DIABETES PATIENTS' CARE BASED ON MOBILE MONITORING

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ABSTRACT

In this paper, we propose a new architecture for diabetes patients. These applications allow the monitoring, patient self-control and communication between patient and doctor. Moreover, as an important study case, we present a mobile monitoring system which allows patients with diabetes to have a constant control of their glucose tendency as well as direct communication with their doctor. We present an application to solve this problem; we share some details of the current implementation, detailing the functionalities achieved so far.

KEYWORDS

Diabetes, Ontologies, Mobile Monitoring, Ubiquitous Computing

1. INTRODUCTION

According to the World Health Organization (WHO), "diabetes is a chronic disease that occurs when the pancreas does not produce enough insulin, or alternatively, when the body cannot effectively use the insulin it produces. Insulin is a hormone that regulates blood sugar. Hyperglycaemia, or raised blood sugar, is a common effect of uncontrolled diabetes and over time leads to serious damage to many of the body's systems, especially the nerves and blood vessels. This is why it is important to keep good glucose levels" (WHO 2008). Furthermore, the WHO estimates that more than 180 million people worldwide are diabetics. This number is likely to be more than doubled by 2030. In 2005, an estimated 1.1 million people died from diabetes. Diabetes-related deaths will increase by more than 50% in the next 10 years.
In order to facilitate people lives, we are working on a mobile monitoring system which allows patients with diabetes to have a constant control of their glucose tendency as well as direct communication with their doctor. Furthermore, we aim to educate these in people in their disease; so that, we are elaborating an education component meant to allow them to know more about the disease and how to make their daily routine more comfortable. As part of our proposal we have included a diet and a prevention unit; these aim to ensure a healthy lifestyle without annoying surprises for the patients.

2. RELATED WORKS

In the last years some researches have been developed in this area, due to the importance that has for the improvement of the way of life of the people's quality of life. Nirmalya (Nirmalya, Gautham et al. 2007) offers the idea of a architecture supporting the merger of efficient context-aware information for healthcare applications assumed as an ambiguous context. It provides a systematic approximation to derive fragments of the context and to handle the probability of ambiguity existing in this context. This framework has been evaluated in the monitoring of elderly people in small home environments. This design has been developed and labelled using Bayesians Dynamics Networks (DBNs) and a rules-based model. In our case, we do not have ambiguity in the data, to achieve this, we define an individual profile for each patient; the functionality this architecture lies on the mentioned profile. Mei (Mei, Widya et al. 2006) propounded the development of a framework for the representation of patients' vital signs. This framework, facilitates the representation of the different existing notations to represent vital signs (FDA (CEN 1999), CEN (CEN 1999), HL7 (HL7 2005), DICOM (DICOM 2004)). For this, it proposes an XML scheme to design the representation of vital signs framework, specifying the existing standards of representation. It is proposed only a representation of the vital signs obtained by the mobile devices creating data sheets with the representations of vital signs that ensue from the mobility of the (patient) users in heterogeneous environments. Our proposal is not based on representation of vital but on the control and interpretation of these. Kebler (Kebler 2007) talks on how to use the context information to improve the analysis of similarity. He talks about three uses of the measure of similarity in the geospatial domain and investigates which aspects of the definition of context by Dey and Abowd (e.g. the identity, the activity, the location or the time) play a crucial role to define the similarity in each of them. A process which treats the request and a set of chosen context parameters considered along a base of specific application knowledge. This alignment is possible via trusting the structure of a shared vocabulary in the base of knowledge and the context information. The considered context parameters are used to influence the result of the similarity analysis. The fundamental key which allows the care handling modules is the behavioural record in the patient's profile.

