An Open Source Solution for Money Bill Recognition for the Visually Impaired User using Smartphones

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Resumen According to estimates made by the World Health Organization there are approximately 285 million people with visual disabilities. In Argentina, it is estimated that there are about 6 thousand blind people per million inhabitants. These people must face daily different situations that generate physical and psychological tension conditioning their quality of life. In particular in Argentina, one of these situations is to recognize and correctly differentiate the denomination of Argentine money bills. The current system used is heavily affected by the usage of the money bills. In this paper, we present the design and development of a novel application for mobile phones that automatically recognize money bills and credit cards. The application was design with the assistance of a visually impaired user. *abstract* environment.

Keywords: visually impaired, image recognition, software innovation

1. Introduction

The Human-Computer Interaction field of Computer Science seeks to design systems that involve computers and support users so that they can perform tasks providing appropriate interactions to their needs and capabilities. This enables the systems to be accepted and used effectively. The term Interaction refers to the relationship between the human and the machine through an interface, which acts as an intermediary between two systems of different nature. More specifically, the interface is defined as the set of components used by users to communicate with computers ([1]). It is a translation system since since both user and computer "speak" different languages.

In order to obtain an effective communication between the user and the computer, the interfaces must be designed with the particular needs of the user to whom the system is directed. Using a valid and effective communication link between both parties is mandatory. Otherwise, interaction would not be possible. Today, with the growth in sales of smartphones ([5]), it is increasingly common

to use mobile applications that facilitate the development of people's daily lives. Technological advances have made possible the appearance of very sophisticated and easy to use software systems, based on the design of interfaces that are very intuitive for the user. To achieve this, modern interfaces are mostly graphic and based on different visual components such as icons, images, videos, and animations. Although this is very advantageous for a sighted person, what happens if that sense is not available or does not work at 100 %? In general, these designs are not conceived to meet the needs of people who are blind or visually impaired, this situation prevents information from being transmitted properly.

According to estimates made by the World Health Organization (WHO) in the world there are approximately 285 million people with visual disabilities, of which 39 million are blind, and 82 % of people who suffer from blindness are 50 years old or older ([3]). With regard to Latin America, it should be noted that of the 26.6 million people living in 2010 with visual impairment, 3.2 million were blind ([2]), and in our country it is estimated that there are about 6 thousand blind per million inhabitants ([4]). These people must face daily different situations that generate physical and psychological tension conditioning their quality of life. Tasks that for most people are simple and routine -like walking on the street, household chores, holding a conversation- can be a very arduous obstacle that is imperceptible to those who do not have this disability.

In particular, one of the situations that a person with visual disability must face when residing in Argentina is to recognize and correctly differentiate the denomination of Argentine money bills. This is because of the identification system for the blind that is currently used consists of small squares in setoff printed in chalcography. The quantity of those squares varies according to the denominations, and which wears very quickly with the use.

In this context, one of the challenges facing the software development community is to ensure that new technologies are adapted and available to all users, ensuring that people with visual impairment can benefit from them. In this work, we present the design and development of a mobile application intended for visually impaired users. The goal of this application is to automatically recognize money bill as well as different type of cards with an easy to use set of interactions.

The remainder of the article is organized as follows. Next section, "Previous Work", presents the research done and the solutions currently available for money recognition by visually impaired users. Then, in section "Proposal & Implementation" our solution is presented and details are given on how it was developed. The set of interaction available is also described. In section "Validation" we present the test cases done to probe the effectiveness of the application. Finally, in the last section, we draw some conclusions and outline future work.

2. Previous Work

Users with decrease or lack of their visual ability compensate this with information obtained by means of other senses. In particular, these people use the

sense of touch and hearing as the main source of information. Over time, there have been various methods for blind people or people with significant visual impairment to have access to information. The main one has been the braille method, a system based on points that allow, by combining them, to have as many symbols as those of the alphabet, making it possible to read through touch ([6]). However the braille system has two major disadvantages, the high cost of its material production and the volume of printed documents as they tend to become cumbersome.

Due to the listed drawbacks and the need for interaction with the user, they have had to look for other methods so that people with visual disabilities could have access to the information. In this field, tiflotechnology faces the objective of developing new technologies or adapting and providing accessibility to existing ones for their use and exploitation by people with visual disabilities ([7]).

There are several strategies on how to help a visually impaired person to identify money bills. Not all of them are based on software development, but in order to keep this paper under the maximum number of pages, we will limit our discussion to software-based solutions. There are two trends in the field of money recognition research, scanner-based systems and camera-based systems.

