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Educational trends in biomedical signal processing

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Abstract

Biomedical Engineering programs are present at many universities all over the world with an increasing trend. New generations of biomedical engineers have to face the challenges of health care systems round the world which need a large number of professionals not only to support the present technology in the health care system but to develop new devices and services. Biomedical Engineering supports patient diagnosis and treatment by installing, testing, calibrating and repairing biomedical equipment; training users; maintaining safe operations. Also, approves new equipment by conducting tests, ensuring adherence to codes and making modifications. This paper presents a solution for biomedical signal processing education, involving real signal acquisition and computer-based processing. The acquired signals also allow a lot of post processing procedures to be implemented in an educational form/way.

Key words: biomedical signal processing, data acquisition, filtering

1. Introduction

Biomedical engineering uses traditional engineering expertise to analyze and solve problems in biology and medicine, providing an overall enhancement of health care. Biomedical engineering is a growing field that advances knowledge in engineering, biology and medicine, and try to enhance human health through inter-disciplinary activities that integrate together the biomedical sciences with the engineering sciences using clinical practice (experiences) [1].

The attentiveness in development of biomedical engineering educational systems has quicken in last years, even they are under development for many decades.In the biomedical engineering research and application field signal processing has kept a central role, being one of the main opportunity for extracting information from acquired biological signals. Nowadays, having a huge number of biological sensors, the signal processing procedures have expanded the area of possible biomedical applications, ranging from sensing, measuring and monitoring to the estimation of human physical and physiological conditions [2]. Therefore, different sensors require several specific signal treatment procedures for different applications, such as movement analysis, biosignals interpretation (EEG, ECG, EMG) or image processing. It must be mentioned that artificial intelligence techniques for biomedical purposes have gained a central role in the last few years enhancing the need for specific signal processing techniques [3].

Biomedical signal processing establishes a powerful area of innovation in medical technology.

The analysis of biomedical signals has become one of the most important methods in numerous research areas including medicine. There is a constant need for the improvement of therapeutic results, extraction of physio-logical information and implementation of clinical procedures for medical application [4].

Biomedical signal processing involves acquiring and preprocessing physiological signals and extracting meaningful information to identify patterns and trends within the signals. Sources of biomedical signals include neural activity, cardiac rhythm, muscle movement, and other physiological activities [5-8].

The biomedical signal processing workflow involves:

- Signal Acquisition
- Signal Visualization and Annotation
- Artifact Removal and Preprocessing
- Feature Extraction

A biomedical engineer must have a qualitative understanding of the importance of biomedical signal processing. Furthermore, the students should be able to apply fundamental signal processing concepts quantitatively to biomedical engineering problems [9].

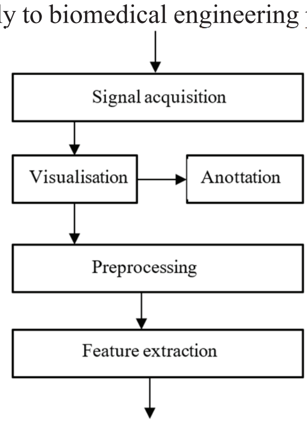

Fig 1 Biomedical signal processing workflow

2. Biomedical signal acquisition

The best approach of biomedical signal acquisition would be that students acquire relevant biosignals from real patients with different cardiac pathologies, but in the university environment this is not possible. To overcome this limitation, university laboratories and research centers can use patient simulator devices like the ProSim 3 patient simulator from Fluke which can simulate ECG signals (with and without arrhythmias), respiration, blood pressure, temperature, etc.

Different ECG parameters can be set, including ECG rate from 30bpm to 300bpm, amplitude from 0.05mV to 5.5mV, ST elevation from -0.8mV to +0.8mV, artefact simulation of 50Hz, 60Hz, muscle, wandering and respiration. The device can simulate different arrhythmia functions including supraventricular, premature contractions, ventricular and conduction defects [10].

These biomedical signals can then be evaluated with dedicated platforms like the MAX30001EVSYS evaluation kit, which includes both a hardware and an evaluation software. The evaluation platform uses the MAX30001 Single-Channel Integrated Biopotential (ECG, R-to-R, and Pace Detection) and Bioimpedance (BioZ) analog frontend for signal acquisition and the MAX32630 Arm Cortex microcontroller unit (MCU) for registers configuration. With the evaluation software, students can study different configurations of gains, sampling rates, cutoff frequencies, etc. A screenshot of the ECG configuration window is presented in Figure 2.

3. Signal Processing

The platform is also able to detect pace pulses, and R – R interval which together with the ECG signal cand be visualized on the plot window.

