EDUCATION OF BIOMEDICAL ISSUES TO THE REGULAR STUDENTS OF THE FACULTY OF ELECTRONIC

Andrzej Izworski, Ryszard Tadeusiewicz, Piotr Augustyniak

University of Mining and Metallurgy, Institute of Automatics
Mickiewicza Ave 30. PL-30-059 Krakow, Poland
email: august@biocyb.ia.agh.edu.pl, phone: (+48.12) 617.38.51, fax: (+48.12) 634.15.68

Abstract: *This paper describes the lectures and laboratory activities concerning the biomedical applications of electronics and their schedule in the five-year MSc study. Some initial issues are obligatory and concern all students regardless their future professional orientation. Another advanced lectures are proposed as optional for the most interested participants. The educational process involves the students also in a series of practical exercises progressively growing in difficulty level.*

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. The single optional lecture at the very beginning became a complex educational approach and delivers yearly 30 graduates with a professional title Master of Sciences in Electronic Engineering highly specialized in biomedical applications. This evolution reflects the general changes of our society, its expectations and the factors influencing the common meaning of the quality of life. The changes were also inspired by the currently promoted role of an engineer in the society, not satisfying himself by the skills to solve technical problems but capable also to a more humanistic approach to find in his environment the most important issues to solve with the traditionally 'technical' methods.

For this reason, in course of the five-year studies in the faculty of electronics, the students from the 'biomedical group' are proposed several lectures introducing to them the wide area of biological and medical applications of technical sciences. Certainly, the participants are technically oriented people and need to have also some biological and medical background that is particularly difficult to teach in the University of Technology. Another problem is the teaching staff experience in biomedicine. The notion of 'experience' has here wide meaning:

- Collaborating with the doctors or medical scientists,
- Knowing the principles of the anatomy, physiology, biochemistry and others,
- Developing of new electronic systems (also including software) for medical purpose,
- Solving biomedical problems with use of statistics, mathematics (including modeling) or numerical methods embedded in the software developed for the biomedical use,
- Having the knowledge of the biomedical market and its trends,

This paper describes the lectures and laboratory activities proposed to the students specialized in biomedical applications of electronics, their aims and covered subjects and the schedule in the five-year MSc EE study.

The lectures proposed to the students generally fall into two categories (tab. 1):

– basic, being also obligatory and giving the very first introduction to the problems of BME,
– advanced, proposed as options, devoted to the presentation of particular BME branches, methods, tools and approaches used for solving BME problems in contemporary clinical and laboratory practice.

As this is typical for the University of Technology, all lectures are accompanied by laboratory exercises or development of technical issues performed by the students.

Table 1. The schedule of biomedical lectures in course of five-year MSc EE study

lecture title	year	category	practical exercises	material engagement	difficulty level
biometry	2-nd	basic	lab	low	low
problems of medical informatics	2-nd	basic	lab	low	medium
foundations of medical electronic equipment	3-rd	basic	lab	high ♣♥	medium
biocybernetics	4-th	basic	lab	medium ♦	medium
automated support of medical diagnostics	4-th	advanced	iss	medium ♦	high
biomedical signal processing	4-th	advanced	iss	medium ♣♦	very high
man-to-machine vocal interaction	5-th	advanced	iss	medium ♦	high
neural networks in biomedical signal processing	5-th	advanced	lab	medium ♦	medium

Notes: lab – one-and-a-half hour meetings in the laboratory classroom
iss – development of one of technical issues from a list on the student's choice
♣ - specialized, expensive medical equipment or special custom-made didactic aids
♦ - specialized or custom-developed didactic-purpose software
♥ - engagement of extra-university personnel

2. Basic lectures

A. Biometry is proposed in the second year of the study. The topic concerns the statistical methods applied to the medical and biological data. Particular solutions are presented to the students, like statistical evaluation of the therapy or assessment of drugs efficacy. The statistical methods in medicine are then used to optimize the therapeutical effects or minimize the costs of the in-hospital care. Another issue concerned by the biometry is the verification of statistical hypotheses on the differences of patient's groups or the therapeutical methods. Some examples of investigations for the correlations in medical data are studied. The final issue consists of examples of medical reasoning based on the data correlation or regression. All examples are presented in context of real clinical data delivered by collaborating institutions. The practical exercises are performed in the computer laboratory. The students are expected to write several standard biometrics procedures (in Pascal or C++) and to test them on the original medical data. The final task is slightly more complicated and consists in solving a given medical problem with use of the appropriate biometry methods.

