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MOBILE DENTIST

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By

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ABSTRACT

As mobile computing devices are becoming more and more popular, mobile users tend to be more demanding. They desire or sometimes require access to information anytime and from anywhere. The traditional concept of timely and reliable access to global information in a distributed heterogeneous database system must be expanded to integrate the new mobile entities such as: mobile people and computers. This leads to the development of mobile database systems which are gaining great popularity nowadays. However, this concept of mobility does not come without new challenges and barriers due to the reduced capacity of network connection, low-bandwidth wireless links, frequent disconnection, higher error rates, limited power sources, limited hardware capabilities, and more. This paper explores the concept of mobility by targeting Windows Mobile powered devices such as Pocket PCs, Pocket PCs Phone Edition, and Smartphones. Moreover, it presents a description and implementation for the activities of Mobile Dentists who would like to have access to their patients' information anytime and from anywhere. Hence, this paper proposes the *Mobile Dentist Application* which is designed and developed to be deployed to Windows Mobile powered devices and to handle several mobile dentists' issues including secure login authentication, managing patients' information, managing patients' appointments, keeping track of patients' payments, recording all dentist's expenses, generating Balance Sheets, including an Artificial Intelligent component, integrating a Smart Reminder Component which automatically sends SMS reminder messages, and generating Statement of Accounts that can be sent via SMS to patients. Furthermore, the Mobile Dentist Application is carefully developed to grant dentists the freedom of movement while having access to their clinics' stock data, accounting data, as well as patients' private data anytime and from anywhere.

TABLE OF CONTENTS

List of Figures.....	v
Chapter 1 – Introduction	1
1.1. What is Mobile Dentist Application?	1
1.2. What is a Windows Mobile Powered Device?	2
1.3. What is Windows Mobile?	2
1.4. Scope of the Project	3
Chapter 2 – Literature Review	4
2.1. What is a Pocket PC?.....	4
2.2. What is a Pocket PC Phone Edition?.....	4
2.3. What is a Smartphone?	4
2.4. Mobile Phones may be the Right Devices for Rural Accessibility	5
2.5. Enabling New Speech Driven Services for Mobile Devices	6
2.6. Grid Computing on Mobile Devices.....	7
2.7. Performance Assertions for Mobile Devices.....	7
2.8. Converting Web Pages for Delivery to Mobile Devices	8
2.9. Efficient Web Search on Mobile Devices	9
2.10. Practical Real-Time Video Codec for Mobile Devices	10
2.11. Content Interaction and Formatting for Mobile Devices.....	10
2.12. Performance Validation on Mobile Devices.....	11
Chapter 3 – The Mobile Dentist Application	12
3.1. User Authentication and Security Issues	12
3.2. MDA Main Menu	15
3.3. New Patient Registration Form	17
3.4. Patients Search Engine Form.....	19
3.5. Appointments Form	20
3.6. Smart SMS Component	22
3.7. Invoice Generation Form	23
3.8. Listing and Managing Patients Invoices.....	24
3.9. The Patient Payment Process.....	26
3.10. Listing and Managing Patients Payments.....	27
3.11. Statement of Account	29
3.12. Managing Clinic Expenses	30
3.13. Listing and Editing Clinic Expenses.....	31
3.14. Balance Sheet.....	32
3.15. Listing and Managing Dentists Notes.....	33
3.16. Managing Appointments Time Interval.....	34
3.17. Copyright Notification.....	35
Chapter 4 – MDA Development and Technical Aspects	37
4.1. What is Microsoft Visual Studio 2005?	37
4.2. What is .NET Compact Framework?.....	38
4.3. What is SQL Server Mobile Edition?	38
4.4. MDA Database Schema.....	39
4.5. ERD Diagram for the MDA Database.....	41
Chapter 5 – Future Work and Conclusion	42
References	44

LIST OF FIGURES

<i>Figure</i>	<i>Page</i>
Figure 1: User Authentication Form	13
Figure 2: Listing and Managing MDA Users	14
Figure 3: Assigning Access Rights to MDA Users	15
Figure 4: MDA Main Menu.....	16
Figure 5: Automatic Enabling and Disabling Menu Options based on User Rights ..	17
Figure 6: New Patient Registration Form	18
Figure 7: Patients Search Engine Form	20
Figure 8: Appointments Form.....	21
Figure 9: Managing Appointments and Setting SMS Reminder Date and Time	22
Figure 10: Smart SMS Component.....	23
Figure 11: Invoice Generation Form.....	24
Figure 12: Listing and Managing Patients Invoices	25
Figure 13: The Patient Payment Process	27
Figure 14: Listing and Managing Patients Payments	28
Figure 15: Statement of Account	29
Figure 16: New Expense Form	30
Figure 17: Listing and Editing Clinic Expenses	31
Figure 18: Balance Sheet (Part 1/2).....	32
Figure 19: Balance Sheet (Part 2/2).....	33
Figure 20: Listing and Managing the Dentists Private Notes	34
Figure 21: Managing Appointments Time Interval	35
Figure 22: Copyright Notification	36
Figure 23: Appointments Table Schema.....	39
Figure 24: Expenses Table Schema	39
Figure 25: Invoices Table Schema.....	40
Figure 26: Patients Table Schema.....	40
Figure 27: Patients Payments Table Schema	41
Figure 28: Users Table Schema	41
Figure 29: ERD Diagram for the MDA Database	41

CHAPTER 1

INTRODUCTION

The rapid advance of technology and especially the mobile computing devices has greatly increased the ability to connect mobile users through both wired and wireless networks. For example, a user can at any time access data through a wireless connection with a portable device while moving from one area to another. This in turn has led users to become more and more demanding by requiring access to information anytime and from anywhere. Moreover, the diversity in the range of information that is accessible to a user is growing at a rapid rate nowadays. For example, mobile users carrying Windows Mobile powered devices can have access at any time and from any place to various types of data, send and receive e-mail or SMS, make phone calls, browse the Internet, and more.

In this paper we explore the concept of mobility by targeting Windows Mobile powered devices such as Pocket PCs, Pocket PCs Phone Edition, and Smartphones. Moreover, we describe and implement the activities of dentists by presenting the Mobile Dentist Application which can be deployed to such mobile devices and used by Mobile Dentists.

1.1. What is Mobile Dentist Application?

The Mobile Dentist Application is a software application designed specially for Mobile Dentists who would like to have access to their patients' data as well as other private data anytime and from anywhere. This application is built and developed to be deployed to Windows Mobile powered devices such as a Pocket PC and to handle several mobile dentists' issues including secure login authentication, managing patients' information, managing patients' appointments, keeping track of patients' payments, recording all dentist's expenses, generating Balance Sheets, including an Artificial Intelligent component displaying a popup balloon notifying the dentist about the patient's health history as well as any other critical health problems, integrating a Smart Reminder Component which automatically sends SMS reminder messages to patients, generating Statement of Accounts that can be sent via SMS to patients, and

more. Furthermore, the Mobile Dentist Application is carefully developed to grant dentists the freedom of movement while having access to their clinics' stock data, accounting data, as well as patients' private data anytime and from anywhere.

