



DIPLOMARBEIT

Pen-based Electronic Medical Record on a Tablet PC in a Medical Practice

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Abstract

The medical sector is seen as one of the main areas for future application of pen-operated Tablet PCs. Some hospitals already use tablets for their work, but often the software has not been developed for Tablet PCs and therefore many potential features and advantages are not exploited. Medical facilities where Tablet PCs have been hardly used so far are medical practices. Very little software has been created specifically for this purpose; often the software in use is adapted regular PC software, which fails to provide a variety of useful pen-based features.

This work aims to create a completely new prototype of pen-based EMR (Electronic Medical Record) software on a Tablet PC using new technologies such as C# and WPF (Windows Presentation Foundation). Some of the special features included are: using gestures for navigation, providing an image annotation tool where the user can write directly on the picture and modify the ink, using it as a communication device and adding audio comments to a record or inputting text with the stylus.

The first part of this master thesis contains some examples that describe medical software for Tablet PCs already on the market and which institutes already have tablets in use. In the main part, the development of the prototype and its usage are described. Due to special ink canvas controls and the new Windows Presentation Foundation, which enable many design possibilities, the text input with the stylus is done directly in the program and is analyzed and recognized afterwards. Various additional features (audio-recording, image-annotation, gestures) were implemented to show several advantages of the Tablet PC use.

The test results of the prototype with several users have shown that the new features are appreciated and can be used efficiently in a medical practice. Nevertheless, some training for more accurate text recognition has to be performed and the process of analyzing has to become more reliable.

Kurzfassung

Eines der Gebiete, für welche den Tablet PCs eine große Zukunft prophezeit wird, ist der medizinische Sektor. Einige Spitäler arbeiten bereits mit Tablet PCs, jedoch wurde die Software meistens nicht speziell für diesen Einsatz entwickelt, weswegen zahlreiche Funktionen und Vorteile fehlen. Besonders in medizinischen Ordinationen werden bis jetzt nur sehr selten Tablet PCs verwendet. Es gibt zwar einige Software-Hersteller, die Applikationen dafür entwickeln, jedoch sind dies oft nur Erweiterungen von gewöhnlichen Programmen für Desktop oder Laptop PCs.

Das Ziel dieser Arbeit ist, einen komplett neuen Prototypen für ein stiftbasiertes elektronisches Patientenkarteisystem (EMR – Electronic Medical Record) auf einem Tablet PC mithilfe von neuen Technologien wie C# und WPF (Windows Presentation Foundation) zu entwerfen. Einige der besonderen Fähigkeiten sind die Benutzung von Gesten für die Navigation, die Annotierung von Bildern und die Modifikation der Eingabe sowie die Benutzung zur Kommunikation, das Einfügen von Audiokommentaren und das Eingeben von Text mittels Handschrift.

Der erste Teil zeigt einige Beispiele von medizinischer Software für den Tablet PC, welche bereits auf dem Markt sind, und Institute, welche Tablet PCs schon einsetzen. Der Hauptteil befasst sich mit der Erstellung und dem Einsatz der Software. Mit Hilfe von Stifteingabe-Feldern (InkCanvas) und der neuen WPF, welche viele Gestaltungsmöglichkeiten bietet, wird die Eingabe mittels Stift und Handschrift direkt im Programm durchgeführt, analysiert und erkannt. Verschiedene zusätzliche Features (Audioaufnahmen, Fotoannotierung, Gesten) wurden eingebaut, um die Vorteile von Tablet PCs zu demonstrieren.

Die Testergebnisse mit einigen Benutzern haben gezeigt, dass die neuen Features gut angenommen werden und effizient in einer Ordination verwendet werden können. Trotzdem wird etwas Training vorausgesetzt um genauere Texterkennung zu erzielen, und auch der Textanalyse-Prozess muss noch exakter werden.

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1. Introduction

1.1. *Motivation*

As a son of a medical practitioner, the author of this master thesis has experienced the advantages and disadvantages of using a regular PC in a medical practice. Several doctors are not very good at using the computer because they have never really learned to operate one. Therefore it is really time-consuming for them to input data using the keyboard and control the program when it does not behave as they expect it to. Because of that they still use paper for some tasks which could be easily done on a computer, if it was not so hard for them to use the user interface. Besides, if they have to go to a different spot in the room they cannot take the PC with them, and for that reason they would have to walk from one side of the room to the other whenever they want to take notes on the computer.

Assuming that many doctors have the same problems, the idea of this study is to use a pen to input data into a portable computer. That is where the Tablet PC comes into play. It was introduced by Microsoft in the year 2002 [1] and hosts its own operating system Windows XP Tablet PC Edition [2]. It has built-in support for pen-input directly on a screen and speech recognition. The user can easily hold the screen with one hand and input data with the other, like someone would do with a regular pen and a sheet of paper. Because of its form the Tablet PC does not look as obtrusive to the patients as a laptop or a desktop PC do. The tablet seems to be a promising solution for the problem mentioned above.

To the author's knowledge in the German speaking software market there is not any program specializing on using a Tablet PC in a medical practice so far. There are some programs in the US market, but most of them are just enhanced desktop programs to use with pen-input. So there is a need for a program mainly just made for the use on a Tablet PC.

1.2. *Contribution and Application*

Although there are a couple of EMR (Electronic Medical Record) programs extended for the use of Tablet PCs in a medical practice, hardly any of them are designed to mainly be used by the stylus. The objective of this work is to create a prototype EMR system for a German-speaking medical practice which is built from scratch to being used on a Tablet PC.

The focus lies on an easy to use interface which can be completely accessed by a stylus. The doctor should not have to rely on a keyboard or computer mouse in any situation. Most of the functions of the application should be accessible with as few clicks as possible. To make work even faster, gestures can be used to call functions or open windows. Gestures are special strokes with the pen that are recognized as a specific command.

Handwritten text will be recognized and stored in the database as typed text. In addition it is possible to open a blank page and write or paint on it whatever wanted and store it with the patient's record. Each single stroke on the page can be edited again after opening the stored document. Furthermore audio notes can be added to the records.

Pictures can be annotated with the stylus and regions of interest can be outlined. The ink can be saved together with the picture and edited later on. All strokes can be selected and modified. The physician or medical staff member can choose from deleting, moving, scaling, or rotating the strokes.

This work shall show the possibilities and advantages of using new and exciting technologies related to the Tablet PC in a medical practice. It demonstrates the easiness of using a pen enabled flat PC. Physicians with few computer skills will be able to work efficiently with the tablet application after a short learning period. The EMR application aims to be used by healthcare professionals in a small clinic or a physician's practice to enable new ways to work and save important time for their patients' care.

1.3. Organization

The first part of this thesis explains the basics of Tablet PCs. It shows the types and functions of tablets and gives the reader some fundamental knowledge. The different form factors, advantages and disadvantages compared to a regular PC will be analyzed. At the end of this chapter some Tablet PC models are introduced.

The next chapter covers the current progress of Tablet PCs in medical healthcare. It explains important things to watch out for when using a tablet in a medical facility. Different applications developed for the use in healthcare facilities are covered and pro and cons are pointed out. The second section of this chapter shows some case studies of clinics already using Tablet PCs.

The implementation of a prototype of an EMR application on a Tablet PC for the use in a medical practice is the main part of this thesis. It explains the used framework for enabling applications to be controlled by a stylus. Furthermore, the application and its functions are described and a guide for using the software is included.

Finally, the EMR software is tested by several users and the results are evaluated and discussed at the end of this work.

2. Tablet PC Basics

A Tablet PC is basically a LCD-screen with an integrated fully functional PC. The input is in most cases done by an electronic pen which can interact directly with the screen. A keyboard to input data is not necessary anymore and the tablet can be used in many different environments.

The Tablet PCs were initiated by Microsoft 5 years ago and have ever since been a niche product on the market. Nevertheless, the devices evolved a lot and nowadays the cost/performance ratio compared to regular notebook PCs is almost the same. Areas where Tablet PCs have been able to draw attention in the last couple of years are healthcare, real estate and education.

The operating system being used on a Tablet PC is either Windows XP Tablet PC Edition or Windows Vista. Both of them enable users to input data with a pen and include some features especially built for the use of Tablet PCs. The software section will address some of the new possibilities.

2.1. *Hardware*

There are many companies having some tablets in their product range. The most important ones are Acer, Averatec, Electrovaya, Fujitsu, Gateway, HP/Compaq, Lenovo/IBM, Motion Computing/Gateway, NEC, Toshiba and Viewsonic. In general they have about two current models waiting for interested customers. The prices range from about \$1000 up to \$3000. The more a user is willing to pay, the more performance he will get – generally, even a \$1000 tablet is equipped well enough to handle most business needs.

As mentioned above, Tablet PCs are LCD-screens with a built-in computer. In fact, this is not true in all cases. Basically, there are two different form factors which differ in usage and design.

2.1.1. Form Factors

Slate and convertible

The two form factors of Tablet PCs shown in Figure 1 are the slate and convertible devices.



Figure 1: Slate by HP [3] and convertible Tablet PC by Lenovo [4]

The slate tablet consists of a screen with built-in computer hardware. It is possible to connect a keyboard through the USB port or plug it into a docking station and use it like a desktop PC. Since it does not come with a keyboard, it is normally lighter than a convertible tablet.

On the other hand a convertible tablet is actually a notebook with the ability of being transformed to a Tablet PC, which is enabled through a hinge. The user only has to turn the screen of his convertible and fold it down on the keyboard. After this move the convertible tablet looks like a slate tablet and can be used in the same way. A big advantage is the possibility of turning it back to a notebook with a keyboard if needed.

Comparing the performance of slates and convertibles there are no major differences at all. Since the hinge of the convertible tablet will be used a lot and is essential for ergonomics, it is important to make sure that it is well designed before spending a lot of money. Some Tablet PCs have a new approach and come with a slide technique, which allows the screen to be moved to the back of the keyboard. The screen does not have to be turned anymore.

UMPC

In 2006 the UMPC (Ultra Mobile Personal Computer) was introduced by Microsoft (see Figure 2). In general it is nothing else than a small sized Tablet PC. The usual screen size is 7" and lower. It can either run on Windows XP Tablet PC Edition or Windows Vista. Because of its smaller size it does not have high end performance, but it is still powerful enough to run most business applications.



Figure 2: UMPC eo by TabletKiosk [5]

The main difference to regular Tablet PCs is that a UMPC has to be touch-sensitive. Therefore every UMPC can either be controlled with a finger or the stylus. However, modern Tablet PCs come with the choice of selecting a touch-sensitive screen so that even the Tablet PC can be controlled by a finger.

2.1.2. Features

Pen

The Tablet PC pen (also called stylus) is the main interaction and input device between the tablet and the user. The main parts are the writing tip, a side button and the eraser on the back (see Figure 3).



Figure 3: Acer Tablet PC pen [6] with button

The pen is held like a regular one and the user can write on the screen like on paper. When the pen is hovered over the screen at a distance of about one centimeter, a cursor is shown on the display underneath the pen to give some feedback to the user. As long as the tip does not touch the screen, no actions are executed. In fact it is similar to moving the mouse-pointer on the screen. If the pen is tapped shortly on the screen, it is the same action like a single left button mouse click. Accordingly, a double tap behaves like a double left button click with a mouse. To simulate a right button mouse click, the side button of the pen has to be pressed and the stylus has to touch the screen shortly. Drag and Drop or multiple selecting are done by holding down the pen on the screen, moving it around on the screen and then releasing it from the screen. The eraser of the pen can be used in special applications like drawing programs or text input to delete strokes made by the pen.

Some pens contain a removable tip so it can be changed if it is worn-out. Since the pen is not connected to the Tablet PC, it can be lost or forgotten somewhere. Some tablets have a compartment for a reserve pen, which is useful in a situation like this. The costs for a new pen are approximately \$30.

Screen

There are some different screen types for Tablet PCs regarding the usage area. Extra bright ones are built for outdoor use, high resolution displays are good for picture related work and touch-sensitive screens enable an additional input possibility. Common display sizes range from 10" to 14", except for UMPCs where sizes are 7" and below. For a real writing feeling it is important that the distance between the pen on the screen and the actual displaying unit behind the security glass is very low so that the tip of the pen and the cursor on the screen seem to be on the same place, no matter what angle it is viewed from. Another significant point is that the screen has a high viewing angle. If the horizontal viewing angle in portrait mode is too low, it can be very irritating if the left eye sees slightly different colors than the right one.

The tablet screens are also pressure sensitive. That means, the harder the pen is pressed on the screen the more pressure is recognized by the screen. This information

is used for example in drawing applications, where higher pressure results in a thicker stroke. It can also be used for signature validation in log on processes.

Some new Tablet PC models also come with the ability of touch sensitive screens. Varying from pen input, the finger cannot be detected if it is hovering above the screen. Since a finger is bigger than a pen tip, it is also less accurate and there are no “extra buttons” on a finger. One big advantage is that no extra input device is required and the finger can never be forgotten or lost by a person.

Accelerometer

An accelerometer recognizes orientation and movements of the Tablet PC. It is often used in tablets to align the desktop and applications to the way the user holds the Tablet PC. If the screen is rotated from landscape to portrait, the desktop automatically rotates with it and the user does not have to align it himself. Another application is to perform certain actions like maximizing the window when, for example, the Tablet PC is moved sharply into one direction.

Security add-ons

Because a Tablet PC is often used in a mobile environment, it is important to secure it against threats. Security plays an essential role in a network. Once a user has access to the network through a computer, he is able to read unauthorized information and harm the system. Therefore latest models are equipped with a finger scanner. The finger has to be slid over the sensor and, if authorized, the operating system will grant access to the user. Another option is to use the signature for logging in. The system checks the pressure, momentum and dynamic of writing and compares it with the data of users in a database. This is far more secure than just comparing the appearance of a signature. A further alternative are built-in chip readers or RFID scanners where the authorized person has to have a personal chip card.

Microphone array

Since Windows Tablet PC operating systems come with speech recognition, it is very important that the audio quality of the digitized voice is very high. Therefore some

Tablet PCs come with a microphone array [7,8], which is useful to isolate the user's voice from ambient noise and recognize the commands and sentences correctly. Especially in public areas like hospitals this is very helpful.

Wireless connectivity

A main characteristic of a Tablet PC is that it is often used on the go, in different rooms in a hospital or company, on the train or at the customer's and patient's home. Consequently Tablet PCs come with rich wireless support. Wireless LAN and Bluetooth are featured in almost all models. Some devices come with built-in 3G (3rd Generation Mobile Standard) support, which allows the user to connect to his company's network with broadband speed from his customer's home without using any landlines.

2.1.3. Mobile Clinical Assistant

The Motion C5 [9] from Motion Computing shown in Figure 4 is the first mobile clinical assistant [10] (MCA), in other words, it is a Tablet PC built for healthcare needs. Motion Computing claims that the mobile device reduces doctors' and nurses' daily paperwork by one hour. The handle allows the users to easily carry the unit around. It runs Windows Vista or Windows XP and comes with special hardware features for medical purposes.



Figure 4: Motion C5 Mobile Clinical Assistant [9]

Disinfectable

The LCD-screen is covered with a splash-proofed sealing and therefore can easily be disinfected. A nurse or doctor can spray some disinfection liquid directly on the

screen and clean the complete unit with a cloth. This is an important issue to keep hospital cleanness requirements.

Barcode scanner

The integrated barcode scanner can recognize drugs as well as the patients through their barcode wristband. Hence the software can check right away if the patient is allergic to a drug or if one drug interferes with another one. The risk of selecting the wrong drug for a patient can be reduced and the EMR software always shows the records of the related patient.

RFID scanner

In a modern hospital all employees can have a RFID chip card for identification to organize the access to all different areas. With the C5 integrated RFID scanner these RFID chip cards can also be used to log on to the system. An authorized person has to put his card close to the reader and will automatically be logged on. In the future it can also be used for drugs when they come with a RFID chip instead of a barcode.

Digital camera

The C5 2.0 megapixel camera is suitable for taking pictures of wounds and documenting their healing process. With the Tablet PC pen these pictures can be annotated afterwards and saved in the records. It can also be used to take a picture of first time patients.

2.2. Software

Tablet PCs run under two different operating systems by Microsoft – Windows XP Tablet PC Edition 2005 and Windows Vista. Windows XP has its own Tablet PC edition because it was introduced after the launch of Windows XP. The new Windows Vista products come with Tablet PC support for all editions. Other operating systems play a minor roll in connection with tablets and are not mentioned here.

2.2.1. Windows XP Tablet PC Edition 2005

Windows XP Tablet PC Edition 2005 is the successor of Windows XP Tablet PC Edition, which was the first Tablet PC operating system from Microsoft. Some of the features especially for tablets are the following:

Tablet Input Panel (TIP)

The Tablet Input Panel is the main interaction tool between the user and the tablet. Written text is converted into typed text and can be included into almost every application. When the pen is tapped on an input box or anywhere where text can be input in a program, a little symbol appears right next to the pen indicating that text can be entered with the pen. After tapping the symbol, the Tablet Input Panel will open. The TIP can be configured to show up right next to the input box or at the edge of the desktop.

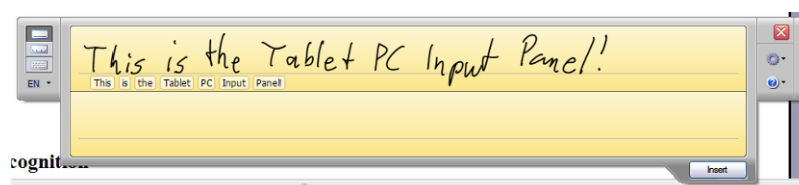


Figure 5: Tablet Input Panel Windows XP [2]

In the TIP the language for recognizing the text can be chosen. Languages currently available are English, French, German, Japanese, Korean, Chinese and Spanish. The input mode can be changed from the normal writing style (Figure 5) to single letter based one or to a virtual keyboard. While writing in the TIP the recognized text is shown in little white boxes below the user's input. If everything is correct, the text can be inserted into the application by tapping the insert button. In case a word is not recognized correctly, a tap on the word in the white box opens a correction panel. The user can choose between different suggestions or edit, remove or add single characters as shown in Figure 6.

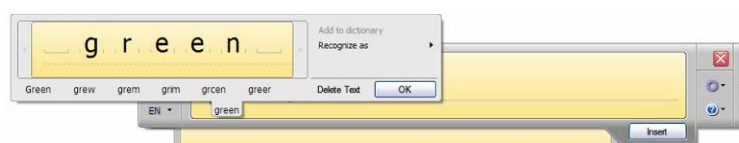


Figure 6: TIP corrections in Windows XP [2]

It can be challenging for the system to correctly recognize words which are not in the dictionary. Such words can be added to the dictionary after they have been corrected and will be more likely recognized accurately next time. Wrong words can also be erased by using the eraser on the back of the pen or by simply scratching them out with the Z-shaped scratching gesture.

Speech recognition

Another input option for the Tablet PC is speech recognition. Languages available with the Tablet PC recognizer pack are English, Japanese and Chinese. German and other languages are not supported yet. Speech recognition should be used in quiet areas to ensure that the accuracy of the recognized words is high.

Gestures

In the TIP some gestures shown in Table 1 can be used to perform actions. Gestures are strokes which have a special meaning. Actions are: Backspace, Space, Enter, Tab and Scratch out.






Gesture	Stroke
Enter	
Space	
Tab	
Backspace	
Scratch out	

Table 1: Windows XP Tablet PC gesture strokes after [11]

Additional software can add support to use gestures anywhere on the desktop to do system wide actions like opening a program.

Snipping tool

With the snipping tool the user can draw a free or defined form with his pen around a picture and copy it for use in another application. The pictures can be annotated and saved or even be sent by email.

2.2.2. Windows Vista

This section will describe the Tablet PC related differences and enhancements in Windows Vista [12] compared to Windows XP. First of all, Windows Vista gives visual feedback for actions like single-tap, double-tap and right-clicking. The new Explorer check boxes let the user select multiple files. In Internet Explorer a panning hand can be used to scroll through the webpage.

Tablet Input Panel (TIP)

The appearance of the TIP shown in Figure 7 is similar to the one in Windows XP with minor changes. The language cannot be changed right away and speech recognition is not a main button in the TIP. The TIP can be located in any horizontal position and be minimized to the side of the screen.



Figure 7: Tablet Input Panel in Windows Vista [12]

What really changed a lot lies behind the TIP – the recognition engine. It now comes with an auto complete feature. When an URL is entered, the TIP will already suggest some URLs as soon as only a part of it is written. The suggestions are based on previous inputs. Erasing words can now be done by some more gestures like strikethrough or M and W shaped strokes. The handwriting recognition works more accurately than in Windows XP. It can also be trained by providing personal handwriting samples to Windows Vista. In addition the recognizer automatically learns from the input and remembers special words and writing style.

Pen flicks

Pen flicks are gestures which can be executed anytime anywhere in an application. With flicks shortcuts can be performed and text can be edited. They can copy, paste or delete text, open the email client or minimize all applications on the desktop. Other flicks can scroll through a webpage or go back to the previous page. Pen flicks can also be customized to satisfy everyone's needs.