Scanner-based Systems are suitable for money counting machines and ATMs. Examples of these types of systems can be found in Trupti and Bawane ([8]). The recognition is made considering the size of the bill as one of the three most important characteristics, as well as color and texture. In addition, in Yaseri et al., ([9]), Ahmed and Mirfa ([10]) and Fatemeh Daraee and Saeed Mozaffari ([11]) can be found different techniques used for recognition through the use of scanners. Because our work is center on smartphones we will focus on Camera-based Systems.

Camera-based Systems allow the recognition of the money by means of capturing the bill by a smartphone camera. It is not necessary to take a picture of the ticket in its entirety, so they are very useful for people with visual disabilities. There are very few applications on this topic. Some are available on software stores such as Google Play or App Store but do not have an exact reference for their scientific contributions.

IDEAL Currency Identifier [12] is an app developed by IDEAL Group, Inc. for Android 2.2 or higher. It is an application that allows the recognition of US dollars (USD). For this, it periodically captures the frames through the camera of the device and processes them quickly to notify the user of the value of the recognized bill. It uses vibration patterns that indicate when the image was recognized and then reports it by voice. One of the advantages it presents is the automatic focus of the camera, which allows adjusting the brightness according to the environment and thus efficiently recognize bills in different lighting conditions. This application uses an image processing technique called template matching, which consists of in making a comparison by regions between stored templates and captured frames. Normally it uses two templates of 100 pixels wide and 100 pixels high, both for the front and for the back of each bill. As a result of this, it can provide information that indicates whether the scanned

part corresponds to the back or to the front of the ticket. Unfortunately, it has some limitations when bills are broken or worn, and when lighting conditions are not appropriate. In the latter case, it does not provide the option to turn on the device's flash and may give erroneous results.

LookTel Money Reader ([13]) was developed by IPPLEX and is available for iOS 8.0 or higher. It is a mobile application that works on iOS to help people identify and count money. It can notify the user, by voice, the amount of money identified. It can also show in the center of the screen with an appropriate font size, the value of the recognized ticket. It has a large database that supports twenty different currencies, including US Dollar (USD), Euro, Dirham of the United Arab Emirates, Japanese Yen, Kuwaiti Dinar. It also supports different languages such as English, Spanish, French, Japanese. It has few limitations regarding the location of the device when capturing an image and it works in real time. One of its best features is that users can start a session and the application can count the amount of money recognized during the session.

ViaOptaDaily ([14]) was developed by Novartis Pharmaceuticals Corporation for Android 4.0.3 and iOS 7.0. ViaOptaDaily is an application that provides an integrated environment to help people with disabilities. One of its feature is the money recognizer, the application can recognize Euro, US Dollar, and Saudi Riyal. Although this application provides several useful services and is compatible with different languages, such as English, French, Arabic, and Spanish, the interaction with the user is quite complicated, because the interface contains many icons and there are no voice commands that facilitate the process.

Floosy ([58]) was developed by I Can See and is available for Android 2.3 and higher. It was created to recognize the Egyptian currency. Unlike of other applications, it uses the color of the image instead of template matching to identify the ticket. For this, it captures frames periodically using the camera of the device. It extracts the characteristics of the image, compares them with their pre-calculated characteristics, and on this basis determines the corresponding value. Because it is based on the color of the image, lighting is a key problem. It behaves differently under different lighting conditions and may fail or give erroneous values when the lighting conditions are not adequate. The application allows using the flashlight and the manual focus of the camera. It must be kept in mind that this affects usability in blind or visually impaired users since it makes the process very complex.

2.1. Solutions Available for Argentine Currency

The Argentine National Institute of Industrial Technology (INTI) has developed a prototype of an open source application that allows recognizing Argentine peso bills from a tablet or cell phone, but that is still in the testing phase so it is not available and does not have an estimated release date. ([15]). There is a project called PROCER ([16]) that is still in the development phase, consisting of a device capable of converting printed text to speech for people who have some kind of reading difficulty, which can be used for the recognition of money bills. Although it is not yet available in the market, it must be kept in mind that

for a person to be able to use it, they will have to acquire the device, which not only generates an additional expense but also requires to take it with them at all times. This could generate unnecessary discomfort taking into account that most people today have a smartphone that could perform this same task.

