Using a Data Warehouse Approach for Mobile Patients

Andreea Ionas, Andreas Meier, Ciprian Pop, Marco Savini, Henrik Stormer

University of Fribourg
Boulevard de Perolles 90
1700 Fribourg

[andreea.ionas|andreas.meier|ciprian.pop|marco.savini|henrik.stormer]@unifr.ch

Abstract: A large number of people already own a mobile phone. In the eHealth area, the usage of this mobile device is becoming more and more popular. Patients can install small applications on their devices that help or guide them in certain situations. Additionally, the mobile devices can be used to transmit all kind of physiological parameters electronically. These parameters are stored on a special server. By analyzing the data, patients can be alerted when the parameters are becoming bad. This paper presents the eSana framework that was developed as an integrated framework to connect patients to medical experts and enable the electronic transmission of physiological parameters. An important step is the analysis of these data. The focus of this paper is to show how eSana provides mechanisms for the automatic analysis of data by utilizing a data warehouse. The data warehouse model and possible analyses will be presented.

1 Mobile Devices in eHealth

Current statistics show that more than 80% of the European population owns a mobile phone [SBD03]. The increasing features of these devices are reasons for using them in the electronic health sector. A promising area is the automated collection of physiological parameters like blood glucose using mobile phones combined with a measuring device. These parameters can be transmitted to a medical expert afterwards.

A number of researchers have worked on the idea of assigning mobile devices to patients. Typically, one can distinguish between the following three approaches:

1. Mobile devices are used to help the patient by providing information

2. Mobile devices are used to transmit physiological parameters

3. Mobile devices are used to alert patients when certain physiological parameters are bad.

The work of Heuwinkel [Heu05] is an example for the first approach. Her system provides help for younger people that are suffering from overweight. During the day, the mobile device guides the young patient. The system proposes the overweight person what and when to eat.

The second approach was done in the MOEBIUS project (Mobile extranet-based integrated user services) [Rei03] [Eik01] who integrated doctors and patients by submitting different physiological parameters. Another finish project was WellMate™ [BrSö99], done in cooperation with Nokia. The idea of WellMate™ was to collect blood glucose values from diabetes patients. These values were transmitted to a service provider using SMS. In a project from the University of Munich [WSH04] a device for measuring the lung functionality was developed. This device is connected to a mobile telephone and sends the values to a server. Vitaphone [Vit05] is a German company that distributes a mobile phone to be used for personal emergency calls. Additionally, the phone can record ECG's and send them to a server using the GSM network.

The third approach is done in the work of Panzarasa et al. [PBLS04]. They propose a system where patients can access their own physiological parameters and send them to medical communication centers. The evaluation is done at an medical communication center. Jung and Hinze [JuHi05] have done a similar work. They propose a mobile alerting system that alerts diabetes patients when certain physiological parameters are bad. Our research goes in the same direction as their work. However, we concentrate on the question of how to analyze the physiological parameters to provide good warnings, which is not the focus of Jung and Hinze.

The aim of this paper is to present eSana, a framework developed as a mobile integrated solution for the communication between patients and medical experts. eSana redefines the communication between a customer/patient and a medical expert by the consequential use of mobile devices for the customer/patient part. Furthermore, eSana supports the patient when physiological parameters need to be transmitted regularly.

The goal of eSana is to combine all three approaches. eSana has been shown to be a good framework for collecting physiological parameters using mobile devices [SIM05], this paper presents how eSana could also be utilized in the third application domain by providing data warehouse analyze tools.

This paper concentrates on the evaluation of physiological parameters (third approach). This is done by showing a data warehouse model for diabetes patients. These patients need to monitor physiological parameters like the blood glucose value regularly. eSana supports them by transmitting these parameters to a data warehouse where they are stored. Data from other sources, as labs, medical practices or hospitals can, also, be integrated in the data warehouse. Using the data warehouse analytic methods, either the patients or the medical experts can analyze certain parameters. The results can be used to warn patients when the parameters are becoming bad.

This paper is structured as follows: The next section will give a short introduction to the eSana architecture. Section 3 shows the main part of this paper, namely the model of the data warehouse for diabetes patients. Section 4 concludes the paper and gives an outlook.