B. Problems of medical informatics are also presented in the second year of the study. The topic concerns all applications of computer sciences in biology and medicine: data storage and management, telecommunication systems, networking, security and data access and signal processing. Some of the world-standardized systems for medical data management (e. g. HL7) are used as examples of hospital informatic system (HIS). Those specialized

software systems consider many aspects of information storage and processing like patient flow, drugs control, statistical data and diagnostic information. The format of information representation may be of any kind: signals, images, text, binary, voice, motion pictures and others. The issue of security of medical data is particularly focussed recently. Various methods of the authorization of the access to the data are discussed in context of legal regulations of the US, UE and our country (e. g. Trusted Computer System Evaluated Criteria, TCSEC). In course of the practical laboratory activities students are expected to develop a working subroutine meeting the assumed criteria in each of the following domain: databases for medicine, access control and authorization, networking in a hospital and multi-layer telecommunication.

C. Foundations of medical electronic equipment is the obligatory lecture dedicated to the third-year students. All main branches of diagnostic, therapeutic and prosthetic application of electronic are concerned in course of the lecture. The theoretical lecture part is devoted to the description of the medical expectances, functions, physical principles of each device and its circuitry, designing details and development rules. The corresponding practical laboratory exercises are introduction to operating an electrocardiograph or a spirometer, observing the functions of hemodialysis equipment or a cardiac pacemaker on a phantom and assisting to the X-ray tomography in the collaborating hospital (for volunteers). Students are expected to develop a technical issue chosen from the list. The analog-signal module of an ECG recorder or the transducer module (blood pressure, temperature etc.) are typically proposed issues. Certainly, the topics concerned in course of this lecture belong to a list being a compromise of its novelty and attractivity on one hand and the material and organization circumstances in our laboratory on the other. We avoid touching the subject that can only be theoretically explained (i. e. spiral tomography). Nevertheless, we pay a particular attention to concern as wide range of different devices as possible in course of the allotted fifteen meetings.

D. Biocybernetics is the obligatory lecture for the fourth-year students. Its goal is describing the fundamental physiological processes from the viewpoint of regulation and control theory. Students, having already a background in the technical applications of automatics, now discover the proportional control or the negative feedback in the nervous or hormonal systems of the living organism. Or, in course of studying the behavior of temperature or illumination receptors, they find the similarity to the analog-to-digital converter. Main goal of this lecture is to schematize the processes of control and information interchanges in the living body. This is considered as a foundation of understanding the principles of physiology and the diagnostics, with the electrodiagnostic in the foreground. The practical exercises in the laboratory classroom are mainly devoted to the mathematical models of the fundamental physiological processes. The models proposed by students are implemented and solved in the software environment and the outputs are subject to verification with use of the real medical data.

3. Advanced lectures

A. Automated support of medical diagnostics is proposed as an optional lecture to the fourth-year students. The main goal of the lecture is the presentation of an algorithmic approach to the medical diagnosis. The advantages of applying this approach are twofold: standardization of the decision path and computer-based support for the medical decisions. The decision process in several exemplary medical domains (i. e. infarct's statement) are transformed to the tree structure and implemented to the expert system software. Simple binary logic-based examples concerned in the foreword meetings are successively complemented by the implementations using the fuzzy logic and the artificial neural networks (ANN). The lecture also provides examples of typical implementations of decision-making

systems in automated medical electronic equipment (e. g. electrocardiograph). The methods of testing the reliability and confidence level of the automatically supported diagnosis are separately discussed during the closing meetings. In case of cardiology, two world-standardized databases are in use. They provide several annotated examples of typical cardiac pathologies. As the practical exercises, students are expected to develop the technical issue chosen from the list. The variety of options includes ECG arrhythmia detector, recognition of tumor patterns in the X-ray images or identification of equilibrium sense disorders based on the nystagmus signals.

