Journal of ELECTRICAL ENGINEERING, VOL. 52, NO. 9-10, 2001, 289–293

COMPUTER SUPPORT FOR ELECTROMYOGRAPHIC STUDIES

Mária Bieliková — Pavol Návrat — Mária Smolárová *

In the paper we report on our results in the EMG-net INCO Copernicus project. We discuss different data representation formats used for collection and management of electromyography (EMG) data. Data representation is described in the context of the proposed multifunctional platform for EMG studies. The platform architecture consists of four layers: data collection, data analysis, learning and education. We concentrate on the data collection layer, which is realised by a set of software tools for collection of data about EMG examination cases (EMMA tool) and EMG normative data (NoDAM - Normative Data Manager and NoDAC - Normative Data Client tools).

K e y w o r d s: electromyographic studies, multifunctional platform, EMG data representation, EMG Markup Language, relational database, distributed data collection.

1 INTRODUCTION

European Research Network for Intelligent Support of Electromyographic Studies (EMG-net) is a research INCO Copernicus project which aims at establishing a research network combining electromyography and information technology (IT). The EMG-net comprises teams of physicians and IT experts from nine Western and Central/Eastern European countries. The EMG-net is a successor of the ESTEEM (European Standardised Telemetric tool to Evaluate knowledge-based EMG systems and Methods) project that first introduced a set of standards for EMG studies [9].

Electromyography (EMG) is a standard method for monitoring neuromuscular activity at the level of bioelectrical signals. The EMG diagnosis is based on a systematic acquisition of numeric and symbolic data. The domain of EMG is broad, covering more than a hundred existing diagnoses, exploiting knowledge belonging to various kinds of data, including about four thousand tests of nerve or muscle structures [12].

The relative complexity of EMG examination raises possible problems for physicians. Some novice practitioners propose excessive tests that are costly, time consuming and painful for patient just because they fear they might omit some relevant tests. Some physicians, on the other hand, tend to propose only a very limited set of tests because from their experience they are able to tell with a high probability results of which tests they need to complete a diagnosis. However, such insufficiently complete examinations may not allow for example to consider cases of associated pathologies. Thus experts in the area of EMG call for some kind of standardisation of the examination procedures. Moreover, to foster a more objective interpretation of test data, standardisation of values resulting from respective tests attributed to healthy population, *ie* defining the so-called normative data, is important, too. Yet, another issue is a more effective reuse of expert knowledge that is crucial in interpreting the data collected during examination and in formulating a diagnosis.

The EMG-net project has been interdisciplinary and international, with several teams working on particular problems. In this paper, we shall not report on project's results as a whole. Quite naturally, we shall restrict ourselves to those that fall within our team's direct responsibility. We shall devote our attention to the problem of distributed EMG data collection, access and manipulation.

The outline of the rest of the paper is as follows. In Section 2, we briefly describe the architecture of the proposed multifunctional platform for EMG studies. Next, in Section 3 concepts of the EMG data collection are summarized. We discuss different formats of EMG data representation in Section 4. In Section 5, we present realisation of the data collection layer by a set of software tools. We conclude the paper with our conclusions.

2 MULTIFUNCTIONAL PLATFORM FOR EMG STUDIES

As a part of the EMG-net project a multifunctional platform for EMG studies has been envisaged. The goal of this effort was to assist practitioners in developing standard examination procedures. This goal can be seen as a first step towards a virtual clinical electromyography laboratory that will integrate available sources of domain knowledge and data with advanced information processing techniques. Incorporating world wide web into the platform's structure has been essential from this point of view.

The platform for EMG studies consists of four layers: data collection layer, data analysis layer, learning layer and educational layer (see Figure 1). Individual layers

* Slovak University of Technology, Faculty of Electrical Engineering and Information Technology, Department of Computer Science and Engineering, Ilkovičova 3, 812 19 Bratislava, Slovakia, E-mail: bielik@elf.stuba.sk, navrat@elf.stuba.sk, smolarova@dcs.elf.stuba.sk

