Department of Computer Science

"Diabetes Care": Providing Advanced Representation of Mobile Diabetes Diary Data to General Practitioner

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PREFACE

The given research is my master thesis for the degree of Master of Science in Telemedicine and e-Helath. The study was performed at the Norwegian Centre of Integrated Care and Telemedicine, Tromsø, and took ten month to end up with the thesis. The development is oriented on diabetes management in general practice. The goal of the research was to develop an application that could provide to a general practitioner advanced representation of patient's measurements, gathered in mobile diabetes diary.

As the result, such application was developed and called "Diabetes Care". The application was developed for both patients and general practitioners. The main purpose of use for patients is to send gathered measurements to a doctor and therefore, the main goal of use for general practitioner is to receive the data and to overview its representation. During the development, the patient module was extended with recommendations and appointments management. For "Diabetes Care" application, a set of statistical rules was developed for an advanced data representation, as well as decision support function was embedded in the rules.

By testing the application, the results of its functioning and its acceptance by medical professionals was documented. Overall, during the software functionality testing procedure, the application showed no faults. According to the usability testing of the implemented application, very promising results were gained. Medical doctors showed agile interest in the application and its development. The simplicity of use, design and the idea of development were highlighted by doctors as strong research aspects. Doctors were prone to think that with possible further extensions and consideration of legal issues, the application can improve quality of diabetes care generally.

Now the thesis is done and I am very happy that I went though an interesting path and gained an unforgettable experience; and I would like to thank people who took place in this process.

First of all, I would like to thank my supervisor Gunnar Hartvigsen and co-supervisor Eirik Årsand for their constant guidelines and important supervision meetings. These meetings were a catalyst for my progress. I appreciate their trust in my abilities to study diabetes management from technological perspective and offering an area of the research.

Additional thank to the Norwegian Centre of Integrated Care and Telemedicine for providing me with a tablet, which supports NFC. It was very important to have it for the development.

Special thanks I would like to address to medical doctor Nils Kolstrup. He was the main medical expert in my research and was participated at every stage of the application development. He spent his time, shared knowledge, and was very interested in the development. Thanks for his responsiveness, ease of communication and open mind.

I also want to thank medical doctors Gerd Ersdal, Gro Berntsen, and Thomas Roger Schopf for taking a participation in my research and being a source of valuable information for the development of the application. Without their medical opinion, this research would not have had such positive outcome as it showed during the testing.

Thanks to Keiichi Sato and Alexander Horsch for their advices and warm support in moments when I needed it.

I thank my beloved parents for believing in me and my abilities, for their boundless support and love. I thank my Mom for being proud of me no matter what and I thank my Dad for keeping in me spirit of success.

Thanks to my very dear friend Andrei who is being with me all the time. I can't imagine how would I go though such hard work without being surrounded of his true support.

Last but not least, I thank my Reader for the interest and attention to the research that is very important to me.

In this thesis, I put my heart, soul and a real faith that the developed application will contribute to technological progress in diabetes management, and as a further result in the future will help people with diabetes to live a healthier life.

Sincerely,

Kristina Livitckaia

Tromsø, July 2014

ABSTRACT

Purpose The purpose of the research is to develop an application that will support diabetes management in general practice. The research solution was implied to allow general practitioner to see advanced represented data that was measured and recorded into mobile diabetes diary by patients with diabetes.

Motivation The development of mHealth applications for patients with diabetes has large variety of mobile diabetes diaries to support self-management for a better life quality. However, these kind of applications do not play substantial role in diabetes care in general practice despite the level of advanced features in such applications. The data is not in particular use by primary care professionals due to the lack of such possibility. Besides, advanced trends representation of daily measurements of blood glucose level, insulin and carbohydrates intake, and physical activity can play significant role in providing prevention and control for diabetes patients based on their personal patterns.

Methods For the research design, engineering approach was chosen. In particular, the study was based on the waterfall model of software development life cycle (SDLS). Mostly, to collect the information for the requirements and to understand medical particularity of diabetes management in general practice, such methods as interview, questionnaire and discussion were used. Participants were four medical doctors and group of technical experts who supported the development on its each step. Usability testing was performed during application prototyping and on the final software testing with users involvement. During the software testing procedure, the application showed no faults.

Results "Diabetes Care" application was developed to support diabetes management in general practice, by helping general practitioner in a more rapid and qualitative way to analyze patient's measurements. For each type of measurements were developed statistics. As well, decision support function was embedded into statistical rules for physical activity and morning glucose levels monitoring. Color representation of the decision support function was oriented on the error minimization and saving time for the rest of the consultation procedure. During the development, the application was extended with appointments and recommendation management functionality for patients.

The application was tested by medical doctors in order to see its acceptance by potential users. Overall, medical doctors expressed highly positive thoughts about the application. "Diabetes Care" was accepted as comfortable to use, understandable, and intuitive. The simplicity of use, design and the idea of development were highlighted by doctors as strong research aspects. Doctors were prone to think that with possible further extensions and consideration of legal issues, the application can improve quality of diabetes care generally.

Conclusion Application testing showed very promising results according to its medical doctors' acceptance. The direction of the research was pointed as an innovative and showed strong interest to the application development from medical perspective. Despite the fact that exclusively two medical doctors have tested the application, the results of each testing procedure were similar. This allows the assumption that relevance of the "Diabetes Care" application should be tested and studied further with possible development in order to identify its potential positive effect on quality of provided diabetes management in general practice.

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CHAPTER 1. INTRODUCTION

1.1 Background and Motivation

Diabetes Mellitus is a chronic disease, in which either not enough insulin is being produced in pancreases or the body is not able to use the insulin effectively. There are three main types of diabetes that can cause its own complications [1, 2, 3, 4, 5, 6, 7]. In 2013 an estimated 5.1 million people have died from diabetes and 548 billion USD were spent in health expenses worldwide. By the year 2035, around 592 million people in the world are expected to have diabetes, which will state a rise of 55% in compare to year 2013 [1].

Without effective management programs to prevent and control diabetes, the burden of diabetes will continue to increase worldwide [1]. According to the World Health Organization (WHO), such paths can be attributed to ***prevention and control*** of the disease. Achieving and maintaining a healthy body weight, performing physical activity of at least 30 minutes a day, reducing healthy eating habits, avoiding tobacco, treating insulin injections and controlling blood glucose level can play crucial role for health stability [1, 3].

Based on the component objects of diabetes prevention and control, today many countries are seriously focused on the management of diabetes in general practice [2, 8, 9, 10, 11, 12, 13]. Diabetes services are provided by a large variety of professionals such as ***general practitioners*** and other primary healthcare professionals and require a strong cooperation with family members of diabetes patients and patients themselves.

Due to the growing usage and functionality development, ***smartphones and tablets are become part of daily life*** for people in different statuses (for instance, children, students, businessmen, patients, etc.). According to a study done by the International Data Corporation (IDC), around 118 million smartphones were sold in 2011 worldwide [14]. Based on the results of other study done by the Pew Internet Research Center, 87% of adults own a cellphone and 31% own a tablet computer; 45% of those cellphones can be considered as smartphones [15].

The development of mHealth applications for patients with diabetes has a ***large variety of mobile diabetes diaries*** to support diabetes self-management for a better life quality [16]. One of such applications was developed by the Norwegian Centre for Integrated Care and Telemedicine (NST) in Tromsø, Norway. The ***"Diabetes Diary" application***, developed by NST, is created to help people with diabetes to manage their health condition by recording into the system of the application such measured parameters as blood glucose level, insulin, carbohydrates and physical activity. Gathered information is stored in the internal database on the device and can be exported into CSV database [17, 18, 19].

However, while this kind of applications is used by patients to support diabetes self-management, they do not play significant role in diabetes care in general practice. Meaning, the data from such applications is not in particular use by general practitioners due to the lack of such possibility. Few studies with a relation to sharing diabetes patients' information with primary care doctors were found; web-based solutions were investigated [20, 21, 22, 23]. However, due to the gained results it was concluded that non-communicable way of sharing information has to be reconsidered and personal communication between patient and general practitioner should be installed for data transfer [20].

As a ***research area*** for the master thesis, the research group at the Norwegian Centre of Integrated Care and Telemedicine (NST) suggested to study if it is possible to extend the

"Diabetes Diary" application with an application dedicated to the medical doctors in primary care. The theme of the research direction was announced as "***Doctor's tablet*** – extended version of the "Diabetes Diary" with doctor's functionality". The research solution has to allow general practitioner to use tablet and to see more statistical data and trends for blood glucose level, physical activity, taken insulin and carbohydrates of a patient that have been gathered such data in the "Diabetes Diary" application and transferred to a general practitioner.

Discovery of the suggested area can play crucial importance for supporting general practitioners' practice in diabetes management worldwide. Such research is a necessity for the further development of the diabetes management, and for possible enhance of the received by patients healthcare quality.

1.2 Goal and Objectives

Due to the research area *(see section 1.1, Background and Motivation),* the ***goal of the research is to develop an application that will support diabetes management in general practice***. This application will be based on a patient's exported database from the "Diabetes Diary" application.

To reach the goal, set of ***objectives*** was set: (***1***) to determine the technological resolution of the research; (***2***) to examine technical and medical literature, acquired knowledge of which will help to proceed the research development; (***3***) to establish contact with medical doctors and technical experts who will be involved in the application development; (***4***) to find and analyze in detail the literature for similar studies that have been done (state-of-the-art); (***5***) to determine the research design and methods to be used; (***6***) to investigate application requirements in accordance with technical and medical needs; (***7***) to design the application user interface that will be apprehended intuitively and favorably by potential users; (***8***) to implement the application and gather test results.

1.3 Research Questions

Based on the research goal *(see section 1.2, Research Goal)*, in order to achieve it, three ***research questions*** about how an application can be developed for a tablet device to support diabetes management in general practice were posed:

(***1***) How the data should be transferred to consider ease of use, speed and security issues?
(***2***) How the application should be designed to meet functionality and usability needs for patient and general practitioners?
(***3***) How the data should be processed and represented for a medical overview?

1.4 Assumptions and Limitations

Assumptions of the research are covering (1) relation between existing "Diabetes Diary" application and the recent development of the "Diabetes Care" application and (2) types of devices used.

(1) ***Relation between "Diabetes Diary" and "Diabetes Care" applications.*** The "Diabetes Care" application is based on the CSV database exported from the "Diabetes Diary" application. Only the data contained in the database can be obtained and represented in an advanced way to a general practitioner. (2) ***Types of devices.*** General practitioner holds any portable Android OS tablet and patient holds any portable Android OS smartphone. Both of the devices contains NFC adapter.

There are four ***limitations of the research*** that effected application development. ***First*** is the most important limitation is narrow range of participants who tested the application. There are only two medical doctors who tested the final implemented application and four who supported the development during its progression. As well, considering the application has two accesses for general practitioners and patients, the application was not tested by the real patients with diabetes. The two reasons were crucial for declining participation are personal reasons and the fact of using other tools for self-management then "Diabetes Diary" application, developed NST. ***Second*** limitation is the fact that participated medical doctors are practicing doctors in Norway, and the specific laws may affect the medical practice and further perception of the developed application. ***Third*** limitation is technical and states that the use of selected NFC technology is rapidly growing, nevertheless still insufficiently developed and does not integrated into a broad range of portable devices. ***Forth*** and the last limitation is lack of time for such sufficiently large-scale development.

1.5 Methodology

As for the ***research design***, engineering approach was used; part of waterfall model of software development life cycle was chosen due to the reason that requirements specification, design, implementation and testing results were the key directions for the application development. The duration of the research took ten months from the introduction of the research area to the implementation and results documenting.

Overall, the research partitioned by objectives *(see section 1.2, Goal and Objectives)*, which were supported by such ***methods*** as literature review, interview, questionnaire, discussion, requirements analysis, software prototyping, usability and software testing *(see Table 1)*.

Medical doctors Nils Kolstrup, Gerd Ersdal, Gro Berntsen, and Thomas Roger Schopf, as well as ***technical experts*** Keiichi Sato, medical informatics and telemedicine group at the Norwegian Centre of Integrated Care and Telemedicine, and participants of Kolarctic Collaboration Event & KINTEMPI project were involved in the development of the application in one way or another. The target knowledge gained from medical doctors was related to diabetes management in primary care, particularity of medical consultations, requirements collection, user interface needs and design of functionalities. Technical experts influenced the application development from the perspective of ethical issues of technology use in medical routine and direction of the possible further extensions of the application.

In Chapter 3, *Materials and Methods*, entire methodology are clarified in details.

1.6 Contribution

The result of in-depth analysis *(see section 2.3, State-of-the-Art)* revealed that previous attempts in the similar direction of the research were at a web-based main solution to regulate insulin and glucose levels. There were no support solutions for general practice routine, which help patients and general practitioners with the ongoing consultation oriented on diabetes prevention and control. This fact indicates that the ***recent development represents a novel direction in the field of diabetes care in general practice***; and also indicates that such application as "Diabetes Care" opens new horizons in the cooperation of patients and doctors in order to improve the quality of diabetes care.

The "Diabetes Care" application was ***received by medical doctors very positively*** *(see section 7.2, Usability Test)*, and in terms of primary care, was strongly pronounced interest in the use of this application and its further development.

Table 1. Objectives of the research and methods used

Objective	***Method***							
	Literature review	Interview	Questionnaire	Discussion	Requirements analysis	Software prototyping	Usability testing	Software testing
To determine the technological resolution of the research								
To examine technical and medical literature, acquired knowledge of which will help to proceed the research development								
To establish contact with medical doctors and technical experts who will be involved in the application development								
To find and analyze in detail the literature for similar studies that have been done (state-of-the-art)								
To determine the research design and methods to be used								
To investigate application requirements in accordance with technical and medical needs								
To design the application user interface that will be apprehended intuitively and favorably by potential users								
To implement the application and gather test results								

1.7 Organization

The ***rest of the thesis is organized*** into Chapters that provides theoretical and practical basis of the application development. The table below is filled with chapters' numbers, name and summary description for each chapter *(see Table 2)*.

Table 2. Organization of the thesis

Chapter	***Description***
Chapter 2. ***Theoretical Background***	This Chapter is devoted to the theoretical background. The target medical field and information related to diabetes as a disease, technological background and state-of-the-art for chosen area of the research are provided to introduce the needed essential knowledge for the development.
Chapter 3. ***Materials and Methods***	In the Chapter, materials and methods used for the research are provided. Research design, procedure and tools, as well as research methods are described.
Chapter 4. ***Requirements Specifications***	The Chapter discloses requirements for the "Diabetes Care" application built upon technological and medical basis. Application description and requirements specifications are presented.
Chapter 5. ***Design***	In this Chapter, the design development is clarified by providing general overview of the application, illustration of the running application, logic behind the data representation and evolution of the design development.
Chapter 6. ***Implementation***	The Chapter provides technical information about implementation process. The source code details are provided in a relation to a specific way of the implementation.
Chapter 7. ***Testing and Results***	In the Chapter, functionality and usability testing of the implemented application are reflected. For both of the tests, procedure and results are provided.
Chapter 8. ***Discussion***	The Discussion Chapter reveals explanation of the testing results, technology used, and an indented use of the application. Future work for further possible application use, functionality extensions, and limitations are stated as well.
Chapter 9. ***Conclusion***	This chapter clarifies evaluation of the application development, concluding remarks and thesis contribution.

CHAPTER 2. THEORETICAL BACKGROUND

In the beginning of the Chapter, diabetes mellitus is explained as a target medical field of the research, its mechanism of affecting human body and overview of diabetes statistics worldwide. Ways to reduce burden of diabetes that are relevant worldwide, are disclosed based on the information provided by the World Health Organization (WHO). Prevention and control is the key in diabetes management. Despite the fact, diabetes services provided by a variety of medical professionals, general practitioners are still play crucial role in diabetes care.

Further, the key technology used for the development is clarified. Android Beam feature specification is disclosed. Near field communication technology is studied from the perspective of historical overview and development, functioning, standardization, its particularity and security concerns and solutions.

State-of-the-art for the area "application software for diabetes management is general practice" is covered by the in-depth analysis of relevant literature using electronic databases such as PubMed (National Library of Medicine and National Institute of Health), IEEE (Institute of Electrical and Electronics Engineers), Journal of Diabetes Science and Technology, and ACM (Association for Computer Machinery). All relevant literature is examined and the results are revealed.

2.1 Target Medical Field

2.1.1 Diabetes Mellitus

Diabetes Mellitus is a chronic disease, in which either not enough insulin is being produced in pancreases or the body is not able to use the insulin effectively. Insulin is a hormone that regulates the movement of glucose from blood to muscles, liver, and fat cells where it is stored for energy. When there is a lack of insulin or insulin does not work correctly, blood glucose levels rise. This causes diabetes or prediabetes. Prediabetes blood glucose levels are not high enough to be diagnosed as diabetes [1, 2, 3, 4, 5]. As of 2013, around 382 million people in the world are diagnosed with diabetes; 175 million are undiagnosed [1].

There are three main ***types of diabetes***: type 1, type 2 and gestational diabetes *(see Figure 1)* [3, 4, 5, 6, 7].

Type 1 or ***insulin-dependent diabetes*** is diagnosed when pancreases do not produce enough or any insulin. It usually develops in childhood and adolescents and patients need to get insulin injections to survive. Symptoms include excessive urination (polyuria), thirst (polydipsia), vision changes, weight loss, fatigue, and constant hunger and can occur suddenly [3, 4, 6, 7].

Type 2 or ***non-insulin-dependent diabetes*** is diagnosed when the body cannot or ineffectively uses insulin. Such type of diabetes usually develops in adulthood. Type 2 diabetes is the most common type with around 90% of diabetes patients having type 2. The symptoms are very similar to type 1 but occur much more slowly, so it becomes harder to diagnose in the early stages [3, 4, 6, 7].

Gestational diabetes is diagnosed when hyperglycemia is detected during pregnancy. Usually detection is because of prenatal tests, not reported symptoms [3, 4, 6, 7].

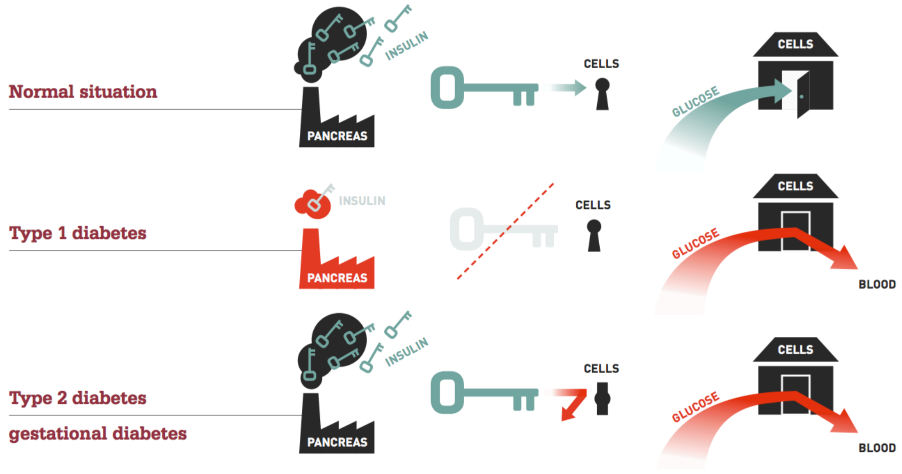


Figure 1. Types of diabetes [1]

Close to 184 million people with diabetes are between the ages of 40 and 59 with 80% living in low and middle-income countries. By 2035 this age group will rise to around 264 million with 84% living in low and middle-income countries. It is expected that all types of diabetes will have a rise of 55% by the year 2035 to around 592 million people *(see Figure 2)* [1, 24].

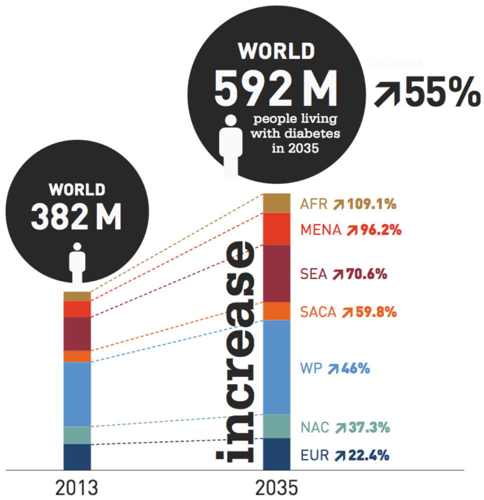


Figure 2. Expectation of diabetes progression by 2035 [1]

Around 246 million people with diabetes are living in urban and 136 million in rural areas. This gap will widen in 2035 with an expected 347 million in urban and 145 million in rural areas. The difference of diagnosed diabetes in gender is not substantial with men having around 14 million more diagnosed than women and expected to rise to 15 million by 2035 [1, 24].

Diabetes is a serious disease and ***might lead to death***. In 2013 an estimated 5.1 million people have died from diabetes and 548 billion USD were spent in health spending. Cardiovascular disease is the major cause of death for people with diabetes and accounts to 50% or more of the deaths. Around 48% of the deaths caused by diabetes where people under the age of 60. The largest amount of people with the disease and the largest amount of deaths are in China, India, USA, and Russian Federation. Gender difference is very small in everywhere but Middle East, North Africa and Western Pacific Regions where women account for more deaths than men but this could be because men die at a higher rate from other causes [1, 24].

Diabetes services are provided by a large variety of professionals such as general practitioners and other primary healthcare professionals. Well-organized and coordinated diabetes services are very important to have good outcomes for people diagnosed with diabetes and prevention of the rise of diabetes in the future. These services need to accumulate knowledge and skills of professionals from primary and secondary care [25, 26, 27].

2.1.2 Ways to Reduce Burden of Diabetes

The previous section *(see section 2.1.1, Diabetes Mellitus)* provides statistics on diabetes worldwide; numbers are very impressive and intimidating. Without effective management programs to prevent and control diabetes, the burden of diabetes will continue to increase worldwide. Therefore it is important and necessary to give special meaning paths to reduce disease. According to the World Health Organization, such paths can be attributed to ***prevention***, and diagnosis and treatments (***control***) [1, 3].

There are multiple ways ***to prevent*** Type 2 diabetes that have shown effectiveness. Achieving and maintaining a ***healthy body weight*** is one of the key steps. ***Physical activity*** of at least 30 minutes a day can play crucial role for health stability. Higher physical activity might be required to maintain healthy body weight. ***Healthy eating habits***, such as eating three to five servings of fruits and vegetable, and lower intake of sugar and saturated fats are very important in diabetes prevention. To decrease risk of cardiovascular diseases, ***avoiding tobacco*** is a necessity [3].

Treatment involves ***insulin injections*** for type 1 diabetes; people with type 2 diabetes can be treated with oral medication but can still require insulin injections. ***Blood glucose control*** is important in both cases. Ending tobacco use is important to not cause complications. These measures also should be accompanied with prevention care [3].

Based on the component objects of diabetes prevention and control, today many nations worldwide are seriously focused on the management of diabetes in general practice. For example, countries such as UK, Australia, and USA are particularly involved in the building of special programs as evidenced by the large range of brochures and guidelines on the topic. Particular all of Europe, including Norway, has a ***mandatory program for diabetes management in primary care*** [8, 9, 10, 11, 12, 13].

2.2 Technology

2.2.1 "Diabetes Diary" Application

"Diabetes Diary" application was developed by the Norwegian Centre for Integrated Care and Telemedicine (NST) in Tromsø, Norway. The main purpose of the application is to help people with diabetes to manage their health condition. The application available for the Android platform and requires at least version 2.2. It is also available for the Apple iOS and requires iOS version 6.0 or later. "Diabetes Diary" is available in both English and Norwegian languages [17, 18, 19].

The application can be described as a tool that provides environment for self-monitoring to record and save into the system such measured parameters as blood glucose level, insulin and carbohydrates intake, and physical activity *(see Figure 3)*. The information is entered manually by the person with diabetes *(see Figure 3-2)*.

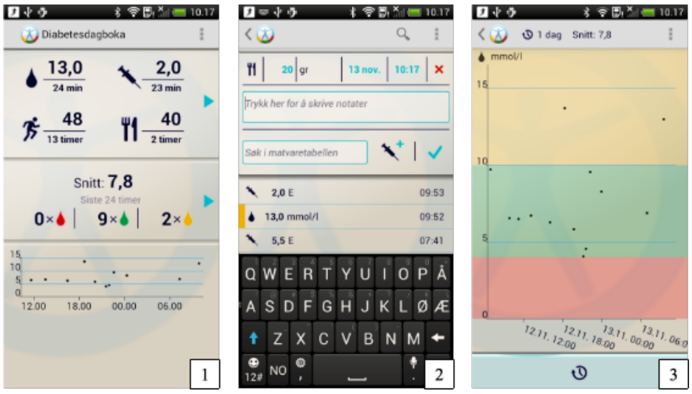


Figure 3. "Diabetes Diary" application [17]

Gathered information is stored in the internal database on the device and is accessible only through the application. Data is not protected and the user must ensure to protect the device though device lock mechanisms. To allow other programs to use the data, it needs to be exported. The application supports such tool and the database can be formatted for CSV *(see Figure 4)*.

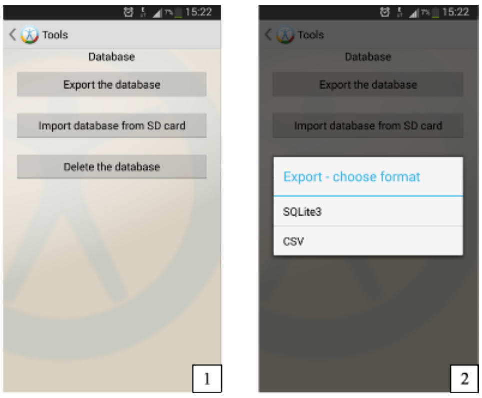


Figure 4. Database export from the "Diabetes Diary" application

2.2.2 Android Beam

Android Beam is a feature that was introduced in Android version 4.0 (Ice Cream Sandwich) and lets data to be transferred using the ***near field communication (NFC)*** technology. Android version 4.0 came out on October 19th, 2011 [28, 29].

Android Beam is not supported by Apple IOS and is limited to Android devices. Starting with Android version 4.1 (Jelly Bean, July 9, 2012) Android Beam is able to send larger files such as photos and videos over Bluetooth. Android Beam with the use of NFC will enable Bluetooth on both devices, pair them and disable Bluetooth once the transfer is complete. To use Android Beam, both of the devices need to support NFC [28, 29].

The process of beaming data is illustrated on the figure below *(see Figure 5)*. Devices need to have lock-screen passed and are placed back to back *(see Figure 5-1)*. A sound will be played when the devices are within four centimeters of each other and are able to send or receive data *(see Figure 5-2, 5-3)*. The content that is going to be shared needs to be displayed in an application that can support it. If the data can be sent, the screen will shrink down and "Tap to Beam" message will display on the top area of the screen *(see Figure 5-4)*. To send the data, the screen needs to be tapped *(see Figure 5-5)*. Either a confirmation or a negative tone will play and the content will shrink off the screen. Sharing is only one direction and the receiving device will not send the content that is displayed, only receive from the sending device [30].

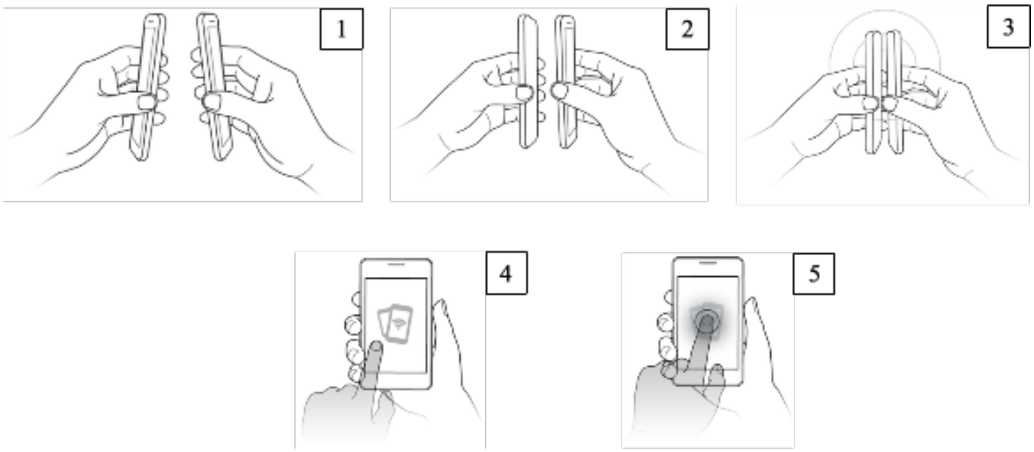


Figure 5. Use of Android Beam feature [30]

2.2.3 Near Field Communication Technology

Nowadays, smartphones and tablets are growing in the usage and functionality. According to a study done by the International Data Corporation (IDC), around 118 million smartphones were sold in 2011 worldwide [14]. Based on the results of other study done by the Pew Internet Research Center, 87% of adults own a cellphone and 31% own a tablet computer; 45% of those cellphones can be considered as smartphones [15].

Smartphones with NFC functionality were introduced in 2001. Based on current rates of adoption of NFC, it is expected to have around 28% of the devices will be NFC capable by 2015 [31]. It can be assumed when compared to personal computers that with the current rate of adoption of smartphones, sooner or later majority of the population will have a device capable of using NFC technology.

Today, NFC technology is used in a large variety of applications such as mobile payment facility, transit and ticketing, advertising, educational systems, and indoor navigation system [14, 32, 33, 34]. Most recently it is starting to be used in medical applications and on e-Health arena in general [35, 36, 37, 38, 39, 40, 41].

This section is describing near field communication technology from the perspective of historical overview and development, operation principles, standards and security concerns.

2.2.3.1 Historical Overview and Development

Modern use of the near field communication technology has a distant evolution of radio frequency identification (RFID) technology. RFID can be traced to World War II when a Russian inventor developed an audio spying device. In 1970s RFID technology was rapidly developed and a first RFID device, which was a transponder with memory, was invented. In 1983, the term "radio frequency identification" was patented as "Portable radio frequency emitting identifier" by Charles Walton [14, 42, 43]. Evolution of NFC technology is illustrated on the figure below *(see Figure 6)*.

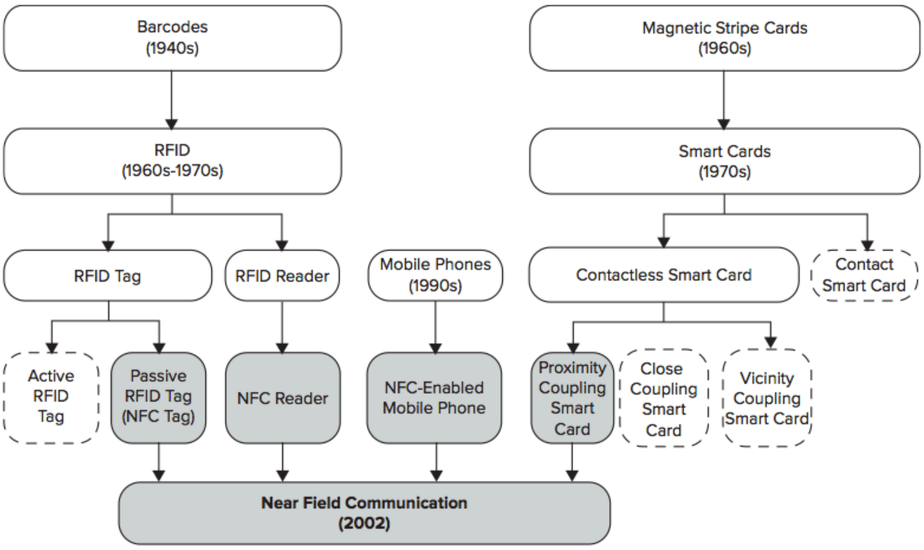


Figure 6. Evolution of NFC technology [43]

Phillips and Sony started development on NFC in 2002. In 2004, the NFC Forum, a non-profit organization, was formed by NXP Semiconductors, Sony, Nokia and Philips. The purpose of the NFC Forum is to bring existing technology and standards of RFID and smart cards to create new and innovative short-ranged communication [43].

Figure 7. Logo of NFC technology [44]

As of July 2013, over 190 companies are involved in the NFC Forum. NFC technology standards are acknowledged by the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC), European Telecommunications Standards Institute (ETSI), and European Computer Manufacturers Association (ECMA). Today, NFC can be considered as a second generation of RFID and a fast developing technology [45, 46, 47].

2.2.3.2 NFC Operation Principles

NFC technology uses bidirectional and short-range wireless communication technology. It applies a 13.56 MHz magnetic field and allows data transfer speeds of 106, 212, and 424 Kbps. NFC-compatible devices need to be held within a few centimeters of each other. Depending on the operating mode, NFC-enabled mobile device can interact with smart objects like NFC tag, NFC reader or another NFC-enabled mobile device *(see Figure 8)* [43, 48].

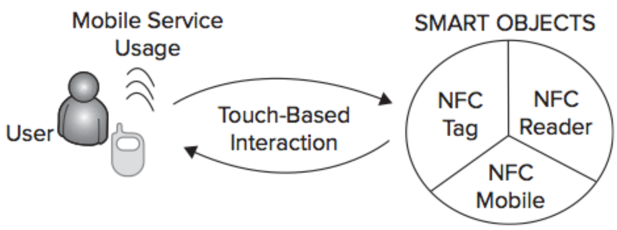


Figure 8. Interaction of NFC-enabled mobile device [43]

There are three different ***operating modes*** for NFC functioning: peer-to-peer, reader and writer and NFC card emulation mode *(see Figure 9)* [43, 48].

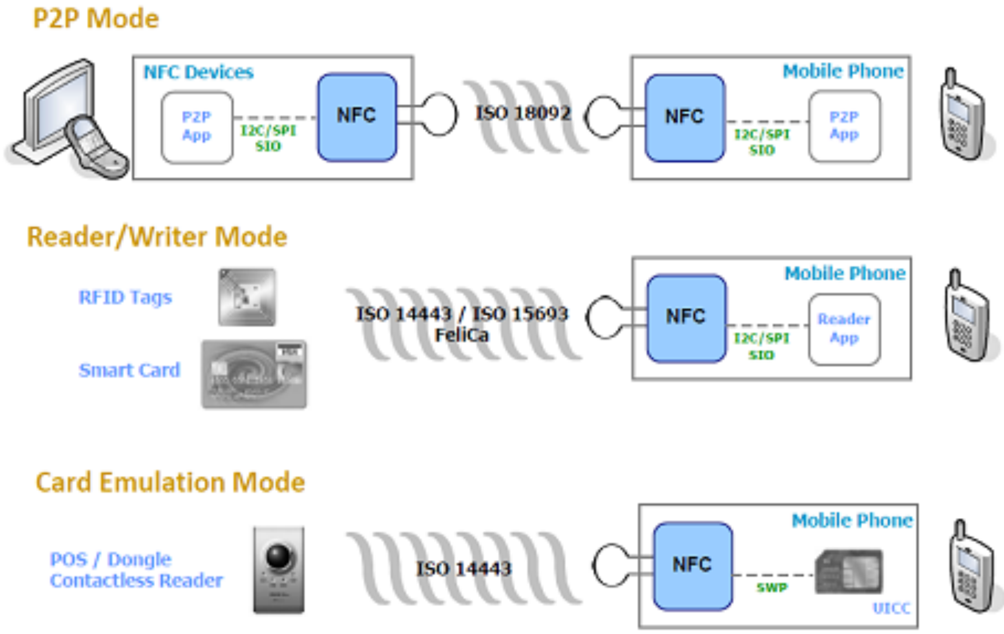


Figure 9. NFC operating modes [49]

In **peer-to-peer operating mode**, NFC devices are able to exchange data in both directions using ISO 18092 standard for communication interface. In ***reader and writer mode***, NFC device is able to read information from RFID tags and smart cards and write information to them. This operating mode uses ISO 14443 / ISO 15693 FeliCa interfaces. In ***NFC card emulation mode***, NFC devices can act as RFID tags and interact with NFC or RFID devices as such. In this mode, smart card capability is added which makes it is possible to use NFC devices as payment, for instance. Card emulation mode uses ISO/IEC 14443 for its communication interface [43, 48].

Without dependency on the operating mode, NFC devices can be used in two ***communication modes***. In an ***active communication mode***, both the initiator and the target provide their own power. In a ***passive communication mode***, the initiator supplies Radio Frequency (RF) energy to the target for power [43, 48].

2.2.3.3 Peer-to-Peer Operation Mode

In the previous section *(see section 2.2.3.2, NFC Operation Principles*) three operation modes were shortly described. However, special attention has to be paid on the peer-to-peer operating mode for the reason this mode is used in the “Diabetes Care” application development.

Two NFC-enabled mobile devices such as phones and tablets can establish connection through peer-to-peer mode. During the operation, they are able to exchange a wide variety of information such as text, multi-media and other files. The connection is bidirectional, meaning that information can be sent both ways. The peer-to-peer operating mode’s radio frequency (RF) communication interface is defined as NFC Interface and Protocol-1 (NFCIP-1) in the ISO/IEC 18092 standard *(see Figure 10)* [43, 48].

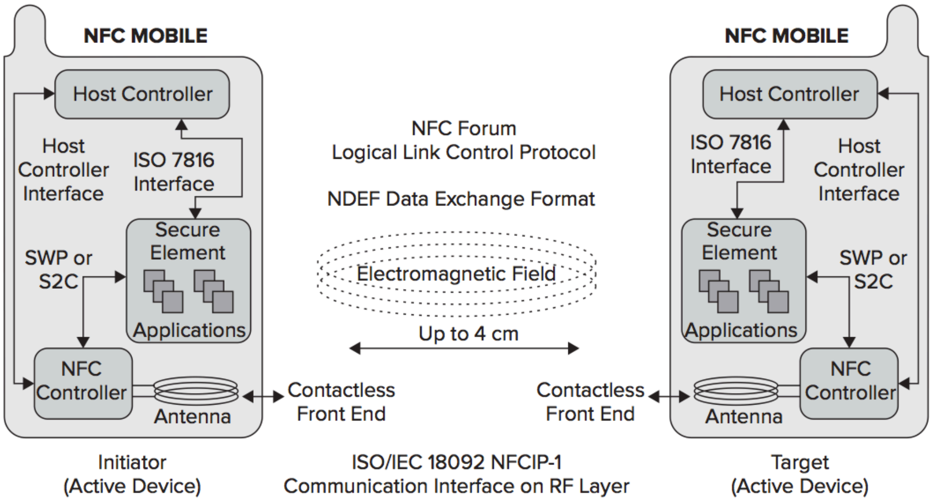


Figure 10. Peer-to-peer operating mode [43]

Before starting the communication, both of the devices are defined as either initiator or target *(see Figure* 12). The two devices need to be within four or less centimeters of each other. The initiator generates a 13.56 MHz magnetic field to which the target listens to and responds after the requests are made. The running application takes over after the initial handshake and makes the decision in the application layer. On the Android operating system, starting with version 4.0, such program is ***Android Beam*** [43].

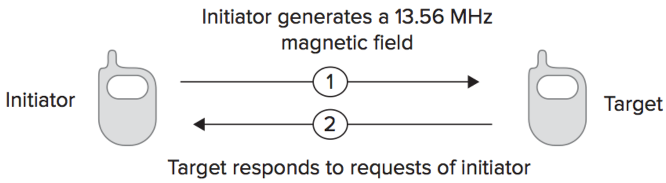


Figure 11. Identification of devices before communication [43]

Protocol stack architecture

Based on the NFC Forum specifications, an NFC capable device that is using peer-to-peer operating mode has the following ***protocol stack*** elements *(see Figure 12)* [43].

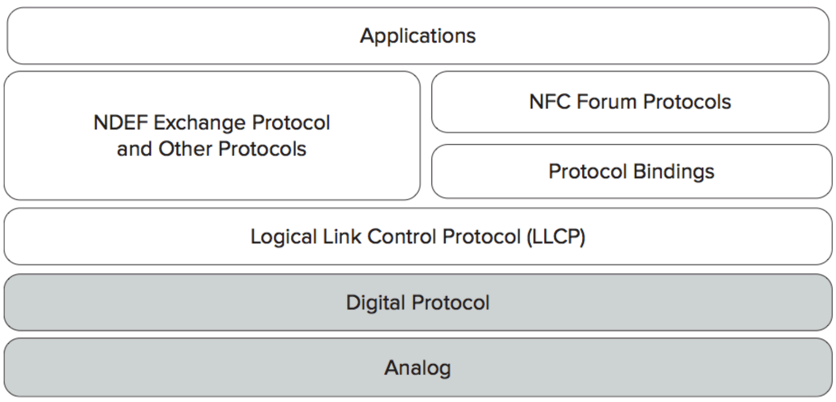


Figure 12. NFC Protocol stack architecture [43]

(1) Standardized by the NFCIP-1, analog and digital protocols are the lower layer protocols. (2) Logical Link Control Protocol (LLCP) lets two NFC devices transfer upper layer information units between each other. (3) Protocol bindings provide standard binding to the NFC Forum protocols and to inter-operate with registered protocols. (4) NFC Forum protocols are defined by the NFC Forum as binding to LLCP. (5) NDEF exchange protocol is responsible for exchange of NDEF messages. Other protocols can be run over the data link layer provided by LLCP. (6) Applications can run NDEF exchange, NFC Forum, and other protocols to share data [43].

SNEP and LLCP

Peer-to-peer exchanges rest on the ***Simple NDEF Exchange Protocol (SNEP)***. Simple NDEF Exchange Protocol (SNEP) is a request-and-response protocol, which allows the initiator to send a request with the type of data that it wants to send. As the next step, the target responds with a requested data. SNEP uses the NFC Forum's ***Logical Link Control Protocol (LLCP)***. SNEP and LLCP are part of the command protocols that include RFID and smart card protocols, which provide compatibility with NFC *(see Figure 13)* [43, 48].

Every operating system implements SNEP and LLCP in its own way. For instance, prior to Android version 4.0, Android's implementation was called the NDEF Push Protocol (NPP). Android version 4.0 and later uses Android Beam as an implementation. When NFC is enabled on the device with Android Beam, Beam keeps NFC radio in active mode and constantly listens for new connections. If another radio is detected, "Touch to Beam" interface will be brought up in any application that is running at that time. With Android Beam, the user interacts with the transfer through the application layer [48].

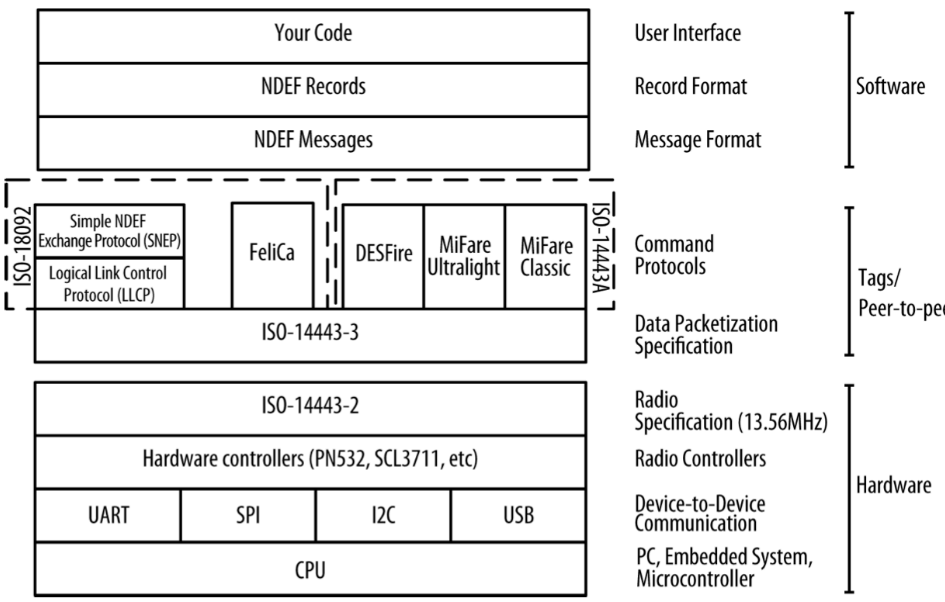


Figure 13. SNEP and LLCP fit into the NFC architecture [48]

2.2.3.4 Security Concerns and Solutions

There are various ***security concerns*** that need to be accounted for consideration, such as eavesdropping, data corruption, data modification, data insertion and man-in-the-middle-attack. However, the high level of NFC security itself and special use of the technology can provide solutions to security threats [14, 50].

Eavesdropping can be a big concern. A third party could capture information transferred through the RF signal. Even though NFC devices need to be close to interacting, it is quite ambiguous to judge the distance at which the data can't be intercepted. Location and the antennas used give a big variance. Passive mode transmission is more complicated to eavesdrop on. ***Applications like Android Beam, which use Bluetooth technology for data transfer, are more secure to eavesdropping*** [50]***.***

Data corruption is essentially a Denial of Service attack. The attack sends a lot of valid frequencies of the data spectrum, confusing the communication between the NFC devices. Data cannot be manipulated. Because the power that is needed to corrupt the data is a lot higher than the power needed by the NFC devices, ***NFC devices are able to detect the attack and block the attacks*** [50].

