OLDES: new solution for long-term diabetes compensation management

D. Novák, O. Štepanková, M. Mráz, M. Haluzík, M. Bussoli, M. Uller, K. Malý, L.Nováková and P. Novák

***Abstract*— EU project OLDES (Older People's e-services at home) aims at developing a very low cost and easy to use entertainment and health care platform designed to ease the life of older people in their homes. The platform is based on a PC corresponding to Negroponte's paradigm of a 100 $ device. OLDES combines user entertainment services (through easy-to-access thematic interactive channels and special interest forums supported by animators) and health care facilities. The pilot case study of diabetes type II compensation under the OLDES framework is presented. Apart from measurement of continuous glucose, blood pressure and weight, the user feeds into OLDES system food daily consumption using interactive food scales via user friendly software interface designed by user-centered design paradigm and obtains advice if necessary.**

I. INTRODUCTION

The main aim of OLDES project is to allow older persons to live as much as possible in their own ambient, with or without the members of their family, when clinical state and family consent that. It addresses to self- or not-sufficient patients suffering with chronic diseases as diabetes. Over three-quarters of the patients that utilize the home health care service are over 75 years old. The OLDES service is assured by a team of various operators: doctors, nurses, social workers, that collaborate with the general practitioner. Sometimes it involves voluntary associations. Figure 2 describes particular stakeholder situation in diabetes care. OLDES home health care service is carried out according to a personalized treatment plan, based on the assessment of the functional state of the patient and care plan.

OLDES promotes healthy life style by providing audio-visual content, or trough the constant monitoring of vital parameters and health state, that allows a more adequate and well-timed treatment of possible diseases. Moreover opportunity of extending the service to a wider number of users and having a great number of available data, relevant to monitor and analyse the patient behaviour and clinical state, is not negligible.

This paper represents OLDES project capabilities within diabetes pilot project. Diabetes mellitus type 2 is a syndrome characterized by disordered metabolism and inappropriately high blood sugar (hyperglycaemia) resulting from either low levels of the hormone insulin or from abnormal resistance to insulin's effects coupled with inadequate levels of insulin secretion to compensate. The characteristic symptoms are excessive urine production (polyuria), excessive thirst and increased fluid intake (polydipsia), and blurred vision. These symptoms are likely to be absent if the blood sugar is only mildly elevated.

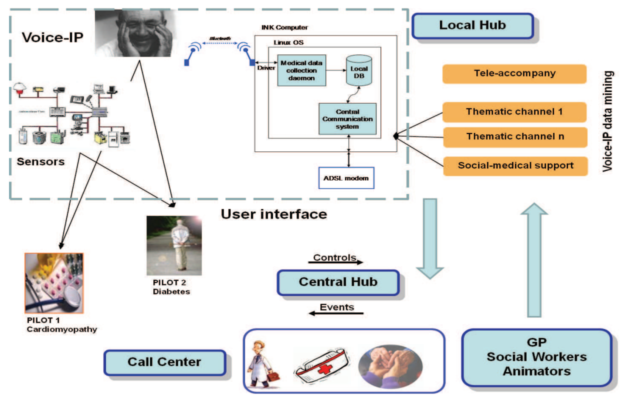

Fig. 1. Oldes architecture

The OLDES architecture consists of two main parts as depicted in Figure 1: *Local Hub* collects physiological data measured by sensors and communication channels implemented by Voice-IP. The information is collected by low-cost INK Laptop and sent via ADSL link to *Cental Hub*. Each senior has a health agenda stored in Central Hub. The senior continuously receives social-medical support by medical doctors, social workers and volunteers situated in the call center. Healthy life style is promoted trough an adequate scheduling of thematic entertainment channels. The feasibility of OLDES concept is evaluated under cardiomyopathy and diabetes pilot project.

