Assessment of stroke patients by whole-body isometric force-torque measurements II: software design of the ALLADIN Diagnostic Device

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Abstract: The steadily increase of new stroke cases each year underlines the urgent need for effective and efficient stroke rehabilitation. The inconsistent use of terminology is a main barrier in the communication between physiotherapists belonging to different 'schools'. Another barrier is the lack of reliable, objective and fast methods for monitoring and predicting functional recovery. Solving this problem is a crucial factor for better utilization of rehabilitation resources.

The ALLADIN solves this problem with the development of a novel mechatronic device for objective measurement of patient recovery. The device acquires forces and torques during execution of daily living tasks. Moreover, natural language audio recordings describing patient recovery are linked to the force/torque measurements with the aim to find markers and milestones of stroke recovery. Finally, it will be possible to predict the recovery outcome purely based on natural language descriptions.

In this paper, the software development for the ALLADIN user is presented.

Introduction

Stroke is a leading cause of long-term disability in the Western world. Every year there are more than 900,000 new stroke cases in Europe. In the USA at least 20% of the stroke survivors is younger than 65 years. This underlines the critical importance of providing an effective rehabilitation with the objective of optimizing the recovery of motor performances, minimizing long-term disability and enabling reintegration and participation in activities of daily life [1]. Structuring of rehabilitation care for stroke patients will result in better outcome and substantially reduced cost [2], [3], [4].

The key to structured rehabilitation care is a reliable prediction system that can rapidly discover markers for recovery. This should assist in the difficult decision to choose between continuing therapy, changing it or stopping it. The motor imagery and movement preparation tests were already used for identification of such markers [5], [6], [7], [8]. Authors in [9] aimed to produce findings that could be expected in order to guide the rehabilitation. Based on isometric torque measurements they found that muscle strengthening leads to an improved functional outcome after stroke. Force/torque (F/T) measurements were proposed as a mean of diagnosis and patient progress tracking tool in [10]. Some attempts to identify markers of functional recovery were made in [11], [12].

The ALLADIN project focuses on the development of a low cost, easy to use force/torque measurement tool. Performance of activity of daily living in stroke patients is sampled. Beside that, patient recovery is described in natural language. Data from both pools will be analyzed to find connections between them.

Differences in terminology between different 'schools' present a barrier in communication between physiotherapists. To overcome this problem labels (based on natural language descriptions) for conformity in the communication and understanding of neurorehabilitation data will be created. Labels will in turn facilitate taking prompt and right decisions in stroke rehabilitation. Clinical assessments and quantitative measurements will become exchangeable. In this way, the wishes of therapists for user friendly and fast but reliable evaluation methods will be fulfilled. ALLADIN will output a numerical code attached to an operational definition of a milestone or

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marker for functional recovery analogous with ICD-9-10 codes.

To achieve these goals the ALLADIN measurement device together with supporting software was developed. A companion EMBEC 2005 paper presents the development of the mechatronic device. In this paper the accompanying software is presented.

Materials and Methods

A top down approach was used during the design of the software. As a first task, identification of the required functionality was done. The software must provide a unified graphical user interface (GUI) to the ALLADIN system, set-up and test the ADD, perform ADD measurements and store data, manage different user profiles and patient profiles (including acquired data and other personal data), synchronize the local and global database and interface with the Personal Digital Assistant (PDA) and speech recognition module.

Based on the required functionality, the software was developed as different modules, comprising a cover application, a data acquisition module, a data visualization module, the database, the automatic speech recognition and the Fastcode module. An overview of the software is presented in figure 1. Different modules were developed and tested separately. The cover application incorporates different modules and presents a consistent view from the perspective of the end user.