Data can be modified through overriding the signal with a stronger one. It is possible to do full or partial modification depending on the encoding used. ***Using 106 Baud in active mode, it gets impossible to modify the data.*** Sensitive data can be sent through Bluetooth using Android Beam. If the answering device takes a long time to answer, the attacker can send its own answer ahead of the answering device [50].

Data insertion is happening when that the attacker inserts messages into the data exchange between two operating devices. There are three possible scenarios. Firstly, when the answering device answers with no delay and the attacker cannot be faster than the correct device and no correct data is received when two devices answer at the same time. Secondly, the device can detect the attacker by listening the channel. Thirdly, ***a secure channel between the two devices can be set in order to protect the data transfer*** [50].

In a **man-in-the-middle-attack**, an attacker tricks both of the communicating devices to communicate through a third device. In this instance it is possible to both send modified data and receive data. ***Man-in-the-middle attack is practically impossible to achieve*** due to the needed perfect emulation of RF fields and restricting the devices to talking to each other directly [50].

2.3 State-of-the-Art

This section reveals review of published literatures related to applications and software intended for medical doctors use to monitor and view data collected by patients through mobile diabetes diaries.

2.3.1 Purpose

Mobile devices are progressing from making simple phone calls to being used as personal computers. There are multiple applications for mobile devices that act as a diary for people with diabetes to help keep track of diabetes related measurements. Systematic review and analysis of literature, that is describing use of the data from mobile diabetes diaries by medical doctors for analysis, was performed as state-of-the-art for the recent thesis.

2.3.2 Data Sources and Search Criteria

Four ***electronic databases*** were used for search of literature relevant to the recent "Diabetes Care" application development. Such databases as PubMed (National Library of Medicine and National Institute of Health), IEEE (Institute of Electrical and Electronics Engineers) Xplore, ACM (Association for computer machinery), and DST (Journal of Diabetes Science and Technology) have been used within April, May and June in 2014.

The following ***inclusion criteria*** were used: (1) papers written in English; (2) papers that have fully included text; (3) papers close or similar to the recent application development. Review articles were ***excluded***. Relevance of each paper was examined by reading the abstracts and full texts.

2.3.3 Search Methods

Multiple journal sources were searched for relevant literature. First of all, where possible, ***MeSH*** (Medical Subject Headings) was used. This simplified the search process, instead of searching in the text of the articles, MeSH term search allows to search through indexed subjects. PubMed and IEEE have the option to use MeSH term search. “Diabetes mellitus” was used as a MeSH search. “Software” or “application” terms were used to search for any software or applications used for diabetes. Further, “mobile device” or “portable device” were used. “Diabetes diary”, “data sharing”, “data transfer”, and “data representation” terms were used to find any literature that talks about a diabetes diary or transfer, sharing, and representation of that data. Publications that were not related to data analysis by medical doctors were eliminated. Duplicated publications were also eliminated.

Table 3. State-of-the-art search results

Database	***Keywords***	***Found***	***Hits***
PubMed	diabetes mellitus[MeSH Terms] AND ("software" OR "application") AND "mobile device"	4	1
	diabetes mellitus[MeSH Terms] AND ("software" OR "application") AND "data transfer"	3	0
	diabetes mellitus[MeSH Terms] AND ("software" OR "application") AND "data representation"	0	0
	diabetes mellitus[MeSH Terms] AND ("software" OR "application") AND "data sharing"	2	0
	diabetes mellitus[MeSH Terms] AND "diabetes diary"	3	1
	diabetes mellitus[MeSH Terms] AND "data sharing"	8	0
	diabetes mellitus[MeSH Terms] AND "portable device"	14	0
IEEE	("MeSH Terms":diabetes mellitus) AND ("software" OR "application"))	22	1
	(("MeSH Terms":diabetes mellitus) AND ("software" OR "application") AND "mobile device")	0	0
	(("MeSH Terms":diabetes mellitus) AND ("software" OR "application") AND "data transfer")	0	0
	(("MeSH Terms":diabetes mellitus) AND ("software" OR "application") AND "data representation")	0	0

	(("MeSH Terms":diabetes mellitus) AND ("software" OR "application") AND "data sharing")	0	0
	(("MeSH Terms":diabetes mellitus) AND "diabetes diary")	0	0
	(("MeSH Terms":diabetes mellitus) AND "portable device")	0	0
	(("MeSH Terms":diabetes mellitus) AND "mobile device")	1	0
DST	application or software in all fields and "mobile device" in all fields	18	3
	application or software in all fields and "portable device" in all fields	7	0
	application or software in all fields and "data representation" in all fields	3	0
	application or software in all fields and "data sharing" in all fields	8	1
	application or software in all fields and "portable transfer" in all fields	0	0
	application or software in all fields and "diabetes diary" in all fields	5	0
ACM	"diabetes mellitus"+monitoring	3	0
	"diabetes mellitus"+"data sharing"	2	0
	"diabetes mellitus"+"data representation"	1	0
	"diabetes mellitus"+"mobile device"	2	0
	"diabetes mellitus"+"portable device"	0	0
	"diabetes mellitus"+"food diary"	0	0
Total		136	7

2.3.4 Results

From the four electronic databases, 136 unique papers were found from which 54 were duplicated. ***82 papers were analyzed*** and ***7 papers were*** identified as ***related*** to the search area *(see Appendix 1, Analyzed articles for state-of-the-art)*. After applying exclusion criteria, ***four papers*** had full texts available and were relevant to the purpose of the state-of-the-art *(see section 2.3.1, Purpose)*. All the articles were read and analyzed. The overview is provided further.

Article 1. The purpose of the study was to support self-management for patients with type 2 diabetes with the use of web-based and smartphone support. Fifteen people participated in the study. The study consisted of four elements: (1) face-to-face meeting and initial telephone consultation, (2) online diaries, (3) written situational feedback, and (4) automatic transfer of blood glucose levels to the smartphone. The patients received a smartphone for this study. A therapist, who was responsible with writing feedback to the patients, had a telephone contact with the patients before the trial. In the online diaries, patients answered 16-19 questions for self-monitoring and awareness of health behavior, thoughts, and feelings. The diaries were filled out three times a day and were reminded by SMS messages. Automated transfer of blood glucose levels to the smartphone was done with the help of a glucose meter and the Few Touch Application (FTA). The therapist would then give feedback. The results of the study showed that out of fifteen participants, eleven evaluated the study as supportive and meaningful. The therapist mentioned that nonverbal communication was a challenge and that face-to-face communication provides more valuable information [20].

Article 2. The purpose of study in the article was to test an effect of data-driven feedback by utilizing a statistics-based feedback module (Diastat) for a diabetes diary for mobile phones. In the study, participants were divided into two groups and were given use of the Few Tough Application (FTA). After four weeks, one group kept using FTA and the second group started to use FTA with Diastat. After twelve weeks, the first group started using FTA with Diastat. FTA was run on a smartphone that was provided with the study or could use their own. Participants were also provided a blood glucose meter and a Bluetooth adapter for connection with the smartphone. Diastat consisted of three modules: (1) Periodicity: 'Typical' blood glucose over 24 hours and over 1 week graphically and 24-hour value and variation on the app's main page; (2) Trend: Using cSiZer-method, multi-scale analysis of registered blood glucose was performed and shown in the graphic trend view; (3) Situation matching: Patients were able to have case-based reasoning tool aiding decision making for administering insulin after recoding their insulin injections [22].

Article 3. The paper describes two projects that were funded by the European Union to help patients with diabetes to report their measurements and receive feedback from a physician. The first project was T-IDDM project (1996-1999), which consisted of a patient unit (PU) and a medical unit (MU). The patient would collect data either manually or automatically from the glucometer, get self-monitoring of blood glucose levels, and deliver monitoring data to the health care center (HCC). The MU would visualize and analyze patient's data, support his or her decision and therapy planning, and exchange messages and therapeutic advices to the patients. Communication was driven by the patient every 7-10 days. The limitations of technology at the time provided a big hurdle. M2DM project (2001-2003) was the second project that focused on overcoming the previous limitations. Patients did not have to have a PC and could upload data through the phone line with the use of a smart modem. Communications became timelier with the help of automatic reminders and notifications. With the addition of smartphones with Bluetooth capabilities, that helped with the connection between glucometer and insulin pump to the HCC. Physician was also able to provide feedback directly to the smartphone [23].

Article 4. SMARTDIAB is a system that consists of a patient unit (PU) and patient management unit (PMU). Using the PU, the patients recorded his or her glucose levels, insulin intake, diet, and physical activity and transmitted them with the use of a cellular phone or a PC to the PMU. PMU was able to be accessed by the patient or a physician. The physician was able to monitor health evolution of the patient with the help of advanced tools for intelligent processing of patent's data. The physician was then able to make recommendation for the patient's treatment. Patient was able to get this feedback through either a cellular phone or thought a web-based interface [21].

2.3.5 Conclusion

All previous attempts at providing communication between medical doctors and patients with diabetes were done through a distance web-based interactions and it was not state as a supplement to the diabetes management in general practice. Face-to-face interaction is still very important to diabetes care. Methods to help primary care doctors to get the information on glucose levels, taken insulin, diet and physical activity during regular checkups will help general practitioner's and patient's interaction, and will support diabetes management in general practice in a way of possible further health outcomes in patients.

2.4 Summary

First, diabetes mellitus disease was explained from the perspective of its mechanism of affecting human body and statistical overview of the disease worldwide. Prognosis related to areas of living, age, and gender are expected by 2035. Ways to reduce burden of diabetes were explained based on the information provided by the World Health Organization (WHO) with a relation of the disease management to the world population. Despite the fact, diabetes services provided by a variety of medical professionals, general practitioners are still play crucial role in diabetes care.

Second, the technological theoretical basis was explained with a relation to the recent application development. Near field communication technology was studied from the perspective of historical overview and development, functioning, standardization and security concerns and solutions.

Third, to provide any close or similar developments to the "Diabetes Care" application, state-of-the-art section was performed. Four electronic databases, such as PubMed (National Library of Medicine and National Institute of Health), IEEE (Institute of Electrical and Electronics Engineers), Journal of Diabetes Science and Technology, and ACM (Association for Computer Machinery), were used in the search for any relevant literature. 84 articles were examined to detect its relevance to the recent development; 4 articles were fully analyzed due to its relevance and described with the relation to the research area.

CHAPTER 3. MATERIALS AND METHODS

In the Chapter, materials and methods used for the research are provided.

The research design is based on the software development life cycle, waterfall model in particular. Such phases as requirements specification, design, implementation and testing are used for the application development. As well, tools that are used for the study are specified.

For the research, both data collection and analysis, and experimental methods have been used. For data collection and analysis, such methods as systematic review, interview, questionnaire, discussion and requirements analysis are used. Software prototyping, usability testing and software testing are used as experimental methods for the research. All of the used methods are disclosed with its relation to the application development.

Critique of the used methods is provided for the each method of the research.

3.1 Research Design and Procedure

Relying on the fact that the main goal for the master thesis is to develop an application, the engineering approach was used research based on the ***software development life cycle (SDLS)***. In particular, ***waterfall model*** has been taken as a source of building development procedure [51]. Requirements specification, design, implementation and testing were key directions on the way to create the application.

3.2 Tools

Tools that have been used for the study are listed in the table below *(see Table 4)*.

Table 4. Tools used for the study

Tool	***Description***
Cacoo.com [52]	Cacoo is online diagram software for creating basic, UML, Android, and other types of diagram [52].
Eclipse Java EE IDE (version: Kepler Release; Build id 20130614-0229) [53]	Eclipse Java EE is integrated development environment that contains all tools for mobile and Web applications development (such as Data Tools Platform, Eclipse Git Team Provider, Eclipse Java Development Tools, Eclipse Java EE Developer Tools, JavaScript Development Tools, Maven Integration for Eclipse, Mylyn Task List, Eclipse Plug-in Development Environment, Remote System Explorer, Eclipse XML Editors and Tools) [53]. The choice of the platform were based on the principle of developing the application for two types of users and for each of them, the application covers completely different goals. As well, such application development is not for individual needs and the choice of the platform from this perspective was clear.
Android SDK (minimum version: 8; target version: 19)	Android software development kit was used for enabling to create application for the Android platform. SDK includes development tools, an emulator, and libraries to build the

	application. Java programing language was used [54].
Libraries (achartengine-1.1.0 [55], GraphView-3.0 [56], android-support [57], ksoap2-android-assembly-2.6.5-jar-with-dependencies [58])	Libraries represent collections of implementations of behavior that a higher level program can use to make system call without the need to have those calls written. Programming languages have built in libraries and custom libraries can be implemented.
Tablet Sony Xperia Z (2013) and **smartphone** Samsung Galaxy Note II (2012)	Tablet with 10,1 inches screen and smartphone with 5,5 inches screen were used to support the development. Both of the devices embedded with NFC adapter and have Android OS version 4.1 Jelly Bean [59, 60].

3.3 Data Collection and Analysis Methods

For data collection and analysis such methods as systematic review, interview, questionnaire, discussion and requirements analysis were used. Each of method is described in a way it was applied to the research development.

3.3.1 Literature Review

As a main method of the literature processing was chosen ***literature review***. In addition to the literature review method, ***systematic review*** was selected. This decision was made due to the fact, that research was required literature with a highest quality (such as international standards) and close association with subjects under consideration in the thesis. State-of-the-art section *(see section 2.3, State-of-the-Ar*t) was performed using systematic review method.

All chosen literature sources were conventionally divided into three ***fields*** such as ***educational, technological and technical*** and ***medical*** based on its contents. Educational field includes literature for thesis writing and theory of organizing information. Technological and technical fields represent all the literature used in the thesis to technical and technological areas of the research, and mostly used for the technological background explanation and state-of-the-art. Medical field contains literature related to the diabetes condition, information about general practice and its content.

3.3.2 Interview, Questionnaire and Discussion

During the study, such methods of data collection, as interview, questionnaire and discussion were used. The following table is offered in regard to the use of these methods, content section is covering the main areas of discussions and interviews *(see Table 5)*. Questionnaires mostly were used for the usability testing of the application. The table includes discussions, questionnaires and interviews with medical doctors (MD, green sections) and technical experts (TE, blue sections) on the fact of meetings. Discussions with supervisors were not documented in the table.

Table 5. Interviews, questionnaire and discussions during the study

Date	Method	Participants	Content
September,	Discussion	Nils Kolstrup	The main purpose of the discussion was the general idea of the orientation of the research. The discussion covered such topics as general practice, use of technology in general practice and important aspects of

2013		(MD)	consultations with patients with diabetes. The result of the discussion was the first image of the application that needs to be developed.
03.10.2013	Discussion Interview	Nils Kolstrup (MD)	The object of the discussion was the first draft of the user interface and the functional content of the future application. Mostly, interview included questions related to the opinion of the medical doctor about the direction of the application development and its possible future exploitation *(see Appendix 2, Interview with Nils Kolstrup, October 2013)*.
21.01.2014	Discussion	Participants of Kolarctic Collaboration Event & KITENPI Project, Arctic Frontiers 2014 (TE)	At the conference, the main topic of the discussion was an importance of such application development, as well as challenges that may face already implemented application.
03.03.2014	Discussion Interview	Gerd Ersdal (MD)	Medical doctor were proposed with updated version of the user interface. Vectors of discussion and interview were within the relevance of the application to the general practice and suggestions about functionality from medical point of view. Also, questions related to the diabetes management in primary care were discussed *(see Appendix 3, Interview with Gerd Ersdal, March 2014)*.
04.03.2014	Discussion	Keiichi Sato (TE)	Meeting with the expert was mainly focused on the value of use case. Field for discussion was the future place of the application in the healthcare sector, particularly in diabetes management in general practice.
05.03.2014	Discussion Questionnaire	Nils Kolstrup (MD)	The discussion was conducted regarding the updated version of user interface and functional changes in the application. Questions, related to statistical rules have to be applied to data representation and decision support, were also discussed *(see Appendix 4, Questionnaire of Nils Kolstrup, March 2014*).
11.03.2014	Discussion	Medical Informatics and Telemedicine group at the Norwegian Centre of Integrated Care and Telemedicine (TE)	It was discussed with technical experts about the development of the application at the time of the meeting. Question about the technological solution of the research was brought on the table. Ethical issues were considered. The result of the discussion was comprehensive revision of the application development.
08.05.2014	Discussion Questionnaire	Nils Kolstrup (MD)	The discussion covered the final version of the user interface, as well as statistical rules

			for the data processing; medical practice in Norway also was discussed. Statistical rules for data representation were finally set *(see Appendix 5, Questionnaire of Nils Kolstrup, May 2014)*.
13.05.2014	Discussion	Gro Berntsen (MD)	The discussion was based on the consideration of the user interface, trust issues and suggestion to be implemented in the possible further extension of the application. Doctor explained technological issues related to the medical routine.
30.06.2014	Discussion Interview	Nils Kolstrup (MD)	The discussion proceeded on the basis of testing of the finished "Diabetes Care" application. The interview was devoted to the relevance of design, quality and satisfaction with the stated requirements from medical and technical perspective. As a result of testing and discussion, medical doctor had noted the great potential of the applications and the need for its further development in order to improve the quality of diabetes management in general practice *(see Appendix 6, Interview with Nils Kolstrup, June 2014)*. Detailed results from the application's test presented in the Chapter 7, *Testing and Results (see section 7.2, Usability Test)*.
01.07.2014	Discussion Interview	Thomas Roger Schopf (MD)	The discussion was based on the testing of the "Diabetes Care" application. Mainly legal issues and future development was discussed. Medical doctor provided his opinion about the application as a result of the master thesis research and functionality of the application. Detailed results from the application's test presented in the Chapter 7, *Testing and Results (see section 7.2, Usability Test)*.

3.3.3 Requirements Analysis

In the research, requirements analysis was used to state a clear representation of the development before the implementation. The analysis was preceded in three ***stages: gathering of requirements, analysis of collected requirements*** and its ***documentation*** *(see Figure 14)*. The results of the last stage are the source for writing Chapter 4, *Requirements Specification*. All three stages of the requirements analysis were based on the ***IEEE Guide to Software Requirements Specification 830-1984*** [61] and Open Process Framework [62].

For analysis, description of the application, its purposes and functions was prepared. User characteristics, assumptions and dependencies of the "Diabetes Care" application were explained as well. Based on this description, the study was considered from the perspective of functional and non-functional requirements. As functionality requirements, use case and activity diagrams were provided to disclose possible activity flows for the main users of the application. Usability, performance, maintainability, security, reliability and efficiency requirements were disclosed from the perspective of non-functional requirements. Most of the non-functional requirements were analyzed using various quality factors *(see Chapter 4, Requirements Specification).*

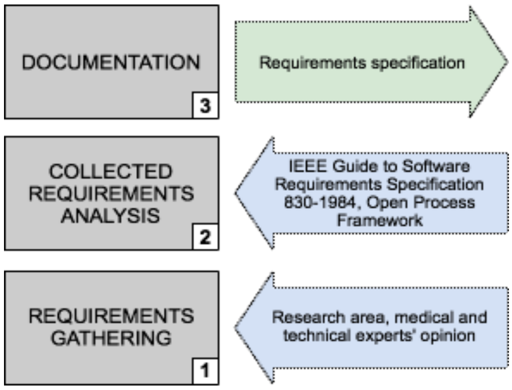


Figure 14. Stages of requirements analysis

3.4 Experimental Methods

Methods as software prototyping, usability testing and software testing were applied to the research as experimental methods. Methods were used in the order it explained in the section: software prototyping first, then usability prototyping and software testing as the last used methods in the group of the experimental methods.

3.4.1 Software Prototyping

Software prototyping method was applied first in the study within used experimental methods. Prototypes were made the way it shown in figure below *(see Figure 15)*.

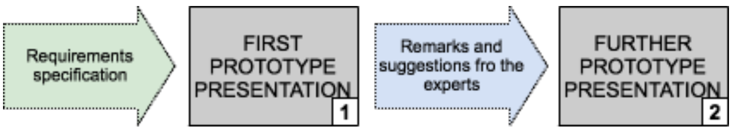


Figure 15. Prototype making

For the first prototype making, developed requirements were applied. Further, this prototype was presented to medical and technical experts in order to improve the application layout. As a next step, the set of collected remarks and suggestions from the experts and doctors were taken into account for the improvement of the first prototype. This procedure took three times as long as the final version of the prototype. Total number of ***major prototypes*** of the application ***counts three versions*** *(see section 5.4, Evolution of the Design Development)*. ***With*** the creation of ***each of the three prototypes user interface and functional principles of application were changed***.

3.4.2 Usability and Software Testing

This type of testing was performed in order to determine whether the user interface is convenient in the way of using the full functionality of the application. Usability testing allowed determining the ergonomic needs for the design. To operate with this method, paper prototypes drawn by hand as well as graphic prototypes were used. Graphic prototypes were created in a way to represent as close as possible the real user interface of the application that will be presented as a result of the implementation.

Think aloud protocol was used during the process of usability testing for better understanding of users' needs. Explanation aloud all operations, which makes the user, was a necessary condition for a successful user interface.

Software testing has been used to demonstrate that the application is made in consideration of the stated requirements, as well as to identify scenarios in which the application is working not properly. Testing process was conditionally divided into three stages: ***intermediate testing in the process of the implementation, final functionality testing*** before introducing the application to medical doctors and ***testing*** the applications ***with medical doctors involving***, after the final testing showed no failures.

Three final testing were made: twice the application was tested by the medical doctors (Nils Kolstrup and Thomas Roger Schopf, *see section 7.2, Usability Testing*), and once demonstration of properly working application was provided to the supervisor (Gunnar Hartvigsen) of the thesis.

For the reason the "Diabetes Care" application is not a commercial product, the assessment was made in accordance with the requirements that have been specified in the Chapter 4, *Requirements Specification.*

3.5 Critique of the Methods Used

To provide criticism of the methods used in the research, the table was created *(see Table 6)*. The table below contain name of the methods and critical appraisal for their use.

Table 6. Critique of the methods used

Methods	Critique of the methods
Data Collection and Analysis Methods	
Literature Review	With respect to this method, it should be noted that part of the sources, which aroused the interest and undeniable direct relation to the writing of the thesis were paid, and in some cases unavailable for purchase. Similarly, lack of publications concerning the use of mobile applications in general practice, in particular in diabetes management, leaves many questions unanswered. During the observation of medical component of the research, part of the literature, related to diabetes management in primary care was in Norwegian language and represented difficulty to understand.
Interview, Questionnaire and Discussion	These three methods essentially can reveal a lot of information that is necessary for the study. Nevertheless, experts and doctors may be interested in issues, coverage of which is limited in the master thesis. For instance, in the process of discussions and interviews, many participants were interested in the development of the "Diabetes Care" applications and have found it necessary further development. Mostly, attention was focused not on what has already been achieved but further development that could be done.

<table>
<tr><td>Requirements Analysis</td><td>Due to the reason, the study is the master level research and no broad access to potential users are available; its requirements analysis were based on the opinion of those few professionals who had the opportunity to participate in the development. This means that the requirements can be directed to a thinner audience of the future users.</td></tr>
<tr><td colspan="2">Experimental Methods</td></tr>
<tr><td>Software Prototyping</td><td>As already noted, the application prototype is created based on the requirements. Given the fact that few experts were able to participate in the evaluation of the research development (three versions of the application prototypes), prototypes were based on the opinion of limited number of experts and doctors. In addition, in should be mentioned that evaluation of the application from the perspective of patients with diabetes were not reached due to the fact asked patients didn't manage to participate. However, during the supervision of the research, it was recommended to focus on the average adult user of such application. The considered prototype of the user interface will be perceived the same by people with or without diabetes from the perspective of use.</td></tr>
<tr><td>Usability Testing</td><td rowspan="2">In the usability testing four medical doctors participated, software testing was conducted by two doctors. In order to evaluate the importance of the "Diabetes Care" application within general practice, more medical experts for testing are needed to be involved. In addition, a large number of experts in testing will allow creating more flexible application, which will be directed to a wide audience of users. As well, the involvement of patients with diabetes will expand patient's version of the application and ensure the use of the application for a purpose.</td></tr>
<tr><td>Software Testing</td></tr>
</table>

3.6 Summary

In this Chapter, materials and methods of the recent research were disclosed. The design of the research is passed on the waterfall model of software development life cycle. Requirements specification, design, implementation and testing were used to drive the application development. Tools for the development are specified as well.

For data collection and analysis, systematic review, interview, questionnaire, discussion and requirements analysis were used. Each of the method is detailed with the procedure of applying and its impact on the application development. Such methods as software prototyping, usability testing and software testing were used as experimental component of the research. Description of methods and its meaning for the application development is provided.

Critique of the each used method in the research was provided as well.

CHAPTER 4. REQUIREMENTS SPECIFICATION

This Chapter discloses requirements specification for the "Diabetes Care" application.

Technological and medical basis of the requirements are introduced based on the research questions stated in the beginning of the development and medical opinion and suggestions of doctors who participated in the development.

There are numerous amounts of different requirements that are created to be applied to developing systems. However, the requirements that effect the "Diabetes Care" application development the most, explained in the Chapter. Functional and non-functional requirements were analyzed.

To describe functional requirements specification for the application, use case and activity diagrams are provided. To describe non-functional requirements specification such requirements as usability, performance, maintainability, security, reliability and efficiency are disclosed in a relation to the application.

During the process of requirements analysis, the IEEE Guide to Software Requirements Specification 830-1984 and Open Process Framework are used.

4.1 Technological Basis of the Requirements

According to the research questions *(see section 1.3, Research Questions)*, the basis of requirements specification should be built upon solution for ***data transfer***, ***design,*** and ***data processing and representation*** *(see Figure 16)*.

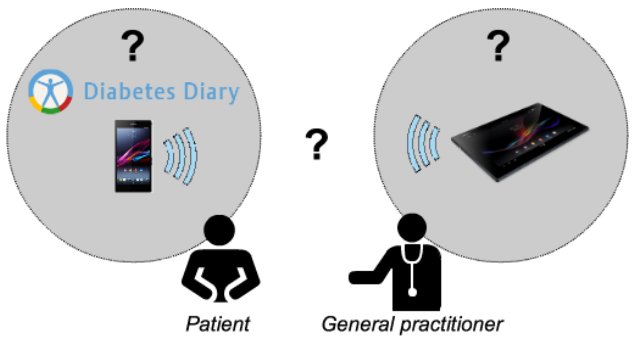


Figure 16. Research questions

The solutions for the mentioned directions are disclosed below.

Data transfer

Due to the fact that the "Diabetes Diary" application is available for both Android operating system (OS) and iOS, ***Android OS has been selected*** for the recent development.

In search of technical solutions, such technologies were considered, ease of use, speed and security of which are combined together. For this reason, an attention was paid to technologies, creation and development of which are relatively new, however, the existence of which has aroused the interest of the technical society. For instance, near field communication (NFC) technology is used on the basis of Android OS, but has recently become a development for iOS [63]. This fact confirms the interest of technical professionals in the use and development of mentioned technology.

In facsimile, near field communication technology has been selected for the current research as the basis for data transfer from patient's device to general practitioner's tablet. Android OS supports ***Android Beam*** feature *(see section 2.2.3, Near Field Communication technology),* which provides paring and data transfer over Bluetooth technology by NFC authentication *(see Figure 17*). Detailed comparative analysis of possibly used technologies for the recent development was performed in the Chapter 8, *Discussion (see section 8.1, Motivation for Technology Choice).*

Figure 17. Graphical representation of the sub solution for data transfer

Design

Since the data passed to the doctor, collected in the "Diabetes Diary" application, it would be appropriate to use the same logic of objects visualization. For instance, icons such as glucose level, insulin, physical activity and carbohydrate should be understandable to the user *(see Figure 18).* The user interface should be comfortable in use and not deliver to its users an inconvenience of use. It means the design should be based on ergonomic principles. For full design description, see Chapter 5, *Design.*

Figure 18. Objects visualization

Data processing and representation

Scheme how process the data for further representation for a medical overview is illustrated below *(see Figure 19)*. The database exported from the "Diabetes Diary" application is stored in CSV format in some folder created by the system of the application. The "Diabetes Care" application running on the patient's device will access the folder and take the database to send to the general practitioner's tablet. Once the patient's CSV database is on the tablet, the system of the "Diabetes Care" application will convert it into DB format and the data will be ready to be represented by the application further. Developed statistical rules for data representation and decision support are explained in the Chapter 5, Design *(see section 5.3, Logic Behind the Data Representation)*.

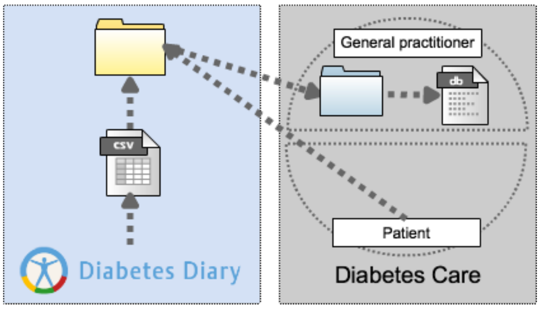


Figure 19. Graphical representation of data processing

4.2 Medical Basis of the Requirements

For the reason, the research proceeded on the basis of the Norwegian Centre of Integrated Care and Telemedicine; the results were based on the characteristics of general practice in Norway. Meetings were arranged with medical doctors *(see Table 5, Interviews, questionnaire and discussions during the study)*. These meetings featured to cover general practice particularity and requirements that have to be met from medical perspective.

According to collected information from meetings with three medical doctors (Nils Kolstrup, Gerd Ersdal, Gro Berntsen), following requirements of diabetes care in general practice for application were identified and analyzed *(see Table 7)*.

Table 7. Particularity of general practice and requirements to meet

Particularity of general practice	Requirement to meet
Approximate time for consultation with any patient is set to 15 minutes for which not only procedure of prevention and control of the disease should be performed but as well to enter the data into the information system which used by general practitioners. Given the fact that patients may have consultations every six months, the time provided for consultation is very limited.	If prompted application will imply additional time for use, it will not be used. The design should be very intuitive to its users (→ *usability, performance*).
Occasionally during the consultation, after general practitioner provides some recommendations, he or she enters the information about patient's condition into the	If the application will allow patients to be used by them, then its status in general practice became stronger (→

information system (using electronic health record), and for a patient this time spent for waiting.	*functionality*).
When patient monitors his or her condition, more often he or she keeps a diary where all records concerning the measurement of glucose level, taken insulin injection, time spent in physical activity, and carbohydrates ate. Often the last three parameters are conducted not regularly in comparison with the first. Patient provides to a general practitioner these measurements, however, to statistically process the data, for example, over the past six months, it may take considerable time and doctors usually do not do it thoroughly.	If the application will reduce the time for processing of statistical data and in addition will include decision support function, it will be vital in the relation of practical use. Also, morning glucose levels are extremely important in diabetes care, and if the application will provide such level it will be considered as very useful for diabetes primary care (→ *usability*).
Most mobile diabetes diaries are designed for patients with diabetes to maintain measurements. Nevertheless, these measurements in such applications do not pose much value to general practitioners.	If the application will allow to use the information from mobile diary, it will be perceived as a promising feature for diabetes management if primary care (→ *functionality*).

4.3 Application Description

The description of the "Diabetes Care" application includes application context and functions, user characteristics, assumptions and dependencies. Such description was created to provide initial understanding of the application in general and the way requirements specification was analyzed. IEEE Guide to Software Requirements Specification 830-1984 [61] and Open Process Framework were used for analysis [62].

4.3.1 Application Context and Functions

The application to support diabetes management in general practice involves ***two types of users***: patients with diabetes and general practitioners. Application will be running on patient's smartphone and general practitioner's tablet and will represent two different applications from the perspective of use, application accesses based on the user identification. The patient version mainly represents data sending function and the tablet's version represents data receiving function and support for general practitioners in diabetes management based on the obtained and represented in an advanced way data. As an extension, it was decided to include in the version for patients appointments and recommendations management based on the discussion results with medical doctors *(see Table 7)*. For instance, such functionality helps to keep all appointments related to diabetes condition and comments based on recommendations suggested by a general practitioner in the application. Due to the reason, the application was divided into major and minor purposes of use.

The ***major purpose of the application use*** is to transfer exported from the "Diabetes Diary" application CSV database that contains information about diabetes self-management of a patient (blood glucose, insulin intake, physical activity and carbohydrates intake measurements) to a general practitioner and process the data in an advanced way with clinical decision support. ***The minor purpose of the application use*** is to manage in the "Diabetes Care" application appointments and recommendations for a patient.

Based on the purposes, there are three ***main and*** two ***minor functions of the application*** that are explained in the table below *(see Table 8)*.
Purposes of use and its resulting of application functions were discussed with medical doctors

and are based on their opinion and suggestions gathered during the development *(see Table 5, Interviews, questionnaire and discussions during the study).*

Table 8. Description of major and minor functions of the application

Major functions	*Description*
Data transfer	The function shall provide CSV database transfer from the patient's device to the general practitioner's tablet. The transmission shall be done by Bluetooth technology over NFC authentication (Android Beam feature).
Data processing and representation	The data shall be obtained and be prepared for a graphical representation in an advanced way (data conversion from CSV to DB). It means the statistics and rules shall be developed to apply to the data representation. The CSV database contains measurements that have to be viewed by a general practitioner in a required way with dependency on period and time.
Decision support	The obtained data represented graphically shall include elements of decision support based on medical documentation and international standards in diabetes management.
Minor functions	*Description*
Appointments management	Appointments management as well as recommendations management shall be supported by the application for patients. It means that application shall allow users save any calendar events related to the diabetes management and record comments from general practitioner based on the data observation. Special templates shall be used to simplify application use for patients.
Recommendations management	

To conclude the application's functions, the diagram was created *(see Figure 20)*. Such diagram shows application frame for both of the types of users and allocation of major and minor functions.

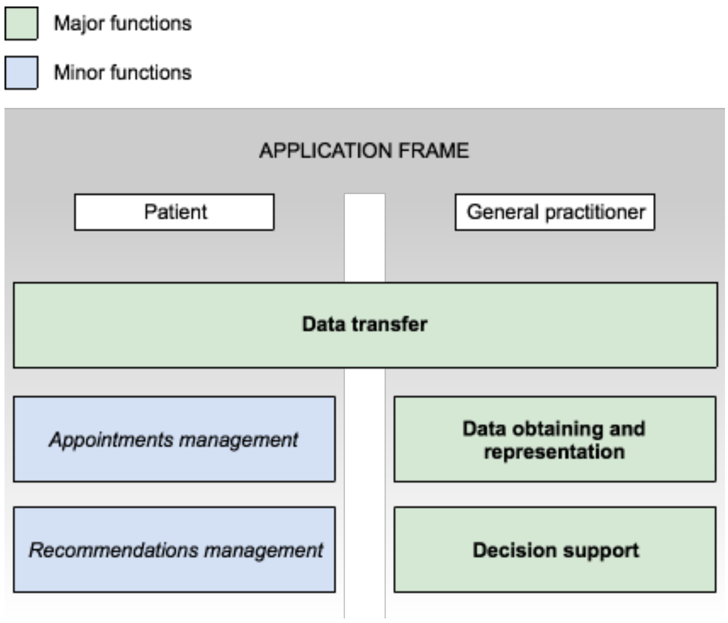


Figure 20. Major and minor functions of the application in its frame

4.3.2 User Characteristics

User characteristics are divided into two main subjects: fact of being patient or general practitioner, and familiarity with devices' use.

Fact of being patient or general practitioner
As it was mentioned earlier, there are two types of users: "Patient" user and "General Practitioner" user. "Patient" user has to be a person with diabetes condition and use "Diabetes Diary" application; "General Practitioner" user has to be a practicing general practitioner.

Familiarity with devices' use
Both of the user types have to be familiar with how to use their portable devices (for example, how to turn on/off device, access applications) and be prone to learn how to use new applications in order it will be needed for a first introduction of the application.

4.3.3 Assumptions and Dependencies

Assumptions and dependencies of the "Diabetes Care" application are structured into four directions: relation between "Diabetes Care" and "Diabetes Diary" application, technology for data transfer, devices used and storage.

(1) ***Relation between "Diabetes Care" and "Diabetes Diary" application***

The "Diabetes Care" application is based on the CSV database exported from the "Diabetes Diary" application. Only the data contained in the database can be obtained and represented in an advanced way to a general practitioner.

(2) ***Technology for data transfer***

The application uses Android Beam feature to transfer the data. The data sent through Bluetooth technology over near field communication authentication. To use such way of data transfer, embedded NFC adapter for both of the devices is a necessity.

(3) ***Devices***

General practitioner holds any portable Android OS tablet and patient holds any portable Android OS smartphone.

(4) ***Storage***

The data added in patient's device (appointments and recommendations management) will be stored in the internal memory of the device. The data transferred to a general practitioner's device will be automatically deleted when the application is completely closed or replaced with a new data if the application was not closed but new patient is transferring his database. Such decision made to protect privacy and possibility of a medical error.

4.4 Requirements Specifications

4.4.1 Functional Requirements

To describe functional requirements specification for the "Diabetes Care" application, use case was provided. In addition, activity diagrams were provided to disclose possible activity flows, or scenarios, for main users of the application (patient and general practitioner).

4.4.1.1 Use Case

It was considered to have three actors in the use case representation: "General Practitioner" actor, "Patient" actor and "Application" actor. All activities in the present use case are considered to be happening in the environment of the application. Use cases for each actor are specified below the use case diagram *(see Figure 21)*. Description of use cases is represented in three tables further *(see Tables 9 – 11)*.

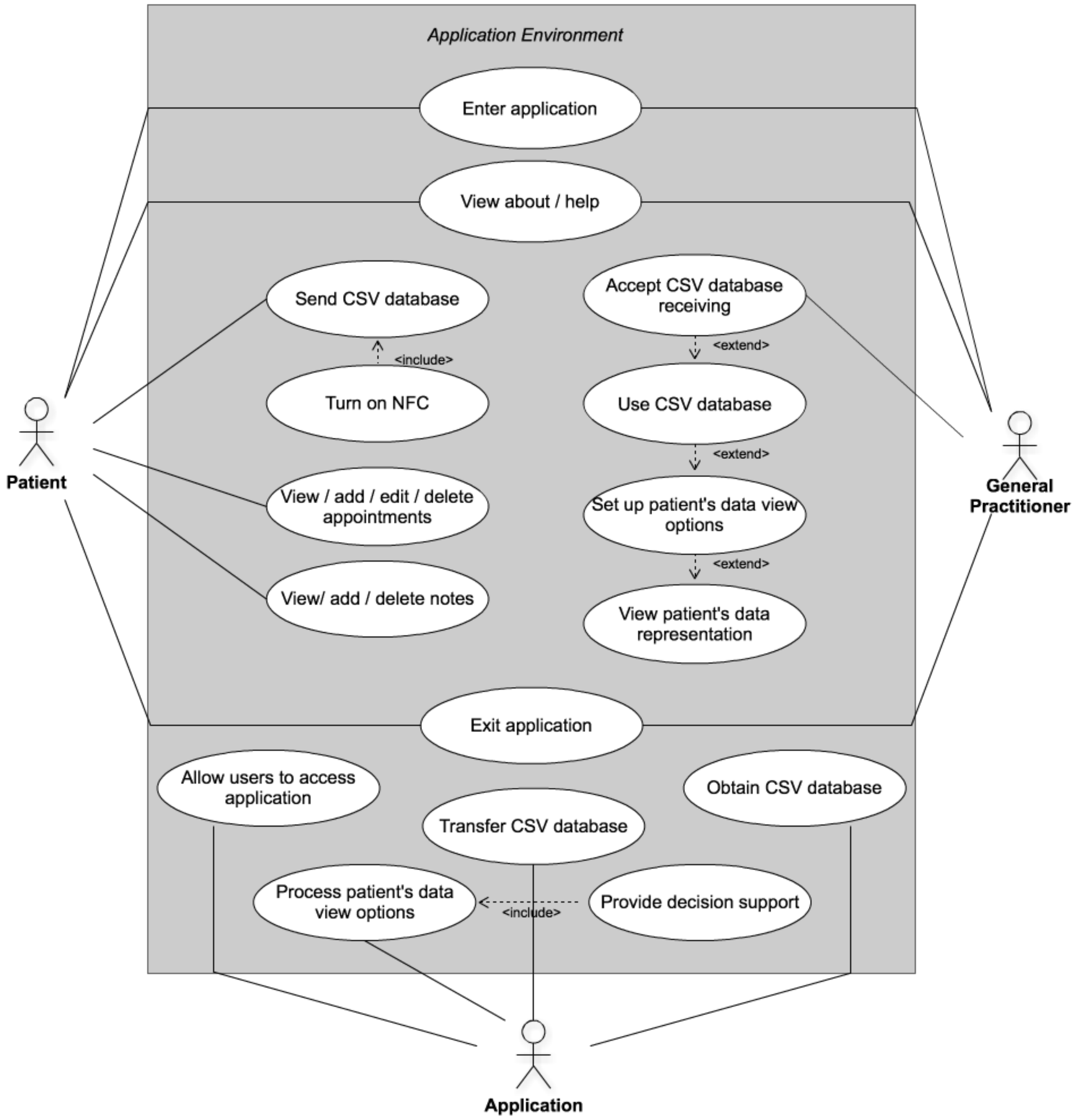


Figure 21. UML use case

Table 9. Description of use cases for "Patient" actor

"Patient" actor	
Enter application	Actor enters the application.
View about / help	Actor accesses such sections as "Help" and "About" for additional information related to the application use.
Send CSV database	Actor sends CSV database exported from the Diabetes Diary application.
Turn on NFC technology	Actor turns on NFC technology in order to send CSV database.
View / add / edit / delete appointments	Actor navigates within "Appointments" section where such functions as view list of appointments, add new appointment, edit existing appointment and delete existing appointment are provided.
View / add / delete notes	Actor navigates within "Notes" section where such functions as view list of notes, add new note and delete existing note are provided.
Exit application	Actor closes the application.

Table 10. Description of use cases for "General Practitioner" actor

"General Practitioner" actor	
Enter / close application	Actor enters the application.
View about / help	Actor accesses such sections as "Help" and "About" for additional information related to the application.
Accept CSV database	Actor accepts CSV database receiving for further procedure.
Use CSV database	Actor uses CSV database for
Set up patient's data view options	Actors sets up CSV database view options in "Calendar" section to view an advanced data representation.
View patient's data representation	Actor views an advanced data representation.
Exit application	Actor closes the application.

Table 11. Description of use cases for "Application" actor

"Application" actor	
Allow users to access application	Actor allows users to access application as a "Patient" or a "General Practitioner".
Transfer CSV database	Actor transfers CSV database in one direction from the "Patient" user to the "General Practitioner" user using Android Beam feature.
Obtain CSV database	Actor obtains CSV database by preparing data for further processing (data converted from CSV to DB).
Process patient's data view option	Actor processes patient's data view according to the request from the "General Practitioner" user.
Provide decision support	Actor provides decision support when the data from CSV database is represented in an advanced way.

4.4.1.2 Activity Diagrams

Activity diagrams are created for both main types of users: "Patient" and "General Practitioner" *(see Figures 22 – 23)*. For each type of users activity diagrams are structured into scenarios to simplify the picture of activity flows. For both of the activity diagrams, tables with description of scenarios for users are provided first *(see Tables 12 – 13)*. By default it is suggested that "Patient" user uses a smartphone with 5-inch screen size, "General Practitioner" user uses a tablet with 10-inch screen size.

Table 12. Description of activity diagram for "Patient" user

Scenario		Description
1	Enter application/ Entrance page	User enters application and starts activity from the entrance page.
1A	View help/about pages	User goes to pages "Help" or "About" to see information related to the application.
1B	Close application	User chooses to close application. To leave the application user has to confirm the request. User can also cancel request to close application and be sent to the entrance page again.
2	Access application	User accesses the system of the application as a concrete type of users from the entrance page.
2A	Access as General Practitioner user	User accesses application as a "General Practitioner" but will be sent back to the entrance page due to the reason the user holds a device with 5-inch screen size and can be accessed as a "Patient" user only.
2B	Access as Patient user	User accesses application as a "Patient" user.
3	Home page	After accessing application as a correct type of users, "Home" page is entered by default. Such activities as send database, close application or view "Help" and "About" pages are available.
3A	Send database	User sends exported from Diabetes Diary application database to "General Practitioner" user. To send the data, user has to confirm data transmission. User cancels data transmission if it is not needed. After data is sent, user is sent to the "Home" page.
3B	View help/about pages	User goes to pages "Help" or "About" to see information related to the application.
3C	Close application	User chooses to close application. To leave the application user has to confirm the request. User can also cancel request to close application and be sent to the "Home" page again.
4	Appointments page	User goes to the "Appointments" page where the accesses to view list of appointments or add new appointments are open.
4A	List of appointments/ View appointments	User view list of appointments that have created before. User has a possibility to choose any existing appointment and see its full content, delete or edit the appointment. Once the appointment is deleted or edited, user is sent back to the list of appointments.
4B	Add new appointment	User adds new appointment. Once the appointment is created, user is sent back to the "Appointments" page.
5	Notes page	User goes to the "Notes" page where the accesses to view list of notes or add new note are open.
5A	List of notes/View notes	User view list of notes that have created before. User has a possibility to choose any existing note and see its full content or delete the note.

