MOLEKULÁRIS BIONIKA ÉS INFOBIONIKA SZAKOK TANANYAGÁNAK KOMPLEX FEJLESZTÉSE KONZORCIUMI KERETBEN 2010-2011

Konzorcium vezető:
Pázmány Péter Katolikus Egyetem

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Semmelweis Egyetem
NORDEX Kulturális és Kereskedelmi Kft.

COMPLEX DEVELOPMENT OF TEACHING MATERIALS FOR MOLECULAR BIONICS BSC AND INFOBIONICS MSC COURSES WITHIN CONSORTIUM
2010-2011

Consortium leader:
Pázmány Péter Catholic Univesity (leader)

Members:
Semmelweis University
NORDEX Cultural and Trading Ltd.

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A borítón Nyíri Gábor (IEM-HAS) képe látható: A hippocampus főneuronjai és interneuronjai.

Cover image by Gábor Nyíri(IEM-HAS): Principal neurons and interneurons of hippocampus.

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Contents

Complex Development of Teaching Materials for Molecular Bionics BSc and Infobionics MSc Courses within Consortium

Preface to the Proceedings of the Closing Conference of
TÁMOP-4.1.208/2/A/KMR-2009-006 Grant

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Keywords - curricula development, molecular bionics, infobionics, TÁMOP 4.1.208/2/A/KMR-2009-006 Grant

I. INTRODUCTION

Information technology and biotechnology are two examples of the most innovative modern technology. Considering the latter, we are witnessing an incredibly fast development and the emergence of a new area. This development is even faster than the development of information technology was in its early stages.

Bionics is the study of the functions of living organisms for the purpose of building mechanical or electronic devices to copy or imitate these functions. For the first time in the history of technology we have instruments that allow us both to observe molecules and molecule-sized parts, and to construct molecule-sized machines. At the same time, computer technology opened up surprisingly new opportunities. Micro-technology and microelectronics together with the recently emerged nanotechnology made it possible to grab and modify the electromagnetic interactions, which determine molecular dynamics.

Using all this new technology, engineers can build machines, that can not only detect the changes or movements of living organisms at the molecular level, but can also react to, interact with and display these physical phenomena. There are several types of these machines; some of them can even be programmed.

Entire series of new molecular imaging systems are being born. New opportunities are opened to develop biotic and abiotic interfaces, smart "prostheses" and “smart” drugs.

Drugs, which can “realize” the needs of the patient by sensing his/her biochemical properties. These properties can be measured by a laboratory: complete chemical and biological laboratories can be built on just one chip, produced by mass production. An example of such a lab is a DNA-determining gene-chip.

The Pázmány Péter Catholic University, Faculty of Information Technology (PPCU FIT), together with the Semmelweis University (SU) were the first universities in Hungary to launch the Molecular Bionics BSc in the year 2008. Subjects, covering these abovementioned incredible topics are taught already at BSc level.

From February 2012 on we also launch the new infobionics MSc, which is probably the first in the world with its curricula and profile. Professionals are going to be trained here, who would be skilled not only in the field of information technology, as it is indicated in the name of the Faculty, and not only in biotechnology, but they also will be experts in understanding and applying the fundamental

quantitative rules of operations of living organisms. They will have the opportunity to be involved in the process of application of the new technology outlined above, and will also be able to shape the new fields in the subject area.

The teachers of both of the molecular bionics BSc and the infobionics MSc have outstanding international reputation. Six of them are members of the Hungarian Academy of Sciences, which is the highest scientific recognition in Hungary, a further ten have a title of Doctor of Science, which is the possible highest scientific degree in Hungary.

This conference volume consists of the summaries of all academic subjects that were developed by the support of the TÁMOP-4.1.208/2/A/KMR-2009-006 grant. We cover the most important subjects of the two degree programs.

II. Project Objectives

The PPCU FIT, SU and Dialog Campus Publisher (DCP) formed a consortium for carrying out the objectives of the TÁMOP-4.1.2-08/2/A/KMR-2009-006 project.

The main purpose of this cooperation is to standardize the professional content of the molecular bionics and infobionics courses, and develop the material in a fairly detailed way.

Teaching materials will be written in English and published on the World Wide Web, so the materials will be available free of charge to all interested parties - in order to make the learning process of these new disciplines easier.

In addition, to help the individuals learning the new concepts in the curricula both in English and in Hungarian, the participants will develop a dictionary of the main notions in English, a bilingual dictionary in English and Hungarian and complete these dictionaries a bilingual glossary of the keywords.

The assessment for the future development of the curricula will be analyzed by the leaders of the two universities. According to the conditions of the TÁMOP grant, this analysis will also lead to proposing rules for obtaining additional credits for the academic plans of the students, for learning some or all of the subjects in English.

III. Results

The work, led by the leading professors of the two universities, resulted in the preparation of the teaching material of seventeen courses in English, -having at least 12 slide presentations for each- and in one computer animation (also in English). More than 12,000 slides organized in lectures have already been placed in the intranet of the PPCU FIT.

The English and the English-Hungarian dictionaries contain more than 2000 headwords, and the same numbers of words are extracted from the dictionary into the bilingual glossary.

Among the subjects, which belong directly or indirectly to the area of bionics and infobionics, one can find an additional topic, which we think is very important for everyone, especially for scientists doing research in the area of bionics or infobionics. This is ethics, to be more precise: bioethics and environmental ethics. In this project an e-book was written in English, dealing with the ethical problems arising unavoidably if one deals with living organisms, especially humans.

The subjects and other additional tasks are listed in Table 1 and 2 at the end of this present paper.

The curricula have been reviewed and analyzed by the leaders of the universities. A study was written by the Dean of the PPCU FIT, involving the future development of the courses, and a proposal for credits for learning the subjects in English.

The authors-, as well as other subject experts, an expert teacher and an English proofreader participated in the development part of the project, which involved altogether not less than 60 people.

The authors, who are not only lecturers but also leading researchers, and in this latter role they also are pioneers of these new disciplines, made an effort to embed the new re-

search results and inventions in–to the teaching materials.

Each subject was proofread by widely recognized experts. The experienced professionals in the DCP Company ensure Proofreading, and a suitable format for the web publishing of the study materials, dictionaries and vocabularies.

IV. Effect of The Project and Future Work

The students enrolled in the molecular bionics BSc program have already access to the study materials from fall 2011 in the intranet of PPCU FIT.

However, these materials are also important source of knowledge for those with an academic background: teachers may get examples for illustrating the applications and usage of the theoretical knowledge. This way they have a chance to integrate this new knowledge into their subjects. Thus, the integration between the subjects already play a significant role in these materials.

Furthermore, the developed materials have not yet exhausted all the possibilities the World Wide Web offers. Other interactive elements may be added to the learning materials, in order to make them suitable for independent learning. This enhancement will be useful not only for Hungarian students - who are willing to take their courses in English - but it would also give us the opportunity to involve some non-Hungarian students in these pioneering courses.

Conclusion and cknowledgment

Based on these facts above, we have every hope that high-quality, valuable material will be published on the web-site http://www.tankkonyvtar.hu, hosted by the Education Social Services Non-Profit Limited Liability Company.

Thanks to the supporters: this project was possible to carry out through funding granted by the New Hungary Development Plan of the National Development Agency, within the framework of the Transport Operational Programme, and the Social Renewal Operational Programme of the European Union, co-financed by the Ministry of Education and Culture.

