Specification and Design Aspects of the Academic Researcher's Assistant (ARA) Software for Mobile Devices

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Abstract— Mobile devices are being widely and increasingly used in many areas of human activity. Designing applications for mobile devices has introduced several new challenges that are currently being addressed by interested researchers and developers. This paper explores different human-computer interaction challenges in designing an Academic Researcher's Assistant (ARA) software application for mobile devices. ARA is a tool for mobile devices designed to provide academic researchers with a practical portable assistant that helps them organize their daily research-related activities. The paper provides details of ARA's organizing principles, software specification, design, and prototype implementation. Several directions of future work are also presented.

Keywords—human-computer interaction, interaction design, mobile devices, requirements specification, use case modeling.

I. INTRODUCTION

Mobile devices are being increasingly used by different people for many purposes. For example, nowadays mobile devices are used in education [1, 2], entertainment [3], military applications [4], global positioning systems (as satellite receivers) [5], communication services [6], and medicine [7]. People of different backgrounds are now considering involving mobile technologies in their daily tasks, be these tasks in their offices, classrooms, homes, or even cars. Academic researchers are part of those who will always look to apply new technologies that support the management of their academic research activities and responsibilities wherever they go. Thus, they will look for a tool that can help them organize different types of academic references and publications, manage grant applications, keep track of their advisement of students, collaborate with colleagues, and more. Although several tools for organizing the researchers' work do exist in today's market, to the best of our knowledge these tools do not have all the features that cover the full set of academic researchers' organizational needs. Some of these tools provide certain features for specific needs but not for all needs. Other tools provide comprehensive functions and features, but do not offer a version for mobile devices.

The need for such a mobile tool for academic researchers prompted us consider designing the Academic Researcher's Assistant (ARA) software. Designing software for mobile devices, however, presents several important human-computer interaction (HCI) challenges. Some of these challenges are hardware-related whereas other are software-related. Human computer interaction is the study of the communication between people and computers, which is particularly visible at the user interfaces level in software and hardware [8].

The paper, in its remaining part, is organized as follows. Section 2 presents an introductory background about mobile devices, including about their uses, types, and operating systems. Section 3 provides details of ARA's requirements specification and use case modeling. Section 4 presents several of the more important aspects of ARA's design. Section 5 describes ARA's prototype. A brief look at related work is provided in Section 6. Finally, Section 7 outlines directions of future work and concludes the paper.

II. BACKGROUND

A common question that seemingly does not have a simple and straightforward answer is: what are mobile devices? Mobile devices could be described in different ways when looking at them from different perspectives. For instance, they can be described in terms of the different types of functions they provide [9]. Some of them, for example, are used for playing full-color games. Other could be used for data services such as e-mailing and Internet browsing. Many mobile devices could also do more than one of these functions, whereas other are designed for a specific functionality.

Another method of describing mobile devices is presented in [10]. This method uses the level of functionality to categorize mobile devices. Limited data mobile devices, for example, are devices that have a small text-based screen and a limited functionality. Basic data mobile devices, on the other hand, have larger (medium-size) and more graphical screens than the previously mentioned ones. Further, enhanced data mobile devices have medium to large screens and offer the functionality of the basic data mobile devices in addition to the ability of running desktop-type of applications on smaller screens. Typical devices that belong to this category are the Personal Digital Assistants (PDAs).

A third way of describing various types of mobile devices consists of distinguishing among the different types of physical

elements users can interact with in a mobile device [9]. Most of the existing mobile devices have buttons that can be pressed to perform a task. Other support the use of touch screens by incorporating a stylus or a small cursor control pad. Yet some other include the capability of voice recognition [11].

Also, mobile devices could be classified as information-focused or communication-oriented devices [9]. In information-focused devices the emphasis is on processing data rather than communicating with each other over a network, while communication-oriented devices emphasize the use of wireless communications.

Mobile devices are being increasingly used by different types of people. In medicine, for example, PDAs are used to support the cardiologists in their medical decision making processes [12]. In education, mobile devices are being increasingly used in different schools and universities under the umbrella of mobile learning or m-learning. Specifically, m-learning is the use of mobile or wireless devices for learning while the learner is on the move [13]. Also, some book publishers are issuing special versions of electronic books, called e-books, that can be read using mobile devices. Another important, representative use of mobile devices is in entertainment: mobile devices are widely used for playing music, watching movies, playing games, and more. Global Positioning Systems (GPS) represent another well-known and important use of mobile devices. In their research, Clegg et al. [14] have found that PDA-based GPS systems can also be very useful for geological mapping projects in remote regions, particularly in situations where there is a limited power supply (such that a tablet PC can not be used) or where the total weight of the equipment carried is an important consideration.