1.2. What is a Windows Mobile Powered Device?

A "Windows Mobile powered device" is a small size mobile device that can be held by hand and is managed by the Windows Mobile operating system [3]. It allows mobile users to make phone calls, send and receive e-mail, manage their contacts, surf the Internet, send and receive SMS (Short Message Service), develop and deploy their own mobile applications to the device, and more. Windows Mobile powered devices come in three flavors: "Pocket PC, Pocket PC Phone Edition, and Smartphone" [3]. While there are several differences between the three, the most visible difference is touch-screen support: Pocket PC and Pocket PC Phone Edition powered devices have touch-screens, while Smartphones do not.

1.3. What is Windows Mobile?

Windows Mobile is a powerful developer platform that allows us to design and build customized applications for mobile devices [3]. Moreover, we can develop our own mobile applications and deploy them to any Windows Mobile powered device so that we can have access to our private data anytime and from anywhere. Several brands of mobile devices operate under the control of the Windows Mobile operating system. For example, we can find Windows Mobile platform on "Dell, HP, Motorola, and i-mate products" [3].

1.4. Scope of the Project

Windows Mobile powered devices are broadly distributed almost everywhere nowadays. What makes these handheld devices popular is their fast hardware development. They provide now high quality screens, cameras, bigger memory capacities, and great communications methods that were not available over the past years. Thus, Windows Mobile takes advantage of the power and fast development of these mobile devices while offering developers a powerful platform for designing and building their own mobile applications. Taking advantage of this highly sophisticated technology allowed us to design and develop the Mobile Dentist Application which can be deployed to such mobile devices. This in turn gave us the opportunity to migrate from desktop to mobile applications development where the mobile user can have access to various types of data anytime, anywhere. The main goal of our Mobile Dentist Application is to allow the dentist to manage and have access to his clinics' stock data, accounting data, as well as patients' private data while moving from one place to another. Moreover, our mobile application can generate automatic statement of accounts and send them via SMS to appropriate patients. The application can also generate automatic reminder messages and send them via SMS to desired patients reminding them of their next appointment's date and time. Thanks to this technology and especially the Windows Mobile powered devices technology which permitted us to achieve all our goals. However, this technology lacks some printing capabilities. We could not generate reports and print them from the mobile device. For example, we could not print our reports such as statement of account or balance sheet due to the lack of printing capabilities or because this technology is not yet directly available to developers. As a consequence, we eliminated any printing options from our Mobile Dentist Application and mentioned that in the future work section of this report hoping that this problem will be solved in the near future.

CHAPTER 2

LITERATURE REVIEW

This chapter presents an overview of the literature and history of mobile computing as well as the Windows Mobile powered devices during the past years.

2.1. What is a Pocket PC?

A "Pocket PC" is mobile device that can be carried by hand and is powered by the Windows Mobile operating system. It comes with mobile versions of Microsoft Office applications such as Word, Excel, PowerPoint, and Outlook Mobile. Many Pocket PCs include "Wi-Fi" to allow the mobile user to connect to and surf the Internet as well as send and receive e-mail messages [3].

2.2. What is a Pocket PC Phone Edition?

A "Pocket PC Phone Edition" includes all the characteristics of a Pocket PC in addition to both wireless network access as well as cellular phone features. With a Pocket PC Phone, a mobile user can connect to and surf the Internet through the wireless connection capability [3]. In addition, the same mobile user carrying a Pocket PC Phone can make phone calls and send and receive e-mail and SMS messages.

2.3. What is a Smartphone?

A "Smartphone" includes all the powerful cellular phone characteristics and is shipped with a smaller set of mobile applications. This device has several hardware limitations such as a small keypad and screen display, limited memory capacity, etc. On the other hand, a Smartphone is an ideal mobile device for business users who just need to send and receive e-mail, manage their calendars and contacts, but who don't want to benefit from the powerful mobile applications such as "Word Mobile, Excel Mobile, and PowerPoint Mobile" [3].

2.4. Mobile Phones may be the Right Devices for Rural Accessibility

Parikh in [1] presented a comparison between the powerful capabilities and hardware restrictions of mobile devices, and how much useful is this technology to the rural users. Some of those limitations include a small screen size which confuses users who are beginners by restricting their decisions; lack of audio feedback which is very important for both beginners and advanced mobile users; small keypad that makes it difficult to type long messages; and more. However, Parikh argued that the "WWW as currently conceived may be an inappropriate model for delivering mobile information services in this context". To illustrate another framework, the author presented "CAM" which is designed for distributing mobile information services in the rural areas. The main advantages of the CAM platform are as follows:

- Scripted - CAM programs are built using scripted actions and functions. As a result, the display limitations of mobile phones as well as the interaction limitations of mobile users fit together nicely with this approach.
- Support for Rich Media - CAM user interaction can be associated with audio and graphics. This in turn can eliminate difficulties and errors generated from user input as well as give the mobile user freedom to send messages without having to use the keypad.
- Can be used Offline - Using asynchronous messaging services like SMS and MMS, CAM can be accessed without an active Internet connection.

2.5. Enabling New Speech Driven Services for Mobile Devices

Data communication is nowadays increasingly spreading to the mobile devices. Mobile users require access to information anytime and from anywhere by using small handheld mobile devices. However, those devices lack the use of "voice commander or speech input". But due to hardware limitations, the voice commander technology is not an easy challenge [2].

Pearce in [2] suggested that special servers should be designed in order to take care of all the computational complexities between the mobile users while using voice commander to perform their daily tasks. Moreover, the author presented a "Distributed Speech Recognition (DSR) system" which is carefully designed and developed to translate and transmit the speech that can be later on recognized and converted into text and vice versa. According to Pearce [2], the key advantages of the DSR system are as follows:

- Improved recognition performance over wireless channels: The use of DSR minimizes impact of speech codec and channel errors that reduce the performance from recognizers accessed over digital mobile speech channels.
- Ease of integration of combined speech and data applications: Many new mobile applications use speech to access wireless internet content. The use of DSR enables these to operate over a single wireless data transport rather than having separate speech and data channels.
- Ubiquitous access with guaranteed recognition performance levels: DSR offers the promise of guaranteed level of recognition performance over every network with no channel distortion coming from the speech codec.

2.6. Grid Computing on Mobile Devices

Mobile devices are often resource limited: processing power is low, battery life is finite, and storage space is constrained. These restrictions slow application execution, and hinder operability. Arguably, applications executing on such devices must be made aware of concurrently-executing applications in order to optimally use the limited resources [4].

