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Trackify: A Robust System For Preserving Money Transactions

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Abstract

Money exchange is one of the most ordinary days to day activities done by humans in the daily market. This paper presents an approach for money tracking over a Blockchain. This approach consists of three core components: serial localization, serial recognition, and Blockchain to store all transactions and ownership transfers. The system was examined with a total of 110 banknotes with different currency types and achieved an average accuracy of 91.17%.

Keywords: image processing; banknote serial number recognition (SNR); blockchain

1. Introduction

Payments can be represented by many forms of cash, check, and credit. Each type of payment requires a certain level of trust[2], except for cash. In cash exchange, the buyer and seller are directly involved in the payment process with no need for a third party member. The paper cash remains the most ordinary form of currency, however, despite being the most commonly used, it is vulnerable to theft[2]. Unlike the credit card, the paper cash cannot be traced once it is lost, unless the lost money serials are in succession.

The serial number constitute the sole source which identifies a banknote from another. Banks typically manipulate the serial numbers on the paper currency to track it in the case of thefts. That headed the more private organizations and individuals exposed as they cannot maintain track of the money they process on a daily bases. The problem is the inability to carefully track the money once it is lost. The stolen money combines with the major money without any clue of which specific papers were stolen. This problem led to the invention of Money marking system[10]. They presented a system that allows the money to be traced to its sources. They stamped each bill with the date of the

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(a) (b) (c)

Fig. 1. The location of serial numbers differs for each money type

transaction along with a unique identifier number of the owner. Typically using the unique identifier allows the owner to notify the police with this identifier and the date of the theft. The information of the transaction can be widely spread to other merchants, so, they refuse the stolen money and contact authorities. The idea was presented in the year 1979 as a USA patent, however, no one thinks about its limitation of maintaining records for all the transactions happening in the market. Nowadays using current technologies with Big Data, cloud storage and Augmented reality we can move this patent to a further dimension.

Moreover, detecting a serial number requires segmenting the serial without operating a fixed location (region of interest) with respect to the banknote dimensions. In Fig 1, there are three samples of different money currencies for Egyptian pounds (10 and 200 EGP). It is remarkable that for three types of Egyptian Money (a) 10 pounds (b) 200 pounds issued in 2016 and (c) 200 pounds issued in 2011 marked in a black box that the position of the serial number is altered from the currency category, and depending on production date too. The numbers are all written in the Hindu-Arabic numeric, and it is the target of our study.

Additionally, currency detection and tracking system [22] used the money tracking to combat the money laundering. Other criminal activities by processing each transaction and storing it on the system server. The system tracks the movement of the money to detect any illegal activities. It employs a device for printing a barcode on each currency paper. A barcode reader is used for processing the transactions which allowed the processing of bulk of money papers while adding a traceable behavior to the money transaction process. However, money tracking should rely on a reliable and trusted network to avoid fraud transactions. Moreover, having a usable currency scanning system must be usable and accessible most of the time without the need for a particular device.

One significant thing while dealing with money transactions is security, globally there is a trend of moving towards virtual money instead of physical money since the invention of Bitcoins and similar currency presented by Satoshi Nakamoto[18].

Introducing a decentralized network that is built with Blockchain to provide a secure network with no crucial point of failure, secured by cryptography, thus the network is adequately protected against attacks and fraudulent activities.

The network is trustworthy as there is no need to trust a third party instead of the system is based on Cryptographic proof. The ledger is maintained by the peers and conflicts are resolved by majority voting. This approach was adopted to implement Bitcoin [18] to allow online payment without having to rely on a trusted-based model. In the same way, Ethereum[1] introduced smart contracts where the parties can agree on a sequence of conditional execution paths based on events.

In this paper, we are presenting Blockchain for money tracking, and our system constructs a reliable network for storing transactions. Conveying the ability to early detect and track unauthorized transactions. The system is capable of scanning the serial numbers efficiently utilizing the mobile camera only, and segmenting the serial number in real-time while the user is counting the money. The presented system does not need to mark a region of interest. This approach allowed the user to count the bulk of banknotes and eliminated the hassle of scanning one banknote at a time. After processing the scanned serials, the system was capable to assign each banknote to a specific user then securely processes the transactions and stores them on the Blockchain Network. The system can be used at the beginning for the retail stores and ATMs, where cash is running on a machine by default, the same for big markets. It is also famous in Europe to pass a big amount of money ”Euros” of type 100, and 500 on Fraud machines to discover it’s originality.

