MedMap: A POWERFUL MULTICHANEL ELG RECORDINGS ANALIZER

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***Abstract* – Study and analysis of multiple recording electrograms in experimental models requires dedicated software for their processing. This software must be quick and efficient in manipulating the enormous amounts of recorded data. Furthermore, the software has to be easily extensible in order to introduce news work methods and analysis algorithms adapted to the needs of each research group. This has led us to develop a modular software package in which introduction of new functionalities will not require the development of a new program, resulting in considerable time savings.**

For development we chose MATLAB, an interactive program with high computing capabilities and powerful tools for graphic visualization. Being a standard platform, developed code can be easily modified and the functionality of any module can be optimised and/or altered at any time, allowing implementation of the latest scientific advances.

This software has been conceived for many applications, although in this paper we focus our experience on the study of fibrillatory processes in experimental models where up to 256 electrograms have been recorded using a cardiac electrical system.

Keywords - **Mapping, spectral analysis, dominant frequency, fibrillatory processes, electrogram.**

I. INTRODUCTION

There are a significative number of research groups that use the cardiac electrical activity mapping system (CEAMS) as their fundamental work tool. Those systems are equipped with appropriate instruments for acquisition from a large number of electrogram (ELG) channels (generally up to 256, though there are systems with more), and a PC or workstation is used to display as much information as possible on screen, offering lots of calculation tools to ease the researcher work. Most of these tools take large calculation times due to the enormous amount of data to handle and the complexity of the involved operations.

The immediate consequence is the well known fact that as time passes the multichannel acquisition equipment remains valid and usable, while it is in the recording systems and the software for processing and visualization where the fast technological advances are reflected.

In addition, the multichannel acquisition equipment is usually tied to specific hardware, which reduces flexibility at the time of making configuration changes. However, the software side is easy to access and quick to improve, and the necessary budget is more affordable.

Because of that, it would be highly desirable to have a platform-independent software package that could be easily fitted to the specific needs of each research group, and in which latest advances in fields like signal processing and data mining could be quickly implemented.

In this paper we describe such a software package: it is easy to use, modular and adaptable to new needs. For its development the MATLAB platform has been chosen, due to its popularity and wide use in medicine and engineering, which ensures that new algorithms and other advances will be quickly be available.

We will make special emphasis on our first application of the package, consisting in the spectral analysis of fibrillatory processes obtained with CEAMS in a perfused rabbit heart experimental model.

On the other hand, it would be very useful to have a complete software package independent from any hardware that could be adapted to the specific needs of each research group, in which latest advances could be easily and quickly integrated (signal processing, data mining, etc.)

In this paper we describe a software package that is easy to use, modular and adaptive to new needs. For its development we have chosen MATLAB, a very widely used platform, not only in medicine [1], but also in engineering applications. Being a well know platform ensures that new advances in signal processing and other related fields will be quickly and easily added to the package.

The present paper makes special emphasis on our first application of the package, consisting in the spectral analysis of fibrillatory processes obtained with CEAMS in a perfused rabbit heart experimental model [2].

II. METHODOLOGY

The first problem we faced was that common acquisition systems have a closed visualization platform that makes access to generated data almost impossible. In order to develop tools that work independently from those systems, first we must be able to read the data files and export to our own format for posterior computation.

After a preliminary study MATLAB (The Mathworks inc., Natick MA, USA) has been chosen for developing our software. MATLAB is a command interpreter (strictly speaking, a just-in-time compiler) with a high-performance language for technical computing that integrates computation,

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Abstract

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visualization, and programming in an easy to use environment. MATLAB is always in constant growing, so any new algorithm is quickly implemented in any of its numerous toolboxes. And it comes already with a data acquisition toolbox.

For the needs of our research, MATLAB offers a big amount of graphical functions for the generation of pseudocolor maps, contours and isopotential lines, and provides functions and algorithms for signal processing in time or frequency domain. We decided to develop our software as a MATLAB toolbox under two elemental premises: simplicity and interactivity.