Chu and Humphrey in [4] stated that grid computing offers an attractive alternative for resource-demanding applications. "The paradigm of Grid Computing as applied to resource limited devices is that somehow the devices can collectively deliver the quality of service needed by the end-user. Currently, grid computing predominately serves computationally intensive scientific and enterprise applications and operates on cluster computers or supercomputers". Therefore, the authors presented "Mobile OGSI.NET" which applies grid computing techniques to mobile devices offering grid service hosting on portable devices. Moreover, "Mobile OGSI.NET" addresses the mobile devices' hardware limitations and discontinuous network connections, factors which differentiate them from traditional computers.

2.7. Performance Assertions for Mobile Devices

Lencevicius and Metz in [5] argued that mobile devices include complicated mobile applications that are subject to various performance conditions. Moreover, they stated that nowadays mobile devices can be used not only for making phone calls but also for connecting to and surfing the Internet, sending and receiving SMS and email messages, using mobile applications, and so on. Moreover, many mobile devices nowadays come with cameras and are capable of taking pictures and capturing movies. As a consequence, Lencevicius and Metz confirmed that "mobile phones host a range of communication-centered applications most of which have performance constraints at various levels. Some of these performance constraints are hard real-time, some of them are soft real-time, i.e., they affect the quality of operation perceived by users" [5].

Lencevicius and Metz concluded that "performance assertions allow specifying performance requirements, mapping them to the source code and validating them during execution. Performance assertions do not provide guarantees

that performance constraints will be never violated. They are tools for testing, not for the formal verification". Therefore, the authors presented a short and powerful platform that permits the identification and justification of the performance requirements for portable devices such as a Pocket PC. By applying this framework on a number of mobile applications, the authors believed that such a "framework will allow performance engineers to rapidly adopt performance assertions" [5].

2.8. Converting Web Pages for Delivery to Mobile Devices

Browsing the Internet from mobile devices is now possible due to the rapid advance of the wireless technology. Yet, portable devices have small screen dimensions and limited hardware capabilities. As a consequence, the content of a web page will be normally bigger than the size of the mobile device screen. Thus, web pages should be converted before delivering them to mobile devices. Yin and Lee in [6] proposed to use a "ranking algorithm similar to Google's PageRank algorithm to rank the content objects within a web page". This technique permits the retrieval of important sections of web pages to be delivered to mobile devices. This in turn improves performance by saving both download time and time spent to scroll information on the mobile device small screen.

The main scheme behind this technique is a "ranking algorithm for elements of a web page. The idea behind the ranking algorithm is to first represent a web page as a graph model and then exploiting the graph structure to rank the elements". As a consequence, Yin and Lee achieved their goal by proposing three interesting ideas: "First, it is possible to represent the HTML web page with a graph structure. Second, based on their ranking algorithm, the system can understand what the most important topic of a web page is. Third, they developed an algorithm to reformat and optimize the subset of the original web page for different mobile device" [6].

2.9. Efficient Web Search on Mobile Devices

With the rapid advance of the wireless technology, mobile computing has gained great popularity nowadays. Chang et al. in [7] suggested that "improving the ease of searching for information on a mobile device can dramatically improve the efficiency of searching for websites information on such devices". Therefore, they focused on "enabling the use of spoken queries with the search engine of a particular website". In other words, Chang et al. presented an approach which uses spoken query to facilitate the process of data searching on a handheld device. The following figure illustrates the structure of the proposed approach [7]:

"A mobile user (IPAQ Client) connects to the server of search engine (IpaqRet) through either a wired or wireless network. If the input query is a speech, the MiPad server is contacted to perform continuous speech recognition. Then, the recognized text is sent to the IpaqRet server to perform information retrieval on articles relevant to the input string. The titles of the relevant article are sent back to the IPAQ client, and displayed on screen in the form of article titles list. Likewise, the information retrieval process for text input is similar to using speech input, except that the input text is passed to the IpaqRet server directly without triggering the MiPad server" [7].

2.10. Practical Real-Time Video Codec for Mobile Devices

Yu et al. in [8] clarified that "real-time software-based video codec" has been extensively used on Desktop computers including fairly strong computing capabilities. However, this cannot be applied to mobile devices which suffer from hardware restrictions and power. On the other hand, recent years have witnessed a rapid development of the mobile devices with wireless connections. Thus, the authors emphasized that with the continuing improvement of storage capacity and computing capability, software-based video coding on mobile devices is becoming economically possible. In addition to that, the appearance of digital cameras for mobile devices also provides conditions for real-time video communication [8].

Hence, Yu et al. "developed a practical low complexity real-time video codec for mobile devices. Several methods that can significantly reduce the computational cost are adopted in this codec. Moreover, a real-time video communication implementation of the proposed codec is also introduced. Experiments show that the loss in video quality is negligible. The proposed codec is very suitable for scenarios where low-complexity computing is required" [8].

2.11. Content Interaction and Formatting for Mobile Devices

Accessing and presenting multimedia contents on limited mobile environments represents a real challenge due to the fact that "mobile devices platforms are subject to various constraints which make the design of adaptable multimedia architectures considerably complex" [9]. On the other hands, due to the limitations of the mobile devices hardware, in addition to the different types of network connections, the difficulty of transmitting multimedia content using such devices is still a challenging issue.

Lemlouma and Layaïda in [9] suggested that "without advanced adaptation techniques, the languages defined for mobile devices such as SVG Mobile, MMS, etc, and designed to provide sufficient functionality to create compelling multimedia presentations, fail to provide functions that consider the targeted mobile client limitations". Thus, the authors presented an "approach that enables the presentation and the access to rich multimedia content for mobile devices. Their goal is to overcome devices limitations and content complexity by providing an advanced

adaptable system that combines content adaptation, formatting, and user interactions. Thus, the obtained content adaptation process allows a finer control on the presentation of multimedia content and an accurate formatting; tackling the limitations related to mobile devices resources and is more suitable for small screen displays" [9].

2.12. Performance Validation on Mobile Devices

Hubbard et al. in [10] emphasized that mobile devices host complicated mobile applications subject to various "non-functional requirements". They concentrated on performance issue focusing on two areas of performance: "software response time and power consumption", although their methods may be also applicable to other performance areas, such as memory consumption. Moreover, they argued that software response time and power consumption requirements are somewhat at odds with each other: "decreasing response time by using more powerful hardware usually means increased power consumption, while decreasing power consumption may lead to slower response times". However, they are tightly connected, since they both depend on both the hardware specifications and on the software execution [10].

