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Assistive Medication Management System for Users with Visual Impairment

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Abstract. Medication management is a complex process and is taken into account of daily activities. Moreover, participation in daily activities could define the wellbeing. On the other hand, the medication management process for visually impaired individuals is more difficult. Nowadays, the technologies like mHealth and RFID, have caused a significant progress in both areas of medication management systems and visually impaired Independent Living. Therefore the aim of this work was to develop an assistive medication management system for visually impaired people in order to improve the medication adherence among them. The development process started by requirements extraction according to goal directed design methodology introduced by Cooper. Then the system, called MedVision was developed, consisting of an android mobile application, RFID device and a medication box with vibration motors and it is developed for Iranian visually impaired individuals in Persian language. At the final step of this study, a functional assessment was performed in order to improve the system even more in next prototypes.

Keywords. Mobile health, mHealth, RFID, medication management, assisted living

Introduction

Medication management is a complex and multiactivity process [1]. It is one of the daily activities [2] and participation in daily activities is one of the important parameters that could define the wellbeing [3]. One of the disabilities which can affect the people's participation in activities of daily living is visual impairment [4]. According to WHO statistics, there are around 285 million impaired vision people around the world [5] and most of them live in low and middle income countries. The prevalence of visual impairment is increasing [6] and one of the causes of this increment is the fact that 82 percent of visually impaired people are older than fifty years old [7] and aging is occurring worldwide [8; 9]. Therefore this impairment might be more prevalent by world aging. According to the impact of visual impairment on participation in daily activities and complexity of medication management, specially to a vision impaired person [10], this group of people with special needs, experience different challenges in medication management process [11].

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Technology can play an important role to improve the medication adherence [12]. Recently, many researches have been conducted, showing the positive impact of employing mHeath on medication adherence [13-15]. On the other hand assistive technologies are potential solutions for disabled people, to increase their independence and quality of life [16] and visually impaired individuals are one of these communities which can take advantage of mobile technology in their lives [17]. Moreover, Internet of Things (IoT) is another concept that is used in some digital products for visually impaired individuals and helps them in navigation and finding the objects [18]. Many systems use Radio Frequency Identification (RFID), for implementation of IoT and it has a potential to support visually impaired people by its vast applications [19]. Then again, researchers have employed RFID in medication administration process in some protocols [20]. In addition to RFID, there are other usable options that could be employed in order to administer the medications. Barcodes and two-dimensional QR codes which reduce the medical errors [21; 22], are two examples for this case. Furthermore, there are a unique identifier on the outer package of medicines in Europe, in order to fight falsification [23]. These identifiers could be used for identification of medications which are manufactured in Europe. According to the fact that barcodes are not unique among manufactured medications that belong to different Iranian companies and the lack of QR codes and other identifiers on many medications packages in Iran, the RFID is the best option. Considering the application of RFID and mhealth in both visually impaired assisted living and medication management areas and potentiality of IoT in data exchange [24] using these technologies and IoT concept, can improve the medication adherence among visually impaired individuals. As a result of this, the goal of this study was to develop an assistive IoT-based medication management system, called MedVision, using the RFID technology and mobile health in order to assist people with visual impairment, to manage their medications as one of their daily activities.

1. Development Methodology

The researchers employed the Goal-Directed Design for the development of current work. This method is an interaction design methodology which has introduced by Cooper [25]. In this design methodology the users' goals are the basis of the designing process. Therefore the designers defined a few personas in order to identify their goals. The needed data for designing the personas could be gathered from literature reviews and previous works, interviews and etc. according to Goal-Directed Design. After goal extraction, some requirements of the system were defined and adapted to the Iranian visually impaired community.

1.1. Requirements

The functional requirements of the system, were extracted as mentioned above. These requirements are listed below:

- Medication identification
- Medication recommendations
- Medication list and regimen
- Medication information like adverse effects

- Medication alert and reminder
- Actions when medication errors occur
- Reporting the adverse effects that experienced
- Medication tracking

According to the mentioned requirements, the system consisted of three parts: 1) RFID device for identification of medications, 2) mobile application for management of the medications and reminders, Also an appropriate infrastructure for voice recording and playing without any extra cost and 3) medication box for locating the tablets/capsules and providing vibration alerts for each compartment as an identifier for scheduled tablets/capsules. The medication recommendations, medication information like adverse effects and actions when medication errors occur are requirements that could be recorded by friend/family member of the visually impaired with the ability of voice recording in smartphones. In addition, the visually impaired user can record his/her voice as experienced adverse effects report in the same way with slightly different user commands. The medication tracking and medication list and regimen are implemented by mobile facilities. The medication list and regimen are achievable by queries on registered medications in database. Moreover, the user could record in smartphone if he/she took the medication or not, therefore the medication tracking would be performed. The reminders and alerts will use both vibration motors and mobile application. Vibration motor is a simple electronic motor which produce circular oscillations in active periods [26]. Vibration motor is an appropriate device for alerting the people with visual impairment because of the ability of stimulating the sense of touch [27]. The mobile application has employed the android mobile manager in order to produce alarms in the specific time on both smartphone and medication box’s vibration motor.