B. Biomedical signal processing is the optional lecture proposed to the fourth-year students. It concerns all problems specific to the extraction of medically important features from the recorded time-series. At the beginning, all technical aspects of ECG signal processing typical to the stand-alone recorders, ambulatory long-term (Holter) analysis and stress test are detaily studied. They are supported by examples of possible algorithmic solutions and implementation dependent conditions. Rarely acquired but medically meaningful cardiac signals: vectocardiography, fetal electrocardiography or polycardiography completes the main area of presentation. The EEG signals processing is presented next with its applications to the epilepsy detection, the visually evoked potentials analysis and brainstem auditory evoked potentials assessment for the objective audiometry. The leading electrodiagnostic techniques are completed by description of electromyography (EMG) and electronystagmography (ENG). Also the EMG and ENG specific signal processing methods are detaily investigated. Some polyelectrographic applications are presented thereafter. Apart from the polycardiography mentioned above, the polysomnography, cardiotocography and electrohisterography are considered as examples of joint electrodiagnostic recording techniques. Besides the signal-specific processing methods, several common problems are discussed in course of the lecture: the data compression techniques and the problem of data loss, the use of approximation for the missing data, finally, the modern mathematics in particular the time-frequency signal representation. This last topic is considered with special attention justified by the constantly growing area of application in biomedical signal processing. Students are expected to develop the technical issue chosen from the list. All proposed problems are complementary and all are procedures of ambulatory ECG diagnostic software. Students have thus the impression to work in the common project at a real manufacturing enterprise.

C. Man-to-machine vocal interaction is proposed to the fifth-year students. The lecture is devoted to the vide range of applications of computerized voice recognition and synthesis. The reason to consider this lecture together with the biomedicaly-oriented lectures is twofold: The issue of automated voice recognition involves many problems typical to the medical pattern recognition or medical signal processing and thus is very similar to the medical applications of modern electronics. The second reason is the use of speech recognition methods to the diagnostic of disorders in the human vocal tract, being a true medical application. The speech recognition involves many methods of advanced mathematics: time-frequency analysis, higher order spectra and others. Students are expected to write their own speech recognition procedure at their choice following the given instruction. All working outcome written in Pascal or C++ is accepted, but for some real time applications the speed optimization is required. The verification is based on the real signal, in case of command recognition procedures the students' voices are used, but in case of pathological speech processing we should rely on the recorded examples.

D. Neural networks in biomedical signal processing is the optional lecture proposed to the fifth-year students. Main goal of this lecture is the description of alternative methods for biomedical signal classification, for the medical decision support and for extraction of medical features. All essential ANN topologies and training methods are detaily discussed and, in course of the laboratory exercises, students are expected to determine their features in application to the real medical data. The neural network approach, however the most difficult to transform to the real-world application, closely simulates the reasoning of the medical expert. This is particularly valid for the classification of signals, where some important information may already be lost at the features extraction stage. Nevertheless, the trained ANN recognizes the pathological pattern among variable-shaped physiological examples. Except for accustomizing the very promising methodology, students are gathering experience in handling the information in the noisy environment of medical data.

4. Concluding remarks

The education of the biomedical-oriented engineers of electronics is a difficult interdisciplinary task. It involves the engagement of medical experts not available at the university of technology. In our case, we are fortunate to collaborate with very dedicated doctors devoting many hours of their spare time for doing voluntary work for our students. In addition, special expenses should be granted from the university for the laboratory equipment. Although some practical exercises might be performed in the general-purpose computer laboratory, we consider incorrect and even unfair teaching the issues of engineering without the background consisting of specialized, clinically used devices. In this area, we are fortunate again to be fairly understood by the financial-responsible manager of the university and to have a close cooperation with the country-biggest ECG-equipment manufacturing enterprise. This cooperation is worth a notice because of the profits to both partners: the university is supported in the equipment purchase and the enterprise may be supplied with the best graduates from our faculty.

Although the BME education profile is well ingrained in our faculty, it is the subject of our constant care. All external circumstances change rapidly and put extra demands on our graduates. Our task is to know today the expectances of tomorrow and to correctly adapt the topics concerned by our lectures. Each graduate having difficulties in his professional live is our failure. Fortunately, they are not very many.

5. Acknowledgment

This work is supported by Aspel S.A., 32-080 Zabierzów Poland, 33 Sienkiewicza St.

References:

[1] Tadeusiewicz R. "Foundations of medical electronic equipment" (in Polish) UMM printed series of course lectures No. 640, Kraków 1978

[2] Tadeusiewicz R., Izworski A., Majewski J. “Biometry” (in Polish) UMM publications, Kraków, 1993

[3] Tadeusiewicz R., Izworski A., Augustyniak P. "Formation of Medical Physics Students in the Field of Electronics Medical Equipment" in Proc. 10-th Congress of the Polish Society of Medical Physics, Kraków Sept. 15-18, 1995, p19

[4] Augustyniak P., Izworski A. "Educational Software for a Student Laboratory of Automated Electrocardiogram Analysis" in Proc. 10-th Congress of the Polish Society of Medical Physics, Kraków Sept. 15-18, 1995, pp 23-25.