ISSN 1335-3632

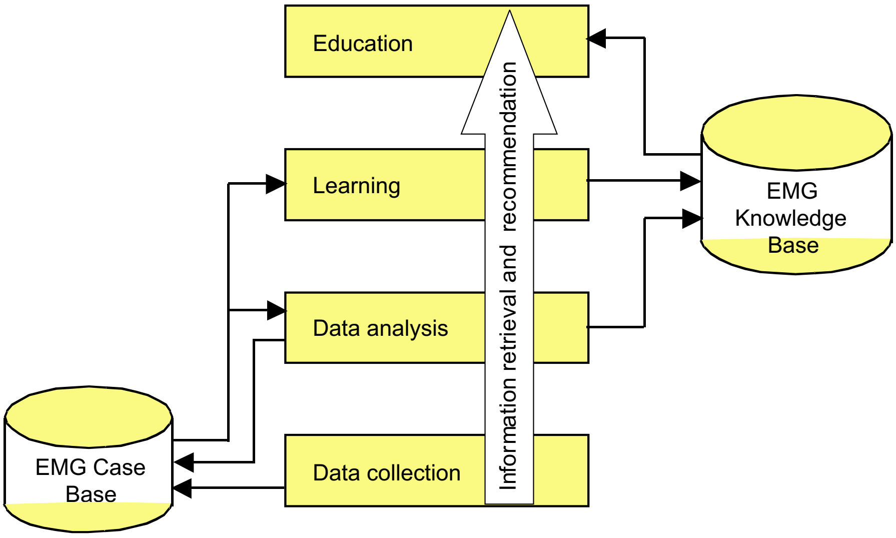

Fig. 1. Multifunctional EMG platform

operate on the EMG data and knowledge stored in the EMG case base and the EMG knowledge base. The architecture of the multifunctional platform for EMG studies evolved from the proposal introduced in [2].

The EMG case base is created by the first layer of the proposed architecture. It contains roughly the following groups of data:

- *general data* (patient, examination),
- *primitive measurement data* (mainly numerical values for conduction velocities, amplitudes, *etc*),
- *symbolic interpretations* of these measurements at various levels of detail (symbolic parameter values, pathophysiological test conclusions, pathophysiological structure conclusions, EMG diagnoses and clinical diagnoses)
- *normative data* which serve for interpretation of the measured values.

The EMG case base is actively used in data analysis and learning layers. These layers consist of a set of data analysis, data mining and machine learning tools. The objective of these tools is to analyse the collected EMG data for consistency, completeness, performing useful statistics and to "mine" new EMG knowledge from the data acquired at the data collection layer.

EMG knowledge is stored in the EMG knowledge base which is realised as a web server containing available consensual knowledge on the EMG domain [12]. The server, practically, reflects the current state of expertise in the EMG domain and provides a possibility to access this expertise via world wide web.

Each layer can use the EMG data and knowledge through information retrieval and recommendation facilities. This part of the architecture is inevitable, mainly due to extensiveness of the EMG domain. One promising approach is sharing the knowledge about the quality of information resources using a combination of content-based and collaborative filtering [11].

3 COMPUTER SUPPORTED COLLECTION OF EMG DATA

EMG data are collected at several levels: the local level, the national level, and the European level. The local level is represented by a particular EMG workplace. The national and the European levels are intended mainly for exchange of the EMG expertise accumulated during years of practice. This would improve the quality of an early diagnosis and prevention of neuromuscular diseases in each particular country, or a whole region. The national level of the EMG data collection becomes also important when the aim of the EMG data collection is the development of normative EMG data.

Computer support of local EMG data collection is realised through a combination of an automated support of data acquisition from the EMG machine and a manual input (or modification) of the EMG data by a physician. Manual input is inevitable at least in the case of inferred data (physician's conclusions). Proposing conclusions at different level of diagnosis can be supported by a decision support tool (analysis or learning layer of the architecture).

The EMG data distribution is supported through a global computer network or Internet. EMG data are stored in a global database, which should be synchronised with local databases in order to contain correct data from all EMG laboratories. In fact, several global databases can exist: global national databases and global regional databases. This hierarchy allows the use of a software tool on all three mentioned levels: local, national and European. Separating particular levels enables the use of the collection software tool in off-line mode, *ie* the physician is allowed to enter the data without Internet connection.

The described hierarchy is employed also for collecting the measured EMG data suitable for normative EMG data determination. To find values that are as representative as possible (to become a true standard), collaboration of several laboratories distributed throughout the territory is inevitable. The measurements are coordinated by the EMG laboratory that should issue requests for EMG measurements to participating laboratories, accumulate, store and monitor the measured EMG values provided by all partners. However, all participating laboratories should closely collaborate on formulating the requests. Well-defined requests strongly influence the results of the process of EMG data collecting because each laboratory can have specific possibilities according to the measured values (also in respect with healthy volunteers).