Touch screen support

Windows Vista includes enhanced touch screen support. Flicks can be performed by a finger and applications can be controlled. A special input called touch pointer enables the user to control even small buttons. It consists of a visual input panel hovering underneath the finger, which shows a left mouse button, a right mouse button, a drag area and a pointer.

2.2.3. Applications

In this section some of the most popular Tablet PC software is listed to give an idea about the usage of Tablet PC applications.

Sticky Notes

Sticky notes are like post-its on the desktop. Anything can be written on a small "piece of paper" and scratched out if not needed anymore. Additionally voice messages can be recorded.

Windows Journal

This application works like a regular notebook. Paper styles and templates like a calendar or to-do list can be chosen and the user can write in different colors or even add pictures to his notes. The text is shown as written and is not transformed into typed text. The highlighter can mark text parts and a cutting tool allows moving selections around the paper.

Microsoft Office

In Microsoft Office 2003 and 2007 the pen can be used to annotate every document. It allows the user for example to write notes anywhere on his Excel sheet or add comments to a Word document. During a presentation in PowerPoint, the lecturer can interact with the slides and point out important parts. In the email program Microsoft Outlook, emails can be written with the pen and are then converted to an image so that the recipient sees the original handwriting.

Microsoft Office OneNote

OneNote is a feature rich application for taking notes and storing them in an organized way like folders. Pages can be added to a folder and notes are added either with or without recognition. It also has a highlighter pen, and a lasso can select and move or delete parts of a page. Audio notes can be connected to the pages and flags can be set for important assignments. A special tool can detect the text from a picture and save it as typed text. A powerful search engine is able to search for audio and handwritten notes. OneNote is an application which can be used in environments where a lot of notes are taken, such as school and university.

3. Tablet PCs in Healthcare

3.1. *Advantages*

One of the main areas where Tablet PCs are expected to be used a lot is healthcare. They make it possible that a doctor can see the patient's record wherever he wants to. No matter whether he is standing by the patient's bedside or he is working in his office. He can take notes with his Tablet PC pen directly on the screen. It does not matter whether he wants to annotate a clinical picture, write on a document or add notes in the patient's record. If he wants to delete some written data, he just has to turn around the Tablet PC pen and erase the information. In a perfect scenario, medical staff members can operate the Tablet PC by only using the pen. They do not have to look for a table to put their notebook on. There is also a compartment in the Tablet PC for the pen, so the doctor can store it there and does not have to look around where he put his pen.

Because of wireless support it is possible to see and add information wherever the user wants to. The patients' history can be viewed at any time, and a medical practitioner can easily connect to medical databases on the internet and get important information about diseases or obtain information from medical encyclopedias [13].

In a perfect environment paper does not have to be used anymore. All findings the medical staff gets on papers from patients or other papers can be scanned into the database system and processed by the doctor on his Tablet PC. He can take notes on the scanned paper and save them. If he likes to, he can hide his notes afterwards and see the original paper.

According to Microsoft [14] the top 10 benefits of Tablet PCs in healthcare are:

- Use one of the most advanced Microsoft operating systems
- Extend the way working with a computer
- Work from anywhere with one of the most mobile PCs ever
- Take all notes electronically

- Collaborate easily and effectively
- Personalize experience
- Enhance patient care and increase productivity
- Deploy and manage Tablet PCs easily
- Unlock patient information
- Help protect critical data

Another advantage is that doctors can comfortably take audio notes while they are standing or record talks with their patients. If in any situation the person using the Tablet PC does not have a free hand to use the pen he still has the opportunity of controlling the Tablet PC with the built-in speech recognition [15] from Microsoft. This feature also enables the medical staff to dictate text. In combination with instant messaging software or voice-over-IP software, the Tablet can be used to communicate within the medical facilities or contact professionals from all over the world.

In a meeting the Tablet PC can be put on the middle of the table and every participant can see the screen and add his own notes to the document with his pen. This can be pretty helpful when they are discussing about an x-ray or MR image and want to outline a special area of the image. With all these features a pretty big amount of time and costs can be saved in the healthcare process.

Besides all these advantages for healthcare professionals the tablet can also be used by the patients themselves, especially in areas concerning filling out forms. In an experiment by Holzinger et al. [16] elderly patients were given a touch sensitive Tablet PC to answer dermatology questions for a survey. The disadvantages of the paper version were the need of retyping them into the database and that partial sighted patients had serious problems filling them out. In a German rheumatology study [17] a test between questionnaires which were filled out on regular paper and a Tablet PC showed that there are no significant differences in the answers given and that in general the patients had no problems using the Tablet PC.

All the money which was spent on papers, pens, markers, folders and binders can now be saved. Notes previously written on paper can now be stored on the server and can be accessed anytime and anywhere, saving time and money.

3.1.1. Tablet PC Security and Authentication

Security and authentication are very important issues in a medical environment. Unauthorized persons are not allowed to see any information about patients or be able to use the EMR-system in any means. Therefore it is important to have a secure logon system for the Tablet PC.

Every Tablet PC comes with a built-in microphone and an electronic pen. People can use either one to verify their identity. The user only has to say his name or write his signature on the Tablet PC's screen. Because of its simplicity it can easily be used by every medical professional.

Krawczyk et al. [18] have shown that a fusion of both verification approaches is most secure and lowers the chance of being falsely rejected. Using the combination the logon process is more accurate and spoofing the system is more difficult. Since no extra hardware is needed for the Tablet PC, it is a cost-effective choice. Writing and talking is a very natural thing and therefore not obtrusive for users.

3.1.2. Tablet PC versus Notebook

At first glance, Tablet PCs are easier to carry around and operate while moving. Microsoft [19] mentions some advantages:

- Convert some Tablet PCs to Notebooks (so called convertibles)
- Tablet PCs have built-in speech recognition
- Tablet PCs have handwriting recognition
- Mobile users can be freed from a desk
- The stylus really is more intuitive and friendly than the mouse

- Any EMR that will work on a desktop will work on a Tablet PC with the added ability of handwriting, voice and mobility

Because of the use of the pen and the Tablet PC, the doctor looks more natural to the patient than he would when he sits behind his laptop and types on the keyboard. This gives the patient the feeling that the doctor pays more attention to him. The tablet is less obtrusive than the notebook.

3.1.3. Tablet PC versus PDA

In the United States already 20% (2003) of physicians use PDAs in their daily work [20]. Tablet PCs and PDAs (Personal Digital Assistant) have some features in common. They consist of a screen being held in a hand and the hardware is integrated beneath it. The main input is done by an electronical pen. The main difference is the size of the screen. While a Tablet PC has a screen size of about 10" to 14", a typical PDA screen is about 2.5" to 4" large [21].

According to MedicalTabletPC.com [22] some advantages of a Tablet PC over a PDA are the bigger screen size and the need for no scrolling. While on a PDA the user cannot really use a full-featured EMR (Electronic Medical Record) system, because of its small size on a Tablet PC he can use it with hardly ever scrolling around. There is enough space to take any handwritten notes. It is easy to read a full-sized page and not only see parts of it.

Tablet PCs also have a better hardware and therefore can use more advanced software. On a PDA a full-featured Windows XP operating system cannot be used. Therefore it is not possible to use some applications people used before or relied on. The only thing which can be done with a PDA but cannot be done with a Tablet PC is to put it in a pocket.

3.1.4. Tablet PC versus UMPC

The Ultra Mobile PC (UMPC [23]) - formerly known as Origami – is a small form factor PC introduced by Microsoft and Intel [24] in 2006, which can be placed between Tablet PCs and PDAs. Like a tablet it consists of a screen with built-in hardware behind it. It also uses the Windows XP Tablet PC Edition 2005 operating system, which basically enables it to run any software that can be used on a regular Windows XP operating system.

The main differences of the UMPC compared to the tablet are the smaller screen size, less powerful hardware and touch screen capabilities, although more and more new Tablet PCs also come with touch screen features. Some of the minimum hardware requirements [25] set by Microsoft are:

- 7" screen or smaller
- Minimum resolution of 800x480 pixels
- Finger touch and stylus controls
- Minimum 30 GB storage
- Weighing 2 pounds or less

The smaller form factor might be an advantage for a doctor as well as a disadvantage. Since it is smaller it also weighs less and therefore it is easier to carry around. The screen is still big enough to show an acceptable amount of information, although the user is forced to use scrolling more often when he accesses internet sites or uses his regular EMR application. EMR software developed for a UMPC could get rid of this drawback.

Ducknet [26] tried to use its EMR program on a UMPC and was pretty pleased with the results. They hardly had to make any changes to the software to make it reasonably to use on a UMPC. The only downside was the requirement of scrolling to see the whole chart.

The cons on the hardware side are not crucial, because an EMR system does not need that much power and therefore it should work on a UMPC without any problems.

Since it comes with wireless access support, it is possible to gather information wherever wanted.

Controlling the UMPC by touching its screen is a nice feature. The only thing is that there should be big controls in the application to make it easy to select the right one with a finger. For reviewing information it might be suitable, but for selecting data or writing a text it is not really applicable. Anyway, this feature could also be easily implemented on new Tablet PC hardware.

In summary a UMPC is like a small Tablet PC. For that reason it can also find its place in healthcare. It depends on the facility and situation considering rather using a UMPC than a Tablet PC. Because UMPCs are brand new devices with relatively high energy consumption, their battery life is not lasting as long as those of tablets. But like with most devices this will change a lot with the next generation.

3.2. *Disadvantages*

Due to the innovative technologies and short time on the market, Tablet PCs are more expensive than regular Notebooks with the same power. Nevertheless, the prices are falling faster and faster as the tablet becomes more mainstream.

If tablet users have to write long texts or often use words which are not integrated in a dictionary, they will most likely be faster writing it with a regular keyboard than using the stylus on a Tablet PC. Though a user not comfortable with a keyboard might as well be faster writing on a tablet. Handwriting-to-text conversion does not work all the time. People might write a little bit different on the tablet to receive better recognition results than they would write on a paper.

Although Tablet PCs are often lighter than a comparable Notebook PC, they can quickly feel heavy in the arm when holding them for a long time. Paper-based charts still weigh less than current Tablet PCs.

Some applications do not support TIP (Tablet PC Input Panel) from Microsoft because they do not use the standard controls from Microsoft Windows. TIP is used to convert handwritten data to typed text and paste it into the program's textbox. For instance, if somebody wants to input an internet address into the Mozilla Firefox [27] browser, the TIP control does not appear.

Some Tablet PCs lack a CD/DVD-drive due to the small size. This is not that big of a problem in healthcare since most of the work is done over the network. In day-to-day work users hardly ever need a CD or DVD. If for some reason they do, they can easily connect a drive with the USB-connector or receive the data from a workstation with a CD or DVD drive.

3.3. Key Application Areas

Healthcare provides many areas where Tablet PCs can be used to enhance the medical processes. According to Motion Computing [28] the key application areas for Tablet PCs in healthcare are:

- Patient registration and administration
- Clinical documentation and Electronic Medical Records (EMR)
- Computerized Patient Order Entry (CPOE) and electronic Medication Administration Records (eMAR)
- Radiological Information System (RIS) and Picture Archival Computer Systems (PACS)
- Home Health and Hospice Care
- Medical Consultations and Patient Education
- Health IT Systems and Practice Management

The main focus of this thesis is about Practice Management and EMR. In a physician's practice a Tablet PC can be used for taking notes, annotating pictures, getting medical information from the internet, recording audio data, using a waiting list or communicating with the medical staff.

eCard and PeeringPoint

In 2005 a new era has begun in Austria: the eCard system was launched. The eCard is a social security chip card which allows Austrian citizens to visit a doctor in their home country and get proper treatment. It displaces the actual health insurance certificate. Whenever a patient comes to a doctor, his eCard is put into a card reader and the system checks if he has a health insurance. After that, a central server in Austria recognizes that this patient is treated by a certain physician and saves that information. This information is later on used for the doctor's billing.

This is only the beginning of a powerful health information system (GIN – Gesundheits-Informations-Netzwerk) which allows doctors to share information with each other or use other advanced features. According to the Austrian Physicians Magazine [29] some of the future abilities are EMR-software updates, online support, transfer of x-ray pictures, accessing health records from other clinics and payment functions. All this is done over a secure network operated by the PeeringPoint Company.

In combination with the Tablet PC the GIN can be very useful for the physician's daily work. Doctors and nurses can access x-ray images or findings from other clinics and display them right on their tablet and view them like they would get the findings and pictures handed over by the patients directly. The patients do not have to think about bringing their documents anymore. This also saves a lot of money because doctors do not have to print and send documents to other doctors anymore, since they can be accessed over the GIN anyway.

Furthermore doctors can access their practice network over a wireless mobile card while they are on a home visit and access their own database, or through the practice GIN connection they could also access the information mentioned above like x-ray images from another clinic. The only problem occurring is that there is no small sized mobile card reader for the eCard so far. In order to access the GIN information, the healthcare professional would have to take the plump card reader with him.

3.4. Requirements

Weight

For a successful use there have to be some requirements met by a Tablet PC. First of all, they should not be too heavy. If a doctor walks around all day with the tablet in his hand, every pound counts. A heavy tablet could frustrate the user and lower the good experience he can have with his device. He might rather run from the PC to the patient and back than carrying a heavy Tablet PC around all the time.

Screen viewing angle

Second the viewing angle of the screen is very important. For example on a Toshiba M200 tablet, the left eye sees slightly different colors than the right does. This can be pretty irritating and can make the user dizzy. It is also important that the doctor does not see different colors when he is analyzing an MR or x-ray picture. If he wants to show a colleague something on the tablet, he needs to have a wide viewing angle, so both of them can see the information at the same time and discuss it. He might not want to turn it left and right all the time.

Screen brightness

Next there is the brightness of the screen. A doctor does not only want to use a computer in pretty dark rooms. He also might use it in a light flooded room. So the brightness has to be really high. A good solution of some Tablet PCs is that they automatically adjust the brightness of the screen to the environment lightning. For example Acer [30] develops some Tablet PCs with automatic brightness adjustment. It is also very important that the screen does not reflect too much light, or else it would not be enjoyable using the tablet under a light source.

Screen size

A significant feature is also the screen size. While a 10" is pretty small to read a full paper-page, a 14" screen makes the whole device heavier. A good compromise for many users is a 12" screen. For larger screens it is most likely that they also have a higher resolution and therefore more information can be shown on it.

Battery life

One of the most vital features is the battery life. A medical staff member does not want to change the battery every two hours. They have to use their Tablet PC the whole day. Some tablets already offer runtimes up to 7 hours. Some batteries are hot-swap-able, which means that they can be changed without shutting the Tablet PC down while it is running.

Form factor

Another decision a doctor has to make is whether he wants to have a slate or convertible Tablet PC. Slate Tablet PCs can only be used as a Tablet PC. The only way to use a keyboard is to connect one. On the other hand convertible Tablet PCs can be converted to a regular notebook. If the user wants to use the tablet as a notebook, he just has to flip the screen from the keyboard and rotate it.

Security

Security is very important in a healthcare environment. Unauthorized people are not allowed to see patients' data. Some Tablet PCs grant access to the operating system by recognizing the signature of an authorized person. Others have a fingerprint scanner build into the screen.

Others

There are some minor features which could be important in some scenarios. For example some Tablet PCs offer a microphone array with up to 3 microphones, so the speech is recognized more accurately. Some tablets come without a CD/DVD-drive. Every user has to estimate whether he needs to use one often or hardly ever before deciding which tablet to buy. Often it is better to use a second battery instead of a CD/DVD-drive to be mobile for a longer time.

3.5. Current Software

Currently there are a couple of software solutions for using the Tablet PC in a healthcare facility. Mostly those applications are adopted from a regular desktop PC application.

3.5.1. Medinotes e

Medinotes [31] is an EMR software for a medical practice (see Figure 8). One nice feature is the organization of data representation in different tabs. So it is easy to open the file of more than one patient at a time. It has a good concept to navigate through it and has multi-tasking features such as opening more than one patient record at the time. The program has four convenient views:

- Practice View

In the Practice View all the events which occur in the practice like today's patients or the mailbox can be viewed.

- Patient View

The Patient View shows all the data related to a patient. More than one Patient View tab can be opened at a time. The tabs are customizable to the medical staffs' own preferences.

- Document View

Here all the program's documents can be viewed and printed if required.

- Object View

In this view all templates can be customized and data like new patients or rooms can be added.

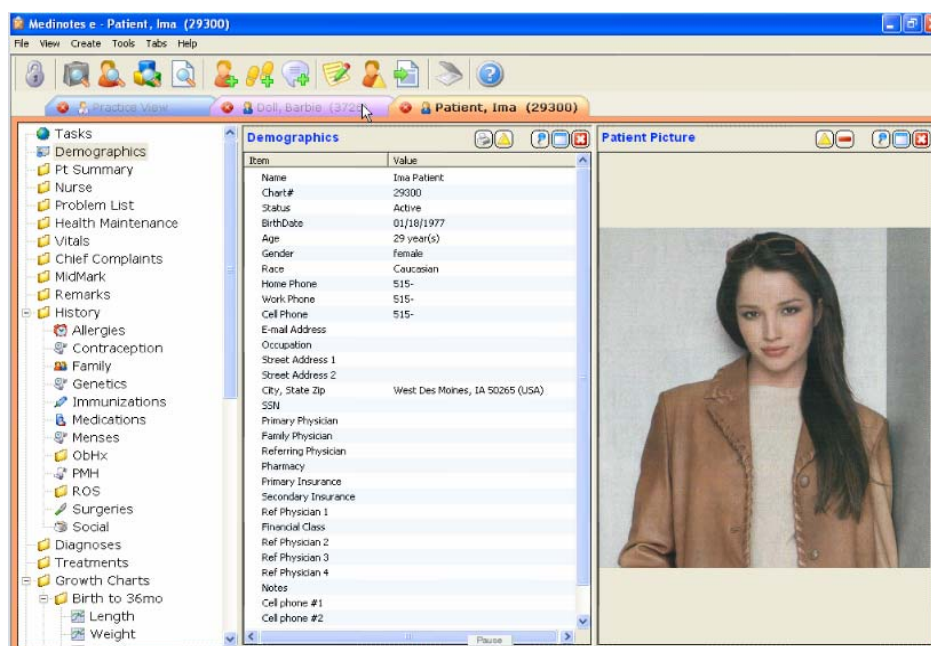


Figure 8: Medinotes e, electronic medical record [31]

3.5.2. Zipchart

Zipchart by Helixys Medical Information Systems [32] shown in Figure 9 is also an EMR software produced for physicians to reduce paperwork. It is designed to be 100% paperless and is a web server based application, which can be accessed from most computers with an internet browser. With a broadband connection, nurses and doctors can use the program at any location they like. If the physician needs to, he can write notes with his stylus directly into the patient's chart. While Medinotes e uses a horizontal layout, Zipchart uses a vertical one, so the doctor has the feeling of looking on a regular paper.

It also comes with an export function which enables the user to export all patients' data to a file and send it to another person. An included PDF function allows the doctor to give the patient's records to him electronically or on paper. Backups of all server data can be made directly at the company's servers away from the clinic to reduce or avoid loss of data.



Figure 9: Helixys Zipchart, main screen [32]

3.5.3. ATS Wunddokumentation (ATS wound documentation)

ATS Wunddokumentation [33] (see Figure 10) is a German program which is used to document the healing process of a wound. With a digital camera a picture of the wound is taken, transferred to the tablet and with the stylus its borders are outlined.

With a simple click in the middle of the wound its size is calculated. At the next appointment the process is repeated and the physician can see if the wound grew bigger or smaller. Handwritten and spoken notes can also be added to the pictures. To accurately recognize handwriting a medical dictionary can be included.

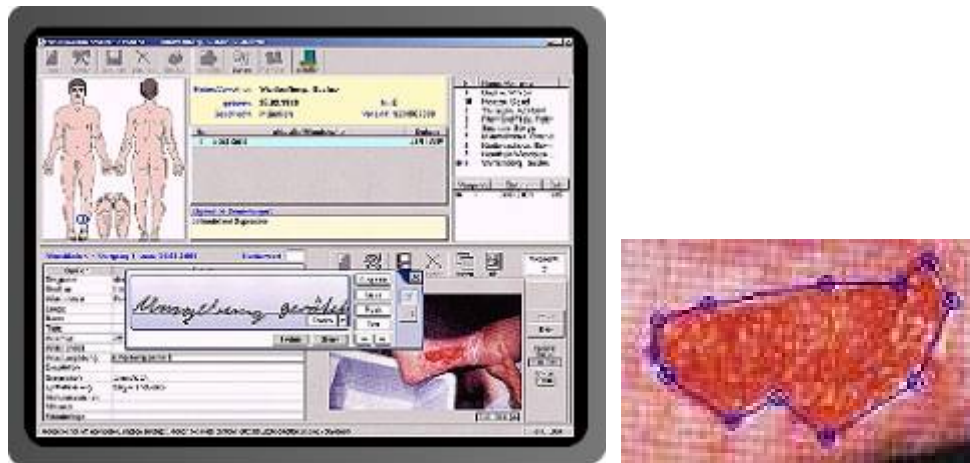


Figure 10: ATS Wunddokumentation, main screen and annotation of a wound [33]

3.5.4. MDTablet

MDTablet [34] is another typical EMR software product. It has a clean appearance and looks organized. On the left side of the application is the navigation bar, where often used features are put into logical groups and where they can be accessed easily. The company chose to use a vertical layout so the tablet is used like a regular chart. Some of the main features are:

- Handwriting recognition
- Voice recognition/transcription
- Complete patient chart printing
- Front office scheduling
- Complete patient document imaging
- Image annotations
- Common drug lists

As shown in Figure 11 the physician can add handwritten notes to a patient's documentation and choose later on whether he wants to convert it to text or not. The application also offers front-table capabilities such as scheduling and patient registration.