Special thanks to the Dean of the PPCU FIT (the leader of the Consorcium), for the opportunity to work in this project. We would like to express our gratitude also to all Authors and other Professionals, Proofreaders, language and teaching Experts and other Participants who provided their assistance, including our Students, for their enthusiasm in the work, which I hope, has been and will be useful not only for our students, but for ourselves as well.

References

[1] Complex Development of Teaching Materials for Molecular Bionics BSc and Infobionics MSc Courses within Consortium, Grant Proposal TÁMOP-4.1.208/2/A/KMR-2009-006, 2009., PPCU FIT (in Hungarian)

[2] Judit Nyékyné Gaizler, The establishment and development of the curricula od Molecular Bionics and Infobionics, PPCU FIT (in Hungarian, Project work)

Table 1 List of subjects

E-book:
Bio-, and environmental ethics
Slide presentations:
Ad hoc sensor networks
Basics to neurobiology
Biomedical imaging
Digital- and neural based signal processing and kiloprocessor arrays
Electrical measurements
Electrophysiological methods for the study of the nervous- and muscular system
Introduction to bioinformatics
Introduction to biophysics
Introduction to functional neurobiology and additional animation
Modeling neurons and networks
Neural interfaces and prostheses
Neuromorph movement control
Organic- and biochemistry
Physics for nanobiotechnology
VLSI design methodologies
World of molecules

Project Task	Person (if not working for PPCU FIT, the institute is written)
TEACHING MATERIALS	
E-book, slide presentations, dictionaries, vocabularies	Authors are listed in the corresponding papers
OTHER PROFESSIONAL WORKS	
Curricula analysis and development(study written in Hungarian)	Judit Nyékyné dr. Gaizler dean of PPCU FIT
Review of curricula	Péter Mátyus, Head of Department of Organic Chemistry, SU
Animation	Imre Kalló associate professor
OTHER PROFESSIONAL WORK FOR ELABORATING STUDY MATERIALS	
Language expert	Márton Péri professional language teacher
Teaching expert	Beáta Kotschy college professor, Sapientia College of Theology of Religious Orders
Proofreaders	Endre Barta, Péter Fürjesi, László Füstöss, Sándor György, Erik Hrabovszky, Gyula Kovács, Lóránt Kovács,János Makó, András Poppe, András Szilágyi, Balázs Újfalussy, András Varró, Lucia Wittner, Géza Zboray
ORGANIZATION, FINANCE	
Project manager	Ferenc Kovács professor emeritus
Project manager	Péter Mátyus professor,Head of Department of Organic Chemistry, SU
Project professional manager	Ágnes Bércesné Novák associate professor
Financial project manager	Éva Szitáné Németh financial manager
Administrative work	Erika Aliné Csereháti, Kriszta Csörgőné König
TECHNICAL HELP	
File formats, preparing web-publishing	Dialog-Campus Publishing and Co.
Server administration	Dávid Tisza
Photo/Photo album Video	József Illés/Zoltán Mandácskó József Illés,
Technical editors of the proceeding of the closing conference	László Füredi

TABLE 2 THE MAIN TASKS OF THE TÁMOP-4.1.2 08/2/A/KMR-2009-006 PROJECT

Introduction to Bioinformatics

A Course Material

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***Summary* – In this paper we discuss the development of an introductory course for bioinformatics. We list the necessary requirements, the competency aimed to achieve, the topics covered by the chapters, and finally some considerations for teaching.**

Keywords - molecular biology; component; bioinformatics; course

I. INTRODUCTION

One way bioinformatics can be broadly defined as the management of the life sciences. As an applied science it uses computer programs to process data archived by modern molecular biology and thus to derive useful new information.

The importance of bioinformatics has grown enormously in the last decade due to the advance and development of high-throughput data acquisition methods primarily that of sequencing. High-throughput sequencing techniques (e.g. next generation DNA sequencing) generate a flood of valuable sequence data which is a challenge for the scientists.

The aim of developing this course material is to provide the students basic knowledge in bioinformatics. The subject of this course is meant to strengthen the bioinformatics problem solving competency of the students as well as their ability to communicate with life science professionals who are the ultimate users of bioinformatics. By taking this course, the students should be able to determine the types of questions the computer programs ("tools") – developed to work with genome and protein data archives – can answer, and to use these tools to gain answers to such questions.

In addition, our teaching material can also be useful for biologists who want to understand the algorithms that are behind the frequently used applications of the net (e.g. BLAST).

A. Prerequisites

Students are supposed to have taken a course on molecular biology and have some basic knowledge of biochemistry and molecular biology. Nevertheless, at the beginning of the course a biology primer summarizes the biological fundamentals necessary for this course so the students can start from an equal level.

They should have also completed an introductory database course since the data to be processed by the bioinformatics tools are stored in databases.

In addition, the students definitely should be competent computer users; however, we do not require knowledge of any specific programming language, because during the presentations very few algorithm details are discussed and – when they are – they are provided in a so-called pseudo language which can be understood without any programming background.

B. Some considerations

Bioinformatics is a relatively new area of science; consequently it is a novel subject of teaching.

In developing the teaching material we used the latest editions of standard bioinformatics textbooks, and the numerous websites of universities, research institutes and public databases (e.g. NCBI) related to this subject. Of course we also used our experience in teaching bioinformatics which has accumulated during the last decade.

Our approach is somewhat different from the conventional way of teaching bioinformatics. As our referee wrote "… this is the first comprehensive bioinformatics course in Hungary which is suitable for teaching students who have only basic knowledge of biology. For the first time the teaching material collects the algorithms used in bioinformatics in a way which is understandable not only for mathematicians. After the course the students will be able to understand, apply and even further develop the most frequently used bioinformatics algorithms."

The choice of topics in bioinformatics is very wide. Since this course is limited to one semester, we had to restrict ourselves to an essential core of material covering the most standard bioinformatics tasks and had to leave some areas untouched (e.g. drug discovery, protein structure).

Another but smaller scale problem: bioinformatics is not standardized and – depending on the authors – the meaning of terms might change somewhat. In the associated terminology file we provide the meanings for terms we found most commonly accepted.

II. RESULT

During the development of the course material we created 12 chapters with 465 slides.

A number of the chapters were necessary to be developed for providing background information: either biology/database knowledge, or detailed method descriptions of various biological data collections.

The first two chapters provide reviews of molecular biology and databases. This helps students to get on an equal level of the prerequisites.

Chapter 3 and 4 cover the most widely known areas of bioinformatics, namely the sequence alignment algorithms and the strategies of BLAST in details. The students are thought a couple of particularly key points in these chapters:

- The cost and the importance of expected execution time is introduced.
- The difference between exhaustive algorithms (Needleman-Wunsch and Smith-Waterman) and heuristic algorithms (FASTA and BLAST) is emphasized.

The fifth chapter deals with the generation of DNA databases: DNA cloning and sequencing. The students can have an insight into the most frequently used molecular biology methods to manipulate DNA.

The sixth chapter summarizes our current knowledge of proteomics. Proteomics is a brand new subject since the high-throughput methods for analyzing proteomes are lagged behind the methods of DNA analysis. However, it is not difficult to predict that proteomics will be one of the most important areas of bioinformatics in the future

Chapter 7 discusses the different DNA and protein sequencing algorithms.

In Chapter 8 we give a picture about the methods suitable for analyzing gene expression. The most important method is the DNA microarray which is discussed in detail. We also deal with the more conventional methods (e.g. EST databases) and the application of gene expression data.

The ninth chapter details different algorithms that can be used for gene prediction in DNA sequences.