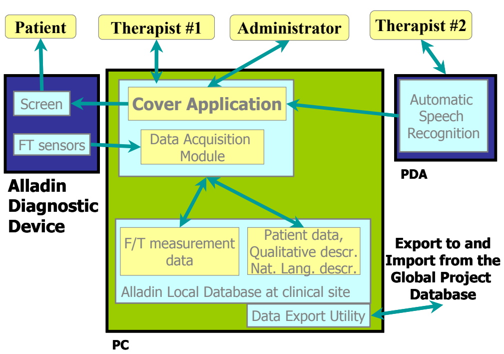

Figure 1. Functional architecture overview

Results

Different user profiles are implemented in the cover application with the aim of supporting a consistent user rights policy. This is necessary to protect confidential patient data. Two main profiles are: the ALLADIN diagnostic device physiotherapist and the natural language physiotherapist. Data created and/or modified by one can't be read by the other. This ensures that findings of one physiotherapist will not skew findings of the other.

The cover application implements all the functionalities requested for the measurements, the management of the recorded data and the general maintenance of the system. It automatically sets-up the ADD and tests its integrity before the measurement. After the measurement is carried out an additional check of the acquired F/T data is done. This virtually eliminates the possibility that errors like loose cables between computer and F/T sensors, sensor temporal overload or permanent damage would occur without being noticed.

F/T sensors measure the performance of Activity of Daily Living (ADL) tasks. The ADL tasks are listed in Table 1. All measurements are isometric (the patient can't move once he is in the ADD) thus actually motion imagination and motion initiation are measured. Before the patient is asked to perform the task, a baseline measurement is acquired. Next, the video is shown, instructing the patient what he is expected to do. During video playback a second measurement is acquired (motion imagination). The patient then tries to repeat the task three times and three motion initiation measurements are acquired. After each measurement the patient has a short pause. During that time the acquired F/T data are visually checked by the physiotherapist. The physiotherapist can mark data as invalid, if for example the patient "forgot" to react when he was asked to perform the task. Each patient is measured (at least) once per week during a period of 30 weeks.

Table 1. Activity of daily living tasks

Drinking
Taking a spoon
Turning a key
Lifting a bag
Reaching to a bottle
Lifting and carrying a bottle

The patient should perform the ADL tasks as naturally as possible. This requires adjustability of multiple parts of the ALLADIN diagnostic device to different body sizes. The cover application stores information about the preferred sizes for each patient. When the physiotherapist enters the patient into the ADD, the cover application instructs the physiotherapist step by step what to do. This guaranties that all steps are executed and that they are executed in the correct order. It also unburdens the physiotherapist.

All data are stored to the database. The database consist of two parts, the local and global (internet based) database. An outline of the database structure is presented in figure 2. The local database exists of a relational database and a set of consistently organized data files. It has been developed in Microsoft Access XP and is accessed using ODBC [13] technology. Files in it are physically located on the same PC, where the measurements are acquired. This ensures that the local database is accessible at any time and that access times are short, guarantying responsiveness of the application that uses it.

The clinical partners upload data from their local databases to the global database on a periodic basis. The data analysis partners can then download the data when needed. The global database is based on a mySQL

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database. Using appropriate drivers it can be accessed through ODBC too. Communication to/from the global database is encrypted through a SSH [14] channel. This ensures that data can't be intercepted by a third person. A simple password protected web interface (with encrypted communication) is an alternative method of access.