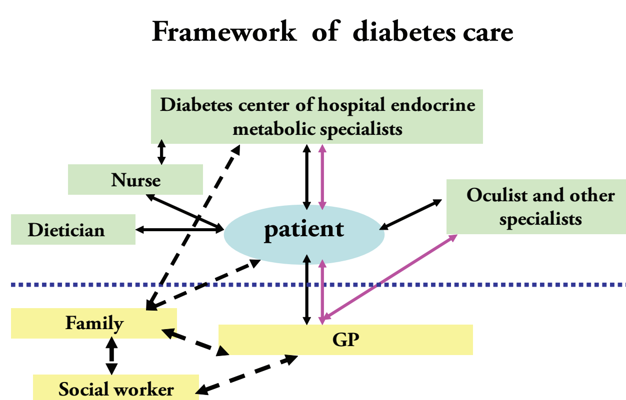

Fig. 2. Stakeholders situation in diabetes care

The main goal of diabetes's pilot is to achieve better compensation of diabetes in hard-to-compensate patients by

D. Novák, O. Štepanková, M. Uller, K. Malý, L.Nováková and P. Novák is with Department of Cybernetics, Czech Technical University in Prague, Czech Republic, xnovakd1@labe.felk.cvut.cz, M. Mráz and M.Haluzík is with Third Department of Medicine, Charles University, Czech Republic, M. Busuoli is with Ente per le Nuove Tecnologie, l'Energia e l'Ambiente-ENEA, Brussels, Belgium

flexible individualized approach to insulin dose adjustment. Diabetic patients are frequently affected by diseases associated with diabetes (eg. arterial hypertension and other disorders of cardiovascular system) and use much concomitant medication which could be cause of many complications (deviations of blood pressure, heart rate, etc.). The system is developed system for monitoring of physiological functions and self-diagnostics of diabetes in form of advisory system for a patient who is ”feeling bad”- this situation is often caused by changes of arterial blood pressure (bad compensated hypertension, hypotension caused by high dose of antihypertensives).

II. Methodology

Oldes diabetes pilot project reflects requirements of modern personal healthcare system (PHR) as a computerized application that stores an individual’s personal health information. PHR part of OLDES system monitors following parameters: continuous glucose measurement, blood pressure, heart rate, weight of patients and weight of patients’ daily food - see Figure 3. The data are gathered using a datalogger device. After the data are transmitted via low cost INK computer to the OLDES central node, the physician can make recommendations of further procedures as acute intervention, event. modification of chronic medication at home conditions without necessity of stay in the hospital, etc. Therefore is a very important to develop and test a suitable user interface between patient and OLDES system.

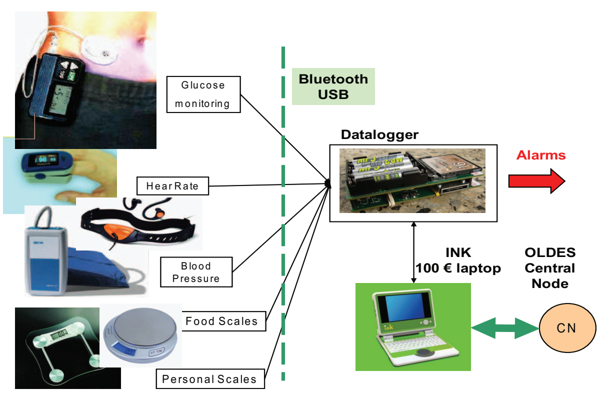

Fig. 3. Main setup of diabetes pilot system sets

Another part of OLDES PHR is based on diabetic diet with restricted amount of sacharides and movement activities. To keep this relatively strict regimen is very difficult and there is not much information among diabetic population how to take the diet, prepare relatively attractive dishes, patients have no motivation for exercising etc.

These patients can use interactive scale connected to a computer database of sacharides amount in frequent foodstuff. Automatic computation of total daily consumption simplifies patient’s control of sacharides intake. The resulting information should be exported to a dietitian who can suggest recommendations for modification of patient’s diet. Furthermore, input from complementary device, namely personal scale for measuring the patient’s weight is included among the monitored data supporting long-period weigh management.

In order to enable patient monitoring and data fusion, datalogger device was designed with 8 A/D converters which enable connecting sensors for measuring temperature, ECG, movements (accelerometers), blood pressure etc. Datalogger is realized using PIC 18F452 microcontroller and allows real-time wireless data transfer via Bluetooth or storing data to a SD memory card together with a timestamp. Wireless Bluetooth technology enables visualization and processing of data acquired from patient on INK computer. Datalogger is a mobile device, which uses open-source technologies [1], enables storing up to 2 GB of data or wireless transfer of data via Bluetooth class 1 interface (up to 100 m distance).

