note. If both the above methods fail, then we must extract the value of the denomination from the note using text extraction. As this is the most computationally intensive method, we only apply this is case of countries such as USA, etc. where both the color and size does not vary too much between the denominations. If both the other methods do not work, this method is sure to work, as all banknotes have the value of the denomination written on the note in at least one place. Thus, any of these three methods works for every note in the set of currencies taken.

The algorithm of the proposed system has been detailed in two parts. The first part (Algorithm 1) details the identification and classification of notes based on empty regions. The second part (Algorithm 2) deals with notes for which we have to use template matching (as they do not have much of empty regions).

Note that the value of r used in the algorithm is the ration of the number of black pixels to white pixels within a particular region. The percentage values that are indicated in the algorithm to identify the notes have been determined by us experimentally.

IV. ALGORITHM

Algorithm 1: Identification using empty regions (in the center, left, or right portions of the note)

1: Convert the image to black and white
2: Extract the center region
3: Calculate r as the ratio of number of black pixels to the number of white pixels
4: if r < 2% then
  4.1: Output: Japanese Yen
  4.2: Determine denomination using text extraction
5: end if
6: Extract the rightmost region
7: Calculate r as the ratio of number of black pixels to the number of white pixels
8: if r < 1% then

8.1: Output: Russian Ruble
8.2: Determine denomination using template matching
9: else if r < 3.7% then
9.1: Output: United Arab Emirates Dirhams
9.2: Determine denomination using text extraction
10: else if r < 4.1% then
10.1: Output: Philippine Peso
10.2: Determine denomination based on color using K-means clustering algorithm
11: else if r < 5.4% then
11.1: Output: Kuwaiti Dinar
11.2: Determine denomination using template matching
12: else if r < 7%
12.1: Output: Hong Kong Dollar
12.2: Determine denomination using text extraction
13: end if
14: Extract the leftmost region
15: Calculate r as the ratio of number of black pixels to the number of white pixels
16: if r < 2% then
16.1: if 'Euro flag' template matches then
16.1.1: Output: European Euro
16.1.2: Determine denomination using text extraction
16.2: else if 'Starry' template matches then
16.2.1: Output: Chinese Renminbi
16.2.2: Determine denomination using Text extraction
16.3: else if 'Armor' template matches then
16.3.1: Output: Singapore Dollar
16.3.2: Determine denomination based on color using K-means clustering algorithm
16.4: else
16.4.1: Output: Saudi Riyal
16.4.2: Determine denomination based on length-by-breadth ratio
17: end if
18: end if

Algorithm 2: Identification using templates

1: if '4 headed lion' template matches then
1.1: Output: Indian Rupee
1.2: Determine denomination using K-means clustering
2: end if
3: Extract the top left region
3.1: if 'Canadian leaf' template matches then
3.1.1: Output: Canadian Dollar
3.1.2: Determine denomination using K-means clustering
4: end if
5: if 'Eagle logo' template matches then
5.1: Output: USA Dollar
5.2: Determine denomination using text extraction
6: end if
7: Extract the top right region
7.1: if 'Kiwi leaf' template matches then
7.1.1: Output: New Zealand Dollar
7.1.2: Determine denomination using K-means clustering
8: end if
9: if 'Plus logo' template matches then
9.1: Output: Swiss Franc
9.2: Determine denomination using length-by-breadth ratio
10: end if
11: if 'Norges' text is found then
11.1: Output: Norwegian Krone
11.2: Determine denomination using K-means clustering
12: end if
13: if 'Pesos' text is found then
13.1: Output: Mexican Peso
13.2: Determine denomination using K-means clustering
14: end if
15: At this point, all checking techniques have failed
15.1: Output: Australian Dollar
15.2: Determine denomination using K-means clustering
16: end

V. RESULTS

To identify the country of origin, we have first segmented the note into a group based on presence or absence of empty regions in certain pre-defined areas. Then, we classify the note by doing template matching with templates that characterize the banknotes from each of the countries in the group.

For demonstration purposes, the Canadian 20 dollar bill is chosen. It is shown in Figs. 2 and 3, before and after preprocessing steps.