Chapter 10 discusses how various data mining techniques are used for clustering genes based on their functionalities.

In Chapter 11 we detail the three approaches (brute force, clique search, and heuristic search) for solving the motif finding problem. This serves a good opportunity to compare the execution times of the different solutions.

Finally, in the twelfth chapter we introduce the morphological and molecular phylogenetics, and then we present three algorithms using different methods (parsimony, distance-based and likelihood-based).

III. Teaching Methods

The slides of these chapters can be presented during lectures, and then we recommend the following additional lab and/or home works:

- Short exercises (e.g. pair-wise sequence alignment).
- So-called "weblems" which are using some sophisticated tools that are to process some biological archives and available free over the internet. Typically, you do not need to install these tools, but rather the calculation can be run through directly a web interface.

A couple of final warnings for the instructors:

- A serious problem with the web is that sites come and go, therefore – even though our slides provide exact tool-websites – you should check the best available tools and archive sites for the exercises at the time when the course is given.
- Bioinformatics is an extremely fast growing field, so when you use this material for teaching, check all numerical data mentioned on the slides, because some might get completely out of date and needs to be updated before the slides are presented.

Introduction to Electrical Measurements

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***Summary* — In this document, a brief summary of the educational material for the electrical measurements course is presented. The presented material gives a general engineering overview for the new students of bionics, information technology and engineering about electrical measurements among their professional subjects. This develops their approach as engineers and inspires the study of the basic courses at a high standard.**

Keywords - biological and medical measurements; measurement of voltage, current, time and frequency; signal processing; GPS; networks and systems; semiconductor basics; nonlinear resistive networks; logic and binary systems; microcontrollers;

I. INTRODUCTION

The students studying engineering and the adjoining areas of engineering are mainly studying theoretical, basic subjects in the course of their first few semesters. The knowledge that they need in the engineering practice and in their later work will be acquired in the course of subsequent semesters. The drawback of this is first of all that they encounter their first engineering problem relatively late, thereby they cannot face their choice of profession early enough, and a possible change of studies will result in the loss of years. Second, the basic subjects often seem to be too tiresome, leaving the students unmotivated. The goal of the electrical measurements course is to give a satisfying solution to both of these problems. It may help students make a mature decision about their choice of profession, giving them information about their choice and helping them decide if they are fit for the engineering work. At the same time, it presents the range of bionics, engineering and information technology that students will encounter later on. The overview and experimenting may be inspiring, giving endurance for the high standard learning of the basic subjects.

In several universities of the USA, there are introductory subjects that serve as the first steps towards an engineering approach, while giving an overview of the problems of the specific areas of engineering. The subject presented here wants to satisfy this function as well.

A. Highschool background

Basically, this subject sets two prerequisites for students: knowledge of mathematics and physics. The learning of these is set for the first semester, and an additional physics revision is also compulsory.

II. METHODS

The goal of the electrical measurements course and material is to give a general view of the basic theory and practice of electrical engineering to the bionics and information technology students who enter university, moreover, without exaggeration, they can catch a glimpse of the whole of information technology, electrical engineering and bionics. The novelty of this material can be found in this fact: it breaks away from the concept that each and every scientific area should be discussed in detail for 1, 2 or 3 semesters, and the whole knowledge is put together at the end of the 3-5 year training. Instead, it aims at a

general knowledge: the theoretical material is constantly supported by practical measurement problems, which strongly motivates students, while the above mentioned general knowledge is created, on which the specific scientific areas may more successfully build the knowledge of the specific subjects.

This material includes the basic elements of network theory, systems theory, analog electronics and digital technology, while also presenting the most modern applications of these areas such as GPS navigation technology, wireless sensor systems and microcontroller embedded systems.

The authors intended to emphasize both basic knowledge and its modern applications.

Because this material is introductory and covers a huge topic area, the expert reader might feel that it is incomplete, but this is only natural as this subject intends only to give the most basic knowledge, the more specific parts will be taught in different courses. By studying all of the materials, the reader will get a full view.

This material is important and useful in the information technological, electrical engineering and medical fields, since measurements is a defining and the most interesting part of these fields. Through this can we approach the more ”tangible” parts of our profession, which is an important motivational element in our concept.

III. Results

We elaborated 12 chapters, 662 slides with lots informative figures. The main chapters are the following:

Introduction and principles of measurements: This chapter discusses the requirements of the course, presents the historical premises of measurements, and discusses the basic concepts of measurements (concept of measurement, uncertainty of measurement, noise and its sources, basic measurement setups and methods).

Uncertainty of measurement: This chapter discusses the questions of the noise and uncer-

Measurement of voltage, current, time and frequency: We present here the basic measurement methods that traditionally give the general modules of more complex instruments and measurement systems.

Fundamentals of signal processing: The chapter presents the basic elements of signal processing and systems theory.

Positioning systems: This chapter primarily discusses the GPS system and the positioning techniques used in WSNs.

Theoratical approach to networks and systems: This chapter gives an overview of the basic laws of electricity.

Semiconductor basics: The chapter intends to give a high standard introduction to semiconductors.

Nonlinear resistive networks: Here we discuss the calculation of the operation point of semiconductor instruments.

Logic and binary systems, basic operations: Here we discuss the foundations of the chapter Microcontrollers.

Microcontrollers: In the lab courses, the programming of microprocessors is practiced, therefore its most basic foundations and functions are presented within this chapter.

Basics of biological and medical measurements: Starting from the traditional medical measurement principles and methods, we proceed to the discussion of the most modern measurement tools.

Laboratory exercises: This chapter gives a brief summary to the LabVIEW programming environment and to the dataflow concept programming. It presents the ELVIS system and its functions used in measurements.

The tendencies experienced in the course of testing show that students find it difficult to adapt to the requirements of this course. The results of the first test do not show the expected outcome, which is an important warning for the students to take this course seriously. According to the anonymous questionnaire at the end of the year and later on, students

structure and material of the course, and about the education during the semester.

IV. CONCLUSION

In addition to giving an insight to the engineering approach, the material of this course gives a practical knowledge that should be used later on. The engineering candidates are beginning to use a real equipped laboratory, making their first experiments and measurement exercises. The course of measurements thereby gives some kind of frame for their studies, since the problems in the thesis are usually closed by measurements and their evaluation.

ACKNOWLEDGMENT

The authors would like to thank the students that they reflected critically and truthfully, thereby forming the structure of this course.

Physics for Nanobio–Technology

Principles of Physics for Bionic Engineering

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In this course nanobio–technology refers to nanoscale engineering with biological and biochemical applications or uses, i.e. to the ways that nanotechnology is used to create inanimate devices to study biological systems. Physics deals with quantitative laws of inanimate nature.

On the nanoscale quantum effects have a dominant sway. Electromagnetic interactions are decisive. To describe devices and objects engineered by nanobio–technology mixed quantum–classical physical models are needed (Non-relativistic quantum electrodynamics).

An inanimate nanobio device can be envisaged as an object built from positively charged nuclei following the laws of classical point mechanics; electrons following the laws of quantum mechanics; and photons, following the laws of electrodynamics, all of them in vacuum, and on a biocompatible energy level. The electron gas follows the Fermi–Dirac, the photon gas the Bose–Einstein statistics.