Preuveneers (Preuveneers and Berbers 2008) has investigated how the mobile phone platform can contribute with individuals diagnosed of diabetes to handle their glucose in blood levels without resorting to no additional systems (beyond the equipment they use nowadays) or without adding any additional activity sensors, as pedometers, accelerometers or heartbeat monitors. Supervising the location and activity of the patient with the mobile phone, recognizing past behaviours and knowing the glucose in blood levels with context information, eases the well informed decision taking regarding the daily medicine doses to reach, and maintain stable glucose levels in blood. The data fed to the mobile phone consists of consumed food and the insulin dose. This aims to identify the sorts of activity, food and physical exercise, which can affect the glucose levels in blood. Participants in this study were people with Type-1 diabetes. Our proposal contemplates a patient measurements monitoring; it is not necessary to know the location of the patient, but it is crucial to know the activities the patient was carrying out then. This allows our system to learn for future situations. Our study case is Type-1 and Type-2 diabetes. Mamykina (Mamykina, Mynatt et al. 2006) presents MAHI (Mobile Access to Health Information) which is an application that monitors patients diagnosed with diabetes, and is capable of acquiring reflexive thought skills for social interaction with diabetes educators. In our proposal is only the endocrinologist who gets involved, since he is the only one who knows the patients' specific profiles. The managing of the reflexive analysis of past experiences is one of the most essential skills in managing diabetes. MAHI is a mobile distributed application that includes a conventional glucometer, a mobile phone with Java support and a Bluetooth adaptor which communicates the mobile and glucometer. On the other hand, the University of Georgetown, Gentag Inc and the International Corporation of Applications of Science (SAIC, NYSE: SAI) (Peeters, Bense et al.) have developed a method for obtaining glucose measure less painfully than usual; with such method, the patient is monitored and his glucose levels captured though a patch placed in his skin, a wireless sensor and a mobile telephone. Benefits can be obtained, as it is the control of an insulin pump or a geo-location of the patient via GPS (GLOBAL POSITIONING SYSTEM) in case of emergency. Bravo (Bravo, López-de-Ipiña et al. 2008), proposes a patient Tele-monitoring process. He proposes using a monitoring device; a person (patient or assistant) should be able of just touching a NFC tag with the phone, in order to launch the mobile phone application. As a result, the monitoring device should be active and the measures sent to the mobile phone through a Bluetooth connection. When the mobile phone obtains the measures, it is in position to make a recommendation. The use of such technologies is contemplated due to the low cost and energy consumption

3. OUR PROPOSAL FOR DIABETES SELF-CONTROL

In this section we present our proposal for the assistance of diabetes patients. We think that our solution is capable of making their lives easier and actually improving their health. For this, we have developed a module-based application, divided in 2 main parts, the specialist and the patient.

As can be seen on the top of Figure 1, the endocrinologist´s application contains the generic modules and profiles; it is the endocrinologist, who completes the profiles with the patients' necessary and significant data. These data helps later on to refine and customize the mentioned modules.
The endocrinologist application consists of two modules: The statistics module created to offer the doctor the progress of each patient and the suggestion module, in charge of giving the doctor some pieces of advice based on the statistics of the patient. Of course, this advice is merely a suggestion for the doctor, who of course has the authority to follow it or not, and it is built upon the guidance of a set of endocrinologists.
The patients' application is composed of the following modules: communications, diet and suggestion, all of them profile-dependent. The diet module relays on the profile since it contains the diet restrictions of the patient. Differently, the alert module will store in the profile a record of these for the doctor to bare them in mind when reviewing the patient case. Apart from these, we have the education module, independent from the profile, but fed by the diet module. Once the personal profile has been completed, the application is ready to be downloaded into the patient's device. We can observe a general schema of the patient side of the application in the lower part of figure 1.