The main drawback of an interactive programming environment is the time the program interpreter takes to read and understand the commands written in plain text. However, MATLAB needs to compile a program only once in a session to run it several times, and modern computers are able to run the precompiled code fast enough for an user interface or small computations. Bottleneck calculations can be programmed in C, compiled to fast machine code in files that MATLAB can link dynamically, and then behave like any ordinary MATLAB script or built-in function, except that they are much faster.

The MATLAB system runs on several platforms (WINDOWS 98 in our case) and behaves exactly the same on all of them. This makes our software platform-independent. Only the C language routines must be compiled for each platform.

III. Results

In this section we will introduce part of the tools that form MedMap, illustrated with pictures generated from our first experience, which consisted on the study of the spectral properties of the electrograms acquired with CEAMS during fibrillatory processes, and the methods used to defibrillate them. The main parameter under study was dominant frequency (FD) in each electrode. In special, left ventricular unipolar electrograms were recorded from 121 unipolar stainless steel electrodes positioned at the epicardial surface of the lateral wall of the left ventricle [3][4].

When the program is run, a series of different windows are open, each one corresponding to the functionality of a different module and used in the study of one or more properties of the data. The set of implemented windows is:

A. Numeric format dominant frequency visualization

This module creates an electrode map. For each electrode the channel number and the dominant frequency (measured over the total length of the recording) are shown. The dominant frequency can be edited and interpolated with adjacent values.

Figure 1 shows how this window looks like.

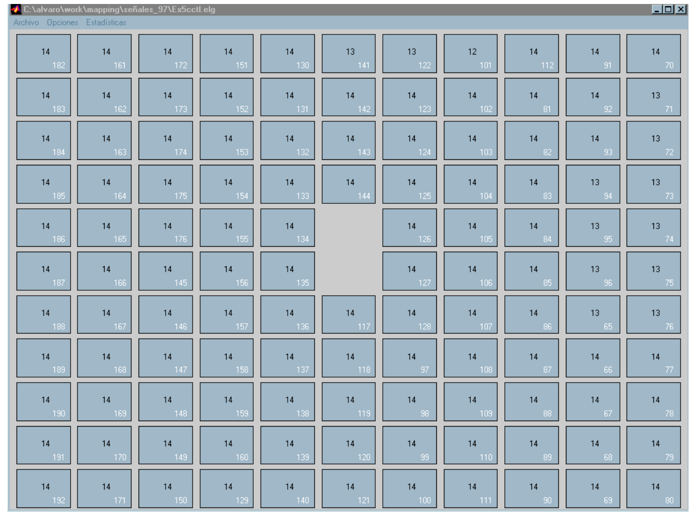

Fig. 1. Example of numeric dominant frequency visualization window. This window displays the channel map with the number of electrode and its dominant frequency value. There is an options window where the number of decimals can be chosen and the value of the frequency can be changed.

B. Isofrequency Map window

This module shows a window that looks pretty much the same than the previous one, but now channel numbers are now shown and a set of isofrequency curves are drawn. There is an option to enable pseudocolor filling using any desired colour map. The number of curves can be chosen and their boundary values can be set manually or generated automatically. The associated value for each curve can be edited, and curves can be hidden or permanently removed in case they are of no interest.

In this window it is possible to export the generated image to a graphic file for posterior use.

Figure 2 shows and example of this window.

C. *Dominant frequency time evolution window*

This module displays a window that contains an electrode map. In each electrode box a graph of the revolution of the corresponding dominant frequency over time (computed every 0.5 seconds) is shown.

This measure is obtained from the spectral anaylsis of each channel with WOSA spectral estimator: data from each channel is split into slices of 512 samples, then each one is windowed with a Hamming window of the same length, and finally the spectral estimation is made with no overlap.

Figure 3 shows and example of this window. For closer detail, the spectrum of each electrode can be calculated in the described way at user-defined intervals, as shown in figure 5. This module is described later.