The physician in an EMG laboratory receives a request containing information about required EMG examinations, requirements on a subject being examined (sex, age, temperature, *etc*) together with additional information, which allows standardisation of the examination process. The measured EMG values (response) are passed to the coordinating laboratory.

4 EMG DATA REPRESENTATION

During the ESTEEM project, the software tool for the EMG data collection (called CASETOOL) was developed together with Communication Protocol EPC/ECCO 3.2 for exchange of the EMG data [8]. Binary ECCO format has been designed as an efficient format from the point of view of storage. Several existing tools use the ECCO format (*eg*, KANDID [6]). Moreover, EMG laboratories, which form the EMG-net consortium, have collected in the last years together more than 1000 EMG examination cases stored in this format. There exists also the so-called *golden EMG data collection* which stores more than 200 examination cases resulted from the consensus of partners from about a dozen of laboratories (each from different country in Europe). The golden part of the EMG case base is intended for data analysis and mining.

The main difficulty with the ECCO format lies in its inflexibility with respect to extensions. The problem arose during the EMG data collection and evaluation. The binary format is also not very suitable for exchange using the Internet for reliability reasons.

In order to preserve continuity in the EMG-net project as well as to support future developments, we proposed using several data representation formats, which range from the binary format (Communication Protocol EPC/ECCO 3.2) through the relational format (represented by a relational database) to the text format (represented in the eXtensible Markup Language).

ECCO is retained in the EMG examination cases collection and management tool in the form of export/import capabilities. The relational format is advantageous because of its flexibility, extensibility and portability. It is used for persistent storing EMG examination cases. The relational format presents also a base for data mining. It is refined on the higher layers according to specific requirements for data analysis and knowledge discovery [7,10].

For the purposes of collaboration, we proposed representation of the EMG data by the eXtensible Markup Language (XML). XML was chosen because of its ability to describe the content of (semi)structured data flexibly and across multiple platforms. The readability of XML documents as well as the availability of software tools supporting XML manipulating was equally important.

An exchange of EMG examination cases is important in the process of consensus exercises, where a group of physicians discusses particular EMG examination case in order to reach consensus regarding an EMG diagnose as well as clinical diagnosis. Distribution of requests and collecting responses serves for collecting data suitable for normative EMG data determination.

The proposed markup language for EMG data exchange (EMG-ML) is supposed to create XML data-centric documents [5]. The EMG-ML reflects contents of the EMG case base. It defines markup for data about the patient's examinations, together with data related to requests and responses used in the process of normative EMG data determination.

It should be noted that data about some patient's examination are to be treated with an extreme care with respect to possible enfringement of individual privacy. However, data are sent in this format for the purpose of collaboration on such themes as consensus exercises where all cases are strictly de-personalised so that personal identification is not possible.

5 DEVELOPED SOFTWARE TOOLS

At the moment the data collection layer consists of a set of software tools aimed at collecting data about EMG examination cases [4] and normative EMG data determination [3].

The software tool for collection of EMG examination cases called EMMA stores and allows manipulation of all the above mentioned data. Moreover, we also incorporated EMG normative data into the design, which serve for accurate examination interpretation. The input and modification of normative data in all the required formats (*eg*, in table format, functional format) together with calculating symbolic parameter values according to these data in an actual test are supported.

Collection of normative data is a complex process which involves collaboration of the coordinating laboratory and the local laboratories. We therefore took the strategy of developing two distinct but communicating software tools: NoDaM (Normative Data Manager) and NoDaC (Normative Data Client). Communication is realised by requests and responses represented in the EMG-ML language.

The NoDaM is directed for the coordinating EMG laboratory. Its primary functions are to produce the correct request document according to physician's requirements, process the data from the response document and to transform them into the EMG case base.