Hubbard et al. showed that mobile device processors lack the speed of their personal computer counterparts for cost and size reasons, while the mobile software is as complicated as the software running on desktop computers. "This forces mobile application developers to spend a lot of time optimizing software performance". Moreover, the authors suggested that mobile device power consumption is primarily important for two critical reasons: "battery lifetime and heat dissipation. Extending battery lifetime supports other non-functional requirements such as usability and availability of the device since the device does not have to be connected to the power outlet and charged as often. Heat dissipation is a key requirement because if too much heat is dissipated in too short amount of time, the device may overheat. It then has to be shut down or it risks being destroyed" [10]. In conclusion, Hubbard et al outlined ideas for future directions in performance validation on mobile devices, based on the current work in model-based validation, application state monitoring and performance assertions.

CHAPTER 3

THE MOBILE DENTIST APPLICATION

Nowadays, mobile users carrying Windows Mobile powered devices can have access at any time and from any place to various types of data, send and receive e-mail or SMS, make phone calls, browse the Internet, and more. As a consequence, dentists nowadays tend to be more demanding. They desire or sometimes require access to their private as well as patients' information anytime and from anywhere. Hence, we describe and implement the Mobile Dentists' activities and present the *Mobile Dentist Application* (MDA) which is especially designed and developed to be deployed to Windows Mobile powered devices and to handle several mobile dentists' issues while granting them the freedom to move and have access to their clinics' stock data, accounting data, as well as patients' private data anytime and from anywhere. In this chapter we will discuss and describe the main components of the Mobile Dentist Application project while presenting several snapshots to illustrate the major concepts adopted and implemented in this project.

3.1. User Authentication and Security Issues

The User Authentication form is the first window that appears when the user (e.g. dentist, secretary, etc.) runs the Mobile Dentist Application (MDA). This form is carefully designed to protect and secure MDA from malicious users and intruders. Hence, each user must provide a valid User ID and Password to be allowed to login to MDA and have access to the appropriate components of the application. Moreover, Passwords are carefully encrypted and decrypted using a hash function so that hackers cannot break the security of MDA and have access to the dentists' private information. The following snapshot (Figure 1) illustrates the MDA User Authentication form where only authorized users can login to the system or change their passwords whenever they wish:

Figure 1: User Authentication Form

In addition, MDA is specially designed to be used by several users such as the dentist, morning secretary, afternoon secretary, etc. while each user can have access to specific parts of MDA. Only the superpower user called administrator (e.g. the dentist) can manage MDA users by creating new users, assigning specific limited rights and tasks to users, modifying users' rights and passwords, and deleting an old user to prohibit him from accessing MDA any more (e.g. in case a secretary quit the job). To do so, the administrator can list all MDA users and then choose the appropriate menu option to manage a specific user's rights, create, edit or delete any user from the list. Figure 2 is a snapshot that illustrates the process of listing and managing MDA users:

Figure 2: Listing and Managing MDA Users

From the menu options at the bottom of Figure 2, the administrator of MDA can select a desired user and then assign specific tasks and access rights to him. For example, the administrator can assign the following access rights to a morning secretary called "Roula": Manage patients' appointments, Display patients' records, Add new patients to the database and Manage patients' invoices and payments. In this case, the secretary, for example, cannot edit an existing patient's record and modify or delete any piece of information from that record because she does not have access right to perform this operation. The following figure (Figure 3) illustrates this example by displaying the access rights of the user "Roula" where each checked box means that the user has access right to the that part of MDA whereas an unchecked box prohibit "Roula" from accessing that MDA part:

Figure 3: Assigning Access Rights to MDA Users

3.2. MDA Main Menu

As mentioned earlier, only authorized users can login to MDA. Once the authentication process is done, the valid user can have access to the Main Menu form of MDA which includes a main menu consisting of four main options: Patient, Income, Expenses, and Tools. Moreover, each main option contains a group of several relevant sub options. For example, the main option "Patient" includes the following sub options related to the dentist's patients: "New Patient", "List/Edit Patient", "Activate SMS", and "Appointments". In this way, all the MDA components are grouped and organized into menu options giving the user an easy and fast access to the different MDA components. Figure 5 is a snapshot of the MDA Main Menu where the four main options are displayed at the bottom of the window:

Figure 4: MDA Main Menu

However, the menu options will be enabled and disabled according to the user's access rights. In other words, the user can only access menu options that the administrator assigns to him. Therefore, this security measurement allows many users to use MDA while granting the administrator the power to give different access rights to different users of MDA. Figure 5 is a snapshot illustrating the concept of enabling and disabling menu options according to each user's access rights. Moreover, Figure 5 illustrates the Main Menu as it appeared once the user "Roula" has successfully logged in to MDA. Notice that the menu options "New Patient" and "Appointments" are enabled because as mentioned earlier, "Roula" has been granted access to those options, whereas the other options "List/Edit Patients" and "Activate SMS" are disabled and thus prohibiting "Roula" from accessing them:

Figure 5: Automatic Enabling and Disabling Menu Options based on User Rights

3.3. New Patient Registration Form

Every New Patient treated by the dentist at the clinic must have a medical record stored in the database of MDA. The process of initiating and generating a new patient's medical record can be done by either the dentist or secretary with appropriate access right. The information that should be registered in the patient's medical record during his initial visit is as follows:

- ◆ Personal Information such as: First Name, Last Name, Birth Date, Mobile#, Home and Email addresses, Patient's Occupation, etc.
- ◆ Medical History including health problems like Heart, Anemia, Hepatitis, Renal, Nerve, Endocrine, Pneumonia, Diabetes, Asthma, Tuberculosis, etc.
- ◆ Whether the patient is allergic to specific types of medicine like Aspirin, Antibiotics, Anesthetics, etc.

- ◆ Whether the patient is under medical care, and if so, the name of his private physician, mobile# and Email address.
- ◆ For female patients, whether they are pregnant and the expected delivery date.
- ◆ A comment field used by the dentist to register any additional information including special remarks and observations about the patient.

Figure 6 is a snapshot of a New Patient Registration Form that can be used by any authorized user of MDA to initiate a new patient's medical record and save it in the MDA database:

New Patient

First Name:

Last Name:

Birth Date: 24/04/2007 ▼

Gender: ▼

Phone:

Mobile:

Address:

Email:

Profession:

General Info | Medical History | Allergies | Others

Cancel Save

Figure 6: New Patient Registration Form

3.4. Patients Search Engine Form

The Patients Search Engine Form is a powerful MDA component that can be used by authorized users to do the following operations:

- ◆ Display a summary list of all patients sorted by First Name and including: First Name, Last Name, Mobile#, Home#, and Email Address for each patient.
- ◆ Searching for a specific patient's medical record by filtering the summary list of patients according to the value entered in the "Find a Patient" box. In other words, the user can type a value in the "Find a Patient" box and the list will be automatically filtered according to this value. For example, if the user enters the value "J" in the "Find a Patient" box, the list will be automatically filtered to display all patients' names starting with the letter "J". If the user continues typing another letter "a" then the list will be automatically filtered again to display all patients' names starting with the new value "Ja", and so on.
- ◆ Edit a patient's medical record. This is done by first searching for the desired patient, selecting his record and then choosing "Edit" from the menu. As a consequence, the entire patient's medical record will be displayed allowing the user to modify any piece of information.
- ◆ Delete a patient's medical record permanently from the MDA database. This is done by searching for the desired patient's record, selecting it and then choosing "Delete" from the menu. However, a delete confirmation dialog box appears asking the user for further affirmation before deleting the patient's medical record permanently from the database.

