Long term management of diabetic patients: a distributed architecture

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Abstract

This paper describes the functional specifications of a telemedicine system prototype, devoted to the Management of Insulin Dependent Diabetes Mellitus. This work is part of the Telematics Application project T-IDDM, funded by the European Commission.

1 Introduction

Diabetes Mellitus is a major chronic disease in western society, characterized by metabolic alterations and long-term morbidities. In particular, Insulin-Dependent Diabetes Mellitus (IDDM) is a disease caused by the destruction of the pancreatic cells producing insulin, the main hormone involved in glucose regulation; IDDM provokes hyperglycemia, polyuria, glycosuria and ketonuria, and may lead to death due to ketoacidosys. IDDM is complicated by the development of retinopathy, nephropathy and neuropathy and cardiovascular diseases.

IDDM patients control their blood glucose levels through exogenous insulin administrations. The onset and development of diabetic complications is strictly related to the degree of metabolic control that can be thus achieved. Recent studies [1] show that a good metabolic control can significantly delay or prevent the development of long-term complications. However, a tight metabolic control involves 3 to 4 insulin injections per day or continuous subcutaneous injections, accurate home blood glucose monitoring, and an increase of the probability of hypoglycemic events. Important improvements in metabolic control optimization may be obtained by using computerized decision-support systems, in order to help patients and physicians in the monitoring and therapeutic assessment task.

The importance of therapy optimization is stressed also by economical reasons: in Europe, 7% of the total health care expenditure is devoted to Diabetes management, [2], while in the United States this percentage is even higher (14.6%). If only a fraction of these costs could be avoided, significant savings for the health care system could be realized.

Following the above statements and previous experiences [3, 4], we believe that considerable improvements could be achieved in the effectiveness and efficiency of IDDM

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care through the use of telecommunication services for the active monitoring of the patients, and of a set of computer-based support systems to allow for more accurate therapeutic decisions .

The above mentioned motivations led to the definition of the *T-IDDM (Telematic Management of Insulin-Dependent Diabetes Mellitus)* project[1] [5].

The project goals can be summarized as follows: 1) the definition of a telemedicine system able to *increase the rate* of data transmission to the diabetologists allowing to *detect in advance* the need for therapeutic protocol modifications and *reducing* unnecessary hospital admissions; 2) the definition of a more active role for the patients during self-monitoring, so that they will be enabled to make *informed and guided decisions* concerning the therapy; 3) the induction of changes in the current diagnostic practice, in medical treatments, and even in the structure of health care models, improving clinical data collection and management for therapeutic, educational and scientific purposes, on the basis of new Telemedicine Services.

In this paper we will outline the more recent developments of the functional specifications of a prototype developed in the Medical Informatics Laboratory (MIL) of the University of Pavia. This prototype will be evaluated within the T-IDDM project as one of the possible implementations of the T-IDDM architecture.

2 System architecture

The system we propose is based on the T-IDDM distributed architecture, in which the IDDM patients' management is divided into several subtasks. The two basic components of the architecture are a *Patient Unit (PU)* and a *Medical Unit (MU)*, interconnected by a telecommunication system. The functional specification of each unit is shown in Fig.1.

The MU is designed to assists the physician in defining a *treatment protocol*, that is the assessment of the insulin regimen, diet and physical exercise, through a periodic evaluation of patient's data. As it is shown in Fig.1, the MU communication module receives messages from the PU, and dispatches them according to their type: if the transmission content is an alarm message, it is immediately shown to the physician, while if the message contains monitoring data, it is stored in a data-base. The monitoring data are then evaluated by the physician, who, by exploiting the results of a high-level reasoning process performed by a therapy advisor module, defines the treatment protocol. The treatment protocol is then communicated to the PU in order to bound the space of its admissible actions. The physician may also send other information to the patients, like the visit schedule or general advice on the treatment management.

The MU functionalities also comprise the possibility of modifying the knowledge exploited in the therapy advisor module, by editing the knowledge base ontology, the set of admissible therapeutic protocols and finally by assessing different mathematical models for glucose metabolism simulation. The MU provides the physician with several additional services, such as Internet links, connections to general practitioners and other hospital institutions, as well as with patients associations.