Fig. 4. Minimed sensor for continuous glucose measurement

Real-time datalogger module is working despite of disconnecting the main battery or its discharge. Li-Ion battery is used and enables duration up to 72 hours, when writing data from A/D converters to the card using 250 Hz sampling frequency.

Patients are monitored by the existing commercial Medtronic system, which ensures continuous or intermittent blood glucose measurements. Guardian Real-Time device [2] has been selected for continuous glucose measurement. Guardian Real-Time is a system designed to monitor glycaemic values continuously during day and night. Measured data are sent wirelessly by the transmitter - see Figure 4 (which is attached to the sensor) to the receiving unit, where they are displayed in the form of a number and of a graph of values. The data are updated every 5 minutes.

When the measured values cross the preset hypo- or hyperglycaemic levels, an alarm or alert is raised in order to inform the patient about the threatening conditions. 3 types of alarms can be produced by the system - high and low alarm (crossing the preset threshold), rate-of-change alarm (too rapid change of glycaemia) and predictive alarm (prediction of hypo- or hyperglycaemia). The sensor is a single-use device with an operation time of min. 3 days. The sensor and transmitter are water-proof and enable the patient to bath or even swim in a pool. The accuracy as well as clinical benefit of Guardian Real-Time CGMS in the compensation of patients with diabetes mellitus was confirmed in a number of clinical trials [2]. To support patient motivation in keeping strict diet, food daily intake is recorded by interactive scale. Diabetic food scale hardware is based on commercial food scale force sensor.

The interactive scales are connected to the INK computer by USB port. Before weighting, the user is asked to selected

	Foodstuff	Energy		Lipids	Proteins	Sugar	Popularity index
4/5		kJ	kcal	g	g	g	
7	Meat						
125	Chocolates						
239	Yoghurts						
240	Danone White	395	96	2,7	4,2	13,1	7
241	Danone Fruit	212	52	1,5	3,8	3,3	3
242	Danone DIA	280	67	1	3	4	5
243	Jogobella Strawberry	420	102	3,1	3	15,3	12
244	Aktivia White	420	102	3,1	3	15,3	7
245	Dr. Bio White	420	102	3,1	3	15,3	0
246	Dr. Bio fruit	277	66	2,4	4	7,3	1

Fig. 5. Example of food consumption table

via graphical interface a weighted food. Summary information about caloric and saccharine content of the measured food is displayed on user screen. Designed database includes table with nutritive funds over most 2500 foodstuffs. Foodstuffs are structured to the single groups and next to the subgroups. Every table's row contains information about food's name, food's popularity index, main- and subgroups' name. The most important columns are of course energy, lipids, sugar and proteins values. If someone chooses concrete food in the table, the popularity index steps over one point. So the most popular foods may be ever sorted on the top of the table - see Figure 5.

The algorithm software layer of OLDES PHR system is depicted in Figure 6. Several knowledge base frameworks (KB) are being designed: *i) LifeMan KB*: supports physician's decision making based on input provided by monitoring devices, *ii) Dietitian KB*: integrates information from interactive channels which gives tips for preparation of attractive food from selected raw material, *iii) DieN (Dietetic Nurse) KB*: supports dietitian decision making based on information provided by interactive food scale, *iv) GlyIn1 KB*: takes as its input results of continuous or intermittent patient's glycemia monitoring in wider range, follows his/her trends of insulin resistance and gives advice on the next insulin dose as well as it recommends change in frequency of intermittent glycemia measurement,*iv) GlyIn2 KB*: advanced version of *GlyIn1*, identifies unusual behavior of disease or of the patient and effective modification his therapy.