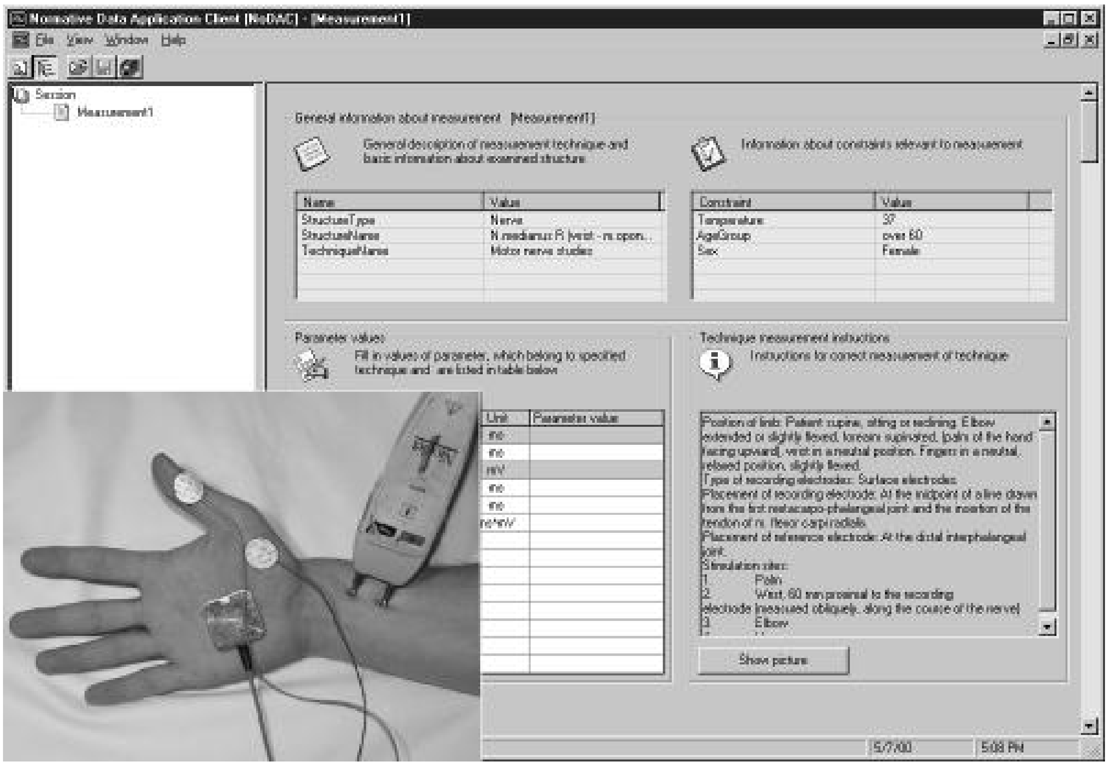

Fig. 2. NODAC measurement screen

The NoDaC software tool allows an examiner to record the values of EMG parameters. It lets him/her to review the requirements from the coordinating laboratory and to send the measured data back in the form of a response document. Our main goal was to keep this tool as simple as possible by providing the minimal functionality actually needed. We therefore designed NoDaC as a dynamic form configured by the request file. Only those parameters specified in the obtained request document are displayed in the form (see Figure 2). The other ones, non-relevant or not required, do not have to be considered.

6 CONCLUSIONS

The presented work is aimed at EMG standardisation by developing a multifunctional platform for EMG studies. We concentrated on data collection and representation which is a crucial task in such a data intensive area as EMG examination.

Our design is realised in a set of software tools aimed at collecting and managing EMG patients' examination cases and collecting data for EMG normative data determination. The developed tools are built on the top of the designed relational EMG data model. Developed software tools serve as a basis for exchange of expertise among a community of neurophysiologists.

We proposed a communication method between the EMG laboratories at different levels (local, national, or European). The communication is based on using the EMG Markup Language developed according to the XML standard. The structure of the EMG-ML documents is flexible so that new types of entities may be easily integrated.

The developed software tools for collection of EMG examination cases and for EMG normative data determination form the first layer of the proposed architecture of the multifunctional platform for EMG studies. The developed tools ease not only collection of EMG examination cases but more importantly reviewing the examination cases during consensus exercises and making decisions about diagnosis.

Acknowledgement

The work reported here was partially supported by project INCO Copernicus, No. 977069, European Research Network for Intelligent Support of Electromyographic Studies EMG-Net and by the Slovak Science Grant Agency, grant No. G1/7611/20.

We would like to thank Pavol Kučera, Pavel Traubner and Peter Záhon from the 1st Department of Neurology, Comenius University Bratislava who provided expert consultations in the EMG-net project.

References

[1] AGRE, G.—ZIÉBELIN, D. (Eds.): Proceedings of Workshop on Application of Advanced Information Technologies to Medicine. Varna, 2000.

[2] AGRE, G.: A Multifunctional Platform for EMG Studies, In: [1], 117–124.

[3] BIELIKOVÁ, M.—KUČERA, P.—NÁVRAT, P.—SMOLÁROVÁ, M.—TRAUBNER, P.—ZÁHON, P. : Computer Support for Normative EMG Data Determination, In: [1], 39-47..