The PU is responsible for two basic tasks. It assists the patients in their self-monitoring activity, by suggesting the insulin dosage adjustments following the control tables contained in the therapeutic protocol. Moreover, the PU deals with automatic

[1] T-IDDM is a project of the Health Telematics sector of the Telematics Application Programme funded by the European Commission

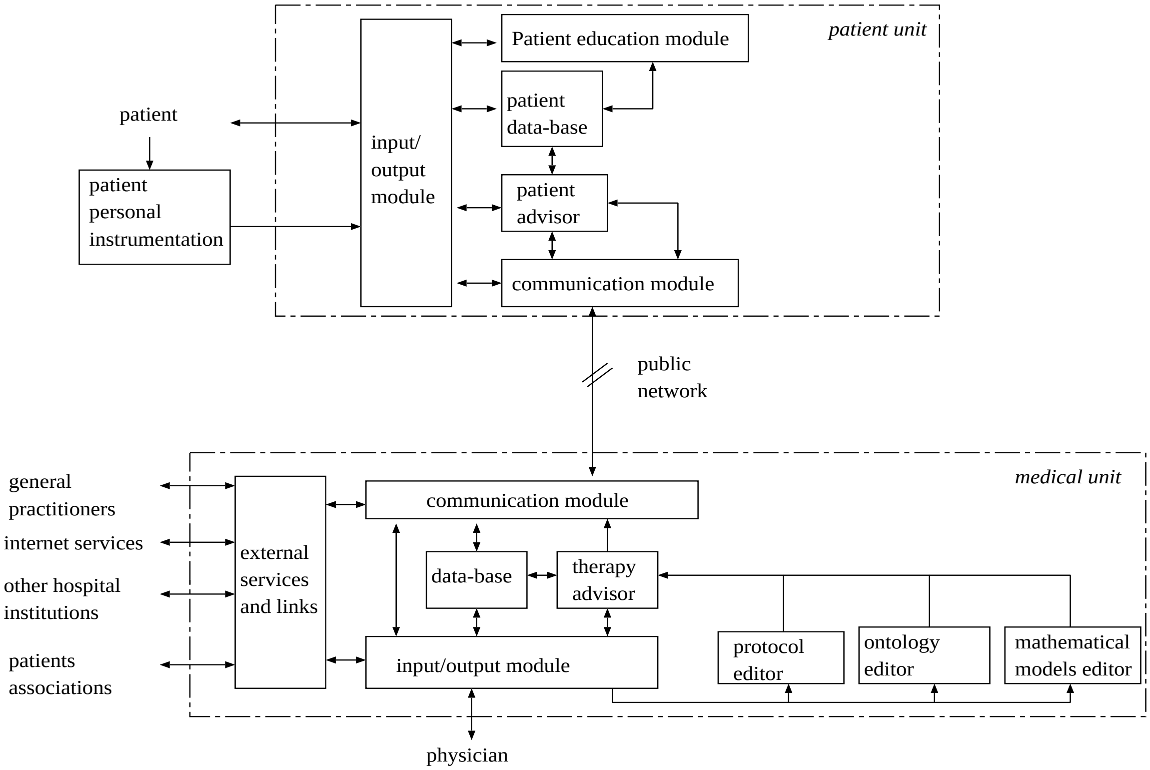

Figure 1: Functional diagram of the distributed architecture

data collection and transmission from the patient's house to the clinic, by communicating the actions (insulin doses and scheduling, meals, extra physical exercise) and the current metabolic state (self-monitored blood glucose, ketonuria, special events).

In this way the MU can follow the actual insulin therapy and the patient's response to it. The PU provides the system interface to the patient and the bridge to the communication network. It contains the software for patient's data collection, consultation, data communication and decision making. The PU also contains an education module, able to support patients in their own disease management.
This architecture is designed to run on a wide and evolving range of hardware, from PCs to workstations, to portable computer devices. At present, the prototype developed at the MIL of the Pavia University has been realized with a PC (Patient Unit) and a network of Sun Sparc Stations (Medical Unit).

