INITIATION INTO THE BIOSIGNAL ENGINEERS COMMUNITY

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Abstract: *This work gives examples of student activities aiming at assisted exploration of the biosignal engineering domain. The first step of this professional formation consists in observing and describing bioelectric phenomena. The last step is management of a real world research and development project in technical but also organization and financial aspects. The concerned educational path is applied in our University for several years and some of our most engaged students became leading engineers or even founded their own enterprises in the biosignal processing domain.*

1. Introduction

Since twenty years the biomedical applications of electronics are subject of lectures in the Institute of Automatics, University of Mining and Metallurgy in Kraków. During these years many circumstances influenced the changes in our approach to the biomedical engineering education:

- The extended range of abilities expected from a modern engineer no longer covered by the traditionally 'technical' domains.
- The political evolution towards the market economy and new demands put forward by the society of increasing purchasing power and life expectancy.
- The technical evolution in the domains of electronics and computer sciences, making the topic more complicated but also more challenging to the future inventors.

Currently, among the graduates from the UMM with a professional degree Master of Sciences in Electronic Engineering (MSc EE), 30 young people a year are highly specialized in biomedical applications.

Certainly, the continuous development of the BME educational profile is very challenging to the teaching staff and, in result many new proposals appear in course of lectures. Certain pedagogy-based rules are in use in order systematize the flow of the issues concerned:

- The order of the issues must follow the general pedagogical path – the direction of growing difficulty is commonly accepted.
- The issues should base on the knowledge of the available experts – the teaching staff of the University of Technology is not able to cover all areas of interest, but fortunately other medical experts in Krakow are willing to cooperate.
- The issues should be reflected in the equipment at certain level available for the laboratory tasks. We hope for better teaching result when students are practically operating the electronic equipment instead of having it theoretically described during lectures.

2. Milestones of the pedagogical path

In this paper we focus on the example pedagogical path, putting aside the problems of experts recruitment and the financial support for the highly specialized laboratory. The described path concerns the development of medical electronic equipment including biomedical signal processing. For this topic, high attention is paid to the practical exercises performed by the students themselves with methodological support of the teacher. The teachers' role here is rather to be an advisor than a supervisor – students are responsible for having completed the tasks correctly, to solve problems and to report all findings in a clear way. This approach assumes high personal involvement and high self-responsibility of each student. Combined with the challenging issue and systematically increasing tasks' complexity, the presented pedagogical path successfully evokes the creativity of future engineers.

The path consists of three elements usually applied during last three years of the five-year MSc EE study:

- Simple laboratory exercises - obligatory and thus performed by all the students, short-term (one hour and a half duration) practical tasks performed in the laboratory classroom. Each task is expected to give a precise answer to the fundamental questions from the closed question list and a short report on the obtained results.
- Development of the technical issue - optional mid-term (three months duration) tasks performed by students (in pairs) interested in the particular subject. The performance of these is not limited to the laboratory classroom. Each issue has to be developed to a technically correct procedure (in the software) or a hardware module working on the universal PCB.
- Management of the BME project – optional long-term (approximately one year duration) project being final masterwork for a degree of Master o Sciences in Electronic Engineering. The candidate is expected to conceive, realize and validate the medical electronic instrument including the appropriate software or the fully functional medical software system. The final report contains the product description, the technical and research documentation, user manual etc.,

After completion of the BME project, the candidate make a public presentation of the outcomes in front of the jury presided by the Head of the Department of Electric, Automatic, Computer Science and Electronic and receives a formal degree of MSc EE. Some outstanding projects interest the manufacturers of medical electronic equipment that establish separate relations with the graduates afterwards. Some projects are commercialized by the enterprises founded by the graduates themselves.

3. Pedagogical methodology

The milestones of the pedagogical path are not ordered randomly. The degree of tasks' complexity increases systematically along with the personal involvement of the concerned students. The students become more and more self-reliant and the contribution of their own inventions in the final outcome dominates the teacher's proposals. On the opposite, the count of the concerned people, initially large because of the obligatory character of simple laboratory tasks, drops down with time as the less interested students leave the biomedical specialization for the other options.

