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Biomedical Distributed Signal Processing and Analysis

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Abstract. The paper deal about the electrophysiology distributed data processing and analysis. The aim of the work was the distance computer environment for biomedical data processing services with effective data visualizing. The system combine end user interactive interaction with biomedical data was realized with the use of rapid calculating by FPGA technology. Combining of these technologies allows a wide range spectrum of users to quick access to proceed biomedical data. This article involved the possible topological proposal and implementation of that biomedical distributed signal processing system.

Keywords: Ultra Fast, Parallel, Signal Analysis, Web Services FPGA, Biomedical

1 Signal Handling

Handling with biomedical data is not uniform and there are not any common standards till today. Many producers in the medical devices mainly contain their own data formats, what means in incompatible. Converting the data seems to be loss-making and between these formats is very limited. Nowadays way is to handling data through a web services interface that provides the user with many advantages. In that case, data storage using a standard XML format is often used and supported by many tools and programming languages.

In concern of medical practice, there is important that biomedical records are moderate from any web sites and networks without the specific programs installed. For this mind, a system of handling of biomedical data were developed, which is based on earlier work of the authors [1] - [4].

The system write on about web system that gives the opportunity to view of stored biomedical data and also allows you to store records in one of three predefined formats – EDF, DAT and XML. As part of this web system application is a viewer of stored records, which replaces the traditional programs and enables a view of recorded data directly on the website without need of additional programs. The

Marek Penhaker, Vladimir Kasik, Vaclav Snasel

system for storage and exchange biomedical data is based on ASP.NET 2.0 platform .NET Framework and Microsoft SQL Server.

For storage of biomedical data is used a data storage server. Every file uploaded to the server has its own unique name that is used as ID in the database. The basic functions of Web applications provide: display a list of all records stored in a database, add a new record and manage users. The Web application has its own biomedical data browser that allows graphical display of such an EEG records from XML file.

A significant part of the application is the application stored biomedical data, providing by display the 20-channels EEG records. It is also possible to modify the scale of the axis and to move the view in a direction of x axis.

Additionally the system were enlarged to evaluate the biomedical data with the detection of real time signals with ultra fast response and accuracy. The precise possibility of the application can be done by FPGA multiparallel system. This hardware is handling data with a data server, but can also be connected to the analog inputs for on-line processing of biomedical signals. [5]

Nowadays, complex applications are being developed, the scope of which exceeds the ability of one person. The development application is usually involved more programmers. In the work were again used part of their applications or other companies. The programmer thus can no longer rely only on himself, as it was in the days of the first operational system. The first tool for modular application development platform for Microsoft Windows is dynamic libraries. [6] - [8]

At the beginning of the 90th years were mostly created separate applications with very little ability to communicate. This deficiency was removed in the mid-90th years, when the company introduced technology Microsoft COM (Component Object Model). The great advantage of component technology is its language neutrality in binary form. For each component was defined interface that facilitates communication between the client and the relevant component. Over time, it became apparent that even the technology has its limitations. Nowadays, the modular architecture of increasingly more used. Components used are usually small and simple. The main disadvantage of COM components is that they hide their internal implementation. The only component that describes the appropriate interface. This prevents inheritance at the source. [9]

2 Problem Definition

Biomedical data representation on different devices was mostly done on local terminals with displaying of measured data using web services. Processing of these data is done either by post-processing after measurement and in minor cases on-line. On-line processing puts high demands on hardware and so this process is destined only for specialized work. Enabling data processing on any number of remote terminals for users working with internet ser currently represents significant progress in training of physician, cooperation and collaborations in real time with ultra fast and inexpensive analysis.

Distance processing of biomedical data was done by using web service terminals is solved several ways. The methods of implementation is described below having a native access in the installation of a powerful multiparalell processor with direct connection to server or database server, providing a web application platform and user cost-effective way of data evaluation.