There are currently several operating systems in use for mobile devices, developed and owned by different companies and programmers. As far as we know, among the current most important operating systems are the Palm OS developed by PalmSource, Inc. (ACCESS Systems Americas, Inc.), the Windows Mobile developed by Microsoft Corporation, the RIM for BlackBerry developed by Research in Motion, the Symbian operating system owned by several companies including Ericsson, Motorola, Panasonic, Nokia, Samsung, Siemens and Sony Ericsson, and several other operating systems such as the Open Palmtop Integrated Environment (OPIE) and the GPE Palmtop Environment.

III. Requirements Specification and Use Case Modeling of ARA

A. Requirements Specification

Software requirements could be functional or non-functional [15, 16]. Functional requirements describe the intended behavior of the software to be built in terms of desired operational facilities and modes of interaction. On the other hand, non-functional requirements represent constraints of various kinds placed on the software. Such constraints include technological constraints, developer constraints, and organizational constraints.

Table I describes the main functional requirements of ARA. The format used in this table is the practical, efficient notation proposed in [16]. Table II describes several non-functional requirements for ARA. Due to space limitations, not all functional and non-functional requirements of ARA are included in these two tables.

TABLE I: FUNCTIONAL REQUIREMENTS

R1	The ARA application shall allow adding, editing, and deleting references.
R2	The ARA application shall allow filtering references into lists.
R3	The ARA application shall allow viewing lists of references.
R4	The ARA application shall allow the printing of lists of references.
R5	The ARA application shall provide a help system to aid the user.
R6	The ARA application shall allow adding, editing, and deleting appointments.
R7	The ARA application shall allow issuing an alarm as a reminder of an appointment.
R8	The ARA application shall allow viewing appointments set on a specific date.
R9	The ARA application should allow adding, editing, and deleting of collaborators' records.
R10	The ARA application should allow filtering collaborators' records into lists.
R11	The ARA application shall allow viewing lists of collaborators.
R12	The ARA application should allow for tracking grant applications.
R13	The ARA application should allow representing collaborators' records as bubbles.

TABLE II: NON-FUNCTIONAL REQUIREMENTS

NFR1	The ARA application shall be written in C#.NET Compact Framework.
NFR2	The ARA application shall address the main HCI challenges for mobile devices with a suitable, operational GUI.
NFR3	The ARA application shall emulate the appearance of an application in its native operating system platform.
NFR4	The ARA application shall emulate the behavior of an application in its native operating system platform.
NFR5	The ARA application shall respond quickly to filter queries changes.
NFR6	The ARA application shall run on a mobile device.
NFR7	The ARA application shall store data on a web server.

B. Use Case Modeling

A use case describes succinctly the relationship between the user and the system. In a use case diagram, the system is

represented by a bounded box labeled with the name of the system. The users are represented by external actors that interact with the use cases represented graphically inside the system's boundary. The use cases, taken in totality, should cover the entire behavior of the system. Figure 1 shows the use case diagram of ARA with two important actors, the generic ARA user and the time, as well as with 17 use cases. These use cases represent the core functionality of ARA, to which new behavior can later be added. Details about the 17 use cases as well as their instance scenarios (in general, one primary scenario and several secondary scenarios for each use case) can be found in [17].