Figure 7 is a snapshot of the Patients Search Engine Form that can be accessed by any authorized user. Notice that a summary list of all existing patients is initially displayed; the "Find a Patient" box is standby waiting for the user to key in any desired value so that the list will be automatically filtered accordingly. Notice also the menu options at the bottom of the form that can be used to edit or delete any desired patient's medical record:

List of Patients

Find a Patient :

	First Name	Last Name	Mobile #	Pho
▶	Amal	xxx	1	1
	Colette	xxx	1	1
	Dounia	yyyy	1	1
	Jack	El-Nar	1	1
	Jad	eeee	1	1
	Joe	Khoury	1	1
	Joey	xxx	1	1
	Johnny	El-Nar	1	1
	Joseph	Nar	1	1
	Mary	Bou Ghosn	1	1
	Miriam	xxx	1	1
	Nader	xxx	1	1

◀ ||| ▶

Delete Edit Close

Figure 7: Patients Search Engine Form

3.5. Appointments Form

Managing patients' appointments is done in this form. The Appointments Form is a powerful MDA component that can be used by authorized users only to register, organize and keep track of all patients' appointments. On the other hand, patients' appointments can be registered every half an hour. However, this time interval can be customized by an authorized user to satisfy the requirements of every dentist. The patients' appointments process is done as follows: Once this component is activated, a list of all appointments of the current date will be displayed. In addition, a monthly calendar will be also display on top of the form allowing the user to select any desired date in order to refresh the list and display the appointments of that selected date. In addition, the user can manage this list by editing an existing appointment or registering a new appointment inside any vacant time interval.

Moreover, while generating a new appointment, the user has the choice to set an SMS reminder date and time for that appointment. In other words, once the SMS reminder date and time is set, the appropriate patient will be reminded via SMS of his next appointment's date and time. In this case, an SMS reminder message will be automatically generated on the reminder date and time and then sent via SMS to the patient, reminding him of his next appointment's date and time. Figure 8 is a snapshot of the MDA Appointments component displaying a list of the current date's appointments and allowing the authorized user to manage patients' appointments:

Figure 8: Appointments Form

The following snapshot (Figure 9) presents the Edit Appointment component where the authorized user can manage an appointment as well as set the SMS Reminder date and time for the desired appointment:

Figure 9: Managing Appointments and Setting SMS Reminder Date and Time

3.6. Smart SMS Component

Smart SMS is a very powerful MDA component that can be activated by authorized users only to initiate the process of generating automatic SMS reminder messages and sending them via SMS to the appropriate patients. Once the Smart SMS component is activated, an envelope icon will be displayed at the upper left corner of the title bar indicating that the Smart SMS Service is now active. This service works in the background of MDA without interrupting the user from using or running other MDA components. In other words, the Smart SMS Service operates as follows: It checks every minute the appointments' reminder date and time and gets a list of patients to be currently reminded. Smart SMS then generates an SMS reminder message and sends it to those patients that should be currently reminded of their next appointments' date and time. After that, a delivery report will be automatically

generated and stored in the Messenger Inbox of the mobile device for delivery confirmation purposes. In Figure 10, the Smart SMS Service is activated. Notice the display of the envelope icon in the title bar. This service can be deactivated at any time by authorized users. In this case, Smart SMS Service stops sending automatic reminder messages to patients and the envelope icon disappears from the title bar:

Figure 10: Smart SMS Component

3.7. Invoice Generation Form

Every patient visiting the dentist at the clinic must be charged for the treatment he receives. This process is done by generating a patient invoice specifying the invoice number, invoice date, patient's full name, work done by the dentist, and the amount due to be paid by the patient. To facilitate the generation of new invoices, a sequential invoice number will be automatically generated by MDA. The default

value of invoice date will be the current date. Then, the authorized user selects the appropriate patient name from the drop down list and specifies the tooth number and work done by the dentist. The system then automatically computes and displays the amount due based on the work done. Figure 11 presents a snapshot of the Invoice Generation Form:

New Invoice

Invoice # : 3

Invoice Date: 21/04/2007

Patient Name: Jack El-Nar

Tooth # : 25

Work Done: Extraction

Amount Due: 120,000

Delete Cancel Save

Figure 11: Invoice Generation Form

3.8. Listing and Managing Patients Invoices

Any authorized user having access right to the List/Edit Invoices Form can do the following operations: Display a list of all patients' invoices including for each invoice: Invoice Number and Date, Patient Name, Work Done, Amount Due, Total Amount Paid, and Net to Pay. The user can also filter that list by Invoice Date, Patient Name, or both. Moreover, the displayed list of invoices can be sorted either by

Invoice Date or Patient Name. The authorized user can also manage a specific invoice by selecting it from the list and then choosing the Edit option from the menu. In this case, the user can modify the contents of an existing invoice. This operation is especially useful when the user generates invoices that contain mistakes. On the other hand, this component contains a powerful Sorting and Filtering options which allow the authorized user to retrieve and display customized lists of patients' invoices. This in turn provides the dentist with various forms of statistical information related to the patients' invoices. For example, a list of invoices generated today can be easily retrieved and displayed to give the dentist an accurate accounting figure, or a list of all invoices related to a specific patient can also be generated to provide the dentist with historical information concerning the amount due, paid and net to pay for each invoice associated to that patient, and so on. Figure 12 presents a sample snapshot illustrating this component. Notice the appearance of a horizontal scroll bar which can be used to display the hidden information by scrolling the list left or right:

Figure 12: Listing and Managing Patients Invoices

3.9. The Patient Payment Process

The Patient Payment Component is specially designed to give the patient the choice to make several payments processes in order to settle his account. In other words, the Payment Component accepts any amount the patient wishes to pay and accumulates it to the patient's account. However, each payment process should be related to a patient invoice. As mentioned earlier, the dentist should issue an invoice for each job done, specifying the patient's full name, the type of work done and the amount due. The patient then is free to pay the whole amount due or to make several payments processes until this amount is entirely settled. Moreover, the same patient might receive another treatment from the dentist where another invoice should be also issued for this second treatment, and so on. This is called a "one to many" concept. In other words, for each patient's invoice there can be one or many payments. This concept is especially important to organize the accounting procedure and to provide the dentist with a clear and organized figure of each patient's accounting status.