The course starts with a glimpse on contemporary scientific world view, and on history of the laws of physics. The designer of nanobio machine should be able to predict the behavior of its machine. The prediction can be based on cut–and–try experience, or on models and simulation. Ab inito physical modeling and simulation are based on quantum–classical dynamical models of machines. The goal of the course is to introduce the quantitative modeling and simulation of nanobio machines. Examples include microscopes (e.g. STM, AFM, fluorescence microscope) which can see at the nanoscale; devices that manipulate and fabricate nano machines; nanoscale sensors and actuators, e.g. plasmonic sensors; machines for energy harvest (e.g. artificial photosynthesis and hydrogen production); devices for medical diagnostics and treatment (e.g. nanoparticles); nano machines (e.g. motors, laser tweezers); and nanoscale bio-inanimate interfaces.

The main chapters include:

1. Classical Mechanics (Basic Concepts of Analytical Mechanics, Mechanics of Many Point-like Bodies, Particle Dynamics in Electric and Magnetic Fields.

2 – 3 – 4 – 5. Classical Electrodynamics (Experimental Foundation, Maxwell's Equations – Boundary Conditions, Time-harmonic Fields, Plane Wave Propagation, Plane Wave Reflection and Refraction; Waveguides, Electromagnetic Radiation and Antennas; Cavity Resonators).

6 – 7 – 8. Quantum Mechanics (A Glimpse of the Quantum Story; Experimental Foundation; Feynman's Path Integral; Schrödinger Equation; Measurements and Operators; Dirac Formalism; Wave Pocket Propagation; Electron Reflection, Transmission and Tunneling; Single Electron in a One-dimensional Periodic Potential; Quantum Well, Quantum Wire, Quantum Dot; Hydrogen and Hydrogen Like Atoms).

8. Many Body Problem and Statistical Models (Multiple Body System with Negligible Interaction between Identical Particles; Equilibrium in Multiple Body Systems; Fermi–Dirac Statistics).

9. Heuristic Models for the Structure of Matter (Structure of Matter; Classical Electrodynamics – Maxwell–Lorentz Equations; Solutions of the Single-Electron Problem – Band Structure of Matter; The Effective Mass Schrödinger Equation; Quantum Well, Quantum Line, Quantum Dot.

10. Heuristic Models for Semiconductors (Semiconductor Materials; Semiconductors in Thermal Equilibrium; Contact Potential; Carrier Transport in Semiconductors).

11 – 12. Interaction of Matter and Radiation (Experimental Foundation; On the Physics of Vacuum; Interactions in Thermal Equilibrium; LASER – The Ruby-laser and the VCSEL; A Heuristic Model of a Two-state Atom in Electromagnetic Field; Perturbation of a Stationary State; Time-dependent Perturbation; Time-evolution Operator – The Propagator).

13. Heuristic Models of Nanoscale Systems (Dynamics of an Individual Isolated Nanoparticle, Nanoparticle in Dissipative Environment; Quantum Interference Devices; Phase Modulation by Electric and Magnetic Fields).

14. Mathematical Appendix (Calculus of Variations; Vector Analysis; Inverse Problems; Hilbert Space; Linear Operators in Hilbert Space; Eigenvalues and Eigenvectors).

VLSI Design Methodologies

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***Summary* — This paper describes the content of the VLSI Design Methodologies course slides.**

Keywords - Circuit design, design flow, integrated circuit, manufacturing process, CAD tools

I. INTRODUCTION

The course has an introductory style, as the topic is wide and has many theoretical and practical details, furthermore prepared to be understandable by non electrical engineering students.

This curriculum is driven by the slide show and the closely related practice. It gives an introduction to the manufacturing of integrated circuits (IC) and their design. Starting from the general aspects, it presents the deep submicron IC manufacturing, the relation of designed structures and the imperfect manufacturing process, the advantages of using modern CAD tools, the design flows of analog and digital systems, and various exotic technologies.

II. STRUCTURE OF THE COURSE MATERIAL

The course contains twelve lessons, each lesson covers a single topic and they are presented as a slide show. These power point presentations follow the same template, namely a brief content description, the material itself sectioned into topics, a concluding page, questions about the content, and finally the recommended literature. In the following chapters the topics are presented.

A. Introduction to Integrated Circuits

This lesson describes the trends that exist in the integrated circuit industry. Both from the aspects of the manufacturing technology and supporting design practices. 3D integration is briefly introduced and its motivations are listed. The ICs are not uniform, several main classes could be found, these variants are described as well, such as silicon or exotic material based technologies, DRAM, FLASH, CPU variants.

B. Manufacturing process

As the basis of design, the manufacturing process is presented. It is emphasized how the process affects the possibilities and difficulties of the circuit implementation. Hence, the connection between the drawn layout and the manufacturing steps is shown in details. The raw material preparation, the doping techniques, the affect of scaling down is presented.

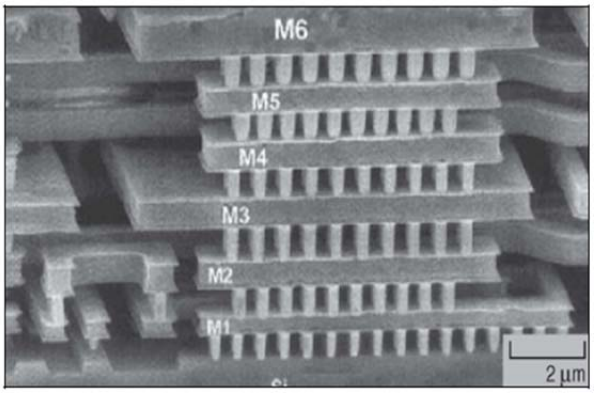

Figure 1. Scanning electromicroscope image of a six metal process.

C. *Building blocks of Integrated Circuits*

When the students are familiar with the process, the circuit primitives are presented, again, along with their technology constraints. Field effect transistors are described in details, along with the available elements, like resistor and capacitor types, inductors inductivity, and other elements. The differences between the designed and manufactured shapes and their behavior (mismatch) are analyzed together with the sources/reasons of the various differences.

D. *Design flows*

After presenting the IC CAD tools in a historical scope, the analog and digital design flows are described. These flows are rather the same at their basic level, but advancing in the hierarchy of design reuse, diverge significantly. The description form and techniques of functionality, parasitic effects and their simulation are shown. In the digital flow the synthesis from standardized cells and modeling the wire/gate delays are the main issues. In the analog design flow, the functionality is used in a much broader sense in solution space, and besides the caracteristics of a correct circuit, the manufacturing mismatch effects and their mitigation techniques are treated as well. Furthermore, a complete lesson is devoted to simulation techniques (e.g. SPICE) as understanding these methods and their limits is a key of the design process.

E. *Power consumption and low power design*

Nowadays a key problem is the power consumption of ICs. This topic covers the reasons why circuits consume power, the difference between static and dynamic power. The technologies of reducing both types are introduced – such as manufacturing, architectural, and software solutions.

F. *Image sensors and their design*

As a good and useful example of other than digital processor technologies, the image sensor design solutions are presented. The difference between CMOS and CCD sensors and their several circuit details are listed along with X-ray, IR imagers.

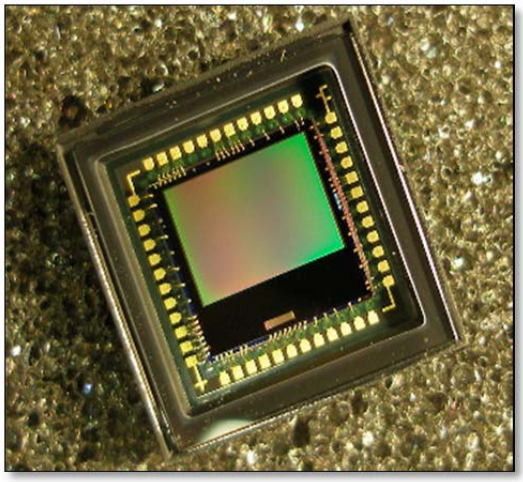

Figure 2. Image sensor chip microphoto.