[4] BIELIKOVÁ, M.—NÁVRAT, P.—SMOLÁROVÁ, M. : Collection and Management of EMG Examination Cases, ERCIM News. No. 45, April 2001, 43–44.

[5] BOURRET, R. : XML and Databases, Technical Report. Technical University of Darmstadt, September 1999.

[6] FUGLSANG-FREDERIKSEN, A.—RONAGER, J.—VINGTOFT, S. : PC-KANDID: an Expert System for Electromyography, Artificial Intelligence Medicine, 1989, 1: 117–124.

[7] GARBAY, C. : Data Mining in EMG: An Agent-Centered Perspective, In: [1], 72–83.

[8] JAKOBSEN, L. S.—FOG, B.—TALBOT, A. : ESTEEM communication protocol, ver. 3.2. ESTEEM report Advanced Informatics in Medicine (A2010), 1993, 1–87.

[9] JOHNSEN, B.—FUGLSANG-FREDERIKSEN, A. : USER-5: EMG dataset specification version 3, ESTEEM report Advanced Informatics in Medicine (A2010), 1994, 1–44.

[10] PILKA, M.—BIELIKOVÁ, M. : User Interface Adaption through Data Mining, Proceedings of DATAKON'2001, accepted for publication.

[11] POLČICOVÁ, G.—SLOVÁK, R.—NÁVRAT, P. : Combining Content-Based and Collaborative Filtering, In: Proc. of ADBIS-DASFAA'2000 — Symposium on Advances in Databases and Information Systems, Y. Masunaga, J. Pokorný, J. Štuller and B. Thalheim (Eds.), MATFYZ press 2000, 118–127.

[12] ZIÉBELIN, D.—VILLA, A. : Building Knowledge Base in Electromyography through the WWW, In: [1], 117–124.

Received 2 June 2001

Mária Bieliková (Doc, Ing, CSc) received her Ing (MSc) in 1989 from Slovak University of Technology in Bratislava, and her CSc (PhD) degree in 1995 from the same university. Since 1998, she is Associate Professor at Department of Computer Science and Engineering at the Slovak University of Technology Bratislava, where she is a member of the Software Engineering group. Her research interests include knowledge software engineering, software development and management of versions and software configurations, adaptive hypermedia and educational systems. She is a member of the Slovak Society for Computer Science, IEE, ACM, IEEE and its Computer Society. She is registered with The Engineering Council, UK as a Chartered Engineer (CEng).

Pavol Návrat (Prof, Ing, PhD) was born in 1952 in Bratislava, Slovakia. He received his Ing (MSc) summa cum laude in 1975, and his PhD degree in Computing Machinery in 1984 both from Slovak University of Technology in Bratislava. He has been with Department of Computer Science and Engineering at the Slovak University of Technology in Bratislava since 1975, but he was also with Universities of Warsaw, Athens, Sheffield, and Kuwait. Since 1996, he is a Full Professor of Computer Science and Engineering. He (co-) authored three books and numerous scientific papers in international scientific journals. In Great Slovakian Encyclopaedia "Beliana", he is co-author responsible for entries related to the field of Informatics. As an editor and co-author, he published a monograph on Knowledge-based software engineering in IOS Press, Amsterdam. He had several contributions at international conferences, including three invited lectures. Frequently, he has been serving in programme committees of international conferences. His scientific interests include automated programming and software engineering, knowledge-based methods for assistance in programming and software development, as well as other topics in software engineering and artificial intelligence. He is a Senior Member of the IEEE and a member of its Computer Society. He is also a member of the ACM and American Association for Artificial Intelligence. Since its foundation in 1992, he is a member of the Slovak Society for Computer Science. Since 1998, he serves as Slovakia's representative in IFIP Technical Committee TC-12 Artificial Intelligence. In 1997, he was elected chairman of the Slovakia Centre of the IEE. Since 1998, he is a fellow of the IEE. He is registered with The Engineering Council, UK as a Chartered Engineer (CEng).

Mária Smolárová (Ing) received her MSc in Computer Science from Slovak University of Technology in Bratislava in 1986. She is currently a teaching assistant at STU, Department of Computer Science and Engineering. She is currently working towards completing her PhD thesis on representation of design patterns in software development. Her research interests include software architectures, software patterns and pattern-oriented development methods. She is a member of ACM and IEE. She is registered with The Engineering Council, UK as a Chartered Engineer (CEng).