2. System Overview

The MedVision system, is developed for android mobile devices which is the most popular smartphone operating system [28] but the mobile application could be easily developed for other smartphone’s operating systems. The mobile application development by Java programming language and using the Android SDK (Software Development Kit). The needed tools for android development and APIs are embedded in SDK. The android application has three main functionalities including 1) management of the alert, 2) gathering the information about medications and 3) providing an infrastructure to record and play the voice as an interface for visually impaired user. The other parts of the system is integrated with the mobile application.

2.1. Use Cases

The use case diagram of MedVision system include two actors according to the fact that the system is a multi-user system. One of them is the visually impaired user and the other one is the person who is volunteer to register the medications in the system and could be a friend or a family member of the person with visual impairment. The main use cases can be divided in three groups including medication registration, reminders and alerts and getting the medication information. Figure 1 presents the use case diagram for the system.

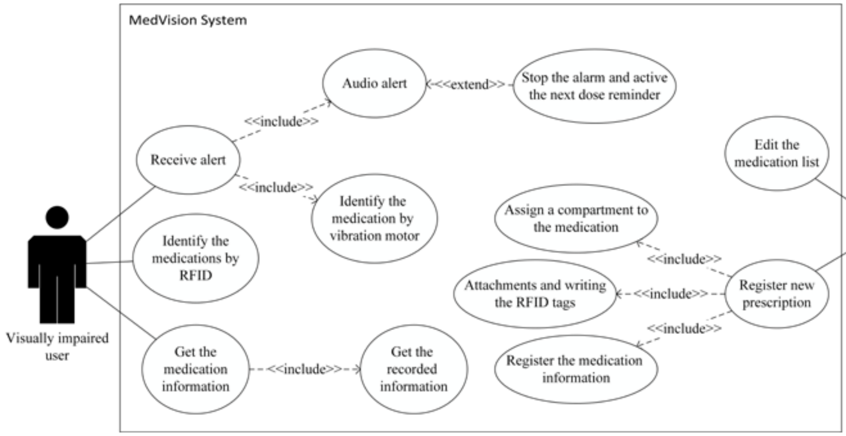

Figure 1. Main use cases of the system

2.2. Architecture Overview

The MedVision System assists the visually impaired people to identify and manage their medications and have access to medications information. Considering the existence of mobile application, RFID device and medication box, the system needs an IoT infrastructure. Since there should be a bidirectional communication between the mobile application and the RFID device, the Bluetooth connection was selected and a Bluetooth module (HC-05) was integrated in the system. Beside the RFID device (including RC522 RFID module), the vibration motors of medication box was connected to microcontroller. The schematic of the RFID device and vibration motors was provided by Proteus 8 software. The data are not exchanged directly between medication box and RFID device but the compartment's number is determined by mobile application in registration process, also the sticky RFID tags are written in this process. Therefore tablets/capsules will be located in specified compartment and the sticky RFID tag contains the medication id which refer to all information including compartment's (vibration motor's) number.

All medications that have been supplied from pharmacy, are registered in a SQLite database by one of the friends/family members of vision impaired user through the mobile application. In the process of medication registration, the medication name and information is recorded by user into the mobile application as one of the steps of medication registration. Moreover the sticky RFID tags attachment is performed and the prescribed tablets/capsules is placed in a specific compartment of medication box. Then, the system provides reminders at the time that is set, by activating an audio alerts. At the same time for the prescribed tablets/capsules, the vibration motor of the intended compartment is turned on which helps the visually impaired person to find his/her medication faster. The medication identification and accessing to medication information are the other features of the system that are available for the visually impaired user through mobile application's user interfaces and RFID device. The modules of this system are connected through Bluetooth connection.

3. System Development and Functional Assessment

3.1. Development of components

MedVision is a multi-component system. In the development phase, vibration motors were mounted on a medication box that was a box comprising of ten 5*5 cm^2 compartments which each of them has one distinct vibration motor. The RFID device was developed according to the designed schematic and the connections between microcontroller's pins, vibration motors, RC522 RFID module and Bluetooth module (HC-05) were established. After that the programming of microcontroller (Arduino Mega 2560) was performed in Arduino 1.8.3 by C programming language.