2. Related Work

In order to develop a money exchange tracking system over a Blockchain, we had to segment and recognize the money serials efficiently before storing them on a reliable network. So, we summarized the related studies on three main components: 1) Tracking 2) Segmentation and Recognition 3) Blockchain

2.1. Tracking

Studying human interactions with money by tracking personal finances have been an interest of many researches[13, 3], which provides a more proper understanding of financial decisions. Examining how people interact with their money (saving, earning, spending, etc.), in order to improve the tools of tracking money. This conveyed the idea to us to track money for improving our financial decisions, and counter illegal activities.

Tracking personal finances and money can be difficult, many methods as [14]. Non-volatile organic ferroelectric memory on banknotes used to properly maintain tracking the whole transactions. While [20] used a serial number since serial numbers are one of the oldest tracking used on banknotes for tracking money. There was habitually an urge to use an external device or a complex method as [14] or adding chips to money. We mutually decided to use a similar way as [20] by traditionally recognizing serial numbers using only mobile phones instead of extra devices.

2.2. Segmentation and Recognition

Localizing text in images represent a very expensive computational cost, that’s because any of the 2^N subsets can be related to the text (where N is the number of pixels, as mentioned in a study of text localization algorithms for complex images [25]. Many methods for text localization and recognition as [27] follow the same pipeline, which starts with text localization, then segmentation, and lastly OCR processing. While other methods focused more on specialized tasks as text localization [27]. Single character recognition [4] Which leads us to Scene text recognition which is getting more interest from many research branches were detecting and labeling characters remains an active topic. Leading to many solutions that start from direct classifiers trained on hand-coded features [6] or multiphase classifiers that consist of different algorithms [21]. While some on edge features, texture shape contexts [4] others are probabilistic models [26]. On the other hand, many algorithms learn features from unlabeled data [11]. Which specifically head us to recognize the characters in images that were studied in the context of scanned documents and books [17].Others worked on recognizing currency serial number[24]. Some related work focused on recognizing Hindu-Arabic digits [19]. Additionally, Massoud et al[15] extended the Hindu-Arabic digits with a real-time capability to be able to recognize the numbers on a video stream. As for our approach, we followed the first pip line starting with text localization going through segmentation then using OCR for the recognition.

2.3. Blockchain

Elsden et al.[7] introduced a typology of Blockchain-based applications in order to address the issues of managing online privacy and peer-to-peer collaboration by including payments, voting, supply-chain tracking, authentication services, and copyright management. Pazantis et al.[23] discussed the importance of maintaining user data on a trust-less model where no need to involve third parties especially when personal data are involved. Zyskind et al.[28] introduced a decentralized personal data management system to address the trust issue and to ensure that users can have control over their data. In the same way, Chanson et al.[5] addressed the same issue, explaining how the current ever-growing capabilities can collect and analyze the user data, then showed how can Blockchain technology enables privacy. Fedosov et al.[8] introduced an interactive system that directly connects the lenders and borrower to distribute physical items. Likewise, recent work of Hepp et al.[9] focused on sharing physical objects. However, it provided an insight into using OriginStamp to preserve the data integrity of the Blockchain. In order to overcome the scalability, limitations regard the number of transactions that can be processed by the network.

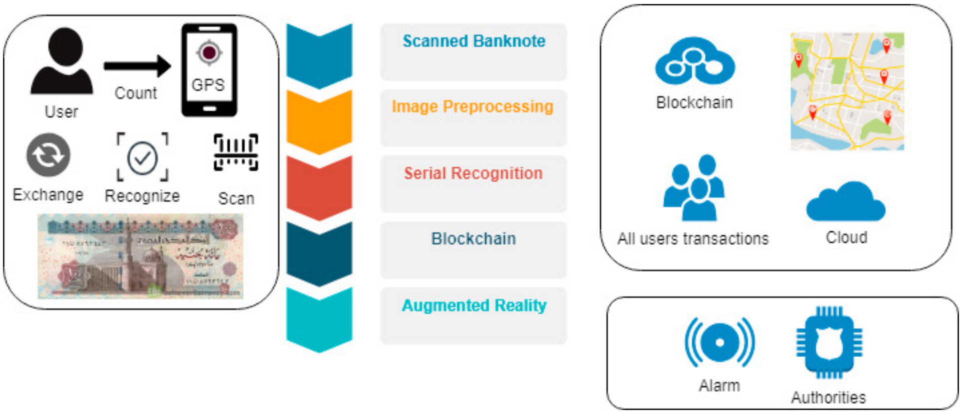


Fig. 2. The serial recognition system

3. Proposed Approach

Our methodology starts by scanning a serial number in real-time from a scanned banknote by the sender user and assign the scanned serials to another user (exchange). The system captures the GPS location while the exchange is happening, so each currency exchange location is tracked. The system takes an image of a banknote and extracts the serial location in real-time, while the user is counting his money. Afterward, the system recognizes the extracted serials and stores the new owner of these serials over the Blockchain as new transactions (Fig 2).