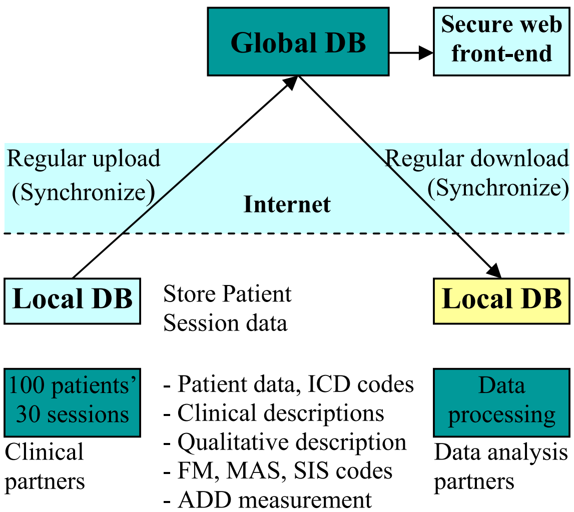

Figure 2. Database structure

The natural language physiotherapist describes the patient in terms of the modified Fugl-Meyer [15], [16], the modified Motor Assessment Scale [17], [18], [19] and the Stroke Impact Scale [20], [21] codes. An innovative human like communication with computer was created to simplify entering the codes. The physiotherapist simply talks to a Personal Digital Assistant (PDA), which records the voice. Audio quality is monitored during recording to detect possible problems like excessive background noise or too loud speaking causing clipping of the recorded signal. Figure 3 shows the voice recording interface with one good and two bad audio recordings. Immediate check of the audio quality ensures that the physiotherapist will not record large amount of data and later discover that data are unusable due to the mentioned problems.

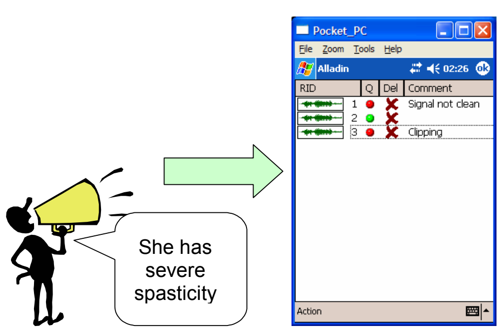

Figure 3. Good and bad audio records

The speech records are automatically converted into text by the automatic speech recognition (ASR) module. Incorrectly recognized words can be manually corrected using an intuitive multimodal user interface. When clicking on a highlighted word, a list of alternatives is offered as in figure 4. After the correct word is selected the ASR module reanalyzes the sentence and tries to correct the remaining words. The user should start correcting the sentence with the most important keyword, as this maximizes the possibility that ASR will be able to correct the remaining words. The ASR module supports speaker adaptation, so its accuracy improves during time.

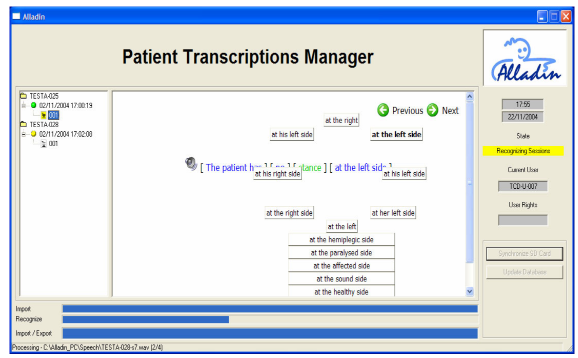

Figure 4. Manual correction of ASR module results

However, ASR is only the first part of processing the audio records. In the next stage the meaning of the audio records has to be found. A domain specific ontology has been developed for this purpose. FastCode and LinkKBase software are used as a basis for this part of the software. They are extended as needed to fulfill the ALLADIN requirements. First, a number of text documents and audio records addressing stroke and stroke rehabilitation were collected. Terminology including synonyms, qualifiers and specifications was extracted from the collected documents. An automated concept generator was developed and used during the implementation of a new natural language understanding scheme. The first version of a generic classification/decision support system was developed. At this moment it's being used during the ALLADIN clinical trial and is continuously updated with new terms and concepts.

Several updates have been required to come up to the expectations of the user, either because of bugs or to increase the functionality. VNC (Virtual Network Computing) ensures smooth software upgrades. VNC is software for remote control, which allows the user to view and interact with one computer (the "server") using a simple program on another computer (the "viewer") anywhere on the internet. Developers of the software can use VNC to upgrade and test the upgraded software. This minimizes the risk of upgrade failures.

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Conclusions

The software has been installed in three hospitals where the ALLADIN clinical trials are running. It is succesfully used since February 2005. The use of separate modules keeps its complexity at a manageable level. Required changes most often need modification of only one single module. This minimizes required work for implementation and testing of the modified software. In case of a problem with software on user's computer, the remote control software ensures quick identification and solving of the problem.

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