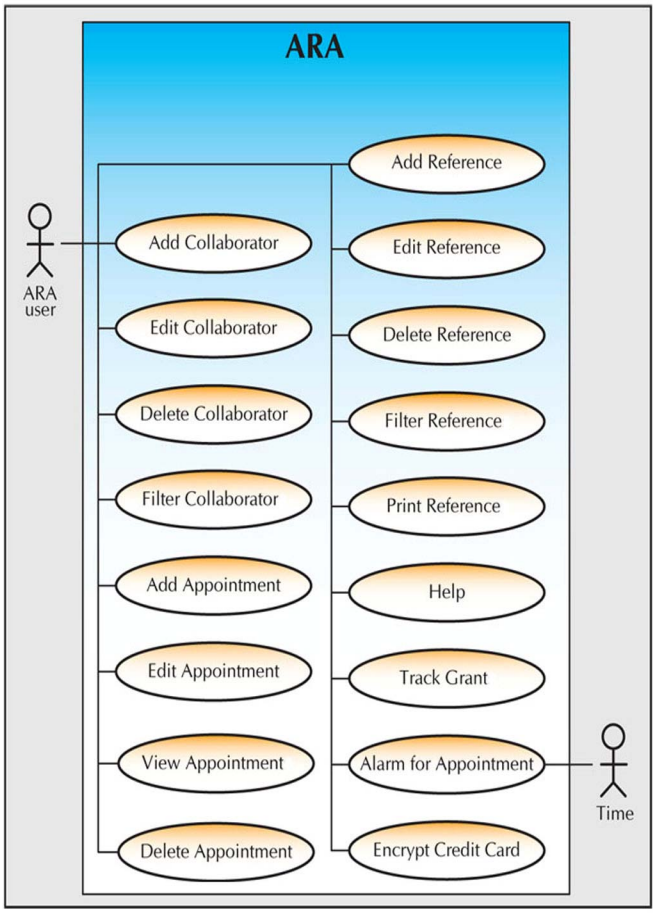

Figure 1. Use Case Diagram of ARA

C. Traceability Matrix

Traceability matrices are not standard model elements of UML but they are very useful for managing functional requirements and mapping them into use cases [16]. Essentially, as shown in Table III, a traceability matrix indicates which requirements are fulfilled by which use cases. Some use cases can fulfill more than one requirement and some requirements can be mapped into more than one use case. The traceability matrix can serve as apractical tool throughout the software development process, as it can help linking requirements to use cases, and uses cases to test cases. Furthermore, the matrix can be used in the early stages of the process to assess using weights (based on priorities) the importance of each use case, thus supporting the project managers in their decision-making process.

TABLE III: ARA'S TRACEABILITY MATRIX (PARTIAL)

	UC 1	UC 2	UC 3	UC 4	UC 5	UC 6	UC 7	UC 8	UC 9	UC 10	UC 11	UC 12	UC 13	UC 14	UC 15	UC 16	UC 17
R1	●	●	●														
R2				●													
R3				●													
R4					●												
R5						●											
R6							●	●	●								
R7										●							
R8											●						
R9												●	●	●			
R10															●		
R11															●		
R12																●	●

IV. DESIGN ASPECTS OF ARA

A. Layered Architecture

Figure 2 shows the layered architecture of ARA software. Specifically, it shows the ARA user interacting with the C# .NET Compact Framework forms on the mobile device [18]. This architecture has three layers, as detailed next.

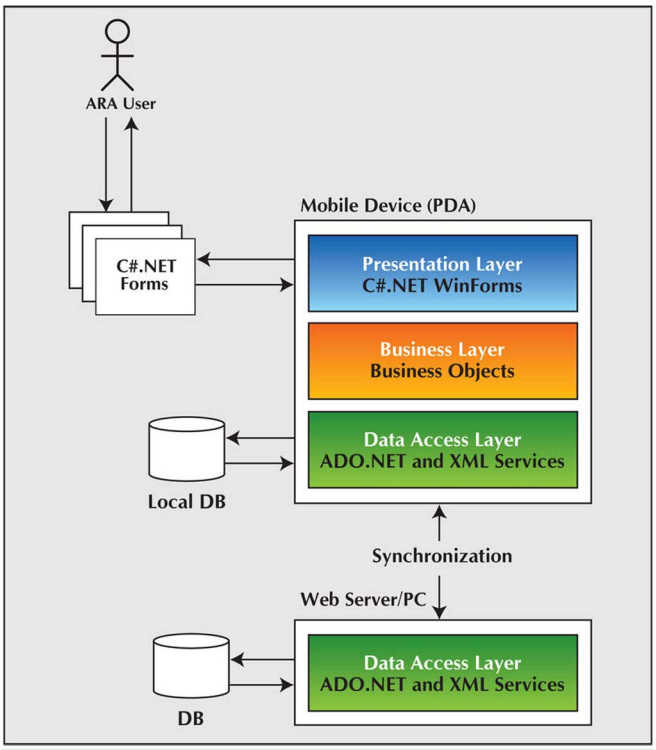

Figure 2. The Layered Architecture of ARA

The Presentation Layer consists of Windows Forms and uses traditional Windows Form controls to display and gather data from the user. The Business Layer consists of a set of objects that encapsulate the logic of the business application [19]. In ARA, this layer includes the object-oriented design

shown and discussed in the next subsection. The Data Access Layer consists of the data access object and the database itself [19]. ARA uses a local database, managed by ADO.NET to temporarily store data on a mobile device. Thus, it can communicate with a larger database on a web server through the Internet or on a PC through active synchronization by using the XML services provided for the C# .NET Compact Framework [18].