2 eSana Architecture

The eSana framework was developed as a mobile integrated solution for connecting a health insurance/company/medical communication center/medical expert with a customer/patient [SIM05]. Many health insurance companies mandate a medical communication center (MCC) to act as a 24 hour medical helpdesk. If no external MCC has been mandated, the health insurance company typically has an internal department, which will act as a medical helpdesk. All customers of the health insurance company can contact the MCC, by different channels. The most popular channel is the phone. A person can call the MCC and ask questions on different medical issues. The MCC gives first medical consulting or guidance for choosing a doctor or a certain drug.

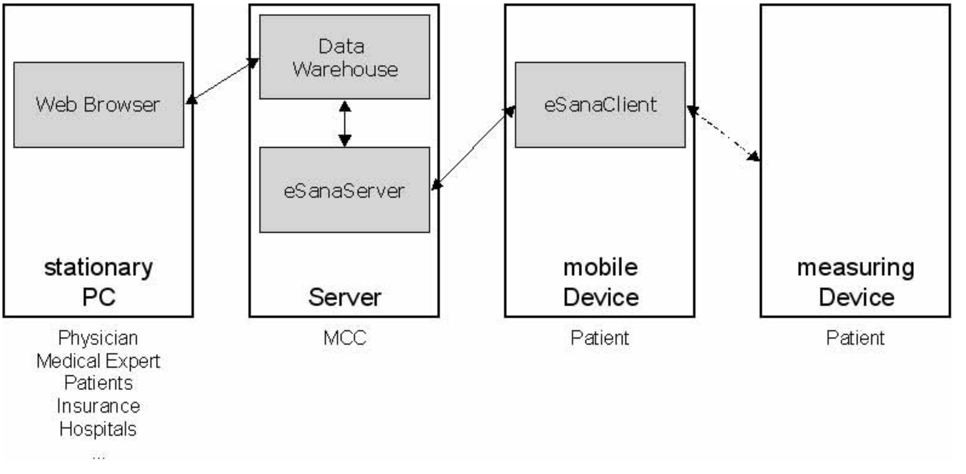

Figure 1 Devices of the eSana Framework

The eSana Framework is illustrated in Figure 1. The measuring device sends the physiological parameter to the mobile device. After the mobile device has received the parameter, it is transmitted to the eSanaServer which is storing the parameter in a data warehouse. For analyzing purposes, physicians, patients and others can access the data warehouse using a web browser.

The eSana architecture extends the communication because customers can use their mobile device to send and receive data automatically (or in exceptional cases also manually). The mobile device runs an application called eSanaClient. This application wraps all eSana client functionalities. Reciprocally there is an eSanaServer application, running on a server maintained by the MCC and accessible on the Internet.

3 Data Warehouse Model for eDiabetes in eSana

Inmon [Inm96] defines a data warehouse as the "subject oriented, integrated, non-volatile, and time-variant collection of data in support of management's decision".

A data warehouse is based on a multidimensional data model. In a multidimensional data model one can differentiate between qualifying and quantitative data. The quantitative data, often referred as facts, are key figures that are used in the decision support. The qualifying data are referred as dimensions. A dimension visualizes an aspect of the analysis context and it contains attributes, which have a hierarchical structure and describe the dimension as accurate as possible.

In the eHealth area, some data warehouse approaches already exist [BTBG05] [BPFP04]. For diabetes patients, Breault et al. show how classification and regression trees could be utilized [BGF02]. Maizlish et al. measured the prevalence of glycemic control for diabetic patients at 7 community health centers [MSH04]. In contrast, this paper presents a data warehouse model that can be used to analyze automatically collected physiological parameters.