There are different ways to add ink to this application. One way is to use the ink conversion tool. The user can write into the upper box with his stylus and in the lower box the recognized text is shown. A list of possible results lets the medical professional choose the appropriate text, in case the recognized text is not the same he meant to write. Another way is to click the textbox and a stylus input panel appears. It looks much like the regular Tablet Input Panel from Microsoft and behaves like it. The third way to input data with the stylus is to write onto a document or on a paper like area and save the ink as ink without converting anything. This is convenient to add a small painting to a text or to put a signature under the prescription.

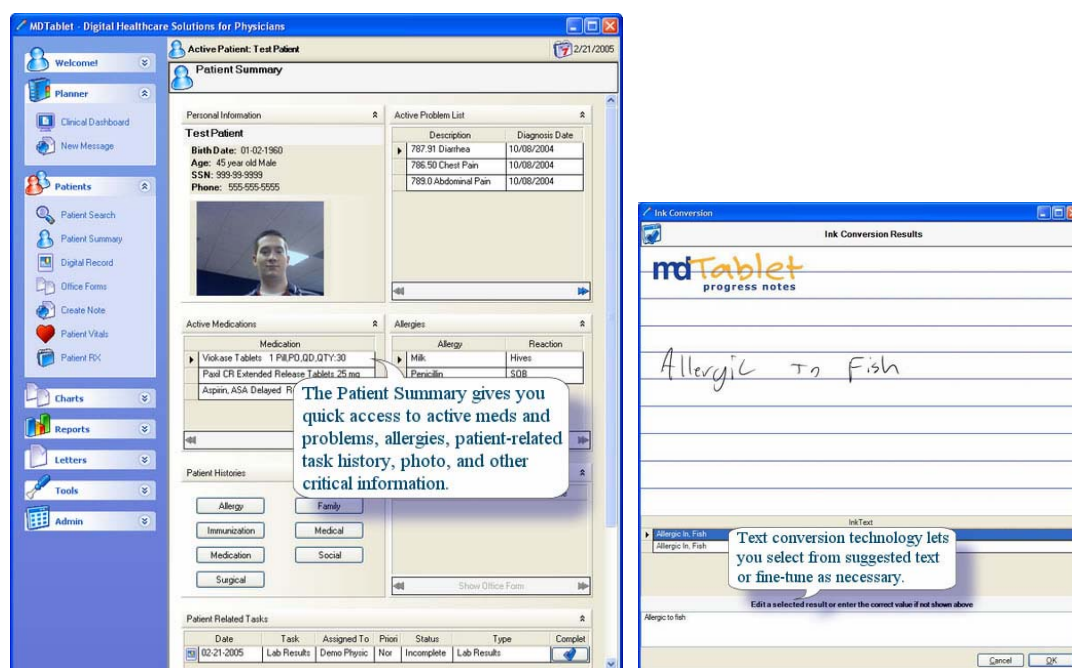


Figure 11: MDTablet main screen and notes window [34]

3.5.5. Accenture Digital Observations

This tool from Accenture [35] is not basically used on a Tablet PC. A nurse can take patients' data at the bedside with a digital pen on a regular paper such as pulse, blood pressure, and temperature. The smart pen recognizes all pen movements on the chart and stores the strokes in the built-in memory. After she is done taking all notes the pen is put into a docking station and all the ink data made by the nurse are transferred to a central server.

The doctor can load the information from the server on his Tablet PC and analyze the information (see Figure 12). Handwritten annotations can be changed easily at all times. The data cannot be lost that quickly anymore and the need of acquiring data a second time is minimized. Every single information has a timestamp and a physician can look through all previous observation charts. This way the doctor always knows if some vital data has changed dramatically.

Some advantages of the system described by Accenture [36] are:

- All observation information can be viewed via a secure Web service interface
- Staff handwriting information is captured – people can be identified
- Every data has a timestamp
- Alerts based on patient's reading – doctor can be informed by SMS or pager
- Nurses will be informed if observations are missing
- Charts can be reviewed and edited on a Tablet PC

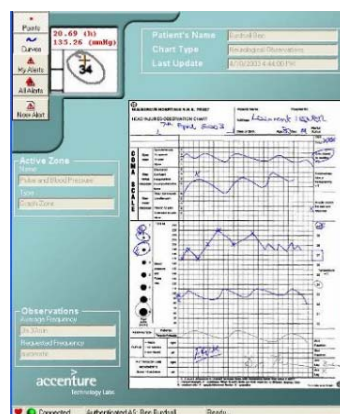


Figure 12: Accenture Digital Observations [36]

3.5.6. ImageTrend EMS Field Bridge

EMS Field Bridge [37] was developed to collect data in the field as quickly as possible. If an accident has happened, EMTs (Emergency Medical Technicians) can use the stylus to outline the findings on the virtual body (see Figure 13). From a dropdown list different patient findings can get selected. The body can be rotated and each portion of it can be annotated. As with most of these applications handwritten notes can also be added.

The system additionally includes some templates which allow outlining the sequence of accident events such as a car crash report. Paperwork is reduced to a very small amount and because of the automated data validation complete records are provided. This can save a lot of time and problems made by missing data cannot happen.

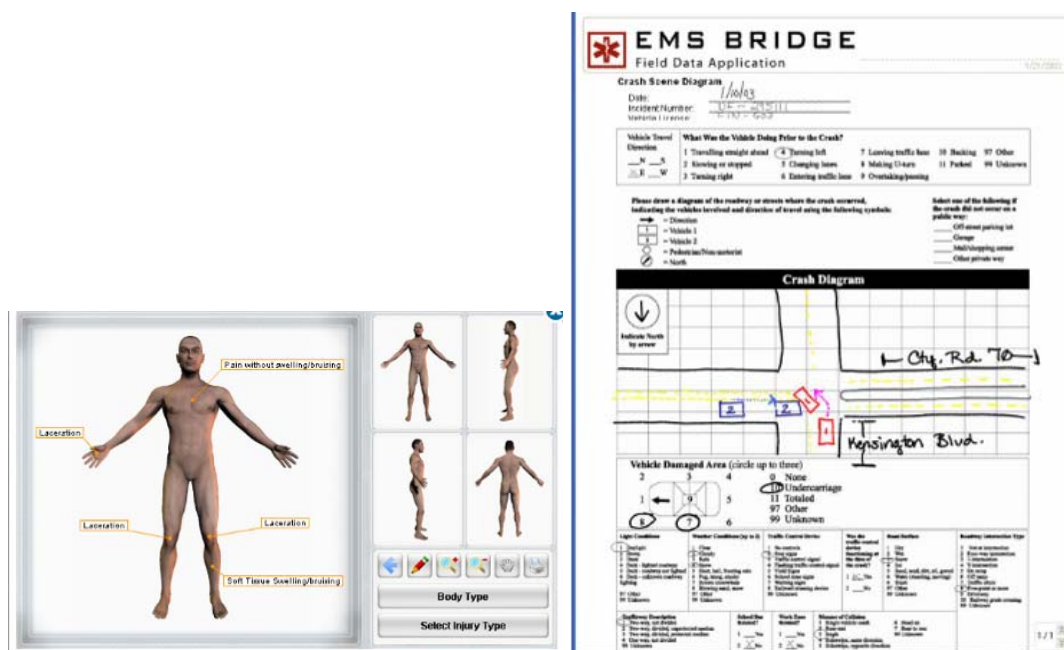


Figure 13: EMS Field Bridge [37]

3.5.7. Medscribber

Medscribber [38] claims to be the first fully functional EMR software built especially for Tablet PCs. It has the same features as a standard EMR application including inking capabilities as shown in Figure 14 and voice recording. It uses client/server architecture and includes a drug database and an ICD-9 (International

Classification of Diseases) catalog. It comes with complete scheduling, a billing interface and patient management.

The screenshot displays the Medscribbler EMR interface. At the top, it shows the patient's name 'Jay Jones, Male, 75' and the date '11/25/2004'. Below this, there are fields for 'Weight' (230 lbs), 'BP' (125), 'P' (72 + reg), and 'Other' (No information). The interface includes a 'Last Doc' field with the date '11/25/2004' and a 'Last Foc' field with the date '11/25/2004'. There are buttons for 'Print', 'Align', 'Save', and 'Exit'. The main area contains two sections of handwritten medical notes. The first section, dated '10/25/2004', describes a patient with 'loss of speech', 'Expressive aphasia', 'word finding difficulty', 'droop of L side of mouth', 'depth of naso labial fold', 'diminished lacrimal reflex III - IV', 'Gripes Symmetrical', 'No pronator drift', 'Said steady Romberg', 'DTRs Symmetrical', 'Oriented x3', 'Word finding difficulty', 'Chest x p carotid bruit', 'Imp CVA (w/reading on ASA)', 'PE stat lab panel', 'CT scan head', and 'Stunt Planix 75mg'. The second section, dated '11/25/2004', describes a patient with 'Diabetes', 'Hypertension', 'Stable IHD', 'have glucose readings 5-7 am's, 8-10 later', 'Hypertension 7.1', 'blood pressure - above goal', and 'walking on cold weather'.

Figure 14: Medscribbler [38]

3.5.8. OneNote EMR Toolkit

This toolkit by “The ableFactory” [39] is very different to the other EMR solutions. It is not a regular EMR application with a database in the back. It is a toolkit to extend Microsoft OneNote [40]. OneNote is a powerful application with great inking features.

If the doctor wants to add a new report for a new patient, he creates the basic data with the toolkit program. The toolkit itself does not support inking capabilities. In the next step he can choose pictures to add to the file. After this a OneNote page is created and the doctor can edit the notes in the Microsoft application.

This program is not that good to use in a regular practice because there are no management functions like a waiting list or a scheduler. It is not a multi user program because it is only installed on the tablet and does not store the data on a database server.

OneNote EMR Toolkit (see Figure 15) is basically a collection of reports. There is no way to make automatic analysis or use billing assistance. For physicians with a small practice and few patients this application might be pretty good, but it is definitely not made for a medium sized or big practice.

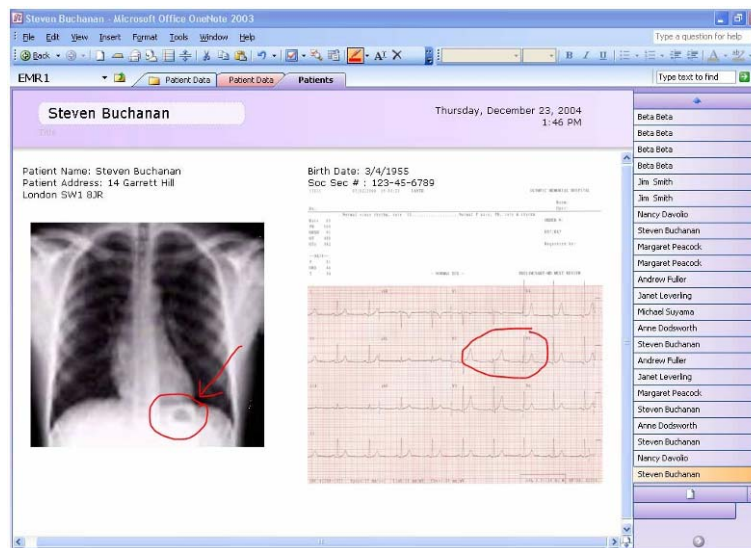


Figure 15: OneNote EMR Toolkit [39]

3.5.9. Conclusion

Some Tablet PC applications already hit the healthcare market and make a good impression. Most of them have handwriting recognition thanks to the Microsoft TIP control. Using the TIP makes it easy to use the stylus to put in text in any regular text field in a program.

In medical facilities health professionals often have to put in data not stored in a regular dictionary. For example if somebody wants to put in the name of a patient called "Hrdlicka" or a diagnosis like "Ulcus Ventriculi" the computer might recognize something like "Hrdlicha" or "Vlcws Ventriali". Correcting those errors rewriting the whole text in a nice handwriting or changing single letters is time consuming and can be frustrating after a while. Therefore it is very important that a special medical and name directory is included into the recognizer software.

Some of the applications use standard sized controls. But for a quick and accurate use with the stylus this controls should be a little bit bigger. For example the height of buttons can be increased and textboxes can be made higher and therefore use a bigger font size. This way information can be read more easily when the doctor or the nurse is on the go.

Most of the programs are just ported from a regular application to allow it to add some Tablet PC features. In this aspect the user interface is not as good as it should be for a Tablet PC. Since a Tablet PC is often used in vertical mode, the layout of the application should be also designed for using it in this mode. Other than that the software can take advantage in using special controls for Tablet PCs such as list boxes, where writing a word on it searches the suitable word in the box and selects it.

Some solutions do not recognize the text and just save the handwritten data. The disadvantage resulting is that the text cannot be searched through. Hence it is important that at least the text gets recognized and is stored in the background connected to the ink for searching purposes. Other than that if a nurse tries to read the handwriting of a physician she might have troubles doing it. Recognized text is also important for automated billing or statistics.

3.6. Medical Facilities using Tablet PCs

Tablet PCs get more and more popular in medical facilities. For example in a study concerning the use of mobile devices in hospitals in Taiwan [41] almost every second mobile device used is a Tablet PC (see Table 2).

Device	Number	Percentage
Tablet PCs	67	47,2
PDA's	33	23,2
Notebooks	19	13,4
Panel PCs	19	13,4
Others	4	2,8

Table 2: Mobile Devices used in Taiwanese hospitals after [41]

The following examples show specific cases where Tablet PCs are used in healthcare environments.

3.6.1. AKH Linz

AKH Linz [42] is a public hospital in Austria founded in 1863. 2000 employees treat 50,000 stationary patients and 5.4 million ambulant patients each year.

The internal electronic nursing record system is now extended by 60 Fujitsu Lifebook T3010s and 60 Fujitsu Lifebook T4010s. A smartcard reader is included to enable secure access and a long lasting battery provides enough energy for a whole workday. The hospital was awarded for innovative and forward-looking healthcare.

Some of the benefits of using Tablet PCs in the hospital are:

- Simplified record keeping
- Seamless nursing records
- Less work for nursing personnel
- Enhanced information quality
- More time for patients

3.6.2. Klinikum Ingolstadt

Klinikum Ingolstadt [43] is a hospital in the south of Germany with 1,100 beds and reaches about 500,000 people. Each year about 25,000 emergency patients are taken to the hospital. About 20 patients have to be treated in the emergency department at the same time.

Before the integration of Tablet PCs in this department, forms were filled out on regular paper and then transferred to the electronic system by another department. This task was pretty time consuming and therefore cost intensive. Now the forms get filled out on the Tablet PC with the application Microsoft InfoPath 2003 [44]. All wards in the hospital now use standardized electronic forms instead of paper forms.

The collected data is saved in XML and gets transmitted to the hospital's main system. Afterwards the medical staff can access the data from every point in the hospital and view it on their Tablet PCs.

With the use of the Tablet PC tasks are finished in less time and the efficiency was raised to a new level. A new feature was added in 2004 to check signatures on the Tablet PC to increase the security.

3.6.3. The Hospice of the Florida Suncoast

The goal of this non-profit organization [45] is to improve the end-to-life care of patients. It is more than 30 years old and serves over 2,300 people a day. The major part of their work is fieldwork at the patient's bedside. Staff members have to take notes of the conditions and feelings of their patients. Before the time of Tablet PCs this was done with laptops or on paper. Less than 50 percent of the data was collected with electronic devices.

Since the laptops have been replaced by 500 Fujitsu LifeBook T3000/T4000 Tablet PCs this percentage has increased to about 70 percent. Organization members point out that the Tablet PCs are easy to use and not as cumbersome as the Laptops. With a battery life of up to 7 hours they never have to charge it the whole day. Because of their natural look Tablet PCs do not look as obtrusive as older Laptop PCs. 50 percent of the tablet-users finish their work at the bed-side, the other half finishes it on their way home or at home.

150 Tablet PCs are equipped with a cellular broadband card. With this device the tablet is connected to the server and the staff members can work in real time on it. The future goal is to work 100 percent online. Now it is no problem to have up-to-date information wherever wanted.

Another approach described by Price et al. [46] allows elderly people to use mobile devices such as Tablet PCs by themselves. Possible applications like reminders, communication with healthcare professionals, measurement and monitoring or

interacting with other patients can improve the life of the patients. Physicians can receive real time data from the patients' home without even being there. Some issues to be kept in mind are security of data transmitting, training of users for operating the device and the costs of the high tech gadgets.

3.6.4. University Hospital of Leipzig

About 4,200 employees work in the University Hospital of Leipzig [47] to treat 48,000 stationary and 260,000 ambulant patients each year. Most parts of the treatment process from check-in to release were made electronically. The only gap was at the patient's bedside. The documentation was taken on paper and there was no access to a lot of information on the servers. Bedside care and documentation are central points in the healthcare process.

To close this electronic gap the hospital upgraded its IT system with Tablet PCs for usage at the patients' bedside in the neurosurgery ward. Now with secured wireless access all relevant data can be retrieved wherever it is needed. The products used by doctors and care personnel are Fujitsu Stylistic Tablet PCs (slate type) and Fujitsu Lifebook (convertible type).

Since the introduction of the Tablet PC in the hospital almost the complete documentation can be done electronically. Doctors and nurses can access data from the EMR system and review radiology and lab results. Because documentation can be done right at the bedside, the information quality has increased and resource planning has been more efficient.

3.6.5. Three Medical Clinics

This case study by Microsoft and Amicore [48] includes the three medical clinics, Bienville Orthopedic Specialists in Mississippi, Middlesex Cardiology in Connecticut and Granite Medical, a multi-specialty practice in Massachusetts, which were using a traditional clinical management system. It was very cost intensive and was not accessible everywhere. Diagnoses and notes were added to the paper-based

chart and filed manually. The risk of losing important data or the access of confidential information by unauthorized people was high. Therefore the goal is to eliminate the paper-based medical charts and integrate patient scheduling and prescription writing into a secure system.

The solution for this problem is a Tablet PC based EMR program by Amicore [49] with wireless access. It includes record keeping, scheduling, prescription writing and messaging. If a patient arrives, a message will be sent from the front desk to the doctor's tablet. This is a tremendous improvement over the former system, because now the doctor knows everywhere at every time where his patients are and can communicate with the clinical staff without using a second device or the need of seeing the nurse personally. Prescriptions can be easily sent from the Tablet PC to the pharmacy's fax machine.

95 percent of taking notes is now done with a series of prompts by the Amicore system on the Tablet PC. The physician can use the stylus to input data on the go and annotate pictures or add audio to the patients' records. Because of the reduced paperwork the time consumed for transcription is lowered.

With the new System the clinics were able to reduce costs and save time. Some of the benefits the three institutions address are:

- Elimination of the need for most file folders and sticky notes
- Saving 100,000 to 200,000 dollars by reducing transcription services
- Reimbursement times from insurances have been lowered by up to 50 percent
- Messaging is quick and easy
- HIPAA (Health Insurance Portability and Accountability Act) requirements are satisfied because of the detailed records
- Clinical staff has access to the newest patient records.
- Data loss is reduced

3.6.6. Conclusion

More than four years have passed since Microsoft introduced the Tablet PC in 2002. In this time quite a lot of healthcare organizations and facilities have adopted the tablet to use in their daily processes. Beginning from small medical practices up to big university hospitals the staff members are convinced of the benefits of this new device.

First it is a big investment getting Tablet PCs, but the money spent on buying them is saved quickly by reduced paperwork, less redundancies, better workflow and easiness of use. The risk of losing data is lowered dramatically because the information is stored electronically and backups are made frequently. Regular handwritten notes or an x-ray picture can be displaced in a wrong folder after the doctor reviewed it and therefore the chance of finding it is pretty small. But if all the information is stored on the database server it will not get lost from there that easily.

Being able to use the Tablet PC on the go is one of the big advantages. Especially in medical facilities or on the field where the healthcare members have to go to the patients the Tablet PC is a great device. With a notebook the user would have to find a table first before he can enter information. This takes time and does not pay if he only has to take short notes. With a tablet he just stands or sits next to the patient taking his notes as he would do with a regular chart. Many physicians and nurses using the Tablet PC mentioned that it is not as obtrusive as a laptop PC and the interaction with the patient is more natural. Since the Tablet PC has a fully featured operating system, it can perfectly be used for communication in the hospital such as instant messaging or taking calls with voice-over-IP software.