		Once the note is deleted, user is sent back to the list of notes.
5B	Add new note	User adds new note. Once the note is created, user is sent back to the list of notes to demonstrate the note is created.

Table 13. Description of activity diagram for "General Practitioner" user

Scenario		Description
1	Enter application/ Entrance page	User enters application and starts activity from the entrance page.
1A	View help/about pages	User goes to pages "Help" or "About" to see information related to the application.
1B	Close application	User chooses to close application. To leave the application user has to confirm the request. User can also cancel request to close application and be sent to the entrance page again.
2	Access application	User accesses the system of the application as a concrete type of users from the entrance page.
2A	Access as Patient user	User accesses application as "Patient" but will be sent back to the entrance page due to the reason the user holds a device with 10-inch screen size and can be accessed as a "General Practitioner" user only.
2B	Access as General Practitioner user	User accesses application as a "General Practitioner" user.
3	Home page	After accessing application as a correct type of users, "Home" page is entered by default. Such activities as use patient's data, close application or view "Help" and "About" pages are available.
3A	Use patient's data	User receives patient's database and, in order to use it, has to request it from the application.
3B	View help/about pages	User goes to pages "Help" or "About" to see information related to the application.
3C	Close application	User chooses to close application. To leave the application user has to confirm the request. User can also cancel request to close application and be sent to the "Home" page again.
4	Calendar page	User goes to the "Calendar" page where the configuration of data representation shall be set up for further procedure.
4A	Set up calendar and time preferences	User choses any period from calendar and time that is needed for representation of calculated data in an advanced way.
4B	View patient's data	User views advanced data representation for all parameters (blood glucose level, insulin intake, physical activity, carbohydrates intake) for a period and time that were set up by the user.

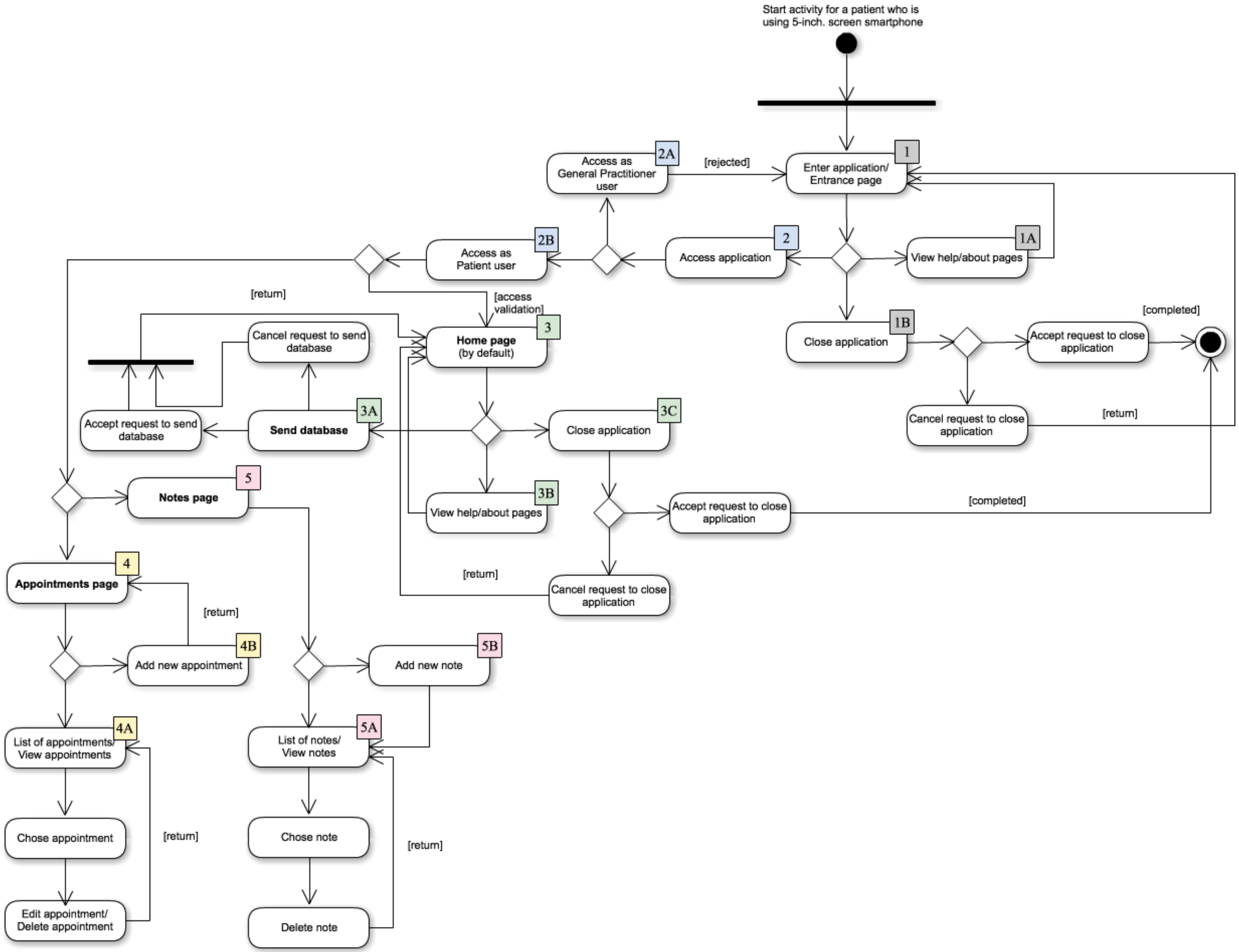


Figure 22. Activity diagram for “Patient” user

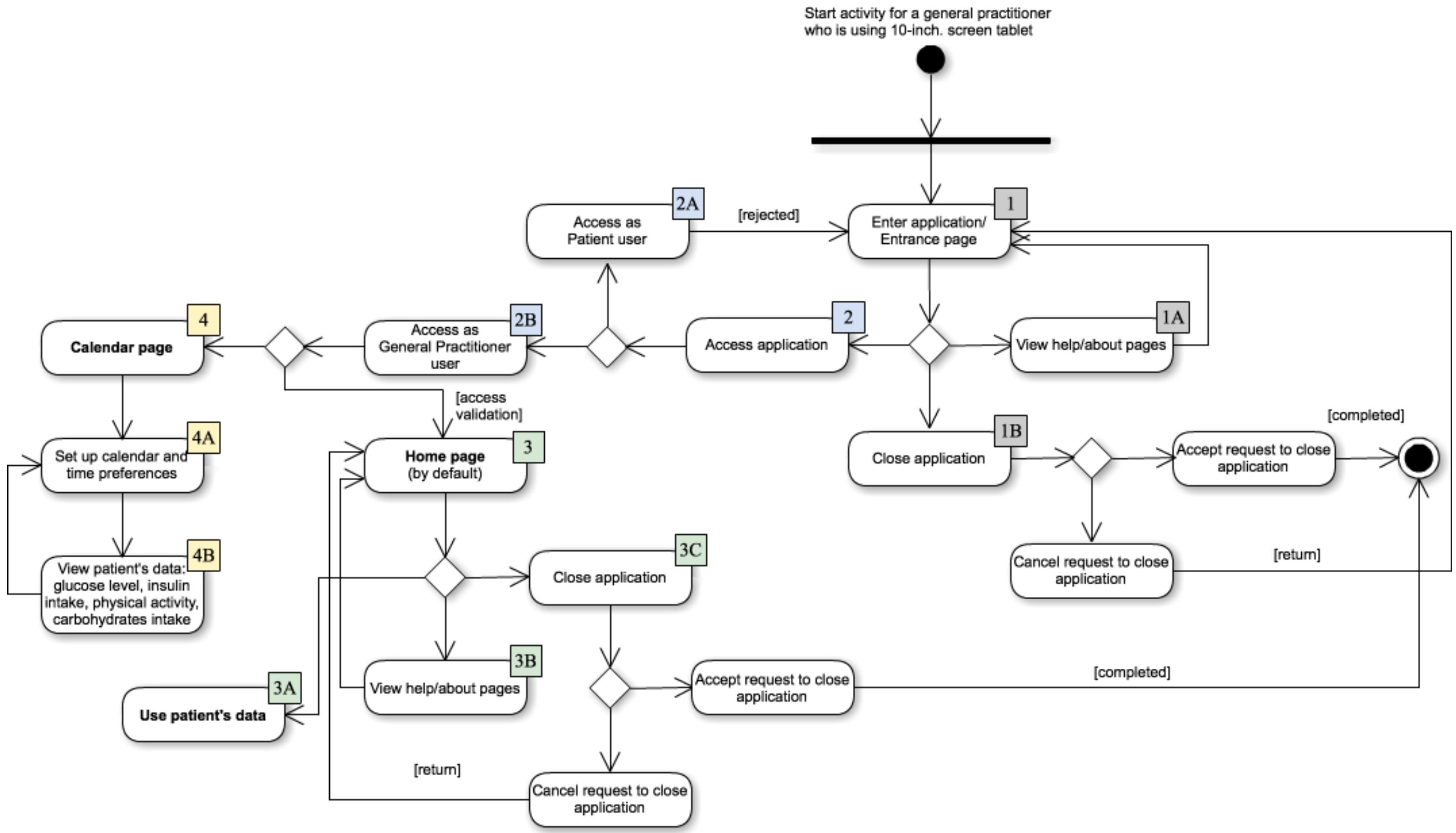


Figure 23. Activity diagram for "General Practitioner" user

4.4.2 Non-Functional Requirements

To describe non-functional requirements specification for "Diabetes Care" application such requirements as usability, performance, maintainability, security, reliability and efficiency were disclosed with its meaning to the application.

4.4.2.1 Usability

Usability requirements reflect effective use of the application by its users. In order to provide a description of usability requirements for "Diabetes Care" application, such quality factors as attractiveness, credibility, differentiation, ease to enter, ease to learn, ease of location, ease to remember, ease to use, effectiveness, error minimization, navigability, preference, retrievability, suitability, understandability and user satisfaction were analyzed *(see Table 14)* [62].

Table 14. Description of usability requirements

Quality factors	*Description of requirements*
Attractiveness	The application's user interface shall be attractive to its users and engage its user's attention. All main functions shall be implemented in the user interface and attract users to proceed with application use. Positive user experience and further willingness of its users to repeat usage should be provided by the application design.
Credibility	The application shall elicit a feeling of trust in its users related to developer's competence and correct output.
Differentiation	The application shall differ from other similar applications and be competitive to them.
Ease to enter	The application shall be easy for its users to use and not require its users to perform additional steps before they can begin to use it. Entrance to the application should be unambiguous and clear and intuitive.
Ease to learn	The application shall be easy for its users to learn how to perform their tasks. Intensive training to learn how to use the application to perform their tasks shall not be required. Tasks performing should be able for the users without prior training.
Ease of location	Help facilities, as well as the application, shall be easy to locate. The application's user interface shall be created in a way for users to access any page without dependency on its location within minimum of time.
Ease to remember	The application shall be easy for its users to remember how to use and perform their tasks. Functionality of each feature in the application should be provided in a way to better recognition for further use.
Ease to use	The application shall be easy for its users to use and to lead its users to perform tasks without errors. Simplicity outside should be applied to the user interface.
Effectiveness	The application should provide to its users more effective tasks performing and improve the effectiveness for its users generally. User's movements required by the application shall be minimized.
Error minimization	The application shall minimize the possibility of errors' appearing made by its users and provide an environment to perform users' tasks without errors. If any error appears it has to be understandable by the

	application's users.
Navigability	The application's user interface shall be intuitive for its users to navigate to main functions and in the frame of the application generally. Physical and psychological comfort for users shall be supported by the application's design.
Preference	The application should be preferred by its users to use instead of other alternatives. The application shall evoke its user's willingness to recommend the application to other parties.
Retrievability	The application shall make possible to process the information in the way it is needed for its users. Flexibility of the data representation should be implemented in the application.
Suitability	The application shall be suitable for both novice and experienced users to use. The application shall be suitable for most adults with diabetes and general practitioners who are managing diabetes care in general practice.
Understandability	The application's user interface shall be intuitive and understandable to its users. User manual for the application shall be unambiguous and logically organized.
User satisfaction	The application shall provide its users satisfaction and be important to its users to continue to use.

4.4.2.2 Performance

Performance requirements represent timing characteristics that have to be applied to the application. To detect performance requirements for "Diabetes Care" application, such requirements as jitter, latency, response time and throughput requirements were explained *(see Table 15)* [62].

Table 15. Description of performance requirements

Requirements	*Description of requirements*
Jitter requirements	The application shall provide correct events appearing based on requests from the users. Once event was requested, it should happen. Events without requests shall not appear.
Latency requirements	The application shall not take too long to complete any user's request. The maximum acceptable time for any task completion but data transmission and export shall be no longer than 2 seconds. The maximum acceptable time for initiating contact between devices and data transmission shall be no longer than 30 seconds. The maximum acceptable time for data export shall be no longer than 5 seconds.
Response time requirements	The application shall not destruct its users due to the made request. Once the user made the request, it has to be understandable. The maximum time delay for any task completion but data transmission and export shall be no longer than 0.5 seconds. The maximum time delay for initiating contact between devices and data transmission shall be no longer than 10 seconds. The maximum time delay for data export shall be no longer than 1 second.
Throughput requirements	The application shall support all use case paths and be tolerant to frequent exploitation of its users.

4.4.2.3 Security

Security requirements provide a status of the application to prevent and react to events related to data sensitivity. Such requirements as access control, integrity and privacy were observed with a relation to the "Diabetes Care" application *(see Table 16)* [62].

Table 16. Description of security requirements

Requirements	*Description of requirements*
Access control requirements	The application shall identify types of users. Devices with a screen size smaller than 7-inch shall be identified as "Patient" user's device and allow access for the type of users; devices with a screen size 7-inch or bigger shall be identified as "General Practitioner" user's and allow access for the type of users. The application shall allow its users to access informative pages before accessing as a concrete type of users.
Integrity requirements	The application shall not transmit "csv" database if authentication over NFC was not preceded or interrupted. The application shall ask the receiver to accept or decline data transfer.
Privacy requirements	The application shall not store any personal information about the users and shall not provide any user identification. Transmitted "csv" database shall be deleted after the application has been closed and entered again; transmitted database shall be replaced by new incoming database to avoid the use of incorrect database.

4.4.2.4 Reliability

Reliability requirements relate to functioning without failures [62]. The application shall operate without failures under appropriate use. The maximum permitted number of failures per one year should be limited to 3 times. The application's mean time between failures shall be at least 3 months. Such listed requirements have been applied to the "Diabetes Diary" application.

4.4.2.5 Efficiency

Efficiency requirements refer to effective use of technical resources. The application provides data transferring through Bluetooth technology over NFC authentication (Android Beam feature), which requires use special hardware. The "Patient" user shall hold a smartphone with running Android OS v.4.0 or higher and embedded NFC adapter. The "General Practitioner" user shall hold a tablet with running Android OS v.4.0 or higher and embedded NFC adapter.

4.5 Summary

In this Chapter requirements specification for the "Diabetes Care" application were analyzed based on the IEEE Guide to Software Requirements Specification 830-1984 and Open Process Framework documentation.

First, technological and medical basis of the requirements was introduced. It was explained from both of perspectives how the requirements specification was effected by research questions and medical opinion.

Second, was provided application description with disclosed context and functions, user characteristics, assumptions and dependencies. Application description was provided for a purpose to evoke initial understanding of the reader about the development.

Then, requirements the most effecting application development were explained. Both functional and non-functional requirements were disclosed in a relation to the application. To describe functional requirements specification, use case and activity diagrams were illustrated. To describe non-functional requirements specification, usability, performance, maintainability, security, reliability and efficiency were introduced.

CHAPTER 5. DESIGN

In this Chapter the design development is clarified.

The general overview of the application and its implemented user interface are illustrated. “Diabetes care” application has two modules (accesses) for different types of users; modules for two types completely defer from each other and cover different functionality purposes. The application was created based on the opinion of medical doctors and technical experts in the field of medical informatics and telemedicine.

Statistical analysis and logic behind the data representation are provided with examples. General procedure, decision support function and rules applied to the data for representing in an advanced way are covered in the Chapter as well. For data representation statistics Norwegian guidelines for diabetes management in general practice was used. The guidelines are similar to others worldwide and decision support function of the application correct without dependency of the country.

During the development process, three versions of the application were revised and final issues were resolved by the implementation. Analysis of changes in user interface is made to show the evolution of the design and how it influenced the functionality.

5.1 General Overview of the Application

“Diabetes Care” application bases on the “Diabetes Diary” application developed the Norwegian Centre of Integrated Care and Telemedicine (NST). Exported data from the “Diabetes Diary” are used in an advanced way to support diabetes management in general practice.

The application has two modules for such types of users as “General Practitioner” and “Patient”. Users have different purposes of the application use. The main purpose for a patient is to send from “Diabetes Diary” exported CSV database to a general practitioner. The main purpose for a general practitioner is to set the received data in the needed way and overview the results.

During the development process, the version for patient was extended with two more minor purposes such as to manage appointments related to the condition and to manage recommendations provided by a general practitioner during the consultation.

Patient’s version is created for a smartphone and general practitioner’s version is created for a tablet. Once the type of device is detected, the only allowed module can be accessed. This was made due to the reason patients are using smaller devices with running “Diabetes Diary” application and general practitioners need bigger screen for the data representation in order to get appropriate data representation view. For more comfortable use, “General Practitioner” user has a landscape mode and “Patient” user has a portrait mode for the application use.

The figure provided further shows the layout of the application structure *(see Figure 24).*

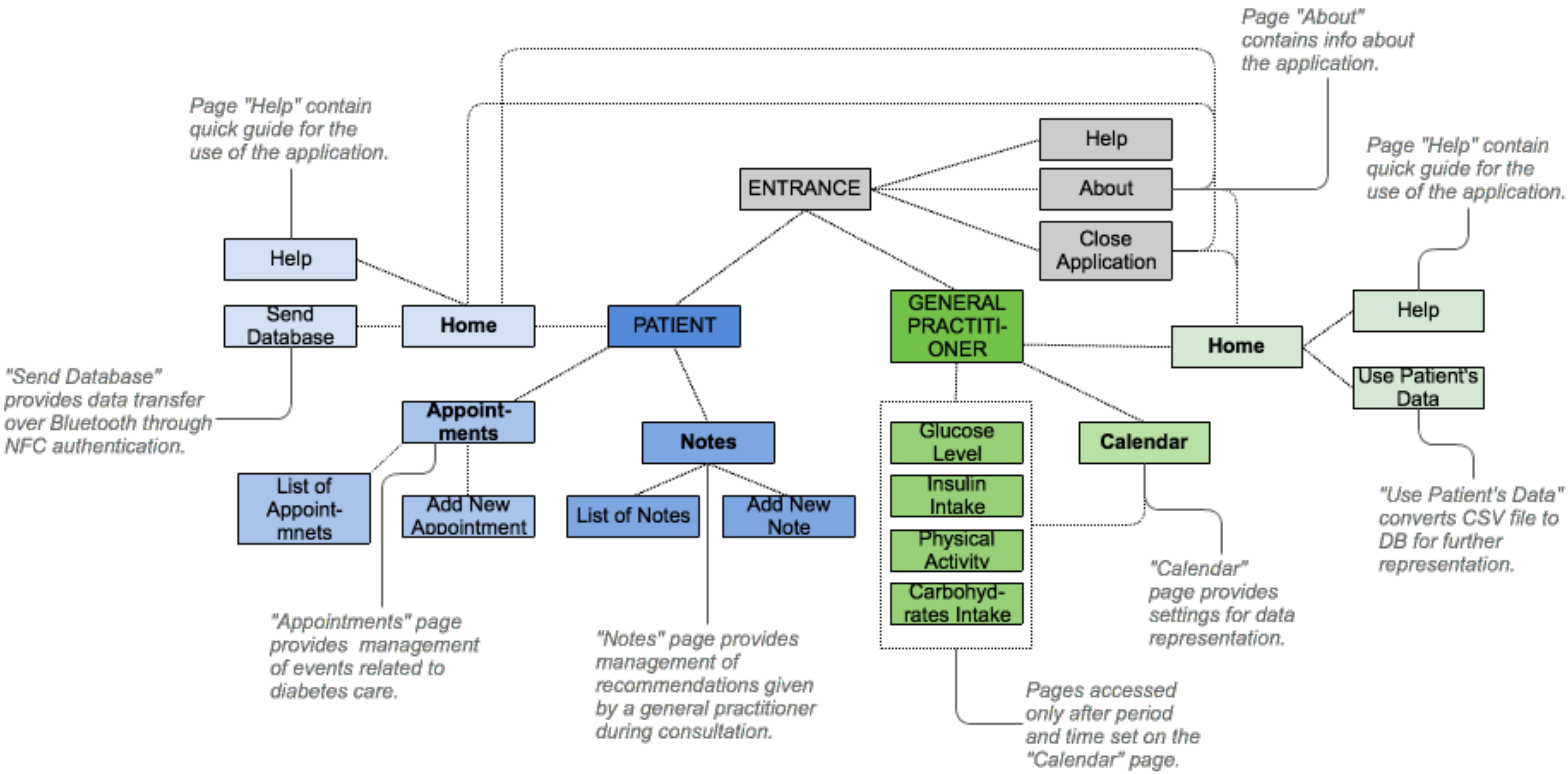


Figure 24. Layout of the application structure

5.2 “Diabetes Care” Application

In this section screenshots for “General Practitioner” user and “Patient” user, made from the running application, are illustrated. User manual for patients is provided in Appendix 7, *User manual for patient*. User manual for general practitioners is provided in Appendix 8, *User manual for general practitioner*.

5.2.1 Icon of the Application

The icon of the application is shown below *(see Figures 25, 26)*. The design of the icon was inspired by the global symbol of diabetes (blue circle) owned by the International Diabetes Federation (IDF) [64].

Figure 25. Icon of the “Diabetes Care” application

Figure 26. Icon of the “Diabetes Care” application on the screen of smartphone and tablet

5.2.2 General Practitioner Access

After the icon of the application has been activated, the entrance page appears for the user *(see Figure 27)*. As it was pointed out earlier, “Patient” module is blocked for “General Practitioner” user and can be accessed from smartphone *(see Figure 28)*. The tablet used for a trial has size of the screen equals to 10,1 inches. When “General Practitioner” icon has been pressed, the confirmation for the access is appeared *(see Figure 29)*. If user toggles “Access automatically all further entrances as General Practitioner user”, the entrance page will not appear next time the user uses the application. “About” and “Help” pages provide basic information about the application and its use. By pressing “Exit” icon, the application will be closed after user’s confirmation *(see Figure 30)*.

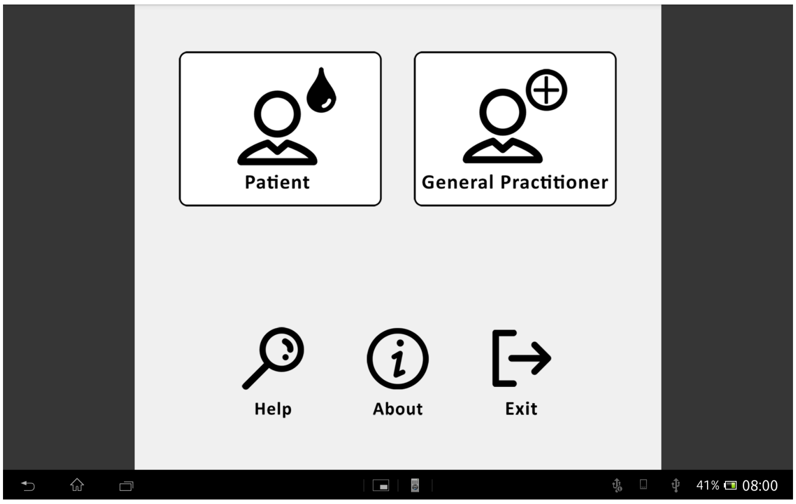


Figure 27. Entrance page for “General Practitioner” user

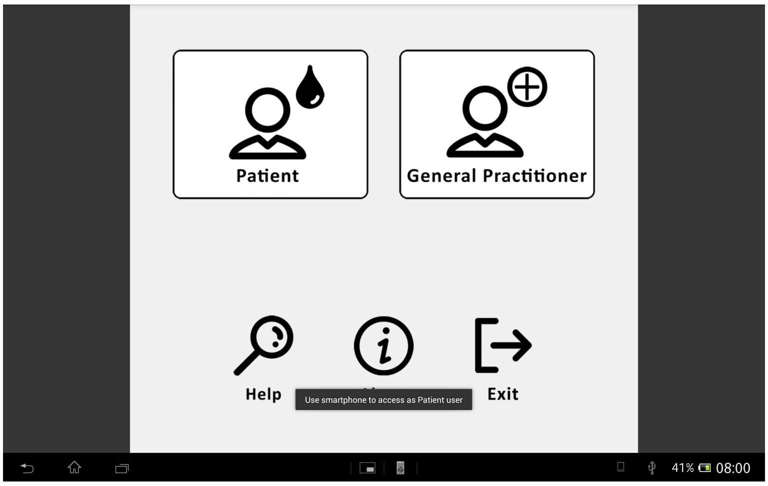


Figure 28. Denied access for “Patient” user

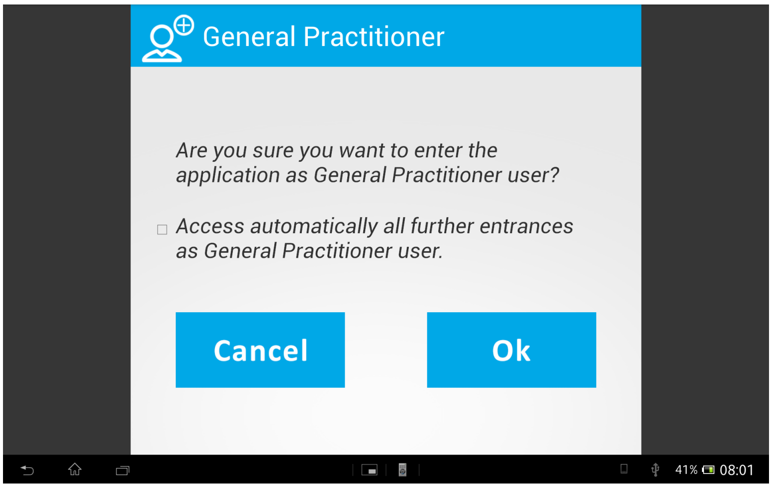


Figure 29. Confirmation to access the application as “General Practitioner” user

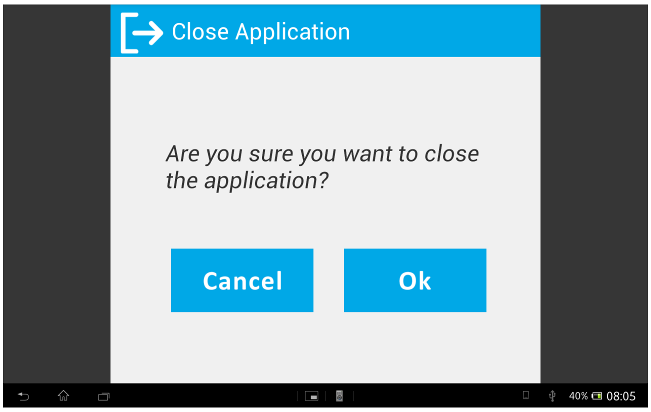


Figure 30. Confirmation to close the application

Once the application accessed as “General Practitioner” user, the “Home” page appears *(see Figure 31)*. Such pages as “About” and “Help” are possible to access from the “Home” page. “Exit” icon for closing application is also on the “Home” page.

Figure 31. “Home” page for “General Practitioner” user

When the pairing process of general practitioner’s tablet and patient’s smartphone are finished, the toast message appears on the screen that the data receiving has to be confirmed by the “General Practitioner” user *(see Figure 32)*.

Figure 32. Invoice about incoming file

The illustration of the process of exporting database, pairing devices and beaming the database is provided in the Appendix 9, *Data transfer*. User has to accept the data receiving to get CSV file from "Patient" user *(see Figure 33)*.

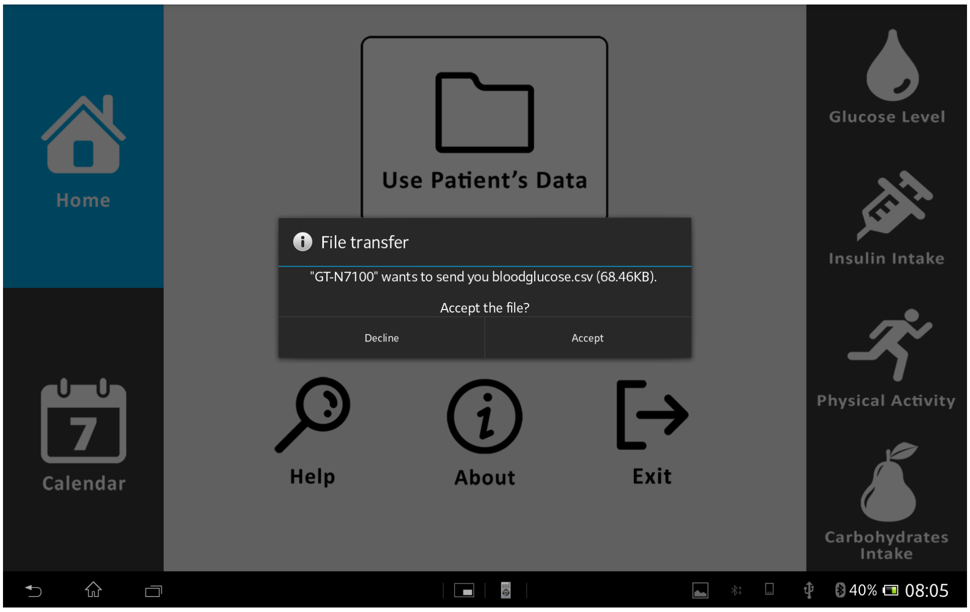


Figure 33. Database transfer

After CSV database is received by "General Practitioner" user, the icon "Use Patient's Data" has to be pressed to convert the database from CSV to DB format for data representation function. Once the data exported, toast message appears on the screen *(see Figure 34)*.

Figure 34. Exporting data for data representation

Further, the application is ready for data representation according to the period and time settings user will set on the "Calendar" page *(see Figure 35)*. User can chose such periods as last 6 months, last 3 months, last month and last week for data representation or set needed period by using "from – to" calendar function. When user presses to set the period manually, the page with real calendar appears. The user can use arrows to list months or to use special navigation tool on the bottom of the scree where with one press any months or year can be found *(see Figure 36)*. Boxes with time preferences can be chosen together, separately or in combination *(see Figure 35)*.

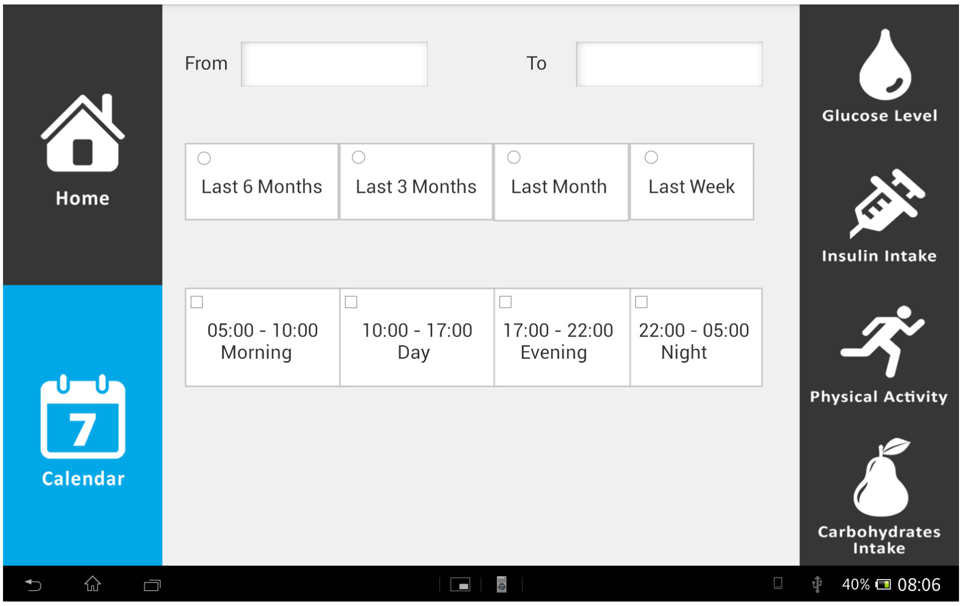


Figure 35. "Calendar" page for "General Practitioner" user

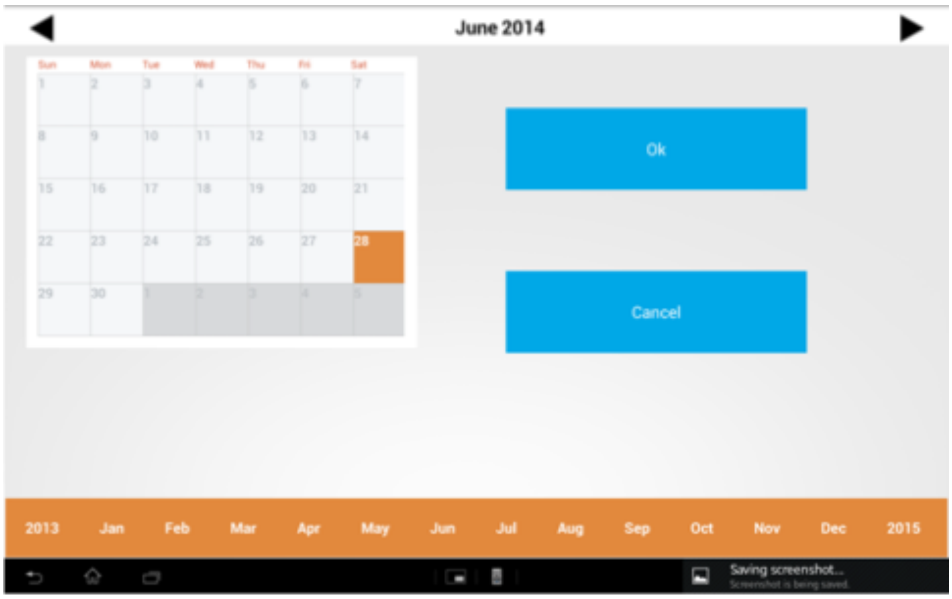


Figure 36. Calendar function for setting period manually

As the next step, after user set period and time preferences, such pages as "Glucose Level", "Insulin Intake", and "Physical Activity" and "Carbohydrates Intake" is available for an advanced data representation view with decision support function for physical activity and morning glucose levels. Further provided examples for data representation from the running application. Statistical rules and logic behind the data representation are provided later in the Chapter *(see section 5.3, Logic Behind the Data Representation)*.

Example 1. User choses period manually from 18.02.2014 to 24.02.2014 for daily average glucose levels. The data is represented according to statistical rules and illustrated below *(see Figure 37)*.

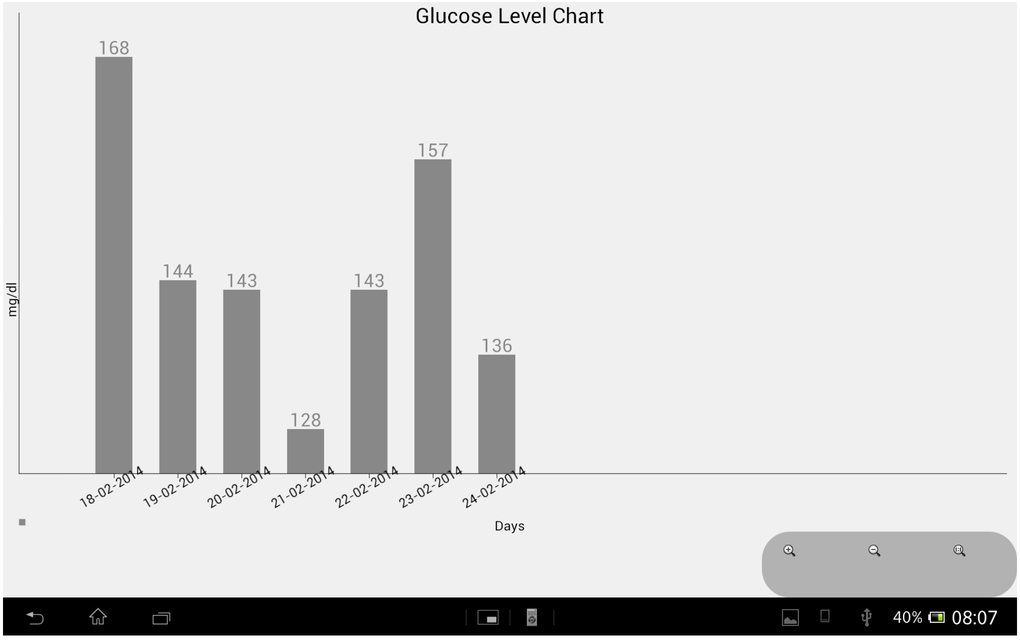


Figure 37. Data representation for glucose levels (1)

Example 2. User choses period manually from 18.02.2014 to 18.04.2014 for daily average glucose levels. The data is represented according to statistical rules and illustrated below *(see Figure 38)*. Graphs with "0" mean shows that a patient entered no data.

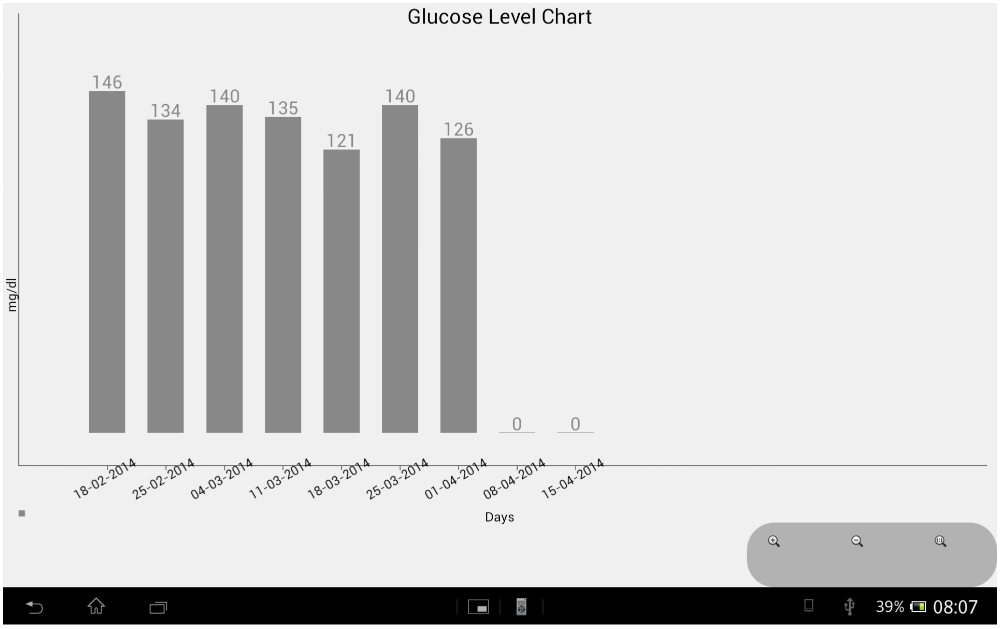


Figure 38. Data representation for glucose levels (2)

Example 3. User choses period manually from 18.02.2014 to 20.06.2014 for daily average glucose levels. The data is represented according to statistical rules and illustrated below *(see Figure 39)*. Graphs with "0" mean shows that a patient entered no data.

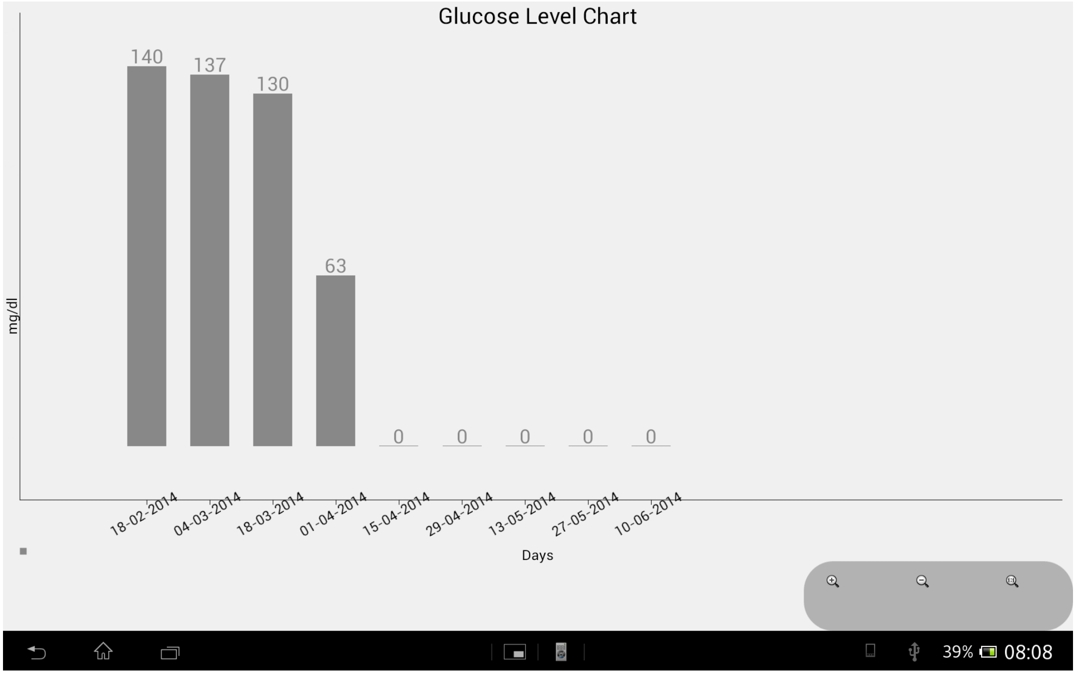


Figure 39. Data representation for glucose levels (3)

Example 4. User choses period manually from 01.03.2014 to 31.03.2014 for ***morning glucose levels*** *(05:00-10:00)*. The data is represented according to statistical rules and illustrated below *(see Figures 40, 41)*.

