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A COMPREHENSIVE STUDY ON FOREIGN CURRENCY RECOGNITION SYSTEMS FOR VISUALLY CHALLENGED PEOPLE AND A FEASIBLE SOLUTION FOR INDIAN CURRENCY RECOGNITION

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Abstract: God created this universe along with all living and non-living beings. Human is one of the best among his creations and in Human beings, eyes are the gift of God to see His creations. As of now, humans are considered as the only developed creatures among His creations and have developed themselves from Stone Age to the Computing Era. As the human civilizations grew up, the transactions have moved from barter system to currency. Every country has its own currency in terms of coins and paper notes. Each of the currency of Individual County has its unique features, colors, denominations and international value. We, all, having been given two beautiful eyes could recognize the currency easily. Yet, many a times, it is not as easy as it seems to recognize a currency. The denomination can easily be recognized for a currency but it becomes difficult to identify a counterfeit currency from the real one. Especially for the blind people, it is a herculean task like finding a needle from haystack. This paper carries out an in-depth study of foreign currency recognition systems and algorithms developed so far in order to propose a new system for Indian currency recognition, especially, for blind people.

Keywords: Indian Rupees, Visually Challenged, Image Processing, Currency Recognition, Counterfeit, Denomination.

1. INTRODUCTION TO INDIAN CURRENCY

Currency recognition is the process of accurately identifying the paper or coin based denomination. The Indian Rupee is the original official currency of India.

The Reserve Bank of India is chief controlling authority for the issuance of the currency. The symbol for Indian rupee is ₹, designed by D. Udaya Kumar. On 15 July 2010, Government of India declared it the official sign for Indian Rupee.

In earlier days, India currency was from 1 Aana to 100 Rupees. The currency had denomination like 1, 5, 10, 20, 25 and 50 in terms of paisa. However, except ₹1 and ₹2 coins, the other coins have been discontinued and new coins of ₹5, ₹10, ₹20, ₹50, ₹100 and ₹500 have been introduced. The currency is available in a denomination value of ₹1, ₹2, ₹5, ₹10, ₹20, ₹50, ₹100, ₹500 and ₹2,000.

Each banknote has its denomination written in 18 Indian languages of which English, Hindi and Devnagari languages are used on front and back side and other 15 regional languages of India on the back side. New notes of ₹2,000 and ₹500 have different size and security features. Now, in India, the ATMs usually dispense ₹100, ₹500, and ₹2000 currency notes.

In recent years, the currency notes are slightly modified to include see through registration on the left side of obverse. Along with this, the year is now printed on the back side. Our neighbor countries try to dump the fake currencies. To prevent such fraudulent, the RBI has introduced so many security features in the currency notes to prevent fraud or printing of counterfeit notes.

In past, Indian coins were also manufactured with heavy metals. However, these traditional coins of different sizes have been discontinued by RBI.

Recently, on November 8, 2016, Hon'ble Prime Minister of India declared cancellation of existing currency of ₹500 and ₹1,000. The reasons that Prime Minister told in his Address are to curb the black money, corruption menace, to stop terror funding and Hawala business.

2. MOTIVATION, EXISTING TOOLS AND APPLICATIONS

The seeds for this work were sowed in late 2006, when one of the author was cheated by receiving a counterfeit currency of ₹500 and had to resolve that issue by destroying that currency. This lead to a loss of ₹500 to author. This sparked a thought in author's mind, that having been given two eyes, if a person could be cheated then any kind of financial cheating could happen to the blind people! From our own experiences, we learned that the currency, be it a coin or note, identification, is really a herculean task for the blind people. This laid down the foundation for our work.

In earlier days, as the previous section discusses, the coins were of different sizes and shapes and hence the identification was quite easy. Since 2011, as discussed in the previous section, RBI put an end to manufacture the coins of different sizes and introduced coins of almost same size and weight. This made the identification of coins more difficult for the blind people. The mixture of old and new coins makes the task tougher. Following are the new size and weights for the different coins as per the new regulations of RBI.

₹5	23 mm	6 g	₹10	27 mm	5.62 g
₹2	25 mm	4.85 g	₹1	22 mm	3.79 g

The paper based currencies have also been changed in their size along with other features. Following are the dimensions for the same.

Due to such minor variations in the size of the paper based currency and frequent addition of new features to enhance the security, the identification for the same becomes more difficult than the coins. And when the currency is counterfeit or tore out, the identification becomes, even more, difficult, for the blinds.