This component can be activated by an authorized user only. The patient payment process is accomplished as follows: The user first enters the Payment Date, Amount Paid and selects the appropriate Patient Name from the drop down list. Then, by clicking the "Get Invoices" option from the menu, a list of unsettled invoices related to the chosen patient will be displayed. The user then is supposed to choose the appropriate invoice to which the payment should be attached. However, to facilitate the generation of new payments, a sequential payment number will be automatically generated by MDA and the default value of payment date will be the current date. Figure 13 presents a sample snapshot of the Patient Payment Process. Notice that the patient "Jack El-Nar" has two invoices unsettled yet. This means that the patient has received two separate treatments from the dentist, thus two invoices, while he did not yet settled the payments of those invoices. In addition, the user has the choice to select whichever invoice to which the payment of "50000" will be attached. The arrow at the beginning of the invoice row indicates that this invoice has been selected by the user:

New Patient Payment

Payment Date: 24/04/2007

Amount Paid: 50000

Patient Name: Jack El-Nar

	Invoice Date	Amount Due	Total Paid	Net
	20/03/2007	45000	0	450
▶	24/04/2007	120000	0	120

Delete Cancel Save Get Invoices

Figure 13: The Patient Payment Process

3.10. Listing and Managing Patients Payments

Any authorized user having access right to the List/Edit Payments Form can do the following operations: Display a list of all patients' payments including: Payment Number and Date, Patient Name, Amount Paid, as well as details about the invoice to which this payment is linked. The user can also filter that list by Payment Date, Patient Name, or both. Moreover, the displayed list of payments can be sorted either by Payment Date or Patient Name. The authorized user can also manage a specific payment by selecting it from the list and then choosing the Edit option from the menu. In this case, the user can modify the contents of an existing payment. This operation is especially helpful when the user generates payments that contain mistakes. On the other hand, this component contains a powerful Sorting and Filtering options which allow the authorized user to retrieve and display customized lists of

patients' payments. This in turn provides the dentist with various forms of statistical information related to the patients' payments. For example, a list of payments generated today can be easily retrieved and displayed to give the dentist an accurate accounting figure, or a list of all payments related to a specific patient can also be generated to offer the dentist a clear and accurate overview of the patient's payments history. Figure 14 presents a sample snapshot illustrating this component. Notice the appearance of a horizontal scroll bar which can be used to display the hidden information by scrolling the list left or right:

Figure 14: Listing and Managing Patients Payments

3.11. Statement of Account

The Statement of Account is a powerful MDA component that can be generated only by an authorized user. This statement presents a thorough and broad overview of each patient's accounting history including details of all invoices and their related payments. Therefore, for each patient's invoice, the following Statement of Account details will be displayed: Invoice Date and Number, Work Done, Amount Due, Amount Paid for this invoice, Balance of this invoice, General Balance, as well as a detailed list of all related payments. Moreover, in case the patient has several invoices, the "Next" and "Previous" menu options will be enabled allowing the user to browse the patient's invoices and have access to all their accounting details.

Another powerful service included in the Statement of Account component is the ability to send a summary of the statement via SMS to the appropriate patient. This is done by clicking SMS menu option. Thus, this service helps the dentist to notify all patients having due balances to settle their accounts. In addition, it keeps the patients updated with the latest accounting figure as well as reminding them to settle any due balances. Figure 15 presents a sample Statement of Account snapshot:

Statement of Account

Patient Name: Jack El-Nar

Inv. Date: 24/04/2007 Invoice #: 3

Tooth # : 25 Work : Extraction

Amt Due : 120000 Amt Recv: 120000

Inv. Net : 0 Balance : 45,000

Payment Date	Amount Paid	Payment #
30/04/2007	40000	3
28/04/2007	30000	2
24/04/2007	50000	1

Close SMS Display Previous Next

Figure 15: Statement of Account

3.12. Managing Clinic Expenses

All expenses related to the dentist's clinic should be registered in the MDA database through this component. This process can be initiated by an authorized user who is in charge of keeping track of the clinic's expenses by activating the New Expense Form and then entering the following expense information: expense date, reference number, expense description, and the amount spent. To facilitate the generation of new expenses, a sequential expense number will be automatically generated by MDA. Moreover, the default value of expense date will be the current date. The following figure (Figure 16) is a sample snapshot of the New Expense Form where used by the authorized user to register all expenses related to the dentist's clinic:

New Expense

Expense # : 1

Expense Date : 26/04/2007

Reference # : 2568

Description : Electricity

Is it Asset ? : ☐

Total Amount : 150,000

Delete Cancel Save

Figure 16: New Expense Form

3.13. Listing and Editing Clinic Expenses

Any authorized user having access right to the List/Edit Expenses Form can do the following tasks: Display a list of the clinic's expenses including: Expense Number and Date, Expense Description, and Amount Spent. The user can filter that list by Expense Date, Expense Description, or both. This list can also be sorted either by Expense Date or Expense Description. Moreover, the user can manage a specific expense record by selecting it from the list and then choosing the Edit menu option. In this case, an authorized user can modify the contents of an existing expense record. This operation is especially helpful when generating expenses that contain mistakes. In addition, this component contains a powerful Sorting and Filtering options which allow the user to display customized lists of the clinic expenses. This in turn provides the dentist with various forms of statistical information related to the clinic expenses during a specific range of dates. For example, a list of expenses from 10/04/2007 until 26/04/2007 can be generated to give the dentist an overview of the expenditure done during that period, or a list of electricity bills can also be displayed during that period. Figure 17 is a sample snapshot illustrating this MDA component:

Expense Date	Description	Amount
26/04/2007	Clinic Items	275000
26/04/2007	Electricity	150000
26/04/2007	Phone Bill	180000
10/04/2007	Maintenance	120000

Total Expenses : 725,000

Delete Filter Sort Edit Close

Figure 17: Listing and Editing Clinic Expenses

3.14. Balance Sheet

The Balance Sheet is a very powerful MDA component that can be generated only by an authorized user. This report presents a thorough and detailed overview of the clinic's accounting status during a particular range of dates. Once the user specifies the period of time, the balance sheet report will be generated and displayed including: Total Income, Total Expenses and Net Profit or Loss during that period of time. In addition, the report also presents a detailed list of the clinic's income representing all patients' payments as well as the clinic's expenses during that period.