3.1 Data Warehouse Model

A data warehouse model for eDiabetes is shown in Figure 2. The characteristic dimensions for the eDiabetes data warehouse are:

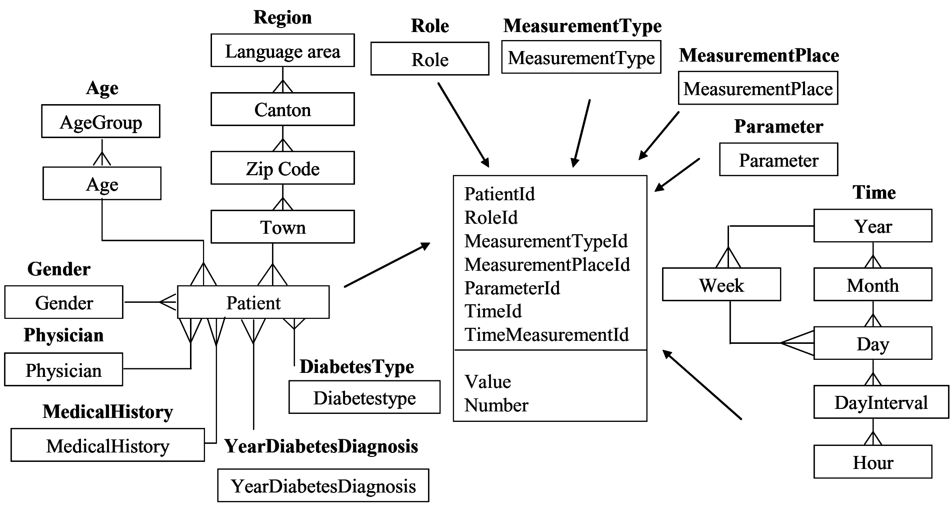

Figure 2: A Data Warehouse Model for eDiabetes.

Gender: This dimension contains the gender of the diabetic patient.

Age: The patient's age can be referred as the age itself, or it can be aggregate to age groups, which are important and interesting from a medical point of view.

Region: The patient's address can be analyzed, regarding language area, canton, zip code or town.

Physician: It is important to know the physician in charge for a patient.

MedicalHistory: This dimension contains the diseases the patients suffered in the past (dyslipidaemia, hypertonia, apoplexy, angina pectoris, cardiac insuffiency) and if there are diseases in his family significant for his disease (apoplexy or diabetes). Dependent of what analysis should be made and which information is needed, this dimension can be more detailed. It can contain information about the disease period and severeness, the treatments the patient is doing, the result and possible complications of the treatments. This dimension can be very complex, and it should be defined in close collaboration with the medical experts that will use this information.

DiabetesType: The patient can suffer from different diabetes types: Type I, Type II or, sometimes, gestational diabetes.

YearDiabetesDiagnosis: The year of the diabetes diagnosis, and thereby the duration of diabetes, is an important issue in analyzing the health evolution and parameters of a patient.

Role: The parameters can be measured by the patient himself, a patients relative, the physician/nurse in charge, medical lab staff etc.

MeasurementType: This dimension contains information concerning the way the parameters were measured: automatic, manually etc.

MeasurementPlace: This dimension contains information concerning the place where the measurement has been made: medical practice, medical lab, home etc.

Parameter: Diabetic patients have to measure several parameters, with different frequency (see table 1). The parameters measuring frequency, shown in table 1 is the minimum necessary. It is desirable that a diabetes patient measures his parameters more often, e.g., blood sugar and blood pressure several times a week, or even daily.

Time: It is necessary that the physician or the patient can see the evolution of his health status over time. Interesting time aggregations are hour, day intervals (morning, midday, afternoon, evening, night or 6-11, 11-15, 15-18, 18-22, 22-6), day, week, month or year.

Other dimension could be necessary or interesting dependent on the information and analysis needs, and also on the availability of data.

One-time	**Yearly**	**Quarterly**
Birth date	Total Cholesterol	Weight
Height	HDL Cholesterol	Fasting blood sugar
Diabetes type	C-peptide	Postprandial blood sugar
Diabetes since	Triglycerides	Blood sugar self-control/day
Oral antidiabetic therapy since	Proteinuria	Blood sugar self-control/week
Insulin therapy	Serum creatinine	HbA1c
Diabetics training	Leg inspection	Severe hypoglycaemia
Nutrition counseling	Eye analysis	Systolic blood pressure
Nutrition plan existence	Urine state (blood, ketones, leukocytes, pH-Value)	Diastolic blood pressure
Blood sugar self-control	Additionally: ECG Ergometry Peripheral neuropathy Autonomic neuropathy	Number of illness days
Blood pressure self control		Number of hospitalization days
Social environment		
Secondary diagnosis		
Personal medical history (smoker, dyslipidaemia, hypertonia, apoplexy, angina pectoris, cardiac insufficiency)		
1st level family medical history (apoplexy or diabetes known)		

Table 1: Measured parameters by diabetic patients and their frequency [PQD03] [GPD05]

The following facts are important:

- *Value*: For monitoring the patients' health status the value of his parameters are decisive. Monitoring the parameters values is very important, if the values come in a risky domain, the physician/nurse in charge must initiate the proper actions. Table 2 shows the normal values of some of the parameters that should be measured.