Figure 1: Currency Notes of Different Sizes

In US, all the denominations are of same size making it difficult for blind people to identify the correct denomination from another. In such situation, the Governments have provided a way to help them to tell apart the different money denominations. In countries like Australia and Malaysia, every denomination is of distinct width and length making the identification easier for the blind people.

In Canada, the currencies have provision of Braille dots representing a specific denomination. Blind people can easily read that Braille dots and know the amount denomination they are holding. In India, the RBI has introduced an embossed pattern for every currency note. But the problem with this embossing is as the currency gets older, the embossed spot gets faded.

Apart from these, the blind people themselves uses their own ways like Folding Money, A Wallet with Many Dividers, Scanners and Assistive Technology etc. to identify money.

3. RELATED WORK ON CURRENCY RECOGNITION

Many attempts have been made to provide a solution for currency recognition since 1992. This section studies all the work that has been done so far in foreign countries for currency recognition in order to denominate the currency and counterfeit currency detection to help the visually challenged people. The currency recognition is mainly based on object detection and image feature extraction. So, following text discusses the work done till date in the areas of currency recognition and image feature extraction.

In 1992, Johan Plomp, introduced an image understanding system. They described object oriented libraries containing definition of image features, operators to deal with those feature and a storage framework. Once the image features are created, links are established from this created features to source features and relation can be established [1].

The first ever direct attempt in currency recognition was made in 1993 by Fumiaki Takeda et. al., [2] They proposed a currency recognition system for US Dollars using neural network with random masks. They developed a downsizing method for neural network by slab like architecture. They noticed that even if the inputs are different, the same slab values can be obtained. Here, the slab values are the sum of input pixels. To avoid the problem which they noticed, they introduced random masks. They showed that on 32-bit computer using conventional bill recognition system, their algorithm worked fine since all US Dollars currencies are similar to each other and have similar color tone.

A genetic algorithm and neural network based optimized mask method was another successful attempt by Fumiaki Takeda and Sigeru Omatu in [3] in 1995 for paper currency recognition. They treated position of masked part as gene and sampled parental masks along with the operations like crossover, selection and mutation. They revealed that repetition of such operations optimizes the masks and currency recognition time can be shortened. To improve the recognition system, they gave another method to classify the US and Japanese currency by speeding up the recognition. They used time series and Fourier power spectra directly as input to neural network. They reduced the input scale to the neural network and thereby preventing the growth of recognition. For recognition, it uses only subset of original dataset which is generated using random masks. (two papers)

Angelo Frosini et. al., in 1996 [4], proposed a neural-based recognition and verification system named BANK (Banknote Acceptor with Neural Kernel) which was based on low-cost optoelectronic devices. It produces a signal associated with the light reflected by the banknotes. The classification and verification is carried out by a group of multilayer perceptrons which are controlled by an external real-time microcontroller based algorithm. The verification phase is dependent on auto-associators to generate separation surfaces in the patterns.

In [5] their work for recognition of paper based currency, Masahiro Tanaka and his colleagues, gave two stage process for currency recognition by image processing, namely recognition and verification. They claimed that the two stage process improves accuracy. They introduced a verification step using Gaussian distribution using probability density to transform the input data to lower dimensional space. This structure, they, named as hybrid neural network and proved accurate and computationally small.

In his work for multiple currency recognition, especially Euro currency, Fumiaki Takeda in 2000, gave an enhanced neuro-recognition system to increase more number of patterns in currency recognition. Here, they used axis-symmetrical mask and two image sensors. Of the two sensors, one is used to discriminate a known image and the other one is used for exclusion of an unknown image. This system was effectively delivered for Euro currency in 2002 [6].

J Sullivan [7] and his team-mates at Oxford presented a Bayesian approach using a learned probabilistic model of image filter-blank output and Monte Carlo method to improve efficiency. They created a probabilistic account of image data using its intensities. However, they claimed that they did not fully addressed the issue of statistical independence. They applied a bank of filters to each image whose output are statistically independent. The responses of individual filters and their distributions are learned from training data. They are used to define a joint distribution for the output of filter bank which they used for object localization.

A principal component analysis based neuro-classifier has been proposed by Ali Ahmadi and his group [8]. Here, data is acquired through some advanced sensors and preprocessed to make array of pixels. They deployed PCA algorithm to extract main features of data and reduce the data size. Along with this, an LVQ network model is used as main classifier system. It has been proved that the reliability has been increased up to 95% when proper number of PCA is taken.