Figure 18 is a sample snapshot of a Balance Sheet report for the month of April 2007. Notice the Net Loss of 605,000 meaning that during this month the expenditure is more than the income. In addition, a detailed list of the income received followed by a list of clinic's expenses during that month are also displayed in this report. However, due to screen size limitations, we present the vertical scroll bar which will be used to scroll the contents of this report up and down:

Balance Sheet

From Date : 01/04/2007
To Date : 30/04/2007

Total Income : 120,000
Total Expenses : 725,000
Net Loss : -605,000

Income Date	Patient Name	Amount Recv
30/04/2007	Jack El-Nar	40000
28/04/2007	Jack El-Nar	30000
24/04/2007	Jack El-Nar	50000

Close Display

Figure 18: Balance Sheet (Part 1/2)

Figure 19 is another snapshot of the above Balance Sheet report displaying the detailed list of the clinic's expenses after the authorized user scrolled the report's contents down:

Total Expenses :		725,000
Net Loss	:	-605,000

Income Date	Patient Name	Amount Recv
30/04/2007	Jack El-Nar	40000
28/04/2007	Jack El-Nar	30000
24/04/2007	Jack El-Nar	50000

Expense Date	Description	Amount	
26/04/2007	Clinic Items	275000	F
26/04/2007	Electricity	150000	F
26/04/2007	Phone Bill	180000	F
10/04/2007	Maintenance	120000	F

Close   Display

Figure 19: Balance Sheet (Part 2/2)

3.15. Listing and Managing Dentists Notes

This MDA component is specially designed for dentists to keep track of their personal as well as professional notes and remarks. The list of notes will be stored in the MDA database and the dentist can have access to it anytime and from anywhere using his mobile device running MDA. In addition, this list can be very helpful for dentists reminding them of the activities to do, items to purchase, etc, whether they are at the clinic or moving from one place to another.

The following figure (Figure 20) is a sample snapshot displaying a list of the dentist's private notes and allowing him to manage that list by using the menu options at the bottom of the form:

Figure 20: Listing and Managing the Dentists Private Notes

3.16. Managing Appointments Time Interval

The Appointments Time Interval Form can be accessed by authorized users only who are granted the right to add or delete appointments' time periods. By default, the appointments' time interval is half an hour. However, this interval can be customized by an authorized user to satisfy the requirements of every dentist. In addition, this list of appointments' time interval is also used by the Appointments Form as described earlier in section 4.5, allowing the dentist or an authorized user to manage and keep track of the patients' appointments based on this time interval list.

Figure 21 is a default list of the appointments' time interval which can be customized by adding new time periods or deleting existing ones:

Figure 21: Managing Appointments Time Interval

3.17. Copyright Notification

The Mobile Dentist Application is entirely designed, developed and implemented by "Jack El-Nar" as illustrated in the Copyright Notification Figure below. Therefore, any unauthorized reproduction or distribution of this application or any portion of it, without the permission and authorization of the author will be considered as an illegal action and may result in severe civil and criminal penalties.

Figure 22 presents the copyright details as well as the release version of MDA. Notice that this is the first version (Version 1.0) of MDA. However, the development of MDA is an on going process allowing us to cope with all the difficulties and problems that faced us during the implementation of this first version.

Therefore, other versions of MDA will be released in the future to handle and manage the various complexities, obstacles and implementation problems as mentioned in the future work section of this report.

Figure 22: Copyright Notification

CHAPTER 4

MDA DEVELOPMENT AND TECHNICAL ASPECTS

MDA has been designed, developed and built using the Microsoft Visual Studio 2005 platform, the .NET Compact Framework, Visual Basic .NET, and SQL Server Mobile Edition. All the patients' personal information, appointments' data, stock data, patients' payments transactions, and clinic's accounting data are very well organized into several data tables stored inside one SQL database called "DentistDB". Each data table contains a primary key field so that data can be stored in a well organized and indexed way and searching for records can be faster and more efficient. In other words, all data generated by MDA is automatically stored and indexed into the appropriate tables inside "DentistDB". This database as well as all its internal data tables and fields have been created using the SQL Server Mobile Edition.

4.1. What is Microsoft Visual Studio 2005?

Visual Studio 2005 is a programming platform developed by Microsoft Corporation to enable developers to design and build various types of applications such as .NET applications, Web applications, as well as Mobile applications. Moreover, Visual Studio can be considered as a tool that allows developers to target both Pocket PC and Smartphone devices powered by the Windows Mobile operating system. In other words, Visual Studio 2005 assists the development of applications that can be easily deployed to Windows Mobile powered devices. In addition, Visual Studio offers the developers the ability to "use managed code with the .NET Compact Framework for user interface-centric applications that require fast time-to-market or rapid application development. As a consequence, developers can have easy access to Web services or data held in SQL Server or SQL Server Mobile Edition". Visual Studio 2005 also includes the Software Development Kit as well as the Emulator Images for several versions of the Windows Mobile operating system to help developers design and build efficient mobile applications.

4.2. What is .NET Compact Framework?

"The .NET Compact Framework brings the powerful programming environment of the .NET Framework to Windows Mobile powered devices. It is a hardware-independent environment for running programs on resource-constrained computing devices. Moreover, it consists of a subset of the .NET Framework class library and also contains classes exclusively designed for it. It also inherits the full .NET Framework architecture of the common language runtime and managed code execution. In addition to that, it supports Visual Basic .NET (VB.NET) and Visual C# development and uses the same class library documentation as the full .NET Framework". The Windows Mobile operating system also includes managed APIs, making it easier for developer to target the underlying Windows Mobile platform directly from within the .NET Compact Framework. In other words, with .NET Compact Framework, developers can use Visual Basic .NET or C# to access a healthy subset of the .NET Framework libraries, as well as the managed APIs that ship as part of the Windows Mobile platform [3].

4.3. What is SQL Server Mobile Edition?

"Microsoft SQL Server Mobile Edition offers essential relational database functionality in a compact footprint ideal for embedding in mobile and desktop applications, including a new generation of occasionally connected dynamic applications. The SQL Mobile engine exposes an essential set of relational database features, such as an optimizing query processor and support for transactions and assorted data types, while maintaining a compact footprint that preserves system resources. Remote data access and merge replication ensure that data from SQL Server databases is delivered reliably, can be manipulated offline, and can be synchronized later to the server, making SQL Server Mobile Edition ideal for mobile and wireless environments" [3].

4.4. MDA Database Schema

As mentioned earlier, all data generated by MDA is automatically organized, indexed and stored into the appropriate tables inside MDA database called "DentistDB". Moreover, each table is made up of several columns (fields) including a primary key field for fast and efficient indexing and data retrieval. The following figures present the schema and structure of each data table created inside the MDA database. Figure 23 presents the structure of the Appointments table where all the patients' appointments information will be stored. Figure 24 illustrates the schema of the Expenses table where all the clinic's expenses will be saved. On the other hand, every patient visiting the dentist must be charged for the treatment he receives. This process is done by generating a patient invoice specifying the invoice number, invoice date, patient's full name, work done by the dentist, and the amount due to be paid by the patient. Figure 25 presents the structure of the Invoices table where all the charges imposed by the dentist will be stored. Figure 26 illustrates the schema of the Patients table where all personal information related to the patients will be saved. Figure 27 presents the structure of the Payments table where all the payments made by the patients will be stored. Figure 28 illustrates the schema of the Users table where all authorized users IDs, Encrypted Passwords, and Access Rights will be stored.