In the future there might not be a way getting around using Tablet PCs in many healthcare areas. Prices for the devices will drop more and more and the gap to notebook PCs will get smaller. In some years seeing a doctor or nurse running around with a tablet in their hands might be a common view.

3.7. Survey Tablet PCs in a Medical Practice

The following three polls were made on the MedicalTabletPC.com [50] site and address the usage of electronic devices and programs in healthcare. Since these polls were made on a webpage where most visitors are already interested in Tablet PCs, the results cannot be assumed for all doctors.

Tablet PC usage

Figure 16 (709 votes represent 100%) shows that 26% of the respondents already use a Tablet PC and 22% are looking for one. A remarkable amount of 40% said that the Tablet PCs are too expensive. Only 5% mention the lack of available software for Tablet PCs.

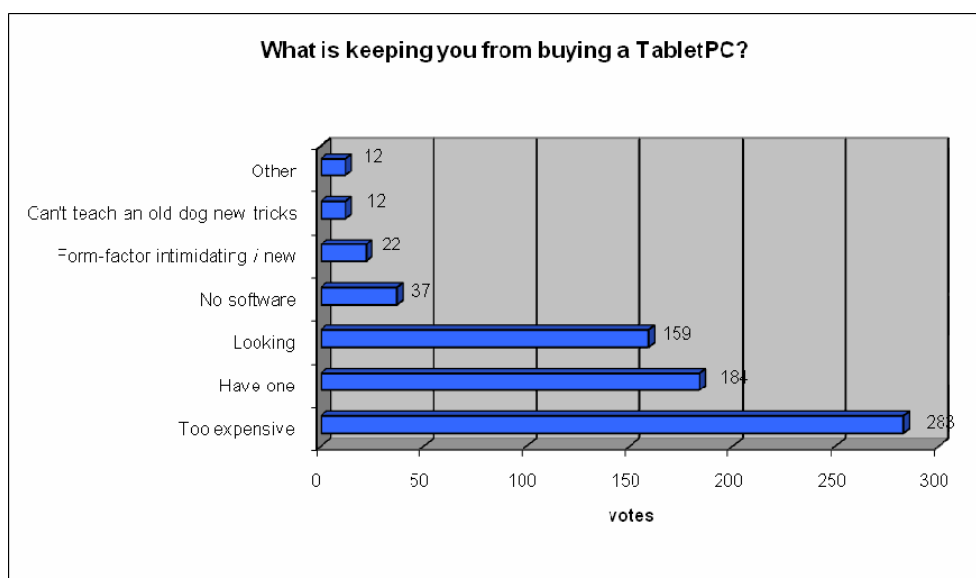


Figure 16: Medical Tablet PC Poll #1 after [51]

Number of Voters: 709

Period: November 2003 – June 2006

EMR usage

The poll shown in Figure 17 (431 votes represent 100%) asks the respondents why they are not using an EMR system. 40% are already using or are looking for an EMR system while 34% fear the unknown. 23% mention that the high costs are keeping them from buying medical record software.

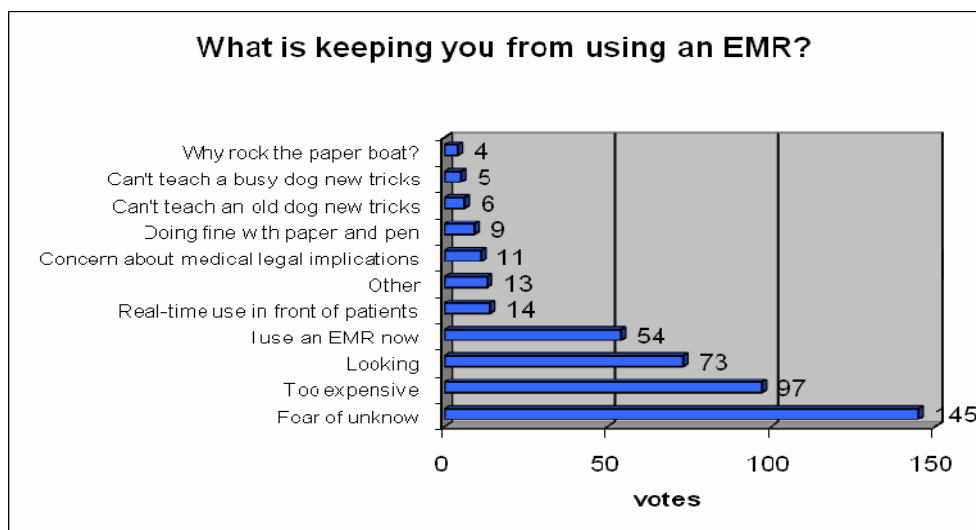


Figure 17: Medical Tablet PC Poll #2 after [52]

Number of Voters: 431

Period: January 2004 - June 2006

Best mobile hardware for clinicians

To the question what the best mobile device would be for clinicians at the point of care (see Figure 18 – 205 votes represent 100%), 75% answered Tablet PC. A second device voted for quite often was a PDA (16%). This shows that Tablet PCs are the preferred alternative to other electronic devices at the point of care.

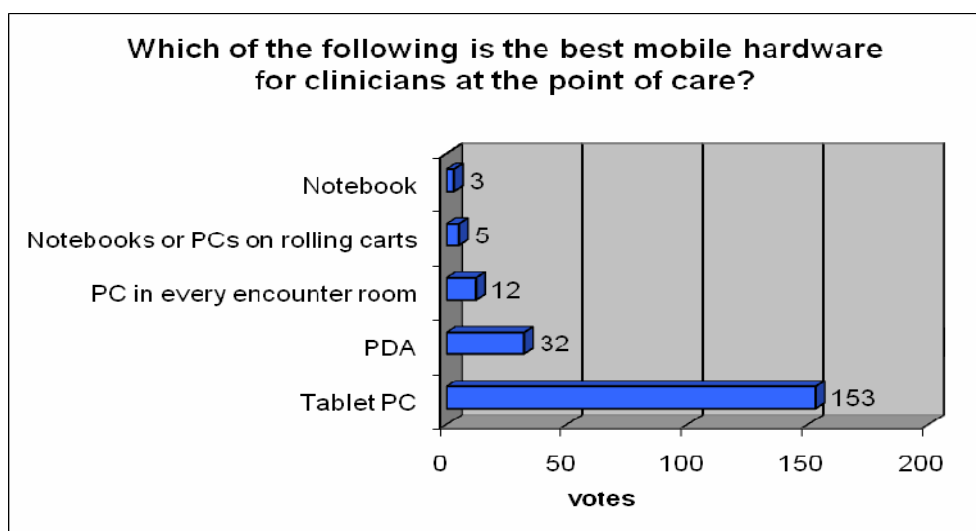


Figure 18: Medical Tablet PC Poll #3 after [53]

Number of Voters: 205

Period: November 2004 – June 2006

4. Tablet PC EMR Implementation

4.1. Overview

The intent of this program is to show the possibilities of a pen based EMR software on a Tablet PC. Especially the unique feature inputting data with the stylus will be the main focus, but also audio and motion detection will be included to extend the possibilities to use the device. The practitioners should be distracted from their daily work by computers as little as possible and spend more time interacting with the patients. This can be achieved by providing an easy to use interface to the user and optimizing the workflow, so any task can be completed with a few clicks.

It is very important that this application was just made for Tablet PCs and is not traditional software which was complemented with stylus support. Therefore input fields are larger than in regular programs and the usage of gestures is included. The EMR system should assist the practitioner wherever possible and help him to have the most recent data at anytime anywhere. These factors can help to provide better care to the patients, save important time, lower paperwork and save money.

Since practitioners are not IT professionals the appearance of the user interface is an important factor to satisfy the look and feel experience of the users. With WPF (Windows Presentation Foundation) the application gets a fresh and dynamic look. In conjunction with the programming language C# a powerful environment is available to enable feature rich software. These programming languages are rather new and with WPF based on XAML (Extensible Application Markup Language) the programming logic can be separated from the user interface sufficiently. More information about these technologies can be found in chapter 4.3 'Available Platforms and Technologies'.

4.2. Software Description and Usage

Handwritten data input into the EMR software will be stored as ink and analyzed text. That way the doctor can even use drawings to add to his comments and the text can easily be searched for. Since this software will focus on the benefits and drawbacks of pen-based applications and their usage, data will just be stored during the active session with some sample records already entered in the program. There is no database or whatsoever behind this application.

4.2.1. Scenarios of Usage

This pen-based EMR software aims to be used by practitioners and nurses in a medical practice. Following scenarios are common:

- Doctor – Patient communication (Figure 19)
 - Anamnesis by doctor
 - Adding a new case/record
 - Annotating x-rays and pictures
 - Taking audio notes
 - Explaining the findings to patient

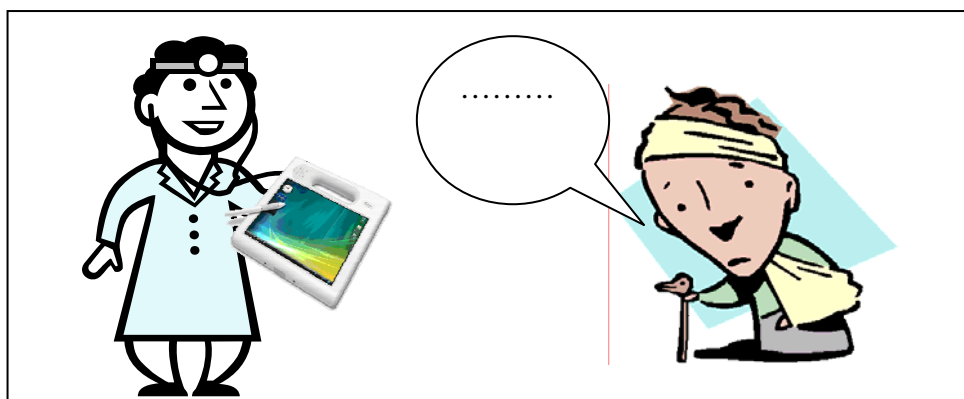


Figure 19: Doctor - Patient communication

- Nurse – Patient communication (Figure 20)
 - Adding new patients
 - Questionnaires

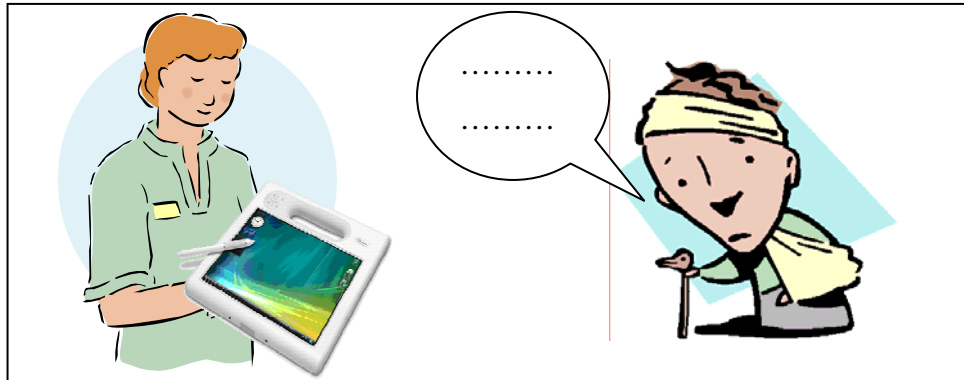


Figure 20: Nurse - Patient communication

- Nurse – Doctor communication (Figure 21)
 - Communication with staff

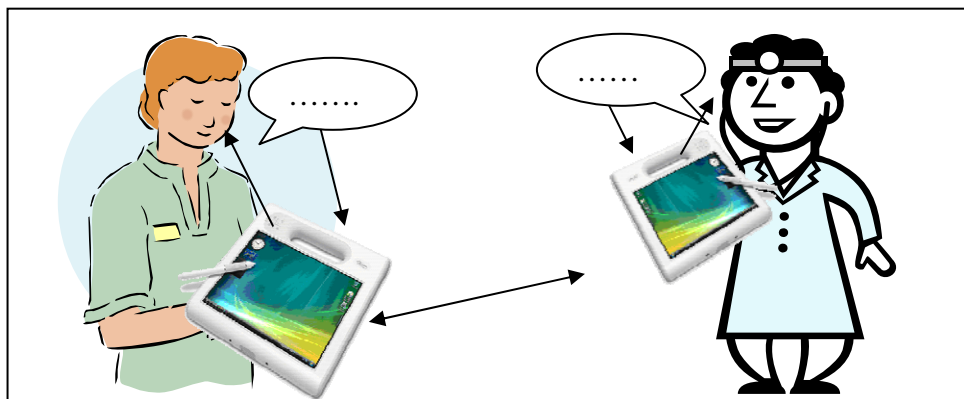


Figure 21: Nurse - Doctor communication

- Doctor – Internet Communication (Figure 22)
 - Using the internet to lookup information

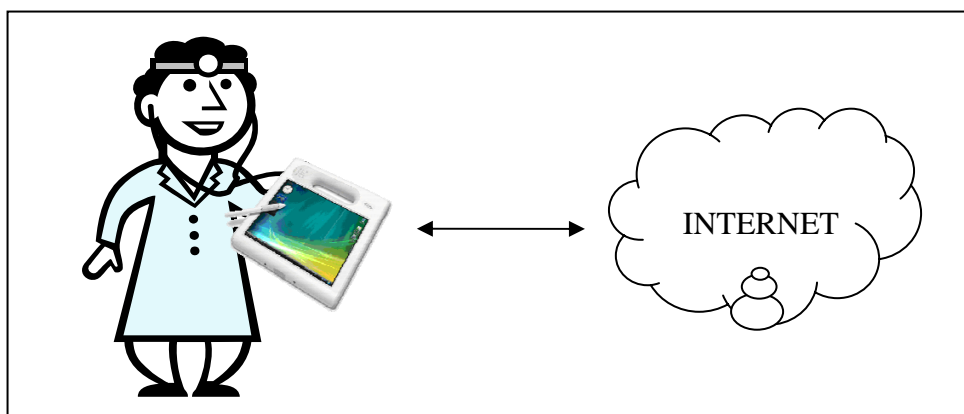


Figure 22: Doctor - Internet communication

The four objects communicating with each other using a Tablet PC are:

- Doctors (with nurses, patients and internet)
- Nurses (with doctors, patients and internet)
- Patients (with doctors and nurses)
- Internet (with doctors and nurses)

The patients themselves will never use the Tablet PC; it will always be operated by the medical staff. This is because the users of the pen-based application also need training to be able to use the program. Anyway, the Tablet PC can be used by the doctor to show records or pictures to the patients and discuss them while looking on the screen.

4.2.2. Software User Interface

Application chart

The chart in Figure 23 shows the different parts of the application. The communication center bar, quick notes bar and navigation bar will be shown all the time. Through the navigation bar the user can quickly change to the patient list, patient info or records pane. Picture annotation, written record and audio recording can be accessed from the records pane.

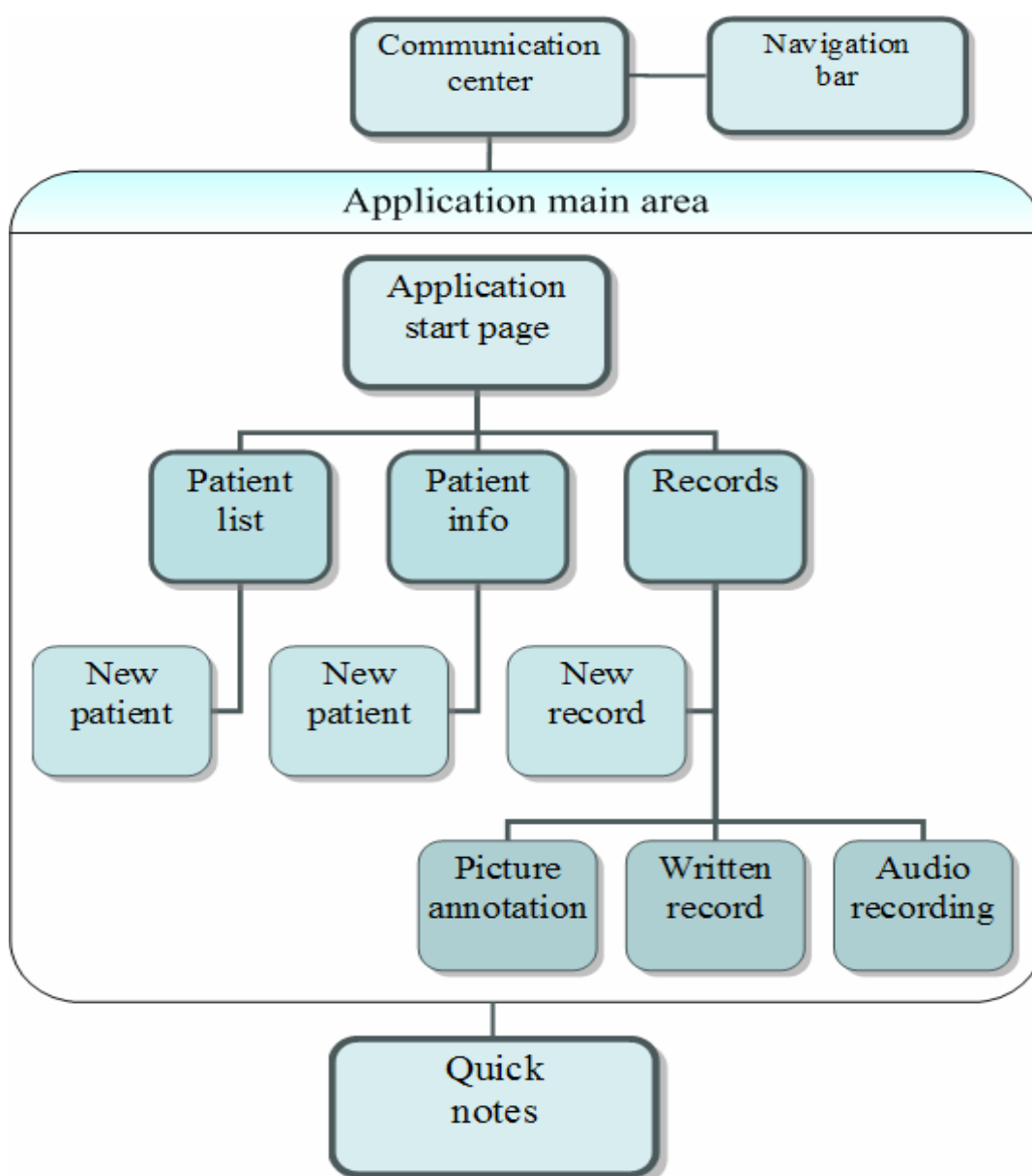


Figure 23: Application chart

Start page

The start page (see Figure 24) is the entry point of the application. From this view the user can choose to go to the patient list, patient info or records pane. At any time in the application the view can be switched to the start page, patient list, patient info or records pane from the navigation bar in the upper right.

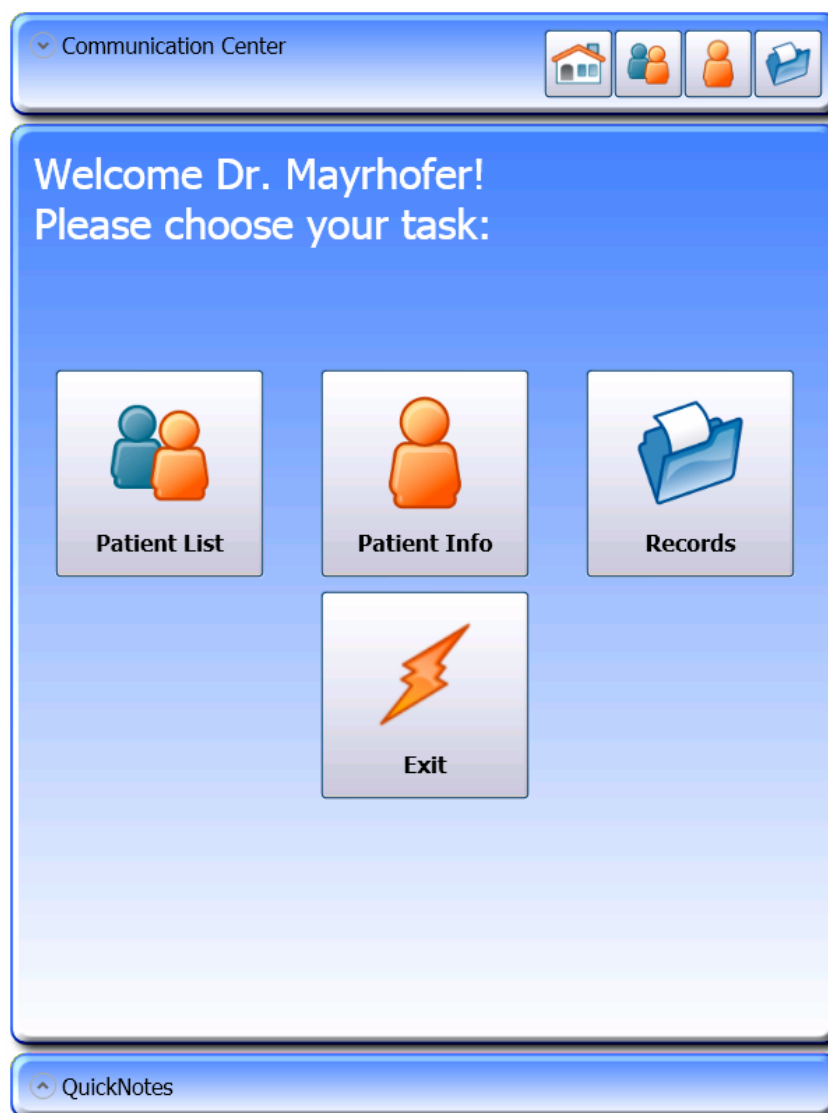


Figure 24: Start page

The communication center and quick notes can also be expanded and used at all times. The exit button will close the application. The upper and lower pane will always stay the same, only the main pane in the middle will change to the chosen view.