- *Number*: It is important to know how often the patient has measured a certain parameter in a given time period. This figure shows the patients compliance, that means if the patient measures his parameter as often and proper as he should. There can be different reasons why a patient doesn't measure his parameters as often as he should. One reason could be the patient has forgotten to measure his parameters and in this situation the physician in charge could remember him by SMS, email or a call. Another reason is the patient's lack of compliance and in this situation the physician must find the proper way to motivate the patient to measure his parameters.

Other facts could be also interesting, the analysis and monitoring needs are decisive here.

PatientId, *RoleId*, *MeasurementTypeId*, *MeasurementPlaceId*, *ParameterId*, *TimeId*, *TimeMeasurementId* are the foreign keys that relates the facts to the correspondent dimensions. There are used two times id's –TimeMeasurementId refers the measurement time of a certain parameter and TimeId refers the time when this measurement was sent to the system. For the eSana framework the measurement time is the same with the transfer time, but, as in the data warehouse, also, exists parameters measured otherwise than with eSana two different Time id's are needed.

Parameter	**Measuring Unit**	**Normal Value**	**Critical value**
Blood sugar	mg/dl	80-110	>=126
	mmol/l	4.4-6.1	>=7
Blood pressure	mmHg	<=140/90	>=160/95
HbA1c	%	<6.5	>=7.5
Total Cholesterol	mg/dl	<200	>=250
	mmol/l	<5.2	>=6.5
HDL Cholesterol	mg/dl	>40	<=35
	mmol/	>1.1	<=0.9
Triglycerides	mmol/l	<1.7	>=2.2

Table 2: Normal values of the parameters [RND05]

3.2 Analyses

The data warehouse enables several analyses. Both the physician and the patient can look to several statistics. The patient may be interested to see if certain behavior as nutrition- and movement program, diabetics training or drug therapy leads to improvements of his health status.

Physicians have to monitor the parameters of their patients permanently. The physician is interested in looking to values of his entire patients' population or just for certain patients.

Some of the possible aggregate analyses for the entire patients collective that are interesting for the treating physician are:

- Distribution of the patients, regarding:
  - HbA1c, in following groups: 5-7%, 7-8%, >8%;
  - Total Cholesterol, in following groups: <5 mmol/l, >=5 mmol/l;
  - Systolic blood pressure in following groups: <135 mmHg, 135-140 mmHg, >140 mmHg;
  - Diastolic blood pressure in following groups: < 85 mmHg, 85-90 mmHg, > 90 mmHg;

- Number of patients that measured all their parameters (HbA1c, Systolic blood pressure, Diastolic blood pressure, Total Cholesterol, HDL Cholesterol, Triglycerides) in a quarter;
- Blood pressure measurement frequency in a given time period;
- Measurement completeness: Number of patients that measured all of the following parameters: HbA1c, blood pressure, weight, Total Cholesterol, HDL Cholesterol, Triglycerides, Proteinuria, Serum creatinine, Leg inspection, Eye analysis, ECG;
- Compliance representation: Number of patients that made following actions: blood sugar self-control, blood pressure self-control, diabetics training, nutrition counseling, patient entered his data.

Through aggregate statistics of his patient collective the physician is able to recognize negligence or completeness of their analyses. He can decide if the patients' self-control behavior is sufficiently or he needs to take measures for changing and improving their behavior. For example, Figure 3 shows that 60% of the patients collective measure their blood sugar correctly, but only about 27 % of the patients measure their blood pressure and attend nutrition counseling and less than 10 % enter their data. The physician has to find out why the patients don't measure their blood pressure and don't attend the nutrition counseling and try to change the patients' behavior. He, also, must motivate them to enter their data; only if the data is available the physician can monitor the patient's health status and initiate proper action if needed.