G. *MEMS technologies*

Another important IC class is that of the micro-electro-mechanical-systems (MEMS). Today, complex MEMS are created integrating moving and electronic parts. A survey is given in this lecture about the manufacturing styles – bulk or surface MEMS, problems that can be solved by these architectures, and the supporting CAD tools as well.

Figure 3. A MEMS test circuit, the course gives details how these circuits are manufactured.

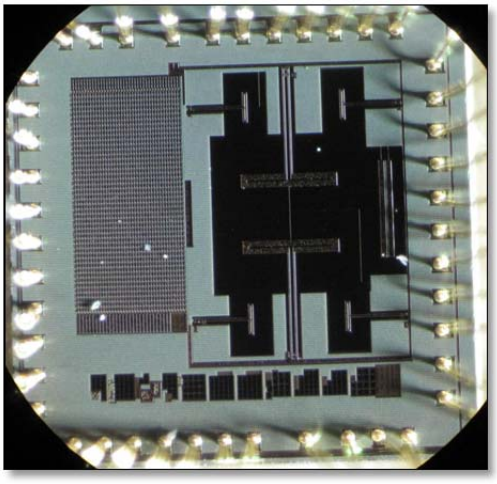

Figure 4. A photo of an integrated circuit that has been designed by the student of this course. More than a dozen students' contribution is integrated in this 180 nm CMOS circuit. They have been designed and later on tested their work in the practice.

H. 3D integration methods

As a final step towards integrated systems, the 3D integration processes is introduced. The motivations, e.g. integrating different technologies, and the main approaches are discussed in details. Several challenges and the drawbacks are emphasized too.

III. CONCLUSIONS

There is a hope that this course will fulfill its role to give a deep knowledge and wide perspective of integrated circuit design, and will attract more students to this field.

World of Molecules

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***Summary* — World of molecules is a subject using bottom-up approach to basic inorganic and organic chemistry. This slide series starts at the smallest level of building blocks for chemical elements and develops step-by-step into the full description of states of matter through detailed description of the constituents of chemical compounds and their rules of interaction and reaction. Furthermore, a basic introduction to organic chemistry is also presented along with introductory molecular modeling and simulation to understand drug research tasks. The main aim of this course is to introduce students to the modern aspects and uses of molecules and through that the usefulness of chemistry.**

Keywords - electron; molecule; compounds; states of matter; mixtures; electrochemistry; thermodynamics; reactions; spectroscopy; nomenclature; reaction modeling; computer aided chemistry; drug research; chemical synthesis; molecular modeling

I. INTRODUCTION

The structured bottom-up approach of molecular physico-chemistry is presented in this slide series titled World of molecules. Defining the building blocks of atoms we can derive compounds, interactions, reactions and processes on the molecular level. Based on this knowledge we present detailed analysis of drug research and development. Organic chemistry laboratory procedures are detailed in order to introduce students to the "making" of the molecules. Introduction to chemical and drug research literature is also featured. Altogether this is presented in approximately 1100 slides.

II. WORLD OF MOLECULES I. INORGANIC CHEMISTRY

A. Periodic System of Elements

From the history of elements, we introduce elementary particles and fundamental interactions, next the structure of atoms through Rutherford's scattering experiment, Bohr-Sommerfeld model and organized into the Periodic table of elements.

B. Properties of Atoms

Starting from the nucleus, isotopes, tables of isotopes, radioactivity, decay modes, Bohr-Sommerfeld model, the quantum numbers, electron structure, and some examples are presented.

C. Dual Nature of Electrons

By introducing the dual nature of light, and considering the particle nature of electron, we get to the wave nature of electrons (by de Broglie), thus the particle-wave duality concept of electrons is presented, which is described by the Schrödinger equation. Solving the equation for different systems: the wave functions of the electron in 1D, the wave functions of the electron in a harmonic oscillator, the wave functions of the electron in 3D, the wave functions of the electron in the Hydrogen atom.

D. Properties of Chemical Bonds, Spectroscopy

Spectroscopy can be divided into absorption spectroscopy and emission spectroscopy. Chemical properties of atoms is introduced, types of chemical bondings, basic properties of

chemical bonds, covalent, ionic and metallic bonds and Hydrogen bonds and van der Waals forces are summarized.

E. Modeling of Electron And Molecular Structure

Modeling of the molecular and electron structure is presented summarizing different methods, e.g. MM, Hartree-Fock, semi-empirical, DFT, Møller Plesset, the used approximations are shown. Furthermore display options and methods are discussed for inorganic chemistry models.

F. Chemical Compounds, Stoichiometry

Compounds and chemical composition is introduced in this chapter, the ambiguity of the chemical formula is shown with stoichiometry. The main groups of chemical compounds and grouping of inorganic compounds, e.g. salts are discussed. The special properties of water underline the importance of this compound.

G. Chemical Equilibria, Acid-Base Theories

Chemical equilibria are considered in gases, acids and bases. Basic information of acid-base theories is presented: Arrhenius theory, Brønsted-Lowry theory, Lewis theory, Pearson theory (HSAB), furthermore superacids and superbases are presented.

H. Case Studies

Case studies for the most important chemical elements are presented with abundance, production and detailed use. The following elements are featured hydrogen, oxygen, carbon, nitrogen, sulphur, sodium, silicon and boron.

I. States of Matter

The states of matter are presented in detail. Gas state with gas laws. Liquid state with description of the properties of liquids based on surface forces. Solid state with crystal lattices and the plasma state.

J. Solutions, Mixtures

The fundamental properties of mixtures, e.g. miscibility and solubility are introduced. Detailed description of azeotropes and eutectic systems is presented. The colligative properties (lowering of vapor pressure, freezing point depression, boiling point elevation and osmosis pressure) are presented.

K. Thermodynamics

A short introduction to chemical thermodynamics via the laws of thermodynamics, defining extensive and intesive quantities is presented. Detailed presentation of heat, entropy, enthalpy, Gibbs free energy and thus the notion and properties of equilibrium is shown.

L. Electrochemistry

The following themes are summarized in this lecture: electrolytes, electrochemistry, concentration cells, galvanic cell, electromotive force, standard electrode potentials, redox reactions and electrolysis.

III. World of Molecules II. Organic Chemistry

A. The structure of the molecules how we see (with spectroscopy)

The following spectroscopic methods are presented in detail: ultraviolet spectroscopy, infrared spectroscopy, ^{1}H-NMR spectroscopy, ^{13}C-NMR spectroscopy, mass spectroscopy, X-ray crystallography. Also examples from the application of ^{1}H-NMR spectroscopy are featured.

B. Organic compounds and nomenclature: why 'organic', conventions and rules

The following order of names is presented for (organic) chemical nomenclature: additive names, radiofunctional names, fusion and Hantschz-Widman names, replacement names, conjuctive names, multiplying names, substitutive names, substractive names, and organic compounds.

C. Chemical reaction types, energy involvement; reactivity and stability

The classification of reactions is demonstrated: electrophilic and nucleophilic, reagent types are detailed and electronegativity of groups is considered.

D. A case study on the design of chemical reaction

The mechanism of 1,3-dipolar cycloadditions and classification of dipoles is introduced. The synthesis of several dipoles, type of 1,3-dipolar cycloadditions and synthesis of pyrazolo[3,4-d]pyridazines are featured with expected and obtained regioisomers.