Communication Center

The communication center (see Figure 25) is shown at the top of the program at all times. It also includes the navigation bar, where the user can quickly change to the start page, patient list, patient info and records pane. It enables the user to communicate with other medical staff members.



Figure 25: Communication Center – collapsed

By clicking on *Communication Center* the pane will expand as shown in Figure 26 and show the communication interface, from where the user can chat with other staff members or call them.

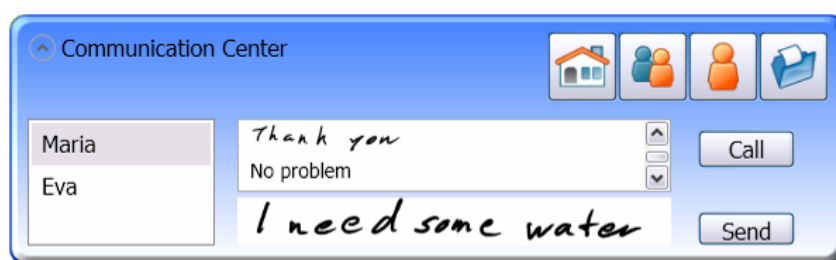


Figure 26: Communication Center - expanded

In the chat interface the doctor can write into the send box with his stylus and the handwritten data will be transferred to the user selected in the left selection box. In this prototype the functionality is just simulated. In Figure 26: Communication Center - expanded' the doctor first writes “Thank you” with his stylus and clicks on the send button. After that the handwritten data gets transferred to the nurse who will see it in the original form. If the nurse is sitting on a regular PC, she can just type in her answer, in this case “No problem”. It gets transmitted back to the doctor’s Tablet PC who will see the answer as typed text. The next message the doctor writes is “I need some water”, which would be sent by clicking the send button again.

Another possibility to communicate with the nurses would be to use the call button to start a VoIP (Voice over Internet Protocol) call. That way the practitioner could use

the built-in microphone and speakers to communicate with other people without using additional devices.

QuickNotes

The QuickNotes pane (see Figure 27) is always shown at the bottom of the application and can be accessed at any time. It is used to take quick notes during calls or just to set a reminder. This data is not stored with a specific patient. It is more or less like a post-it note for private or medical issues.



Figure 27: QuickNotes - collapsed

By clicking on the QuickNotes pane it expands (see Figure 28) and shows an ink-canvas, where the user can write or draw into with his stylus. This data will not get analyzed and is only saved as ink.

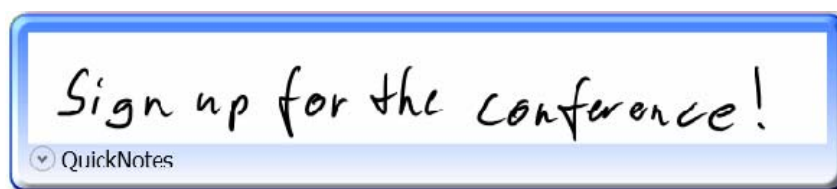


Figure 28: QuickNotes - expanded

There is only one QuickNotes canvas, so if the doctor wants to add something new he can simply turn around his stylus and use it as an eraser. By pressing the back of the pen on the screen the strokes being hit will disappear. By holding the stylus the right way again the canvas automatically switches to insertion mode and the user can add new notes to the QuickNotes panel.

After the note is written to the canvas the panel can be collapsed again by tapping on QuickNotes. That way there is more space for the main pane again.

Patient list

At the patient list panel (see Figure 29) the doctor can select the patient he wants to edit. By hovering over a patient with the stylus the intended record will zoom in smoothly to have a better look at it. When the user moves to the next record the previous one will zoom out to its normal size again. By tapping on the record the view will instantly change to the records panel of the selected patient.



Figure 29: Patient list

Another way to select a patient is to write the name of the patient in the canvas above the patient list. The entered data is automatically recognized and the name is

searched for in the patient list. If there is a match the view will again automatically switch to the patient's records.

By clicking on the *New* button a new patient can be added to the system; a file dialog will appear (see Figure 30) where a picture for the patient can be selected. This picture can be taken with a camera using a third party program.

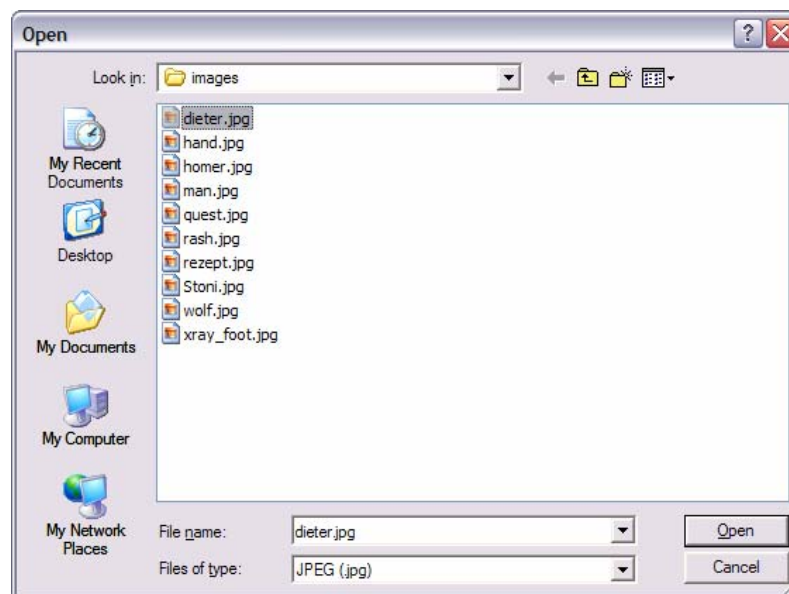


Figure 30: Open patient image

After selecting the picture and opening it the application will change to the patient info panel, where additional data for the patient can be entered.

Patient info

The patient info panel (see Figure 31) is used to create new patients or edit their basic data such as name, address, birthday, insurance, mobile phone number and some comments. After clicking the *NEW* button a new patient will be created and a picture for the person is selected in the same manner as using the *NEW* button on the patient list panel, where an open dialog for selecting a picture will pop up.

After the picture is selected and opened, the user can enter his desired data into the canvas with the stylus. The software will analyze the inked data and show the recognized text below the canvas. If the doctor sees that the recognized text is not

what he intended to write, the back of the pen can be used to erase parts of the ink and rewrite it.

The screenshot displays a Tablet PC EMR interface. At the top, a blue header bar contains a 'Communication Center' button with a dropdown arrow and four icons: a house, two people, a single person, and a folder. Below this is a patient information form for Dieter Mayrhofer. The form includes a photo of a young man, a 'Name' field with 'Dieter Mayrhofer' (with a 'NEW' button), an 'Address' field with 'Church-street 8' and '1030 Vienna' (with a 'Dieter Mayrhofer' label), a 'Birthday' field with '6-9-1982' (with a '6-9-1982' label), an 'Insurance' field with 'BVA' (with a 'BVA' label), a 'Mobile' field with '0664/8932748' (with a '0664/8932748' label), and a 'Comment' field with 'No comments' (with a 'No comments' label). At the bottom, a blue bar contains a 'QuickNotes' button with an upward arrow.

Communication Center	
	Name: Dieter Mayrhofer NEW
	Address: Church-street 8 1030 Vienna
Birthday:	6-9-1982
Insurance:	BVA
Mobile:	0664/8932748
Comment:	No comments
QuickNotes	

Figure 31: Patient info

The address box features two lines to write text into. If two text lines are entered, a line break will also be inserted in the recognized text.

The ink is always reanalyzed when the stylus is out of reach or when it leaves the borders of the canvas. This way the ink is not analyzed all the time and there will not be a lack of recognition speed, which would result in slower overall recognition and delay times.

Records

The records panel (see Figure 32) consists of the records info/tools pane on the top, the edit pane in the middle and the records list on the bottom. The edit pane can be used for image annotating or for taking notes for a record.



Figure 32: Records panel - annotating pictures

Records info/tools pane

On the records info/tools pane (see Figure 33) the user can choose between (buttons from left to right) adding a new record, printing the record (only a dialog will show up, printing itself is not implemented), playing audio records, recording audio, switching to the taking notes pane and switching to the picture annotation pane.

On the left a picture of the selected patient is shown with information displayed for name, street and birthday.



Figure 33: Records info/tools pane

By clicking on the *NEW* button a new record will be created; an open dialog will pop up to let the user select a picture – such as an x-ray image, image of the wound or a rash – which can be annotated later on. If the practitioner does not want to use a picture, than he can just click *Cancel*, otherwise he clicks on *Open*. It is the same process as opening a new picture when creating a new patient. The new record will show up with today's date in the records list.

The printer button will just open a regular printer dialog. It does not have any function implemented, so if *Print* or *Cancel* is pressed, no activities will be started and the dialog will only close.

If the speaker button is clicked, an audio record saved with this patient record will be played back over the Tablet PC's speaker if available. The playback will stop at the end of the record.

With the microphone button the practitioner can take audio notes with the integrated microphone by clicking on the button. While recording, the background of the button will change to red indicating that recording is in progress. If the user is done with talking he can again click on the microphone button to stop recording.

Notes taking

Clicking on the pen button will change the edit pane to the notes taking pane shown in Figure 34.



Figure 34: Notes taking pane

There are two canvases on the notes taking pane: the title canvas and the text canvas. The title should shortly explain the case; the text will include all specific data. All entered handwritten data will be analyzed and the recognized text will be shown below the canvas. The title entered here will also be shown in the records list.

To evaluate the usability of different input modes this pane also supports the entry of data by using the stylus with the regular TIP (Tablet Input Panel) control (see Figure 35) from Windows. The TIP control can usually be used in any programs with regular text edit boxes.

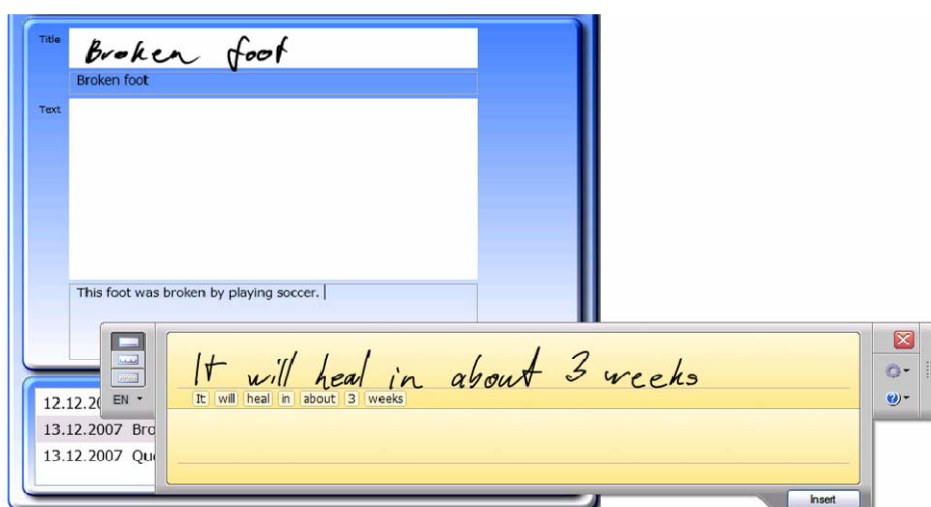


Figure 35: Notes taking pane - TIP control

The disadvantage of the TIP control is that it will not save any handwritten data; it will only save the recognized text. By just using the TIP control the user would not be able to add drawings to his notes. One benefit is that a list of possibilities of recognized words can be shown and selected from. Rather than erasing and rewriting a word the correct word can just be chosen.

Picture annotation

The picture annotation pane (see Figure 36) is used to annotate pictures such as x-ray images, wounds of the patient or pictures of any kind of the human body. It can also be used for answering questionnaires or filling out and signing prescriptions.

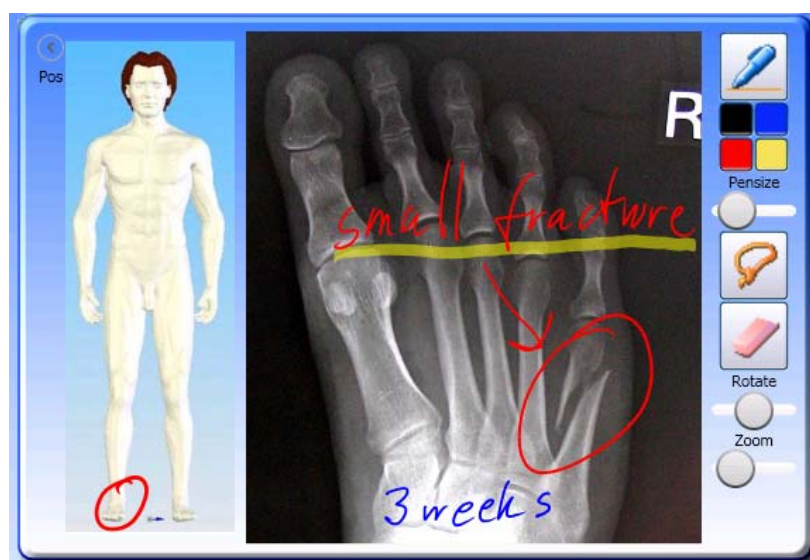


Figure 36: Picture annotation pane

The Picture annotation pane is split into three different areas: the position marking area, the picture annotation area and the annotation toolbar.

Position marking area

In the position marking area the position of the image relative to the patient can be marked on the person shown in the pane. For example, if there is an x-ray of the right foot, the doctor marks the right foot in the position pane. This pane can always be collapsed or expanded by just clicking on *Pos* on the left side. When collapsed there will be more space for annotating the image in the middle.

Image annotation area

The image in the middle is the actual image being used for annotations. The stylus can be used to draw on the image, mark areas, delete strokes, change the pen color, rotate/resize strokes and zoom into the picture. If a stroke is extended outside of the image, the canvas will grow. All strokes will be stored for the image and will be recreated when going back to this record.

Annotation toolbar

The pen button in the toolbar is used to switch to inking mode. Below that button are four small blocks for selecting the color to write with: three permanent colors (black, blue and red) and one text marker color yellow. The permanent colors will completely overwrite everything under the stroke; the text marker color will let the image shine through the stroke like a regular text marker. The pen-size slider will regulate the thickness of the strokes being painted. By moving it to the left it will get smaller, by moving it to the right it will get bigger.

The lasso button will change the stylus to a selection tool. Strokes can be selected by either tapping on them or drawing a circle around them.

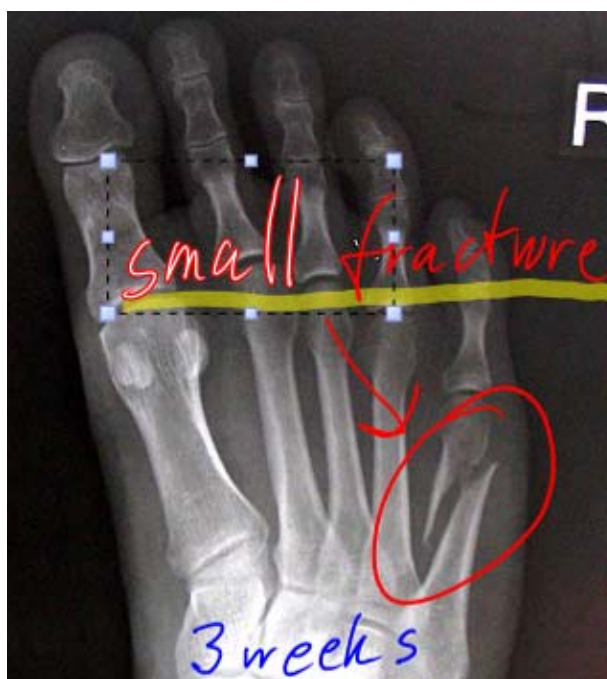


Figure 37: Selected strokes

After selecting the ink a box will appear around the selected ink and the strokes will be highlighted like in Figure 37. They can be resized by dragging one of the little blue boxes set on the bounding box. With the rotation slider the selected strokes can be rotated (see Figure 38) to the left or to the right by up to 180 degrees.

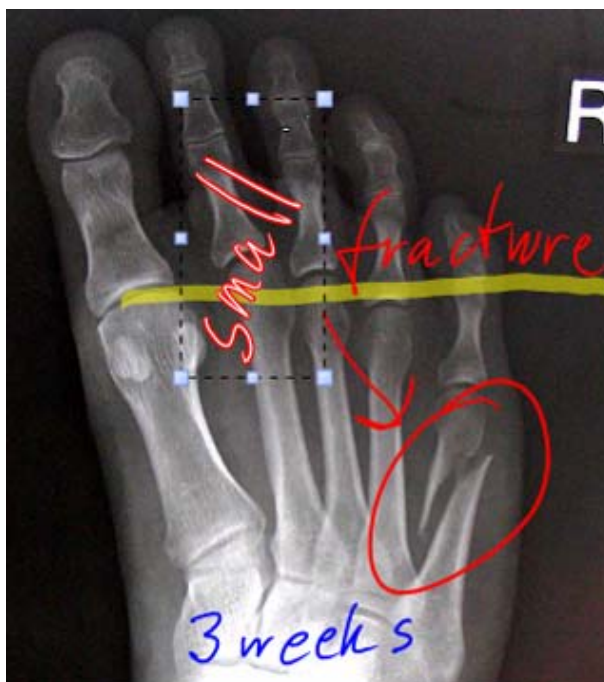


Figure 38: Rotating strokes

Ink can be deleted by both using the back tip of the stylus or by selecting the eraser in the toolbar and using the regular tip of the stylus. The eraser is set to completely remove one stroke when it gets hit.

The last tool on the toolbar is the zoom slider. By moving it to the right the image will zoom in, by moving it to the left the image will zoom out. When using the slider the complete image including the strokes will be zoomed. That way the strokes always stay in the same proportions to the image.

Records list

At the bottom of the records pane is the records list pane (see Figure 39). Here the different records can be chosen and will be immediately shown in the edit pane. By holding down the stylus and moving it the list can easily be scrolled through. When adding a new record it will appear in the list.

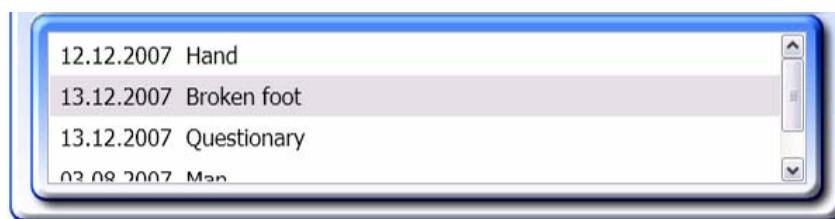


Figure 39: Record list

4.2.3. Gestures

Gestures are special moves done with the pen anywhere in the application to perform certain actions. They can also be done by using the mouse, but it feels more natural to do them with a stylus. An application where gestures are used is for example Mozilla Firefox, where the user can easily go back and forward in the history of the websites.

In this EMR Tablet PC software gestures (see Table 3) are used to scroll forward and backward between different patients, maximize or minimize the window. Anywhere in the application the user can perform these gestures. All that needs to be done is pressing the button on the stylus and draw a special shape on the screen. After the gesture gets recognized it will perform the action. For example, if a line is drawn to the right, the application will switch to the next patient, if a line is drawn to the left, the previous patient will be selected. When drawing a line to the upper right, it will maximize or normalize (depending on the state of the window) the application; by drawing to the bottom left it will minimize the window. A shape drawn like an X will close the application. In addition there is also an audio playback telling the user the action he just performed. The gestures are actually recognized by the third party application Symbol Commander from Sensiva [54], which will tell the active

application what gesture was applied to the active window so it can perform certain tasks.







Gesture	Stroke
Next patient	
Previous patient	
Maximize window	
Minimize window	
Scratch out	
Exit application	

Table 3: Gestures in the EMR application

One more gesture is implemented in the software natively. With the scratch out gesture, parts of the text can be scratched out and will be deleted immediately. This can be used in any canvas where text is the main input.