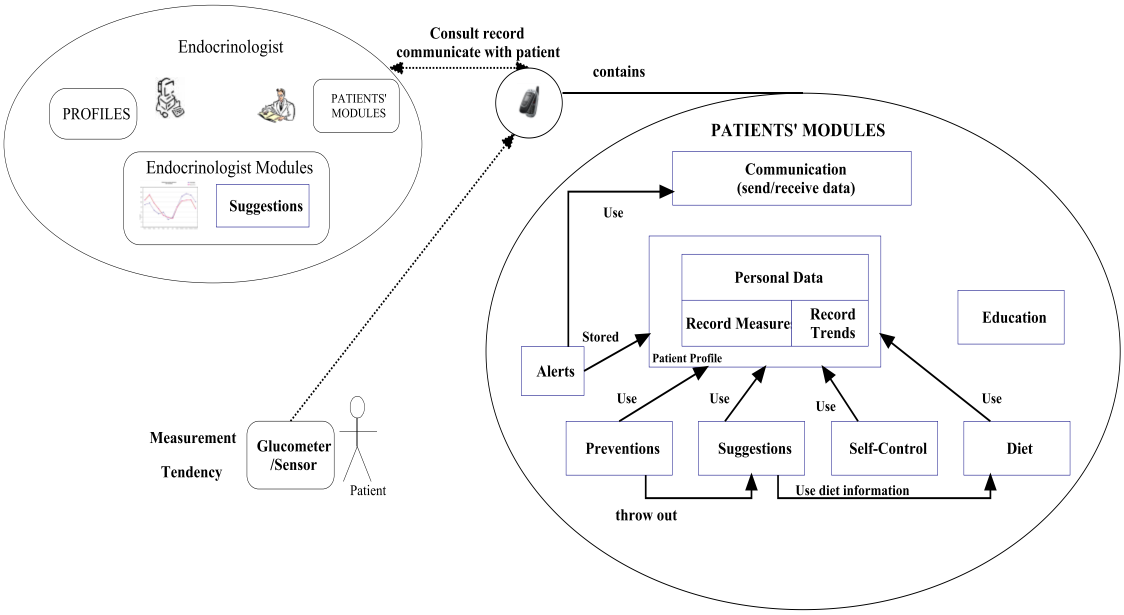

Figure 1. Diabetes case Schema

A glucose sensor is the source for the patient´s application. The received data show the tendency value, but we do not discard using an old fashion glucometer as the source. These data needs to be contrasted with the average values set by an endocrinologist (90 mg/dl – 160 mg/dl). For these values the application is set to offer a suggestion or positive reinforcement (suggestion module). These figures are also stored in the mobile device, packed according to the frequency specified on the profile by the endocrinologist and later on sent through the communication module to the doctor's application. This module is directly responsible for all the communication between the doctor and the patient; that is, sending the glucose values, special recommendations by the doctor, profile updates, and alerts among others. The alert module is constantly supervising the glucose levels and alarms the emergency services for assisting the patience in case of extreme values.
The suggestion module lays on the diet module to present suggestions about beneficial food. Among its functions, the diet module contains a list of healthy and forbidden food; in order to limit this, it can read the profile data about allergies and food for other kind of diseases the patient could have. It, as well, contains a list of suitable menus for diabetes patients.
The diabetic education module, independently of the profile, presents information on demand about the illness, habits and preferable behaviours to live with this condition avoiding health complications.

The prevention module analyses the glucose level, trying to associate defined activities to dangerous glucose values and triggering the suggestion module to avoid repetition of these.

For achieving this, the module is set with a calendar, where the user can introduce his schedule or isolated activities and the application analyses the glucose levels registered during the activity. If the activity causes the patient to have abnormally high or low levels, this fact is learned and the application will start the suggestion module the following time this activity is programmed. As the main feature of the system, the profile deserves to be discussed separately. The user´s profile, patient´s in this case, contains data regarding age, sex, diabetes debut, weight, allergies, physical activity, diseases related to diabetes, and physical disabilities. This sort of data will be initially provided by the endocrinologist, as well as the required daily carbohydrates intake, and so on. The profile will progressively grow as the user interacts with the system.

Interaction with the self-control module: The data regarding the glucose levels is stored in the profile as a permanent record. This module accesses this information and uses it to display graphs and statistics as well as the raw data of course. This will help the patient enhance his self-control, realising glucose levels that can be improved under his own effort.

Interaction with the communication module: When the contact between the patient and the specialist begins via the system, the profile is fed with the also sent out glucose levels. This sending can be via mobile internet connection (e.g. WI-FI) or offline, at the doctor’s consult by USB device.

The frequency with which data should be sent out depends also on the profile. A person whose tendency graphs indicate very irregular glucose levels precise a shorter checkups frequency, i.e. he needs more constant attention than a person whose graphs show regular levels. In any case this value is decided and set by the specialist. Every alert launched by the system, urgent or not, is on a permanent record within the profile. It is this module, the communications one, the responsible for sending them out and storing them in the profile. This enables the endocrinologist to keep track of them, justify them and find out why they were triggered, even if they were caused by failure to follow the suggestions of the system. The specialist’s statistics module works with these figures as received establishing a priority between patients, assuring the patients the best care and easing the doctor’s duty.

Interaction with the suggestion module: According to the limitations and other parameters included on the profile, the mobile device offers the user some suggestions and pieces of advice based on endocrinologists’ recommendations. We are working on a database of suggestions which contemplates factors such as mobility requirements which needs to be contrasted with profile mobility values avoiding the system to miss-advice patients. An example of this could be the case of a patient using crutches. This would be incorporated to the profile by the endocrinologist and the system would look for alternatives that would not imply legs movement.