In 2003, Ali Ahmadi discussed about the reliability of the neuro-classifiers for paper based currency recognition. They used a local Principal Component Analysis (PCA) to remove the non-linear dependencies among the variables and to extract the important features of the data. In this method, the data space is divided into self-organized map, called SOM, and on each region PCA is performed. Later, to classify, an LVQ (linear Vector Quantization) is used. They tested it on 1200 samples of USD to check the reliability of the classifier and it was near about 100% [9].

In [10] their work about currency recognition using neural nework, Er-Hu Zhang et. al., talked about extracting information from the images with noises. They gave a method to remove the impact of noises in images using linear transformation of image gray. They used edge detection to obtain edge characteristics from images and divided that information into different areas to get the number of edge characteristics pixels in those areas. These pixels are used as input vectors to the neural networks and using three layers BP NN sorting recognition, the currency is identified.

At NOKIA research center, Wei-Chao Chen and his teammates [11], developed a robust image feature extraction method. They implemented their SURF algorithm for computing the image features on NOKIA mobiles. Having captured the image, they calculated interest point, repeatable angle and descriptor under SURF algorithm. With this, matching the image with the feature database, the approximate nearest neighbor is decided. After performing geometry consistency check the actual image objects are identified. Their algorithm has been used in image search, object recognition and augmented reality applications.

Hassanpour and Hallajian, in [12] 2007, proposed a new feature extraction technique using texture characteristics for recognition. They employed hidden Markov chain to model the texture of paper based currency in a randomized process. They tested the method on more than 100 denominations of paper based currencies of the different countries like USA, EU, UAE and Iran.

Wang and Liew, in their work [13], used information based color representation for image classification. They stated that histogram of high resolution images contain redundant information while same for low resolution images do not contain enough information in order to classify the images properly. With this in mind, they proposed a method that takes correlation of the neighboring components of the color histogram and removes the redundant information from it. For this, they generates a high resolution uniformly quantized histogram from the captured image. Then redundant bins are removed and correlated bins are combined. This is done to increase the accuracy in classification. This information is used to evaluate the classification capacity of the feature set and iteratively the algorithm generates the histogram with its corresponding features. They proved its accuracy by implementing it on adult images to classify the images into benign and erotic images. For classification purpose, they used Ada-boost and SVM classifier.

Xu Li, in his paper, proposed a currency reader based on mobile camera for visually challenged people. This currency reader is specially made for US currency. It performs real-time processing on captured image of currency and tells the denomination. He developed background subtraction and perspective correction algorithm for currency identification. For training purpose, an efficient Ada-boost framework is used.

It processes 10 frames/second and achieves false positive rate of 10-4 [14].

For Sri Lankan currency, Gunaratna and teammates developed an ANN based currency recognition system. They used gray scale compression to minimize the false rejection of currency SL Rupee notes. A special linear transformation is used to de-noise the currency notes without losing vital currency features. This transformation performs mapping between original gray scale and smaller gray scale range of 0 to 125. After de-nosing and transformation, edge detection algorithm is applied so as to properly identify old and new currency notes. At the end, a three layer ANN is used to classify the notes and the currency is identified [15].

An image is captured via camera and that image input is given for processing in Nurlaila's work. In processing phase, image is converted into binary and gray scale. The region of interest is cropped and various functions like dilation, erosion, threshold and complement are performed on it. Later, a three layered ANN is used wherein, first layer processes the weights by a nonlinear function. These are again multiplied by interconnection weights and go to second layer. The same process is repeated at third layer which is output layer. The output gives the denomination of the currency [16].

Jianbiao He et. al., [17], in 2008, designed an ARM and uClinux based system to recognize the currency notes. For data acquisition at real-time processing, uClinux was not capable enough and hence RTLinux was introduced later for the same. A real-time control layer was added to handle the real-time hardware level interrupts. In this, the data acquisition is performed by kernel as a high priority task at control layer. By this, they improved the data acquisition for paper based currency identification.

In [18] designing of assistive device for blind in currency recognition, Remi Parlouar and group, used bio-inspired image analysis software to identify the denomination of the currency. They used real-time object identification system to increase the reliability of the system. The system prototype has been tested for daily use by the blind people and found reliable.