4.2.4. Accelerometer

The accelerometer built into the Tablet PC can be used to perform certain tasks when the tablet is being shaken or moved quickly. This feature is enabled by another third-party software which analyzes the movements and can perform different actions. Moving the Tablet sideways or up and down will start the following applications:

- Skype [55] messenger

When the Tablet PC is moved quickly from the right to the left or visa versa when in portrait mode, it will open the Skype messenger shown in Figure 40. By simply double tapping on the person's contact it will be called. The user (e.g. doctor) can communicate with the user on the other end (e.g. nurse). If he wants to go back to the EMR system, he can close the messenger or just click on the other application.

Another possibility is to exchange the Skype messenger by the MSN messenger, which also supports chatting between two parties by just sending the handwritten text and not converting it to typed data making communication simpler.

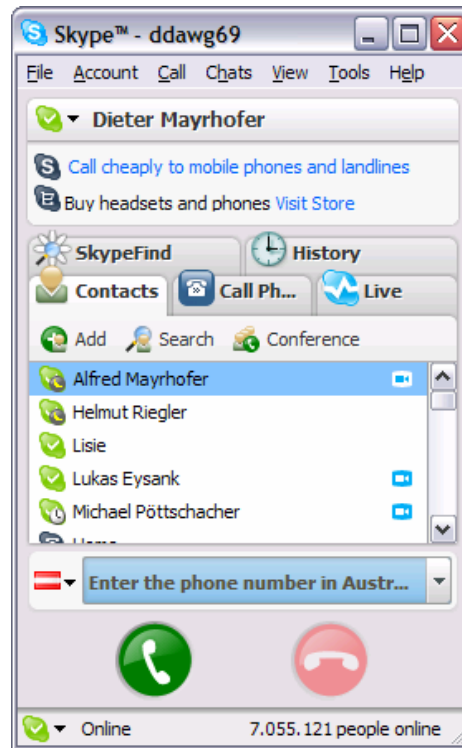


Figure 40: Skype messenger [55]

- Microsoft Internet Explorer [56]

Moving the tablet quickly up or down when in portrait mode will launch the Internet Explorer. There the doctor can for example look up special information about diseases or use it as a helpful device to explain medical findings to the patient. The reason why Mozilla Firefox is not chosen here is that it does not support stylus handwriting entry.

4.2.5. Screen Rotation

Since the Tablet PC includes an accelerometer chip, it can also adjust the screen alignment to the position the screen is used in. If the doctor is using the Tablet PC in portrait mode and he comes into a situation, where he would like to use it in

landscape mode, he simply has to turn the device to the desired position and press the adjust button on the Tablet PC and the application will rotate to the right position.

4.2.6. Pen Function Keys

On the top of the Tablet PC Toshiba M200 above the screen are 4 special pen function keys which can be activated by tapping them with the pen. By hovering over them they will show on the screen which function will be executed. These functions can be set inside the Toshiba settings tool. Common features are copy, paste or changing the screen resolution.

4.2.7. Summarization

The different user-computer interaction tools are:

- Handwriting entry into the canvas
- Drawing into the canvas
- Gestures
- Accelerometer/Screen rotation
- Pen function keys

4.3. Available Platforms and Technologies

There are two different operating systems which allow Tablet PC applications to be run on. One of them is Microsoft Windows XP Tablet PC Edition, the other one is Windows Vista (all versions). Differences between those two operating systems concerning pen input are described in section 2.2.2 ‘Windows Vista’. For developing the EMR program Windows XP with .NET Framework 3.0 runtime and Windows SDK was used, but it can either be run on Windows XP Tablet PC Edition or Windows Vista, which does not need any additional runtimes. To run the application on Windows XP, the Microsoft .NET Framework 3.0 Redistributable Package [57] has to be installed.

At the time of publishing there were two different kinds of Software Development Kits (SDK) for Tablet PC applications – Tablet PC SDK Version 1.7 and Windows SDK 6.

4.3.1. Tablet PC SDK Version 1.7 for Windows XP

This SDK has to be included in the project to enable Tablet PC specific controls in Windows applications using Win Forms or COM platforms. Programming languages that can be used are:

- Visual C# - .NET Framework required
- Visual Basic .NET - .NET Framework required
- Visual C++
- Visual J#
- Visual Basic 6.0.

The most important controls provided by this SDK exposing a *Microsoft.Ink.Ink* object are:

- InkPicture – Enables a picture to be inked on

- InkEdit – A special edit box, where ink will be translated and shown as typed text
- InkOverlay – Enables to collect, erase or select ink, must be attached to a window or a custom control
- InkCollector – Enables to collect ink, must be attached to a window or a custom control

The Ink object of the control can hold *Microsoft.Ink.Stroke* objects and manipulate them.

4.3.2. Windows SDK 6 and .NET Framework 3.0 using WPF

The Windows SDK 6 for Windows Vista goes a totally new way in ink development. The ink controls and objects are now included in the core system and are included in *System.Windows.Controls* and *System.Windows.Ink*. For the user interface rendering WPF (Windows Presentation Foundation) is used. The two controls provided by the SDK are:

- InkCanvas – can collect ink into a stroke object
- InkPresenter – can render ink

The two controls can easily be put above any other control like an image presenter, text edit field or even a button. It can for example also be included as a separate item into a list-box. This way the Windows SDK 6 offers much more possibilities to design the user interface than the Tablet PC SDK 1.7 does. The strokes (*System.Windows.Ink.Stroke*) are collected in the stroke-collection (*System.Windows.Ink.StrokeCollection*).

There are two programming languages available to create programs for .NET Framework 3.0 and WPF:

- Visual C#
- Visual Basic .NET

To run the program under Windows XP, .NET Framework 3.0 has to be installed on the system, for Windows Vista no additional components have to be installed.

4.4. *Used Platform and Technology*

The Windows SDK 6 (including .NET Framework 3.0) was used to develop this application because it supports the use of the new user interface WPF, which enables the developer to completely separate the visual appearance from the logic behind the program. Another point is that the user interface design can be made dynamic and does not have to be static. Also the ink controls can be used more flexibly and be included everywhere easily. C# was taken as programming language, which is a JAVA like programming language introduced by Microsoft.

The key components and programs used for developing the EMR program are:

- C# - .NET Framework 3.0 (program logic)
 - Visual Studio 2005 [58] and components
- WPF – Windows Presentation Foundation (program UI-design)
 - Microsoft Expression Blend [59]

Since the chosen technologies are pretty new, many of the components and Microsoft Expression Blend are still in the beta state. The tools still worked pretty fine and did not crash a lot.

4.4.1. C# - .NET Framework 3.0

The object-oriented programming Language C# was introduced by Microsoft together with the .NET Framework in 2001. The code is mostly compiled into a Common Intermediate Language (CIL), which can again be compiled and executed by the Common Language Runtime (CLR) on operating systems running the .NET Framework. Many aspects of C# are pretty similar to JAVA.

Some of the main differences between C# and C++ are:

- Restricted pointer usage
- Global variables or functions are not allowed
- Garbage collection in C#
- Strict Boolean type
- No multiple inheritance

Since the program is targeted to use WPF, the author of this study decided to take C# upon Visual Basic .NET as the programming language for personal preferences.

4.4.2. Visual Studio 2005

Visual Studio 2005 is one of the most used development suites to program in C#. When creating a new application Visual Studio will create basic program code to get started. WPF and .NET Framework 3.0 is not supported by Visual Studio 2005, the components have to be installed separately.

Here are the components which need to be installed to develop Tablet PC software targeting WPF applications described on the Microsoft homepage [60]:

- Visual Studio 2005
- Visual Studio Extensions for NET Framework 3.0 Beta1
- Mobile PC and Tablet PC Software Development Kit September Release, which provides access to the InkAnalysis and COM RealTimeStylus classes.
- NET Framework 3.0 Runtime Components Beta 1
- NET Framework 3.0 SDK for the NET Framework 3.0 Runtime Components September 2005 CTP or Windows SDK 6

Using the newly released Visual Studio 2008 Beta 2 (formerly known as ORCA) would probably not require installing all these additional components, but that was not tested by the author of this work. Visual Studio 2008 is already made for developing under Windows Vista and therefore will also include its technologies.

After installing all these components a new project in C# for Windows WPF can be created. Because WPF is a new technology provided by .NET Framework 3.0, it can be found under this section shown in Figure 41:

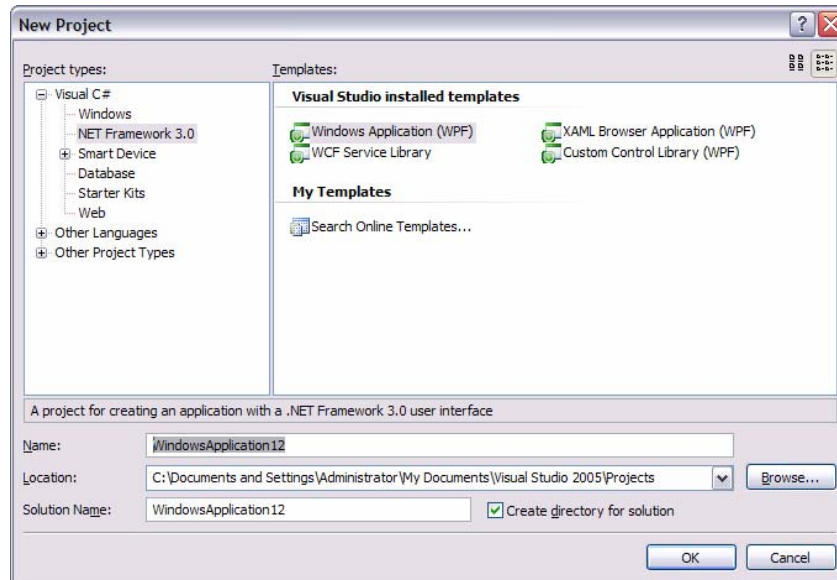


Figure 41: Creating a WPF project

To be able to analyze ink, the *Ink Analyzer* library has to be included into the project as shown in Figure 42. It can receive strokes and analyze them, after that the result can be taken from the object.

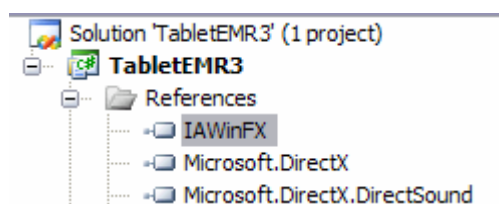


Figure 42: IAWinFX - Ink Analyzer component

This is all what has to be set up to start developing an application in WPF with ink support. Creating WPF designs is implemented poorly in the current Beta version of the Visual Studio Extensions for .NET Framework 3.0. Even creating events like a button click has all to be coded and takes a lot of time, there is no basic code generation. Therefore for designing the user interface the software Microsoft Expression Blend was used, which will be discussed later.

4.4.3. WPF – Windows Presentation Foundation

Windows Presentation Foundation (WPF) [61] [62] is a new presentation framework for Windows XP and Windows Vista developed by Microsoft. It describes a completely new user interface which allows colorful animations, 3D content and dynamic applications. The program code for the design structure is held in XML code called XAML (Extensible Application Markup Language).

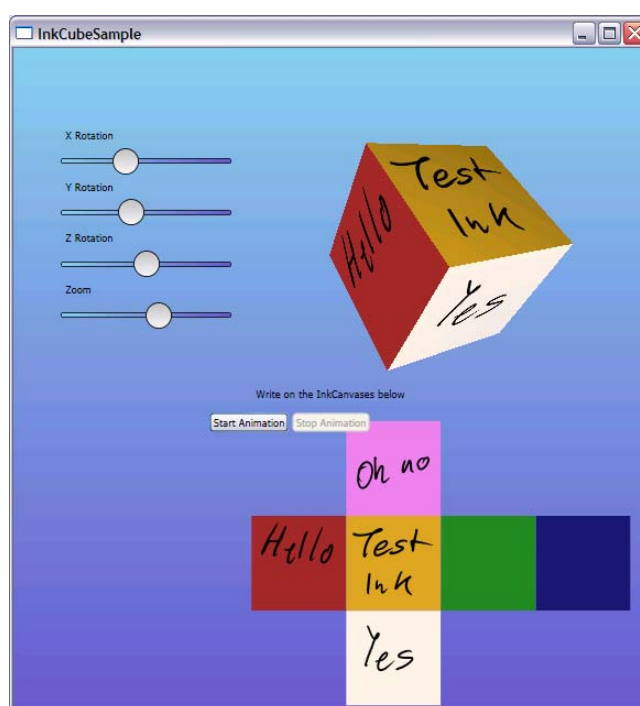


Figure 43: InkCubeSample in WPF by Microsoft [63]

Controls and graphics are merged in WPF and the layout can be set statically or dynamically. The various controls and items of the program can be set in different panels. Some panel types can automatically arrange the positions of all objects. Another new thing is that all kinds of controls can be put into another control. For example an ink-canvas, a textbox and a checkbox can be put into a button control and they will still be accessible. Also ink can be drawn on a surface and in real-time it will be duplicated on a 3D cube (see Figure 43: InkCubeSample in WPF).

Data binding is a very useful tool to connect objects or lists to controls such like text-boxes, labels or list-boxes. The data source can also be an XML-file or another control in the WPF application. This way data transfer can easily be achieved. The

next step is to define data templates for objects. If, for example, an object includes the family name, a link to the person's picture and his favorite color, a data template can be designed, which will create a button with the image of the person centered in it, the name of the person being shown on the bottom and the background color of the button being the favorite color of the person. This template only has to be designed once, whenever the object is supposed to be rendered like that, the data template can be set for this instance.

The following sample (Figure 44) shows a basic WPF application with a button and textbox on the top and a button with an integrated picture and textbox:

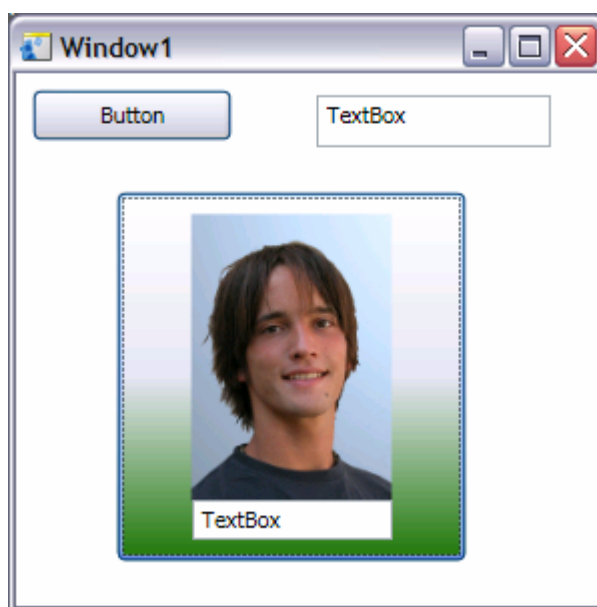


Figure 44: Simple WPF application

The following code (see Code 1) describes this layout. The main tag is *window*, which includes some attributes for some of the window settings. Inside the *window* is a *grid* control, which allows controls to be put anywhere inside of it; they can even overlap each other. The two basic controls on the top are set by the tags *button* and *textbox* with some positioning and sizing numbers. After that comes the *button* including the *picture* and *textbox*. It is marked again with a regular *button* tag, but this time the button also has contents. The first one is the *button.background* tag, which sets the background color of the button. The next tag is a *stackpanel*. Other than in a grid, in this panel the controls set inside are located one below the other.

The image and textbox control set in the buttons do not need any positioning attributes, since they get positioned automatically.

```
<Window
  xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
  xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
  x:Class="UntitledProject6.Window1"
  x:Name="Window"
  Title="Window1"
  Width="300"
  Height="300"
  xmlns:d="http://schemas.microsoft.com/expression/blend/2006"
  xmlns:mc="http://schemas.openxmlformats.org/markup-compatibility/2006"
  mc:Ignorable="d">

  <Grid x:Name="LayoutRoot">
    <Button d:LayoutOverrides="HorizontalAlignment"
      HorizontalAlignment="Left" Margin="8,8,0,0" VerticalAlignment="Top"
      Width="100" Height="26" Content="Button"/>
    <TextBox HorizontalAlignment="Left" Margin="150,11.362,0,0"
      VerticalAlignment="Top" Width="117" Height="26" Text="TextBox"
      TextWrapping="Wrap"/>
    <Button d:LayoutOverrides="VerticalAlignment"
      HorizontalAlignment="Left" Margin="50,59,0,22" Width="175">
      <Button.Background>
        <LinearGradientBrush EndPoint="0.5,1" StartPoint="0.5,0">
          <GradientStop Color="FFFFFFFF" Offset="0"/>
          <GradientStop Color="FFE3E5F0" Offset="0.5"/>
          <GradientStop Color="FF1E7607" Offset="1"/>
        </LinearGradientBrush>
      </Button.Background>
      <StackPanel Width="100" Height="Auto">
        <Image Source="Passbild_klein.jpg" Stretch="Fill"/>
        <TextBox Text="TextBox" TextWrapping="Wrap"/>
      </StackPanel>
    </Button>
  </Grid>
</Window>
```

Code 1: Simple WPF application

4.4.4. Microsoft Expression Blend

Microsoft Expression Blend [59] is a new application to design WPF user interfaces (see Figure 45). It can be used like a vector graphics designing software and all kind of WPF controls can be added to the layout. It enables the user to add videos, animations, dynamic controls and 3D content.

A big advantage of Microsoft Expression Blend and WPF is that user interface designers can work mostly independent from the code behind the application. Adobe (Macromedia) Flash like animations and transformation can be achieved by using the

timeline feature of WPF. The properties tab lets the designer change the various properties of the controls and drawing elements.

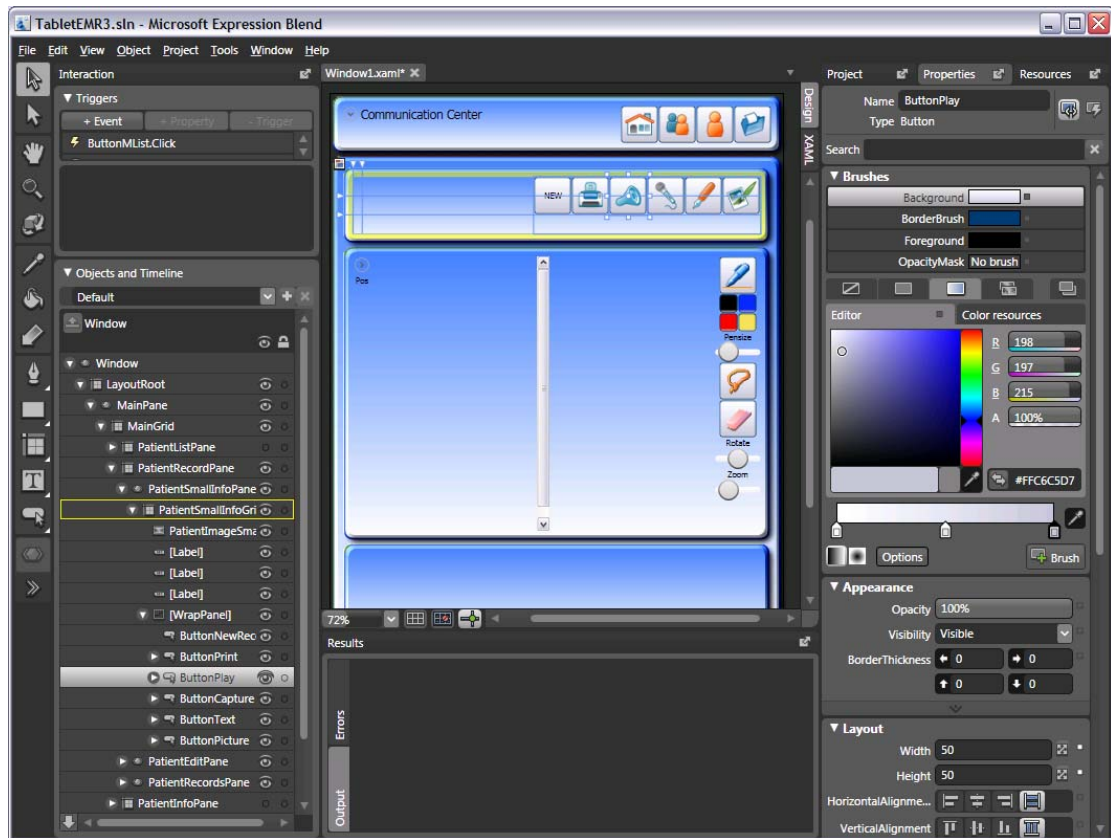


Figure 45: Microsoft Expression Blend [59]

Custom controls can be created by adding styles or templates to the controls and putting them into a new layout. The purpose of styles is to change the values of properties of controls such as background color; the purpose of templates is to not only modify simply values of the control, but also change the structure of the control. Therefore items in a control can be added or rearranged (for example adding a background picture to a button). To individually present data a data template can be created for e.g. objects or xml-data.

By clicking the event button in the properties tag, events can be created for a control. When adding an event like click or drag for a control, Expression Blend will generate the basic code for it, write it into the corresponding C# file and open Visual Studio so that the developer can add functionality to the event.

4.5. Technical Realization

This section will describe important and interesting coding parts and also 3rd party software, which was used for some gestures and the accelerometer features.