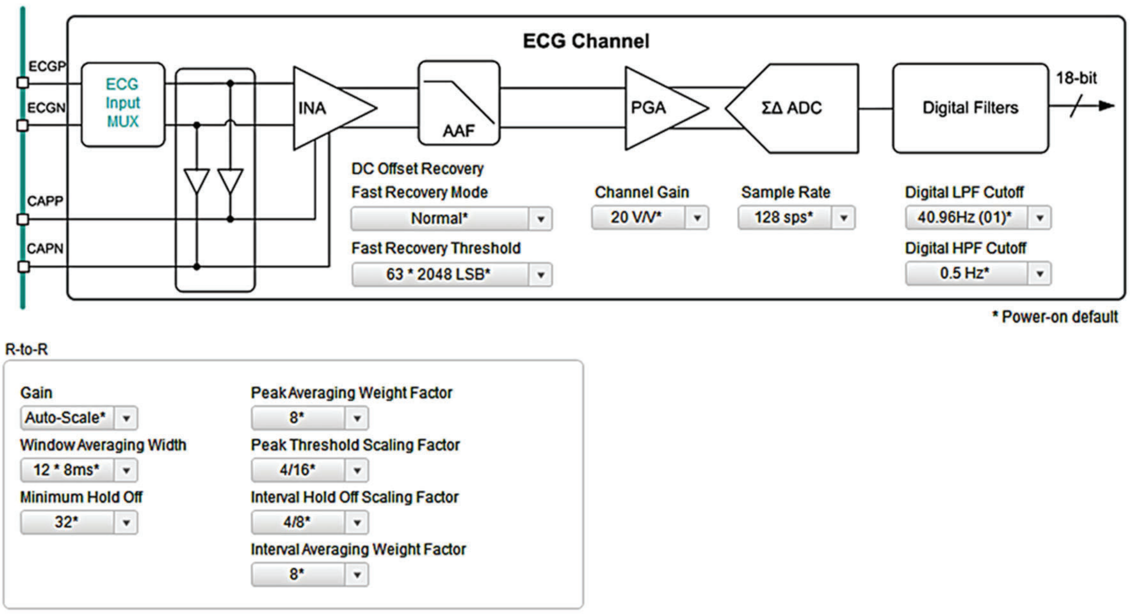

Fig 2 ECG configuration window of the MAX30001 evaluation software

sThis is a handy tool for students to evaluate the plot against different parameter configurations. Figure 3 presents different ECG signals generated by the ProSim 3 patient simulator with and without artefacts:

a) Clean ECG signal
b) ECG signal with 50Hz artefact
c) ECG signal with muscle artefact
d) ECG signal with respiratory artefact
e) Atrial fibrillation, coarse signal

The signals were acquired using the MAX30001EVSYS evaluation kit.

For more advanced study of the biomedical signals processing, students will use SPICE simulator software's like PSPICE from Cadence Design Systems. The MAX30001 Evaluation software gives the ability to save the measured biomedical signal waveforms as csv (comma separated values) file. The ECG plot, saved as csv file, contains the time in seconds for the sampled signal with the highest sampling rate of 7.8125ms, the ECG raw sample values and the ECG filtered sample values, both in mV.

In the SPICE medium the csv file containing the signal waveform will be loaded in the file-input piecewise linear voltage source (VPWL_FILE). Students than have the ability to implement different filter topologies to reduce artefacts, measure the R-R interval, calculate the heart rate variability (HRV), etc. Figure 4 presents the acquired raw ECG signal generated using ProSim 3 patient simulator for an Adult, having 80bpm (beats per minute) heart rate and 1mV signal amplitude, acquired using the MAX30001EVSYS evaluation kit.

As seen in Figure 4a the signal is unfiltered, the 50Hz noise is clearly visible. In Figure 4b the same waveform is shown but this time using the filtered segment from the same ECG csv file.

The signal plot from Figure 4b can be used by students as a reference in their work to implement different filtering technics for the signal presented in Figure 4a. From the acquired signal, the students can learn and practice different technics to find the R-R interval, heart rate variability (HRV) etc.