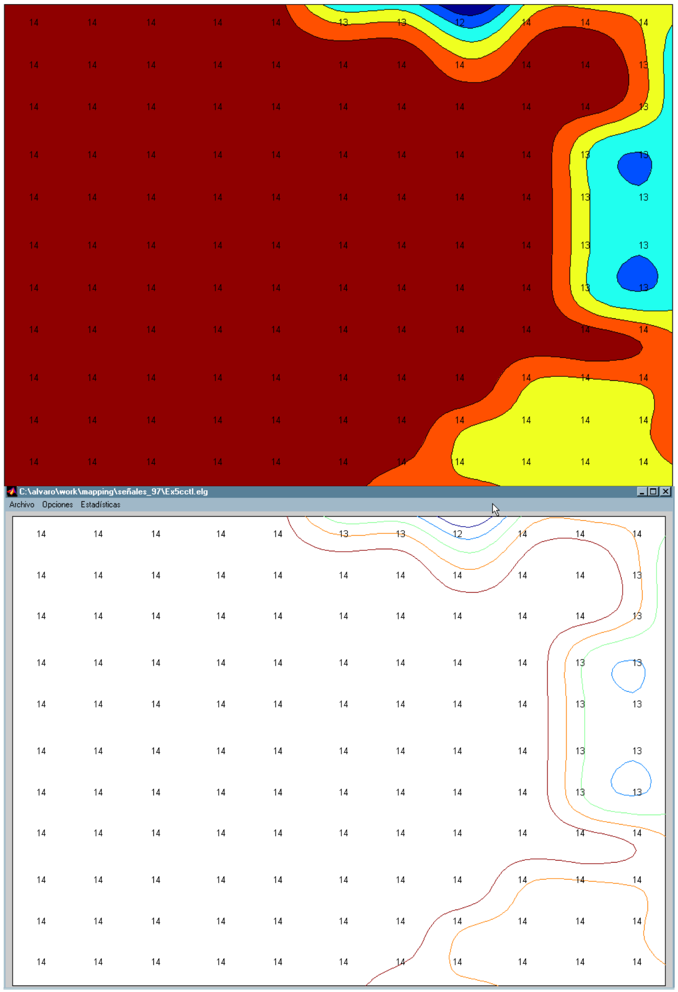

Fig. 2. Isofrequency map representation window with filling option on (top) and filling option off (bottom). For every window there are one or more option windows where parameters can be changed. The user can change the number of displayed isofrequency lines, the number of decimals shown in each frequency value, select what data must be shown with pseudocolors, hide or remove a isofrequency line, or just manually set the value of each curve.

D. *Statistics visualization window*

The purpose of this module is to accelerate the labour of the researcher by providing an automatic calculation of a set of statistics frequently used in bioengineering.

In addition, a "box & whiskers" diagram is plotted, which summarizes the set of dominant frequency values.

Figure 4 shows the window of this module.

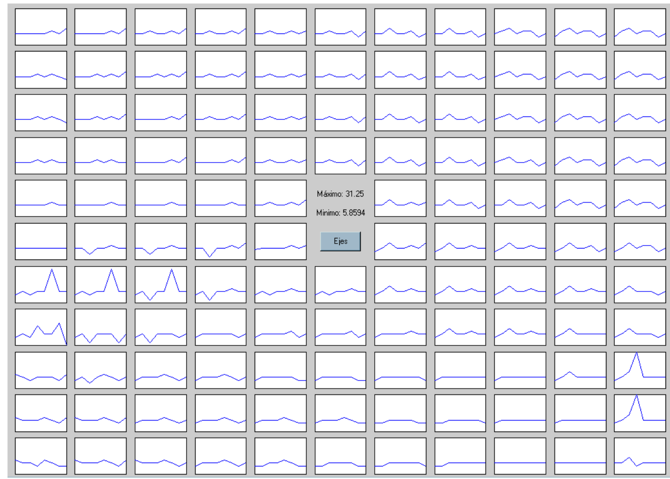

Fig. 3. Example of the dominant frequency time evolution window. The dominant frequency is calculated every 0.5 seconds and then plotted in its respective channel box. The scale of all the graphs can be manually set.