The proposal of multiparalell ultrafast system for biomedical processing is the tasks that can be used in very large scale of integration composition of FPGA - Field Programmable Gate Array. With the FPGA technology are these features possible not only for off-line processing of saved data, but also the possibility of real time evaluation and data handling to distance physicians by web services. [10]

In cases where the digitized signal is processed in several steps, it is preferred to use a computer-operated pipelining. Typically, such calculations are solved by computer, however it does not perform these operations simultaneously but in sequential manner. Such a conventional approach requires higher CPU computing power. In addition the time required to calculate is difficult to predict and the whole situation has an impact on the safety of the calculation. The solution, which better reflects the computational structure for the signal processing is distributed architecture in both the system and the units inside the chip. Therefore, there is the FPGA technology utilized, in which the calculating phases are designed in separate processing modules. [10]

3 New Methods Description

Biomedical data processing requires specifically detection variety in stored measurements. The variety is evaluated qualitative and qualitative parameters and the time parameters. The proper evaluation in variety is usually not often easy, due the biomedical signals volatile on quasi periodic or stochastic characteristics and could also be changed by artificial or physiological artifacts.

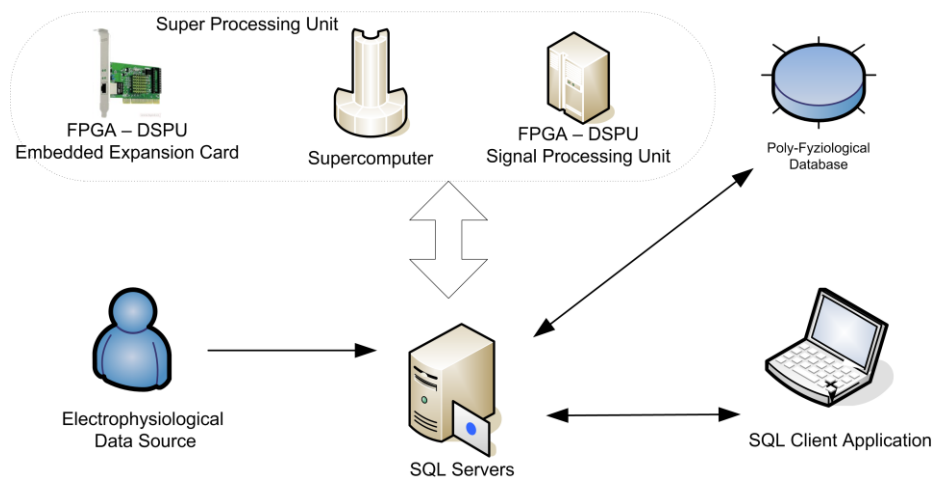


Fig. 1. Overall system structure for distributed signal processing.

The way of ultra speed real time data processing should be connected with the computing demands of data handling. Fig. 1.

The multivariate mathematical transformations currently provide a very efficient and effective algorithm for detection and manipulation of biosignals, whatever is used for implementing many of the calculation estimate, especially at the local workstations. Using the multivariate mathematical transforms is easy thanks to the number of steps in one subscription by $2 \times n$, all the same for use on large real-time huge biomedical data it requires fully ultra fast parallel computing with high discharge. Implementation of this option can be currently done with just two possible architectural designs. First one is a huge supercomputer with many processors linked with tiny data pipelines and the other is a ultra fast parallel computing with FPGA technology, which is nevertheless similar to these with supercomputer ability. In this point of view, there are three alternatives to fast signal processing as shown in Fig. 2.

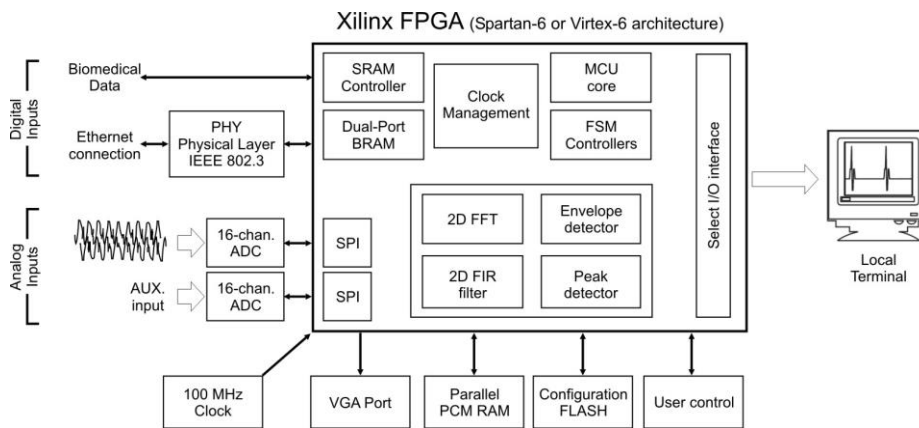


Fig. 2. FPGA – DSPU Detailed Structure.