3.1. Serial Localization

In order to localize the banknote serial, the user counts his money using his fingers scrolling under the camera of the mobile phone. While the user counts the money, the system captures these counts and processes the frame. Fig 3 shows user counting bulk of Egyptian pounds (200 EGP) using finger scrolling.

When the system processes the frames, it is difficult to localize the serial location exactly, since the processing is on bulk money. According to some algorithms were used to detect the serial location, it will be power consuming if all the frames were processed, so the system processes on one frame per three frames[16]. The system gets captured RGB frames of banknotes (Fig 4a). Later, converts those frames into a gray level (Fig 4b). Finally, blur the frame by using the *GaussianBlur* with the size of (3, 5), to reduce the noise in the frame (Fig 4c).

The system further converts the pre-processed frame into a binary one, by using the *threshold* binarization (Fig 4d). Consequently, the serial number digits on the banknotes, sometimes have some discontinuous particles (i.e. the digits

Fig. 3. Counting money using fingers scrolling and the system detects the serial number location in real-time

(a) (b) (c) (d) (e)

Fig. 4. (a) The original(RGB) image of 200 Egyptian pounds banknote; (b) The grayed image; (c) The blurred image; (d) Image binarization; (e) Morphological filtering

are not clear enough) and some further noise. On the contrary, to further reduce the noise, the *morphologyEx* filter is applied to the binary frames (Figure 4e), this filter smooths the boundaries and removes the dark dots isolated in the bright regions.

The morphological filtered image is then segmented for discovering the digits of the serial numbers from the large banknote image. Hence, the system finds the contours of the binary image using the *findContours* method and then extracts the straight bounding border from each contour as shown in (Fig 5a). The system filters the borders by putting some constraints on each border, such as width, height, and aspect ratio where $aspectratio = height/width$ (Fig 5b). All the borders that satisfy these constraints are considered as digits.

In order to extract the digits on the serial, the system calculates the Manhattan distance to get the distance between each border, but first, the system sorts these borders from left to right to make it easy to get the appropriate distance in quick time. The system extracts the serial according to the nearest seven borders, then this is mostly the correct serial number (Fig 5c). The number of the nearest borders can be configured and redeployed according to the targeted currency. As well as, the system takes the first digit and the last digit and creates a border that fits all the serial number digits (Fig 5d). At last, this border sent to the number recognition model to be recognized.

3.2. Serial Recognition

The recognition engine is a server that is based on Tesseract (Open Source OCR Engine)[12] for recognizing numbers. Whereas, implementing engine with Tesseract gave us the ability to adapt to any currency just by changing the dataset.

3.3. Blockchain

We have changed some components of the Blockchain to adapt the traceable structure that we are introducing. After the recognition, a request is sent to the banknote owner, where he/she chooses whether to complete the transaction or not. Upon accepting, the original banknote owner sends a transaction request, so, he/she can transfer the ownership of

(a) (b) (c) (d)

Fig. 5. Image segmentation: (a) Displaying all the borders without any filtration; (b) Filter the borders by width, height and aspect ratio; (c) Extract the digits on the serial numbers; (d) Extract the whole serial number

the banknote using the mobile application. In order to verify the integrity and ownership of the banknote, the owner creates a signature using his private key, transaction location, and the new owner public key. According to, the server verifies the signature and validates if the transaction is initiated by the real owner using the public key provided along with the transaction. Afterward, the transaction is confirmed and attached on the Blockchain. The Blockchain consists of several blocks that hold the confirmed transactions. Each block consists of transactions, timestamp, nonce and the previous block hash that is used to generate the new block hash. Each new block is linked to the last block of the chain. This link is created by using the previous block hash in the process of mining the new block hash, this assures the inability of any external changes as the node is able to verify the whole chain by checking the validity of the hashes. However, the previous changes affect the high-level components of the blockchain. As future work, further customization within the core logic regards the block structure, verification and storage are needed for optimizing blockchain performance on a larger scale.