Interaction with the diet module: Something similar occurs with the diet module. This module contains, as previously stated, a list of forbidden and suitable foods, plus appropriate menus with the needed carbohydrates quantity to fulfil the daily requirements set by the endocrinologist for this patient. For this, the system accesses the profile data where it is able to notice special diets or food allergies. Following the same principle as the suggestion module, it is set to skip these foods. If our system, for example, is creating a list of suitable food for a lactose allergic person; it will avoid milk, yoghurts or milkshakes and suggest an alternative for these. The daily caloric intake can be found in the profile written there by the endocrinologist especially for this patient.

Interaction with the prevention module: As mentioned before, the profile holds the glucose data obtained from the sensor; the prevention module reads these data to analyse it in relation with the activities scheduled, if any. So that if the patient writes down the date he is performing a presentation, and during that time he experiences a dramatic descent in the tendency, the application will make the proper suggestion this time, and learn from it, so that, next time a presentation is programmed the suggestion module will launch its advice before the activity begins.

4. ONTOLOGIES IN DIABETES: STUDY CASE

Parting from the generic ontological diagrams, applicable to any condition, in this section we will show how they turn out when applied to diabetes. WHO defines diabetes as chronic disease which can be differed by the treatment or the origin as insulin dependent, not insulin dependent, malnutrition related, etc. Furthermore, it can have other diseases and/or allergies associated and can lead to a series of complication (ophthalmologic issues, renal, neurologic, blood vessel damage, and states of Diabetic Ketoacidosis) (WHO 2008). It is showed in figure 2.

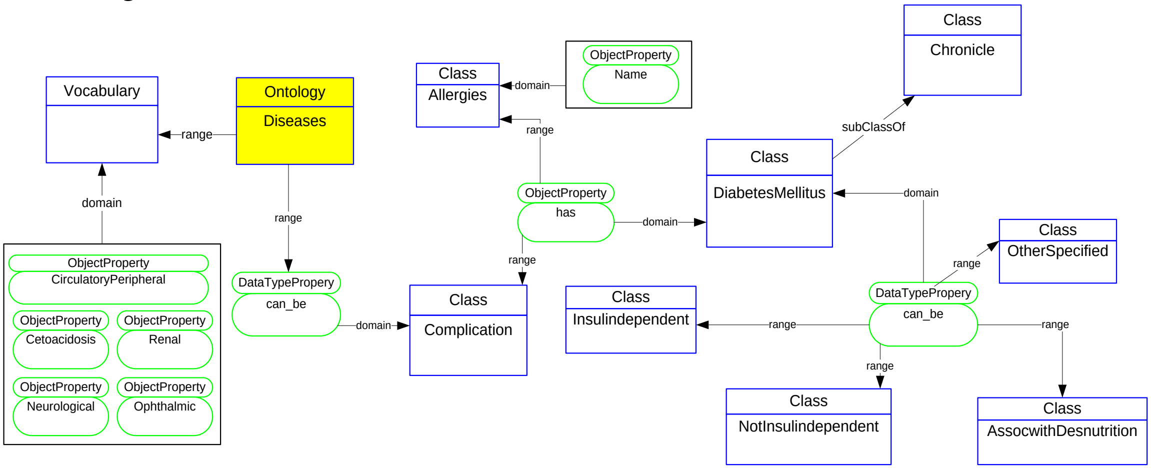

Figure 2. Diagram specification defining diabetes as a chronic disease.

It might also be of interest the ontological diagram, showed in figure 3, defining the medical treatment for this disease. A treatment, generally, as previously explained can be pharmacological of based on a plan of activities (diet, physical exercise, etc). Within the first type, we can make a subsequent classification between medicines orally ingested or injected ones. The earlier ones, in the case of diabetes, are suitable for type-II diabetes, called oral antidiabetic drugs; the inyectable ones are, therefore, meant to treat Diabetes Type-I: injected insulin, where additionally can be made a later categorisation of the sort of insulin according to the speed of its effect (fast or slow).