That down describe the system of transmits saved biomedical data to the coprocessors unit for processing on request. Processed data are giving back after processing of data server, from where may be displayed on the web system. [11]

There are the three possibilities of co-processing units: a) FPGA – DSPU (Digital Signal Processing Unit) like Embedded Expansion Card b) FPGA – DSPU like stand-alone unit with an Ethernet connection and c) supercomputer like an alternative. Possibility and b of all options are established on FPGA programmable logic, which uses the same hardware and software accession in data housing. Hardware design is based realized by parallel implementation of some sub-algorithms in cooperation with the DSP units. Software design allows to process complex calculations and algorithms supporting MicroBlaze soft processor supplement Fig. 3.

In generally is the co-processing unit including FPGA is designed in such ways. The one solution is a PCI flaring card for managing data from server. Mentioned solution is effective and allows to make maximum signal transmission throughput server and the signal processing unit. The main drawback is necessary off a fixed location of the unit and modification of the data server configuration at the same time,

which may not be advisable. Differ solution from co-processing unit is a standalone module for to be connected through a communication network. Anywhere the standard Ethernet network with TCP / IP protocol is applied. The advisable of the solution is not just freedom of data server positioning, and also a possibility to use this unit with more servers and / or clients on the network. [12] Network feature, withal, poses claims on the network communication module, containing requirements for proper safety and maintenance of data transmission in the network. The unit is equipped with a 2x16 channels for digitizing analog biomedical signals and their processing in real time. Data throughput is limited primarily by sampling rate of ADC, which is outside the chip, so it can be further customized according to application requirements. The Ethernet layer circuitry enables the web interface functions extension of the unit. This functionality is used for options parameterization of control units and also for data communication with co-processor unit.

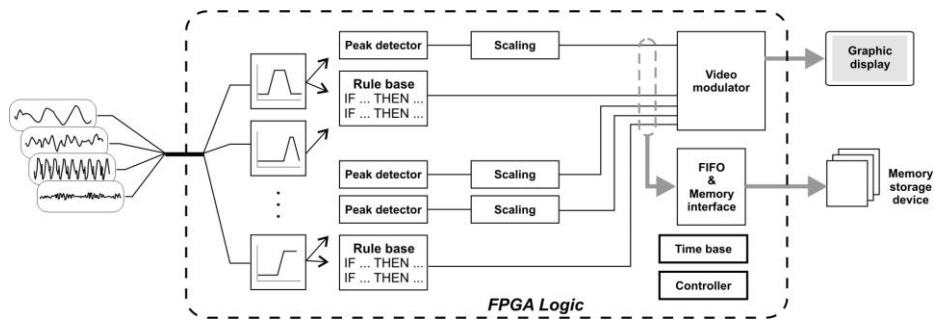


Fig. 3. Fundamental structure of DSP units connection with FPGA Device.

An FPGA - DSPU Unit is a powerful computational tool for rapid evaluation of biomedical signals in real time. Individual calculation algorithms as frequency filters, peak detection, envelope detection and further, are implemented in hardware. Target architecture for implementation is Spartan-6 or Virtex-6 FPGA with soft-core MCU option. For fast data storage are available either fast FPGA Block RAM inside FPGA or off-the-chip fast static memory with parallel access. The advantage of using FPGA is also expanded diagnostic possibilities of digital circuits either in FPGA or in digital circuits around the chip. The logic inside the FPGA design also includes a VGA interface for real-time monitoring of calculated data or diagnostic variables of the system. [13]

In case of dataflow the FPGA – DSPU co-processing unit come second link between web server and SQL server. The operation of FPGA is driven by a web service that transmits commands to the unit. Partial digital biosignal processing algorithms on signal from SQL Server is realized in on real time. The encountered signals is processed by web services and offered to the authorized physician's web service. [14]