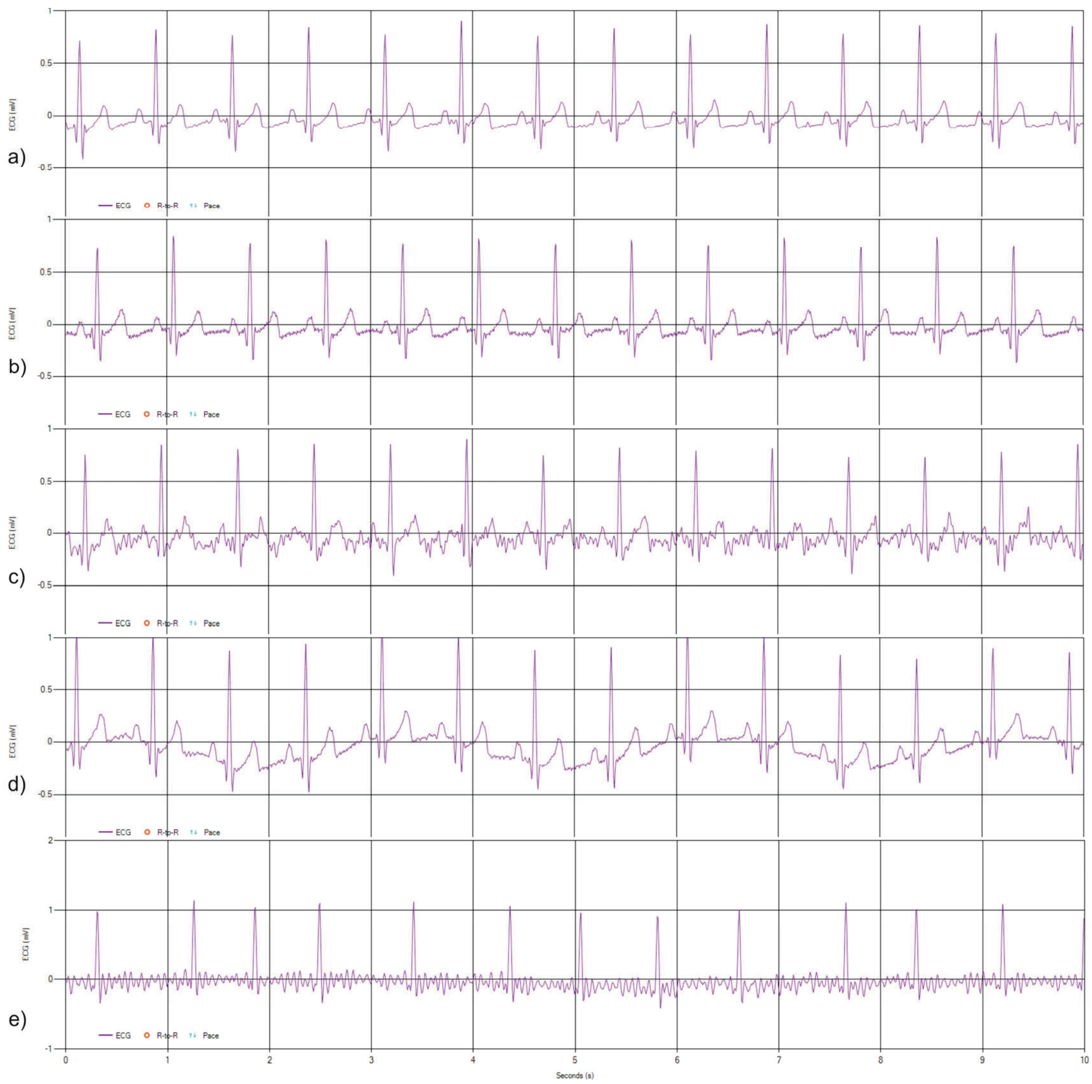

Fig 3 Different ECG signals generated by the ProSim 3 patient simulator

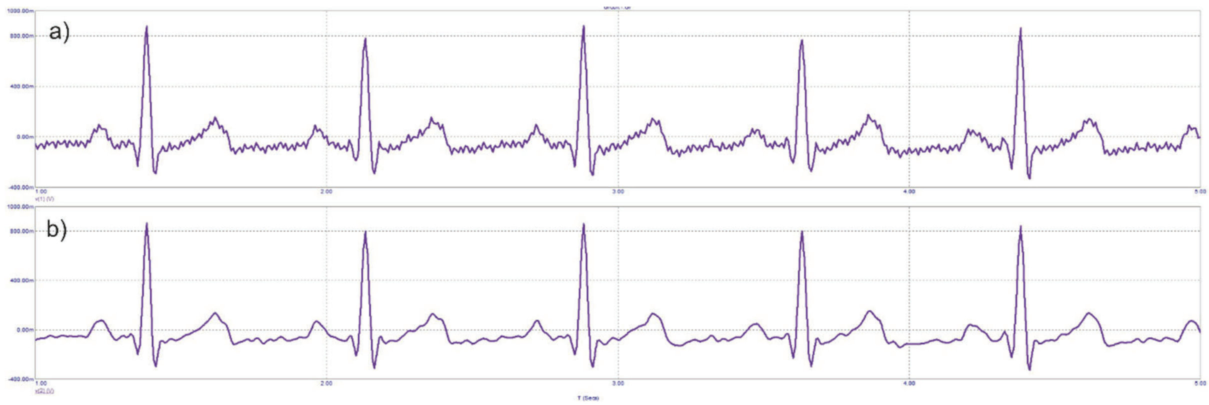

Fig 4 Raw and filtered ECG signals acquired using the MAX30001EVSYS evaluation kit