B. *Class Diagram*

Class diagrams are software modeling elements useful in illustrating the relationships that exist among the different classes that compose the system [16]. The analysis class diagram of the main ARA components is shown in Figure 3. Specifically, the main components of the class diagram are: appointments, references, collaborators, and grant applications. There are also other components in ARA that are not shown in this figure but are part of the Presentation Layer, discussed earlier. Classes not shown in Figure 3 include the .NET Compact Framework user interface classes [18].

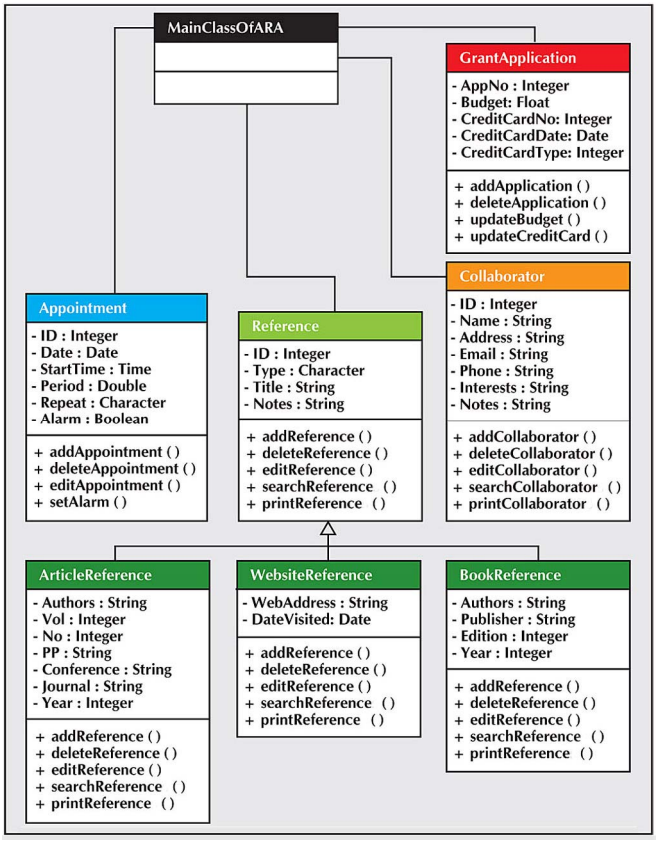

Figure 3. Class Diagram of ARA's Main Components

C. *State-Chart Diagram*

For illustration purposes, Figure 4 depicts the main state transitions of the Collaborators class during ARA's execution. Specifically, the diagram describes the basic behavior of the system in response to external stimuli and indicates the various states of ARA's Collaborators class as well as the possible transitions between these states.

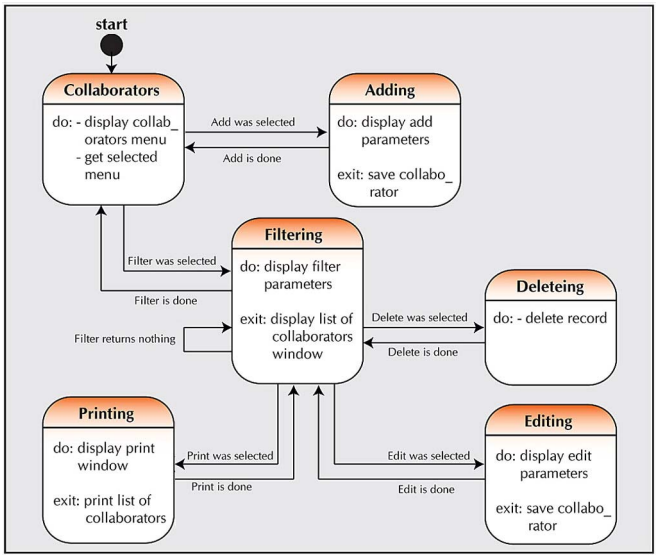

Figure 4. State-Chart Diagram of ARA's Collaborators Class

V. PROTOTYPE DETAILS

This section provides a brief description of the forms that implements ARA's functionality. Due to space limitations, only two screenshots of ARA "in action" are shown. More details about ARA's prototype can be found in [17]. The screenshots presented in Figures 5 and 6 show ARA running on the Microsoft Pocket PC 2002 Emulator provided with the Microsoft Visual Studio .NET 2003 Integrated Development Environment (IDE) [20].

