Recognizing Currency Bills Using a Mobile Phone: An Assistive Aid for the Visually Impaired

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ABSTRACT
Despite the rapidly increasing use of credit cards and other electronic forms of payment, cash is still widely used for everyday transactions due to its convenience, perceived security and anonymity. However, the visually impaired might have a hard time telling each paper bill apart, since, for example, all dollar bills have the exact same size and, in general, currency bills around the world are not distinguishable by any tactile markings. We propose the use of a broadly available tool, the camera of a smart-phone, and an adaptation of the SIFT algorithm to recognize partial and even distorted images of paper bills. Our algorithm improves memory efficiency and the speed of SIFT key-point classification by using a k-means clustering approach. Our results show that our system can be used in real-world scenarios to recognize unknown bills with a high accuracy.

Author Keywords
Camera Phone, Currency Identification, Visually Impaired.

ACM Classification Keywords
H.5.2 User Interfaces: User Centered Design, Prototyping.; K.4.2 Computers and Society: Social Issues - Assistive Technologies for Persons with Disabilities

General Terms
Algorithms, Design, Performance, Experimentation

INTRODUCTION
The community of visually impaired people has long been clamoring for currency that is accessible and readily distinguishable by all. Unfortunately, different denominations of U.S. and Canadian dollar bills have all the same size and so blind individuals still have to rely on the honesty and goodwill of others in order to identify their money. Such individuals have been forced to come up with practical but quite fragile and easy to forget methods to organize their bills in their wallets by folding some bills while keeping those of other denominations straight, or even storing different denominations in different pockets. Consequently, relying on the assistance of others when using these currencies, has become a fact of life for most visually impaired individuals living in these countries. In places where bills have different sizes based on their denomination, other issues can arise, as the differences amongst the various denominations could be very small to be of any assistance. Even where the use of tactile markings on bills has been employed, the natural wear and tear of all bills can easily remove any such markings. Finally, assistive devices or software on the market solving this issue has been limited and usually very expensive. In [2, 4, 5] researchers have attempted to use specific and specialized techniques for locating and identifying certain regions or the actual numbers on bills. However, any such specialized techniques can be fragile and hard to port from one type of currency to another. In addition, such techniques suffer from the fact that they do not take advantage of the vast research in image feature extraction that took place in the field of computer vision in the last years.

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A CAMERA PHONE CURRENCY RECOGNITION SYSTEM
Most pictures taken by a visually impaired user would not capture the entire currency bill It is also guaranteed that the image captured may not always contain the place where the currency amount is written. Currency notes can also be folded while the picture is being taken. Further, one cannot make any assumption about the orientation, the position or the clarity of the image taken of the currency bill. To solve these issues, our system uses an adaptation of the Scale Invariant Feature Transform (SIFT) [3], on a continuous stream of images. SIFT is an ideal choice since it can perform robust classification in the face of positional, orientation, rotation and scale variants. This allows us to identify bills using any distinguishing characteristic found on them without the number printed on the bill needing to be exposed to the camera. In fact, the bill can even be folded or at an angle. The user can simply launch the application and place the bill in front of the camera. After a few seconds and Without any user interaction, the denomination can be read aloud using synthetic speech. However, "SIFT is known to be a strong, but computationally expensive feature descriptor", [6] as comparing potentially hundreds of SIFT descrip-

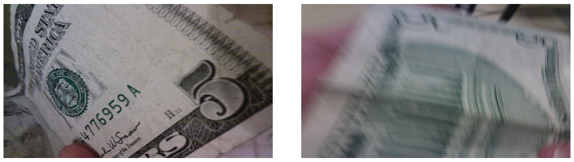

Figure 1. Images misclassified or classified with very low confidence

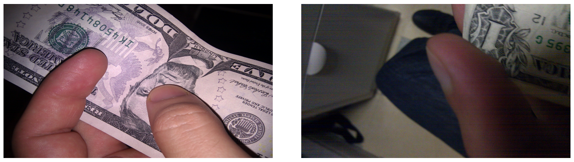

Figure 2. Images with occlusions

tors in real-time on a mobile device with limited compute resources might be infeasible. In order to make this process more efficient we have added a technique of clustering feature vectors and using only the K-means nearest neighbors for bank-note classification.

CURRENCY IDENTIFICATION ALGORITHM

Our training set consists of a collection of very clear training images taken under various luminosity conditions. More training images are artificially created by rotating the existing ones by 90, 180 and 270 degrees. We also fix the luminosity of the images employing the Gray World Algorithm [1]. Then, we use the SIFT algorithm to generate the key-points of all the training images. to enhance the speed of recognition, we use the K-means clustering technique to separate and reduce the number of the feature vectors of the training set.

In the testing phase, we first transform the images of the currency bill into black/white and fix the luminosity as above. Then, we compare the key-points of each image to the k-mean cluster points in the reduced feature vector space of the training images and determine the nearest neighbors in this vector space. This allows us to determine to which class, i.e. to which currency denomination, each key-point belongs and calculate a confidence measure based on the entropy. The latter indicates how certain we feel that the testing image belongs to a certain currency denomination. If the neighbors are evenly split between labels for example, we would want a confidence of zero. Finally, we output the highest probable class label as the currency value of the testing image.

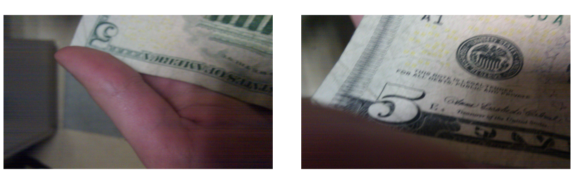

Figure 3. Images with luminosity issues

EVALUATION

We considered a set of 91 training images of \$1, \$5, \$10 and \$20 dollar bills and a set of 82 testing images that were captured by a visually impaired user. Naturally, these images are full of occlusions and are distorted.

Using our algorithm, we were able to achieve around 93% detection accuracy for currency recognition among these four categories of US currency bills. The images that were misclassified or had low confidence of classification were poorly shot images Figure 1.

Using a much larger dataset, a few but not the majority of failure cases were caused by occlusions as illustrated in Figure 2. In the same dataset, the lighting conditions seem to affect accuracy very little as the luminosity effects of shadows were shown to create errors in only a handful of images, Figure 3.

CONCLUSION

We have presented the early design, implementation and evaluation of a mobile currency recognition system that provides high detection accuracy for visually impaired users. We do acknowledge that more work needs to be done to test its robustness across a large mix of currencies.

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