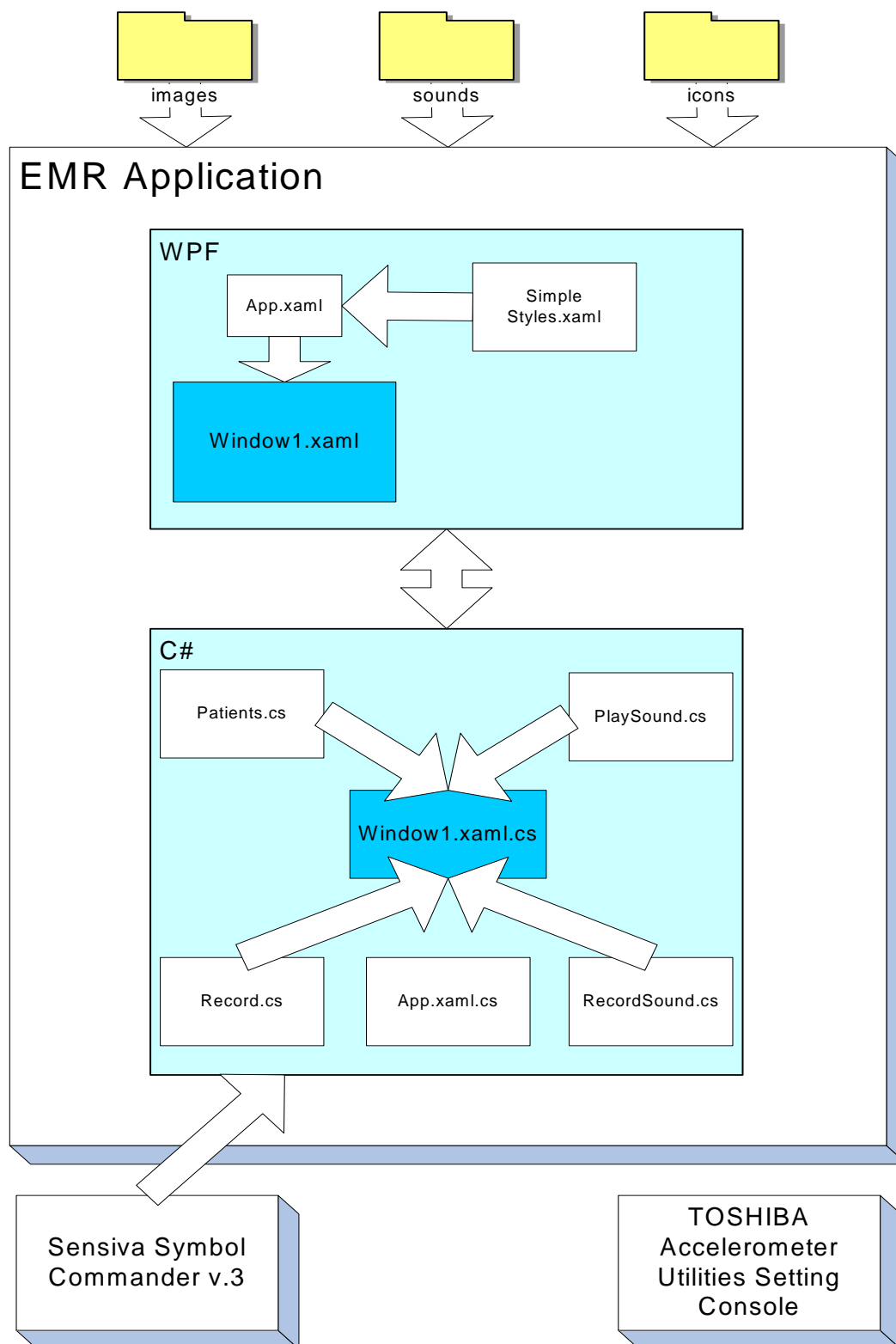


Figure 46: EMR development structure

Figure 46 shows the development structure of the Tablet PC EMR software. The main parts of the application are the WPF (xaml) and C# (cs) files. The WPF part consists of three files: *Window1.xaml*, *Simple Styles.xaml* and *App.xaml*. In *App.xaml* resources can be defined, in this application *Simple Styles.xaml* is set there; it contains styles for the controls. *App.xaml* also has a reference to *Window1.xaml*, which includes the design and structure of the Application.

The two xaml files *App* and *Window1* have a corresponding C# file *Window1.xaml.cs* and *App.xaml.cs*. *App* does not contain any interesting code for this project, in *Window1* all important logic and communication with the user interface is located. *Patients.cs* and *Record.cs* contain classes for patients and their records, which will store all the specific data. The *PlaySound.cs* and *RecordSound.cs* files contain classes which can record and playback audio files using DirectX.

The 3rd party software Sensiva Symbol commander collects gestures from the stylus and simulates keyboard input. These inputs get analyzed by *Window1.xaml.cs* and certain activities will be executed. The gestures will only get handled, if they are performed on the user interface of the EMR application

In the TOSHIBA Accelerometer Utilities Setting Console the programs are set, which will get executed when moving the Tablet PC quickly sideways or up and down. It does not interact with the EMR application; it will only open the Internet Explorer or the Skype messenger.

The folders images, sounds, icons contain resources for the program. In the images folder pictures for the patients and their records are stored. The sounds folder contains audio files, which were recorded by the EMR application's feature to record sound. Icons for the program user interface are stored in the icons folder.

4.5.1. WPF – XAML

Styles

The following code (Code 2) and figure (Figure 47) show a style named *ContentControlBlue*, which is used for most of the panels. The code is part of the file *Simple Styles.xaml*.

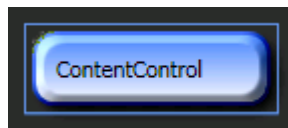


Figure 47: ContentControlBlue

```
<Style x:Key="ContentControlBlue" TargetType="{x:Type ContentControl}">
  <Setter Property="Template">
    <Setter.Value>
      <ControlTemplate TargetType="{x:Type ContentControl}">
        <Grid>
          <Rectangle StrokeThickness="2" RadiusX="10" RadiusY="10"
            Margin="3,3,3,3" Stroke="#FF0935BF">
            <Rectangle.BitmapEffect>
              <BitmapEffectGroup>
                <BevelBitmapEffect/>
                <DropShadowBitmapEffect/>
              </BitmapEffectGroup>
            </Rectangle.BitmapEffect>
            <Rectangle.Fill>
              <LinearGradientBrush EndPoint="0.5,1.013"
                StartPoint="0.5,-0.006">
                <GradientStop Color="#FF417EF8" Offset="0"/>
                <GradientStop Color="#FFFFFFFF" Offset="1"/>
              </LinearGradientBrush>
            </Rectangle.Fill>
          </Rectangle>
          <ContentPresenter Margin="15,15,15,15"/>
        </Grid>
      </ControlTemplate>
    </Setter.Value>
  </Setter>
</Style>
```

Code 2: Style ContentControlBlue

The style tag defines a new style with the key called *ContentControlBlue*. The key will be used to identify the style. The target type classifies which controls will be able to allow this style; in this example the target type is a content control. The grid tag is used to position the rectangles and the content presenter. The bitmap effects provide the rectangles with shadow, fillings and 3D effects. Inside of the rectangles the content presenter will be positioned with a margin of 15 pixels on each side, so the content will not overlap with the border of the rounded edges. The content

presenter is the area where other contents (e.g. images, buttons, and labels) will be placed.

To set the defined style for a content control, which is for example located in a grid, the attribute *Style* has to be set to "{DynamicResource ContentControlBlue}" (see Code 3). When the content control is rendered now, it will have the look of the *ContentControlBlue* style.

```
<Grid x:Name="LayoutRoot" Opacity="1">
  <ContentControl HorizontalAlignment="Stretch" x:Name="PatientEditPane"
    Style="{DynamicResource ContentControlBlue}"
    VerticalAlignment="Stretch" Grid.ColumnSpan="3" Grid.Row="1" >
```

Code 3: Setting the Style ContentControlBlue

Data binding

The following picture (Figure 48) shows a data binding sample of the application. The picture, name, street and birthday of the patient are presented by using data binding. Depending on which object in the patient collection is selected in the C# code, the info pane will show the appropriate information.



Figure 48: Data binding sample patient info

Before data binding can be used, the data context has to be set. The data context defines what object will be used for data binding. This can either be done in the XAML file or in the C# code. In this application (see Code 4) the data context for the main grid was set in the file *Window1.xaml.cs* to the *PersonFactory pfactory*, which includes all the patients' information.

```
private PersonFactory pfactory = new PersonFactory();
MainGrid.DataContext = pfactory;
```

Code 4: Setting the data context

The next step is to connect the controls with the data from the selected patient. This is done by setting the appreciated attribute to "{Binding Path=Type}" (see Code 5). For the image the *source* attribute is bound with the picture path, for the labels the *content* attribute is bound with the certain string object. The program now looks one level after each other, where it can find a data context. When it gets down all the way to the *MainGrid*, it finds the data context *pfactory*. Now the active item in the *pfactory* collection is determined and its values for picture, name, address and birthday will get bound to the controls.

```
<Image HorizontalAlignment="Left" Margin="0,0,0,0.977"
        x:Name="PatientImageSmall" Width="Auto" Grid.RowSpan="3"
        Source="{Binding Path=Picture}" Stretch="Uniform"/>
<Label HorizontalAlignment="Left" Margin="10,0,0,0"
        VerticalAlignment="Center" Width="Auto" Height="24.414"
        Content="{Binding Path=Name}" FontSize="16" FontWeight="Bold"
        Padding="1,1,1,1" Grid.Column="1"/>
<Label Width="Auto" Content="{Binding Path=Address}" FontSize="16"
        FontWeight="Bold" Padding="1,1,1,1" HorizontalAlignment="Left"
        Margin="10,0,0,0" VerticalAlignment="Center" Grid.Column="1"
        Grid.Row="1"/>
<Label Width="Auto" Content="{Binding Path=Birthday}" FontSize="16"
        FontWeight="Bold" Padding="1,1,1,1" HorizontalAlignment="Left"
        Margin="10,0,0,0" VerticalAlignment="Center" Height="24.414"
        Grid.Column="1" Grid.Row="2"/>
```

Code 5: Data binding sample

Data templates

Data templates are used to present data in a special way and reuse this template for different parts in the program.

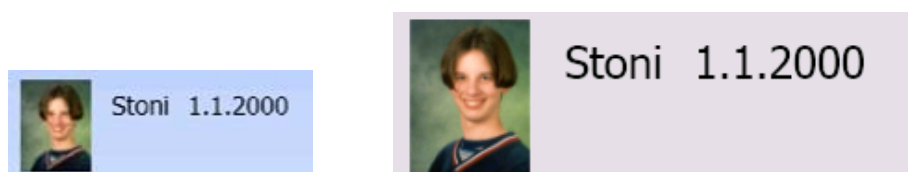


Figure 49: Person data template

The person data template binds the picture source, name and birthday string and shows them in a horizontal stack panel. Event triggers are added to start animations when the stylus enters or leaves the area of the stack panel. The zoom animation which will be performed (see Figure 49 and corresponding Code 6) is described in the storyboard tags.

```

<DataTemplate x:Key="PersonTemplate">
  <DataTemplate.Resources>
    <Storyboard x:Key="OnStylusEnter1">
      <DoubleAnimationUsingKeyFrames BeginTime="00:00:00"
        Storyboard.TargetName="stackPanel"
        Storyboard.TargetProperty="(FrameworkElement.LayoutTransform).
          (TransformGroup.Children)[0].(ScaleTransform.ScaleX)">
        <SplineDoubleKeyFrame KeyTime="00:00:00.2000000" Value="1.7"/>
      </DoubleAnimationUsingKeyFrames>
      <DoubleAnimationUsingKeyFrames BeginTime="00:00:00"
        Storyboard.TargetName="stackPanel"
        Storyboard.TargetProperty="(FrameworkElement.LayoutTransform).
          (TransformGroup.Children)[0].(ScaleTransform.ScaleY)">
        <SplineDoubleKeyFrame KeyTime="00:00:00.2000000" Value="1.7"/>
      </DoubleAnimationUsingKeyFrames>
    </Storyboard>
  </DataTemplate.Resources>
  <StackPanel Orientation="Horizontal" x:Name="stackPanel">
    <StackPanel.LayoutTransform>
      <TransformGroup>
        <ScaleTransform ScaleX="1" ScaleY="1"/>
        <SkewTransform AngleX="0" AngleY="0"/>
        <RotateTransform Angle="0"/>
        <TranslateTransform X="0" Y="0"/>
      </TransformGroup>
    </StackPanel.LayoutTransform>
    <Image Source="{Binding Path=Picture}" Width="50" Height="50"
      x:Name="image"/>
    <Label Content="{Binding Path=Name}" FontSize="14"/>
    <Label Content="{Binding Path=BirthDay}" FontSize="14"/>
  </StackPanel>
  <DataTemplate.Triggers>
    <EventTrigger RoutedEvent="FrameworkElement.Loaded"
      SourceName="stackPanel"/>
    <EventTrigger RoutedEvent="Stylus.StylusLeave"
      SourceName="stackPanel">
      <RemoveStoryboard
        BeginStoryboardName="OnStylusEnter1_BeginStoryboard"/>
    </EventTrigger>
    <EventTrigger RoutedEvent="Stylus.StylusEnter"
      SourceName="stackPanel">
      <BeginStoryboard x:Name="OnStylusEnter1_BeginStoryboard"
        Storyboard="{StaticResource OnStylusEnter1}"/>
    </EventTrigger>
  </DataTemplate.Triggers>
</DataTemplate>

```

Code 6: Person data template

To add this data template to the target listbox *ListboxPatients*, the *ItemTemplate* attribute has to be set to the data template *PersonTemplate* (see Code 7):

```

<ListBox HorizontalAlignment="Stretch" Margin="0,80,0,0"
  x:Name="ListboxPatients" VerticalAlignment="Stretch"
  Width="Auto" Height="Auto" Background="#7EFFFFFF"
  IsSynchronizedWithCurrentItem="True"
  ItemsSource="{Binding Mode=OneWay}"
  ItemTemplate="{DynamicResource PersonTemplate}"
  MouseUp="ListboxPatients_MouseUp"/>

```

Code 7: Setting the data template

InkCanvas

The *InkCanvas* control can display and collect strokes. It can be defined with the *InkCanvas* tag (see Code 8) and the name attribute can be set to get access to the collected strokes and change properties such as drawing attributes. This *InkCanvas* for the image annotation has a data binding for its strokes to the *RecordFactory Recfac*. If the *Mode* attribute is set to *TwoWay*, the strokes in the *InkCanvas* will automatically change when they are changed in the *Recfac/Strokes* object or visa versa. Notice that the ink only gets collected in the *InkCanvas*; it is not analyzed and recognition has to be performed on the strokes separately.

```
<InkCanvas ClipToBounds="true" MinHeight="0" MinWidth="0"
           x:Name="EditImageCanvas" Width="Auto" Height="Auto"
           Background="#80E0ED2A" RenderTransformOrigin="0.5,0.5"
           Strokes="{Binding Path=Recfac/Strokes, Mode=TwoWay,
           UpdateSourceTrigger=PropertyChanged}">
```

Code 8: InkCanvas control

4.5.2. C#

Patient.cs

This file contains a class called *Person* (see Code 9), which holds the recognized strings, the *Recordfactory* and the *StrokeCollections* for all the strokes from the *InkCanvases* linked to it. The *PersonFactory* is derived from the *ObservableCollection* class and contains *Person* objects. For example the recognized string from the *namestroke StrokeCollection* will be stored in the string *name*.

```
public class Person : INotifyPropertyChanged
{
    private string name;
    private string address;
    private string birthday;
    private string insurance;
    private string mobile;
    private string email;
    private string picture;
    public RecordFactory recfac;

    private StrokeCollection namestrokes;
    private StrokeCollection addressstrokes;
    private StrokeCollection birthdaystrokes;
    private StrokeCollection insurancestrokes;
    private StrokeCollection mobilestrokes;
    private StrokeCollection emailstrokes;
    ...
}
```

```
public class PersonFactory : ObservableCollection<Person>
{
    ...
}
```

Code 9: Patient.cs

Records.cs

This file is built up similar to the *Patient.cs* file, but except for the patient's information it contains all the data for the records of the findings of the patient. The class *Record* (see Code 10) represents one record from the patient including all the ink data and the recognized strings. Two strings for an image and a sound file store the path to the file. The *RecordFactory* class contains multiple records and is referenced by each *Person* object.

```
public class Record : INotifyPropertyChanged
{
    private string date;
    private string title;
    private string text;
    private string image;
    private string sound;
    private StrokeCollection strokes;
    private StrokeCollection titlestrokes;
    private StrokeCollection textstrokes;
    private StrokeCollection posstrokes;
    ...
}

public class RecordFactory : ObservableCollection<Record>
{
    ...
}
```

Code 10: Records.cs

RecordSound.cs and PlaySound.cs

These two files contain classes called *RecordSound* and *Playsound*. They reference DirectX to record and playback sound. The audio data is stored in a wave file. For implementation of this part of code, the DirectX SDK samples were used for references.

Window1.xaml.cs

This file is the main entry point of the application where all the data get initialized, strokes are recognized and programming logic is implemented. Like mentioned before, none of the data in this application is stored in databases or files (except

pictures and sounds). So after the application is closed, all entered data is lost. During the execution of the program the data is stored in various objects referencing the *Person/PersonFactory* and *Record/RecordFactory* class. Following (Code 11) is an example of the creation of a Person and Record dataset:

```
pfactory.Add(new Person("Dieter", "Achtergasse 7", "6.9.1982", "BVA",  
    "0664/1210403", "ddawg@gmx.at", path + "dieter.jpg"));  
pfactory[pfactory.Count - 1].Recfac.addRecord("12.12.2007", "Hand",  
    "Stitches", path + "hand.jpg",  
    "../../../sounds/1_1.wav");
```

Code 11: Adding a person and record

One of the most important parts of this application is the analyzing of the strokes which is done by the method *InkToText* (Code 12):

```
private string InkToText(InkCanvas myc)  
{  
    if (myc.Strokes.Count == 0)  
        return "";  
  
    InkAnalyzer analyzer = new InkAnalyzer();  
    analyzer.AddStrokes(myc.Strokes);  
  
    AnalysisStatus status = analyzer.Analyze();  
  
    string message = "";  
  
    if (status.Successful == true)  
    {  
        message = analyzer.GetRecognizedString();  
    }  
    else  
    {  
        message = "analyze failed";  
    }  
  
    return message;  
}
```

Code 12: InkToText

The *InkCanvas*, which contains the strokes to be analyzed, is passed to the method by an argument. A new *InkAnalyzer* called *analyzer* is created and the strokes from the *InkCanvas* are added to it. The analyzing is started by the method *analyzer.Analyze*; if it was successful, the recognized string will be returned. Depending on which recognition language is set on the Windows operating system, it will be used by the analyzer.

