A Camera Phone Based Currency Reader for the Visually Impaired

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ABSTRACT

In this paper we present a camera phone-based currency reader for the visually impaired that can identify the value of U.S. paper currency. Currently, U.S. paper currency can only be identified visually and this situation will continue for a foreseeable future. Our solution harvests the imaging and computational power on camera phones to read these bills. Considering it is impractical for the visually impaired to capture high quality image, our currency reader performs real time processing for each captured frame as the camera approaches the bill. We developed efficient background subtraction and perspective correction algorithms and trained our currency reader using an efficient Ada-boost framework. Our currency reader processes 10 frames/second and achieves a false positive rate of approximately 10^{-4}. Major smart phone platforms, including Symbian and Windows Mobile, are supported.

Categories and Subject Descriptors

K4.2 [**Social Issues**]: Assistive technologies for persons with disabilities

General Terms

Human Factors

Keywords

Visually Impaired, Camera Phone

1. INTRODUCTION

There are approximately 10 million blind or visually impaired people in the United States, and various visual disabilities [1] limit many daily activities especially using cash or for financial transactions. Often currencies are printed on different sizes of paper or with different texture for people with visual disabilities to touch and recognize. However, in the U.S. these user-friendly features are not provided for the visually impaired. The blind community initiated a law suit against the discrimination of the Department of the Treasury and won the case on May 20, 2008 [2]. Although this situation may eventually be resolved from the engraving and printing process, it may be a prolonged process and will be expensive to replace all currency already in use. Dedicated devices such as "Kurzweil reader"[3] have been introduced to help reading currency, but they are often bulky and expensive. Novel systems such as iCare[4] have also been developed to help the visually impaired people with pattern recognition. iCare uses a wearable camera for imaging and a PC for computation. We propose an alternative solution - employ the ubiquitous camera phone[5] to identify different denomination in an instant and inexpensive way.

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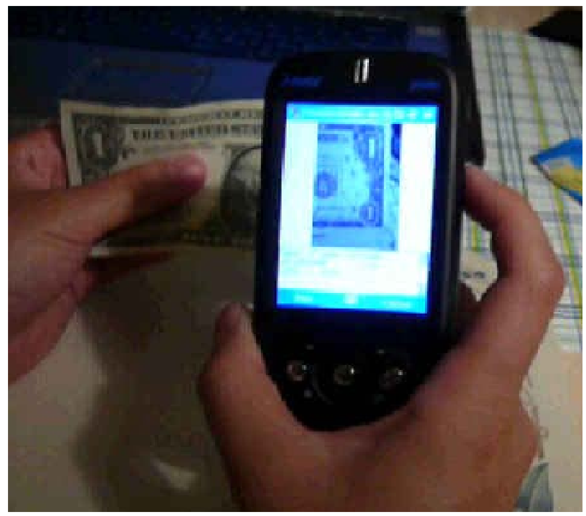

Figure 1: Currency reader for the visually impaired

The combined imaging and computational of new devices power has inspired us to embed image processing and computer vision algorithms into the devices. Although for this project we target for reading currency, the designed framework can be extended to help the visually impaired identify other objects as well.

A typical mobile pattern recognition system asks the user to take a snapshot and then the system tries to recognize the result. If the image is imperfect, the recognition may fail and the user will have to repeat the process. But we cannot expect a visually impaired user to perform such tasks and it is impractical to ask them to take high quality pictures for recognition. We choose to process the image in real time which provides a much smoother user experience. Our currency reader reads the video stream from the view finder and attempts to simultaneously locate and recognize every frame (approximately 10 frames per second), so the user can get instant response as the camera approaches the currency.

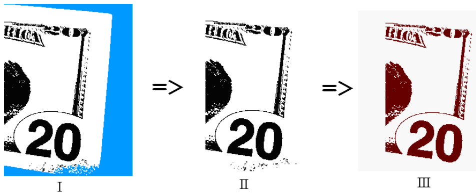

Figure 2: Background subtraction and feature area extraction

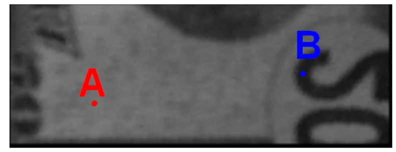

Figure 3: Normalized feature area and random pixel pair

2. SYSTEM

Our currency reader does not require extra or specialized hardware, since our algorithm relies on existing visual features for recognition. It can work on either side of a bill and the recognition result can be spoken out via the phone speaker or communicated through vibration. Figure 2 shows the feature areas used for currency recognition.

2.1 Background Subtraction

In order to detect and recognize the bill, we first remove irrelevant background. After binarization, black pixels touching the boundary (Figure 2-I) of the image are regarded as background since the bill always has a white boundary that separates itself from the backgrounds. After background subtraction, some noise (Figure 2-II) might still exist. We further refine the location of a bill by running a breadth-first-search(BFS) from the image center to remove the remaining noise. The complexity of this step is linear in the number of pixels in the image and after processing we know the exact position of the feature area (Figure 2-III). We then normalize the area to a rectangle with an aspect ratio of 4:1 for recognition (Figure 3).

2.2 Training and Recognition

We collected 1000 samples of captured images of each side of the most common U.S. bills. Each has four potential areas to recognize, two front and two back. We also collected 10000 samples of general scenes which are not currency. For each side of a given bill, we use Ada-boost[6] to train a strong classifier from a set of weak classifiers. The weak classifiers must be computationally efficient because hundreds of them must be computed in less than 0.1 second.

We define a weak classifier using 32 random pairs of pixels in the image. A random pair of pixels have a relatively stable relationship in that one pixel is brighter than the other. An example of a random pair is shown in Figure 3 where pixel A is brighter than pixel B. The advantage of using pixel pairs is that their relative brightness is not affected by environmental lighting variations. Since the same relationship may also occur in general scenes, we select the pairs that appear more frequently in the inliers (currency images) and less frequently in the outliers (non-currency images).

A weak classifier will provide a positive result if more than 2/3 pairs are satisfied and negative otherwise. The 10 weak classifiers selected based on Ada-boost form a strong classifier that identifies a bill as long as it appears in the image. To recognize a bill we only need $32 \times 10 = 320$ pairwise comparisons of pixels. Our system is trained to read $1,$5,$10,$20,$50 and $100 U.S. bills and can process 10 frames/second on a Windows Mobile (iMate Jamin) phone at a false positive rate $< 10^{-4}$.

3. CONCLUSION AND EXTENSION

We described our currency reader which assists the people with visual impairments in recognizing U.S. dollar bills. It should be pointed out that this framework is general so that new notes (e.g. the new $5 printed in 2007) can be easily added to the system. A challenge is how to distribute the software to the end users. Although we can put the software in the Web, the visually impaired may not have the knowledge and skill to download and install the software themselves. It requires the collaboration of service providers and probably government support to promote this application. We will test the usability of our solution with visually impaired users and find potential improvements. The major concern of our evaluation is the time of responding i.e. how long it will take a user to recognize a bill using the device running our software. We will also test if they feel comfortable with the way that the result of recognition is communicated.

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