Blind-Droid Wallet was developed by Oleg Taystruk for Android 2.3 or higher. It is a free application that allows you to recognize money bills from different countries, in particular, Argentina. It is designed especially for people with visual disabilities, so its interface does not represent a difficulty. The money is scanned by the camera and the application communicates by voice the value of it. One of the advantages that it presents is that it does not require an internet connection, so once it is installed it can be used when it is needed. However, it is not enough to install the application on the device that is going to be used since it is only preconfigured for the recognition of US dollars. In order to detect Argentine pesos, the user must download and install an additional module that is available called Blind-Droid Wallet - ARS. After doing some tests, we found out that Blind-Droid Wallet could not be configured on some devices, eg. on Samsung Galaxy A3. In the devices where it was successfully configured, 6 bills of the 16 bills available in Argentina could be correctly recognized, which represents 37.5 % of the tickets. The lack of recognition of some bill is due to the fact that the database was not updated to the new bills that have entered into circulation in our country in recent years, such as the $200 (issued on 10/26/2016) and $500 (issued on 06/29/2016). Even though the last update was made on October 7, 2015, the application does not recognize tickets that have been issued prior to that date, such as the $50 bill (issued on 03/02/2015) and the $5 bill (issued on 10/01/2015). Finally, the application is not open source, so it is not possible to update the database to the new bills in circulation.

WhatIsThis ([17]) is an Android application (2.1 or higher) created by students from Universidad Nacional de La Matanza. The application allows users with visual impairment to use their Android phones to read printed texts and recognize bills. Although the application was published on Google Play, it is not currently available for downloading, so it was not possible to install it for evaluation.

3. Proposal & Implementation

This software arises from a real need to satisfy a requirement raised by a blind person. This person, despite having managed to acquire a degree of significant autonomy in their daily lives, still has to deal with money bills that are not prepared for the visually. Based on interviews with the user and a subsequent investigation, it was determined that the situation posed was not only a particular need but was part of a common problem of people with visual impairment residing in Argentina ([18]). Based on the aforementioned, an investigation was carried out, which was developed in the previous section, where the different alternatives and software products accessible to people with visual disabilities were analyzed. Based on this, and taking into account that the Android ope-

rating system heads the ranking of the most used operating systems, it was proposed to design and develop a mobile application for the Android platform with which blind or with a high degree of visual disability they can distinguish the nomination of the different Argentine bills. Our goals were to:

- Increase the autonomy of people with visual disabilities, facilitating the development of daily life and encouraging their integration into society, through of the use of an application that provides independence in money management in cash, without requiring the help of a sighted person.
- Provide a simple and accessible interface that allows improving usability and user experience in the use of smartphones. For this, the application should have a very simple interface that will not present any type of difficulty to the user that wants to use it and it will not get in the way of the task they are doing.
- Provide availability at all times, without the need to require the use of data or Internet connection, so that it can be used anywhere and at any moment.
- Develop an open source and accessible application so that it can be updated to recognize new bills and freely adapted to new needs.
- Provide a free solution to the problems raised, available for download for anyone.

Given the proposed goal, we decided to implement "What's in my wallet?", a prototype system that provides assistance to people with visual disabilities for the recognition of money. We also add the recognition of credit cards and other cards that are commonly used locally.

Based on the tests carried out with the application listed in the "Previous Work" section, it was concluded that most of the applications make a abusive use of voice synthesizers, repeatedly notifying the user information that already knows. In addition, many interfaces, although they have been designed for people with visual impairment, carries graphic elements that hinder its usability, since they require, for example, that the user interacts in a specific place on the screen. Another aspect to consider was that many applications provide instructions to the user every time he executes them, without taking into account that after several uses the person has already learned to use it.

Our software capture frames periodically using the device's camera. When a bill or card enters the camera viewport, the application quickly processes the captured image and determines the denomination, communicating it by voice and in real time. The application provides a very simple and easy to use interface. When the user uses it for the first time, he/she listens to the instructions and then the interaction will be done only by means of tapping anywhere on the screen. All the information that is transmitted to the user is by sound means.

A key feature and one of the main contributions of our work is how the bills and cards are recognized. For this matter, we used an Augmented Reality (AR) framework. Our application does not have any AR feature but a very important aspect of an AR application is how they detect markers. An AR marker is a distinctive pattern that can be recognized by using image processing techniques and it' s used as a frame of reference to place a virtual object. This means

that AR frameworks include very high-end efficient image recognition systems. In these frameworks, the AR markers are preloaded and the framework can quickly determine if it found a marking and which it is. This can be used to our advantage; in our application, the markers are the bills and cards (Figure 1), which are preloaded into AR framework. When "What's in my wallet?" is running the AR framework constantly tries to detect a marker, and when it successfully does it tells which marker is it. We take this response and transform it into sound. The flashlight of the phone, if available, is used automatically by the application. If the application detects that the light conditions are not appropriate then the flashlight is turn on with the involvement of the user.

Figura 1. Characteristic points found by the Vuforia algorithm to identify the bill of $50.