3 Communication issues

The tools and the functionalities provided by the MU have been previously described in [7]. Here we will show in greater detail how we exploited emerging information technologies in our system in order to implement the previously described architecture.

We chose to base the communication within the system on the HTTP protocol. This choice is motivated by several factors: HTTP is a standard protocol and HTTP clients are widely available; the HTTP protocol is also very simple to implement and manage. Moreover, HTML, the language used for information presentation within an HTTP-based environment, provides good facilities for the low-cost creation of structured multimedia documents, endowed with graphical and user input handling capabilities. This means that a system based on HTTP and HTML is able to produce high-quality hyper-textual

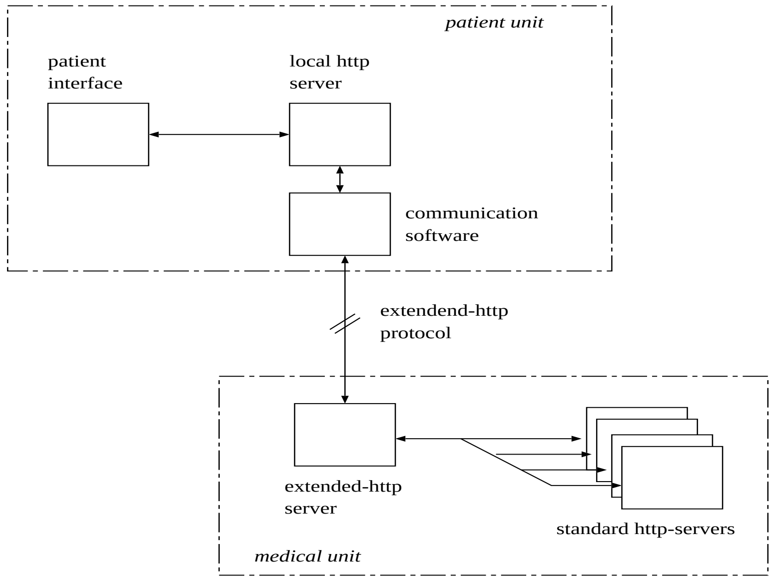

Figure 2: The communication scheme

output that can be used as a graphical user interface.

In order to implement and integrate the high-level reasoning tools that constitute the MU, we developed an HTTP server written in Common Lisp. The server is able to receive requests in HTTP form, to execute one or more Lisp functions according to the request received, and to present the output of the execution as HTML code. Applications can be loaded inside the server, that can be configured to invoke them when it receives an appropriate request, and become available at once to every user who has access to the HTTP protocol.

The Common Lisp server enables the user to interact with different applications using the same common interface based on a standard hypertext framework, with hypermedia capabilities. In this way the system is completely transparent for the user, that may exploit the full capabilities of the different services independently of their physical location.

The PU design must take into account several additional features, related to the peculiarity of the patient/physician connection. The necessity of preserving information security and privacy, and the requirement of using low-cost public telephone networks, hamper the utilization of standard HTTP protocol in order to perform the client-server connection. We have hence organized this communication in the following way: the PU interface is realized in HTML and is a client of an internal HTTP server. This server activates dedicated procedures able to open the connection, and to send the data to the MU server, by using an extended version of HTTP, called STSP (Server To Server Protocol). STSP provides special actions that allow for a bidirectional exchange of data between the MU and the PU. The utilization of STSP improves the security and privacy of the communication, and makes it also possible to implement special functions such as data-base access and therapeutic protocol transmission. This transmission scheme could enable the MU to serve as a *fire-wall* for the PU, providing the patient a number of limited services available in Internet and preserving the confidentiality of patient/physician communication.

4 Further developments

This paper outlines the functional specifications of a telemedicine system project for the management of IDDM. At the moment, the control strategies to be implemented in the MU and PU are under study. Preliminary results of the work carried on are reported in [6, 7]. The modules implementation has started as well as the development and testing of a library of innovative algorithms and heuristic methods, coming from the Artificial Intelligence (AI) context and from modeling and control theory.

This prototype will be evaluated within the T-IDDM project, as a possible implementation of the proposed architecture.

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