Column Name	Data Type	Length	Allow Nulls	Unique	Primary Key
AppointDate	nvarchar	10	No	No	Yes
AppointTime	nvarchar	8	No	No	Yes
PatientID	smallint	2	Yes	No	No
Reminder	bit	1	Yes	No	No
ReminderDate	nvarchar	10	Yes	No	No
ReminderTime	nvarchar	8	Yes	No	No

Figure 23: Appointments Table Schema

Column Name	Data Type	Length	Allow Nulls	Unique	Primary Key
ExpenseID	smallint	2	No	Yes	Yes
ExpenseDate	nvarchar	10	Yes	No	No
ReferenceID	smallint	2	Yes	No	No
Description	nvarchar	15	Yes	No	No
Asset	bit	1	Yes	No	No
Amount	int	4	Yes	No	No

Figure 24: Expenses Table Schema

Column Name	Data Type	Length	Allow Nulls	Unique	Primary Key
InvoiceID	smallint	2	No	Yes	Yes
InvoiceDate	nvarchar	10	Yes	No	No
PatientID	smallint	2	Yes	No	No
ToothID	tinyint	1	Yes	No	No
WorkDone	nvarchar	15	Yes	No	No
AmountDue	int	4	Yes	No	No
TotalPaid	int	4	Yes	No	No

Figure 25: Invoices Table Schema

Column Name	Data Type	Length	Allow Nulls	Unique	Primary Key
PatientID	smallint	2	No	Yes	Yes
FirstName	nvarchar	15	Yes	No	No
LastName	nvarchar	15	Yes	No	No
BirthDate	datetime	8	Yes	No	No
Phone	nvarchar	8	Yes	No	No
Mobile	nvarchar	8	Yes	No	No
Address	nvarchar	15	Yes	No	No
Email	nvarchar	20	Yes	No	No
Profession	nvarchar	15	Yes	No	No
HeartProblem	bit	1	Yes	No	No
EndocrineProblem	bit	1	Yes	No	No
NerveProblem	bit	1	Yes	No	No
RenalProblem	bit	1	Yes	No	No
BloodProblem	bit	1	Yes	No	No
Hepatitis	bit	1	Yes	No	No
Anemia	bit	1	Yes	No	No
Asthma	bit	1	Yes	No	No
Pneumonia	bit	1	Yes	No	No
Rheumatisms	bit	1	Yes	No	No
Tuberculosis	bit	1	Yes	No	No
OtherProblems	nvarchar	15	Yes	No	No
Antibiotics	bit	1	Yes	No	No
Anesthetics	bit	1	Yes	No	No
Aspirin	bit	1	Yes	No	No
OtherAllergies	nvarchar	15	Yes	No	No
MedicalCare	bit	1	Yes	No	No
Prescription	nvarchar	15	Yes	No	No
Gender	nvarchar	1	Yes	No	No
Pregnant	bit	1	Yes	No	No
DeliveryDate	datetime	8	Yes	No	No
Physician	nvarchar	15	Yes	No	No
PhysicianMobile	nvarchar	8	Yes	No	No
PhysicianEmail	nvarchar	20	Yes	No	No
Comments	nvarchar	30	Yes	No	No

Figure 26: Patients Table Schema

Column Name	Data Type	Length	Allow Nulls	Unique	Primary Key
PaymentID	smallint	2	No	Yes	Yes
PaymentDate	nvarchar	10	Yes	No	No
InvoiceID	smallint	2	Yes	No	No
AmountPaid	int	4	Yes	No	No

Figure 27: Patients Payments Table Schema

Column Name	Data Type	Length	Allow Nulls	Unique	Primary Key
UserID	nvarchar	15	No	Yes	Yes
UserPassword	nvarchar	15	No	No	No
UserName	nvarchar	30	No	No	No
UserRights	nvarchar	30	No	No	No

Figure 28: Users Table Schema

4.5. ERD Diagram for the MDA Database

The above MDA database tables are related to each other using two main types of table relationships: "One to One" and "One to Many" relationships. For example, each Invoice can be issued to one and only one patient. Each payment process should be related to one and only one patient invoice. On the other hand, for each patient's invoice there can be one or many payments made by that patient. Figure 29 presents the Entity Relationship Diagram (ERD) which clearly illustrates the relationships between all the data tables of the MDA database:

Figure 29: ERD Diagram for the MDA Database

CHAPTER 5

FUTURE WORK AND CONCLUSION

The rapid advance of the mobile computing technology has greatly increased the ability to connect mobile users through both wired and wireless networks. Thus, handheld mobile devices are now equipped with high quality screens, cameras, better memory capacities, and powerful communications methods that were not available in the past years. On the other hand, what makes these devices popular is their fast and on going hardware development and improvement. As a consequence, mobile users nowadays tend to be more and more demanding, desiring or sometimes requiring access to information anytime and from anywhere. In this paper we explore the concept of mobility by targeting Windows Mobile powered devices such as Pocket PCs, Pocket PCs Phone Edition, and Smartphones. Therefore, we present a description and implementation for the activities of Mobile Dentists who would like to have access to their patients' information while moving from one place to another. Hence, this paper proposes the *Mobile Dentist Application* (MDA) which is specially designed and developed to be deployed to Windows Mobile powered devices and to handle several mobile dentists' issues including secure login authentication, managing patients' information, administering patients' appointments, keeping track of patients' payments, recording all dentist's expenses, generating Balance Sheets, including an Artificial Intelligent component, generating Statement of Accounts that can be sent via SMS to desired patients, and integrating a Smart Reminder Component which automatically generates reminder messages and sends them via SMS to appropriate patients reminding them of their next appointments' date and time. In conclusion, the main goal of our Mobile Dentist Application is to grant dentists the freedom of movement while having access to their clinics' stock data, accounting data, as well as patients' private data anytime and from anywhere.

Further work is still needed to support the on going development process of our Mobile Dentist Application as well as to handle and manage the various difficulties, obstacles and problems that faced us during the implementation of this first version of MDA using the Windows Mobile Platform technology. However, the major challenge we faced during the implementation process is the lack of any printing capabilities provided by this technology. In other words, we could not generate reports and print them from the mobile devices running our MDA. For example, we could not print our MDA reports such as Statement of Account or Balance Sheet due to the lack of any printing capabilities or because this technology is not yet directly available to developers. As a consequence, we eliminated any printing options from the first version of MDA, while keeping our on going research and efforts and hoping that this problem will be solved in future release versions of our Mobile Dentist Application.

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