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Guest editorial

Biosignal Processing: various concepts, various applications – but a common drive

Perhaps the computer-averaged transients system (CAT) [3] is familiar to some older readers: a very expensive system based on discrete electronics that served to average evoked responses by synchronous averaging. The duration of segments was about 500 samples; often this procedure was carried out offline to allow the use of slow motion replay of tape recorders, because the available sampling rates were too low. This is an example of history in Biosignal Processing.

Signal processing (the basis of Biosignal Processing) reached its prime when digital computers entered the laboratory: 40 years ago, the first laboratory computers such as the PDP 8, PDP 12 and PDP 11 provided standard interfaces for on-line process control, which includes analog-to-digital (AD) and digital-to-analog (DA) converters – this was the kick-off of the explosive spreading of digital signal processing. Versatile treatment of data using a program instead of passing them through dedicated electronic circuitry such as filters became the state of the art. Certainly, real-time operation such as closed-loop control of an experiment was still difficult owing to the limited processor speed; also in online digital processing, the limitations because of the causality continue to exist. However, in a number of applications, a possible alternative is online data recording by computer and subsequent off-line evaluation, which now provides new features, including block operations such as FFT and convolution with non-causal impulse response functions (e.g., ideal Gaussian low-pass). Other "dreams" of signal processing researchers came true, such as sophisticated adaptive solutions, complex event detection, iterative approximations, etc. In particular, processing of two-dimensional signals (image processing) benefited from these developments.

Certainly, Biosignal Processing represents a field in which online operation is a salient requirement. Thus, progress in digital signal processing has applied to this field too, even if the bulk of efforts now concern off-line evaluation of biomedical signals. Today, the main approaches include [2]:

- Optimizing traditional linear concepts;
- Processing of non-stationary signals;
- Development of model-based and adaptive solutions;
- Sophisticated pattern recognition and event detection;
- Stochastic signal analysis and estimation; and
- Non-linear methods such as neural nets, fuzzy techniques and non-linear dynamics.

Most of these topics are somehow represented in this interesting collection of papers on Biosignal Processing. The coverage of topics is not complete owing to the restricted number of possible contributors within the region of the professional societies involved: the German Society for Biomedical Engineering in VDE (DGBMT), the Austrian Society for Biomedical Engineering (ÖGBMT) and the Swiss Society for Biomedical Engineering (SGBT).

The articles published in three Special Issues on Biosignal Processing of *Biomedizinische Technik/Biomedical Engineering* were arranged according to the traditional application fields. The first issue already published [10] covered some review-type papers on theoretical issues of signal evaluation, on physiomonitoring, and on EEG and ECG analysis as a general introduction to the field of Biosignal Processing.

The present second issue presents papers on various concepts of Biosignal Processing, and reports on some specific applications.

The next issue of *Biomedizinische Technik* (printed as Issue 1 of Volume 52 in 2007) will continue this series, before presenting two bulk sets of reports on the classical topics of ECG and EEG.

But what is the common thread running through the papers of this issue? First, in a theoretical study, Winterhalder et al. [11] compare four different linear methods to determine interactions between dynamic systems and the direction of the corresponding information flow. These dynamic (sub)systems could be different centers of the brain from which EEG signals are recorded, and the EEG channels from these scalp locations are analyzed for interactions. This type of evaluation of multiple signal sources recorded simultaneously needs a data-handling concept for effective data mining; such a concept is presented by Mikut et al. [6]. They broadly describe the system design and demonstrate its advantages using two clinical applications: myoelectric control of a hand prosthesis and gait analysis. A similar application (treadmill walking) is used by Schablowski-Trautmann and Gerner [8] to show their concept for state space analysis to explore non-linear dynamics in motor control. This theoretical concept is also used for movement control in rehabilitation by the same research group [9]; a specific problem is to realize such a system for real-time operation. The investigation of back muscle fatigue by comparing different recordings is reported by Rzanny et al. [7]; these authors provide evidence of a significant correlation between electrophysiological and metabolic changes for changes in muscle workload. Another step towards more practical application is represented by the work of Fleischer et al. [5]; they show how exoskeleton legs and hands can be successfully controlled by appropriate EMG evaluation. Again, rehabilitation is the focus of this contribution. Dambier et al. [4], however, turn attention from the biomedical field to ergonomics, whereby physiological signals are evaluated to estimate a driver's status. Real vehicle driving tests require sophisticated biosignal evaluation, because the complex driving situation affects the driver dynamically and, consequently, the stationarity of the signals recorded. Finally, the contribution of Brix et al. [1] is a good example that biomedical signal analyses of 1- and 2-dimensional signals are sometimes combined; the authors describe methods for analysis of tracer kinetics combined with MRI techniques. All papers offer extensive reference lists for further reading.

Certainly, this series of papers (including those of the other two issues) represents only a sample of the worldwide efforts on Biosignal Processing: a Web search engine offers approximately 40,000 hits for the search term "biosignal processing". This initiative to give a flavor of Biosignal Processing activities with a focus on German-speaking countries does not really match the sampling theorem to guarantee completeness of this survey. However, it does show the manifold aspects of Biosignal Processing and demonstrates various efforts in this area of research – and the common drive of all researchers engaged in this still developing field.

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