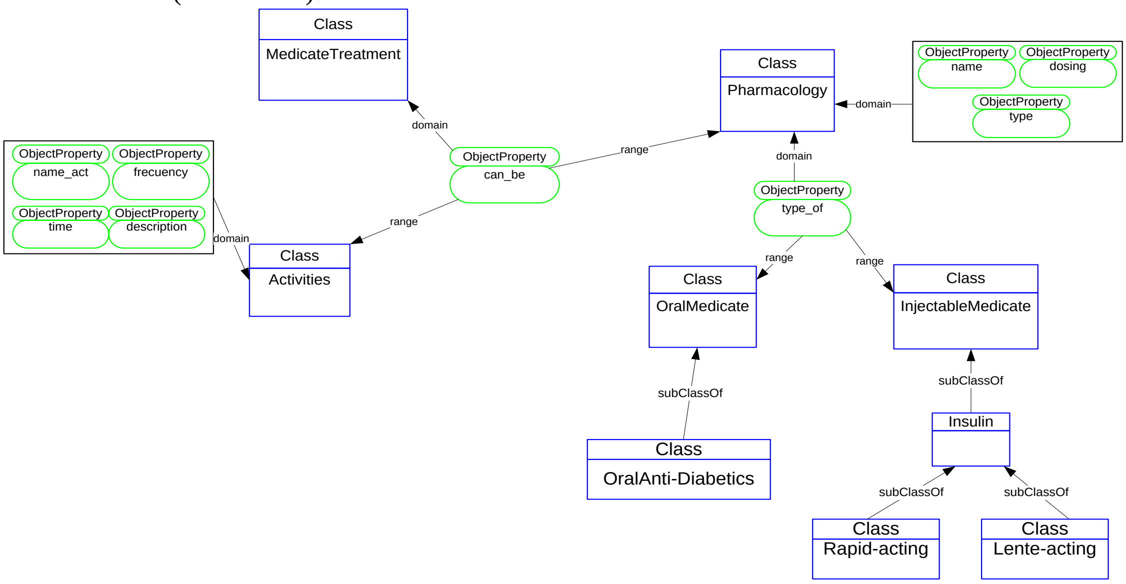

Figure 3. Medical treatment specification for the study case: diabetes.

Another module that can be customised for this condition, and which can significantly impact the life of a person with diabetes, is diet.

In figure 4 it can be seen that the diet module contains data regarding food, which in the case of diabetes, are classified under three groups: forbidden food, advisable food, and restricted food. Inside the first group we can find those one which are harmful, such as fat, sugar, candy, industrial pastry, etc. within the second category, we find food that can be eaten but with quantity restrictions, e.g. dairy products (due to the fat these contain, it is advisable to ingest them skimmed or semi skimmed). At last, the advisable food for a diabetic person's diet, examples of these are vegetables, meat and fishes not with high fat content. Parting from these latter ones, the module generates customised menus for the patient. Equally, ontologies can be adapted to other diseases, when generating patient mobile monitoring applications.