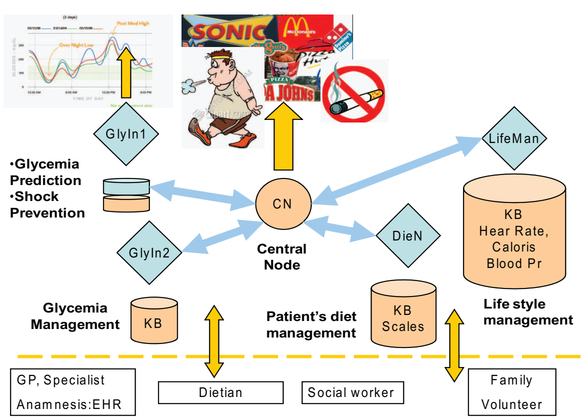

Fig. 6. Software diabetes pilot design

III. Results and Discussion

The aim of the OLDES project is to provide a complex new interactive IT tools supporting independent life of seniors. Since all the envisaged tools count upon active involvement of their users, it is clear that the process cannot be reduced to development of novel IT functionalities. It is most important to ensure that the intended users are able (and willing) to access the offered functionalities in a simple way - this is the purpose of the user interface (UI) which consists of 2 separate parts: - TUI: tangible user interface (remote controller) and - GUI: graphical user interface. The applied approach relied on close cooperation with the target users during paper and software prototype testing which is ensured in a specialized usability laboratory.

OLDES substituted classical keyboard with a remote controller in order to ease interaction with the system. The main idea of the remote control was to ensure functionality combining features offered by tele-tex (familiar from the standard TV sets) and by a joystick-like navigation system. The initial suggestion shown in Figure 8 was inspired by the concept of standard TV re-mote controller. It consists of: *i*. Top button: jump to the Home screen of the specific OLDES settings. *ii*. Joystick buttons denoted by arrows which enable navigation in menus, *iii*. Colored Teletex-like buttons serving mainly for quick access to important issues in menu.

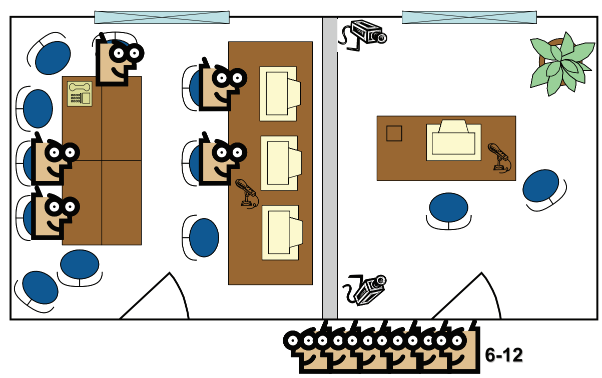

Fig. 7. Usability Lab: the observer and the participant room

The usability lab consists of two rooms - a participant room and an observer room, see Figure 7. In the first one, the user interacted with the technology (software and hardware environment) under evaluation, as if working alone or with a moderator. All resulting data (e.g. audio and video recordings or events performed on the monitor screen like pressing buttons on user-software interface) were fed into the observer room (next to the testing room), where evaluators monitored all sources on independent screens. Evaluators could communicate with users from the control room via microphone connected to a speaker in the testing room.

During the last decade, lot of attention has been devoted to the problems of usability and how it can be improved [3]. Extensive experience points to the fact that the design of interactive systems cannot follow the same strategy as that applied in other fields of engineering design [4], where the initial design decisions can be carried out analytically without relying on a prototype. We have designed the OLDES personal health care system interface by iterating paper and software prototyping design.

The main goal of the paper prototyping [5] was to design suitable user-interface for elderly suffering from diabetes. The user-interface guided the user through all the necessary steps that he or she experienced when trying to accomplish tasks, e.g. measurement of glucose level, weight, blood pressure or choice of appropriate food according to the recommended amount of saccharine. The paper-prototyping testing conclusions had clearly influenced the software prototype design.

During software prototyping, the user was accompanied by a moderator who was guiding him during the usability test. The moderator tried to give the clues as little as possible and to push the user ahead if the user was apparently lost or confused. The user designed himself the user interface according to his point of view. Several mock-ups had been prepared in advance as main menu and sub-menus, icons, titles of the menus. If user suggested any issue and the prepared components were not ready than colored-papers were used substituting the issues as menus, the value of glycemia or picture - see Figure 8.