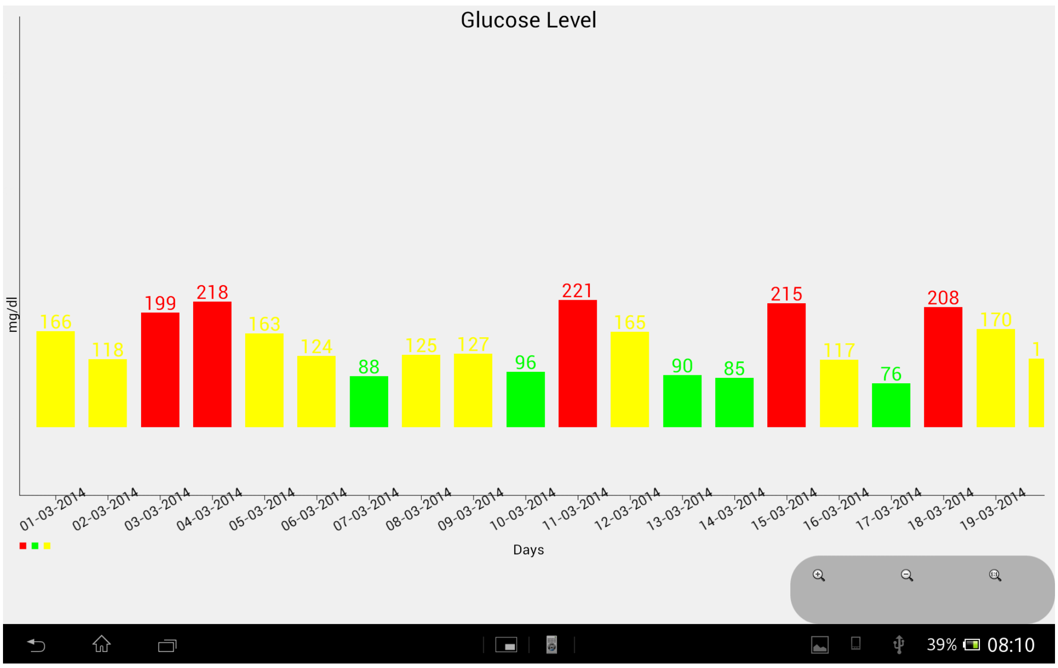


Figure 40. Data representation for morning glucose levels (4a)

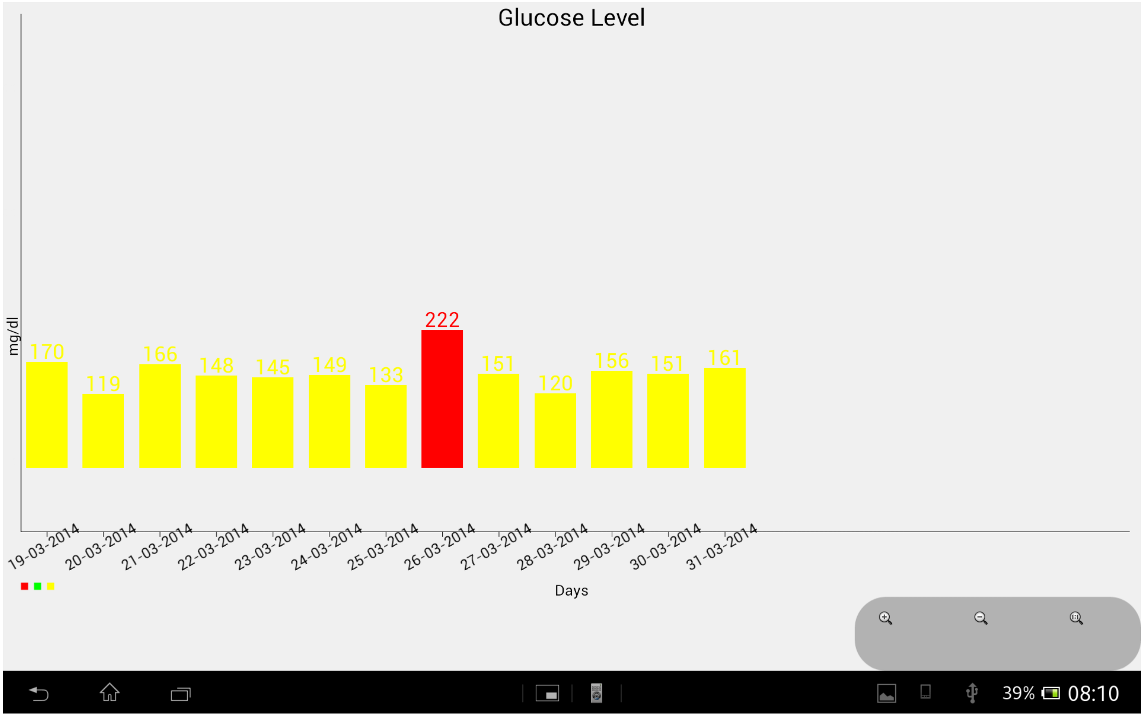


Figure 41. Data representation for morning glucose levels (4b)

Example 5. User choses period manually from 04.03.2014 to 10.03.2014 for daily insulin intake. The data is represented according to statistical rules and illustrated below *(see Figure 42)*.

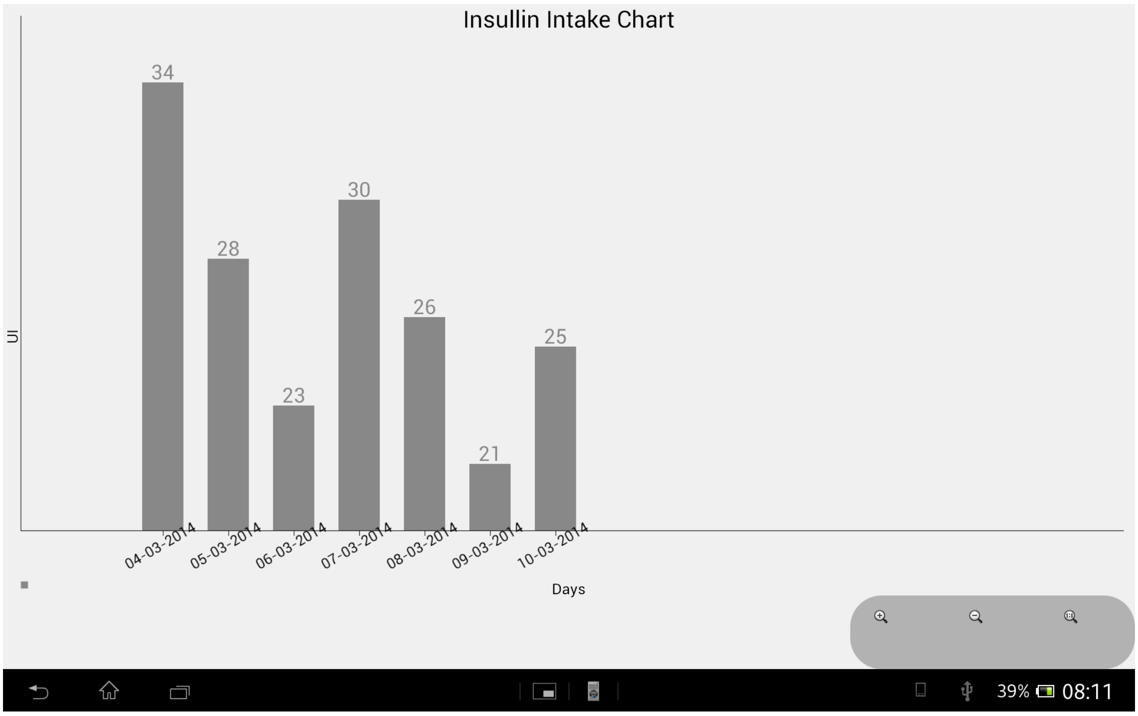


Figure 42. Data representation for insulin intakes (5)

Example 6. User choses period manually from 04.03.2014 to 22.05.2014 for daily average insulin intake. The data is represented according to statistical rules and illustrated below *(see Figure 43)*. Graphs with "0" mean shows that a patient entered no data.

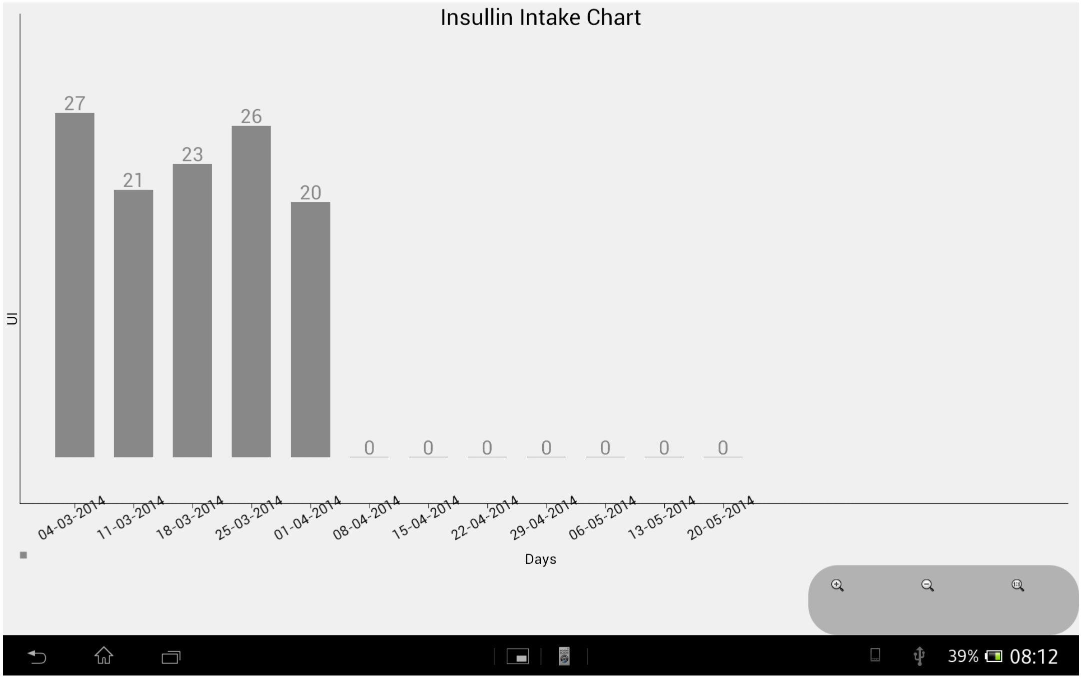


Figure 43. Data representation for insulin intakes (6)

Example 7. User choses period manually from 04.03.2014 to 20.06.2014 for daily average insulin intake. The data is represented according to statistical rules and illustrated below *(see Figure 44)*. Graphs with "0" mean shows that a patient entered no data.

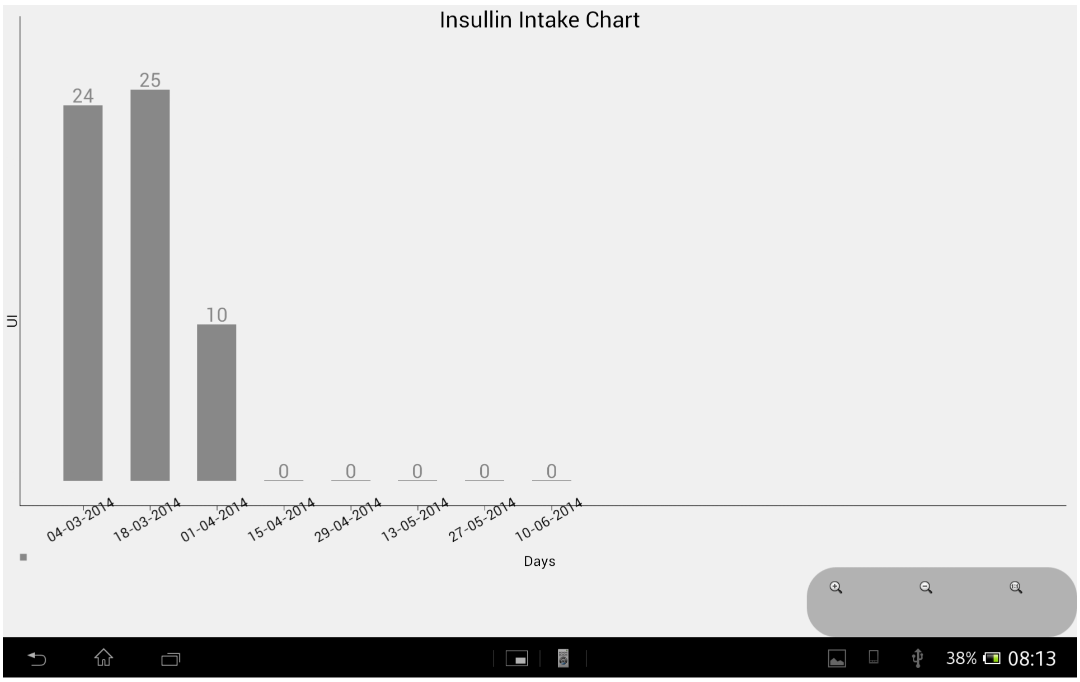


Figure 44. Data representation for insulin intakes (7)

Example 8. User choses period manually from 22.02.2014 to 28.02.2014 for daily physical activity. The data is represented according to statistical rules and illustrated below *(see Figure 45)*. Graphs with “0” mean shows that a patient entered no data.

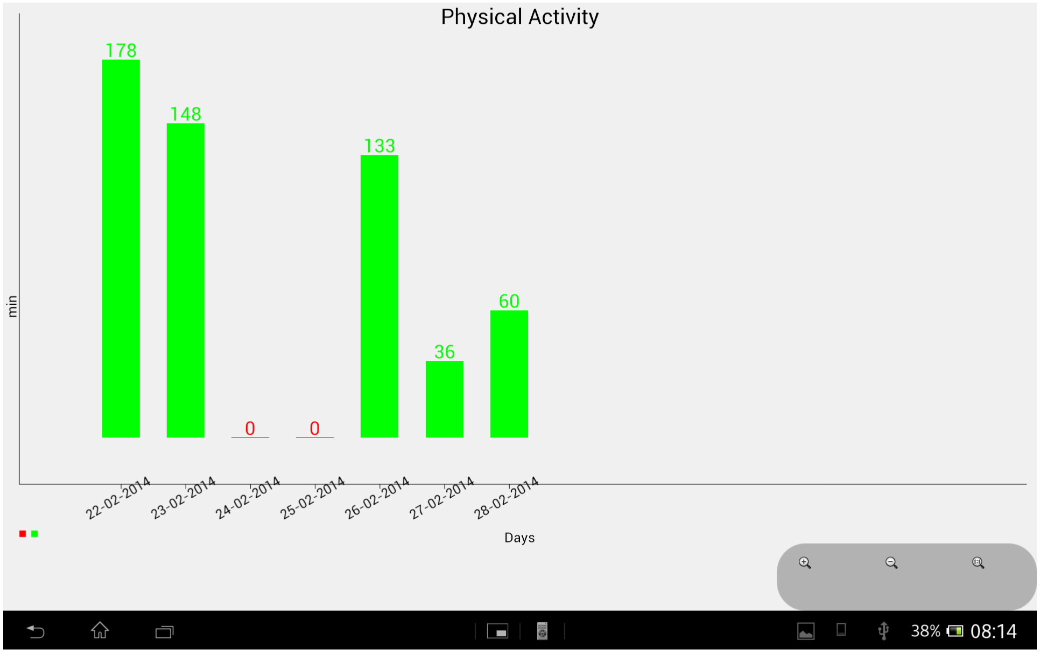


Figure 45. Data representation for physical activity (8)

Example 9. User choses period manually from 22.02.2014 to 22.05.2014 for daily average physical activity. The data is represented according to statistical rules and illustrated below *(see Figure 46)*. Graphs with “0” mean shows that a patient entered no data.

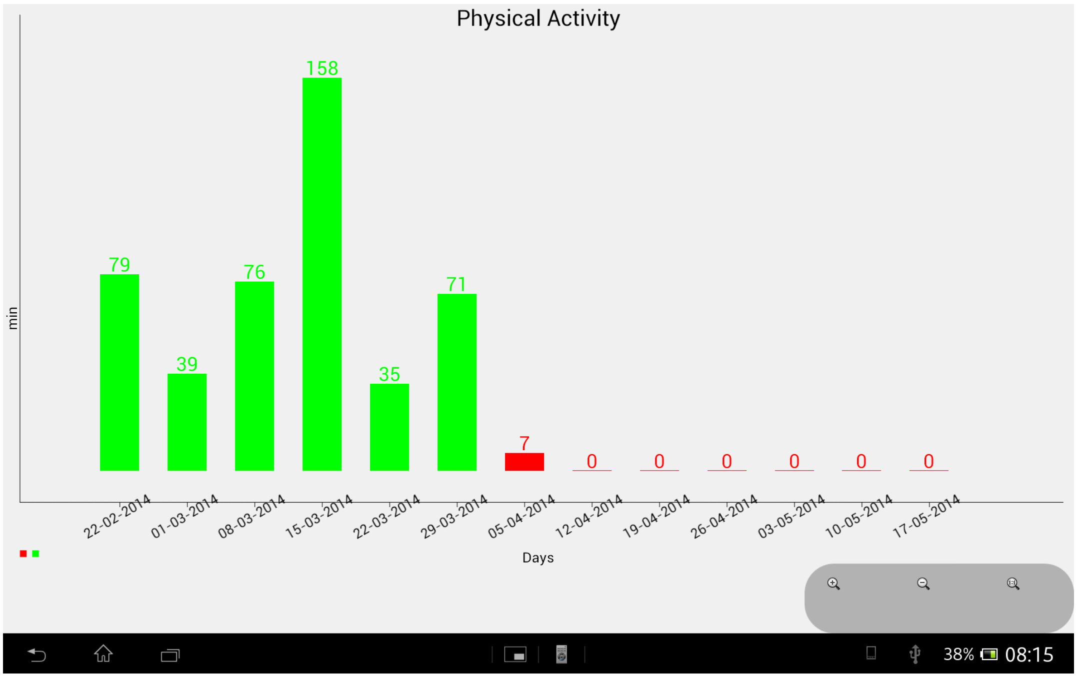


Figure 46. Data representation for physical activity (9)

Example 10. User choses period manually from 22.02.2014 to 29.05.2014 for daily average physical activity. The data is represented according to statistical rules and illustrated below *(see Figure 47)*. Graphs with "0" mean shows that a patient entered no data.

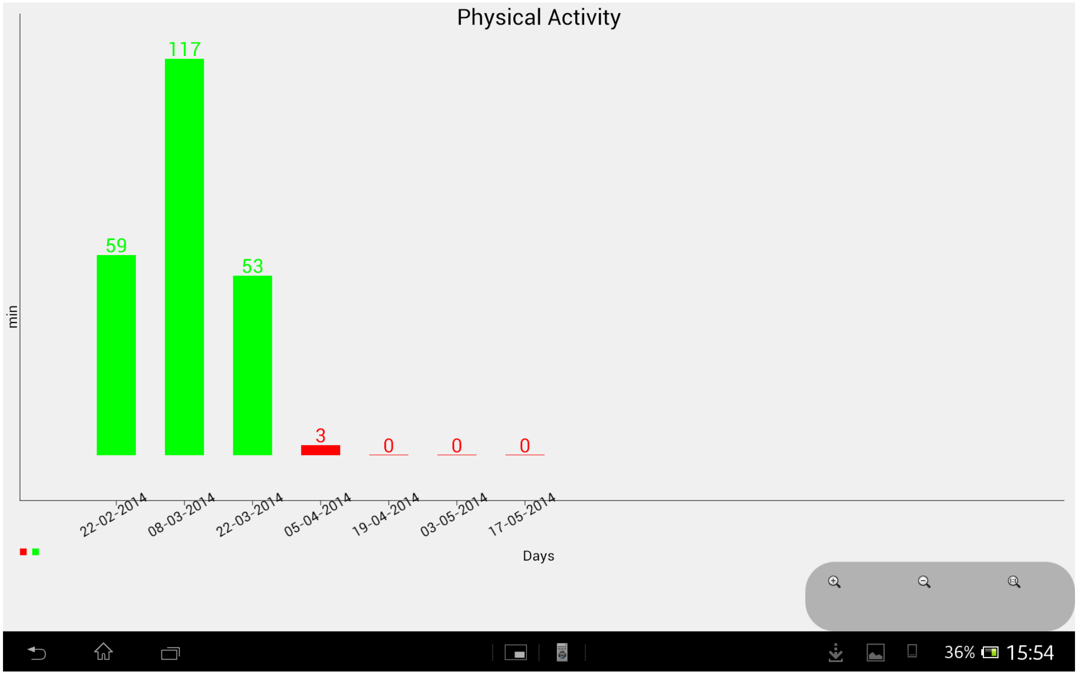


Figure 47. Data representation for physical activity (10)

Example 11. User choses period manually from 01.03.2014 to 14.03.2014 for daily carbohydrates intakes. The data is represented according to statistical rules and illustrated below *(see Figure 48)*.

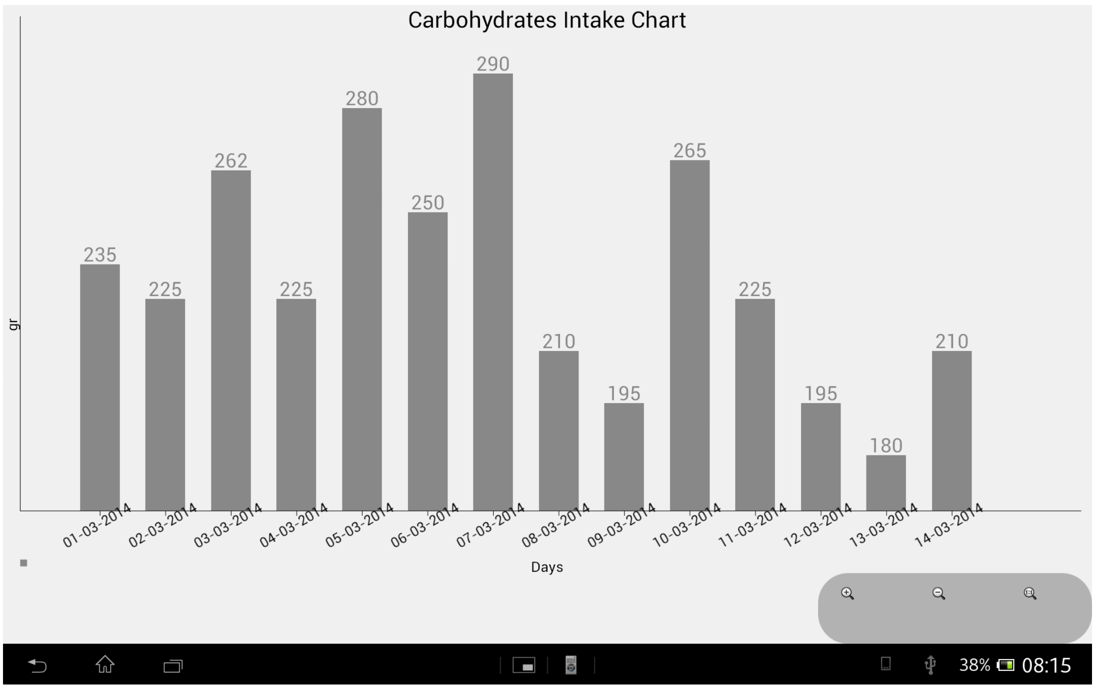


Figure 48. Data representation for carbohydrates intake (11)

Example 12. User choses period manually from 01.03.2014 to 20.05.2014 for daily average carbohydrates intakes. The data is represented according to statistical rules and illustrated below *(see Figure 49)*. Graphs with "0" mean shows that a patient entered no data.

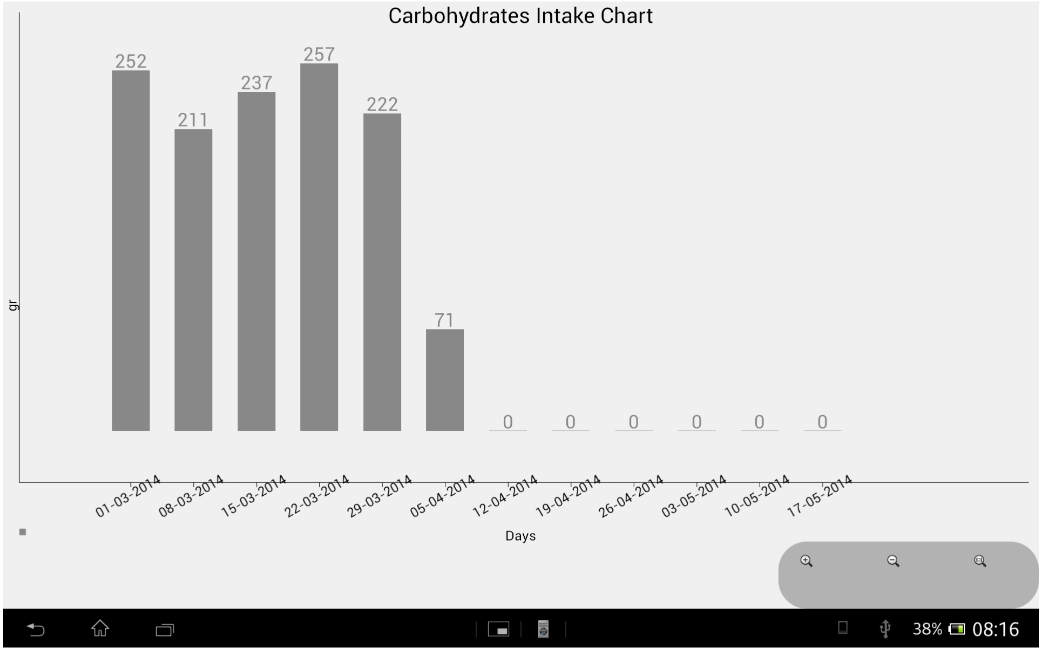


Figure 49. Data representation for carbohydrates intake (12)

Example 13. User choses period manually from 01.03.2014 to 06.06.2014 for daily average intakes. The data is represented according to statistical rules and illustrated below *(see Figure 50)*. Graphs with "0" mean shows that a patient entered no data.

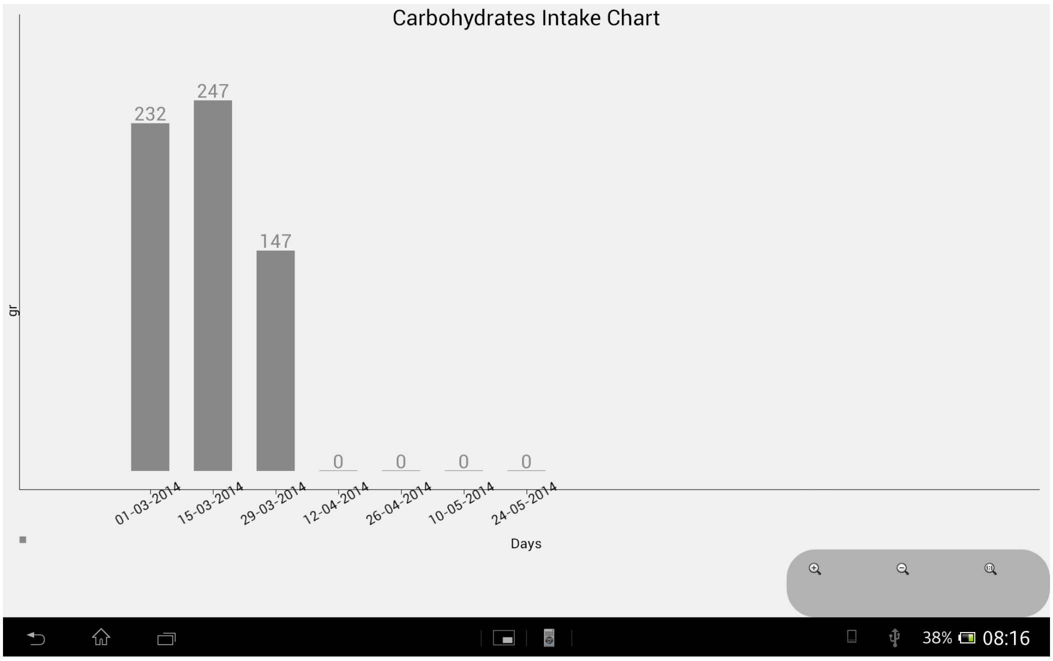
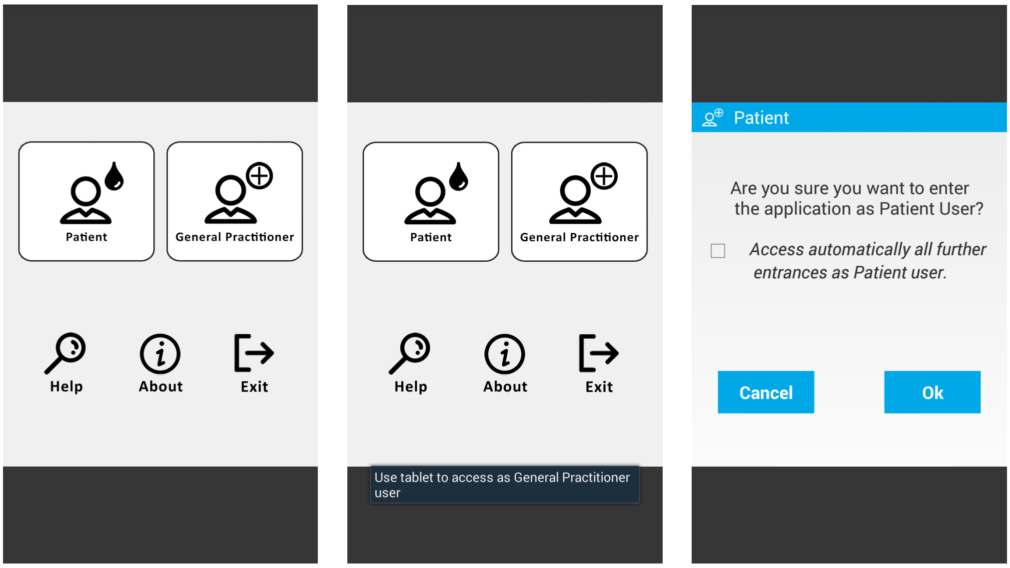


Figure 50. Data representation for carbohydrates intake (13)

5.2.3 Patient Access

After the icon of the application has been activated, the entrance page appears for the user *(see Figure 51)*. As it was pointed out earlier, "General Practitioner" module is blocked for "Patient" user and can be accessed from tablet *(see Figure 52)*. The smartphone used for a trial has size of the screen equals to 5,5 inches. When "Patient" icon has been pressed, the confirmation for the access is appeared *(see Figure 53)*. If user toggles "Access automatically all further entrances as Patient user", the entrance page will not appear next time the user uses the application. "About" and "Help" pages provide basic information about the application and its use.



Figures 51 – 53 (from left to right). Application access for "Patient" user

Once the application accessed as "Patient" user, the "Home" page appears *(see Figure 54)*. Such pages as "About" and "Help" are possible to access from the "Home" page. "Exit" icon for closing application is also on the "Home" page.

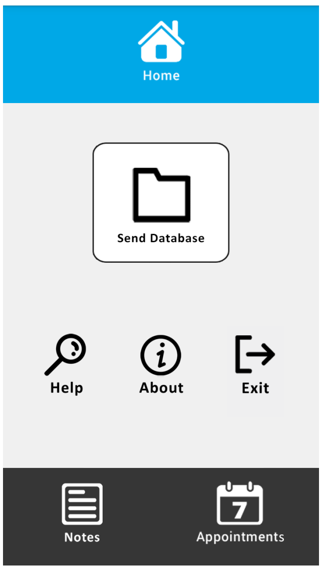


Figure 54. "Home" page for "Patient" user

By pressing “Exit” icon, the application will be closed after user’s confirmation *(see Figure 55)*.

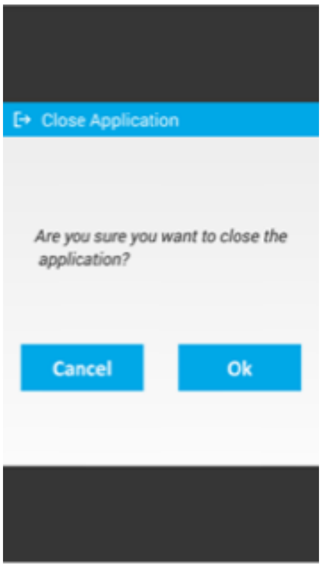
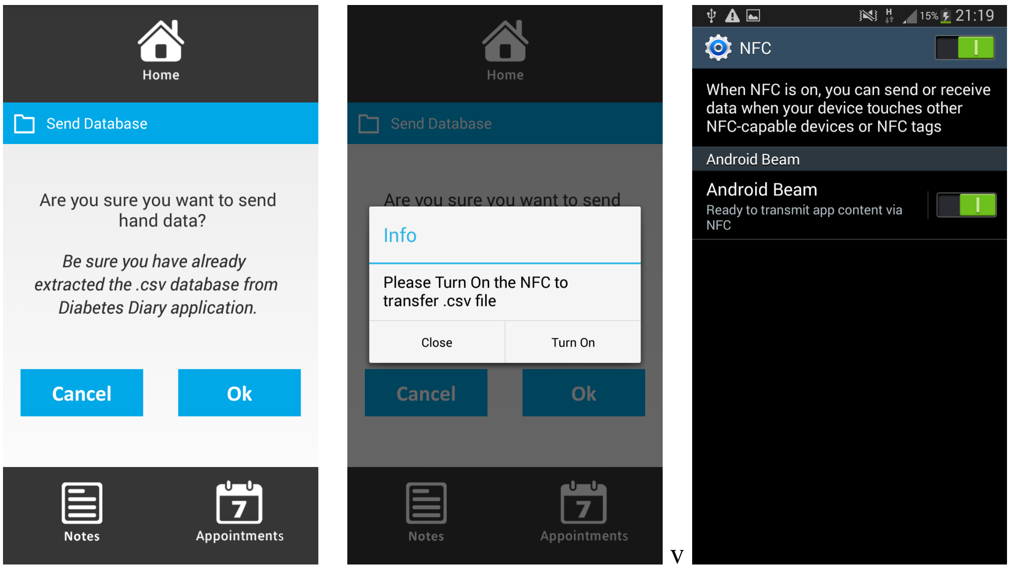


Figure 55. Confirmation to close the application

To transfer the database to a general practitioner’s device user has to press “Send Database” icon *(see Figure 56)*. If user presses “Ok” button but NFC technology is not activated, user will be asked to do so without leaving the application *(see Figures 57, 58)*.



Figures 56 – 58 (from left to right). Process of NFC activation

Once the technology turned on, user press “Ok” button again and the data is ready to be sent *(see Figure 59)*. The illustration of the process of exporting database, pairing devices and beaming the database is provided in the Appendix 9, *Data transfer.*

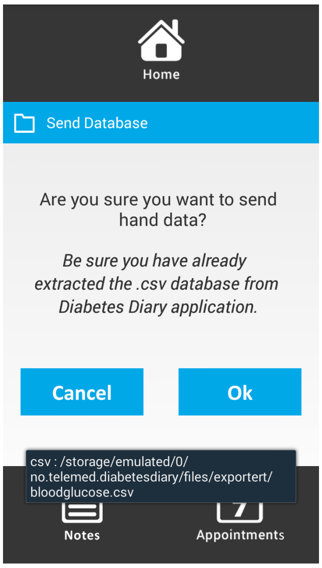
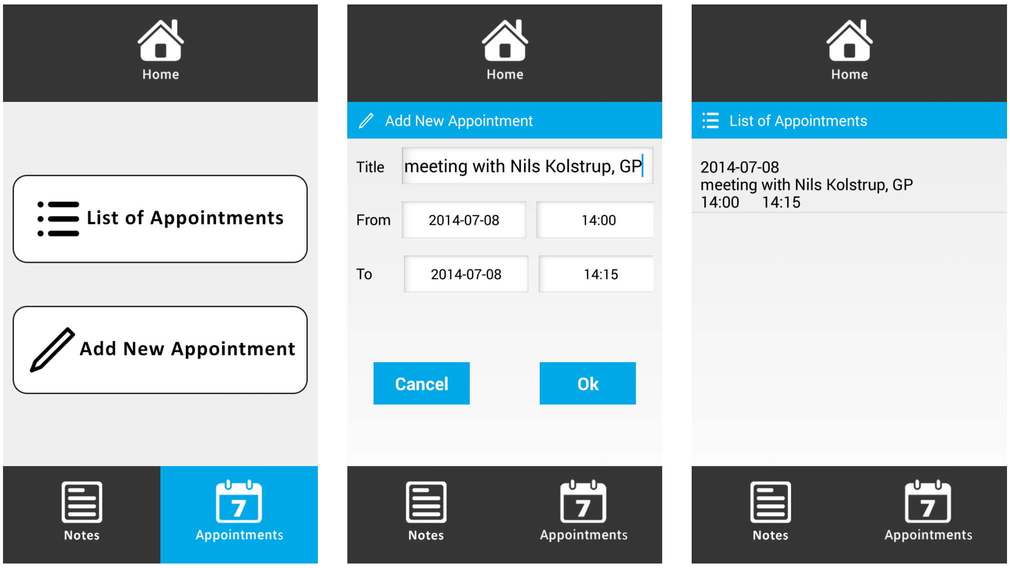
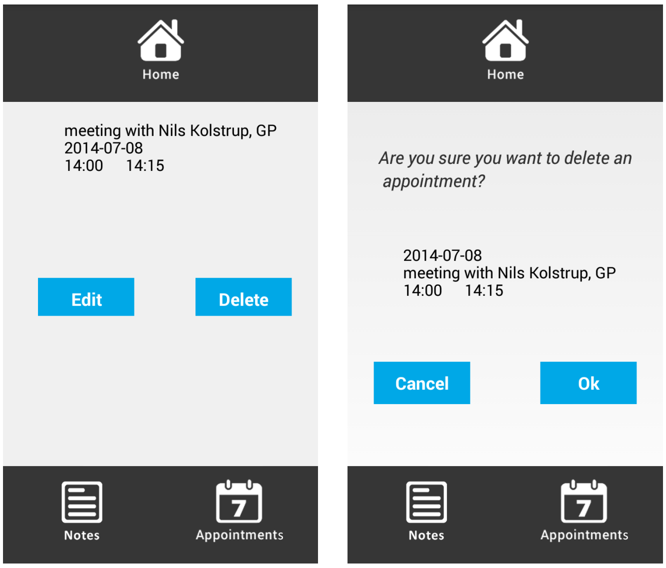


Figure 59. Database is ready to be sent

To manage any events related to diabetes (including appointments with general practitioner and other clinical purposes), “Patient” user accesses “Appointments” page. To add new appointment, user has to press “Add New Appointment” icon, and to see list the event to press “List of Appointments” button *(see Figure 60)*. The process of adding appointment is below *(see Figure 61)*. When appointment is created, the user automatically sent to the page “List of Appointments” *(see Figure 62)*. User can edit of delete chosen appointment *(see Figure 63)*. Before the appointment will be erased from the memory, user will be asked to confirm the procedure *(see Figure 64)*.

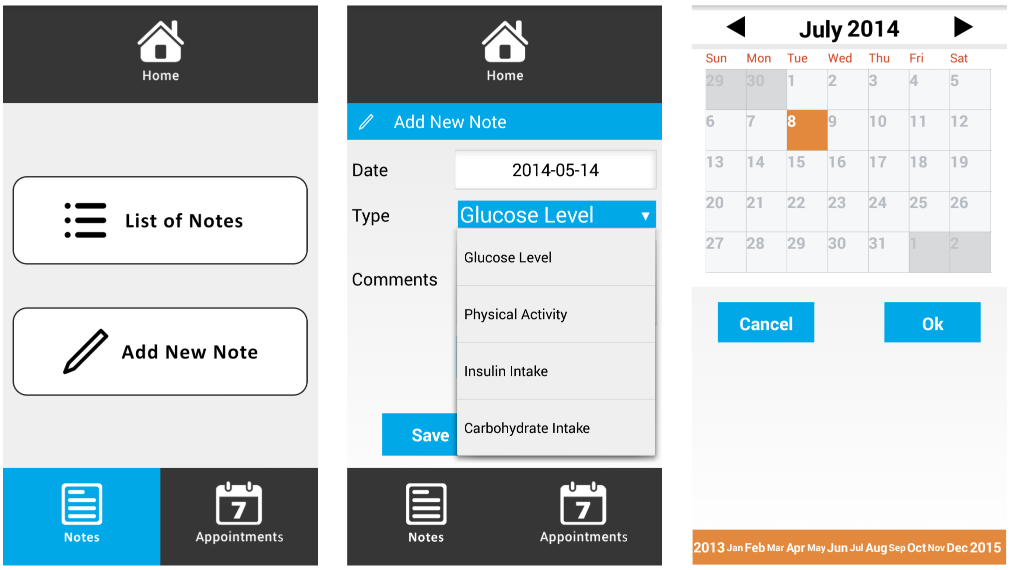


Figures 60 – 62 (from left to right). Appointments management for “Patient” user, creating appointment



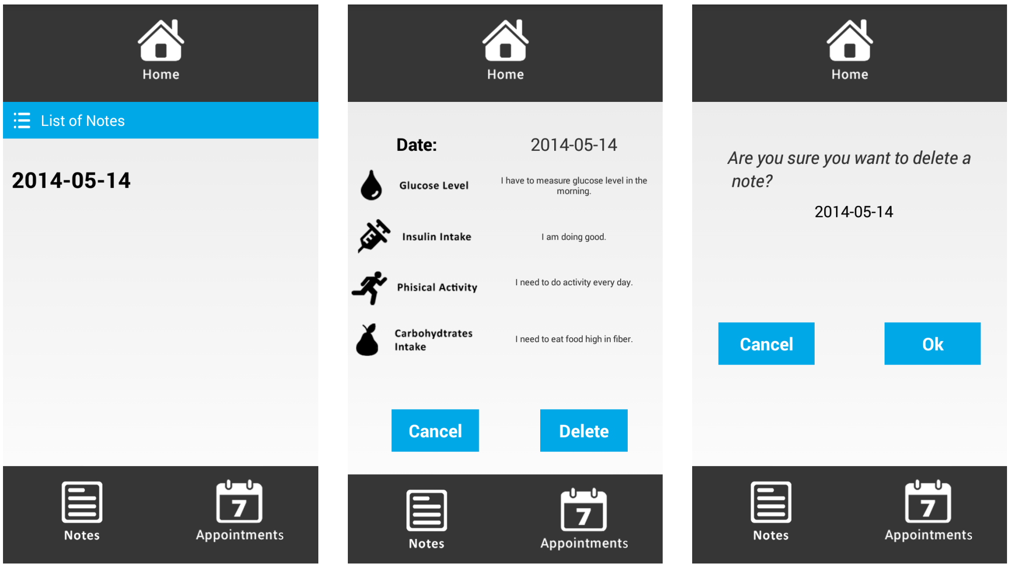
Figures 63 – 64 (from left to right). Appointments management for "Patient" user, deleting appointment

To manage recommendation given by a general practitioner during the consultation, user accesses "Notes" page *(see Figure 65)*. While general practitioner uses clinical information system to enter information about the patient, patient uses this time to add objectives for self-management into the "Diabetes Care" application, based on the given advices from the general practitioner. To add information, "Patient" user presses "Add New Note" icon and the page with special template appears *(see Figure 66)*. When user adds date, the calendar appears *(see Figure 67)*.



Figures 65 – 67 (from left to right). Recommendations management for "Patient" user, creating note

Once the note is created, the user automatically sent to the page "List of Notes" *(see Figure 68)*. To see created note, user pressed it. Created note can be deleted after user's confirmation *(see Figures 69, 70)*.



Figures 68 – 70 (from left to right). Recommendations management for "Patient" user, viewing and deleting note

5.3 Logic Behind the Data Representation

In the section, the statistical rules that have been applied to the data representation are revealed. It should be noted that the whole process of statistics appliance to the data to be represented in an advanced way were ***discussed and agreed with medical doctors*** (Nils Kolstrup, Gerd Ersdal) due to the purpose to meet the needs of data representation from medical perspective to support diabetes care for general practitioners' routine.

5.3.1 General Procedure

CSV file exported from the "Diabetes Diary" application contains pure data with measurements for four parameters (blood glucose level, taken insulin, physical activity done and taken carbohydrates), dates and time of the day (morning, day, evening, night) when each of the parameter was saved into the system of the application. This data is used by the "Diabetes Care" application to represent its content in an advanced way with decision support function.

The data representation ***procedure contains two steps*** *(see Figure 71)*.

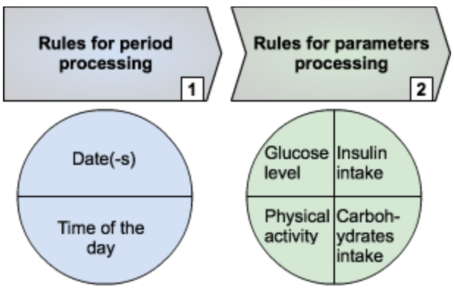


Figure 71. General procedure of data representation

The first step is to process the data by the chosen period. The set of rules has to be applied to the part of data, which states dates and time of the day to keep statistical mean calculation correct in a relation to the chosen further parameter. The first step was called ***"rules for period processing"*** *(see section 5.3.3, Rules for Period Processing)*.

The second step is to process the data by the chosen parameter. Rules have to be applied to the part of data, which states the chosen parameter (blood glucose level, taken insulin, done physical activity and taken carbohydrates) within period of chosen dates and time of the day in the first step, in order to calculate the data appropriately to the chosen parameter. Parameters have different statistical rules for representation. The second step was called ***"rules for parameters processing"*** *(see section 5.3.4, Rules for Parameters Processing)*. Rules for parameters processing are divided into four directions: glucose level processing, insulin intake processing, physical activity processing and carbohydrate processing.

After two steps of rules are applied to the data, it's represented in graphs to a general practitioner. On the top of each graph are mainly mean measurements of the chosen parameter and on the bottom of each graph is stat date of the chosen period.

5.3.2 Decision Support

Decision support function is applied for morning glucose levels (from 05:00 to 10:00) and physical activity according to the Norwegian guidelines of the diabetes management in general practice *(see Table 17)* [9]. Such decision was made due to the reason the application development was supported by the Norwegian Centre of Integrated Care and Telemedicine. However, such standards are the same on the international level and the use provided decision support is appropriate worldwide [27].

Table 17. Rules for decision support

If	physical activity	less 30 minutes a day	then show graph (-s) in	in red color
		more than 30 minutes a day		in green color
	morning glucose level	less than 72 mg/dl or more 180 mg/dl		in green color
		more 108 mg/dl but less or equals 180 mg/dl		in yellow color
		more or equals 72 mg/dl but less 108 or equals mg/dl		in green color

5.3.3 Rules for Period Processing

Based on the period chosen by a general practitioner, the data will be set for one of the rules provided in the table below *(see Table 18)*.

Table 18. Rules for period processing

If chosen period	less or equals 31 days (1 month)	then show graph (-s)	for each day (max 31 graphs)
	more 31 days but less or equals 92 days (3 months)		for each 7 days (max 12 graphs)
	more 92 days (3 months) but less or equals 366 days (12 months)		for each 14 days (max 24 graphs)
	more 366 days (12 months) but less or equals 732 days (24 months)		for each 28 days (max 28 graphs)
	more 732 days (24 months) but less or equals 1098 days (36 months)		for each 56 days (max 18 graphs)
	more 1098 days (36 months)		for each 84 days

The whole day (24 hours) divided into 4 boxes: 1) from 05:00 to 10:00; 2) from 10:00 to 17:00; 3) from 17:00 to 22:00; 4) 22:00 to 05:00. One, two, three of all boxes can be chosen at the same time.