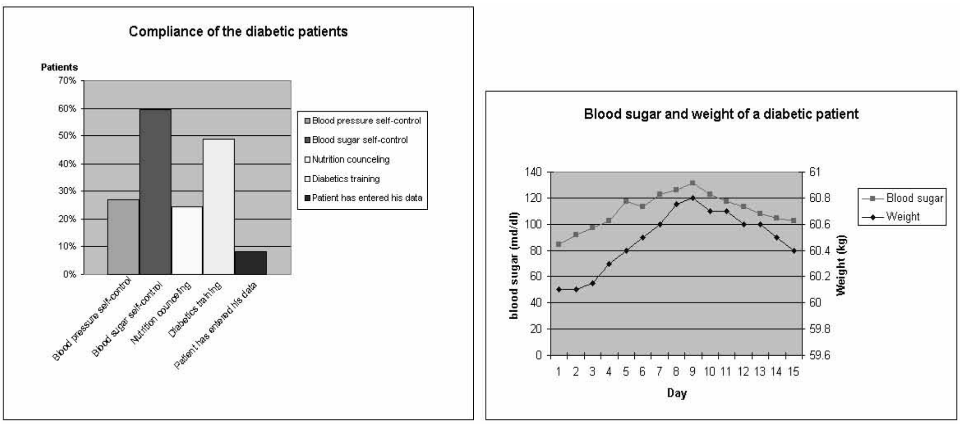

Figure 3 Parameters for patients' population and individual patients

Further on the physician must supervise the evolution of several parameters for his patients. He can analyze how the parameters of a particular patient evolve (Figure 3), and he can initiate the proper action if the health status of the patient demands it or if the patient has forgotten to measure a certain parameter or he hadn't done it right.

4 Steps towards a Medical Communication Center

The data warehouse is the core of a medical communication center. The medical communication center is for patients/people with medical questions 24/24 and 7/7 available, even they are abroad. Often patients are overstrained by finding out who is the right person/institution for their medical issue. It is in the patients' interest if they have just one contact point, where they can get the necessary information and, if needed, be directed to the appropriate medical person/institution. The medical communication center could act as a central contact point between several care provider and the patients. Beside it's role as a central contact point the medical center could offer several services, such as: demand management, disease management programs, second medical opinion, medical compliance, medical hotlines and tele-consulting, monitoring and emergency management, world-wide medical assistance.