Figure 2: Original Image

Once the image has undergone preprocessing, to identify the country of origin, we template match it against the templates of all the countries within its group.

For Canadian notes, we have chosen to use the maple leaf that is present in the top left corner as a template, as it is present in all the Canadian notes, and is a simple enough image.

Figure 3: Pre-processed image

The result of template matching is shown in Fig. 4

Figure 4: After template matching

Once the country has been determined, the denomination should be identified. This can be based on color, size, or text extraction. The color of the note can be used to differentiate notes such as Canadian Dollar, Mexican Pesos, etc., as they vary in color significantly between different denominations. This can be seen in Fig. 5 where all the Canadian notes are displayed.

Figure 5: All Canadian notes

Size can be a differentiating factor when the different denominations are of significantly different size. This can be used for Swiss Franc, etc. The different denominations of the Swiss Franc and their relative sizes are shown in Fig. 6 for comparison.

Figure 6: All Swiss notes

We used Tesseract to train the system with the necessary information. The US 2 dollar note is taken as example. We resize it, and then de-noise it so that background noise is removed. This is essential to extract clean text. The image is then cropped to the area which holds the text. The text reads the denomination of the note in words.

Figure 7: Original image

Figure 8: Region of interest

We apply adaptive threshold, followed by bit-inverse to the cropped image. The adaptive threshold converts the image to only Black/White form. The bit-inverse interchanges the black and white bits, so that we get black text against white background.

Figure 9: Processed ROI

We the feed the above image to tesseract. It consequently detects the characters and gives the desired output. The average time for determining the value of the various banknotes has been tabulated in the Table II.

Overall, we have found that our system is able to accurately recognize most of the countries and denominations correctly (93.3% accuracy, where accuracy is defined as the number of notes correctly identified divided by the total number of notes tested). This is a much better result than that of the crude algorithm, which fails to recognize more than half of the given test images accurately. The crude algorithm that we used did a brute force comparison of the pixel by pixel mean square distance for each image.

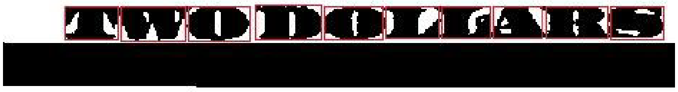

Figure 10: After text extraction

TABLE II. RESULTS

S No.	*Country of Origin*	*Average Time for Brute Force (sec)*	*Average Time for Proposed System (sec)*
1	Australian Dollars	27.4	9.70
2	Canadian Dollars	25.56	1.89
3	Chinese Renminbi	29.89	7.84
4	American Dollars	29.27	8.03
5	Danish Krone	28.5	4.23
6	Euro	30.24	7.9
7	Hong Kong Dollar	28.89	5.7
8	Indian Rupee	27.83	4.22
9	Indonesian Rupiah	26.13	5.2
10	Kuwaiti Dinar	25.56	3.71
11	Mexican Peso	24.5	5.8
12	Norwegian Kroner	28.3	2.07
13	New Zealand Dollar	31.18	3.56
14	Philippine Peso	28.3	7.06
15	Japanese Yen	30.03	2.02
16	Russian Rubles	32.3	8.34
17	Saudi Riyal	21.36	3.94
18	Singapore Dollar	27.6	3.9
19	Swiss Franc	30.29	4.19
20	UAE Dirhams	28.44	6.78
	Average	**28.0785**	**5.304**

VI. CONCLUSION

In conclusion, we have designed a system that accurately identifies both the country of origin and the denomination of a given banknote. Our system currently supports twenty of the most common currencies, but can easily be extended to more countries based on the method we have previously described. When compared with the crude algorithm of pixel by pixel comparison, our algorithm is considerably more accurate, and takes less time. We have thus learned that our proposed algorithm is able to identify currency and denomination in an average of 5.3 seconds, which is a considerable improvement over the crude algorithm. However, our proposed system only considers a limited number of currencies. There are 180+ currencies that can be included in the system, and we have chosen to only do for 20 of the most common ones. Also, the system should be effective in identifying notes that are mutilated. Our system is not effective under this consideration. This can be worked on in the future.

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