The *InkSearch_StylusUp* method (see Code 13) calls the *InkToText* method to recognize the ink received from the *InkSearchCanvas* (*object sender*). It is called each time the stylus does not touch the tablet screen anymore. Once the ink is analyzed, the recognized string will be searched in the *PersonFactory* *pfactory*. If the name is found, the application will change to the patient's record view.

```
private void InkSearch_StylusUp(object sender, StylusEventArgs e)
{
    string sname = InkToText(sender as InkCanvas);
    LabelSearchInkAnalyzed.Content = sname;

    foreach (Person p in pfactory)
    {
        if (p.Name == sname)
        {
            ListBoxPatients.SelectedIndex = pfactory.IndexOf(p);
            hideall();
            PatientRecordPane.Visibility = Visibility.Visible;
        }
    }
}
```

Code 13: InkSearch_StylusUp

The following code (Code 14) sets the ink drawing attributes for the *EditImageCanvas* and *InkPosition* canvas. It is called when the red button is clicked. Attributes such as *Color*, *Height* and *Width* of the pen tip get set. The *IsHighlighter* attribute defines whether the strokes will be transparent or not. The *EditingMode* can be set to *EraseByPoint*, *EraseByStroke*, *GestureOnly*, *Ink*, *InkAndGesture*, *None* and *Select*.

```
private void ButRed_Click(object sender, RoutedEventArgs e)
{
    InkPosition.DefaultDrawingAttributes.Color = Colors.Red;
    EditImageCanvas.DefaultDrawingAttributes.Color = Colors.Red;
    EditImageCanvas.DefaultDrawingAttributes.IsHighlighter = false;
    EditImageCanvas.DefaultDrawingAttributes.Height = 1.5;
    EditImageCanvas.DefaultDrawingAttributes.Width = 1.5;
    EditImageCanvas.EditingMode = InkCanvasEditingMode.Ink;
}
```

Code 14: Setting ink canvas attributes

The selected ink gets rotated, when the *rotateSlider* is changed (see Code 15). To be able to rotate the ink some calculations have to be performed. First the selected strokes are retrieved and the center point is calculated. A transformation matrix is created which sets the matrix depending on the differences between the last two

rotation angles and the center point of the strokes. The transformation matrix is then applied on the strokes.

```
private void rotateSlider_ValueChanged(object sender, RoutedEventArgs e)
{
    double newrotate;
    Point myp;
    Matrix mat = new Matrix();

    StrokeCollection myStrokes = EditImageCanvas.GetSelectedStrokes();

    myp = new Point(myStrokes.GetBounds().X + myStrokes.GetBounds().Width /
        2, myStrokes.GetBounds().Y + myStrokes.GetBounds().Height
        / 2);
    newrotate = rotateSlider.Value;

    mat.RotateAt(newrotate - oldrotate, myp.X, myp.Y);
    myStrokes.Transform(mat, true);
    oldrotate = newrotate;
}
```

Code 15: Rotating ink

Sensitive Symbol Commander recognizes the gestures and simulates a keyboard entry (see 4.5.3 ‘Third Party Software’). This entry is caught by the method *Window_PreviewKeyUp* (see Code 16). If, for example, the left gesture was performed, the key combination *ALT+Left* will be sent to the application. When it is recognized by the method, the next patient in the listbox *ListBoxPatients* will be selected and the new data will be shown on all views in the program.

```
private void Window_PreviewKeyUp(object sender,
    System.Windows.Input.KeyEventArgs e)
{
    if ((lastkey == Key.LeftAlt && e.Key == Key.Left))
        if (ListBoxPatients.SelectedIndex > 0)
            ListBoxPatients.SelectedIndex--;

    if ((lastkey == Key.LeftAlt && e.Key == Key.Right))
        if (ListBoxPatients.SelectedIndex < ListBoxPatients.Items.Count)
            ListBoxPatients.SelectedIndex++;

    lastkey = e.Key;
}
```

Code 16: System gesture

Another way to receive gestures are ink canvas gestures. In this example the *InkText* canvas can collect scratch out gestures (see Code 17). If ink is scratched out in the canvas, this behavior will be recognized and special actions will be performed. Here a rectangle containing the area of the strokes made by the gesture is created. After

that the confidence of the recognition and the type of gesture is checked. If everything is fine, all the strokes which were hit by the scratch out will get detected by the *HitTest* and then will get removed from the ink canvas.

```
private void InkText_Gesture(object sender, InkCanvasGestureEventArgs e)
{
    Rect scratchRect = e.Strokes.GetBounds();
    ReadOnlyCollection<GestureRecognitionResult> gestureResults =
        e.GetGestureRecognitionResults();

    if ((gestureResults[0].RecognitionConfidence ==
        RecognitionConfidence.Strong) &&
        (gestureResults[0].ApplicationGesture ==
        ApplicationGesture.ScratchOut))
    {
        StrokeCollection deleteStrokes = InkText.Strokes.HitTest(scratchRect,
            10);

        if (deleteStrokes.Count > 0)
            InkText.Strokes.Remove(deleteStrokes);
    }
}
```

Code 17: Application ink gesture

4.5.3. Third Party Software

Sensiva Symbol Commander

Sensiva Symbol Commander [54] can detect different gestures and perform actions. The next picture (Figure 50) shows what tasks are executed when the gesture left is recognized. As action type the command checkbox is selected, the special command which is executed is *Back* (*ALT+Left*). This can be caught by the Tablet PC EMR application by checking for the keyboard entry *ALT+Left*.

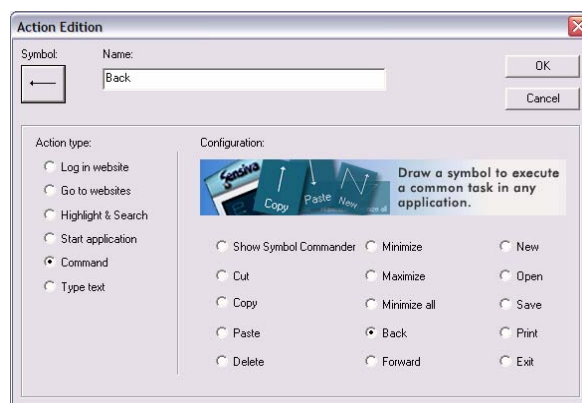


Figure 50: Sensiva Symbol Commander gesture edit [54]

TOSHIBA Accelerometer Utilities Setting Console

With the Accelerometer Utilities Setting Console from Toshiba [64], commands can be executed when the Tablet PC is moved quickly sideways or up and down. In Figure 51 the instant messaging application Skype will be started and a sound will be played back when the device is quickly moved left and right.

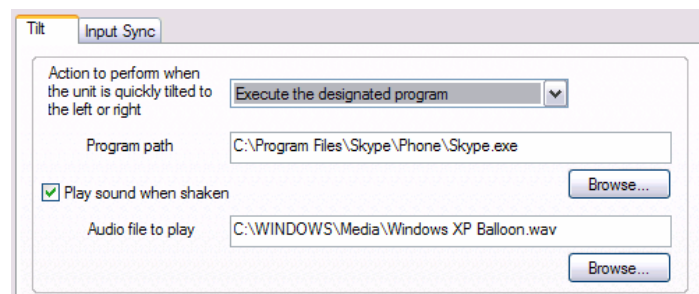


Figure 51: TOSHIBA Accelerometer Utilities Setting Console [64]

5. Field Trial

5.1. Setup

Five persons were chosen to test the EMR software on the Tablet PC. Each test took about 45 minutes. The test persons attending the test were:

- General practitioner, m, 60 - A
- General practitioner, m, 55 – B
- Neurologist, m, 28 - C
- Receptionist in medical practice, f, 52 - D
- Student, f, 24 - E

The test Tablet PC was a 2004 Toshiba M200 [64], which is a convertible Tablet PC running Windows XP Tablet PC Edition 2005 with 1.5 GHz Centrino CPU, 1.25 GB of RAM and 60 GB hard disk. The native resolution of the 12.1” screen is 1400 x 1050 and the unit weights 2 kg (4.4 lbs).

The test setup was as follows:

- Explanation of the Tablet PC and pen
- Explanation and demonstration of all features of the EMR software
- Supported test of the EMR software by the test person
- Answering the questionnaire by the test person

During the test notes were taken about the usage and noticeable troubles of the test person. After the test every participant had to answer a questionnaire containing one part to answer 42 questions with a value 1 (Very Good, Absolutely) to 5 (Very Bad, Not At All); the other part consists of eight open questions which had to be answered by text. The raw questionnaire can be viewed in Appendix A ‘Questionnaire Pen-based EMR Use’.

5.2. Results

The following tables show the summarized results of the first part of the questionnaire. The answers are from 1 (Very Good, Absolutely) to 5 (Very Bad, Not At All). The letters in the cells represent the persons from above and their answers.

5.2.1. Technical Background

All of the participants stated that they have good or medium computer skills and different experience levels with EMR software. The usage of communication software or looking up additional information on the work computer differs between the test persons. Most testers have never or just hardly used Tablet PCs before but have heard about it. Three out of five participants (*C*, *D* and *E*) know how to write with the 10-finger system on the keyboard (two of them very well). Table 4 shows the exact results:

Statement	1	2	3	4	5
Technical background					
My computer skills are		CE	ABD		
My experiences with EMRs on a regular PC are		BD	A	C	E
I use the EMR to display data from patients	D	AB		C	E
I use the EMR to enter data for patients	BD		A	C	E
I use communication software on my work computer		E	CD		AB
I use the work computer to look up additional information (e.g. information about diseases on the internet or in another program)		C	E	AB	D
I can write on the keyboard with the 10-finger system	DE		C		AB
I have heard about Tablet PCs before	CE		ABD		
I have used a Tablet PC before			E	C	ABD

Table 4: Questionnaire technical background results

5.2.2. Look and Feel of Hardware

In general the test persons thought that the Tablet PC was rather good to hold, especially the pen felt good in the hand. What everybody did not like too much (judged with 3) was the weight of the Tablet PC; it gets pretty heavy after a while.

The visibility of the screen was judged with *medium* to *very good*. One of the two persons who have no 10-finger-system skills would absolutely prefer a Tablet PC over a regular PC (person *A*); the other one (person *B*) did not tend to a special input device. The two persons (*D* and *E*) with very good 10-finger-system skills tend to like a regular PC more. Person *C* with medium 10-finger-system skills did not prefer any of the two input devices. Table 5 shows the exact results:

Statement	1	2	3	4	5
Look and feel of hardware					
The Tablet PC feels comfortable to hold		ADE	C	B	
The stylus is easy to hold	ACD	E	B		
The weight of the Tablet PC is			ABCDE		
The visibility of the screen is	AE	CD	B		
I would prefer the Tablet PC over a Notebook/Regular PC	A		BC	DE	

Table 5: Questionnaire look and feel of hardware results

5.2.3. Software Usage

Four out of five answers the design and the navigation of the software is good/very good. The participants liked the ability to control and write text (without recognition) with the stylus. The recognition of the text was for many people sometimes bad and had to be corrected several times, which did not work out successfully every time. On the other side practitioner *A*, who has average computer and keyboard skills, had very few entry errors and correcting them worked out fine. The same person also mentioned that he is faster inputting text with the stylus than with the keyboard.

Words which are not in the dictionary are not recognized very well. This problem can be overcome by adding all these words to the dictionary. Another problem is that the recognizer sometimes detects the numbers 4 and 6 incorrectly. The participants said that they thought that recognition would work a lot better when they would have more time to train their handwriting and try to write more nicely.

Only test person A, who did not know the 10-finger-system, thought that he was faster inputting text with the stylus than with the keyboard. The comfort of inputting text with the pen compared to the keyboard was judged with *bad* to *very good*. Most persons meant that they liked to use the direct text input with the pen on the ink canvas better than using the Microsoft tool TIP (Tablet Input Panel) to input text into a text box.

The test persons mostly liked the image annotation features such as writing, transforming, deleting, rotating and zooming very much and thought that they were working well. Also the panel with the image of a person, where the position of the annotated picture can be marked, is very good. The recording and playback of audio was stated with *good/very good* and worked well. Navigating through the patients worked great; using the search feature was judged with *good/very good*. The participants liked to perform the gestures for navigating through patients and scratching out strokes. The gestures were mostly recognized right. The shake feature, chat interface and quick notes panel also pleased the test persons (rated with *good/very good*).

In summary the participants liked most of the features but did not perform very well inputting text in order to receive correct recognition results. Correcting the errors took quite a lot of time, which the users would not have when they are in front of a patient. Training to have a better recognition output or using the advanced recognizer from Windows Vista, which learns the handwriting of each user, could solve this problem and lessen recognition errors. Table 6 shows the exact results:

Statement	1	2	3	4	5
Software usage					
The design of the software is	ADE	C	B		
The navigation between the different pages is	DE	ABC			
I never get lost in the program	E	ABCD			
Inputting text (without recognition) and controlling the program with a pen rather than a keyboard/mouse is	ADE	BC			
The recognition of the text is	A		E	BCD	
Correcting recognition errors is	A		CDE	B	

I am faster inputting text with the stylus than with the keyboard	A			BCD	E
I feel more comfortable inputting text with the stylus than with the keyboard	A	C	B	DE	
The entry with InkCanvas is better than with TIP (Tablet Input Control)	ACD	B		E	
The ability of making drawings while writing is	ADE	BC			
The image editing feature overall is	ACDE	B			
Transforming, rotating, deleting ink in images is	CDE	AB			
Marking positions of images on the person is	ABCDE				
The zoom feature for pictures is	DE	ABC			
The recording/playback audio feature is	ACE	BD			
Navigating through patients/records is	ABCDE				
The search feature for patients is	CE	ABD			
The gesture feature is	ACDE	B			
The gestures are always recognized right	ABCE	D			
Performing tasks by shaking the Tablet PC is	AC	BDE			
The usage of the chat interface of the Tablet PC is	ADE	BC			
The QuickNotes feature of the Tablet PC is	ACDE	B			

Table 6: Questionnaire software usage

5.2.4. Overall

The overall experience of the software was judged by the users with *moderate* to *very good*. Especially the ability to review data was stated by all persons with *very good*. The ability to enter data was mostly good, but the users were not satisfied with the recognition results. It has to be estimated for all input fields whether it is important to recognize the handwritten text and store the results together with the ink or it is sufficient enough to just store the handwritten text as ink alone.

Two of the doctors (A and C) would tend to use the pen-based EMR in their practice. The other testers judged this question with 3 (*moderate*). They might prefer to stay with their old system because they are used to it and get around with it well, but they would also consider using an EMR on a Tablet PC in the future. Three users (A, D and E) thought that it was easy to use in any situation like standing, sitting or at the

bedside. All participants mentioned that it was not as obtrusive as a regular PC when used in front of the patients. The question whether the user would be willing to pay 20% more for the Tablet PC hardware to use it or not was answered from *rather not* to *absolutely*. Table 7 shows the exact results:

Statement	1	2	3	4	5
Overall					
The overall experience with the software is	A	DE	BC		
The software is easy to use to review data	ABCDE				
The software is easy to use to enter data	A	CDE		B	
I would like to use a pen-based EMR in my practice	A	C	BDE		
It is easy to use anywhere (standing, sitting, bedside)	ADE		BC		
I would pay about 20% more for a Tablet PC to use pen-based EMR software	A	BC	E	D	
I would feel more comfortable using a Tablet PC instead of a notebook/desktop in front of the patients	A	BCDE			

Table 7: Questionnaire overall results

5.2.5. Comments by the Participants

In common the users liked the new way to enter data, but they thought that the recognition results had to get better and were taking a lot of time if they were recognized incorrectly. They said that more training would result in a better recognition. A big plus for the Tablet PC is the mobility and the usage in any situation and that patients' data can be viewed easily and fast. The interface of the software was found to be very user friendly and to feature many different ways to enter data (write, draw, speak and annotate). One person mentioned that he did not like to write long sentences with the tablet because it took too much time for him. Another doctor had great experiences with writing text and would like to use the system right away. One of the doctors did not like the heat that was created by the Tablet PC and felt uncomfortable. A good additional feature would be a save button, so the data does not get saved automatically and the user can choose to save or remove the entered data. What most of the users mentioned on the things they did not like was the weight of the Tablet PC. A lighter one would improve the usage. As an additional feature an automatic word completion would be great.

6. Conclusion and Discussion

The work has shown that the acceptance of EMR software on a Tablet PC with pen input is good. Doctors with bad keyboard skills seem to be more comfortable with it than receptionists who are used to write on a keyboard very well and have a stationary workplace. Also the users liked the idea that they do not have to sit behind their regular PC all the time and can communicate better with the patients. Navigation between different pages, selection of various features and usage of gestures work well and accurately by just using the pen. One issue is the weight of the test Tablet PC. However, this could be solved by using newer, lighter devices.

In particular, the users found the image annotation tool to be very intuitively and therefore were quite pleased. It works very well on Tablet PCs and cannot be implemented on a regular PC in such a manner because the use of the mouse or touchpad is not as accurate (for example drawing a circle). The participants mentioned that it felt very natural to annotate the pictures and to use the back of the pen to delete the ink. This tool helps them perform daily work more efficiently and keep additional data directly with the picture. Also, the ability to use the Tablet PC as a communication and chat device was appreciated by the participants.

Another important topic of this study was writing text in the application. As long as the text did not have to be recognized, the satisfaction was very high. This works perfectly in areas where the handwritten text does not have to be analyzed, such as taking notes for the user's own needs. It needs to be determined in which areas it is important to have recognition and in which areas it is not. The users appreciated having a relatively large space to write on, such as they do on paper. The recognition of the text was quite diverse among the individuals testing it. Depending on the handwriting, some users had good recognition results; others had to correct their errors rather often, which took a significant amount of additional time. This is not acceptable during real work, but the problem could be overcome by training the user's handwriting. One statement that came from most of the participants was that they thought the recognition results would be much better if they had more time to train their handwriting. Participants with fewer typing skills were more satisfied with inputting text with the stylus, because they felt more comfortable than with the

keyboard. It turned out that users who wrote in print had better results than users who wrote in cursive. Correcting errors in print was also easier, because the participant was able to erase just a single character instead of the whole word. For names and medical terms it is very important that they are recognized correctly; therefore it is essential that these special words are included into the recognition dictionary to have accurate results.

This work has shown that EMR software written especially for Tablet PCs can provide new efficient features and possibilities such as using image annotation, reviewing data anywhere and using it as a communication device at any place. It makes sense that the software is used by doctors and nurses more than by receptionists, who normally remain at their desk and usually do not need to annotate pictures. Nevertheless, one important area where further improvements are still needed is the handwriting recognition. The other possibility would be that the users learn to write the way the analyzer recognizes the ink best. It is possible that the recognition engine of Windows Vista provides much better results, since it does not only have fixed recognition rules but also learns from the way the user writes and saves this additional information for further recognitions. This would have to be evaluated in another test.

With some handwriting and general training, this software and device can be used in a medical practice. There are several open questions that need to be addressed. One question is how to get the images into the Tablet PC. Previously stored pictures and x-rays can easily be opened, but new pictures (e.g. showing a wound) would have to be captured first. One good option would be a Tablet PC with a built-in camera to take a picture right away. Another question is the authentication of the users, which was not addressed in the prototype. New Tablet PCs with a fingerprint reader would be a possible choice. These questions could be evaluated in another work.

The prototype can be extended to provide a complete EMR or the experience and results received with it can be used to create a new pen-based client for an existing EMR system where the database could be adapted to store the ink and pictures if not supported so far.

This study has shown that an innovative EMR on a Tablet PC offers many new possibilities to be effectively used in a medical practice and can positively change the way doctors work today.

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Appendix

A Questionnaire Pen-based EMR Use

EMR ON A PEN-BASED TABLET PC



Profession: _____

1...Very Good, Absolutely

Age: _____

5...Very Bad, Not At All

Gender: _____

Statement	1	2	3	4	5
Technical Background					
My computer skills are					
My experiences with EMRs on a regular PC are					
I use the EMR to display data from patients					
I use the EMR to enter data for patients					
I use communication software on my work computer					
I use the work computer to look up additional information (e.g. information about diseases on the internet or in another program)					
I can write on the keyboard with the 10-finger system					
I have heard about Tablet PCs before					
I have used a Tablet PC before					
Look and Feel of Hardware					
The Tablet PC feels comfortable to hold					
The stylus is easy to hold					
The weight of the Tablet PC is					
The visibility of the screen is					
I would prefer the Tablet PC over a Notebook/Regular PC					
Software Usage					
The design of the software is					
The navigation between the different pages is					
I never get lost in the program					
Inputting text (without recognition) and controlling the program with a pen rather than a keyboard/mouse is					
The recognition of the text is					

Correcting recognition errors is					
I am faster inputting text with the stylus than with the keyboard					
I feel more comfortable inputting text with the stylus than with the keyboard					
The entry with InkCanvas is better than with TIP (Tablet Input Control)					
The ability of making drawings while writing is					
The image editing feature overall is					
Transforming, rotating, deleting ink in images is					
Marking positions of images on the person is					
The zoom feature for pictures is					
The recording/playback audio feature is					
Navigating through patients/records is					
The search feature for patients is					
The gesture feature is					
The gestures are always recognized correctly					
Performing tasks by shaking the Tablet PC is					
The usage of the chat interface of the Tablet PC is					
The QuickNotes feature of the Tablet PC is					
Overall					
The overall experience with the software is					
The software is easy to use to review data					
The software is easy to use to enter data					
I would like to use a pen-based EMR in my practice					
It is easy to use anywhere (while standing, while sitting, at the bedside)					
I would pay about 20% more for a Tablet PC to use pen-based EMR software					
I would feel more comfortable using a Tablet PC instead of a notebook/desktop in front of the patients					

What do you like about Tablet PCs in general (not the EMR software)?

What do you not like about Tablet PCs (not the EMR software)?

What do you like about the EMR software?

What do you not like about the EMR software?

How is your experience with the handwriting recognition?

What additional features would you like?

Why would you/would you not use the pen-based EMR software in your practice?

Any other comments?

Curriculum Vitae

Personal Information

Name	Dieter Mayrhofer
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Education

since 2006	Technical University of Vienna, Austria, Master program Medicine and Computer Science
2003 – 2005	Technical University of Vienna, Austria, Bachelor program Medicine and Computer Science, passed with distinction
1997 – 2002	Higher Technical College Wiener Neustadt, passed with distinction

International Experience

July 2007	Representing the Technical University at the 6 day International IPHIE Master Class for Medical Informatics 2007 in Hall in Tyrol
Oct 2006 – Feb 2007	Round the world trip
2000 – 2001	Exchange Year Sanger High school CA, USA

Work Experience

Aug 2004 – Aug 2007	IBM Austria, Wien
May – July 2005	Seibersdorf Research, Austrian Research Centers
Dec 2002 – May 2003	Software Department Theresian Military Academy, WN
July 2000	MCW - Medical Computer Ware in Vienna

Publication

Andreas Baierl, Eva Derndorfer, Theres Vogel-Lahner, Dieter Mayrhofer, Christian Pichler, Andrea Klostermann, Heiko Reitner: Diet of students in rural areas. In: Journal for nutritional medicine, Ärzteverlagshaus, issue 2007; 9 (1) 13 – 18.