In [19], Debnath et. al., presented a currency recognition system using Ensemble Neural Network. (ENN) Here, a negative correlation is used to improve the accuracy in identifying the individual parts in an ensemble of the captured image. The individual neural networks are trained in ENN using negative correlation only. Since the currency in the marked could be old or new and tempered too. So, first the captured image is converted into gray scale and compressed in the desired scale. After this, each pixel of such compressed image is give as an input to the ENN. It has been tested and proved that the system can recognize currency which is highly noisy and old. Here, ENN is used to classify the currency into appropriate denomination. The system is developed for Bangladeshi Taka.

Using Local Binary Pattern (LBP), Junfang Guo proposed a block-LBP algorithm to extract characteristics of a Chinese currency image. In this, they decomposed the image into M X N blocks. The LBP value of every pixel is calculated and a histogram is generated which is called block-histogram. The block-histogram is then normalized and image features are extracted. The verification is done by comparing it with the templates in order to improve the reliability [20].

For recognition of eroded currency notes, Fatemeh Daraee developed an algorithm using wavelet transform for Farsi currency [21]. Here, the front and back sides are extracted using face-detection algorithm. Later, the central part of the currency, containing the texture, is extracted and in this region wavelet transform is applied to extract the features of the currency. With these features, using classifier, the denomination is decided and it is proved to be 80% accurate while testing.

To identify the numbers written on the paper money, Ke-Yong Shao et. al., [22] developed a method to prevent illegal trade. From pretreatment of the paper currency to identifying the digits on the note, they went through profound process. They developed the identification method based on change in the intersection between the digit character and horizontal line or arc. In the method, the distance between two points from left to right side is calculated upon change in line of intersection and compared with threshold value to determine if there is an arc or not? Here, the local difference value is confirmed through programming and highly adaptable. When classification features are less, the computing will be low and hence identification is quick and accurate up to 97.5%.

In [23], Chi-Yuan Yeh and his teammates gave method to identify the counterfeit notes using multiple kernel support vector machines to minimize false rate. Here, each banknote is divided into partitions and for each partition, the luminance histogram is created and taken as input to the system. Each partition is mapped with a kernel and then all the kernels are combined using linear weights into a matrix. Optimal weights with kernel matrices are obtained using semi-definite programming. Here, only non-negative kernels weights are considered along with the sum of the weights set to the unity in order to achieve computational efficiency in terms of time and space. The method is proved as the best in its category of SVM based counterfeit currency identifier.

In their work for banknote recognition [24], Hasanuzzaman and group at CUNY, proposed a component based framework using Speeded Up Robust Features (SURF). They proved that SURF is better in collecting and analyzing class-specific information and adaptable to viewpoint changes. Along with this, SURF handles noise, image rotation, scaling and illumination changes and proved 100% effectiveness on the tested dataset.

For Persian banknotes recognition, F Poorahangaryan et. al., developed a wavelet and ANN based algorithm. In this banknotes images are captured using scanner and they are converted into gray scale images first. On this, discrete wavelet transform is applied on it to extract the features of the currency notes. At the end, a multilevel artificial neural network is used to classify the currency in one of the eight class of denominations. The algorithm is proved 99.12% accurate upon tested on 320 samples of Persian notes [25].

In order to identify the Mexican banknotes with their color and texture features [26], Farid, Jair and Asdrubal, used artificial vision. For color, they used RGB space and for texture features, they used Local Binary Pattern (LBP). They also used Wiener pre-processing filter to de-noise the currency notes. The currency recognizer proved to be effective on severely worn, torn and mistreated notes.

To improve the performance of the currency recognition systems, Shan Gai et. al., gave a new feature extraction method using Quaternion Wavelet Transform. It gives one shift invariant and three other phases based on the applied algorithm arithmetic. Here, the Generalized Gaussian Density (GGD) is applied to capture the statistical characteristics of coefficients generated by QWT. At the end, neural network is used as a classifier to denominate the banknote. The authors tested the algorithm and is having higher recognition rate [27].

In their work for Pakistani currency recognition [28], Ali and Manzoor proposed a method by selecting appropriate feature of the currency. In the process, the captured image of the currency is preprocessed using gray scale conversion, de-noising and binary conversion. During feature extraction, various features like Euler number, area, height, width, aspect ratio etc. are extracted from the captured image. Here, MAT file is used the store image features extracted and are used for the classification purpose in order to identify the currency accurately.