Another logical reason for the presented order of tasks is the growing base of knowledge of the students. Initially they build the answers and the solutions basing on the lecture or bibliography, but only the simple tasks may be completed in this way. And we find hardly possible to pass the spirit of 'discovering' or 'inventing' in this way. Fortunately, students gather their own experience and knowledge and, when only stimulated by the growing expectances from the teaching staff, learn to use them as a background for their own ideas. That prepares the future engineer to the conceptual work.

Third reason for the assumed order of tasks is the 'zoom out' concept of presentation of the area of biomedical engineering presented hereafter.

The simple laboratory tasks are experimental background for the past theoretical lecture (time interval one-two weeks) and evoke questions to explain and discuss in course of the future lectures. Its principal goal is to discover practical limitations and issues concerning the implementation of the theoretical knowledge. From this viewpoint the students are observing how the things work without touching them with their own ideas. Their attention is focussed on the most 'technical' layer of the problem. This corresponds to the duties of the technician in the industry that in general is instructed what and how to do. Despite the precisely formulated questions, some issues develop the conceptual thinking (i.e. proposals for answering problems intentionally omitted during the lecture). The laboratory tasks are for students also a decision stage whether to continue the specialization in BME or not. The experienced teaching staff is also able to distinguish the most involved students in the population.

Development of the technical issue faces the student towards a particular technical problem having at least one correct solution. The problem is formulated as a set of initial assumptions and a technically correct working outcome is expected as the result. No additional remarks or suggestions are made unless the student completely fails with his own ideas. Certainly, the teaching staff supports the students acting as an advisor and answering the questions or proposing the supplementary trials to do. The self-criticism is expected from the student developing the technical issue: the repeating trying – verifying approaches, inventing alternative solutions, making justified choice between alternative methods introduces the student to a real engineer's work. This task corresponds to duties of the engineering staff in the industry that has to know how to approach and solve particular technical problem in BME. However, for a group of students, a set of complementary real-world engineering problems is proposed giving them a feeling to work at the common employer. This enforces the spirit of responsibility and the care of the outcome.

Management of the BME project situates the student in the simulated chair of manager of technology in an enterprise. Since the task is equivalent to the MSc EE masterwork, the particular topic is chosen by the candidate from a registered list of proposals. The candidate is expected to develop a device or the software from the conceptual stage to the final fully functional prototype. He is also responsible for temporal and financial management of the project in a given framework in witch he is supported by the supervisor. All the technical solutions need to be justified on a technical or economical background. The candidate calculates the interest of finding an optimal solution and, when inventing new methods, is expected to assess them. Preparing the final report, the candidate should study the area of application of the outcome and its potential users, and explain the necessity of developing such product. This introduces him to the studies of the market in a real enterprise. Another part of the final report, probably the most difficult but obligatory, is the user manual. The student should accept the end-user point of view and clearly describe the function and operating of the device (or software). Avoiding the 'technical' language in the manual is the foundation of the future collaboration of engineers with the medical world. And finally, for the hardware-based projects, the study of the components availability in the market and the deliverability terms should be done as well as the list of technological processes to be ordered from third-party (i. e. the PCB's or housing manufacturing). The final examination in the form of public presentation is the last element preparing the student to the oral presentations, speeches and discussions with his future working party, supervisors or customers. Management of the BME projects gives students the most general outlook on the BME and its role in the contemporary world.

4. Examples of students' tasks

At the level of simple laboratory tasks all the tasks are displayed in an ordered list and are performed during the meetings every week. At two upper levels the list of proposals is displayed at least one month before the date being deadline for the students' choice. In exceptional cases the modifications of the tasks are allowed accordingly to the candidates proposal. At the highest level, the task list has to be approved by the Head of Department, who is the president of the jury receiving the final MSc EE examination. The duration for the development of technical issue is administratively limited to a semester and the management of the BME projects has no administrative limit but the students usually start their work by designing a working schedule that is accepted or corrected by the supervisor.