5.3.4 Rules for Parameters Processing

As it was mentioned earlier, rules for parameters processing divided into four directions, such as glucose level processing, insulin intake processing, physical activity processing and carbohydrate processing. For each parameter statistical rules are applied *(see Table 19)*.

Table 19. Rules for parameters processing

Glucose level processing

If chosen period	less or equals 31 days	then calculate graph (-s) as	mean (sum for each day divided into times for each day)
	more 31 days but less or equals 92 days		sum of means (sum for each day divided into times for each day) divided into amount of days
	more 92 days but less or equals 366 days		
	more 366 days but less or equals 732 days		
	more 732 days but less or equals 1098 days		
	more 1098 days		

Insulin intake processing

If chosen period	less or equals 31 days	then calculate graph (-s) as	sum for each day
	more 31 days but less or equals 92 days		mean (sum for the whole period and divide into amount of days)
	more 92 days but less or equals 366 days		
	more 366 days but less or equals 732 days		
	more 732 days but less or equals 1098 days		
	more 1098 days		

Physical activity processing

If chosen period	less or equals 31 days	then calculate graph (-s) as	sum for each day
	more 31 days but less or equals 92 days		mean (sum for the whole period and divide into amount of days)
	more 92 days but less or equals 366 days		
	more 366 days but less or equals 732 days		
	more 732 days but less or equals 1098 days		
	more 1098 days		

Carbohydrate intake processing

If chosen period	less or equals 31 days	then calculate graph (-s) as	sum for each day
	more 31 days but less or equals 92 days		mean (sum for the whole period and divide into amount of days)
	more 92 days but less or equals 366 days		
	more 366 days but less or equals 732 days		
	more 732 days but less or equals 1098 days		
	more 1098 days		

In Appendix 10, *Examples for period processing*, examples are provided with logic for data representation for each of the parameter based on rules for period processing that applied first. All data used for examples are based on CSV database of a real patient provided for a recent development by the Norwegian Centre of Integrated Care and Telemedicine.

5.4 Evolution of the Design Development

To describe the evolution of the design it was decided to overview each of the version of the design and its influence on the functionality of the final application. Only medical doctors and technical experts who influenced the application design development the most were mentioned in the versions' development.

Prototype version 1

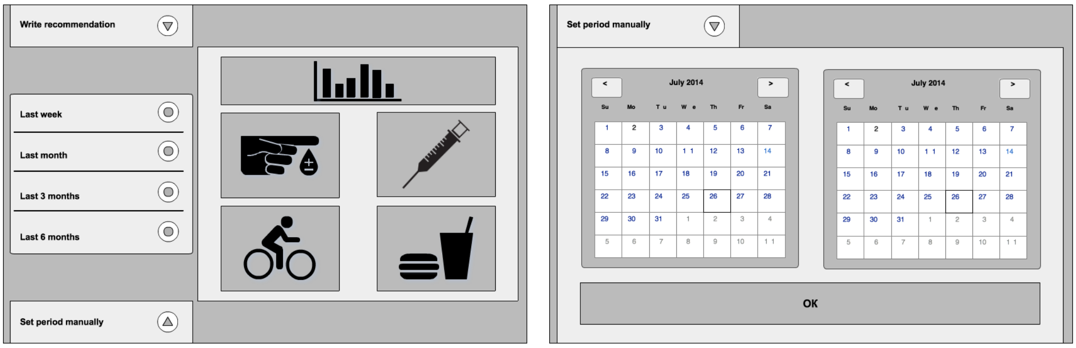
The first version of the application was created in September 2013 and was influenced by medical doctor Nils Kolstrup. The attention was concentrated on the general practitioner's use of the tablet and the main functionality of the application was divided into two directions: to represent the data view in an advanced way and to provide recommendation support for a patient. The data representation was used by the meaning the data from CSV file has to be obtained in a way general practitioner needs to see it and the second function, recommendation provision, was used to create recommendation notes or a patient and send it back to his or her device. The recommendation functionality was suggested to be used by a patient during the time, when a general practitioner will enter the information about the patient into clinical information system. Also, in the version it was suggested to use user identification information.

After second discussion with Nils Kolstrup, it was suggested to remove user identification due to security issues and find another way to make sure that the data used for overview is the data of the user who sent the data last times.

The design overall were comfortable to use and the doctor mentioned few times the simplicity of it and very appropriate colors and manner of navigation for a clinical use. Few sketches of the user interface are provided below *(see Figures 72 – 74)*.

Figures 72 – 74. Graphical user interface of the application, version 1

Prototype version 2
The second version of the application was created in October 2013 and was influenced by medical doctor Nils Kolstrup. The issues of the first version of the design were resolved and provided with a new view of the user interface. Sketches of user interface are provided below *(see Figures 75 – 76).*



Figures 75 – 76. Graphical user interface of the application, version 2

The second version was presented on the Arctic Frontiers 2014 conference (Kolarctic Collaboration Event & KITENPI Project). Technical experts and medical doctors were interested in the design and it was recommended to use color highlighting to show the user the steps he or she is doing. Nils Kolstrup also highlighted the significance of the design and recommender to “keep it as simple as possible” during the further development. Also, it was mentioned that appointments management for a patient could be a bonus in the use if it will be very easy and intuitive.

Meeting with medical doctor Gerd Ersdal showed the interest of medical professional in such development. “It would be nice to use such kind of device. I would, probably, use it when the patient has not stable condition; otherwise, I know what is going on with a patient and what to expect. If a patient is showing up once a year and the result of HbA1C test significantly differs from the last check, the tablet will help quite a lot.” – said Gerd. Gerd advised to have even more simplicity in the use of the tablet.

Meeting with technical expert Keiichi Sato changed the whole direction of the development since he pointed out that patients are not allowed to user general practitioner’s tablet and patients have to hold their own devices to record the recommendations. Also, the development can’t called “doctor’s tablet” is it will be used by his or her patients as well. The group of technical experts in medical informatics and telemedicine based at the Norwegian Centre of Integrated Care and Telemedicine agreed with highlighted remark.

Prototype version 3
Based on the conclusion of the technical experts and medical doctors, the revision of the application development was made. The version for patients’ use was designed and the application became more extended in its use. The version for patients’ use was created and recommendation management was removed from doctor’s tablet. Overall, the version of the application had major changes *(see Appendix 5, Questionnaire with Nils Kolstrup, May 2014).*
In the March 2013, the application became a system with two accesses and different functionality.

According to the design, doctors expressed their opinion about the application use. “I like the design! It’s great! It is very simple to understand and statistics representation is just what I need." – said Nils Kolstrup. "I think it's interesting. The design looks easy to understand and I understand the functionality" – said Gro Berntsen.

The third version was suggested to be used as a final version and only minor details were considered later to be adjusted to a comfortable and appropriate use. Later, the third version influenced by medical doctor Nils Kolstrup with resolved all discussed issues was implemented *(see section 5.2, "Diabetes Care" Application).*

5.5 Summary

In this Chapter the design development of the "Diabetes Diary" application was illustrated.

The development of the application was based on the opinion of medical doctors and technical experts in the field of medical informatics and telemedicine.

The application is created for two types of users: "General Practitioner" and "Patient". Users have different purposes of the application use and based on this fact, the application is created in a way to support activity for both of the types of users. The main functionality for "Patient" user is to transfer the exported CSV database from the "Diabetes Diary" application. As two minor functions were implemented such functions as appointments and recommendations management. The main functionality of the application for "General Practitioner" user is to receive the data sent from patient's device and to view its representation in an advanced way with decision support functionality.

Logic behind the data representation was provided by statistical rules and explanation of it based on the examples with the real patient's data from CSV database. Norwegian guidelines for diabetes management in general practice were used for data representation statistics. Despite this fact, the application is appropriate for use without dependency on any country due to the fact that diabetes guidelines are similar in their aims worldwide.

Evolution of the application design was explained by the brief analysis of its versions.

CHAPTER 6. IMPLEMENTATION

This Chapter represents implementation part of the development.

Implementation process is provided by the explanation of all resources were used, description of the implemented Android projects and description of the source code. The whole layout of the "Diabetes Care" application in a relation to the java sources, and snippets in the matter to facilitate understanding of how technically the application were resolved, are provided.

6.1 Starting Point

For "Diabetes Care" application development, ***Android Operating System*** (OS) was chosen. There are many OS with NFC development support, and recently Android OS is not only one of the leading OS in the world but also the leading in the NFC development [65, 66]. It was decided to base the application of the chosen platform. ***Java*** programming language was used for the implementation.

For the development Eclipse Java EE IDE, Android SDK and libraries were used.

Eclipse Java EE IDE (version: Kepler Release; Build id 20130614-0229)
Eclipse Java EE is integrated development environment that contains all tools for mobile and Web applications development (such as Data Tools Platform, Eclipse Git Team Provider, Eclipse Java Development Tools, Eclipse Java EE Developer Tools, JavaScript Development Tools, Maven Integration for Eclipse, Mylyn Task List, Eclipse Plug-in Development Environment, Remote System Explorer, Eclipse XML Editors and Tools) [53].

Android SDK (minimum version: 8; target version: 19)
Android software development kit was used for enabling to create application for the Android platform. SDK includes development tools, an emulator, and libraries to build the application. Java programing language was used [54].

Libraries (achartengine-1.1.0, GraphView-3.0, android-support, ksoap2-android-assembly-2.6.5-jar-with-dependencies)
Libraries represent collections of implementations of behavior that a higher level program can use to make system call without the need to have those calls written. Programming languages have built in libraries and custom libraries can be implemented [55, 56, 57, 58].

6.2 "Diabetes Care" Android Project

"Diabetes care" android projects is a project that consists of application source code and resource files. The project eventually gets built into an .apk file that can be installed onto a device to be run, as an application. The structure of provided implementation of "Diabetes Care" application is structured as in the table below *(see Table 20)*.

Table 20. Structure of provided implementation

Source	***Description***
AndroidManifest.xml	Every application requires AndroidManifest.xml file to be present in the root directory. The XML file names Java package for the application, describes components of the application, determines processes which will host application components, declares permissions that the application needs to access protects parts of API and interact with other applications and permissions that are needed for other applications to interact back, sets minimum level of the Android API that needs to be used, and lists libraries that the application needs [67].
assets/	This folder is empty.
gen/	Contains java files generated by ADT, such as R.java file and interfaces created from AIDL files [67]. Purpose of R.java file is to quickly access resources in the project and is automatically generated when the android application is built. The file contains unique identifiers for elements in the *res* directory such as drawable, string, layout, and color. The unique identifiers are usually 32bit numbers. When the resources are added or deleted, R.java file is automatically updated [68].
libs/	This folder contains private libraries. Such libraries as achartengine-1.1.0.jar, GraphView-3.0.jar, android-support-v4.jar, ksoap2-android-assembly-2.6.5-jar-with-dependencies.jar were used. Achartengine-1.1.0 library that helps charting of graphs [55]. GraphView-3.0 is used to create diagrams in a graph view [56]. Android support library serves to provide backward-compatibility to previous versions of the Android framework APIs [57]. Ksoap2 provides efficient and lightweight SOAP (Simple Object Access Protocol) client library [58].
lint.xml	Lint is a tool that check the Android project for potential bugs. It also improves optimization for correctness, security, performance, usability, accessibility, and internationalization [69].
DiabetesCare.apk	This is compiled application that could be installed onto a portable device.
proguard-project.txt	The ProGuard tool shrinks, optimizes and obfuscates the code. It removes unused code and renames classes, fields and methods with obscure names. The .apk file becomes smaller and harder to reverse engineer [70].
project.properties	This file contains project properties, such as the build target and is integral to the project [67].
res/	This folder contains application resources, such as drawable files, layout files, and string values. Following folders are provided: color/ (this folder contains XML files that are used to manage colors for the user interface); drawable/ (this folder contains bitmap files (PNG and XML files that are used for describing drawable shapes or drawable objects that contain multiple states); layout/ (this folder contains XML files that are compiled into screen layouts (or part of a screen); menu/ (this folder contains XML files that are used to define application menus) [67].
src/	The folder contains Activity files, which are stored at src/*project/diabetecare/patientcare/(ActivityName)*.java. All java source code files are in the folder [67].

6.3 Source Code Description

To provide a clear view of the activity files of the source code (java files contain in the folder src/), the figure was created, which contains ***layout of the application and java activity files*** responsible for the functioning of each part of the "Diabetes Care" application *(see Figure 77)*.

Using snippets, parts of source code are explained further. Such programming resolution of the technological tasks as screen ***size detection and access to modules, period processing, decision support, graphical data representation, "no.telemed.diabetesdiary/files/exporter" folder accessing and NFC enabling*** are provided in the same-name sections.

6.3.1 Screen Size Detection and Access to Modules

To provide correct access for users, patient and doctor modules were set to identify devices as "phone" (smartphone) and "tab" (tablet). Once "phone" is identified, access to patient module is available, to access doctor module, the device has to be identified as "tab" and landscape mode should be set in order to more comfortable use *(see Snippet 1)*. If "Patient" user accesses application from tablet device, module will be blocked *(see Snippet 2)*. If "General Practitioner" user accesses application from smartphone device, module will be blocked *(see Snippet 3)*. Such decision was made to protect both of the users from ambiguous use of the application. Activity file for the procedure is ***MainActivity.java***.

Snippet 1. Detection of tablet device

```
float scaleFactor = metrics.density;
float widthDp = widthPixels / scaleFactor;
        float heightDp = heightPixels / scaleFactor;

float smallestWidth = Math.min(widthDp, heightDp);

if(smallestWidth > 720) {
    Tab="ten";

    if(widthDp>heightDp)
    {
        screen="landscape";
    }
    else
    {
        screen="portrait";
    }
}
else if(smallestWidth > 600) {
    Tab="seven";
    if(widthDp>heightDp)
    {
        screen="landscape";
    }
    else
        screen="portrait";
    }
```

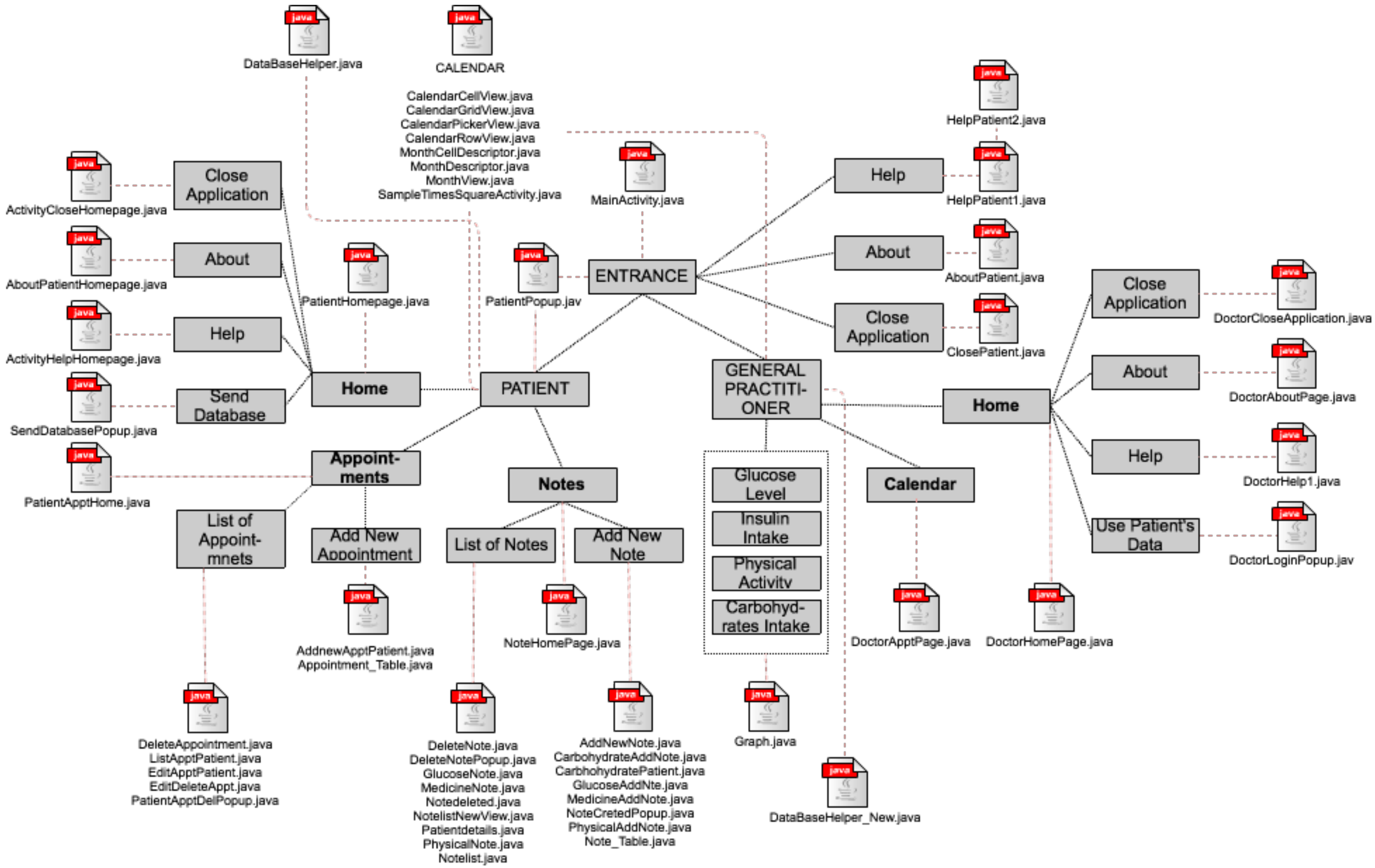


Figure 77. Layout of the application with java sources

Snippet 2. Patient module blocking from tablet

```
if (Device.equals("TVDPI") || Tab.equals("ten") )
{
Toast.makeText(getApplicationContext(), "Use smartphone to access as Patient user",
Toast.LENGTH_LONG).show();
}
```

Snippet 3. Doctor module blocking from smartphone

```
if (str.equals("phone") )
{
Toast.makeText(getApplicationContext(), "Use tablet to access as General Practitioner user",
Toast.LENGTH_LONG).show();
}
```

6.3.2 Period Processing

Rules for period processing are provided in the Chapter 6, *Design (see section 6.3.3, Rules for Period Processing)*. The implemented rules are disclosed in the snippet below *(see Snippets 4, 5)*. Activity file for the procedure is ***DoctorApptPage.java***.

Snippet 4. Period processing (to be continued)

```
if(month == 1 && current.equals("month"))
{
        Time_Limit="1";
        Days="31";
        end_date=today_day();
        start_date=get_start_date(end_date,month);
        System.out.println("month =1 Days:"+days_count);
}
else if(month == 3 && current.equals("month"))
{
        Time_Limit="7";
        Days="92";
        end_date=today_day();
        start_date=get_start_date(end_date,month);
        System.out.println("month =3");
}
else if(month == 6 && current.equals("month"))
{
        Time_Limit="14";
        Days="184";
        end_date=today_day();
        start_date=get_start_date(end_date,month);
        System.out.println("month =6");
}
```

```
else if(month == 0 && current.equals("month"))
{
        Time_Limit="1";
        Days="7";
        end_date=today_day();
        start_date=get_start_date(end_date,month);
        start_date=prev_day(end_date);
        System.out.println("Days = 7 :"+start_date);
}
else if(days_count <= 31)
{
        Time_Limit="1";
        days_count++;
        Days= String.valueOf(days_count);

        end_date=to;
        start_date=from;
        System.out.println("days:"+days_count);
}
else if((days_count > 31 && days_count <= 92) )
{
        Time_Limit="7";
        Days= String.valueOf(days_count);
        end_date=to;
        start_date=from;
        System.out.println("Days = 31 - 92:"+Days);
}
else if(days_count > 92 && days_count <= 366 )
{
        Time_Limit="14";
        Days= String.valueOf(days_count);
        end_date=to;
        start_date=from;
        System.out.println("Days = 92 - 366:"+Days);
}
else if(days_count > 366 && days_count <= 732 )
{
        Time_Limit="28";
        Days= String.valueOf(days_count);
        end_date=to;
        start_date=from;
        System.out.println("Days = 732 - 366:"+Days);
}
else if(days_count > 732 && days_count <= 1098 )
{
        Time_Limit="56";
        Days= String.valueOf(days_count);
        end_date=to;
        start_date=from;
        System.out.println("Days = 732 - 1098:" +Days);
}
else if(days_count > 1098 )
{
        Time_Limit="84";
        Days = String.valueOf(days_count - 1098);
        end_date=to;
        start_date=from;
        System.out.println("Days > 1098:"+Days);
}
```

6.3.3 Decision Support

Statistics for decision support are also provided in the Chapter 6, *Design (see section 5.3.2, Decision Support)*. The implemented statistics for physical activity and glucose levels are below in the snippets *(see Snippets 6, 7)*. Activity file for the procedure is ***DoctorApptPage.java***.

Snippet 6. Decision support for physical activity

```
else if(graph_title.equals("Physical Activity"))
     {
               titles = new String[] { "", "" };
              System.out.println("Physical Activity  :");

              double list1[] = new double[200];
         double list2[] = new double[200];
         for(int i=0;i<xCount.size();i++)
              {
                        double am = amount.get(i);

                        if(am <= 29)
                        {
                                  list1[i]=am;
                                  list2[i]=0;
                                  System.out.println("amount  :"+am);
                        }
                        else
                        {
                                  list1[i]=30;
                                  list2[i]=am ;
                                  System.out.println("else amount  :"+i+" "+am);
                        }
              }
         values.add(list2);
         values.add(list1);

         int[] colors = new int[] { Color.GREEN, Color.RED };
       renderer = buildBarRenderer(colors);
               setChartSettings(renderer, graph_title, "Days", "min", 0,
                              12.5, 0, 120, Color.GRAY, Color.LTGRAY);
     }
```

```
else if(graph_title.equals("Glucose Level"))
{
        titles = new String[] { "", "" ,"",""};
        double list1[] = new double[200];
    double list2[] = new double[200];
    double list3[] = new double[200];
    double list4[] = new double[200];

    for(int i=0;i<xCount.size();i++)
        {
            double am = amount.get(i);

            if(am < 72 )
            {
                list1[i]=am;
                list2[i]=0;
                list3[i]=0;
                list4[i]=0;
                System.out.println("am > 72  amount  :"+am);
            }
            else if(72 < am && am <= 108)
            {
                list1[i]=72;
                list2[i]=am;
                list3[i]=0;
                list4[i]=0;

                System.out.println("72 < am && am <= 108 amount  :"+am);
            }
            else if(108 < am && am <= 180 )
            {
                list1[i]=72;
                list2[i]=108;
                list3[i]=am;
                list4[i]=0;

                System.out.println("108 < am && am <= 180  amount  :"+am);
            }
            else if( am > 180 )
            {
                list1[i]=72;
                list2[i]=108;
                list3[i]=180;
                list4[i]=am;

                System.out.println("am > 180  amount  :"+am);
            }
        }
    values.add(list4);
    values.add(list3);
    values.add(list2);
    values.add(list1);

    int[] colors = new int[] { Color.RED, Color.YELLOW, Color.GREEN ,Color.RED };
 renderer = buildBarRenderer(colors);
        setChartSettings(renderer, graph_title, "Days", "mg/dl", 0.5,
                12.5, 0, 300, Color.GRAY, Color.BLACK);
}
```

6.3.4 Graphical Data Representation

The data representation is implemented into graph with set of rules and statistics. According to the parameters that patient garters using "Diabetes Diary" application (glucose levels, insulin intake, physical activity and carbohydrates intake), the data representation is implemented due to the patient's measurements *(see Snippet 8)*. Activity file for the procedure is ***Graph.java***.

Snippet 8. Graphical data representation

```
multiRenderer.setChartTitle(""+graph_title+" Chart");
if(graph_title.equals("Carbohydrates Intake"))
{
        multiRenderer.setYTitle("Carb");
}
else if(graph_title.equals("Physical Activity"))
{
        multiRenderer.setYTitle("Minute");
}
else if(graph_title.equals("Insullin Intake"))
{
        multiRenderer.setYTitle("U.I");
}
else if(graph_title.equals("Glucose Level"))
{
        multiRenderer.setYTitle("mg/dl");
}
multiRenderer.setXTitle("Days");
```

6.3.5 Accessing Folder "no.telemed.diabetesdiary/files/exporter"

To transfer patient's CSV database from smartphone device to tablet, the system of the application (patient module) accesses the folder with exported CSV database from the "Diabetes Diary" application. Pointed procedure is illustrated in the following snippet *(see Snippet 9)*. Activity file for the procedure is ***SendDatabasePopup.java***.

Snippet 9. Folder accessing

```
String filee = "no.telemed.diabetesdiary/files/exportert/example.csv";
                File sd = Environment.getExternalStorageDirectory();

                List<File> files = getListFiles(new File(sd,
"no.telemed.diabetesdiary/files/exportert"));

                if(!files.isEmpty())
                {
 File csv = files.get(0);

 if(csv.exists())
 {
Toast.makeText(getApplicationContext(), "csv : "+csv.toString(),
Toast.LENGTH_LONG).show();
```

6.3.6 NFC Enabling

To transfer patient's CSV database from smartphone device to tablet, NFC technology is used. If the technology turned off, the user doesn't need to go into settings of the device and find it. To simplify the use of the application, the system accesses user to settings with simple user interface to turn on the technology and proceed with data transfer *(see Snippet 10)*. Activity file for the procedure is ***SendDatabasePopup.java.***

Snippet 10. NFC enabling

```
if(mAdapter == null) {
 showMessage(R.string.error, R.string.no_nfc);
 return;
}
  else
  {
  android.nfc.NfcAdapter mNfcAdapter=
android.nfc.NfcAdapter.getDefaultAdapter(v.getContext());
  if(!mNfcAdapter.isEnabled()) {

      AlertDialog.Builder alertbox = new
AlertDialog.Builder(v.getContext());
alertbox.setTitle("Info");
alertbox.setMessage("Please Turn On the NFC to transfer .csv file");
alertbox.setPositiveButton("Turn On", new DialogInterface.OnClickListener() {
   @Override
   public void onClick(DialogInterface dialog, int which) {
      if (Build.VERSION.SDK_INT >= Build.VERSION_CODES.JELLY_BEAN) {
         Intent intent = new Intent(Settings.ACTION_NFC_SETTINGS);
         startActivity(intent);
      } else {
         Intent intent = new Intent(Settings.ACTION_WIRELESS_SETTINGS);
         startActivity(intent);
      }
```

6.4 Summary

In the Chapter, an explanation of the implementation process of the "Diabetes Care" application was provided.

Chapter includes all major information about tools were used for the development, structure of the implemented and provided source code, layout of the application with all presented java activity files and detailed explanation of programming resolution of the application functions that were needed to be handled to answer the research questions *(see section 1.3, Research Questions)*.

CHAPTER 7. TESTING AND RESULTS

This Chapter reflects to the application testing and its results.

Testing procedure in general is split into functionality and usably testing of the implemented application. Full functionality test is performed based on functional and non-functional requirements (performance, security, reliability and efficiency). Results of the usability testing are represented based on medical opinions while application use, interviews after the trials and further discussion.

The results related to the implemented "Diabetes Care" application are made in the end of the Chapter.

Testing was conditionally divided into two stages: the first stage represents ***functionality test*** proceeded before the application passed to medical doctors to test; the second stage represents ***usability test*** of the implemented application by medical doctors as the main users. User feedback is documented.

Two devices were used for testing: ***tablet*** Sony Xperia Z with 10,1 inches screen, and ***smartphone*** Samsung Galaxy Note II with 5,5 inches screen. Both of the devices embedded with NFC adapter and have Android OS version 4.1 Jelly Bean.

7.1 Functionality Test

Once the application has been fully implemented, the test was done in order to identify the correct functionality of the application and to fix faults upon their detection. Full functionality test was performed on 26th of June 2014 and no omissions were detected. Overall, application operation was performing correctly. Functionality and non-functional requirements (performance, security, reliability and efficiency) were checked. The procedure and results of functionality test are provided in the tables further *(see Tables 21 – 23)*. Results of non-functional requirements check are in the table further as well *(see Table 24)*.

Table 21. Functionality test for general module

Test Case ID	Objective	Test Steps	Expected Result	Actual result (+/-)	
				5-inch device	10-inch device
GENERAL MODULE					
GEN01	Verify clicking on "Diabetes Care" application launch icon	Click on "Diabetes Care" application launch icon	(1) "Diabetes Care" application must be launched; (2) entrance page must display icons "Patient", "General Practitioner", "Help", "About" and "Exit" both in portrait and landscape mode in a relation to the screen size of the device.	+	+
GEN02	Verify clicking on "Help" icon	On entrance page, click on "Help" icon	Clicking on "Help" icon should open help page, application manual details and how to use the application.	+	+
GEN03	Verify clicking on "About" icon	On entrance page, click on "About" icon	Clicking on "About" icon should open information about the application.	+	+
GEN04	Verify clicking on "Exit" icon	On entrance page, click on "Exit" icon	(1) Clicking on "Exit" icon should pop up exception message "Are you sure you want to close the application?" with "Ok" and "Cancel" button option; (2) clicking on "Ok" button should close the application; (3) clicking on "Cancel" button should remain in the application.	+	+
GEN05	Verify clicking on device back button	On entrance page, click on device back button	(1) Clicking on device back button should pop up exception message "Are you sure you want to exit?" with "Ok" and "Cancel" button option; (2) clicking on "Ok" button should close the application; (3) clicking on "Cancel" button should remain in the application.	+	+
GEN06	Verify entrance page graphics	Check entrance page graphics	Entrance page graphics should be as per design layout.	+	+

Table 22. Functionality test for patient module

Test Case ID	Objective	Test Steps	Expected Result	Actual result (+/-)	
				5-inch device	10-inch device
PATIENT MODILE					
PAT01	Verify clicking on "Patient" icon	On entrance page, click "Patient" icon	(1) Message should be displayed "Are you sure you want to enter the application as "Patient" user?" with "Ok" and "Cancel" button option and box with message "Access automatically all further entrances as "Patient" user; (2) clicking on "Ok" button should display patient home page; (3) clicking on "Cancel" button should display back entrance page; (4) if box was toggled, next time clicking on "Diabetes Care" application launch icon, patient should automatically start from patient Home page.	+	
PAT02	Verify patient home page	Check patient home page. Prerequisite: patient module should be accessed	Patient home page should display icons "Home", "Send Database", "Help", "About", "Exit", "Notes" and "Appointments".	+	
PAT03	Verify clicking on device back button	On patient home page, click on device back button. Prerequisite: patient module should be accessed	(1) Clicking on device back button should pop up exception message "Are you sure you want to exit?" with "Ok" and "Cancel" button option; (2) clicking on "Ok" button should close the application; (3) clicking on "Cancel" button should remain in the application.	+	
PAT04	Verify clicking on "Help" icon	On patient home page, click on “Help” icon. Prerequisite: patient module should be accessed	Clicking on "Help" icon should open help page, application manual details and how to use the application.	+	
PAT05	Verify clicking on "About" icon	On patient home page, click on “About” icon. Prerequisite: patient module should be accessed	Clicking on "About" icon should open information about the application.	+	

PAT06	Verify clicking on "Exit" icon	On patient home page, click on “Exit” icon. Prerequisite: patient module should be accessed	(1) Clicking on "Exit" icon should pop up exception message "Are you sure you want to close the application?" with "Ok" and "Cancel" button option; (2) clicking on "Ok" button should close the application; (3) clicking on "Cancel" button should remain in the application.	+	
PAT07	Verify clicking on "Send Database" icon	On patient home page, click on “Send Database” icon. Prerequisite: patient module should be accessed	(1) Clicking on Send Database icon should pop up message "Are you sure you want to send hand data?" "Be sure you have extracted the .csv database from "Diabetes Diary" application" with "Ok" and "Cancel" button option; (2) clicking on “Ok” button should proceed further; (3) clicking on “Cancel” button should return to patient home page.	+	
PAT08	Verify the database file is sent successfully	In case id PAT07, click “Ok” button. Prerequisite: patient module should be accessed	Clicking on “Ok” button, the latest CSV file should get exported from “no.telemed.diabetesdiary” folder and the file should be sent via Android Beam to other device with “Diabetes Care” application running and general practitioner module accessed.	+	
PAT09	Verify appointments page	Click on “Appointments” icon. Prerequisite: patient module should be accessed	Appointments page should be displayed with two icons: “List of Appointments” and “Add New Appointment”.	+	
PAT10	Verify page with list of appointments page	In case id PAT09, click on “List of Appointments” icon. Prerequisite: patient module should be accessed	Clicking page with list of appointment should display all appointments.	+	
PAT11	Verify functions to edit and delete appointments	In case id PAT10, click any appointment Prerequisite: patient module should be accessed	(1) Clicking on “Edit” button should provide function to edit the appointment; (2) selected appointment should get edited properly and get saved; (3) clicking on “Delete” button should provide function to delete the appointment; (4) selected appointment should get deleted from the database with exception message "Are you sure you want to delete an appointment?" with "Ok" and "Cancel" button option; (5) clicking on “Ok” button will delete appointment; (6) clicking on “Cancel” button should return back to the page.	+	
PAT12	Verify function to add	In case id PAT09, click on	(1) Clicking on “Add New Appointment” icon should	+	

	new appointment	"Add New Appointment" icon; fulfill the template. Prerequisite: patient module should be accessed	display page with appointment template; (2) clicking on "Ok" button will create new appointment if template is fulfilled; (3) clicking on "Cancel" button should return back to the home page.		
PAT13	Verify notes page	Click on "Notes" icon. Prerequisite: patient module should be accessed	Notes page should be displayed with two icons: "List of Notes" and "Add New Note".	+	
PAT14	Verify page with list notes	In case id PAT13, click on "List of Notes" icon. Prerequisite: patient module should be accessed	Clicking page with list of notes should display all notes.	+	
PAT15	Verify functions to delete notes	In case id PAT14, click any note	(1) Clicking on "Delete" button should provide function to delete the note; (2) selected note should get deleted from the database with exception message "Are you sure you want to delete a note?" with "Ok" and "Cancel" button option; (3) clicking on "Ok" button will delete note; (4) clicking on "Cancel" button should return back to the page.	+	
PAT16	Verify function to add new note	In case id PAT13, click on "Add New Note" icon; fulfill the template. Prerequisite: patient module should be accessed	(1) Clicking on "Add New Note" icon should display page with note template; (2) clicking on "Ok" button will create new note if template is fulfilled; (3) clicking on "Cancel" button should return back to the list of notes.	+	
PAT17	Verify all pages graphics	Check all pages graphics	All pages graphics should be as per design layout.	+	

Table 23. Functionality test for general practitioner module

Test Case ID	Objective	Test Steps	Expected Result	Actual result (+/-)	
				5-inch device	10-inch device
DOCTOR (GENERAL PRACTITIONER) MODULE					
DOC01	Verify clicking on "General Practitioner" icon	On entrance page, click on "General Practitioner" icon	(1) Message should be displayed "Are you sure you want to enter the application as "General Practitioner" user?" with "Ok" and "Cancel" button option and box with message "Access automatically all further entrances as "General Practitioner" user; (2) clicking on "Ok" button should display doctor home page; (3) clicking on "Cancel" button should display back entrance page; (4) if box was toggled, next time clicking on "Diabetes Care" application launch icon, doctor should automatically start from doctor home page.		+
DOC02	Verify doctor home page	Check doctor home page. Prerequisite: doctor module should be accessed	Doctor home page should display icons “Home”, “Calendar”, “Use Patient’s Data”, “Help”, “About”, “Exit”, “Glucose Level”, “Insulin Intake”, “Physical Activity” and “Carbohydrates Intake”.		+
DOC03	Verify clicking on device back button	On doctor home page, click on device back button. Prerequisite: doctor module should be accessed	(1) Clicking on device back button should pop up exception message "Are you sure you want to exit?" with "Ok" and "Cancel" button option; (2) clicking on "Ok" button should close the application; (3) clicking on "Cancel" button should remain in the application.		+
DOC04	Verify clicking on "Help" icon	On doctor home page, click on “Help” icon. Prerequisite: doctor module should be accessed	Clicking on "Help" icon should open help page, application manual details and how to use the application.		+

DOC05	Verify clicking on "About" icon	On doctor home page, click on “About” icon. Prerequisite: doctor module should be accessed	Clicking on "About" icon should open information about the application.		+
DOC06	Verify clicking on "Exit" icon	On doctor home page, click on “Exit” icon. Prerequisite: doctor module should be accessed	(1) Clicking on "Exit" icon should pop up exception message "Are you sure you want to close the application?" with "Ok" and "Cancel" button option; (2) clicking on "Ok" button should close the application; (3) clicking on "Cancel" button should remain in the application.		+
DOC07	Verify that the database file is received successfully	Accept CSV database from other device “Diabetes Care” application running and patient module accessed; on doctor home page, click on "Use Patient’s Data" icon. Prerequisite: doctor module should be accessed	Clicking on "Use Patient’s Data" icon should convert CSV format of database to DB and export it for further procedure, toast message “Exporting…” should appear.		+
DOC08	Verify calendar page	Click on “Calendar” icon. Prerequisite: doctor module should be accessed	Clicking on “Calendar” icon should open calendar page with a display containing following boxes: “From”, “To”, “Last 6 months”, “Last 3 months”, “Last months”. “Last week”, “05:00 – 10:00 Morning”, “10:00 – 17:00 Day”, “17:00 – 22:00 Evening” and “22:00 – 05:00 Night”.		+
DOC09	Verify period representation	In case id DOC08, check different periods using boxes. Prerequisite: doctor module should be accessed	Graphs should be displayed according to the rules for period processing: less or equals 31 days, then show graph (-s) for each day; more 31 days but less or equals 92 days, then show graph (-s) for each 7 days; more 92 days but less or equals 366 days, then show graph (-s) for each 14 days; more 366 days but less or equals 732 days, then show graph (-s) for each 28 days; more 732 days but less or equals 1098 days, then show graph (-s) for each 56 days;		+

			more 1098 days, then show graph (-s) for each 84 days.		
DOC10	Verify glucose level data representation	Click on “Glucose Level” icon. Prerequisite: doctor module should be accessed			+
DOC11	Verify insulin intake data representation	Click on “Insulin Intake” icon. Prerequisite: doctor module should be accessed			+
DOC12	Verify physical activity data representation	Click on “Physical Activity” icon. Prerequisite: doctor module should be accessed			
DOC13	Verify carbohydrate intake data representation	Click on “Carbohydrates Intake” icon. Prerequisite: doctor module should be accessed	All parameters should be displayed correctly in graphs with applied statistical rules and for chosen period.		+
DOC14	Verify decision support function	In cases id DOC10 and DOC12, check decision support function	Graphs for glucose levels should be displayed according to the rules for decision support: if less than 72 mg/dl or more 180 mg/dl then in red, if more 108 mg/dl but less or equals 180 mg/dl then in yellow, if more or equals 72 mg/dl but less 108 or equals mg/dl then in green. Graphs for physical activity should be displayed according to the rules for decision support: if less 30 minutes a day then in red, if more than 30 minutes a day then green.		+
DOC15	Verify all pages graphics	Check all pages graphics	All pages graphics should be as per design layout.		+

Table 24. Performance, security, reliability and efficiency requirements check

	Achieved	Not achieved
Performance		
Jitter requirements	+	
Latency requirements	+	
Response time requirements	+	
Throughput requirements	+	
Security		
Access control requirements	+	
Integrity requirements	+	
Privacy requirements	+	
Reliability	+	
Efficiency	+	

7.2 Usability Test

Throughout the development period, a usability testing was conducted on prototypes several times due to user interface and appropriate functionality improvements. Final usability testing was performed after the application has been implemented and checked for the correct and stable functioning.

7.2.1 Procedure

For the final usability test, ***two medical doctors with clinical practice as general practitioners*** were involved (***Nils Kolstrup*** and ***Thomas Roger Schopf***).

Nils helped throughout the development, and was the main medical doctor from the perspective of medical expertise. Thomas has been involved only for the final usability test. This means that he knew nothing about the application, and was informed about its development during the meeting, which was proceeded with the testing. Such action was made to raise an independent medical opinion on the relevance, quality and usability of the "Diabetes Care" applications.

The same usability test procedure was used for both of the doctors. First, ***doctors were using the application*** and expressed their thoughts about usability requirements that were set in the Chapter 4, *Requirements Specifications (see section 4.4.2.1, Usability)*. Then, the ***interview*** continued the meetings with questions related to the detection of medical opinion about the application use in general *(see Appendix 6, Interview with Nils Kolstrup, June 2014)*. Nils and

Thomas were asked the same interview questions. Both interviews were held and followed by ***discussion***.

7.2.2 Results

Results are documented in the tables below. First, based on the application test, usability requirements *(see section 4.4.2.1, Usability)* were checked based on doctors' comments of their impression while testing *(see Table 25)*. Then answers on the interview questions were collected and documented *(see Table 26)*. Overall, both of the doctors expressed highly positive thoughts about the implemented application. Both of them mentioned that the application is an innovative and they were hoping to see further PhD research for further extension. Nils pointed out that application could be used today by its quality and functionality; however, some legal issues have to be considered before its starting since the application represents clinical use.

Table 25. Usability requirements testing

	Positive	Positive with notes to improve	Negative
Attractiveness	Nils, Thomas		
Credibility	Nils, Thomas		
Differentiation	Nils, Thomas		
Ease to enter	Nils, Thomas		
Ease to learn	Nils, Thomas		
Ease of location	Nils, Thomas		
Ease to remember	Nils, Thomas		
Ease to use	Nils, Thomas		
Effectiveness	Nils, Thomas		
Error minimization	Nils, Thomas		
Navigability	Thomas	Nils	
Preference	Nils, Thomas		
Retrievability	Nils, Thomas		
Suitability	Nils, Thomas		
Understandability	Nils, Thomas		
User satisfaction	Nils,	Thomas	

Table 26. Interview with doctors after application testing

	Nils Kolstrup	Thomas Roger Schopf
Date and duration	*31.06.2014, 1 h. 30 min.*	*1.07.2014, 1 h. 30 min.*
Detected functionality faults	*Not detected*	
Question	***Answer***	
(1) What is your first impression about the working application?	"Perfect! It's perfectly working."	"This is nice."
(2) What did you like in the application the most and what didn't you like?	"I like simplicity. Fantastic how it's easy to go. I think this application has a design that other medical systems should be built like. Very easy to use but I see so much work under its use." "It is not like I don't like something but I would like to see further extension."	"I like to see such development in the diabetes management, especially many patient uses mobile diabetes diaries but I think the development should be continued further because when it comes to medical practice, there are many restrictions to additional devices use."
(3) Do you see in the use of the application future possible development of diabetes management?	"Yes."	"Yes, it is possible with further extension."
(4) Would you consider use of such application in your practice? Why?	"Yes. It is very simple to use and I think it will help me in daily practice with diabetes patients."	"I see that it shows lots of statistics but its view is simplified. True, this can save time."
(5) Is it comfortable to use application? Is application understandable and intuitive?	"Yes. It is very easy to use and I feel comfortable. I like it."	"Yes."
(6) What would you like to add to the application that could play crucial role in further use?	"I would like to add some blinking navigation. For example, the icon I have to press next will be shown in other color. Also, I would like to have all transferred data in my system I use. So, it has to be there somehow."	"I think the possibility to transfer data further to the computer will be important. I would like to have shared with me data in electronic health record."
(7) Do you think this app with possible extensions can improve quality of diabetes care generally?	"Yes, I think it can."	"This application is something that is very interesting for further development. With extensions it could very interesting to use."

7.2.3 Feedback

Apart from the interviews and discussions, both doctors were asked to provide their truly personal feedback with pointing out all positive and negative moments of using "Diabetes Care" application in the provided format.

Nils Kolstrup: "I think it's fantastic. It is very simple to use, useful. I like that patient's part of the application is managing appointments and doctor's recommendations. I think this is very important to take heath more serious. I like that design is similar for doctors and patients and it makes it clear. I understand that this application depends on other one, developed by NST, and there are not many patients who use it; but I think this is not a problem. Once this application will be proven to be effective for doctors, patients will use "Diabetes Diary" and "Diabetes Care".

Thomas Roger Schopf: "I really think this is something interesting and I am very surprised that no one did it before. It should be done. I see its purpose and I think this is good but then it comes to medical practice, we are very limited. I assume the shared file should be in my computer but this is further development. As I see the application depends on "Diabetes Diary" that created at NST and what I think that use of your application could increase use of "Diabetes Diary" because patients will know that that data will help doctor to provide better care."

7.3 Summary

The Chapter was reflected to the application testing and its results.

Testing process was divided into two stages: the first stage represents functionality test and the second stage represents usability test of the implemented application.

Full functionality test was performed based on functional and non-functional requirements (performance, security, reliability and efficiency). Results for both types of the requirements were provided. Overall, application operation was performing correctly.