3. Experimental results

The obtained results presented on figures 3,4 show the efficiency of the used procedures. They can perform many different experiences, to set the used parameters in order to achieve the proposed goals.

Also, the different filtering techniques which can be implemented allow a good perception of the main issues in biomedical signal processing. The results are instantaneous viewable, the performed procedures can be evaluated quickly and accurately.

The used equipment allows a good practical experience in biomedical engineering is of great importance in terms of understanding concepts and assisting the retention of learning. These kind of hands-on experience as was presented, can be particularly beneficial in supporting the theoretical explanation of the acquisition, processing, and displaying of biomedical signals.

4. Concluding remarks

The huge interest in biomedical engineering area and a fast development of connected engineering fields provides opportunities both for educators and graduates to develop several teaching materials, methods and practical approaches.

This study has presented an evaluation kit and procedures to assist undergraduate students in their comprehensive understanding of the basics of biomedical engineering and how bioelectric signals are measured, acquired, analyzed, and processed to eliminate noise.

This kind of technology helps both the instructor and students to achieve the basic and necessary knowledge in this field.

The role and the need of biomedical engineering education is obvious, so this kind of educational kits, procedures are very important in the future engineering education.

References

[1] M. Akay (2012), *Biomedical signal processing*, Academic Press, London, UK, London, UK, 2012.

[2] J. D. Bronzino (2000), *Biomedical engineering handbook 2*, 2, Springer Science & Business Media, Florida, USA 2000.

[3] Greenberg JE, Delgutte B, Gray ML. Hands-on learning in biomedical signal processing (2003). IEEE Eng Med Biol Mag. Jul-Aug;22(4):71-9.

[4] Foulds RA, Bergen M, Mantilla BA. Integrated biomedical engineering education using studio-based learning (2003). IEEE Eng Med Biol Mag. Jul-Aug;22(4):92-100

[5] Kubicek, J.; Penhaker, M.; Krejcar, O.; Selamat, A. Modern Trends and Applications of Intelligent Methods in Biomedical Signal and Image Processing. Sensors 2021, 21, 847.

[6] Norton B.. Bioengineering programmes rise to meet the challenge of a young science (2000). Nature 403:463–65

[7] Allen RH, Acharya S, Jancuk C, Shoukas AA. Sharing best practices in teaching biomedical engineering design (2013). Ann. Biomed. Eng.;41:1869–1879

[8] M. Sawan, et al. (2021), *Emerging Trends of Biomedical Circuits and Systems,* Foundations and Trends® in Integrated Circuits and Systems: Vol. 1: No. 4, pp 217-411

[9] Bibbo D, Kijonka J, Kudrna P, Penhaker M, Vavra P, Zonca P. Design and Development of a Novel Invasive Blood Pressure Simulator for Patient's Monitor Testing. Sensors (Basel). 2020 Jan 1;20(1):259.

[10] Galya G, Evgeniya G, Krasimir C (2022). Cardiodiagnostics Based on Photoplethysmographic Signals. Diagnostics. 12. 412.

[11] J. Hampton, D. Adlam (2019) *The ECG Made Practical*, Elsevier Health Sciences, Digital version.

[12] Zeng R, Yue RZ, Tan CY, Wang Q, Kuang P, Tian PW, Zuo C. New ideas for teaching electrocardiogram interpretation and improving

classroom teaching content. Adv Med Educ Pract. 2015 Feb 10; 6:99-104.
[13] Little B, Mainie I, Ho KJ, Scott L. Electrocardiogram and rhythm strip interpretation by final year medical students. Ulster Med J. 2002;71(1):96.
[14] Simonsohn AB, Fischer MR. Evaluation of a case-based computerized learning program (CASUS) for medical students during their clinical years. Dtsch Med Wochenschr. 2004; 129:552–556.
[15] Hudson JN. Computer-aided learning in the real world of medical education: does the quality of interaction with the computer affect student learning? Med Educ. 2004; 38:887–895.