The android application was developed in Android Studio. According to target group of this study, the application was designed in Persian language. The application user interfaces (UIs) are divided to UIs for people with visually impairment and UIs that are used for medication registration. Two kinds of user interfaces (UIs) were employed for visually impaired user. In the first UI type, the designer divide the screen of smartphone with two buttons. Therefore the visually impaired user can be guided by audio commands to touch the top half of screen for a specific task and bottom half of screen for another one (Figure 2.a). Another UI, is comprising of nine direction in the screen which each direction is representative of the number from one to nine. Each number is corresponding to a particular task. In this type of the UI the audio command announces the task of each number and the user drag his/her finger on the screen in order to input a number for specifying a certain task. For example, the number two will be selected by dragging the finger from middle of screen to top (Figure 2.b).

a) b)

Figure 2.**a)** nine-directions UI for visually impaired users' navigation **b)** two-buttons UI for visually impaired users

The registration process which is performed by one of the friend/family member of visually impaired user, has different UI design. The user register the name, dose and name of the physician in one page. In addition, the type of medication (tablet/capsules, liquid and etc.), being prn (as needed) or not and the time of first dose and frequency when the intended medication is not prn are registered in next pages. In the following steps, the name of medication and some information of medication will be voice recorded by the user in two steps. Moreover, the number of compartment that the user places the tablets/capsules in it is selected. At the end of process the sticky RFID tags will be attached on the medicine cardboard box by the person who is assisting visually impaired person. The Figure 3, shows these pages of application.

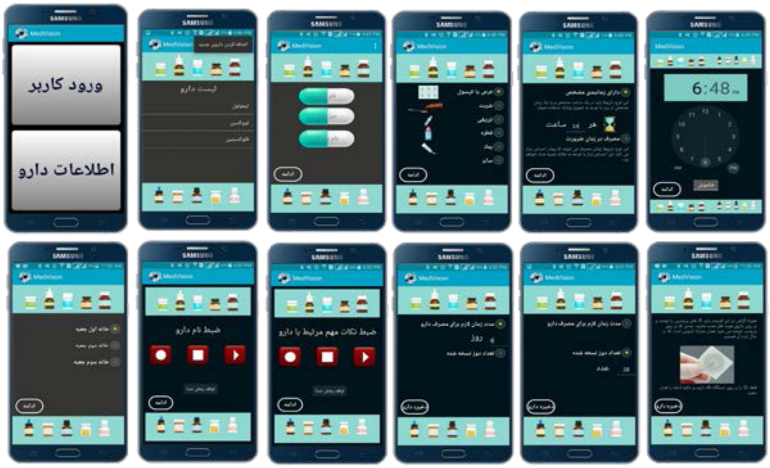

Figure 3) registration process of a scheduled tablet by friend/family member

After development of UI, the SQLite database of this system was designed and developed as a table named medicationList that had 11 attributes. At the last step of the programming, sending and receiving of data by Bluetooth infrastructure was accomplished.

3.2. Functional Assessment

After development of the system, researchers assessed the system functionally. In this functional assessment a software engineer tested all functions of the system to insure that they works properly. Afterwards, discovered bugs were fixed. Moreover, the mobile application was deployed on three device with different screen sizes in order to find out if the designed UIs are responsive on all screen sizes and the appearance of the UIs were improved. Then three visually impaired users tested the system and stated their points of view about the system usability, ease of use and efficiency in their responds to three questions of developers about these criteria. The participants stated that the system is usable for people with this disability and indicated that, a decrease in system dimensions to be as small as commercial medication boxes, could make it easier to use and increases its portability. Also all of them believed that this system can improve the medication adherence among this community and increase their independence at the same time.

4. Conclusion and Future Works

This paper proposed MedVision, a multicomponent system comprising an android mobile application, a medication box and a RFID device for visually impaired individuals which improves the medication adherence. The innovation in this system was the use of vibration motors in order to provide vibration alerts as a medication identifier that can be received by user’s sense of touch. Another distinction of this study from previous studies that have proposed a medication management system is the design method that is specific to visually impaired people and their needs. To the best of authors' knowledge there isn't any system that have been designed by this design approach. Future improvements include employing the natural language processing and speech generation in order to make the medical webpages accessible for this group. Moreover this system can be integrated with systems that recognize the drug-drug interactions in order to decrease dangers of these interactions.

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