E. Computational chemistry methods

Organic chemical approach to molecular modeling is presented summarizing 'classical' mechanics methods, quantum mechanics methods. Defining basic sets, basics via examples.

F. Reactivity

The following properties of chemical reactions are detailed inductive and field effect, resonance and steric effect, hyperconjugation and the energy profile of chemical reactions.

G. Drug research and development: some current aspects

The description of drug–receptor/enzyme interaction is the key to understand the principle of drug action. Methods for development of new drugs are e.g. *de novo* design, SOSA (selective optimization of side activities), furthermore the options for therapies are summarized.

H. Important hints for practices of organic synthesis

Laboratory equipment and parts of preparation are described. The following processes and tasks in the laboratory environment are detailed: liquid-liquid extraction/washing, drying, filtration, distillation, crystallization, classification, chromatography and purification.

I. Explore the known information: The importance and illustration of the literature search and databases

Useful tools and applications for retrieving information, chemical databases, university databases, free databases, and protein databases and illustrated in detail with hands-on screenshots.

IV. Summary

World of molecules is a subject using bottom-up approach to basic inorganic and organic chemistry. The previous subchapters detail that this slide series starts at the smallest level of building blocks for chemical elements and develops step-by-step into the full description of states of matter through detailed description of the constituents of chemical compounds and their rules of interaction and reaction. Furthermore, a basic introduction to nomenclature and organic chemistry is also presented along with introductory molecular modeling and simulation to understand drug research tasks. Case studies and synthetic organic chemistry laboratory protocols are described. Also, the basic introduction to drug research and development underlines the need for us to better understand the underlying chemical principles to be able to enhance drug design and development tasks.

The main aim of this course is to introduce students to the modern aspects and uses of molecules and through that the usefulness of chemistry.

Modeling Neurons and Networks

What Algorithms Does the Brain Use for Information Processing?

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***Summary* —This document describes the teaching materials we developed to introduce the basic concepts of computational neuroscience to Master's level students at the Faculty of Information Technology at Pázmány Péter Catholic University.**

***Keywords* - Neurobiology; theory; computer simulation; biophysics; dynamical systems**

I. Introduction

The subject named "Modelling Neurons and Networks" is intended to provide an introductory treatment of several important topics in computational (also called theoretical) neuroscience. These topics include cellular biophysics, the processing of synaptic inputs in single neurons, the dynamics of feedforward and recurrent neuronal networks, and some basic mechanisms of learning and memory. On the other hand, several equally important topics, such as the coding and decoding of information in neuronal spike trains, are only touched upon, and could easily serve as the core of a second subject.

The subject introduces students to the repertoire of methods which are routinely used in the theoretical analysis of the function of the nervous system. Competent use of essential mathematical tools, user-level computer skills, as well as some knowledge of basic neurobiology are presumed, but all of these competencies are further developed during the course.

II. Contents of the Subject

A. *Prerequisites*

Before taking this course, students should have completed their basic university-level mathematical training, including the following subjects: linear algebra, differential equations, probability theory, and numerical methods. They are also assumed to be familiar with the basic facts, concepts, and experimental methods of neuroscience. Finally, they are supposed to be competent in the use of personal computers. Some other skills, such as experience with Linux/UNIX operating systems, and knowledge of certain branches of theoretical physics (such as dynamical systems) and engineering (such as signal processing), are also useful and likely to enrich the learning experience.

B. *Course topics*

The contents of this subject include many of the topics which are traditionally taught in courses titled "Computational neuroscience" or "Theoretical Neuroscience" around the world. The present course bears a different title partly to emphasize the fact that it focuses on a subset of the possible topics, providing ample insight into known mechanisms of information processing in single nerve cells and biological neural networks, while neglecting other important fields such as the information-theoretical description of neural coding and decoding, or biologically-based models of cognitive processes and behavior.

In somewhat more detail, the course deals with the following topics:

1. Detailed models of single neurons:
   - Biophysical foundations of neuronal activity
   - Signal propagation in passive dendrites: the cable equation
   - Signal propagation in the axon: the Hodgkin-Huxley model
   - Multicompartmental modeling, neural simulators
   - The diversity of ion channels and their role in neuronal function
   - Processing and integration of excitatory and inhibitory synaptic inputs
   - Understanding excitable neurons as dynamical systems
2. Modeling network dynamics using simplified model neurons
   - Rhythmic network activity and synchronization
   - Attractor dynamics as the basis of short-term and long-term memory
   - Computations in feedforward and recurrent networks
3. Modeling synaptic plasticity and learning
   - Biophysical mechanisms of neuronal plasticity
   - Dynamics of the synaptic matrix in neuronal networks

III. TEACHING MATERIALS

In the context of the TÁMOP project, we developed a new set of English slide presentations, organized into twelve topics, and comprising a total of approximately 450 slides. Besides explanatory text, the slides contain over 100 figures, and approximately 200 equations. To our knowledge, the material discussed is not covered by any single existing textbook or teaching aid. Rather, the course combines material which may be found in popular textbooks with the description of important recent results from the primary literature, and adds several unpublished examples from the author's own research. In addition, four of the slide presentations actually contain detailed guides to hands-on experimentation with (two different types of) neural simulation software, meant to be taught in a computer lab environment. These computer-based exercises complement the more traditional lecture format of the other presentations. They are supposed to bring about a deeper understanding of the concepts encountered during the lectures via guided exercises and independent exploration, introduce some additional concepts, and, importantly, familiarize the students with programs which have become widely used research tools in the computational neuroscience community.

Introduction to Functional Neurobiology

Neurobiology II.

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***Summary* — This subject provides a deep analysis and illustrates with experiments of the operation of neuronal networks by putting a particular emphasis on the processing of olphactory- and visual information, the function of the thalamus, hippocampus, and the somatosensory- and visual cortices. Emphasis is also given to the conclusions drawn from the disorders of the central nervous system. Separate lectures deal with theoretical and practical problems of modeling the operation of individual neurons and neuronal networks, the diagnostic and experimental potentials of the modern imaging techniques and the therapeutic approaches from the employment of stem cells to the high tech neurosurgery tools.**

***Keywords* - principal neurons, interneurons, synapse, neural network, action potentials, field potentials, ion channel, information coding, neuron- and network models, oscillations, pathological neuronal function, imaging techniques, neuro-invasive procedures**

I. INTRODUCTION

The examination of the physiological and/or pathological operations of the living organisms, as well as *in vitro* or *in vivo* interventions on it require (i) the development and everyday usage of special tools, the size of which extend from the nano- to macro world and (ii) the collection, processing and display a huge amount of data. In the lectures we review the theoretical aspects and experimental works through which the co-operation of the nerve cells and their building of functionally different networks may be understood. To be more precise, we undertake to explain the significant difference in functionality of single nerve cells and that of the cellular networks formed by the individual neurons. Additionally students learn the classical and data recording and processing methods, and the potentials and limitations of the currently used experimental-, analytical-, and test methods on the structure and function of the central nerve system.

A. Prerequisites:bakcground knowledge

The subject is offered to students, who already have a thumbnail image on the structure and function of the nervous system, and thus they have acquired the sufficient knowledge about the cellular elements and the organization rules of the CNS. These students are familiar with the spatial orientation, relationship and function of the major units of the CNS, the structural and functional characteristics of the cellular elements, as well as the types and operation of receptors and ion channels.