4. Experiments and Results

4.1. Recognition Accuracy

4.1.1. Setup

In order to test the segmentation accuracy, we run an experiment on four classes of money 5, 10, 20, 100 and 200 with the quantities 22, 22, 22, 22 and 22 respectively, we added 20 old paper with random quantities and calculated there detection accuracy with a mobile device with 12 MP camera, a Snapdragon 636 Chipset, 1.8 GHz octa-core CPU, an Adreno 509 GPU, and 3GB RAM that provided a stable 30 FPS through the experiment.

4.1.2. Recognition Accuracy

We have repeated the test for each money class recognition three times then calculated the mean accuracy for each class and the total accuracy for all the classes combined in Table 1.

Table 1. Accuracy of counting process.

Class	5	10	20	100	200
Accuracy	84.84%	91.68%	87.18%	95.45%	96.7%
Total			91.17%		

4.1.3. Results

The results show that our method has achieved an average accuracy of 91.17% for the given 433 money bills. The accuracy in the category of 20 Egyptian pounds was low due to the geometric decorations which are near to the serial number that leads the algorithm to fail to capture the pattern of the serial number. In contrary, the category of 100 Egyptian pounds tended to reach the highest accuracy as the geometric decorations tend to be further from the serial, and have less overall decoration around the serial number. The average accuracy was reasonably accepted. We believe that increasing the dataset for Hindu-Arabic digits can enhance the accuracy of recognition.

4.2. Counting Time

4.2.1. Objective

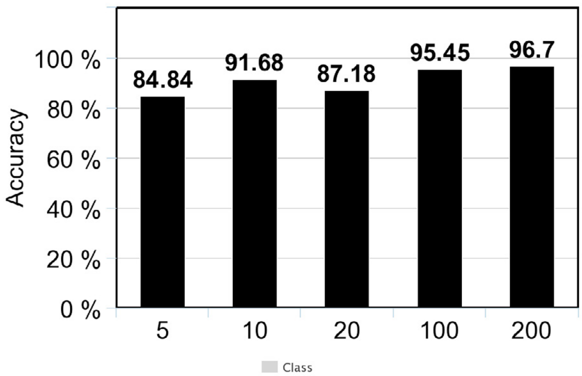
In this experiment, we were aiming to measure the time spent on counting the money in real-time using three methods: 1. Native counting without any tracking capabilities as it is not tied with any constraints to any system. 2. Counting using a fixed location (region of interest) 3. Counting using Trackify

4.2.2. Setup

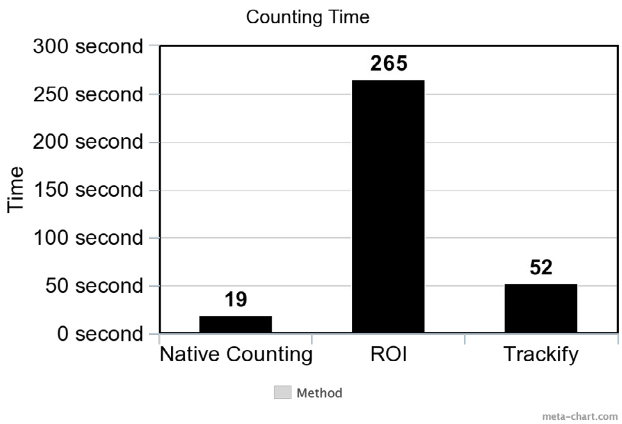
We ran the experiment on two classes of money 10 and 20 with the quantities 12 and 10 respectively. And used the same mobile device of the previous experiment,

4.2.3. Results

We have repeated the experiment for each method of counting -with a total of 22 banknotes- three times then calculated the average time. The results show that the native counting took 19 seconds, since it does not need any device or a system, it is just a trivial counting. The counting with a fixed location for the serial took 265 seconds, as it needs to manually adjust and tune the serial under the fixed location drawn on the screen. Whereas the counting with our methodology took only 52 seconds, since Trackify detects the serial location automatically.



(a)



(b)

Fig. 6. Results: (a) Accuracy of counting process for each money class; (b) Counting time

5. Conclusion

In this paper, we have presented a money tracking system using the serial number printed on it. The system segments the serial using image processing techniques. The system converts the scanned image to a Grayscale image, then reduces the noise by the Gaussian blur, then converts the image into a binary image using threshold binarization, and lastly, applies a morphological filter. Afterward, the system uses Tesseract OCR for recognizing the numbers that were segmented by the image processing, and finally stores all the transactions on a Blockchain network. This system reached an average accuracy of 91.17% over the experimental results. For future work, the system can be improved by adding more value to money to attract users using the system frequently and showing some heat maps for exchange Geo locations. Also, the experiments can be conducted under normal sunlight, instead of a light bulb.

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