For the final usability test, two medical doctors with clinical practice as general practitioners were involved. Testing procedure was built upon documenting first impressions about achieved quality factors of usability, interviews and discussions.

Results of the usability testing were represented. First, results of the test on usability requirements based on doctors' opinions are made. Second, based on the interview questions, doctors' answers were documented. Overall, both of the doctors expressed highly positive thoughts about the implemented application. Both of them mentioned that the application is an innovative and they were hoping to see further PhD research for the area.

Apart from the interviews and discussions, both doctors were asked to provide their truly personal feedback with pointing out all positive and negative moments of using "Diabetes Care" application.

CHAPTER 8. DISCUSSION

This Chapter arrays discussion related to the motivation for technology choice, intended use of the application, testing results, limitations and future work.

Motivation for technology choice provides an explanation of Android Beam feature. Comparative analysis of possible for use technologies and their overview is provided.

Intended use of the application is elaborated based on the information collected from meetings with medical professionals during the applications development. Comparative analysis of the consultation flow for diabetes management used today and consultation flow with use of the application is performed.

Testing results section is based on the results of usability testing by two medical doctors. The results are analyzed based on the usability requirements examination, interviews and discussions.

Five the most sufficient limitations in the research are clarified.

Two direction of possible future work as further application development are identified and elaborated.

8.1 Motivation for Technology Choice

For the development, ***Android Beam*** feature was chosen as the main technology for "patient – general practitioner" data transfer. The reason for the technology choice lays on the results of the comparative analysis made on the first stages of the research *(see Table 27)* [32, 78].

In the table, highlighted sections with a green color represents technology specifications based on set-up time, range, usability, level of ease of use, selectivity, use cases and consumer experience that are the most attractive to be applied for the data transfer. To use the technology, all sections must be highlighted in green, which is only possible if two technologies, such as NFC and Bluetooth (Android Beam) or NFC and Wi-Fi Direct will be combined (S Beam).

Android Beam was introduced with Android version 4.0. It uses ***NFC*** technology to establish connection between two mobile devices and then uses ***Bluetooth*** for data transfer. The connection time, ease of use, and high rate of data transfer make it perfect for data transfer. Unlike ***S Beam***, which uses ***NFC*** for connection set-up and ***Wi-Fi Direct*** for data transfer, any Android mobile device running version 4.0 or higher can connect [71]. This makes it perfect for the "Diabetes Care" application because it will not require the use of only Samsung Galaxy devices. For the matter, Android Beam was chosen.

Table 27. Comparison of NFC, Bluetooth and Wi-Fi Direct

	Near Field Communication [44]	**Bluetooth** [72]	**Wi-Fi Direct** [73]
Set-up time	<0.1ms	~10s	~10s
Range	Up to 20cm	Up to 60m	Up to 200m
Usability	Human centric, intuitive	Data centric	Data centric
Level of ease of use	Easy	Medium	Medium
Selectivity	High, given, security	Given	High, given, security
Use cases	Pay, get access, share, initiate service, easy set-up	Network for data exchange, headset	Network for data exchange, printer, remote
Consumer experience	Simply connect	Configuration needed	Configuration needed

One more table was created with overall information about all the analyzed technologies *(see Table 28)*.

Table 28. Overview of possible used technologies

Technology	About
Near Field Communication [44]	Near field communication (NFC) is a communication that uses magnetic induction between two loop antennas. The band that it operates is a radio frequency ISM band of 13.56 MHz. Although working distance of NFC is up to 20 cm, the effective distance is around 4 cm. Set-up time is less than a second and it makes the technology very fast and easy to use. The devices just need to touch each other for the connection to be established. The supported data rates are 106, 212, and 424 kbit/s. The speed and the need to be in a close proximity make it not a great choice for large data transfer. Another drawback of NFC is the adoption rate. Apple has yet to release a phone with NFC chip. Apart from using it as a data transfer method, NFC has a popular use as a payment method. Quick set-up time, the use of passive communication mode, and security due to the need of close proximity make it easy and effective way to pay for services such as public transportation [43, 48, 74].

Bluetooth [72]	Bluetooth is a wireless communication technology standard to exchange data. It works using UHF radio waves in the ISM band from 2.4 to 2.485 GHz. Bluetooth v3.0 supports speeds of up to 24 Mbit/s. The range and speed make it a very good method to exchange large amounts of data between two devices. The biggest drawback is the time it takes for the devices to connect. Unlike NFC, the user has to set-up the connection, which has varied set-up time depending on the knowledge of the user. The connection set-up time takes around 10 seconds [75, 76, 77].
Wi-Fi Direct [73]	Wi-Fi Direct is a way for two or more devices to be connected without the need of a router. It is close to ad-hoc mode. The speeds and distance that it can achieve depend on the type of Wi-Fi adapter. Wi-Fi Alliance promises speeds up to 250 Mbit/s compared to around 11 Mbit/s in ad-hoc mode. The set-up is also a lot simpler than ad-hoc mode. Another advantage of Wi-Fi Direct is that it is support by a lot of different devices. Mobile devices running Android, IOS, or Blackberry OS can connect with each other to share data. Prior to Android version 4.0, the only support for Wi-Fi Direct was on Samsung devices with the support of proprietary S Beam [78, 79].

8.2 Intended Use of the Application

On the basis of the information collected from meetings with medical professionals throughout the entire period the applications development *(see Table 5, Interviews, questionnaire and discussions during the study)* were identified details of the diabetes management on the medical consultations with patients. In order to demonstrate the conditional use of the application, the table was created with the process of consultation ongoing today and those, which is calculated under the condition of use of the “Diabetes Care” application *(see Table 29)*.

According to the table, recently patients share paper-based diabetes diary with general practitioner and it takes approximately 10 seconds. The use of the application will not increase that time dramatically and will take around 20 seconds.

Further, general practitioner uses the diary to overview the measurements. Such procedure can take up to 5 minutes to evaluate patient’s data. Also, the statistical analysis could be incorrect due to limit of time and enormous amount of information. For instance, measurements for glucose level can reach up to 9 times a day, 63 a week, 252 a month and 1512 a half of year. To analyze such numbers is not possible due to the consultation time and it will require high accuracy with statistical calculation. The example was given for glucose level measurements but such measurements as insulin intake, physical activity and carbohydrates intake are also will require time for analysis. If general practitioner will use tablet with running “Diabetes Care” application, the time spent on overview patient’s data will vary from 2 to 3 minutes but the application, implemented with statistical rules, analysis, and decision support, will provide accurate data for any period and parameter general practitioner wants to see.

As it was noticed in Chapter 4, *Requirements Specifications (see section 4.2, Medical Basis of the Requirements)*, recently, while general practitioner uses the information system to record the data about patient’s condition and progress, patient is waiting. With use of the “Diabetes Care” application, patient can use this time to record into the system recommendations received from a doctor using special template, which created in a way of very simple and intuitive use.

Explained intended use of the “Diabetes Care” shows that the application will not require additional time on the consultation but will support general practitioner’s practice and provide patient's use (appointments and recommendations management); and by the last, based on the medical opinion of all participated in the development medical doctors *(see Table 5, Interviews, questionnaire and discussions during the study)*, the attitude to given by general practitioner recommendations will be received more attentive by most patients.

Table 29. Comparison of consultation today and with use of the "Diabetes Care" application

	Consultation today	**Consultation with use of "Diabetes Care" application**
Type of patient's data	Paper-based diabetes diary	Electronic database with measurements
Time to share data	10 seconds	20 seconds
Time to overview patient's data	Up to 5 minutes	Around 3 minutes
Statistical accuracy	Low	High
Volume of data processing	Low	High
Decision support	No	Yes
Patient involvement into consultation while waiting	No	Recommendations and appointments management

8.3 Testing Results

This section highlights the results of the "Diabetes Care" application testing by medical doctors with clinical practice as general practitioners. Nils Kolstrup and Thomas Roger Schopf were involved into final usability testing of the implemented application. The procedure of the testing was the same for both of the doctors and included (1) usability requirements examination, (2) interviews based on the trial and followed (3) discussions.

(1) ***Usability requirements examination***

As for usability requirements examination, quality factors as attractiveness, credibility, differentiation, ease to enter, ease to learn, ease of location, ease to remember, ease to use, effectiveness, error minimization, navigability, preference, retrievability, suitability, understandability and user satisfaction were posed. Doctors expressed their impressions during the trial according to all of the requirements *(see section 7.2.2, Results)*. The scale of measure included positive, positive with notes to improve and negative impression. Both doctors had positive impressions about all the requirements but two. Nils's impression about navigability was positive with notes to improve, as well as Thomas's impression about user satisfaction was also positive with notes to improve.

(2) ***Interviews***

Based on doctor's answers on seven main questions included in the interviews *(see section 7.2.2, Results)*, the following conclusion was made. (1) Both of the medical doctors expressed very positive first impression. (2) The simplicity of use, design and the idea of development were highlighted by doctors as strong sides of the application. (3) Both of doctors saw in the use of the application future possible development of diabetes management. (4) Both of doctors considered use of the application in their practice. (5) The application was accepted as comfortable to use, understandable and intuitive. (6) Further data transfer to doctor's stationary computer and navigability were considered for further development. (7) Both of doctors were prone to think that with possible further extensions and consideration of legal issues, the application can improve quality of diabetes care generally.

(3) ***Discussions***

Overall, both of the doctors expressed highly positive thoughts about the implemented application. Both of them mentioned that the application is an innovative and they were hoping to see further PhD research for further extension. Nils pointed out that application could be used today by its quality and functionality; however, some legal issues have to be considered before it's starting since the application represents clinical use. Doctors provided their concluding feedback about the "Diabetes Care" application.

Nils Kolstrup said, "I think it's fantastic. It is very simple to use, useful. I like that patient's part of the application is managing appointments and doctor's recommendations. I think this is very important to take heath more serious. I like that design is similar for doctors and patients and it makes it clear. I understand that this application depends on other one, developed by NST, and there are not many patients who use it; but I think this is not a problem. Once this application will be proven to be effective for doctors, patients will use "Diabetes Diary" and "Diabetes Care".

Thomas Roger Schopf also provided feedback***:*** "I really think this is something interesting and I am very surprised that no one did it before. It should be done. I see its purpose and I think this is good but then it comes to medical practice, we are very limited. I assume the shared file should be in my computer but this is further development. As I see the application depends on "Diabetes Diary" that created at NST and what I think that use of your application could increase use of "Diabetes Diary" because patients will know that that data will help doctor to provide better care."

8.4 Limitations

Throughout the development, five limitations were found.

(1) The "Diabetes Care" application is based on the CSV database exported from the "Diabetes Diary" application. It shows strong dependency of "Diabetes Care" on "Diabetes Diary" application, developed by the Norwegian Centre of Integrated Care and Telemedicine. General practitioners will not be able to use the "Diabetes Care" unless patients will use "Diabetes Diary". Moreover, only the data contained in the CSV database can be obtained and represented in an advanced way to a general practitioner.

(2) Narrow range of participants who tested the application is a very important limitation. There are only two medical doctors who tested the final implemented application and four who supported the development during its evolution. As well, considering the application has two accesses for general practitioners and patients, the application was not tested by the real patients with diabetes. The two reasons were crucial for declining participation are personal reasons and the fact of using other tools for self-management then "Diabetes Diary" application.

(3) Participated in the research medical doctors are practicing doctors in Norway, and the specific laws may affect perception of the "Diabetes Care" application.

(4) The use of selected NFC technology is rapidly growing, nevertheless still insufficiently developed and does not integrated into a broad range of portable devices.

(5) The lack of time was considerable limitation due to sufficiently large-scale development.

8.5 Future Work

For the further research in development of the applications, it was identified two principal directions. These directions were formed under the influence of participated medical doctors and technical experts during the recent research *(see Table 5, Interviews, questionnaire and discussions during the study)*. Directions were easy enough to identify since professionals, independently of each other were interested in the same topics.

(1) ***Further data transfer into electronic health record***

All the doctors who were involved in the development noted that it would be very significant advance of the application, if possible to use the obtained patient's data in the information system, which mainly used by general practitioners as an electronic health record. This issue touches resolution of technical issues such as the way of further data transfer and data format. Prospectively, external NFC adapter could be used to allow data transfer from portable device to stationary computer. Also, the data format has a large value. For example, it is now possible to take a screenshot of data representation by pressing one button, however, such way of data capture requires a further detailed study. As well, legal issues are needed be taken into account. Use of such solution could not be state in the laws and it means the way of the technical resolution of the further extension should be based on the law.

(2) ***Integration of patient module of the "Diabetes Care" into the "Diabetes Diary" application***

In most, technical experts noted this direction. Integration of patient module of the "Diabetes Care" application will expand the "Diabetes Diary" greatly, as well as it might be more comfortable to use for patients. Thus, partly integration of the two mentioned applications will provide a stronger system to diabetes self-management and management in general practice. This issue is due to be analyzed in details for the applications' integration decision.

8.6 Summary

This Chapter arrayed discussion related to the motivation for technology choice, intended use of the application, testing results, limitations and future work.

In motivation for technology choice section an explanation of the Android Beam choice instead of pure technologies as NFC, Bluetooth and Wi-Fi Direct was provided; also the explanation of the S Beam elimination from final choice was justified. Comparative analysis of the possible for use technologies and its overview was provided as well.

Intended use of the application was elaborated based on the information collected from meetings with medical professionals throughout the entire period the applications development. Comparative analysis of the consultation flow for diabetes management used today and consultation flow with use of the application was performed. Use of the “Diabetes Care” shows that the application will not require additional time on the consultation but will support general practitioner’s practice and provide patient’s involvement (appointments and recommendations management).

Overview of testing results based on usability requirements examination by two medical doctors, interviews and discussions with them was documented. Overall, both of the doctors expressed highly positive thoughts about the implemented application.

Research limitations were clarified.

Two direction of possible future work as further data transfer into electronic health record and integration of patient module of the “Diabetes Care” into the “Diabetes Diary” application were found the most arousing for the further studies.

CHAPTER 9. CONCLUSION

9.1 Concluding Remarks

Research group at the Norwegian Centre of Integrated Care and Telemedicine (NST) suggested as a ***research area*** for the master thesis theme "Doctor's tablet – extended version of the "Diabetes Diary" with doctor's functionality". The decided research solution was expected to allow general practitioner to use tablet and to see advanced statistical data and trends for blood glucose level, physical activity, taken insulin and carbohydrates of a patient that have been gathered such data in the "Diabetes Diary" application, developed by NST. Due to the research area, the direction for the development was indicated. The ***goal of the thesis*** research was to develop an application that will support diabetes management in general practice. In the beginning of the research the future application was called ***"Diabetes Care***" and was implied for two users: patient and general practitioner.

To achieve the goal, three main ***research questions*** were proposed and were connected to research resolutions for (1) data transfer, (2) design, and (3) data processing and representation.

(1) ***Data transfer***

Because of the "Diabetes Diary" is available for Android operating system (OS), and the version is more extended then iOS application version, it was decided to continue development with Android OS. Based on the chosen software, ***Android Beam*** feature was chosen as the main technology for "patient – general practitioner" data transfer. It uses ***NFC*** technology to establish connection between two portable devices and then uses ***Bluetooth*** for data transfer. The connection time, ease of use, and high rate of data transfer make it appropriate for data transfer in clinical environment.

(2) ***Design***

The "Diabetes Care" application designed with two modules for such types of users as "General Practitioner" and "Patient". Users have different purposes of the application use. The main purpose for a patient is to send from "Diabetes Diary" exported CSV database to a general practitioner, while the main purpose for a general practitioner is to set the received data in an advanced way to overview patient's measurements over the time. Patient's version is created for a smartphone and general practitioner's version is created for a tablet. Patient's version was extended with recommendations and appointments management due to the suggestions of medical doctors. From functionality and usability perspectives, the application is designed due to collected medical requirements during the thesis research.

(3) ***Data processing and representation***

Patient's database with all measurements related to the diabetes self-management could be exported from the "Diabetes Diary" application in CSV format in folder named "no.telemed.diabetesdiary/files/exporter" on the patient's device. The exported database is used for further processing. The suggested solution was the "Diabetes Care" application, which is running on patient's device, accesses the folder and take the database to send to a general practitioner's tablet. After the CSV is transferred to the tablet, the system of the "Diabetes Care" application converts it into DB format. Further data processing includes data representation. For the data representation process, statistical rules, including rules for clinical decision support, were developed. The scheme how the data will be represented we strictly discussed with medical doctors. It was confirmed to represent the data into graphs in a relation to a chosen period and time. The statistical analysis and decision support function for glucose level, physical activity, taken insulin and carbohydrates differ from each other.

After the solutions in the relation to data transfer, design, and data processing and representation were found, the "Diabetes Care" application has been implemented and tested. First, the quality and stability of functioning were checked; no faults were found. Then, final usability test took place in a matter to evaluate the development results. Two medical doctors, Nils Kolstrup and Thomas Roger Schopf, were involved into final usability testing of the implemented application. The procedure of the testing was the same for both of the doctors and included usability requirements examination, interviews based on the trial and followed discussions.

Based on usability requirements examination, both doctors had positive impressions about all set of the requirements but navigability and user satisfaction; these two was also positive but with notes to improve. According to the interview and discussions, both of the medical doctors expressed very positive first impression and highlighted simplicity of use, design and the idea of development. The use of the application was considered by both of the doctors, as well, as the fact that application was comfortable to use, understandable and intuitive. Overall, Nils and Thomas saw in the use of the application future possible development of diabetes management and were prone to think that with possible further extensions and consideration of legal issues, the application can improve quality of diabetes care generally.

Despite the fact that exclusively two medical doctors have tested the application, the results of each test were similar. This allows assuming that relevance of the "Diabetes Care" application should be tested and studied further with possible development.

9.2 Thesis Contribution

Novel effort in diabetes management in general practice

As a state-of-the-art, systematic review of literature that is representing similar research developments was performed. The results allowed to conclude that all previous attempts at providing communication between medical doctors and patients with diabetes were done only through a distance web-based interactions and it was not state as a supplement to the diabetes management in general practice. Moreover, no literature showed systems with advanced statistics for data representation and no studies were found for decision support function of obtained patient's data. Due to the fact, the conclusion is made that there are no similar solutions worldwide that are oriented on support of diabetes management in general practice by sharing patient's measurements with a doctor during the consultation for further advanced statistical analysis with decision support provision.

Advanced statistical analysis and decision support

The application is developed to support diabetes management in general practice, by helping general practitioner in a more rapid and qualitative way to analyze patient's measurements of glucose levels, insulin intakes, physical activity, and carbohydrates intakes over time. Each type of measurements was developed statistics in a way to reflect information depending on the precise period of time. For example, if the cause of patient's recent condition is started precisely 50 days ago, doctor has a possibility to see mentioned period in a few seconds. As well, decision support function was embedded into statistical rules. With the "Diabetes Care" application doctor see insufficiency or prosperity of patient's physical activity, as well as morning glucose levels that are among the most important aspects of the diabetes prevention and control. Color representation of the decision support function is oriented on the error minimizing and saving time for the discussion on the consultation between general practitioner and patient, which is very important human factor for psychological comfort of a patient.

Acceptance of the application by medical doctors

Application testing showed very promising results according to medical doctors' acceptance of the "Diabetes Care". Doctors who tested the implemented application expressed highly positive attitude to the application use. The direction of the research was pointed as an innovative and doctors showed strong interest to the application development.

Involvement of patients in recommendation management

As was noted by medical experts during the study, greater involvement of the patient in the diabetes self-management has a positive impact on patient's health. The application gives an opportunity for a patient to use the time on consultation that doctor spends for filling out the electronic health record. At this time, patient can record doctor's recommendation that were provided in a respect to glucose level, insulin intake, physical activity or carbohydrates consumption. For that matter, a special template for information input and representation were developed. This additional resolution of "Diabetes Care" application can help patients with self-monitoring of the medical recommendations implementation.

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LIST OF APPENDICIES

APPENDIX 1. ANALYZED ARTICLES FOR STATE-OF-THE-ART

Article	Author (-s)	Source
18F-FDGPET/CT: diabetes and hyperglycemia.	Niccoli-Asabella A, Iuele FI, Merenda N, Pisani AR, Notaristefano A, Rubini G.	Nucl Med Rev Cent East Eur. 2013;16(2):57-61. doi: 10.5603/NMR.2013.0035.
Integration of a mobile-integrated therapy with electronic health records: lessons learned.	Peeples MM, Iyer AK, Cohen JL.	J Diabetes Sci Technol. 2013 May 1;7(3):602-11.
The development and feasibility of a web-based intervention with diaries and situational feedback via smartphone to support self-management in patients with diabetes type 2.	Nes AA, van Dulmen S, Eide E, Finset A, Kristjánsdóttir OB, Steen IS, Eide H.	Diabetes Res Clin Pract. 2012 Sep;97(3):385-93. doi: 10.1016/j.diabres.2012.04.019. Epub 2012 May 10.
An intensive insulinotherapy mobile phone application built on artificial intelligence techniques.	Curran K, Nichols E, Xie E, Harper R.	J Diabetes Sci Technol. 2010 Jan 1;4(1):209-20.
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The potential of cellular technology to mediate social networks for support of chronic disease self-management.	Roblin DW.	J Health Commun. 2011;16 Suppl 1:59-76. doi: 10.1080/10810730.2011.596610.

Applications of urinary proteomics in biomarker discovery.	Shao C, Wang Y, Gao Y.	Sci China Life Sci. 2011 May;54(5):409-17. doi: 10.1007/s11427-011-4162-1. Epub 2011 Mar 31.
Sustaining remote-area programs: retinal camera use by Aboriginal health workers and nurses in a Kimberley partnership.	Murray RB, Metcalf SM, Lewis PM, Mein JK, McAllister IL.	Med J Aust. 2005 May 16;182(10):520-3.
Health care provider quality improvement organization Medicare data-sharing: a diabetes quality improvement initiative.	Ballard DJ, Nicewander D, Skinner C.	Proc AMIA Symp. 2002:22-5.
Use of the Physician Insurers Association of America database as a surveillance tool for diabetes-related malpractice claims in the U.S.	Meredith V, Cook CB, Penman A.	Diabetes Care. 1998 Jul;21(7):1096-100.
Increased gait variability in diabetes mellitus patients with neuropathic pain.	Lalli P, Chan A, Garven A, Midha N, Chan C, Brady S, Block E, Hu B, Toth C.	J Diabetes Complications. 2013 May-Jun;27(3):248-54. doi: 10.1016/j.jdiacomp.2012.10.013. Epub 2012 Dec 4.
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Preliminary evaluation of a skin conductance meter for detecting hypoglycemia in diabetic patients.	Pickup JC.	Diabetes Care. 1982 May-Jun;5(3):326-9.
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SMARTDIAB: A Communication and Information Technology Approach for the Intelligent Monitoring, Management and Follow-up of Type 1 Diabetes Patients	Mougiakakou, S.G. ; Bartsocas, C.S. ; Bozas, E. ; Chaniotakis, N. ; Iliopoulou, D. ; Kouris, I. ; Pavlopoulos, S. ; Prountzou, A. ; Skevofilakas, M. ; Tsoukalis, A. ; Varotsis, K. ; Vazeou, A. ; Zarkogianni, K. ; Nikita, K.S.	Information Technology in Biomedicine, IEEE Transactions on (Volume:14 , Issue: 3) May 2010
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Bayesian analysis of blood glucose time series from diabetes home monitoring	Bellazzi, R. ; Magni, P. ; De Nicolao, G.	Biomedical Engineering, IEEE Transactions on (Volume:47 , Issue: 7) July 2000
Designing patient-centric applications for chronic disease management	Tsalatsanis, A. ; Gil-Herrera, E. ; Yalcin, A. ; Djulbegovic, B. ; Barnes, L.	Engineering in Medicine and Biology Society,EMBC, 2011 Annual International Conference of the IEEE Aug. 30 2011-Sept. 3 2011
Development of a fully automated closed loop artificial pancreas control system with dual pump delivery of insulin and glucagon	Jacobs, P.G. ; Youssef, Joseph El ; Castle, Jessica R. ; Engle, Julia M. ; Branigan, Deborah L. ; Johnson, Phillip ; Massoud, Ryan ; Kamath, Apurv ; Ward, W.Kenneth	Engineering in Medicine and Biology Society,EMBC, 2011 Annual International Conference of the IEEE Aug. 30 2011-Sept. 3 2011
Identification of hypoglycemic states for patients with T1DM using various parameters derived from EEG signals	Nguyen, L.B. ; Ling, S.S.H. ; Jones, T.W. ; Nguyen, H.T.	Engineering in Medicine and Biology Society,EMBC, 2011 Annual International Conference of the IEEE Aug. 30 2011-Sept.

		3 2011
E-Health towards ecumenical framework for personalized medicine via Decision Support System	Kouris, I. ; Tsirmpas, C. ; Mougiakakou, S.G. ; Iliopoulou, D. ; Koutsouris, D.	Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE Aug. 31 2010-Sept. 4 2010
A Fuzzy Expert System for Diabetes Decision Support	Chang-Shing Lee ; Mei-Hui Wang	Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on (Volume:41 , Issue: 1) Feb. 2011
A Healthy Lifestyle Coaching-Persuasive Application for Patients with Type 2 Diabetes	Fico, G. ; Fioravanti, A. ; Arredondo, M.T. ; Ardigo, D. ; Guillen, A.	Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE Aug. 31 2010-Sept. 4 2010
BlackSea TeleDiab: Diabetes computer system with communication technology for black sea region	Pruna, S.S. ; Dixon, R. ; Harris, N.D.	Information Technology in Biomedicine, IEEE Transactions on (Volume:2 , Issue: 3) Sept. 1998
OLDES: New solution for long-term diabetes compensation management	Novak, D. ; Stepankova, O. ; Mraz, M. ; Haluzik, M. ; Bussoli, M. ; Uller, M. ; Maly, K. ; Novakova, L. ; Novak, P.	Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE 20-25 Aug. 2008
MediNet: Personalizing the self-care process for patients with diabetes and cardiovascular disease using mobile telephony	Mohan, P. ; Marin, D. ; Sultan, S. ; Deen, A.	Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE 20-25 Aug. 2008
Automated creation of transparent fuzzy models based on decision trees - application to diabetes diagnosis	Tsipouras, M.G. ; Exarchos, T.P. ; Fotiadis, D.I.	Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE 20-25 Aug. 2008
The implementation of a Quality-Net as a part of the European project DIABCARE Q-Net	Gerlach, K. ; Kaeding, A. ; Kottmair, S. ; Westphal, D. ; Henning, G. ; Piwernetz, K.	Information Technology in Biomedicine, IEEE Transactions on (Volume:2 , Issue: 2) June 1998
Performance of insole in reducing plantar pressure on diabetic Patients in the early stages of the disease	Zequera, M.L. ; Solomonidis, S.	Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE Aug. 31 2010-Sept. 4 2010
Kinetic Modeling of the Glucoregulatory System to Improve Insulin Therapy	Salzsieder, E. ; Albrecht, G. ; Fischer, U. ; Freyse, E.-J.	Biomedical Engineering, IEEE Transactions on (Volume:BME-32 , Issue: 10) Oct. 1985
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Data acquisition in a wireless diabetic and cardiac monitoring system	Harvey, P. ; Woodward, B. ; Datta, S. ; Mulvaney, D.	Engineering in Medicine and Biology Society,EMBC, 2011 Annual International Conference of the IEEE Aug. 30 2011-Sept. 3 2011
The electromyogram (EMG) as a control signal for functional neuromuscular stimulation. I. Autoregressive modeling as a means of EMG signature discrimination	Hefftner, G. ; Zucchini, W. ; Jaros, G.G.	Biomedical Engineering, IEEE Transactions on (Volume:35 , Issue: 4) April 1988
Experiments with repeating weighted boosting search for optimization signal processing applications	Sheng Chen ; Xunxian Wang ; Harris, C.J.	Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on (Volume:35 , Issue: 4) Aug. 2005
Data mining for blood glucose prediction and knowledge discovery in diabetic patients: The METABO diabetes modeling and management system	Georga, E. ; Protopappas, V. ; Guillen, A. ; Fico, G. ; Ardigo, D. ; Arredondo, M.T. ; Exarchos, T.P. ; Polyzos, D. ; Fotiadis, D.I.	Engineering in Medicine and Biology Society, 2009. EMBC 2009. Annual International Conference of the IEEE 3-6 Sept. 2009
Mobile Applications for Diabetes Self-Management: Status and Potential	El-Gayar O, Timsina P, Nawar N, Eid W.	J Diabetes Sci Technol. 2013 Jan 1;7(1):247-62.
Enhanced 911/Global Position System Wizard: A Telemedicine Application for the Prevention of Severe Hypoglycemia—Monitor, Alert, and Locate	Dassau E, Jovanovic L, Doyle FJ 3rd, Zisser HC.	J Diabetes Sci Technol. 2009 Nov 1;3(6):1501-6.
Evolution of Data Management Tools for Managing Self-Monitoring of Blood Glucose Results: A Survey of iPhone Applications	Rao A, Hou P, Golnik T, Flaherty J, Vu S.	J Diabetes Sci Technol. 2010 Jul 1;4(4):949-57.
The Current Status of mHealth for Diabetes: Will it Be the Next Big Thing?	Klonoff DC.	J Diabetes Sci Technol. 2013 May 1;7(3):749-58.
Virtual Reality and Interactive Gaming Technology for Obese and Diabetic Children: Is Military Medical Technology Applicable?	Talbot TB.	J Diabetes Sci Technol. 2011 Mar 1;5(2):234-8.
Pilot Study Using Mobile Health to Coordinate the Diabetic Patient, Diabetologist, and Ophthalmologist	Tsui I, Drexler A, Stanton AL, Kageyama J, Ngo E, Straatsma BR.	J Diabetes Sci Technol. 2014 Apr 14. pii: 1932296814529637
Monitoring Artificial Pancreas Trials Through Agent-based Technologies: A Case Report	Lanzola G, Scarpellini S, Di Palma F, Toffanin C, Del Favero S, Magni L, Bellazzi R	J Diabetes Sci Technol. 2014 Mar 2;8(2):216-224.
The Scope of Cell Phones in Diabetes Management in	Ajay VS, Prabhakaran D.	J Diabetes Sci Technol. 2011 May 1;5(3):778-83.

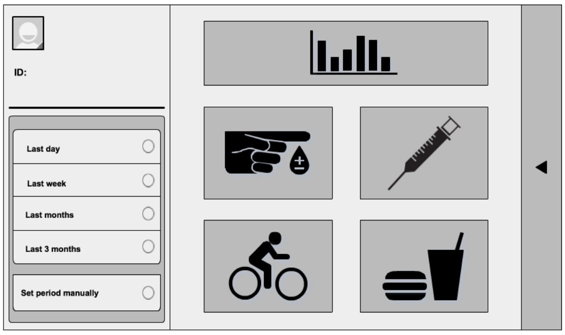
Developing Country Health Care Settings		
Model-driven diabetes care: study protocol for a randomized controlled trial.	Skrøvseth SO, Årsand E, Godtliebsen F, Joakimsen RM.	Trials. 2013 May 14;14:139. doi: 10.1186/1745-6215-14-139.
Going Mobile with a Multiaccess Service for the Management of Diabetic Patients	Lanzola G, Capozzi D, D'Annunzio G, Ferrari P, Bellazzi R, Larizza C.	J Diabetes Sci Technol. 2007 Sep;1(5):730-7.
The Impact of Mobile Monitoring Technologies on Glycosylated Hemoglobin in Diabetes: A Systematic Review	Baron J, McBain H, Newman S.	J Diabetes Sci Technol. 2012 Sep 1;6(5):1185-96.
Integrative Gaming: A Framework for Sustainable Game-Based Diabetes Management	Kahol K.	J Diabetes Sci Technol. 2011 Mar 1;5(2):293-300.
The Potential Use of Radio Frequency Identification Devices for Active Monitoring of Blood Glucose Levels	Moore B.	J Diabetes Sci Technol. 2009 Jan;3(1):180-3.
A Heads-Up Display for Diabetic Limb Salvage Surgery: A View Through the Google Looking Glass	Armstrong DG, Rankin TM, Giovinco NA, Mills JL, Matsuoka Y	J Diabetes Sci Technol. 2014 May 18. pii: 1932296814535561.
Bringing the Artificial Pancreas Home: Telemedicine Aspects	Lanzola G, Capozzi D, Serina N, Magni L, Bellazzi R.	J Diabetes Sci Technol. 2011 Nov 1;5(6):1381-6.
Guidelines for Optimal Bolus Calculator Settings in Adults	Walsh J, Roberts R, Bailey T.	J Diabetes Sci Technol. 2011 Jan 1;5(1):129-35.
Can Wireless Technology Enable New Diabetes Management Tools?	Hedtke PA.	J Diabetes Sci Technol. 2008 Jan;2(1):127-30.
Using the Widely Available Blood Glucose Meter to Monitor Insulin and HbA1c	Yu Xiang, Tian Lan, Yi Lu	J Diabetes Sci Technol May 29, 2014 1932296814532875
Recent Advances in Free-Living Physical Activity Monitoring: A Review	Andre D, Wolf DL.	J Diabetes Sci Technol. 2007 Sep;1(5):760-7.
Automatic Data Processing to Achieve a Safe Telemedical Artificial Pancreas	Hernando ME, García-Sáez G, Martínez-Sarriegui I, Rodríguez-Herrero A, Pérez-Gandía C, Rigla M, de Leiva A, Capel I, Pons B, Gómez EJ.	J Diabetes Sci Technol. 2009 Sep 1;3(5):1039-46.
Noninvasive Measurement of Plasma Triglycerides and Free Fatty Acids from Exhaled Breath	Minh Tdo C, Oliver SR, Flores RL, Ngo J, Meinardi S, Carlson MK, Midyett J, Rowland FS, Blake DR, Galassetti PR.	J Diabetes Sci Technol. 2012 Jan 1;6(1):86-101.
Problems and Practical Solutions in the External Quality Control of Point of Care Devices with Respect to the Measurement of Blood Glucose	Wood WG.	J Diabetes Sci Technol. 2007 Mar;1(2):158-63.
Microformats: Three Proposed	Bernard Farrell	J Diabetes Sci Technol. 2007

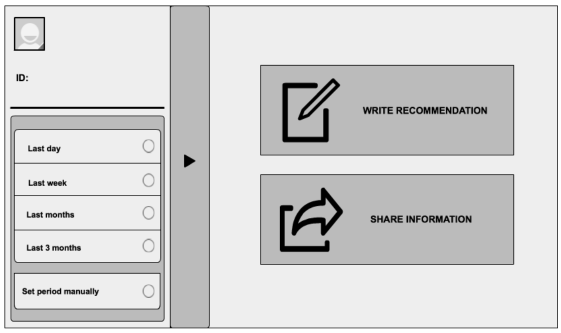
Standards for Solving the Need for Standard Data Presentation		Mar;1(2):245-250
Approaches to Display of Multiple-Point Glucose Profiles: A UK Patient's Perspective	Daniel Kay	*J Diabetes Sci Technol July 2, 2014 1932296814541245*
Review of Designing an Information Processing Ware for a Diabetic Chip	AL-Sheikh YT, Andrade JD, Millington J, Wong A.	J Diabetes Sci Technol. 2008 Sep;2(5):873-81.
Missing Elements Revisited: Information Engineering for Managing Quality of Care for Patients with Diabetes	Connor MJ, Connor MJ.	J Diabetes Sci Technol. 2010 Sep 1;4(5):1276-83.
An Analysis of Data Management Tools for Diabetes Self-Management: Can Smart Phone Technology Keep Up?	Ciemins E, Coon P, Sorli C.	J Diabetes Sci Technol. 2010 Jul 1;4(4):958-60.
Data Standards in Diabetes Patient Registries	Richesson RL.	J Diabetes Sci Technol. 2011 May 1;5(3):476-85.
Diabetes Research in Children Network: Availability of Protocol Data Sets	Ruedy KJ, Beck RW, Xing D, Kollman C.	J Diabetes Sci Technol. 2007 Sep;1(5):738-45.
Mobile Phone-Based Self-Management Tools for Type 2 Diabetes: The Few Touch Application	Arsand E, Tatara N, Østengen G, Hartvigsen G.	J Diabetes Sci Technol. 2010 Mar 1;4(2):328-36.
Data Mining for Improved Cardiac Care	R. Bharat Rao, Sriram Krishnan, Radu Stefan Niculescu	ACM SIGKDD Explorations Newsletter Volume 8 Issue 1, June 2006 Pages 3-10

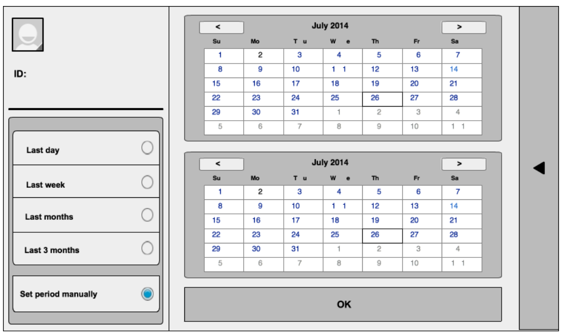
APPENDIX 2. INTERVIEW WITH NILS KOLSTRUP, OCTOBER 2013

Questions

1. Does a medical doctor need to keep the data (any kind on information about the patient) from patient's device after session?
2. Could it be a solution to delete the data automatically or manually in the end of the consultation?
3. What kind of statistical data (in a relationship to diabetes) needs to be obtained by a medical doctor on the session?
4. Does doctor usually make any notes during the consultation? Are they paper-based or electronic notes? If yes, what kind of notes are made and could it be useful to share part of written notes with a patient (or patient receives only recommendation and notes made by a doctor are have to be stored into a clinical health record of the patient)?
5. Will it be an important addition in the application to have a calendar (or list of chronologically divide appointments) with information about all the scheduled sessions with diabetes patients? If yes, what is the most appropriate way to mention a concrete patient (ID, real name, etc.)?
6. What are the most needed features (requirements from medical point of view) are expected by a doctor to be in the application?
7. What is an approximate time range for a single consultation? Are there any particular questions that discussed with all of the patients each consultation?
8. Will it be comfortable for a doctor to make notes from the consultation using a tablet device? If yes, will such feature, as possibility to print out the notes is needed?
9. Could you provide feedback on first sketches of the application based on the figures below?







APPENDIX 3. INTERVIEW WITH GERD ERSDAL, MARCH 2014

Questions

1. Can you provide an explanation for consultation flow with diabetes patient? How long does it last and what kind of recommendations is given to a patient usually?
2. Will it be important to have a tool that will provide data from electronic diabetes diary?
3. Do you think that such application could be an important development, and if so, why?
4. What major and functionalities such application should support?
5. Can you tell your expectations from medical perspective about such application?
6. Would you consider use of the application in your practice?
7. What do you think should be in the application?
8. Do you see any issues that could be dangerous in the use of such application?
9. Could you provide feedback on sketches of the application based on the figures below?

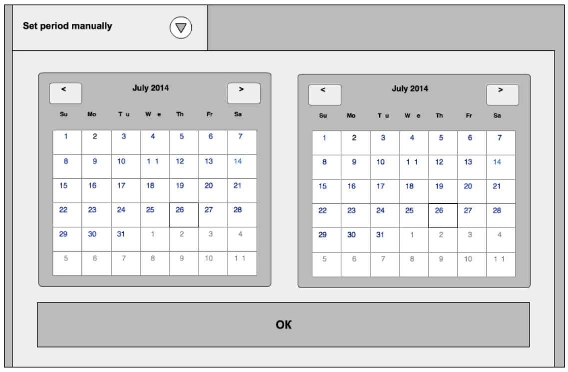


Photo of Gerd Ersdal (medical doctor) during the meeting
Made by Kristina Livitckaia

APPENDIX 4. QUESTIONNAIRE OF NILS KOLSTRUP, MARCH 2014

Questions

1. What are few the most important reasons to use such application? List.
2. What are few the most important reasons that will lead to a tool rejection on practice? List.
3. Do you consider any use of the tool for diabetes management support? Yes or no.
4. Based on the provided idea of user interface, do you find it easy to understand? Yes or no.
5. What do you like in the design and what don't you like?
6. Can you share your device with a patient? Yes or no.
7. Should patient have his own version of such application?
8. What are your suggestions about patient's version? List.
9. Do you think such development is a promising? Yes or now.
10. Do you prefer to use tablet by operating one or two hands?

Photo of Nils Kolstrup (medical doctor) during the meeting
Made by Kristina Livitckaia

APPENDIX 5. QUESTIONNAIRE OF NILS KOLSTRUP, MAY 2014

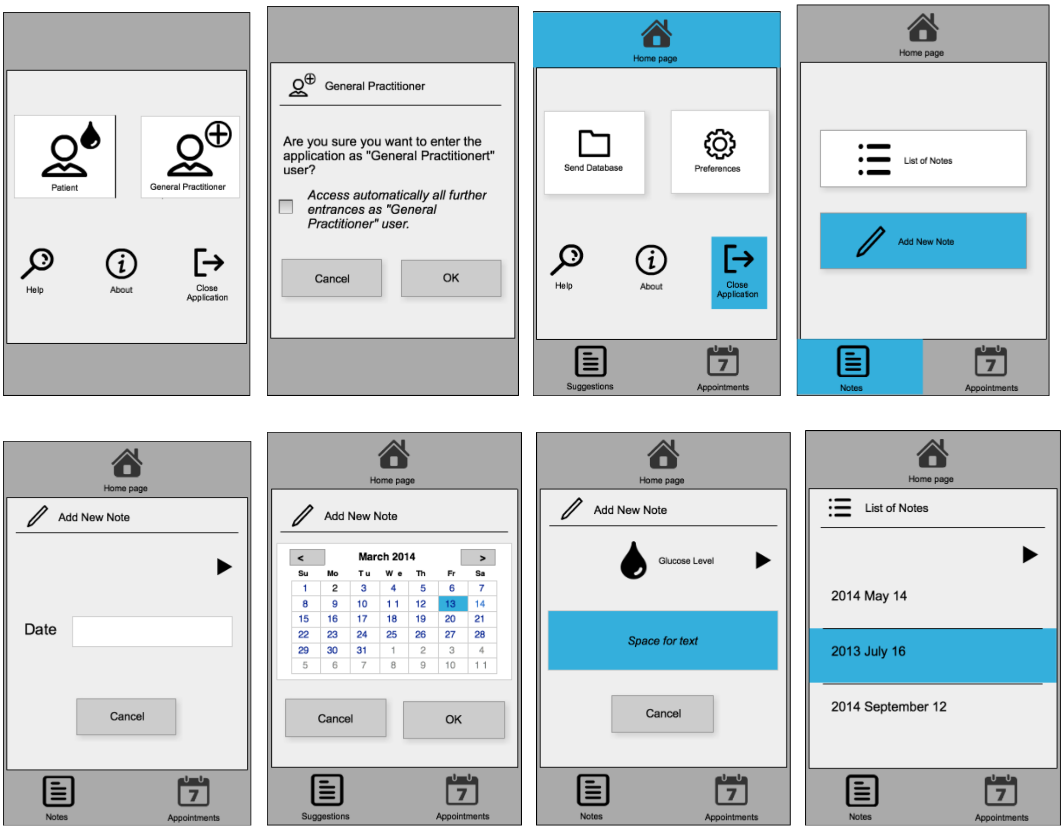
Please, see user interface for doctor and patient and answer the questions.

Doctor module

Questions (to be continued)

1. Do you like the design of the system based on the last update? Yes or no.
2. Do you see issues to improve? Yes or no. If yes, elaborate.
3. Do you feel that doctor module is comfortable to use? Is it intuitive? Yes or no.
4. Is everything is like you expected, better or worse?

Patient module



Questions (continued)

5. Do you agree with the resolution of appointments and recommendations management for patients? Yes or no.
6. Do you think patients will use the application? Yes or no.
7. Do you see issues to improve?
8. Do you find such application as a tool to support diabetes management in general practice? Yes or no.

APPENDIX 6. INTERVIEW WITH NILS KOLSTRUP, JUNE 2014

Questions after usability testing of the implemented application

1. What is your first impression about the working application?
2. What did you like in the application the most and what didn't you like?
3. Do you see in the use of the application future possible development of diabetes management?
4. Would you consider use of such application in your practice? Why?
5. Is it comfortable to use application? Is application understandable and intuitive?
6. What would you like to add to the application that could play crucial role in further use?
7. Do you think this app with possible extensions can improve quality of diabetes care generally?

Photo of Nils Kolstrup (medical doctor) and Annelill Bruun Flaamo (social worker at NST) during the testing
Made by Kristina Livitckaia

APPENDIX 7. USER MANUAL FOR PATIENT

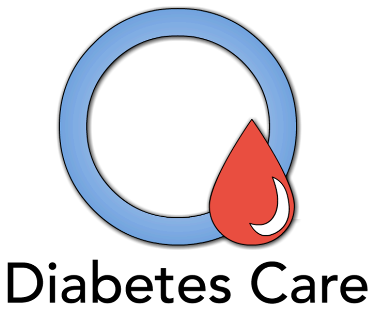


Figure 1

USER MANUAL FOR "DIABETES CARE" APPLICATION

(PATIENT MODULE)

Opening "Diabetes Care" Application

To open the "Diabetes Care" application click on the "Diabetes Care" (*Figure 1*) icon as shown in *Figure 2*.