The formal prerequisite is the subject “Basics of Neurobiology”.

B. Topics

The lectures on the topics of sensory systems (perception and processing of the somatosensory, olphactory and visual information) motor systems (somatomotor system, basal ganglia and cerebellum) and the rhythm-generating-, thalamocortical, and hippocampal systems are structured at a similar manner; following the introduction of morphological, neurochemical and electrophysiological characteristics of the structural elements of the networks, the functional specifics of the net-

work activity is demonstrated, and finally details are given about network-related information coding and decoding, information processing and storage.

There are also lecture series, which explain the theoretical background and practical significance of the electrophysiological methods used in neuroscience and neurosurgery, and the modern imaging techniques. The pathological operation of the nervous system is also presented in a series of lectures by demonstrating the morphological and functional alterations in epilepsy, Alzheimer's disease, motor system disorders (especially Parkinson's disease) and anxiety/depression and conclusions are drawn for the altered network activity and potential restoration approaches.

The pathological alterations of the nervous system and the resulting malfunctions can be cured by modern neurosurgical interventions, which are based on accurate and complex analyses of diagnostic images, and pre- and intraoperative electrophysiological recordings. The demonstration of these processes flashes the practical (therapeutic) achievements of information technology to the interested audience.

II. RESULTS

The specific issues based mainly on the research of internationally respected lecturers. This knowledge is completed by the latest results available in the literature. Besides presenting results of the experiments on photo slideshows, the understanding of the measurements, experiments and examinations are facilitated by video demonstrations.

More than 1000 slides are has been created. The animation showing neuronal activity in the hippocampus, the development of synchronous cellular activity, and the putative operation of information filtering to separate signal from noise during learning have a special value and offer an easy way of understanding basic network functions.

ACKNOWLEDGEMENTS

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Electrophysiological Methods for the Study of the Nervous- and Muscular-systems

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The course makes the students familiar with the topics of electrophysiology, the major recording techniques, and the relationships among the fields of bioelectromagnetism. They get acquainted with electrophysiological techniques and devices used in neuroscience and in every day's clinical practice. The great advantage of the electrophysiological methods is that we can study nervous and muscle function in intact organisms or with minimal damage of the functioning tissue. Electrophysiology is a broad area of biosciences. In the course we deal only the bioelectric processes of the nervous and muscle systems since they are most interesting from the point of information technology.

The first lectures basic bioelectrical phenomena of nerve cells are discussed. When a nerve impulse travels along a nerve fiber action potential can be recorded. This bioelectric phenomenon is a concomitant of the biological process of the nerve conduction however at the same time the potential changes play active role in the spread of the excitation. This dual nature of bioelectricity is strongly emphasized.

Connection between the living tissue and the recording apparatuses is realized by the electrodes. In this interface connection is formed between electron conductor and electrolyte conductor. Ideal electrode does not exist living tissue is a chemically aggressive medium for electrodes: there is always a chemical reaction between the electrode and the tissue. Critical problem of electrophysiological electrodes are the electrode stability and biocompatibility: on the one hand, electrodes have to withstand the chemically aggressive living tissue, on the other hand, electrode-caused harm to the living tissue has to minimized. Chronically implanted electrodes of different type pacemakers must operate for decades.

Recording techniques of neuroelectric signals can be categorized form the membrane potential of the single neuron recorded by intracellular microelectrodes to the electroencephalographic activity (EEG) of the brain recorded by macroelectrodes on the scalp surface. Lectures of the course offer detailed survey of in vitro and in vivo methods. Extracellular single unit recording technique earlier was regarded as a purely research method nowadays it is applied in human brain computer interfaces. Computer based multichannel EEG recording makes possible the mapping of brain processes with good time resolution and application of complex mathematical signal processing methods offers possibility the forewarning of epileptic seizures. Beyond the electrical activity noninvasive recording of the magnetic signals produced by the brain serves also as a diagnostic tool. Good spatial resolution of magnetoencephalography makes it a good complement of EEG.

Surface recorded brain oscillations time locked to sensory stimuli – called event related

potentials (ERP) – became essential in studying perceptional and other psychological phenomena and serve as one of the a basic tools of cognitive psychophysiology. Recording of early components of ERPs can be used as diagnostic method to reveal pathology of sensory pathways even in unconscious patients e.g. the objective audiometry using the brainstem auditory evoked potentials. One of the lectures of the course deals with the different forms of the ERPs.

Recording of the bioelectrical activity of striated muscles can be used for diagnosing of pathology of the motor part of the nervous system as well as the muscles themselves. In the clinical practice needle electrodes are used for the localization of pathological changes. Surface electrodes are applied in psychological research as well as in sport- and work-physiology to analyze optimal performance of muscles. The lecture dealing with electromyography describes both of these techniques and applications.

Computer methods become more and more important in analyzing bioelectrical signals. In the last lecture of the course we give an overview of the mathematical methods that are used for electrophysiological signal processing.

Understanding of brain functions and pathology needs collaboration of researchers of different disciplines. Information technology and bioengineering fields gain more and more importance both in neuroscience and in the related clinical areas. At the same time bio inspired solutions become essential in man-made systems. In preparing the material of the present course we intended to give and overview of electrophysiological methods that may be useful for students with engineering as well as biological interest.

Neural Interfaces and Prostheses

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The course makes the students familiar with the new developments of neural engineering in the field of neuroprosthetic devices that can substitute motor, sensory or cognitive functions that might have been damaged as a result of an injury or a disease. These devices make direct interfaces with the peripheral and central nervous system. Some of these devices are already routinely used in the clinical practice like the cochlear prostheses for restoring hearing others are still in the developmental or experimental phase. Neural interface is a connection between the living tissue and a man-made device, in most case a bioelectrode. Neuroprosthetic research is integrating different fields of medical and engineering disciplines. New discoveries in this field are always the result of close collaboration of experts in most different areas of research. In the course we intend to give a survey of divergent areas of neuroprosthetics.

In the first lectures of the course the basics of bioelectrical processes of nerve cells are summarized and the effects of electrical stimulation in the excitable tissues are discussed. The electrical stimulation to activate peripheral nerves innervating muscles affected by paralysis is called functional electrical stimulation (FES). In a lecture the clinical applications of FES combined by different forms of orthoses are discussed. In the last decade spectacular development was made in the neural control of limb prostheses. The nerve reinnervation technique resulted in the development of the “bionic arm” that is controlled by the intentions of the patient through myoelectric signals.

Navigation methods like stereotaxic technique and frameless neuronavigation made possible minimal invasive neurosurgery. Neuronavigation is based on fusion of CT, MR, and angio images by a neurosurgical planning software. The planning software can precisely locate the size, shape and location of the brain tumor, lesion or abnormality. Modern “bloodless neurosurgery” by “Gamma knife” does not require the skull to be opened for performance of the operation. Studies demonstrate savings of more than 50% of direct costs associated with microsurgery.

Stereotaxic implantation of electrodes in humans made possible the chronic deep brain stimulation (DBS) in movement disorders. The target area is also localized by recording of the neural activity along the electrode track. DBS is a neurosurgical treatment involving the implantation of a battery-powered neurostimulator which sends electrical impulses to the target area of the brain through the implanted electrode. The neurostimulator is usually implanted under the skin of the chest and wires go under the skin to the electrodes. The patient can program the neurostimulator by radiofrequency way. In the lecture the Parkinson’s disease is used as an example since DBS is most widely and most successfully used in patients suffering in medication resistant Parkinson’s disease. DBS is not a cure but suppresses the motor symptoms and high-

ly improve the quality of life of the patients. In the last decade DBS also became generally accepted as treatment in dystonia, essential tremor, Tourette's syndrome, obsessive–compulsive disorder and depression. The physiological mechanisms of the DBS are still not clear. The different hypotheses are discussed. The most accepted view is that DBS has a suppressing effect on the pathological rhythm of the target area neuronal networks.