When ARA starts, it displays the Main Menu form (Figure 5). This form is divided into two main sections: the buttons and the menu bar.

Figure 5. ARA's Main Menu

When a button is tapped with a stylus on a mobile device, another form will open, associated to the button that was tapped. These buttons include: Manage References, Manage Collaborators, Appointments, and Grant Applications. The last button is the Exit, which ends the ARA application by closing all the screens and erasing ARA's execution image from the main memory. Unlike the menu bar present in almost all regular PC applications, the menu bar in mobile devices is placed at the bottom of the form, not at the top.

Both Figure 5 and Figure 6 display the menu bar used in ARA, which consists of three parts: Menu, Exit, and Help. Some details of the menu bar's menus and submenus are shown in Figure 6.

Figure 6. Sample Menu Items in ARA

VI. Related Work

This section looks briefly at software tools that have certain similarities with ARA. Most of these tools are used to retrieve and manage references, several are used as software organizers, and other are primarily software notebooks. None of these tools include the entire set of specific features and support needed by an academic researcher for organizing his or her daily activities. ARA is not providing all the needed features and support either, but it attempts to make available some more of the specific functions that could help researchers in organizing and keeping track of their daily activities. Also, in the future, ARA will aim to include even more such functions and features, for the benefit of researchers not only from the academia, but also from other scientific environments and organizations. In our view, the primary difference between ARA and almost all of the existing tools is that ARA is a software application designed to run on mobile devices, which makes it a portable tool that can be used by researchers almost everywhere (e.g., on a plane, in a train, on a mountain, in a park, etc.).

Significant useful tools with related purposes include Thomson ISI ResearchSoft's Reference Manager 11 [21], which is a computer software that provides, among other facilities, an Internet Reference Searcher to search the World Wide Web for references, a Database Manager to organize the researcher's data, and a Bibliography Builder to create bibliographies. Microsoft OneNote 2007 [22] is another practical, noteworthy software application, focused primarily on gathering and organizing information to simplify the search for specific data. Thomson ISI ResearchSoft's EndNote X [23] is a very well-known program used by numerous researchers, scientists, librarians, and students. In principal, EndNote X can be utilized to search online bibliographic databases, organize references, and create bibliographies and figure lists. A practical web-based application is the Ultimate Research Assistant [24], which is an advanced Internet knowledge mining tool that can be used to search the World Wide Web for references and list them on a web browser by priority. Papyrus Bibliography System and Knowledge Manager, by Research Software Design [25], is another computer program that can assist researchers through its bibliography system and knowledge manager capabilities. This software tool, currently available for free download, can import bibliographic references and locate references by field and can be combined with a word processor to produce formatted manuscripts and bibliographies.

VII. Future Work and Conclusions

There have been several good parts completed in the ARA project to create a tool capable of assisting academic researchers in their daily research-related tasks. However, even with the work done on the prototype so far, there is still substantial more work needed to make the tool comprehensive. In the long run, ARA could be seen as the first step into creating a tool capable of handling many of the numerous tasks an academic researcher needs to be assisted with. On a shorter timeframe, one major improvement to the current version of ARA is to implement printing lists of references, collaborators, appointments, and grant applications (including specialized budget and budget justification forms). Although the design and modeling of these parts has been already completed, the coding is still to be done.

Another interesting enhancement to the current version of ARA is to allow for presenting the collaborators' records as bubbles. Each bubble could represent a collaborator's record with a brief list of his/her research interests and perhaps a number of key ideas put forth by the collaborator. The ARA user would have the ability to graphically manipulate bubbles and organize them visually. Developing this feature in the future will help the ARA user to group collaborators on topics and projects as well as generate lists of collaborators in a much faster and enjoyable way. This feature can apply to references as well, including for filtering references to generate specific lists.

The goal of this paper was to introduce ARA and present several of its more relevant specification and design aspects. ARA was designed and developed to provide the academic researchers with a mobile tool that can assist them in their daily research-related activities. ARA proposes a software tool for mobile devices designed to include certain features that are not supported in other researcher's assistant tools, such as managing grant applications. Numerous other functions and features that can assist researchers in their daily tasks could be incorporated in future versions of the ARA tool.

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