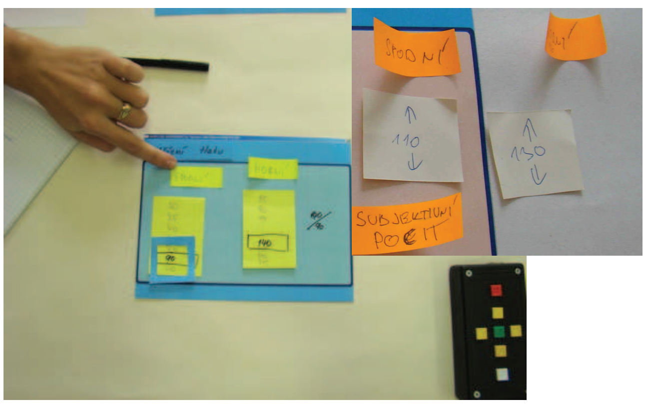

Fig. 8. Entering systolic and diastolic blood pressure: half of seniors preferred to select correct value from the list of possible numbers using Up-arrow and Down-arrow on the remote controller. Another half preferred to select the value step by step not seeing at the same time all possible values as can be seen in the upper sub-figure

During the software prototype test sessions in the usability lab the user was seated in the testing room along with the moderator. All the user's actions were monitored in the observer room by means of two video cameras (front and rear view) and audio recording see - Figure 9.

Even inexperienced computer users were able to accomplish the set of defined tasks in 30 minutes period. The experienced users spent 10-15 minutes to accomplish defined task. All of them agreed that the OLDES system was user friendly.

IV. CONCLUSIONS AND FUTURE WORKS

The diabetes pilot study was intended to increase quality of life and independence of elderly diabetics, reduced the complication rate and need for hospitalisation.

Monitoring of physiological parameters and controlling food intake including patient's weight management contributed to better compensation of diabetes, especially in

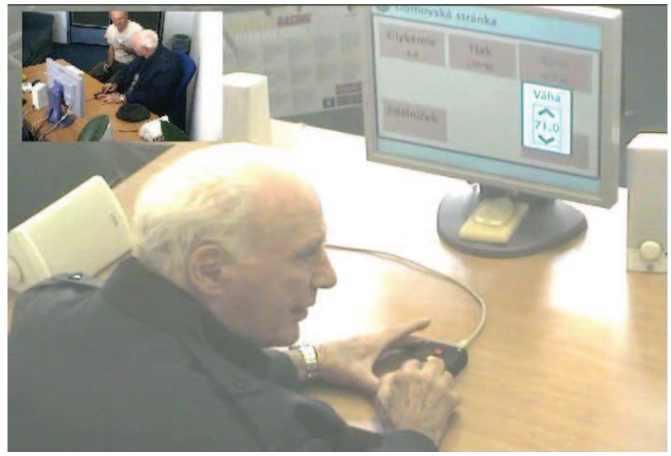

Fig. 9. Example of software prototyping set-up. The senior was confused due to misinterpretation of some buttons in the remote con-troller during the test. He approached the moderator in seeking an advice. However, the moderator tried to intervene as little as possible (left upper outlet figure). The subject (after some afford) succeeded to enter his weight to the system using the remote controller.

connection with glucose continuous monitoring system. Physician or nutrition therapist had better conditions for effective management of patient's therapy, especially in case of complicated patient.

The user-centered design approach allowed the user to be involved in testing the design ideas when performing some well defined tasks in a usability laboratory. It contributed significantly to risk reduction of new technology rejection by the target elderly group.

ACKNOWLEDGMENT

The project was supported by STREP IST-2005-045282-AAL OLDES (Older People's e-services at home) and by Ministry of Education, Youth and Sport of the Czech Republic with the grant No. MSM6840770012 entitled "Trans-disciplinary Research in Biomedical Engineering II".

REFERENCES

[1] V. Gerasimov, "Datalogger, open source technology,mit." [Online]. Available: http://vadim.oversigma.com/Hoarder/Hoarder.htm

[2] B. et al., "Alarms based on real-time sensor glucose values alert patients to hypo- and hyperglycemia: the guardian continuous monitoring system," *Diabetes Technol Ther*, 2004.

[3] M. D., *The Usability Engineering Lifecycle: A Practitioner's Handbook for User Interface Design*. Morgan Kaufann, 1999.

[4] S. D., J. C., W. M., and M. S, *User Interface Design and Evaluation*. Morgan Kaufann, 2005.

[5] S. C., *Paper Prototyping: The Fast and Easy Way to Design and Refine User Interfaces*. Morgan Kaufann, 2003.