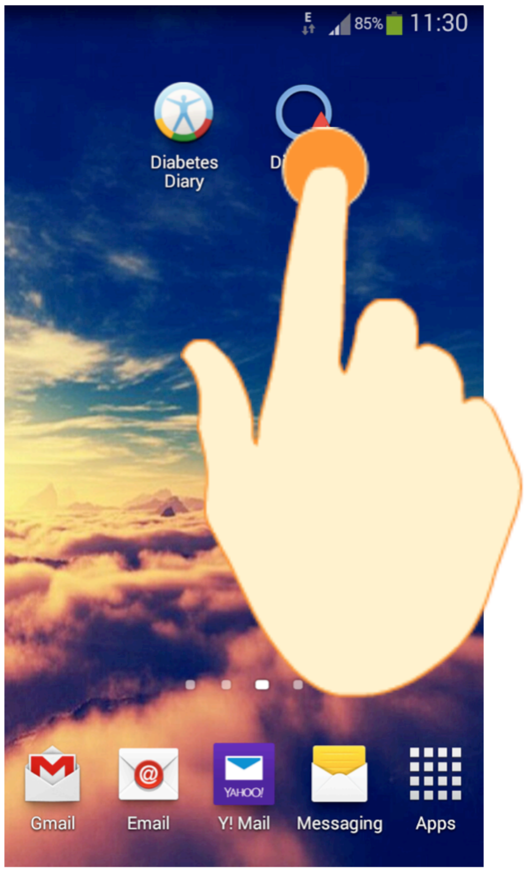


Figure 2

Selecting Patient Access

After opening the application, you will be presented with the entrance page as in *Figure 3*.

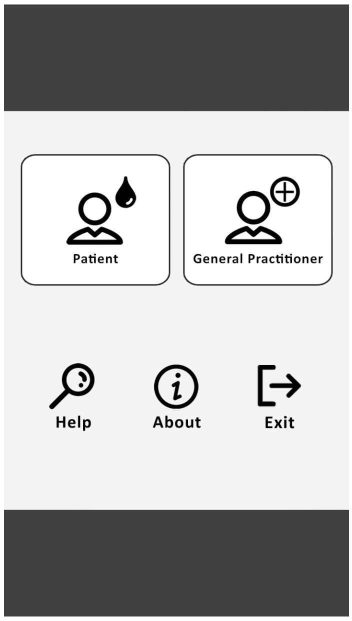


Figure 3

As shown in *Figure 4*, press the "Patient" icon.

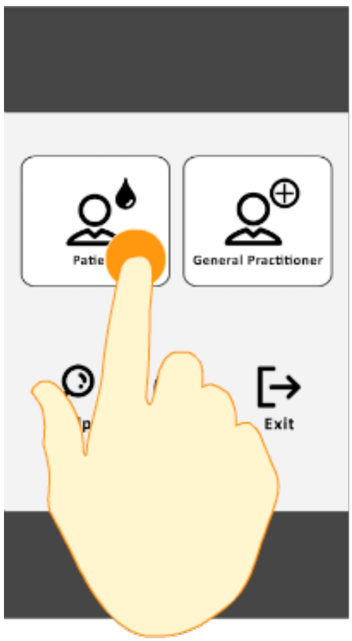


Figure 4

Confirmation of Patient Access

After selecting “Patient” access, you will be presented as shown in *Figure 5*.

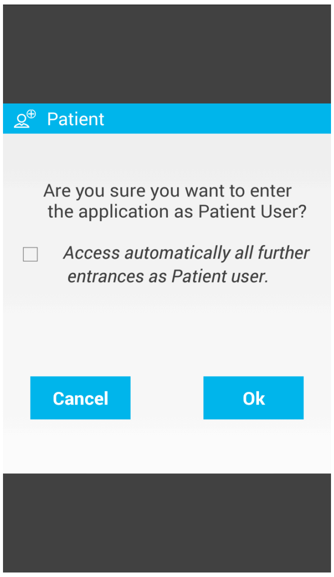


Figure 5

Press “Ok” as shown in *Figure 6*. You can also toggle the “Access automatically all further entrances as “Patient user” to bypass this screen for the further uses.

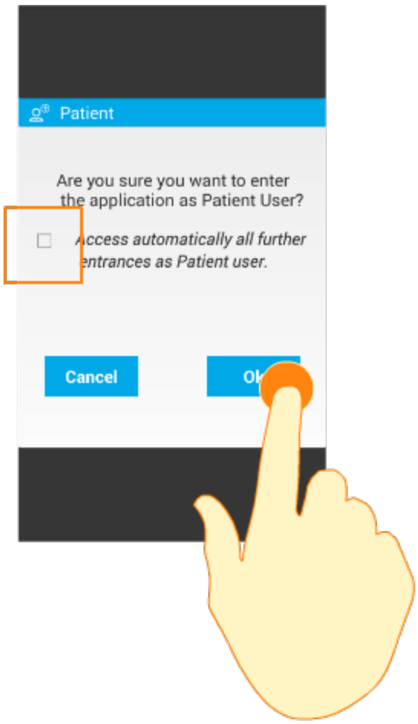


Figure 6

Sending “Diabetes Diary” Database

After entering, you will be presented with the home screen as shown in *Figure 7*.

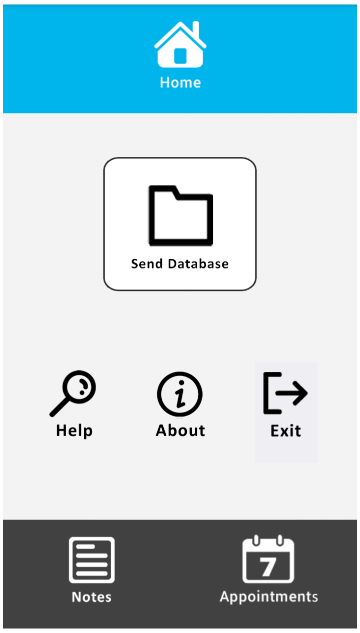


Figure 7

To send your data, press “Send Database” as shown in *Figure 8*.

Figure 8

You will be presented with transfer confirmation screen as shown in *Figure 9*.

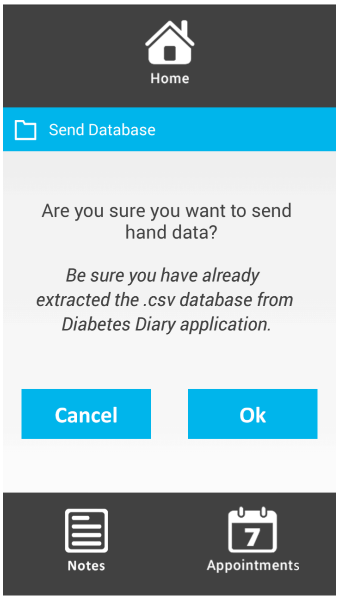


Figure 9

To confirm the transfer press "Ok" as shown in *Figure 10*. Further, place two devices back to back and touch any place on the screen.

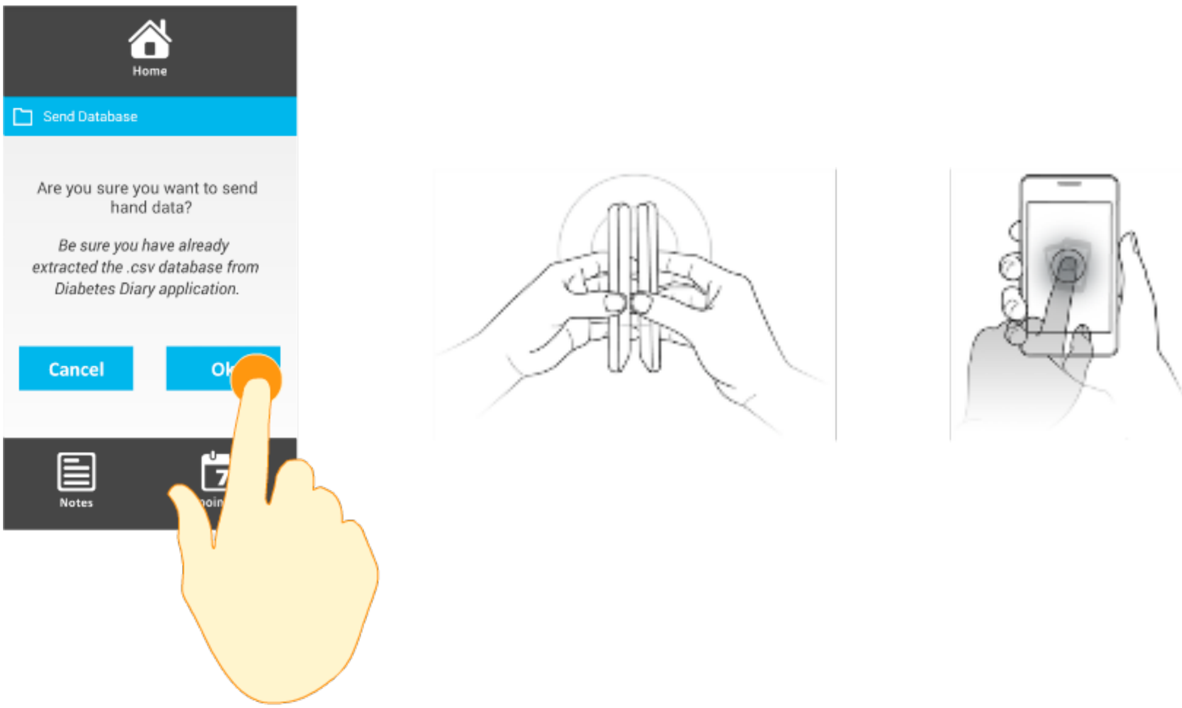


Figure 10

Turning on NFC

If NFC is not turned on, you will be presented with an option to turn it on as shown in *Figure 11*.

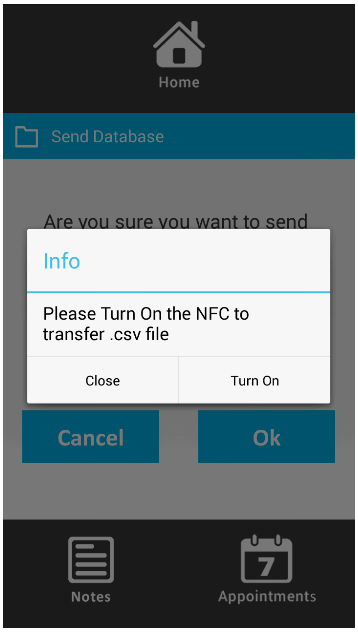


Figure 11

After pressing "Turn On" in *Figure 11*, you will be sent into settings screen. Make sure NFC is toggled as shown in *Figure 12*

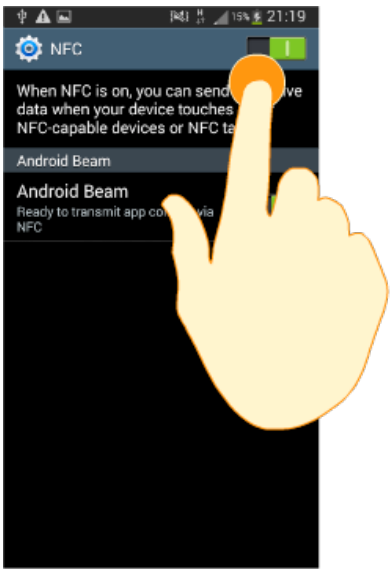


Figure 12

Notes Management

After clicking on the “Notes” you will be presented with the notes page as shown in *Figure 13*.

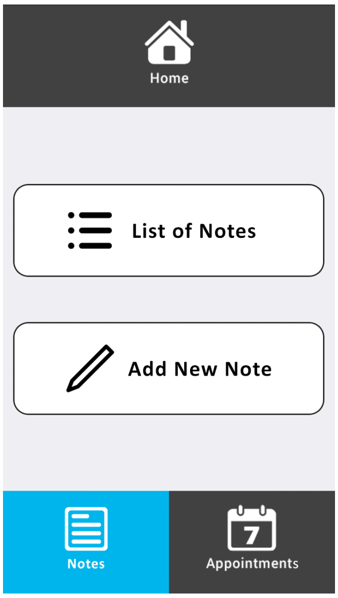


Figure 13

To add new note, click on “Add New Notes” as shown in *Figure 14*.

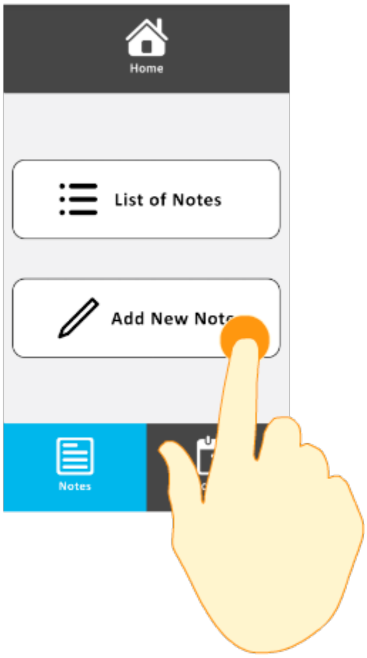


Figure 14

To select the date for the note, click on the "Date" text field as shown in *Figure 15*.

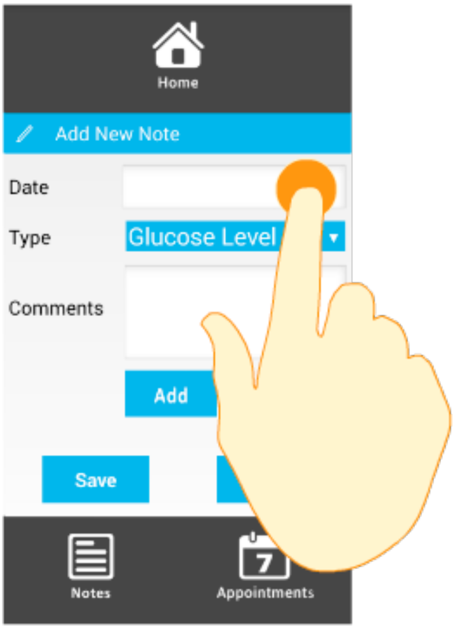


Figure 15

Select the date and click "Ok" to confirm as shown in *Figure 16*.

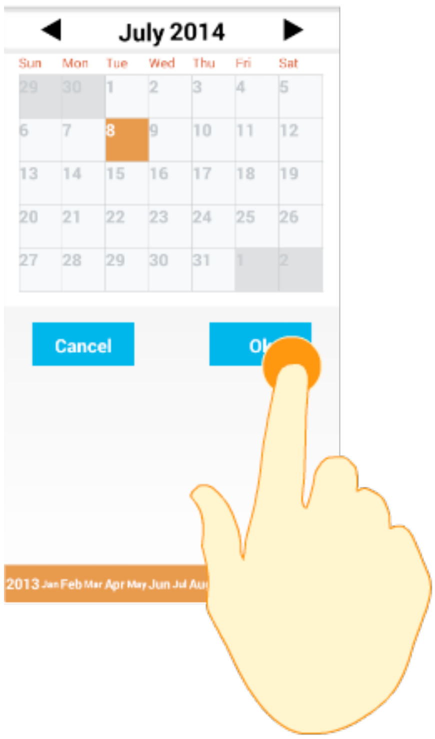


Figure 16

Select the type of note you would like to add from the drop down menu as shown in *Figure 17*.

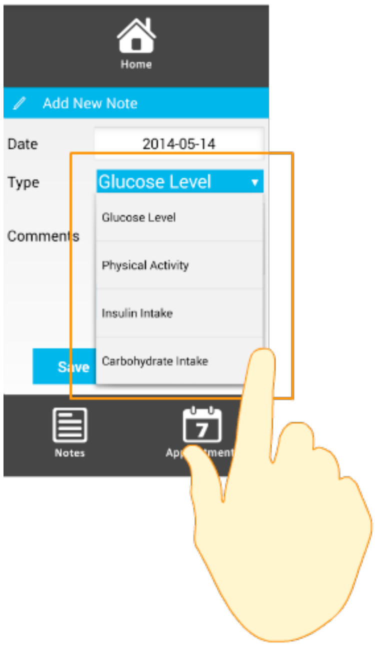


Figure 17

You can type in a comment in the text field and press “Add” as shown in *Figure 18*

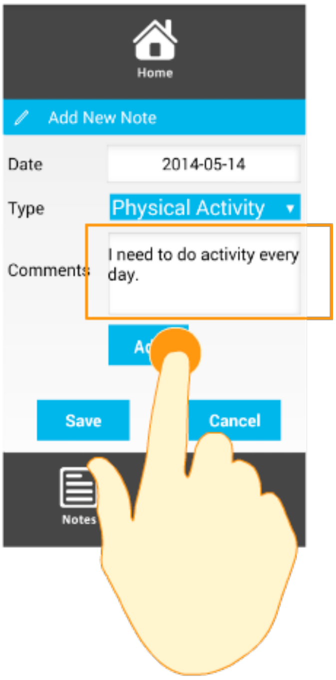


Figure 18

After you are done adding all the notes, click "Save" to save them as shown in *Figure 19*.

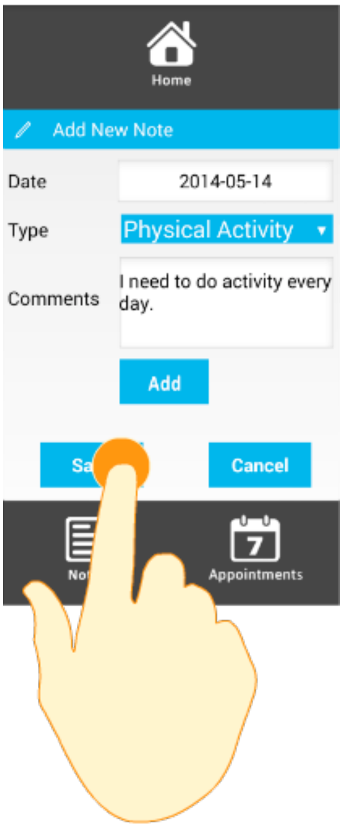


Figure 19

Viewing Existing Notes

On the “Notes” page, click on “List of Notes” to display the list of notes as shown in *Figure 20*.

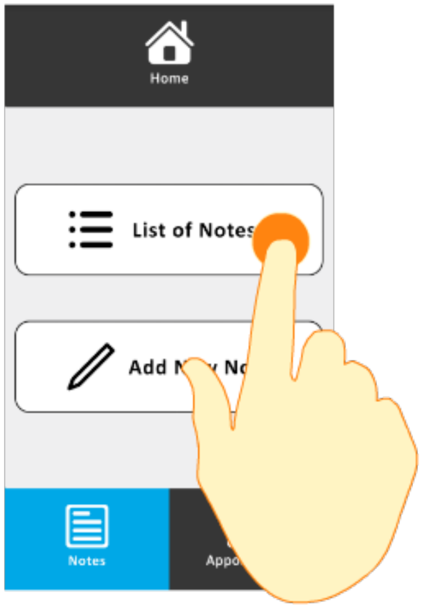


Figure 20

Click on the date to view the notes available on that date as shown in *Figure 21*.

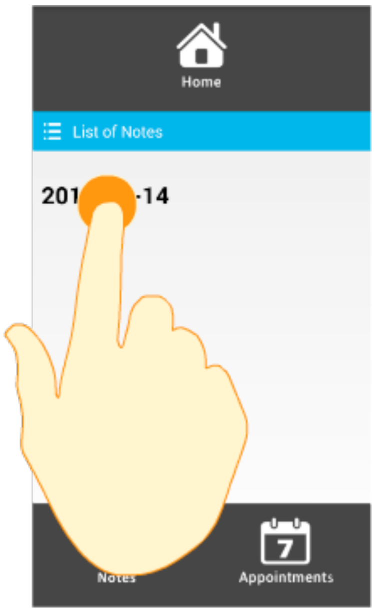


Figure 21

Deleting Notes

After clicking on the date, you will be presented with all the notes for that date as shown in *Figure 22*.

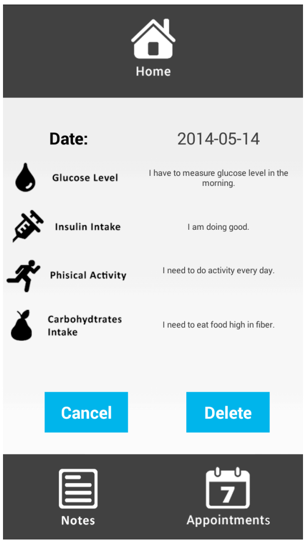


Figure 22

To delete the notes, click on "Delete" button as shown in *Figure 23*. Further confirm deleting.

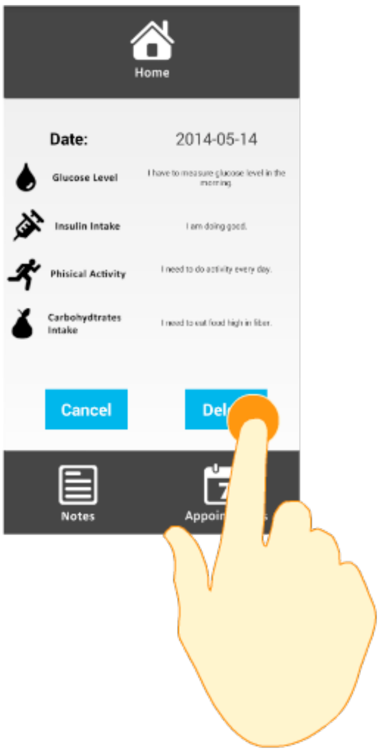


Figure 23

Adding New Appointments

After click on the "Appointments" button, you will be presented with appointments page as shown in *Figure 24*.

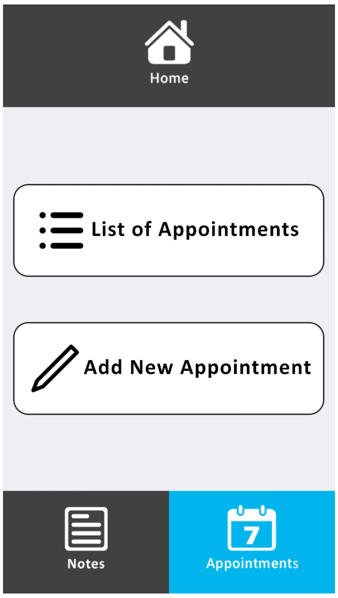


Figure 24

Click on "Add New Appointments" to add new appointment as shown in *Figure 25*.

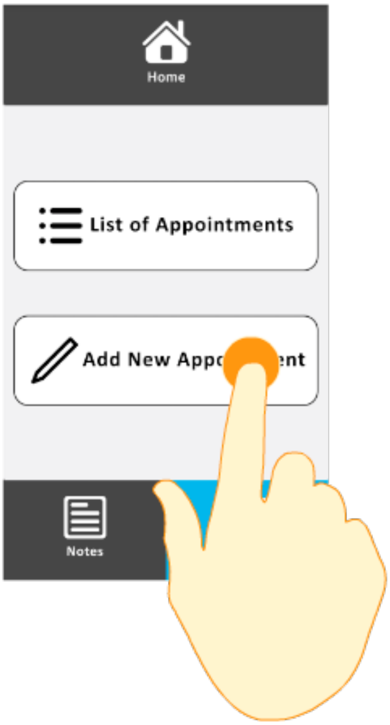


Figure 25

Fill in the title of the appointment in the “Title” text box and the date in the “From” and “To” text fields as shown in *Figure 26*.

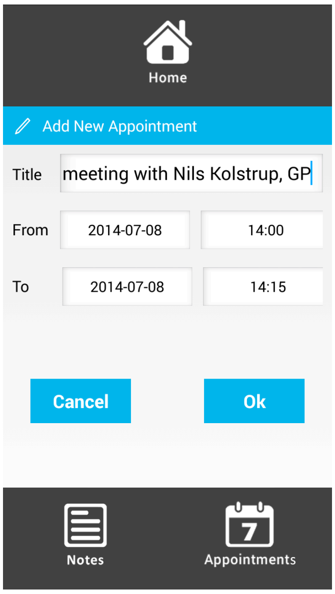


Figure 26

Click “Ok” to save the appointment as shown in *Figure 27*.

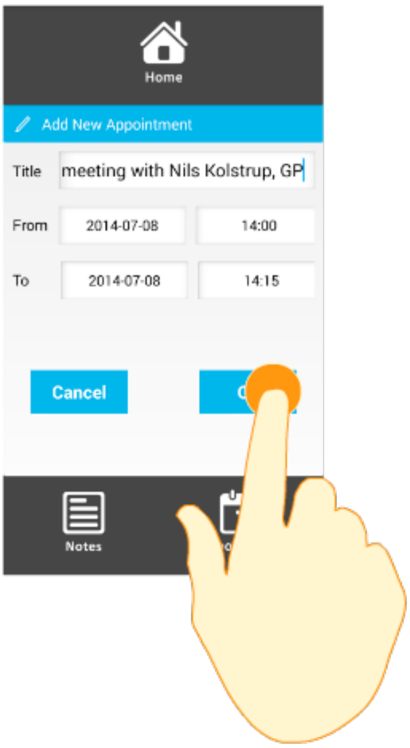


Figure 27

Viewing Appointments

Click on “List of Appointments” to see the list of appointments as shown in *Figure 28*.

Figure 28

Click on the appointment you would like to see as shown in *Figure 29*.

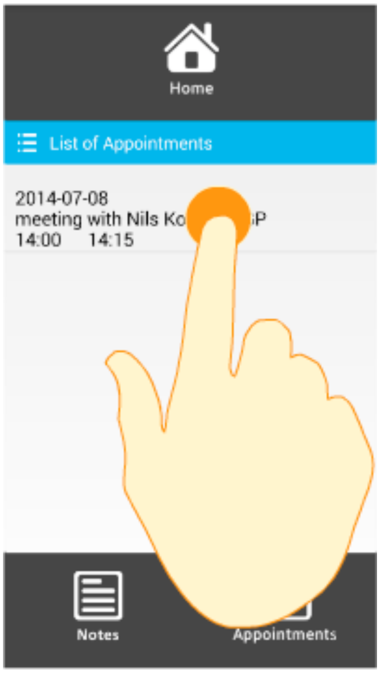


Figure 29

Editing and Deleting Appointments

To edit an appointment, click on “Edit” button as shown in *Figure 30*.

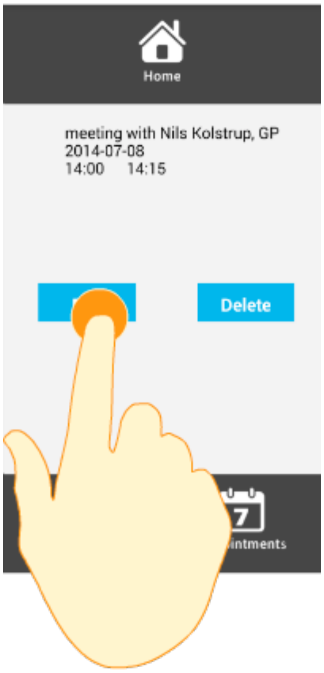


Figure 30

To delete an appointment, click on “Delete” button as shown in *Figure 31*.

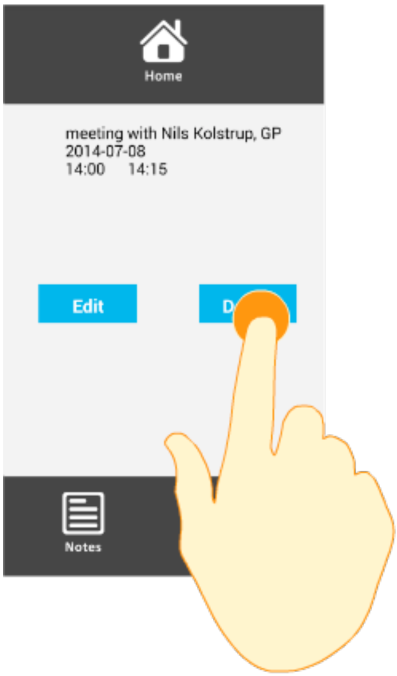


Figure 31

Deleting Appointment

After pressing "Delete" on the appointment screen, you will be presented with deleting confirmation. Click on "Ok" as shown in *Figure 32*.

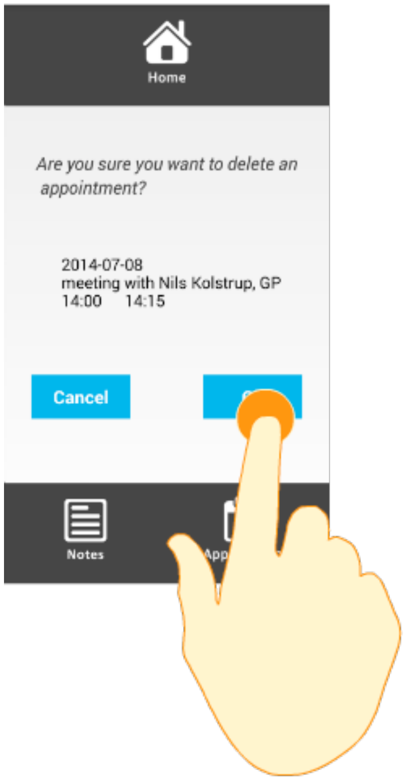


Figure 32

Closing Application

On the home screen, you can access "Help", see "About" application information, and "Exit" the application as shown in *Figure 33*.

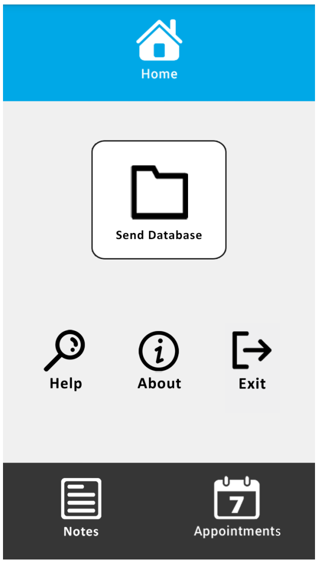


Figure 33

After clicking on "Exit", you will need to confirm it by clicking on "Ok" as shown in *Figure 34*.

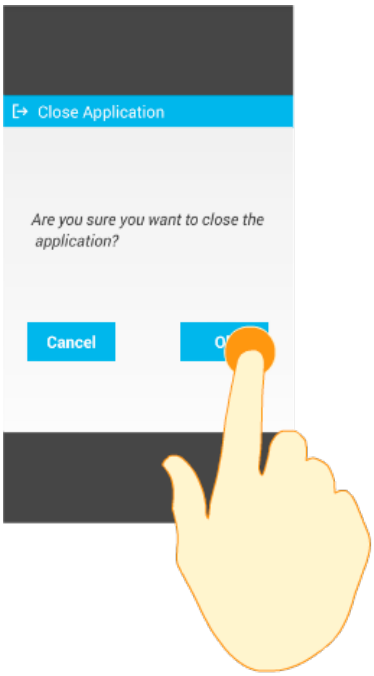


Figure 34

APPENDIX 8. USER MANUAL FOR GENERAL PRACTITIONER

Figure 1

USER MANUAL FOR "DIABETES CARE" APPLICATION
(GENERAL PRACTITIONER MODULE)

Opening "Diabetes Care" Application

To open the "Diabetes Care" application click on the "Diabetes Care" (*Figure 1*) icon as shown in *Figure 2*.

Figure 2

Selecting General Practitioner Access

After opening the application, you will be presented with entrance page as shown in *Figure 3*.

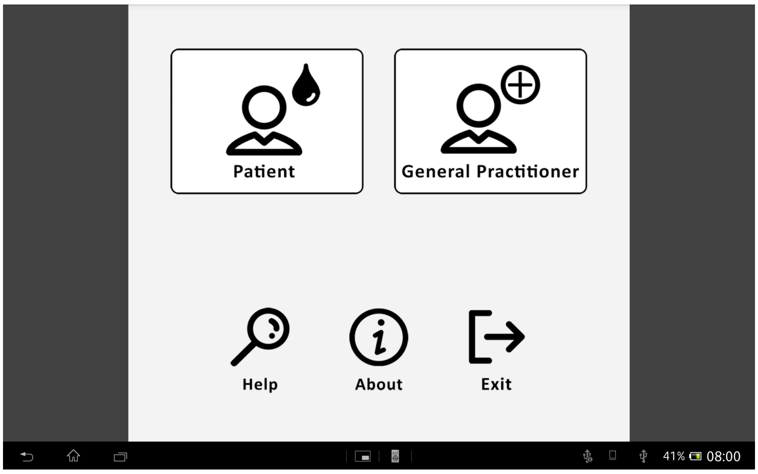


Figure 3

As shown in *Figure 4*, press the "General Practitioner" icon.

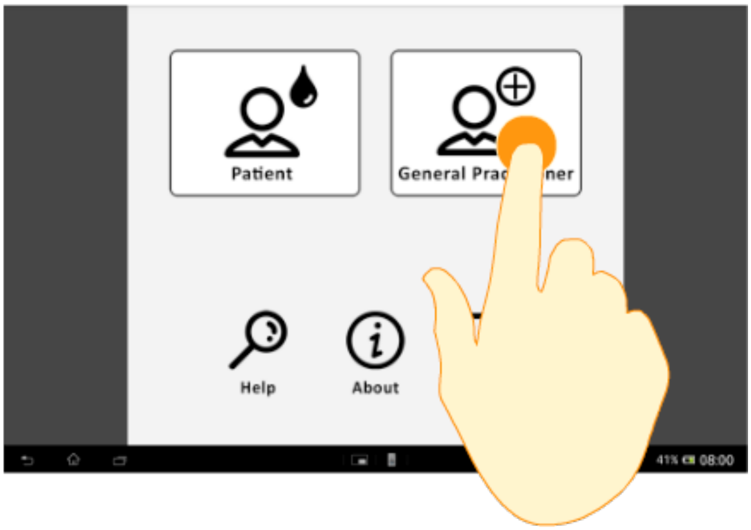


Figure 4

Confirmation of General Practitioner mode

After selecting "General Practitioner" mode, you will be presented with confirmation of the access as shown in *Figure 5*.

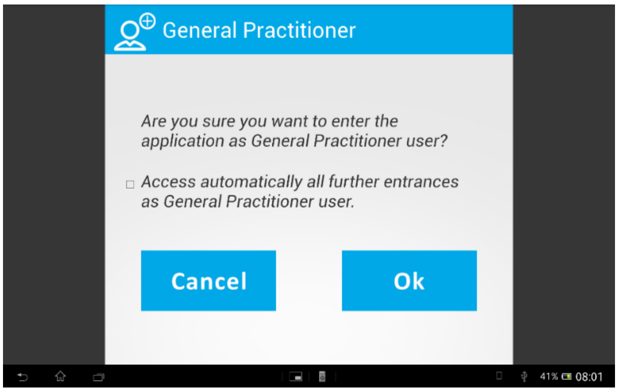


Figure 5

Press "Ok" as shown in *Figure 6*. You can also toggle the "Access automatically all further entrances as General Practitioner user" to bypass this screen for the further uses.

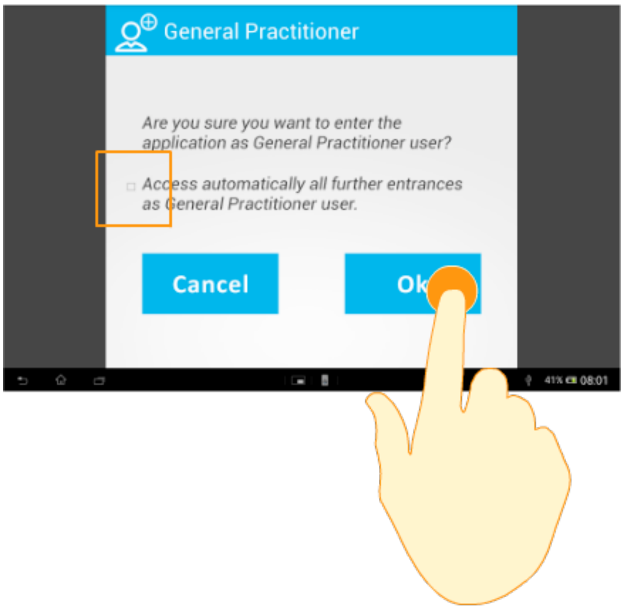


Figure 6

Accepting Transfer of Patient's Data

After initiating the NFC transfer, you will be presented with *Figure 7*.

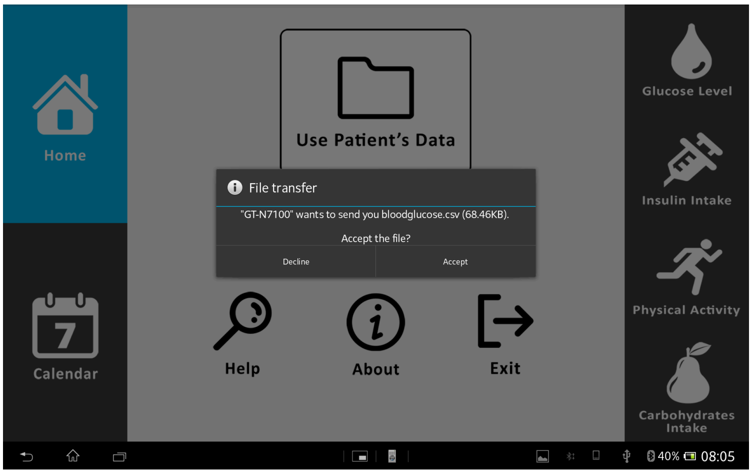


Figure 7

Press "Accept" to accept the transfer of the patient's data as seen in *Figure 8*.

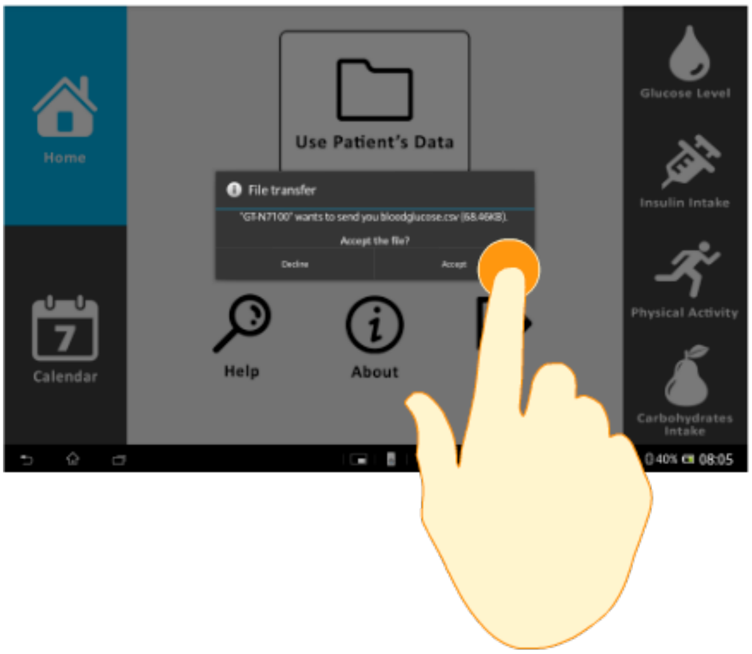


Figure 8

Loading Patient's Data

After the transfer of the patient's data, you will be back at the home screen as seen in *Figure 9*.

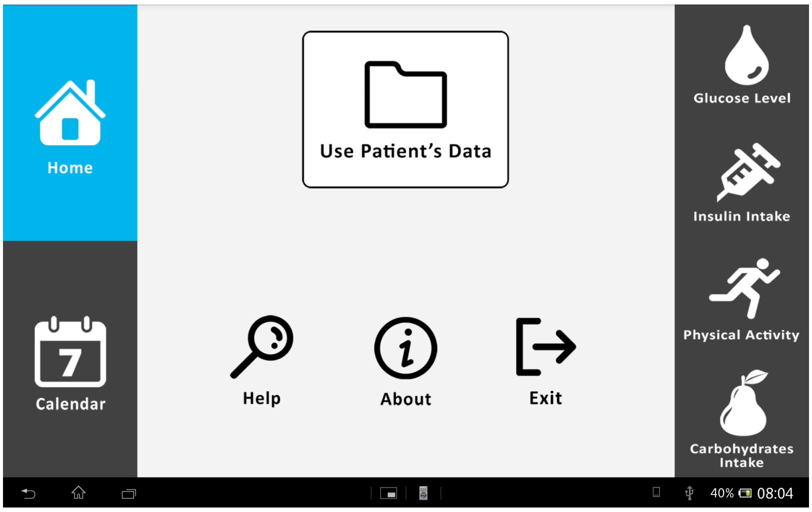


Figure 9

To use the transferred data, press "Use Patient's Data" as seen in *Figure 10*.

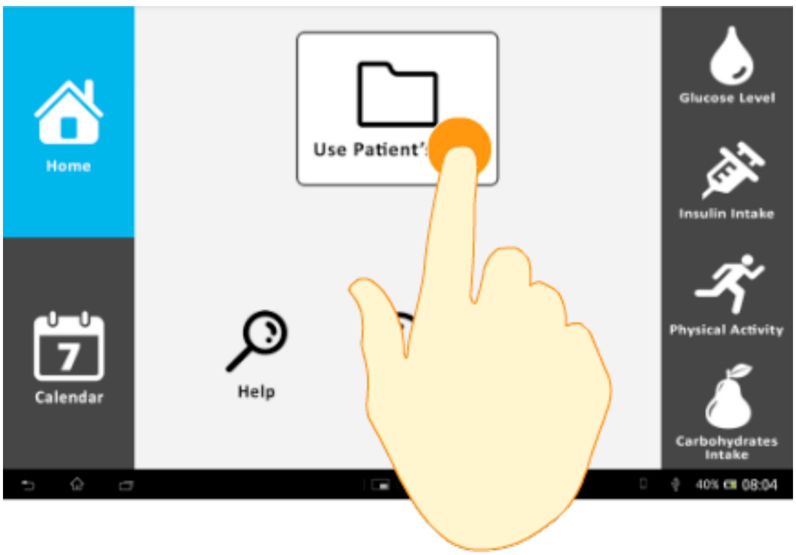


Figure 10

Entering Calendar Page

Press the "Calendar" button to select the data ranges for the patient's data to be displayed further as shown in *Figure 11*.

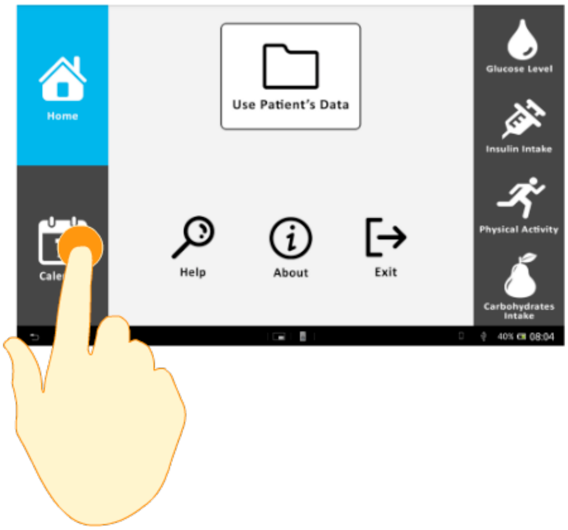


Figure 11

Selecting the Period of Patient's Data

After accessing the calendar, you will be presented with screen as shown in *Figure 13*.

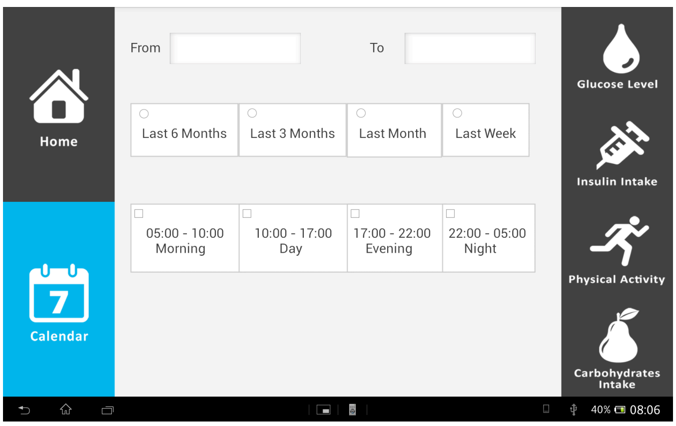


Figure 12

To select specific data period, use “From” and “To” text fields as shown in *Figure 14*.