The definition, design and implementation of the application interactions with the user were done under a User Centred Design strategy ([19]) and with consideration of the work done by Batusek & Kopecek in [20]. Based on them, the following decisions were made. When the user runs the application, he can choose if he wants to listen to the instructions or directly going towards the desired functionality. The user's interaction with the system, through touches, can be done in anywhere on the screen. In each of the screens, the system will only provide information referring to the state of the application, in order to avoid repeated and annoying voice notifications to the user. The main functionality of the application, which consists of scanning and recognition of Argentine money bills and some other objects, will be done automatically without the need for the user to interact through a touch on the screen. The application will have the automatic focus of the camera set so that it does not require the user intervention. The application will handle the flash automatically so that the user does not worry about the luminosity of the environment. The system will communicate to the user only the relevant information regarding the state of the application. The result of the recognition of an object will be provided briefly and accurately. The application was implemented for Android using Android Studio. The source project is a 97MB rar file (available here `https://goo.gl/2qUZP7`) and the appli-

cation is a 7.97MB file (available `https://goo.gl/36VTM5`). There is also a user manual available, but only in spanish for the moment (`https://goo.gl/hBaeAq`) "What's in my wallet?" is available in Google Play (Figure 2) for free. It has been downloaded more that a thousand times with a review score of 4.7.

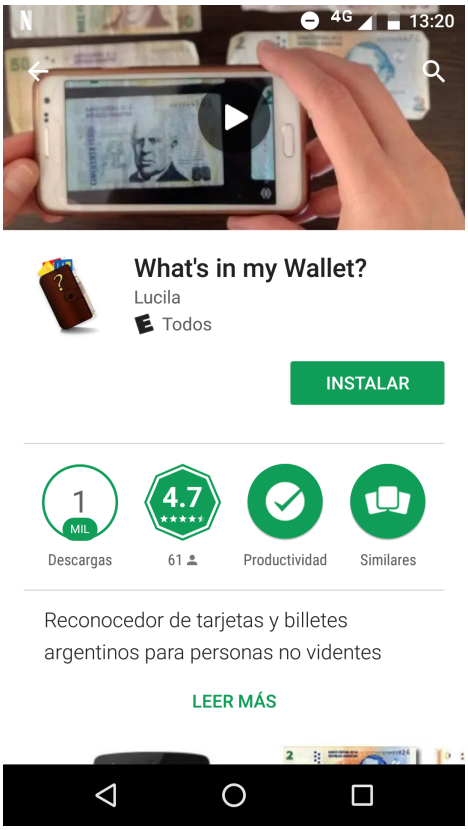

Figura 2. "What's in my wallet?" is available in Google Play for free. It has been downloaded more that a thousand times with a review score of 4.7.

4. Validation

A statistical analysis was performed that allowed evaluating the behavior of the prototype in different conditions. In the first part, a group of bills in circulation under different degrees of illumination was evaluated. The hit rate for the implemented system gave a result of 97.5 % for a high or medium environmental lighting, and 97.91 % without ambient lighting. Through this result, it is possible to affirm that scanning is successful in most cases. In a second part, the bills were

exposed to different conditions that altered the capture of the image, obtaining satisfactory results in most cases. This allowed corroborating that the application still works when the conditions in which the scanning is performed are not optimal. In addition, it should be noted that no false positives were obtained in the analysis, which is very important in an application of this style that is used in financial transactions. Several usability evaluations were conducted and the user managed to successfully complete all the proposed tasks. However, some of them required extra help. For this reason, it is recommended that the first time the application be used, it should be done in the company of a sighted person who explains the instructions to the visually impaired user.

5. Conclusions & Future Work

In the present work, we presented the design and development of a mobile application specifically designed for users with visual disabilities. This work arose from a real need raised by a blind person and that is part of a common problem of people with visual impairment residing in our country. As explained earlier in the article this problem consists in the difficulty which represents for a person with visual impairment the recognition of money bills in Argentina. During the development of this work new ideas have emerged, some of which have been incorporated as additional functionality, and others that have been left open and are expected to be implemented later. The following are the lines of work that are proposed to be followed in the future: Expand the database of the application so that it recognizes the currency of various countries. Also add the currency conversion option, through which a person could scan a bill from any country to obtain the equivalent value in the desired currency and vice versa. In this way the number and diversity of users who would use the application would be expanded, since, if a person with visual disability travel abroad, or if a tourist with vision problems visit our country, they could use the application to recognize the value of money and perform business transactions autonomously. We would like to allow the user to customize the database by adding images so that later they are recognized. It would be very important to test the application with people who have different degrees and types of visual impairment and based on this adapt and improve the interface so that it can be used by a greater number of users. Finally, it can be stated that as an outcome of this particular research work a totally positive experience was obtained. The conducted research work is an example of how software systems can be used to overcome daily life difficulties of people with visual disabilities.

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