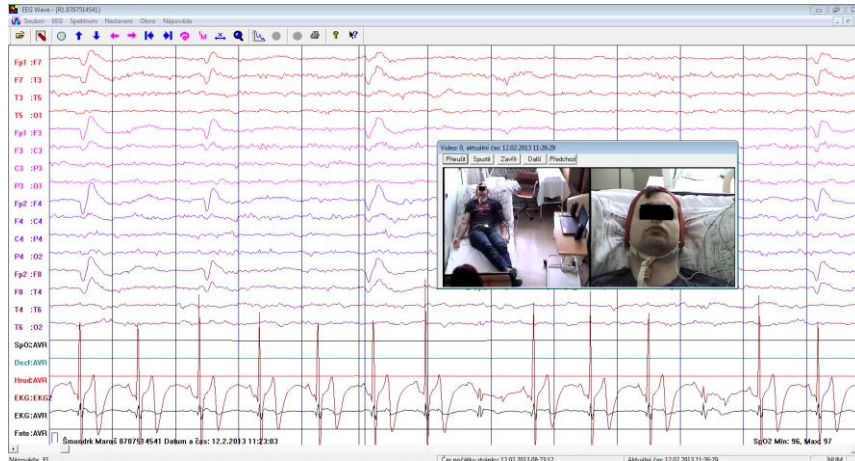


Fig. 4. Evaluation of medical image in real-time processing of input image gives a result in terms of reference points, whose position is further evaluated.

The advance of the realized tests is the system for the EEG evaluation on patients and their correspondence to epileptic attack. To determine the EEG signal was used multivariate mathematic transform. Also to determine individual patient images in clinical practice were used as a method for digital image processing Fig. 4 line of epileptic attacks was evaluated by detection algorithm that was tested to locate any balanced points in the image. Situation of these points and their movements is based on subsequent in classification the patients signal manifestation Fig. 5.

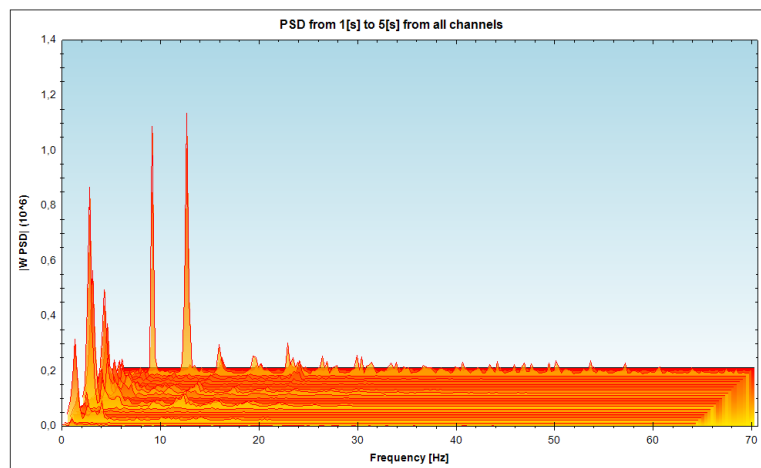


Fig. 5. Power spectral density by CSA for all channels in the selected time period from ultrafast capable system with multiparalel processing algorithms that detected the preliminary signs of epileptic attack in frequencies 7, 11 and 40Hz to 60 Hz.

Application of epileptic attack recognized from EEG records were used multivariate mathematical transform methods implemented on an FPGA gantry. In the same time the fundamental parameters of signal were derived from EEG signal and mainly variety in magnitude and frequency characteristics is evaluated. Likewise, there was examine retardation in the similarity signal propagation within all channels between the first signs of attack in EEG and the corresponding video signals.

4 Conclusion

The introduced problem solution manipulation, detection of signals in real time with multi processing ultra fast processing by FPGA usage carries new possibilities for common workplace, but also for customer of web applications for access and visualization also with additional possibility of processing the far-out signals in real time. The introduced system was tested on a real polysomnographic video records and well verified by application of this system. There were instead traditional methods of epileptic seizure artifact detection determined.

The traditional ways of biosignal processing are very common, but there is a lot of information outside the traditional way of perception. There are hidden information in the measured biosignal especially in high frequencies which are not yet consternate on. We can access the information in the same way of as previous methods for low frequency analyzing, but at can take a lot of human-machine time with weak results. The proposed way of processing introduced in this article is based on multi parallel signal processing with ultra extremely high potential of recognition the even small changes of signal behavior.

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Marek Penhaker, Vladimir Kasik, Vaclav Snasel

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