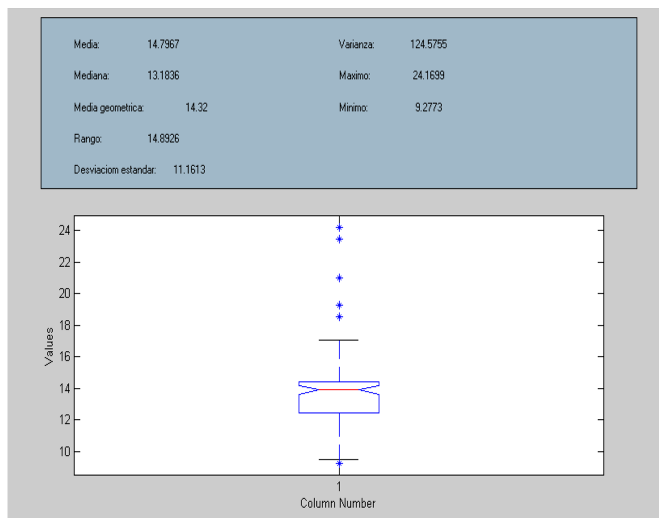

Fig. 4. Example of the statistics that can been obtained from the dominant frequency of the whole set of channels, such as mean value, standard deviation, median values, etc. We can also see a 'box & whiskers' diagram.

E. *Spectrum visualization window*

When using numeric frequency representation window, some of the values may be incoherent, due noise which causes errors in frequency estimation. Then it is necessary to obtain a more accurate value if we want to plot a correct isofrequency line map.

This window displays a plot with the ELG record associated to one channel and a set of spectrum plots whose time intervals are defined by the user from 0.5 to 4 seconds. In addition, a set of cursors allows the user to get the values from each plot at any time. Figure 5 shows this window.

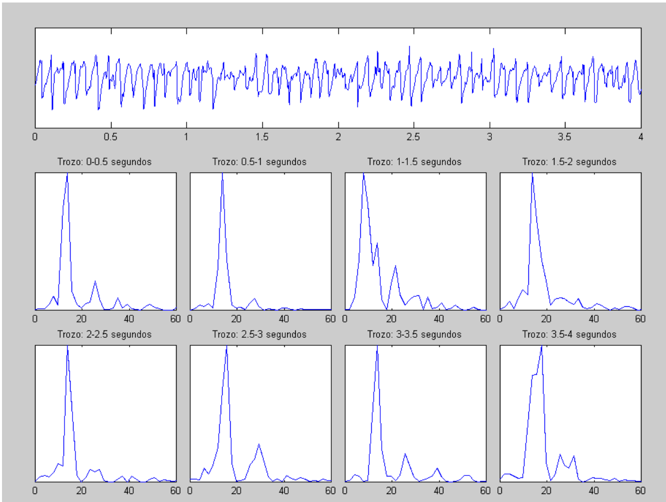

Fig. 5. View of the spectrum visualization window. The evolution of spectrum can be observed in steps from 0.5 to 4 seconds. Likewise, the temporal ECG waveform can be shown in order to appreciate changes in the rhythm that can vary the properties of the spectrum at any time.

IV. Discussion

In this paper we presented a new tool developed for the research of Fibrillation Processes [5] with an experimental method: analysis of dominant frequency evolution in time. As the tool is modular and extensible, many more modules and functions will be soon available, such as detection of fiducial points for QRS [7] and transformation of body surface data [9].

Due to the large amount of data available in the whole set of used records, the program must be fast, flexible, easily modifiable and easy to use. Regarding speed, modern computers can perform complex tasks in an insignificant amount of time. Furthermore, functions that are no to be changed (such as file management functions) can be implemented in high-level language and compiled in order to increase execution speed. The software is also easily modifiable because it is implemented as scripts of a maths interactive program and the code can be changed at any time. Integration of new algorithms is almost automatic, which gives the software a wide range of expansion capabilities. Finally, the use of a graphic user interface makes its use easy and intuitive.

V. Conclusion

We are confident that our package will help simplifying the work of research groups of medical doctors, making automatic a task that was mostly manually done until now, requiring much time due to the large amount of data involved. It will also offer a wide range of new possibilities, from complex additional computations to new ways of graphical representation, such as time-frequency distributions and wavelet transforms [10]. As of now it has been successfully used in the study of Fibrillatory Processes and the methods used to stop them. It has helped us to accelerate the research tasks thanks to its ability to plot isofrequency maps and to process independent ELG channels. These abilities will be soon complemented with many more in order to build a complete and useful tool for medical research.

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