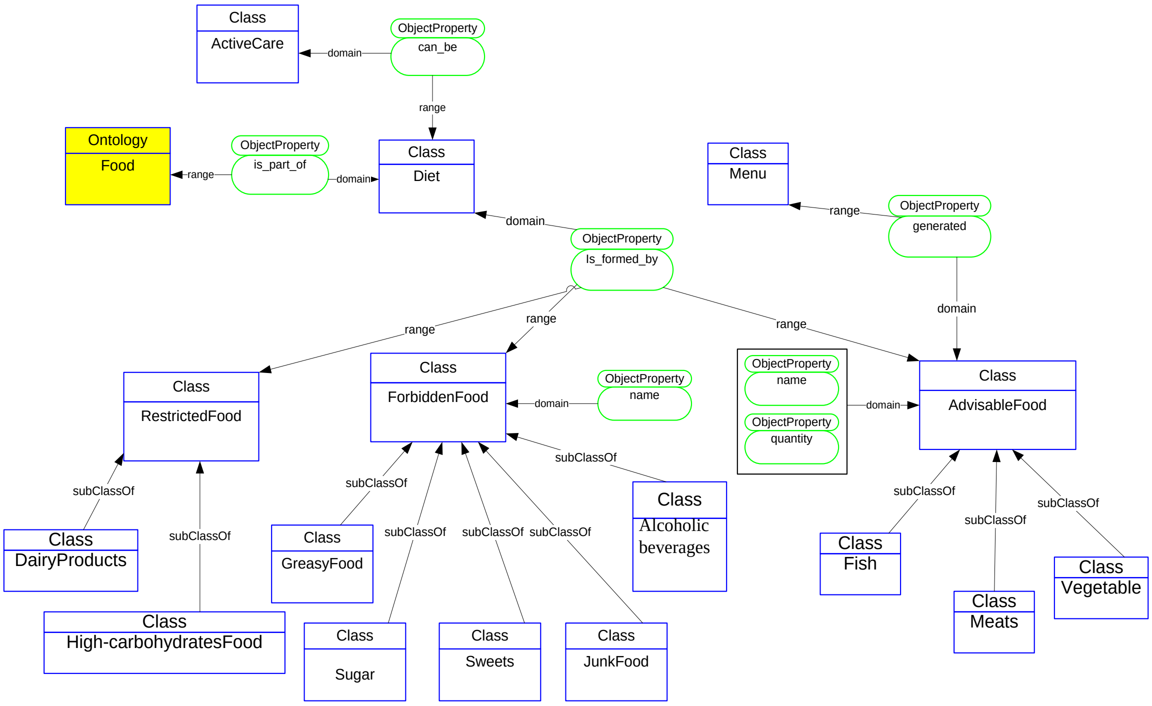

Figure 4. Diet diagram specification for the study case Diabetes.

5. APPLICATION FOR DIABETES MONITORING

As previously described, the application uses the J2ME technology to communicate with a continuous glucose sensor. This sensor sends at a fixed rate a glucose measurement which the application will read and store.

This value is analysed in context with the previous ones to obtain the tendency and advised accordingly. Based on the data stored in the profile the application will filter the database proposals of advice; Parameters such as age, mobility and allergies are taken into consideration for this filtering. As part of the profile we find the meals' schedule, which also helps deciding when a suggestion is advisable. This customization enables the application to select an accurate suggestion for each patient.

The purpose of this suggestion module will be keeping the patient at, what we have named, the safe zone; this is, between 90 mg/dl and 180 mg/dl. When the glucose value is lower than this range and the tendency is to continue descending, the application will advise the patient to ingest a carbohydrate unit, figure 5(a); of course, this will not happen if the next or previous meal is very close. A carbohydrate unit increases the sugar in blood which is necessary for the cells to generate energy.

If recommendations are not followed properly hypoglycemia, abnormally low blood sugar, might occur, in this case, the patient may lose consciousness and will need assistance. Some patients are able to feel when this situation is starting to happen, and take countermeasures; however, many other will feel much disoriented and will not be able to react by themselves. This is why we have designed an alert module which will call on the health authorities, figure 5(b), to assist him.

In figure 5(c), hyperglycemia, abnormally high blood sugar, occurs; in this case an insulin dose is mandatory. Our application calculates the right amount and suggests it to the patient. Before this extreme is reached, suggestions are displayed proposing some physical exercise if possible. By avoiding the hyperglycemia, we manage to prevent complications as hyaline arteriolosclerosis, polyphagia, polyuria y polydipsia. The following symptoms are common for the hyperglycemia, starting with the classic hyperglycemic triad: Polyphagia, Polydipsia and Polyuria, blurred vision, fatigue, weight loss, and dry mouth in a first place. By avoiding the hyperglycemia, we manage to prevent long scale effects as poor wound healing, recurrent infections and chronical complications as heart disease and stroke, diabetes retinopathy (eye disease), diabetes neuropathies, erectile dysfunctions and kidney failure.