In [29], Hongli Yu and Yingyong Zou developed a money number identification system to quickly identify the numbers on the currency notes. They used gray value accumulation for quick positioning and edge detection to get the ROI using least square method. In addition to this, geometrical rotation and gray adjacent interpolation is also used. Using characteristics of character structures, imaginary line and point of intersection features a recognition judgment tree is created to recognize the character. It is proved as highly accurate during the simulation.

Muhammad Sarfaraz [30], in his work, developed an intelligent system for currency recognition based on interesting features and correlation between images. For classification purpose, here, Radial Bases Function Network is used. The system was tested for 110 Saudi Arabian currencies with all possible test cases, like worn, torn, tilted notes etc. and found 91.51% accurate.

SM Saifullah and his team proposed a method for Bangladeshi currency recognition [31]. Upon capturing the image, the image is smoothened using masking in order to remove the noise. After this, the image is converted into gray and binary scale. With this, the image is segmented in terms of color, intensity, texture etc. to extract the image features. Finally, the pattern matching module decide if the currency is fake or real.

Tuyen Danh Pham et. al., developed a system to recognize the currency, fake or real, and denominate using one-dimensional line image sensor. Here, only visible light is used to identify the soiled, creased, torn or worn note. The classification of the currency is done using features extracted from the region of interest (ROI) containing little texture. A 1-level discrete wavelet transform is used to differentiate between a real and fake note. Later, the optimum DWT features representing the real and fake note are obtained based on linear regression with data measured by densitometer. The features are given as input to SVM classifier to identify the denomination of the currency[32].

In [33] and [34], Vishwas et. al., reviewed research works that have been proposed for Indian currencies and proposed a feasible solution for the same. Apart from these proposed research works, in India, real implementations of currency recognition techniques are available in ATMs and Banks. But they are affordable to the banks only, not to everyone! So there is a need to develop an affordable device or tool for the blind people in India to help them in currency identification.

4. THE PROPOSED SOLUTION FOR INDIAN CURRENCY RECOGNITION

Looking towards the need for having an affordable product that can help the visually impaired people in currency identification, we intend to devise an image processing algorithm which would be lighter in terms of computing. The proposed product will be based on the concepts of ubiquitous computing and Internet of Things. The overall process is divided into three major parts called Image Capture, Image Identification and Text-to-Speech Conversion. The following figure shows the sequence of processes that will take place in iCure.

A. iCapture

In first phase, the image of the currency will be captured by the handheld device of the blind person. It is quite possible that the captured image might not be in proper position while capturing it. So the very first step would be to re-set the image and using segmentation, remove any other background things captured apart from currency note.

B. iProcessor

Secondly, the image will be processed based on various image processing techniques Histogram, Vector Quantization, Feature Extraction etc combined with a novel algorithm for currency verification and denomination recognition. Output of this phase will be sent to iSpeaker to convert the text into speech.

C. iSpeaker

In its final stage, the recognized currency's denomination is converted into speech so that the blind person can hear the voice and be able to know about the denomination of the currency.

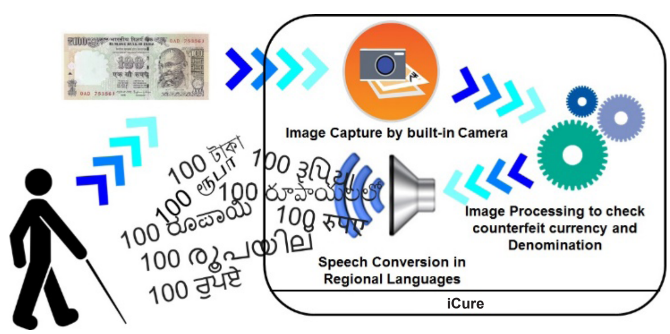

Figure 2: The iCure Process

5. CONCLUSION

This paper reviews the work that has been carried out for foreign currency recognition. The authors have proposed various techniques of currency denomination starting from digit extraction and identification to direct pattern recognition algorithms. Many methods of counterfeit currency detection have also been proposed. The research works proposed, across the globe for currency recognition systems, have successfully been converted into working models or devices for various currencies. But, for Indian currencies, a handy product has not been developed that could help, especially blind people, to recognize that if the currency is counterfeit or not. In India, real implementations of currency recognition techniques are available in ATMs and Banks only which are not affordable to everyone! So there is a need to develop an affordable device or tool in India for the blind and other people as well to help them in currency identification.

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