A. Simple laboratory task (example)

Title: Standard ECG processing stages

Aims: Introduction to the basic procedures of the ECG processing: QRS-detection and classification, rhythm measurements, distinction of ventricular beats, measurements of intervals P duration, P-Q, QRS duration, QT and QTc.

(All the italic printed questions are to be concerned in the final report)

1. Read the file d:\lab\ECG\e_sam10.dat and start the detector procedure. *Why the leading beats are not detected? Why the detection mark is delayed from the QRS peak?* Verify the correctness of the detection. *Indicate the false positive and false negative detections. Calculate the sensitivity and specificity of the detection method.*
2. Read the file d:\lab\ECG\e_sam12.dat (the signal contains ventricular tachycardia) and start the detector procedure and next the calculation of the RR intervals. *Are all the beats detected correctly? Explain the reason of bad detector behavior at very fast heart rates. Propose a reasonable solution* (the expected answer is: shorten the moving integral window).
3. Read the file d:\lab\ECG\e_sam13.dat (the signal contains two ventricular escape beats of different shapes) and start the detection procedure and next the beats classification procedure. *Are the ventricular beats classified in separate groups? Are the ventricular beats classified in one group? Are the sinus beats classified in one group?* Decrease the value of tolerance until the classifier assigns sinus beats to different classes. *Note this value.* Increase the value of tolerance until the classifier assigns ventricular beats to one class or misclassifies them with the sinus beats. *Note this value. Calculate the tolerance margin for this file.*
4. Etc.

B. Development of the technical issue (example)

Tile: Correcting the tachogram

The heart rate variability test (HRV) is commonly used for diagnosis of the relations of sympathetic and parasympathetic nervous system. The basic parameters can be derived from the raw tachogram by the use of statistics, but in common belief of cardiologists, the relations of spectral power in given frequency ranges are more appropriate for diagnosis. The raw tachogram of a Holter 24-hour recording is given in the table **`int RTach[200000]`** in milliseconds of RR interval. It has to be corrected for the following reasons:

- only sinus-originated beats are to be considered, and all other must be replaced by virtual events (not necessarily of the same count) at the appropriate moments
- the raw tachogram is irregularly sampled time function (the RR-interval is measured only at the points of occurrence of QRS-peak) and must not be directly processed by Fourier transform.

Propose the method of correcting both problems. Write a procedure having the raw tachogram as input (from disk file) and the corrected tachogram sampled at 2 Hz as output (to disk file). Consider the case of recording starting or ending with beats that has to be replaced.

C. Management of the BME project (example)

The task consists of designing, building and setting in operation a prototype of a battery operated remotely programmable three-channel recorder of the ECC, blood pressure and lung volume. The surface ECG is fed directly to the circuitry (5 mV full scale, 12-bit resolution). The blood pressure is measured with use of piezoelectric transducer and the lung volume is estimated with use of strain gauge. In ECG channel, the sampling frequency is 250 Hz and 20 Hz in the remaining channels. The storage media is the 2MB PCIMCIA-ATA electronic disk and a new file is opened each time the recording is started. Each file contains the recording start- and endtime, the active channels and the signal. The recorder is remotely operated via a serial communication port using a 1mW radio-modem module. The command set is limited to 'start', 'stop', active channels' definition and the settings of on-board real-time clock.

5. Concluding remarks

The education of the engineer of electronics working in the BME area is the long and expensive process. Several general rules applied in course of the education process facilitates the teachers role:

- the evolution from the easier to more difficult issues,
- the evolution from technical details to generalized outlook,
- the increasing of difficulty level and expectances,
- the increasing of students personal involvement and confidence.

By the final examination, the candidate is no longer a subject of the educational process but he (or she) becomes the professional partner of the teacher. The graduates often occupy the exposed posts of technology managers in BME-related enterprises or sometimes establish their own independent business. Few of them continue the education on the PhD study in our University. But regardless the future careers, the graduates always willingly collaborate with the university staff.

6. Acknowledgment

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