Assistive Device for the Blind Based on Object Recognition: an Application to Identify Currency Bills

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ABSTRACT
We have developed a real-time portable object recognition system based on a bio-inspired image analysis software to increase blind people autonomy by localizing and identifying surrounding objects. A working prototype of this system has been tested on the issue of currency bill recognition encountered by most of the blind people. Seven blind persons were involved in an experiment which demonstrated that the usability of the system was good enough for such a device to be used daily in real-life situations.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: User-centered design, Prototyping. K.4.2 [**Social Issues**]: Assistive technologies for persons with disabilities.

General Terms: Design, Experimentation, Human Factors.

Keywords
Blindness, low vision, currency reader, object recognition.

1. INTRODUCTION
A previous study presented the design of an assistive device for the blind based on artificial vision to enhance their autonomy in navigation [1]. Many assistive devices have been developed to help blind people in their daily life, and the number of separate systems has grown to unpractical proportions. Devices relying on artificial vision are among the most useful as they can be truly general purpose and replace several apparatus at once. There would be a great advantage to rely on a single device with video capabilities to perform all kind of tasks that require visual analysis. The aim of this study was to evaluate the possibility to add another function based on vision to the assistive device previously presented in [1]. As few portable systems are able to recognize currency bills [2][3][4] -often with mixed results and for a high price tag-, we have selected the issue of currency bill recognition for the implementation of a new function to our device. The usability of systems based on artificial vision is generally low because the user must capture several pictures for a proper recognition [2]. This is not the case with our system as recognition occurs continuously on the video stream of the camera.

Euro bills, as well as other currency bills, have different size depending on their face value and some specialized devices use this feature to tell them apart. The disadvantage of this method is that it is specific to a given currency and that it provides no guarantee that this is really a bill that has been "recognized". Furthermore, some currencies, such as Canadian or American dollars can be distinguished only from their visual aspect. To address this issue, we designed a portable device which is able to recognize currency bills based on visual cues only.

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2. HARDWARE AND SOFTWARE
The software was running on an UMPC (Ultra Mobile PC) VAIO UX1-XN with an Intel Core Solo processor U1500 at 1.33 GHz. Video images were captured by a low quality 320x240 pixels webcam and headphones were used for audio feedback.

The image captured by the webcam was processed by an image analysis software called Spikenet [5]. The image analysis is mainly based on the extraction of characteristic saliencies, i.e. high contrast variations, in the pattern that has to be recognized. Spikenet is able to recognize and locate targets in images after a supervised training phase and is highly robust to scale, contrast, brightness and noise variations [6]. We built all the object models to recognize the 5€, 10€, 20€ and 50€ bills from just one image sample per bill. To preserve the selectiveness of the classification, we have chosen each sample in a particular region of each bill, which contained characteristic saliencies that differ enough from one bill to the others. Each sample was rotated by steps of 12° to cover all the orientations. This finally results in 120 training samples for the four bills ((360°/12°) x 4 bills). Following this training phase, the device was able to detect a particular region of each bill (close to the plastic strip, Figure 1), within a range of three to ten centimeters, regardless of the bill orientation and at a rate of five images per second. The false positive rate could be evaluated below 10^{-8}, as no false positive classification had been observed in the context of this experiment.

Figure 1. The detected region is surrounded in red and the plastic strip in blue

During the experiment, the feedback was provided by the replay of a sound file stating the face value of the detected bill.

3. EXPERIMENTAL PROTOCOL
Seven blind people participated in this study. Their task was to identify five bills from 5€ to 50€. The subjects had first a quick tutorial to learn how to use the system. The verbal instructions we gave were helping them to maximize their efficiency with the device. This device had been developed following the principles of user-centered design. Several design choices were validated through pre-tests with blind people. The corpus of comments and remarks from these pre-tests was also compiled in a precise instruction set to

use the device, which determine in large part its ergonomics. The instructions given to the subjects were as follow:

- Find the plastic strip on the bill
- Fold the bill in half, keeping the plastic strip side up
- Grasp the camera and feel its orientation by extending a finger on its back
- Put the webcam lens in contact with the center of the half-bill
- Move the webcam backwards progressively, until the bill value is announced

The subjects were then allowed to manipulate freely the device during five minutes. This training phase was useful to minimize the disparity between the subjects, as some of them were more familiar than others with electronic devices. Finally, we asked the subjects to identify a set of five bills and we measured the elapsed time to achieve this task.

4. RESULTS

The accuracy was 100% correct as all bills were correctly identified and all subjects performed the sorting task flawlessly. The time measured showed that in average, the subjects completed the task within one minute, which corresponds to an average recognition time slightly above ten seconds per bill. This result is satisfying, according to the fact that the subjects spent more time to find the plastic strip and fold the bill than to actually use the device. The measured performance is an improvement over a similar device [7] that had also perfect accuracy scores but required on average more than 20 seconds per bill recognition.

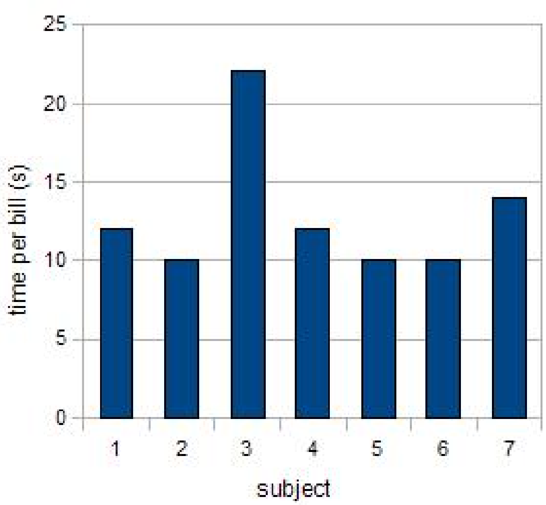

Figure 2. Average recognition time per bill for the seven subjects. The elapsed time is rounded to the nearest second.

The subjects were systematically asked about the utility, the usability and the response time of the device and any eventual improvement they could think about. The feedback was very encouraging as all subjects reported that this device would increase their autonomy because it can be quickly mastered and presents a convenient response time. They also favorably foresee the extension of the visual recognition to other classes of similar objects such as cans or cards, which is simple to implement within the current model learning architecture.

5. CONCLUSION

The object recognition method that has been used in this study to analyze the bills is very general and would work on any paper currency in the world with only minimal changes. For currencies where bills lack tactile cues such as the plastic strip, a workaround would be to use four samples per bill instead of one. This would decrease the rate of recognition to 1-1.5 image per second, which would require an additional user-centered session to restore a similar level of usability. The evaluation has also proven that deformations due to perspective, unavoidable in our context, are handled correctly by the system as a single trial was usually sufficient to recognize a bill (except for subject 3 which moved the camera too quickly).

The usability of the system in a real-world situation with potential end users was good, as six of the seven subjects declared that they would acquire such a device if available at a reasonable price.

This generic object recognition system could then be integrated in mobile systems such as camera phones and in our assistive device to extend navigation and object localization capabilities [8]. Future work would address other specific issues clearly identified by the blind community, following the idea that vision-based systems should be able to handle most of these issues.

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