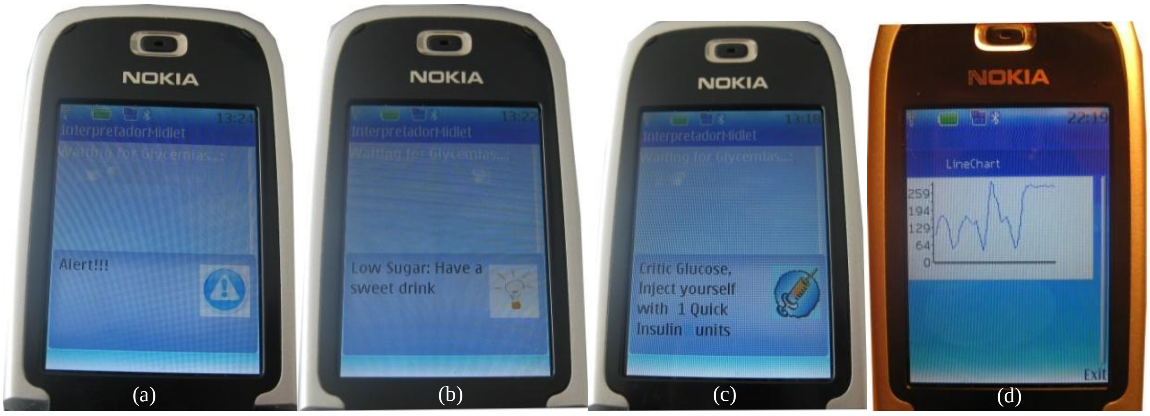

Figure 5. (a) Carbohydrate suggestion, (b). Alert module triggered, (c). Insulin dose proposal, (d). Unattended 24 hours' glucose graph

At any time, graphs regarding the patient progress are available. This feature is similar to the one for the doctor application. Graphs regarding daily statistics or each 8 hours are clear examples of the potential graphs that can be displayed like the one on figure 5(d), displaying the unattended 24 hours of a regular patient.
Our application relies on a continuous glucose sensor, which for black box texts is being simulated, as per figure 6(a), continuity on the data allows a thorough control of the patient as well as tranquillity and quality of like. Nevertheless the application can be used as a complement for regular glucometers, as long as these allow some sort of data exporting technology, figure 6(b).

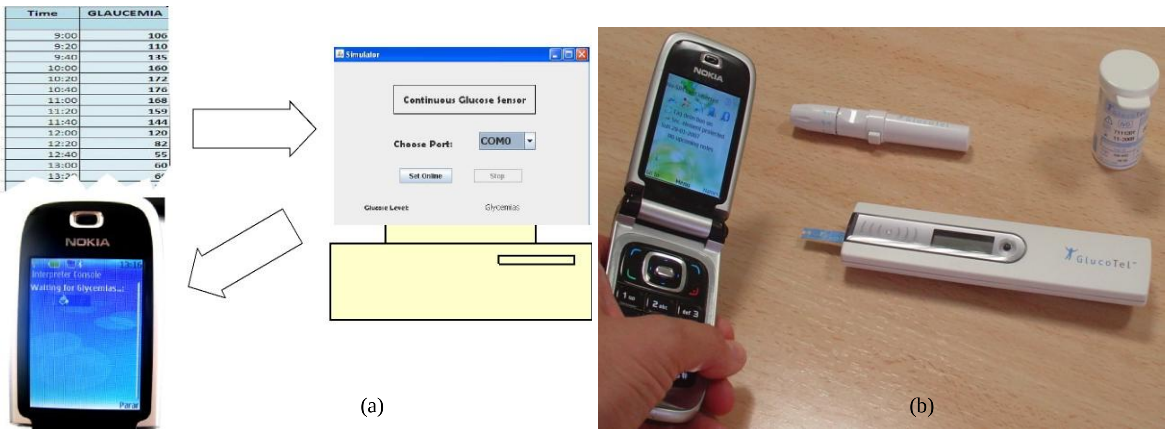

Figure 6. (a). Continuos glucose sensor simulation, (b). Communication between mobile phone and glucometer

The circle closes up when these data are sent through to the doctor and he can, via his application, review the patient' progress and correct the dose if necessary. The data used for this application as the personal profile is also input by the doctor by means of his desktop application which will set up the mobile one, so that it can be transferred to the patient's mobile phone via any communication technology.

6. CONCLUSION

Our main goal with this Project is to ease the day-by-day life of people with a chronic condition. We aim to suppress the frequent visits to the doctor´s, the dangerous and late misinformation providing them a manner to enhance their self-control in relation to their condition. In the specific case of diabetes, we intend to avoid complications that can lead to the death. We want to ensure that these people do not suffer any avoidable damage due to the lack of time, education or even mobility. We propose a mobile application that will enable them to be constantly controlled, via reading from a continuous glucose sensor, and in touch with the specialist, this application is complemented by a desktop applications installed on the specialist computer for him to review and correct the treatment. This solution will provide a continuous patient monitoring, to improve the communication between patients and doctor and it will allow generating an automatic architecture for the individual profiles of each patient, self-control and education modules for their condition.

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