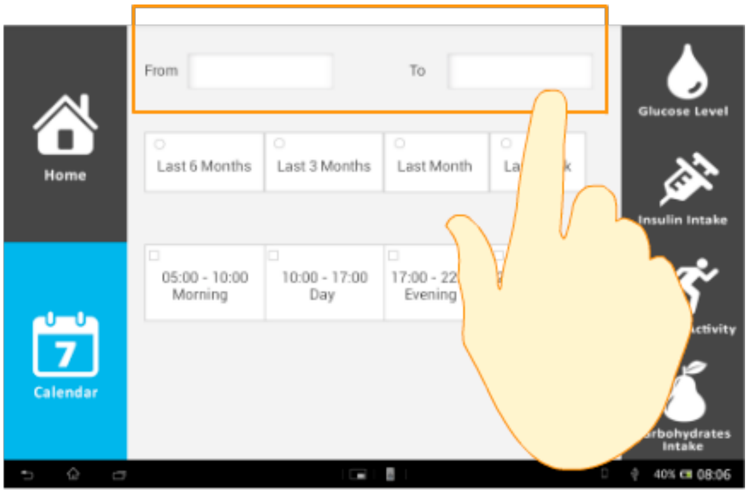


Figure 14

Data period can also be used from the predefined list as shown in *Figure 15*.

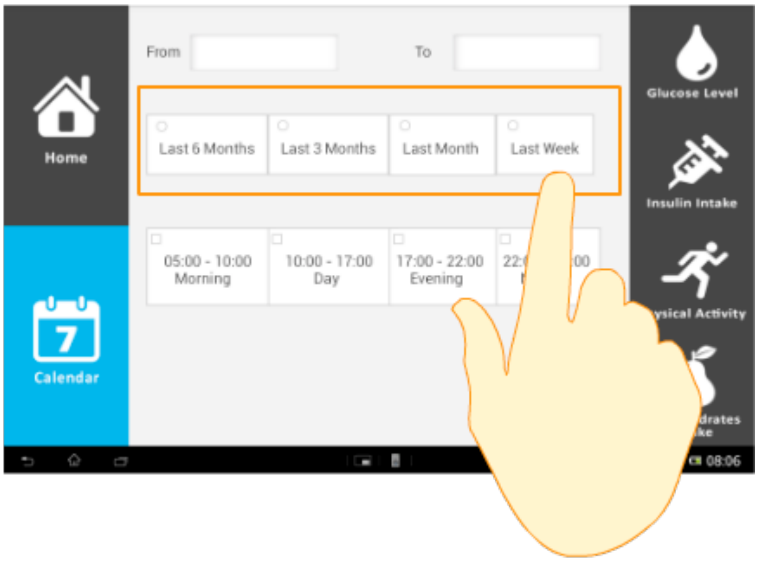


Figure 15

Lastly, you can select the timeframes of the data as shown in *Figure 16*.

Figure 16

To view the data representation for selected period, press on the desired data type as seen in *Figure 17*.

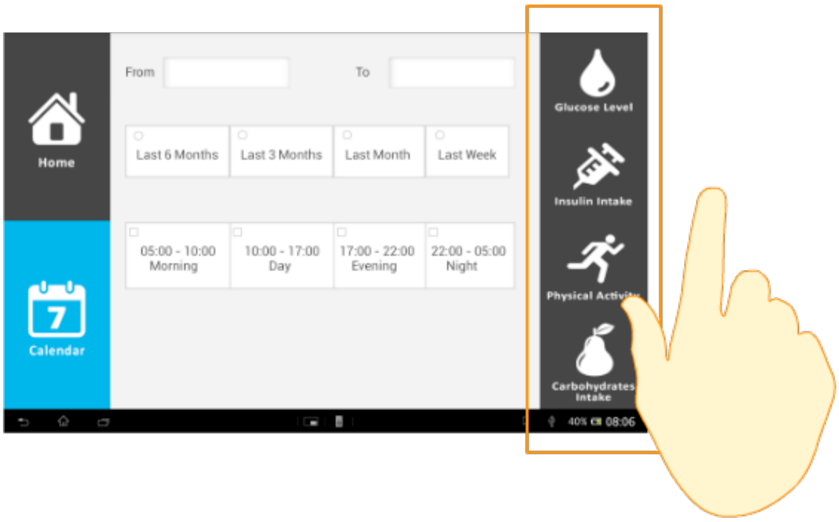


Figure 17

To zoom out the represented data, use two fingers and move them apart as shown in *Figure 18*.

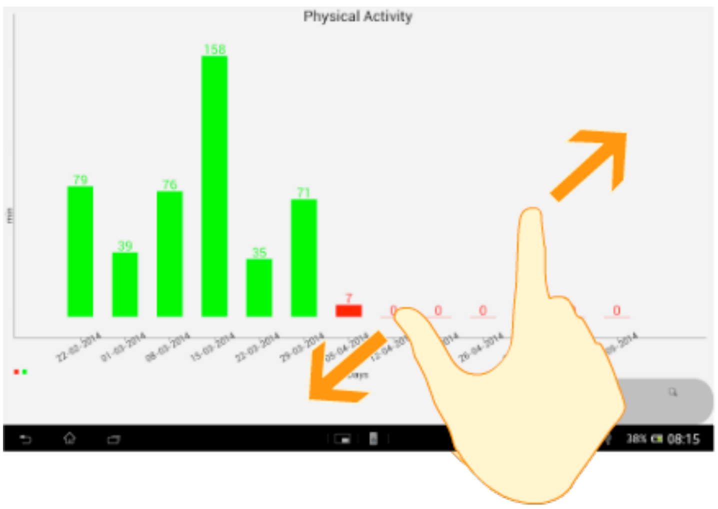


Figure 18

To zoom in the represented data, slide two fingers together as shown in *Figure 19*.

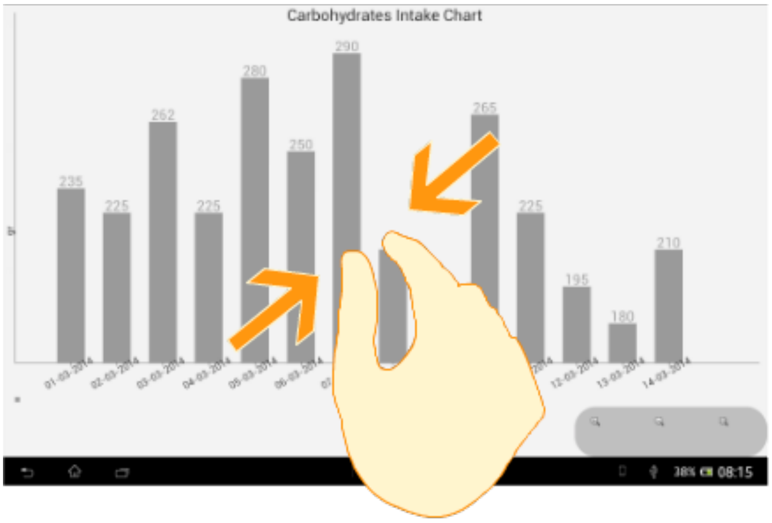


Figure 19

To scroll through the represented data, slide one finger left or right as shown in *Figure 20*.

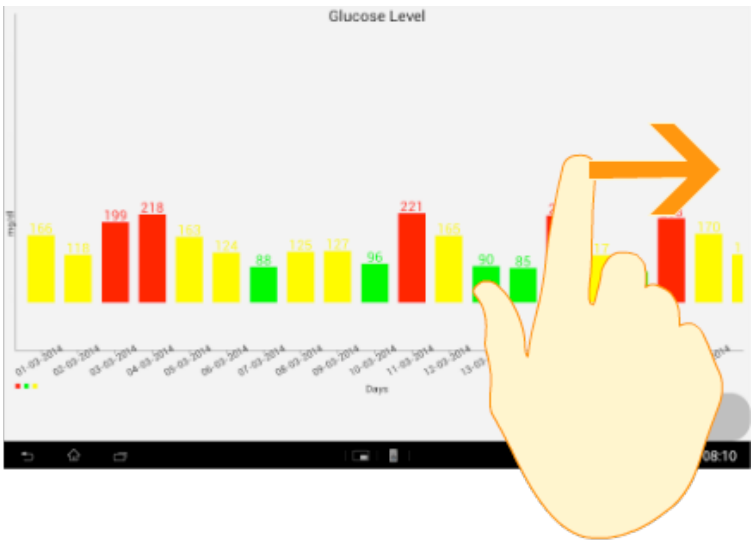


Figure 20

Help, About and Exit

On the home screen, you can access help information in “Help”, see information about the application in “About”, or exit the application in “Exit” as shown in *Figure 21*.

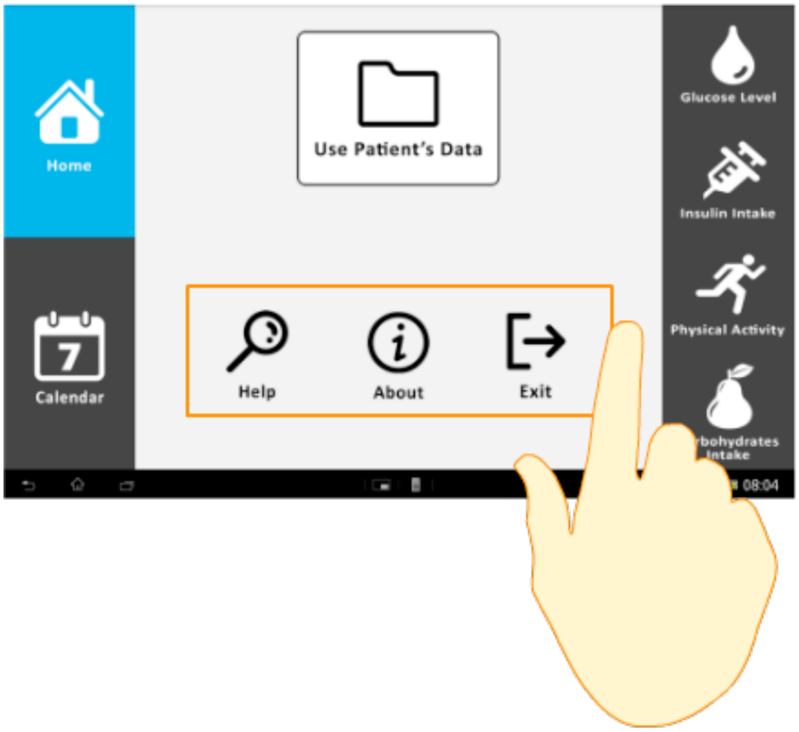


Figure 21

Closing the Application

After pressing the "Exit" button, you will be presented with the confirmation screen as shown in *Figure 22*.

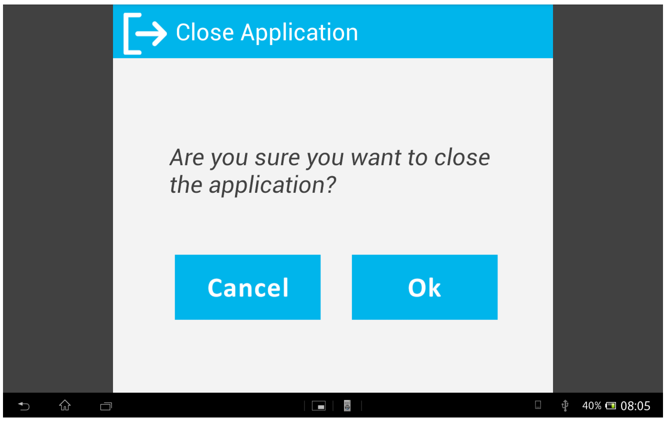


Figure 22

To continue with closing, press "Ok" button as shown in *Figure 23*.

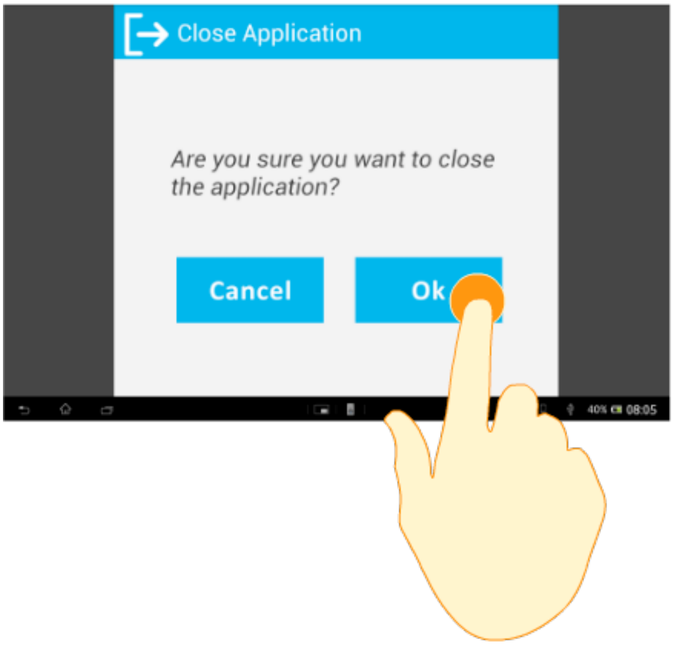
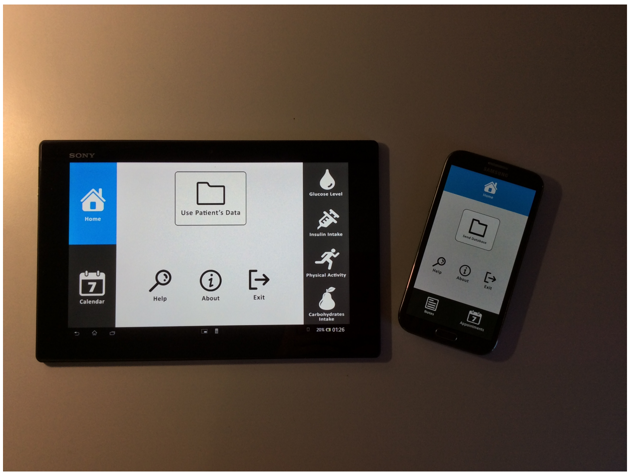


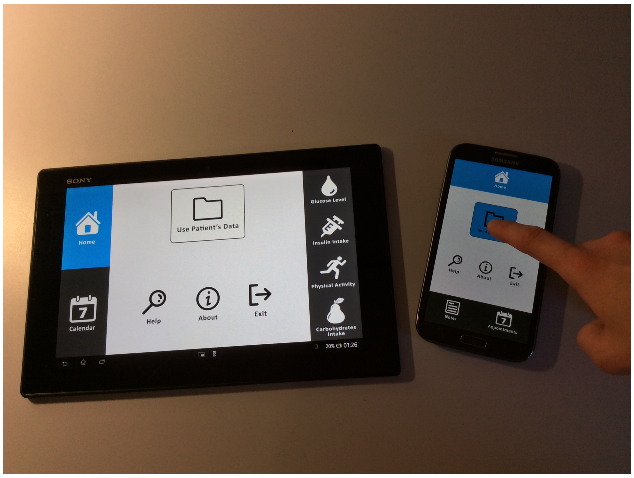
Figure 23

APPENDIX 9. DATA TRANSFER

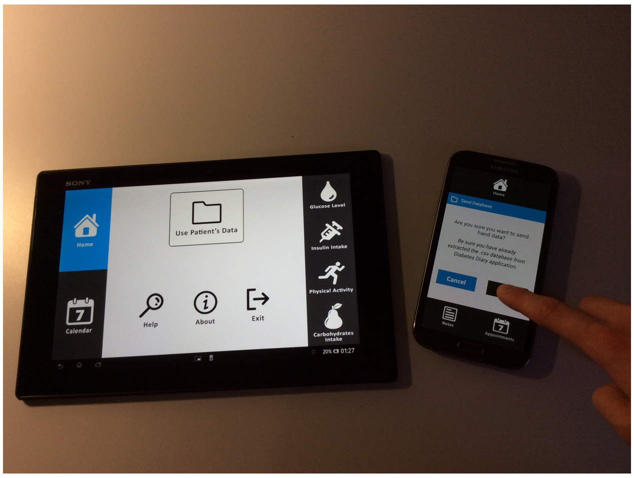
Step 1. Application is accessed by general practitioner and patient.



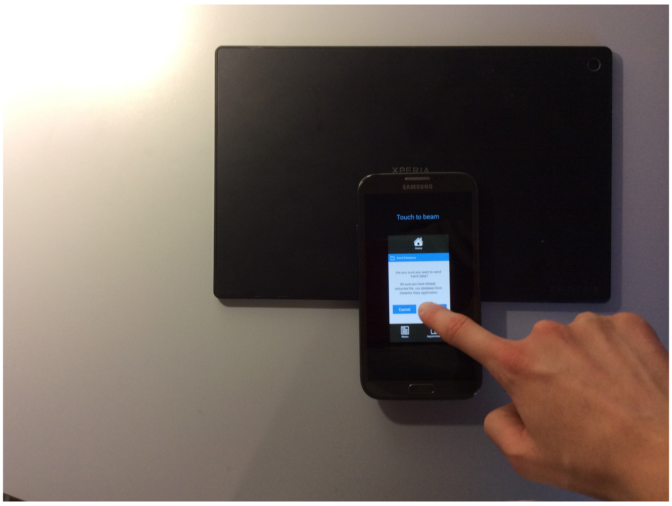
Step 2. Patient pressing "Send Database" icon on the home page.



Step 3. Patient is accepting data transfer by pressing "Ok" button.



Step 4. General practitioner and patient touch devices. Patient presses any space on the screen.



Step 5. General practitioner receives notification about an incoming file. “Accept” button has to be pressed to confirm the receiving.

All photos made by Kristina Livitckaia

APPENDIX 10. EXAMPLES FOR PARAMETERS PROCESSING

Glucose Level Processing

Example 1

Chosen period: 18.02.2014 – 24.02.2014

It has to be 7 graphs based on the rules for period processing (if chosen period less or equals 31 days then show graph (-s) for each day).

Data from sample CSV database are provided below *(see Figure 1 – 2)*.

50	blood	18/02/14 07:33	147
51	blood	18/02/14 00:13	163
52	blood	18/02/14 09:43	131
53	blood	18/02/14 11:38	151
54	blood	18/02/14 14:39	194
55	blood	18/02/14 15:42	180
56	blood	18/02/14 17:02	48
57	blood	18/02/14 18:48	134
58	blood	18/02/14 20:25	177
59	blood	18/02/14 22:09	266
60	blood	18/02/14 23:29	258
61	blood	19/02/14 03:19	56
62	blood	19/02/14 07:38	104
63	blood	19/02/14 09:48	203
64	blood	19/02/14 14:20	201
65	blood	19/02/14 15:56	95
66	blood	19/02/14 18:03	94
67	blood	19/02/14 19:36	70
68	blood	19/02/14 20:59	254
69	blood	19/02/14 23:21	222
70	blood	20/02/14 07:11	137
71	blood	20/02/14 09:28	216
72	blood	20/02/14 13:07	175
73	blood	20/02/14 11:35	61
74	blood	20/02/14 14:54	133
75	blood	20/02/14 18:30	206
76	blood	20/02/14 20:33	134
77	blood	20/02/14 19:39	155
78	blood	20/02/14 22:40	66
79	blood	21/02/14 00:31	106
80	blood	21/02/14 07:12	139
81	blood	21/02/14 09:53	119
82	blood	21/02/14 13:05	141
83	blood	21/02/14 15:18	230
84	blood	21/02/14 17:17	82
85	blood	21/02/14 19:37	155
86	blood	21/02/14 21:55	83
87	blood	21/02/14 23:00	98
88	blood	22/02/14 00:38	117
89	blood	22/02/14 07:47	184
90	blood	22/02/14 09:35	215
91	blood	22/02/14 12:00	119
92	blood	22/02/14 14:56	102
93	blood	22/02/14 17:06	100
94	blood	22/02/14 19:12	104
95	blood	22/02/14 22:36	216
96	blood	22/02/14 23:46	128
97	blood	23/02/14 00:28	85
98	blood	23/02/14 07:47	173
99	blood	23/02/14 11:33	199
100	blood	23/02/14 14:08	148
101	blood	23/02/14 15:43	115
102	blood	23/02/14 19:12	130
103	blood	23/02/14 21:33	282
104	blood	23/02/14 22:35	124
105	blood	24/02/14 00:30	114
106	blood	24/02/14 07:49	98
107	blood	24/02/14 09:54	165

Figure 1. Screenshot from CSV database for chosen period for glucose level (to be continued on page)

108	blood	24/02/14 11:27	146
109	blood	24/02/14 13:54	173
110	blood	24/02/14 15:25	174
111	blood	24/02/14 17:14	70
112	blood	24/02/14 18:55	105
113	blood	24/02/14 21:53	211
114	blood	24/02/14 20:51	166
115	blood	24/02/14 23:40	71
116	blood	25/02/14 07:16	123
117	blood	25/02/14 09:22	159
118	blood	25/02/14 11:20	123
119	blood	25/02/14 12:59	106
120	blood	25/02/14 16:08	167
121	blood	25/02/14 17:13	193
122	blood	25/02/14 18:26	141
123	blood	25/02/14 20:04	96
124	blood	25/02/14 23:15	89
125	blood	26/02/14 07:52	108
126	blood	26/02/14 10:49	115
127	blood	26/02/14 13:19	83
128	blood	26/02/14 15:03	111
129	blood	26/02/14 15:39	109
130	blood	26/02/14 19:05	229
131	blood	26/02/14 21:07	72
132	blood	27/02/14 08:49	117
133	blood	26/02/14 23:31	68
134	blood	27/02/14 11:40	85
135	blood	27/02/14 13:13	96
136	blood	27/02/14 15:17	65
137	blood	27/02/14 17:06	127
138	blood	27/02/14 18:45	111
139	blood	27/02/14 20:03	182
140	blood	27/02/14 21:13	145
141	blood	27/02/14 22:59	85
142	blood	28/02/14 07:09	150
143	blood	28/02/14 09:44	79
144	blood	28/02/14 12:15	86
145	blood	28/02/14 14:06	93
146	blood	28/02/14 15:53	73
147	blood	28/02/14 18:19	180
148	blood	28/02/14 21:24	218
149	blood	28/02/14 19:53	240
150	blood	28/02/14 23:36	237
151	blood	01/03/14 07:16	77
152	blood	01/03/14 09:19	254
153	blood	01/03/14 10:19	235
154	blood	01/03/14 11:42	136
155	blood	01/03/14 14:37	44
156	blood	01/03/14 16:50	116
157	blood	01/03/14 18:35	166
158	blood	01/03/14 20:13	133
159	blood	01/03/14 20:56	74
160	blood	01/03/14 21:59	114
161	blood	02/03/14 07:20	118
162	blood	01/03/14 23:51	120
163	blood	02/03/14 10:03	218
164	blood	02/03/14 11:36	136
165	blood	02/03/14 13:19	120
166	blood	02/03/14 15:16	124
167	blood	02/03/14 18:24	104
168	blood	03/03/14 00:01	149
169	blood	02/03/14 21:31	200
170	blood	02/03/14 19:13	96
171	blood	03/03/14 08:08	201
172	blood	03/03/14 08:48	197
173	blood	03/03/14 10:35	73
174	blood	03/03/14 15:26	181
175	blood	03/03/14 12:54	149
176	blood	03/03/14 17:56	49
177	blood	03/03/14 19:27	178
178	blood	03/03/14 21:25	160
179	blood	03/03/14 22:43	193

Figure 2. Screenshot from CSV database for chosen period for glucose level (continued)

Calculation for the chosen period is below.

18.02.2014: 147+163+131+151+194+180+48+134+177+266+258 = 1849
n = 11 (amount of times)
1849 / 11 = 168.09—>168 (graph 1)

19.02.2014: 56+104+203+201+95+94+70+254+222 = 1299
n = 9 (amount of times)
1299 / 9 = 144.33 —> 144 (graph 2)

Further is the same calculation logic as for days 18.02.2014 -19.02.2014.
20.02.2014: … = 142.55—> 143 (graph 3)
21.02.2014: … = 128.11—> 128 (graph 4)
22.02.2014: … = 142.77—> 143 (graph 5)
23.02.2014: … = 157 (it is graph 6)
24.02.2014: … = 135.72—> 136 (graph 7)

For the data representation in the application for the chosen period see Figure 37 in the thesis.

Example 2
Chosen period: 18.02.2014 – 18.04.2014
It has to be 9 graph based on the rules for period processing (if chosen period more 31 days but less or equals 92 days then show graph (-s) for each 7 days).

Data used for calculation is contained in sample CSV. *For the data representation in the application for the chosen period see Figure 38 in the thesis*.

Calculation for the chosen period is below.

Graph 1: 18.02.2014 – 24.02.2014

18.02.2014: 147+163+131+151+194+180+48+134+177+266+258 = 1849
n = 11 (amount of times)
1849 / 11 = 168.09

19.02.2014: 56+104+203+201+95+94+70+254+222 = 1299
n = 9 (amount of times)
1299 / 9 = 144.33

Further is the same calculation logic as for days 18.02.2014 -19.02.2014.
20.02.2014: … = 142.55
21.02.2014: … = 128.11
22.02.2014: … = 142.77
23.02.2014: … = 157
24.02.2014: … = 135.72

(168.09+144.33+142.55+128.11+142.77+157+135.72) / 7 = 145.51—> 146 (graph 1)

Further is the same calculation logic as for graph 1 (graph 2 – graph 9).

Example 3
Chosen period: 18.02.2014 – 20.06.2014
It has to be 9 graphs based on the rules for period processing (if chosen period more 92 days but less or equals 366 days, then show graph (-s) for each 14 days).

Data used for calculation is contained in sample CSV. *For the data representation in the application for the chosen period see Figure 39 in the thesis*.

Calculation for the chosen period is below.

Graph 1: 18.02.2014 – 03.03.2014

18.02.2014: 147+163+131+151+194+180+48+134+177+266+258 = 1849
n = 11 (amount of numbers)
1849 / 11 = 168.09

19.02.2014: 56+104+203+201+95+94+70+254+222 = 1299
n = 9
1299 / 9 = 144.33

Further is the same calculation logic as for days 18.02.2014 -19.02.2014.

20.02.2014: … = 142.55
21.02.2014: … = 128.11
22.02.2014: … = 142.77
23.02.2014: … = 157
24.02.2014: … = 135.72
25.02.2014: … = 133
26.02.2014: … = 111.87
27.02.2014: … = 112.55
28.02.2014: … = 150.66
01.03.2014: … = 132.25
02.03.2014: … = 142.57
03.03.2014: … = 153

(168.09+144.33+142.55+128.11+142.77+157+135.72+133+111.87+112.55+150.66+132.25+142.57+153) / 14 = 139,60—>140 (graph 1)

Further is the same calculation logic as for graph 1 (graph 2 – graph 9).

Insulin Intake Processing

Example 1
Chosen period: 04.03.2014 – 10.03.2014
It has to be 7 graphs based on the rules for period processing (if chosen period less or equals 31 days then show graph (-s) for each day).

Data from sample CSV database are provided below *(see Figure 3)*.

1017	insulin	04/03/14 01:00	3
1018	insulin	04/03/14 07:20	7
1019	insulin	04/03/14 08:51	2
1020	insulin	04/03/14 12:41	1
1021	insulin	04/03/14 14:54	2
1022	insulin	04/03/14 15:00	5
1023	insulin	04/03/14 17:23	4
1024	insulin	04/03/14 17:53	3
1025	insulin	04/03/14 20:16	4
1026	insulin	04/03/14 21:07	3
1027	insulin	05/03/14 00:41	2
1028	insulin	05/03/14 01:46	3
1029	insulin	05/03/14 09:58	6
1030	insulin	05/03/14 11:32	2
1031	insulin	05/03/14 14:45	3
1032	insulin	05/03/14 16:27	2
1033	insulin	05/03/14 17:27	3
1034	insulin	05/03/14 20:11	2
1035	insulin	05/03/14 20:42	3
1036	insulin	05/03/14 22:53	2
1037	insulin	06/03/14 09:22	6
1038	insulin	06/03/14 10:55	3
1039	insulin	06/03/14 12:47	4
1040	insulin	06/03/14 18:31	4
1041	insulin	06/03/14 20:03	2
1042	insulin	06/03/14 23:04	4
1043	insulin	07/03/14 00:48	1,5
1044	insulin	07/03/14 07:54	7
1045	insulin	07/03/14 11:33	6
1046	insulin	07/03/14 16:15	3
1047	insulin	07/03/14 17:49	3
1048	insulin	07/03/14 19:51	3
1049	insulin	07/03/14 20:41	3,5
1050	insulin	07/03/14 22:37	3
1051	insulin	08/03/14 00:39	3
1052	insulin	08/03/14 07:48	4
1053	insulin	08/03/14 11:41	2
1054	insulin	08/03/14 12:11	5
1055	insulin	08/03/14 16:05	5
1056	insulin	08/03/14 18:45	1,5
1057	insulin	08/03/14 21:12	1,5
1058	insulin	08/03/14 22:03	4
1059	insulin	09/03/14 07:34	4,5
1060	insulin	09/03/14 12:12	4
1061	insulin	09/03/14 14:05	2
1062	insulin	09/03/14 16:06	6
1063	insulin	09/03/14 20:26	4
1064	insulin	10/03/14 07:43	4,5
1065	insulin	10/03/14 12:10	5
1066	insulin	10/03/14 16:48	5,5
1067	insulin	10/03/14 18:37	2
1068	insulin	10/03/14 21:02	4
1069	insulin	10/03/14 22:48	4

Figure 3. Screenshot from CSV database for chosen period for insulin intake

Calculation for the chosen period is below.
04.03.2014: 3+7+2+1+2+5+4+3+4+3 = 34 (graph 1)
05.03.2014: 2+3+6+2+3+2+3+2+3+2= 28 (graph 2)
06.03.2014: 6+3+4+4+2+4 = 23 (it is graph 3)
07.03.2014: 1.5+7+6+3+3+3+3.5+3 = 30 (graph 4)
08.03.2014: 3+4+2+5+5+1.5+1.5+4 = 26 (graph 5)
09.03.2014: 4.5+4+2+6+4 = 20.5—>21 (graph 6)
10.03.2014: 4.5+5+5.5+2+4+4 = 25 (graph 7)

For the data representation in the application for the chosen period see Figure 42 in the thesis.

Example 2
Chosen period: 04.03.2014 – 22.05.2014
It has to be 12 graphs based on the rules for period processing (if chosen period more 31 days but less or equals 92 days then show graph (-s) for each 7 days).

Data used for calculation is contained in sample CSV. *For the data representation in the application for the chosen period see Figure 43 in the thesis.*

Calculation for the chosen period is below.

Graph 1: 04.03.2014 – 10.03.2014

04.03.2014: 3+7+2+1+2+5+4+3+4+3 = 34
05.03.2014: 2+3+6+2+3+2+3+2+3+2= 28
06.03.2014: 6+3+4+4+2+4 = 23
07.03.2014: 1.5+7+6+3+3+3+3.5+3 = 30
08.03.2014: 3+4+2+5+5+1.5+1.5+4 = 26
09.03.2014: 4.5+4+2+6+4 = 20.5
10.03.2014: 4.5+5+5.5+2+4+4 = 25

(34+28+23+30+26+20.5+25) / 7 = 26.64 —> 27 (graph 1)
Graph 2: 11.03.2014 – 17.03.2014

11.03.2014: 4.5+5+5+4.5+2.5+3 = 24.5
12.03.2014: 1+5+5+4.5+4 = 19.5
13.03.2014: 1.5+6+2+3+6 = 18.5
14.03.2014: 3+5+4.5+3+5 = 20.5
15.03.2014: 7+4+2+2+4+2.5 = 21.5
16.03.2014: 5+3+1+2+2+2+5+2+1.5 = 23.5
17.03.2014: 4+2.5+3.5+2.5+4+2+2 = 20.5

(24.5+19.5+18.5+20.5+21.5+23.5+20.5) / 7 = 21.21 —> 21 (graph 1)

Further is the same calculation logic as for graph 1 (graph 3 – graph 12).

Example 3
Chosen period: 04.03.2014 – 20.06.2014
It has to be 8 graphs based on the rules for period processing (if chosen period more 92 days but less or equals 366 days, then show graph (-s) for each 14 days).

Data used for calculation is contained in sample CSV. *For the data representation in the application for the chosen period see Figure 44 in the thesis.*

Calculation for the chosen period is below**.**

Graph 1: 04.03.2014 – 17.03.2014

04.03.2014: 3+7+2+1+2+5+4+3+4+3 = 34
05.03.2014: 2+3+6+2+3+2+3+2+3+2= 28
06.03.2014: 6+3+4+4+2+4 = 23
07.03.2014: 1.5+7+6+3+3+3+3.5+3 = 30
08.03.2014: 3+4+2+5+5+1.5+1.5+4 = 26
09.03.2014: 4.5+4+2+6+4 = 20.5
10.03.2014: 4.5+5+5.5+2+4+4 = 25
11.03.2014: 4.5+5+5+4.5+2.5+3 = 24.5
12.03.2014: 1+5+5+4.5+4 = 19.5
13.03.2014: 1.5+6+2+3+6 = 18.5
14.03.2014: 3+5+4.5+3+5 = 20.5
15.03.2014: 7+4+2+2+4+2.5 = 21.5
16.03.2014: 5+3+1+2+2+2+5+2+1.5 = 23.5
17.03.2014: 4+2.5+3.5+2.5+4+2+2 = 20.5

(34+28+23+30+26+20.5+25+24.5+19.5+18.5+20.5+21.5+23.5+20.5) / 14 = 23.92 —>24 (graph 1)

Further is the same calculation logic as for graph 1 (graph 3 – graph 8).

Physical Activity

Example 1
Chosen period: 22.02.2014 – 28.02.2014
It has to be 7 graphs based on the rules for period processing (if chosen period less or equals 31 days then show graph (-s) for each day).

Data from sample CSV database are provided further *(see Figure 4)*.

Calculation for the chosen period is below.

22.02.2014: 80+60+38 = 178 (graph 1)
23.02.2014: 60+55+33 = 148 (graph 2)
24.02.2014: no data —> 0 (graph 3)
25.02.2014: no data —> 0 (graph 4)
26.02.2014: 100+33 = 133 (graph 5)
27.02.2014: 36 (graph 6)
28.02.2014: 60 (graph 7)

For the data representation in the application for the chosen period see Figure 45 in the thesis.

	A	B	C	D	E
1	Type	Timestamp	Blood glucos	Insulin	Activity
2	activity	22/02/14 15:22			80
3	activity	22/02/14 18:00			60
4	activity	22/02/14 21:23			38
5	activity	23/02/14 13:04			60
6	activity	23/02/14 14:34			55
7	activity	23/02/14 21:50			33
8	activity	26/02/14 11:21			100
9	activity	26/02/14 20:09			33
10	activity	27/02/14 20:32			36
11	activity	28/02/14 19:15			60
12	activity	01/03/14 20:18			40
13	activity	04/03/14 21:28			33
14	activity	05/03/14 12:00			60
15	activity	05/03/14 23:30			35
16	activity	06/03/14 14:18			68
17	activity	07/03/14 21:30			38
18	activity	08/03/14 20:18			45
19	activity	09/03/14 22:10			60
20	activity	10/03/14 21:02			35
21	activity	12/03/14 11:00			70
22	activity	12/03/14 18:39			80
23	activity	14/03/14 11:15			240
24	activity	15/03/14 11:30			300
25	activity	16/03/14 11:36			270
26	activity	17/03/14 11:25			240
27	activity	19/03/14 21:00			20
28	activity	19/03/14 22:15			30
29	activity	20/03/14 13:47			20
30	activity	20/03/14 19:35			40
31	activity	21/03/14 11:20			75
32	activity	21/03/14 14:00			50
33	activity	21/03/14 21:52			60

Figure 4. Screenshot from CSV database for chosen period for insulin intake

Example 2
Chosen period: 22.02.2014 – 22.05.2014
It has to be 13 graphs based on the rules for period processing (if chosen period more 31 days but less or equals 92 days then show graph (-s) for each 7 days).

Data used for calculation is contained in sample CSV. *For the data representation in the application for the chosen period see Figure 46 in the thesis*.

Calculation for the chosen period is below.

Graph 1: 22.02.2014 – 28.02.2014
22.02.2014: 80+60+38 = 178
23.02.2014: 60+55+33 = 148
24.02.2014: no data —> 0
25.02.2014: no data—> 0
26.02.2014: 100+33 = 133
27.02.2014: 36
28.02.2014: 60

(178+148+0+0+133+36+60) / 7 = 79.28 —> 79 (graph 1)

Graph 2: 01.03.2014 – 07.03.2014
01.03.2014: 40
02.03.2014: 0

03.03.2014: 0
04.03.2014: 33
05.03.2014: 60+35 = 95
06.03.2014: 68
07.03.2014: 38

(40+0+0+33+95+68+38) / 7 = 39.12 —> 39 (graph 2)

Further is the same calculation logic as for graph 1 (graph 3 – graph 13).

Example 3
Chosen period: 22.02.2014 – 29.05.2014
It has to be 10 graphs based on the rules for period processing (if chosen period more 92 days but less or equals 366 days, then show graph (-s) for each 14 days).

Data used for calculation is contained in sample CSV. *For the data representation in the application for the chosen period see Figure 47 in the thesis*.

Calculation for the chosen period is below**.**

Graph 1: 22.02.2014 – 07.03.2014

22.02.2014: 80+60+38 = 178
23.02.2014: 60+55+33 = 148
24.02.2014: no data —> 0
25.02.2014: no data —> 0
26.02.2014: 100+33 = 133
27.02.2014: 36
28.02.2014: 60
01.03.2014: 40
02.03.2014: 0
03.03.2014: 0
04.03.2014: 33
05.03.2014: 60+35 = 95
06.03.2014: 68
07.03.2014: 38

(178+148+0+0+133+36+60+40+0+0+33+95+68+38) = 59.21 —> 59 (graph 1)

Further is the same calculation logic as for graph 1 (graph 2 – graph 13).

Carbohydrates Intake Processing

Example 1
Chosen period: 01.03.2014 – 14.03.2014
It has to be 14 graphs based on the rules for period processing (if chosen period less or equals 31 days then show graph (-s) for each day).

Data from sample CSV database are provided below *(see Figure 5)*.

602	carb	01/03/14 07:48			40
603	carb	01/03/14 13:14			40
604	carb	01/03/14 14:46			20
605	carb	01/03/14 15:00			15
606	carb	01/03/14 17:20			40
607	carb	01/03/14 18:49			30
608	carb	01/03/14 21:03			15
609	carb	01/03/14 22:17			35
610	carb	02/03/14 07:53			35
611	carb	02/03/14 11:39			30
612	carb	02/03/14 15:22			0
613	carb	02/03/14 16:06			30
614	carb	02/03/14 17:17			45
615	carb	02/03/14 18:26			15
616	carb	02/03/14 20:37			40
617	carb	02/03/14 22:15			30
618	carb	03/03/14 00:14			10
619	carb	03/03/14 08:51			40
620	carb	03/03/14 10:59			40
621	carb	03/03/14 11:10			15
622	carb	03/03/14 14:09			15
623	carb	03/03/14 16:26			50
624	carb	03/03/14 17:57			20
625	carb	03/03/14 18:26			32
652	carb	06/03/14 15:41			15
653	carb	06/03/14 18:30			40
654	carb	06/03/14 20:01			20
655	carb	06/03/14 21:34			30
656	carb	06/03/14 23:12			10
657	carb	07/03/14 07:54			55
658	carb	07/03/14 10:44			10
659	carb	07/03/14 11:33			50
660	carb	07/03/14 13:47			20
661	carb	07/03/14 16:14			30
662	carb	07/03/14 17:49			25
663	carb	07/03/14 19:41			20
664	carb	07/03/14 20:42			30
665	carb	07/03/14 22:11			50
666	carb	08/03/14 07:48			20
667	carb	08/03/14 10:41			20
668	carb	08/03/14 12:11			50
669	carb	08/03/14 14:34			0
670	carb	08/03/14 16:05			50
671	carb	08/03/14 18:45			10
672	carb	08/03/14 20:18			10
673	carb	08/03/14 20:37			15
674	carb	08/03/14 21:12			15
675	carb	08/03/14 22:03			20
676	carb	09/03/14 00:38			20
677	carb	09/03/14 07:34			20
678	carb	09/03/14 12:12			40
679	carb	09/03/14 16:06			50
680	carb	09/03/14 18:29			5
681	carb	09/03/14 20:25			40
682	carb	10/03/14 07:43			20
683	carb	10/03/14 09:15			20
684	carb	10/03/14 12:10			50
685	carb	10/03/14 16:00			25
686	carb	10/03/14 16:48			60
687	carb	10/03/14 18:37			20
688	carb	10/03/14 20:52			20
689	carb	10/03/14 21:11			10
690	carb	10/03/14 22:46			40
691	carb	11/03/14 07:49			25
692	carb	11/03/14 11:36			45
693	carb	11/03/14 17:15			60
694	carb	11/03/14 19:07			35
695	carb	11/03/14 20:24			10
696	carb	11/03/14 22:04			30
697	carb	09/03/14 10:45			20
698	carb	11/03/14 23:41			20
699	carb	12/03/14 08:42			40
700	carb	12/03/14 12:32			50
701	carb	12/03/14 17:07			45
702	carb	12/03/14 20:44			45
703	carb	12/03/14 22:35			15
704	carb	13/03/14 08:17			45
705	carb	13/03/14 10:46			15
706	carb	13/03/14 14:52			20
707	carb	13/03/14 16:54			15
708	carb	13/03/14 17:57			20
709	carb	13/03/14 19:06			45
710	carb	13/03/14 21:03			20
711	carb	14/03/14 09:13			50
712	carb	14/03/14 11:52			30
713	carb	14/03/14 12:40			10
714	carb	14/03/14 13:30			50
715	carb	14/03/14 17:29			20
716	carb	14/03/14 20:47			50

Figure 5. Screenshot from CSV database for chosen period for physical activity

Calculation for the chosen period is below.

01.03.2014: 40+40+20+15+40+30+15+35 = 235 (graph 1)
02.03.2014: 35+30+0+30+45+15+40+30 = 225 (graph 2)
03.03.2014: 10+40+40+15+15+50+20+32+40 = 262 (graph 3)
Further is the same calculation logic as for days 01.03.2014 – 03.03.2014.
04.03.2014: … = 225 (graph 4)
05.03.2014: … = 280 (graph 5)
06.03.2014: … = 250 (graph 6)
07.03.2014: … = 290 (graph 7)
08.03.2014: … = 210 (graph 8)
09.03.2014: … = 195 (graph 9)
10.03.2014: … = 265 (graph 10)
11.03.2014: … = 225 (graph 11)
12.03.2014: … = 195 (graph 12)
13.03.2014: … = 180 (graph 13)
14.03.2014: … = 210 (graph 14)

For the data representation in the application for the chosen period see Figure 48 in the thesis.

Example 2
Chosen period: 01.03.2014 – 20.05.2014
It has to be 12 graphs based on the rules for period processing (if chosen period more 31 days but less or equals 92 days then show graph (-s) for each 7 days).

Data used for calculation is contained in sample CSV. *For the data representation in the application for the chosen period, please, see Figure 49 in the thesis*.

Calculation for the chosen period is below.

Graph 1: 01.03.2014 – 07.03.2014

01.03.2014: 40+40+20+15+40+30+15+35 = 235
02.03.2014: 35+30+0+30+45+15+40+30 = 225
03.03.2014: 10+40+40+15+15+50+20+32+40 = 262

Further is the same calculation logic as for days 01.03.2014 – 03.03.2014.
04.03.2014: … = 225
05.03.2014: … = 280
06.03.2014: … = 250
07.03.2014: … = 290

(235+225+262+225+280+250+290) / 7 = 252.42 —> 252

Graph 2: 08.03.2014 – 14.03.2014

Further is the same calculation logic as for days 01.03.2014 – 03.03.2014.
08.03.2014: … = 210
09.03.2014: … = 195
10.03.2014: … = 265
11.03.2014: … = 225
12.03.2014: … = 195

13.03.2014: … = 180
14.03.2014: … = 210

(210+195+265+225+195+180+210) / 7 = 211.42 —> 211 (graph 1)

Further is the same calculation logic as for graph 1 (graph 2 – graph 12).

Example 3
Chosen period: 01.03.2014 – 06.06.2014
It has to be 7 graphs based on the rules for period processing (if chosen period more 92 days but less or equals 366 days, then show graph (-s) for each 14 days).

Data used for calculation is contained in sample CSV. *For the data representation in the application for the chosen period, please, see Figure 50 in the thesis*.

Calculation for the chosen period is below.

Graph 1: 01.03.2014 – 14.03.2014

01.03.2014: 40+40+20+15+40+30+15+35 = 235
02.03.2014: 35+30+0+30+45+15+40+30 = 225
03.03.2014: 10+40+40+15+15+50+20+32+40 = 262

Further is the same calculation logic as for days 01.03.2014 – 03.03.2014.
04.03.2014: … = 225
05.03.2014: … = 280
06.03.2014: … = 250
07.03.2014: … = 290
08.03.2014: … = 210
09.03.2014: … = 195
10.03.2014: … = 265
11.03.2014: … = 225
12.03.2014: … = 195
13.03.2014: … = 180
14.03.2014: … = 210

(235+225+262+225+280+250+290+210+195+265+225+195+180+210) / 14 = 231.92 —> 232 (graph 1)

Further is the same calculation logic as for graph 1 (graph 2 – graph 7).