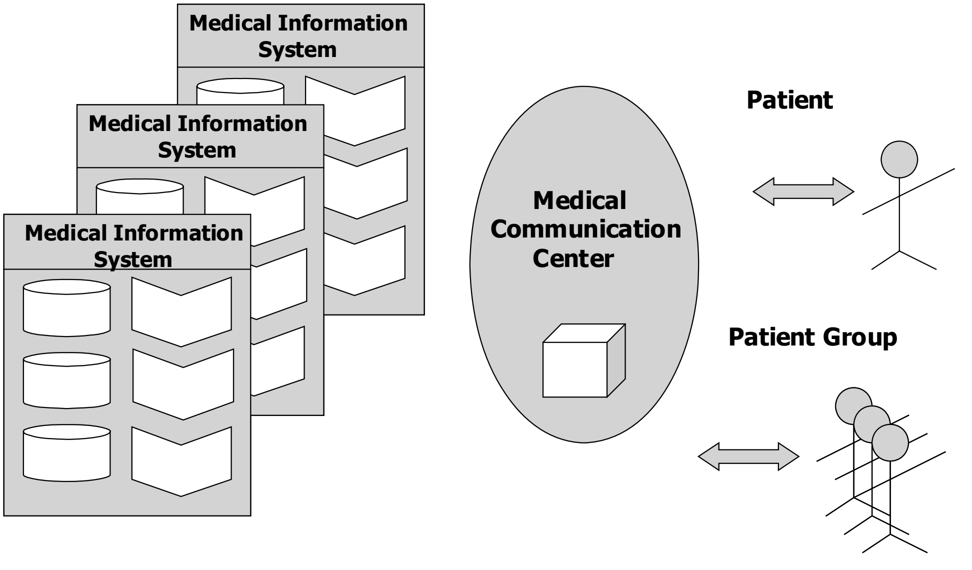

Figure 4: Data Warehouse: a precondition for Patient Relationship Management

Patients' data from different medical information systems must be integrated, so that, on the one hand, patients don't have to say there whole story over and over again, and, on the other hand, all information about the patient is connected and available. The data availability is a precondition for knowing the patient's medical history and giving him the proper advices concerning his medical issue. For integrating the data and making it easily accessible and analyzable a data warehouse must be used. Through a data warehouse data from all available sources is integrated and made available for the responsible caregiver and physicians, so that they are able to make the right decision about their patients. For supervising the health status of his patients the physician can make different analysis of a certain patient or patient group. The patient and different stakeholders, dependent on their authorization and interest can also see different data analysis. The medical communication center as a central and always available contact point with the data warehouse as the integrated data pool represents the premise for Patient Relationship Management.

References

[BGF02] Breault, J.L. & Goodall, C.R. & Fos, P.J.: Data Mining a diabetic data warehouse. Artif. Intell. Med. September-October, 26(1-2), 2002

[BrSö99] Brännback, M., & Söderlund, R. (1999). Interactive Support Service for Wellness Support: A Research Agenda. *TUCS Technical Report 258.*

[BTBG05] Breant, C. & Thurler, G. & Borst, F. & Geissbuhler, A.: Design of Multi Dimensional Database for the Archimed Data Warehouse. Stud. Health Technol. Inform., 116, 2005

[BPFP04] Blewett, L. A. & Parente, S.T. & Finch, M.D. & Peterson E.: National Health data warehouse: issues to consider. Journal of Healthcare Information Management (JHIM), 18(1), 2004

[Eik01] Eikemeier, C. & Dyson, A. & Reichlin, S. & Beglinger, C. The application of mobile communications technologies to clinical trials. *World Congress on the Internet in Medicine*, 2001

[GPD05] Gesundheits- Pass Diabetes: Idee, Handhabung, Behandlungsrichtlinie, Zielwerte, Homepage: http://www.diabetikerbund-hamburg.de/broschueren/broschuere_gesundheitspass_diabetes.htm, last checked 26.01.2005

[Heu05] Kerstin Heuwinkel: Digitale Patienten-Begleiter am Beispiel Adipositas permaxima, Workshop on eHealth, Proceedings of the GI-Jahrestagung, 2005

[Inm96] Inmon W.H.: Building the Data Warehouse Second Edition, Wiley, 1996.

[JuHi05] Jung, D.; Hinze A.: A Mobile Alerting System for the Support of Patients with Chronic Conditions. Proceedings of the 1st Euro Conference on mobile Government (mGov), 2005

[MSH04] Maizlish, N. A. & Shaw, B. & Hendry, K.: Glycemic control in diabetic patients served by community health centers. Am J Med Qual. 19(4), 2004

[PBLS04] Panzarasa, S., Bellazzi, R., Larizza, C. & Stefanelli, M. (2004). A Careflow Management System for Chronic Patients. *Medinfo* (pp. 673–677).

[PQD03] Project "Qualitätssicherung Diabetes", project report of the Institute For Medical Informatics and Biostatistics, 2003

[Rei03] Reichlin, S. Combining Telemedicine and Disease Management: Concepts and Experiences. Proceedings of the Congress on new generation of wearable systems for e-health, 2003

[RND05] Relevante Normwerte für die Diabetes-Therapie, Homepage: http://www.diabetiker-linz.at/Relewante%20Normwerte.htm, last checked 01.03.06

[SBD03] Statistisches Bundesamt Deutschland: Ausstattung privater Haushalte mit Informations- und Kommunikationstechnik, Statistik von 1998 und 2003, http://www.destatis.de/basis/d/evs/budtab6.php, last checked 25.10.05

[SIM05] Stormer, H. & Ionas, A. & Meier, A.: Mobile Services for a Medical Communication Center - The eSana Project. Proceedings of the First European Conference on Mobile Government, 2005

[WSH04] Wolf, B. & Scholz, A. & Henning, T. (2004) Mobilfunk-gestützte medizinische Wissensbasis mit sensorisch interaktiven Systemen, Electrosuisse Vol 1

[Vit05] Vitaphone (2005). The Vitaphone Homepage: http://www.vitaphone.de/en/emergency_mobile_phone/, last checked 20.2.05