A special noninvasive form of brain stimulation is the transcranial magnetic stimulation (TMS). TMS apparatus generate rapidly changing magnetic field in a coil held close to the head. The weak electric currents induced by this magnetic field change causes excitation or inhibition in the neurons of the stimulated area of the brain. TMS causes minimal discomfort, allowing the functioning and interconnections of the brain to be studied. The TMS lecture deals with the principles and techniques of TMS and examples of possible clinical applications are mentioned.

Sensory prostheses are the subjects of three lectures. Two of them deal with the hearing aids. After a short introduction of the biology of hearing, the possibilities and types of auditory prostheses will be detailed, focusing mainly on cochlear implants, but we will show other solutions too, ranging from the middle ear implantable hearing devices to methods in experimental stage like the auditory brainstem implants and auditory midbrain implants. The subjects of the third lecture are the visual prostheses. The retinal implants are discussed in more detail but other solutions like stimulation of the optic nerve and the visual cortex are also mentioned.

There are diseases or pathological states when the muscle system of the patients is totally paralyzed and they are unable keep contact with their environment. A special group of neuroprosthetic devices, the “brain computer interfaces” (BCIs) give promise for these patients. These devices translate the brain electrical signals for communication with the external world as well as for manipulation of technical devices such prostheses and microprocessors. We devoted three lectures to this topic giving detailed survey of both noninvasive and invasive BCIs. The present day BCI systems are in experimental phase but some noninvasive BCIs are already commercially available. A new area of BCI application is the games and virtual reality. BCI research became very popular in the recent years, new applications will emerge and the BCI systems will become part of our everyday life.

Neuromorph Movement Control

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***Summary* — This educational material has been prepared in the frame of a project initiated by the European Union and the European Social Fund. Development of the special course titled "Neuromorph Movement Control" is briefly summarized here.**

I. INTRODUCTION

Mathematical theories and computer-simulation is widely used to reveal or predict human movement patterns. The neuro-musculo-skeletal system has special material, geometric, biomechanical and neural properties. These levels of the human motor apparatus are investigated. Studying and better understanding control strategies applied by the human nervous system during movement planning and movement execution is the main object of this course. An important issue is to understand how the levels of this hierarchical system, the nervous system, the muscles and joints interact to produce coordinated motion of limbs or other parts of the body.

Highschool background

The students must have knowledge and ability to understand and to use mathematical methods such as linear- analytic- and statistical- methods, and mathematical theories of human movement control. The knowledge of Newtonian mechanics is essential and basic knowledge in neuroscience is also required. Students who intend to work on development of prosthetic devices and man machine interfaces are encouraged to listen the course.

II. RESULTS

The lectures are based on earlier knowledge in the field of human motor control research. Additionally we employed our own research and teaching experience and show examples for solution to questions arised in human motor control. It is presented, how anatomical, biomechanical, physiological parameters of human movements can be measured and modeled. Furthermore we present on the elaborated slides, how changes of the external environment affect movement performance. The students learn what kind of optimization criteria might be employed by neural control of human limb movements when the motor task can be solved in an infinite number of ways.

III. METHODS

With elaborated 12 chapters, 444 slides with lots illustrative figures and photos, such as this below.

Figure
A sample slide from a particular chapter with illustrative figures and pictures.

In the course different types of movement analyzing systems are also presented to illustrate how kinematic and muscle activity patterns are measured and analyzed. It is also

discussed how measurements can be compared with predicted movement patterns based on mathematical models. Examples for the design and application of engineering methods in medical rehabilitation like artificial control of human movements are summarized.

The importance of modeling human movements is increasing as modern methods in informatics and engineering are available to discern human movement characteristics that were hidden before. The construction of models of neural control and mechanical execution of human movements helps the diagnosis of movement disorders and predicts the outcome of clinical intervention and medical rehabilitation.

Introduction to Wireless Communication Networking Technologies

Ad hoc and Sensor Networks

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***Summary*— The purpose of the course "sensor and ad hoc networks" is to provide a comprehensive introduction of wireless networking technologies to the students. Besides the technological introduction the course gives an insight into the protocols and the corresponding algorithms which form the foundation of networking. Hence, the course material does not only aim at taking stock of the current wireless networking technologies but it also focuses on the underlying principles. In this way, students are exposed to the comprehensive foundations of wireless communication which will help them to adopt to emerging technologies and to keep their knowledge up-to-date throughout their later engineering career.**

Keywords: wireless communications, ad hoc networks, wireless sensor networks

I. INTRODUCTION

The development of wireless communication has been exploded in the last ten years and poses serious challenges to the traditional wired communication. Two of the most researched areas in the domain of wireless communication are the *ad hoc* and *sensor* networks.

The course objective is to introduce the students to the foundations of wireless networking, highlighting its major challenges, its engineering solutions and its main applications.

The main strength of the course material that it managed to successfully integrate the algorithmic foundations with up-to-the-minute technologies. In this way the students can obtain general skills and knowledge as well as specific details about the current systems. The course can be taught both in information technology and electrical engineering programmes, as it touches upon both protocol-related and implementation oriented issues.

At the same time, the summary sections give an overview of the knowledge the students of the info-bionics programme require.

The material may serve as the first step in the area for those students who have research inclination and later want to further advance their knowledge in the domain of wireless networking.

II. MATERIALS ALREADY AVAILABLE AND USED FOR THE COURSE

The topics related to ad hoc networks is a standard part of the curricula of other universities. But those courses do not detail the sensing applications. In general they focus on the challenges of wireless communication but do not delve deep enough into the challenges of applications.

On the one hand the course is a basic part of the curriculum of the technical informatics programme, especially for those students who choose the Communication Engineering track. On the other hand, it is strongly recommended to those students in the programme of molecu-

lar bionics who are specializing in the fields of Bionic Interfaces and Bio-nano measurement devices.

Parts of the course material are included in the following books:

- A. Molisch, Wireless communications, Wiley-IEEE Press, 2005.
- A. Goldsmith, Wireless communications, Cambridge university press, 2005.
- C.S.R. Murthy and B.S. Manoj, Ad Hoc wireless networks: architectures and protocols, Prentice Hall PTR Upper Saddle River, NJ, USA, 2004.
- E.H. Callaway, Wireless sensor networks: architectures and protocols, CRC press, 2004.
- D. Gislason, Zigbee Wireless Networking, Newnes, 2008.
- G.Z. Yang and M. Yacoub, Body sensor networks, Springer-Verlag New York Inc, 2006.

The references listed above provide a wide range of basis knowledge. But the real challenge of the course is to present a comprehensive foundation which addresses all the engineering challenges and list the corresponding practical solutions. This must be done on such a mathematical platform which takes into account only those skills which have already been obtained in the studies preceding the course. The books above cannot fulfill these objectives by themselves.

Dr. András Oláh can successfully guide the students through the course. Furthermore, as his research area is wireless communication, he can expose the students to the newest results of the field.

One of the research areas of Prof. Dr. János Levendovszky is also wireless communication and their technological challenges (wireless detection, channel equalization, energy aware routing in wireless sensor networks). He lead several projects in the filed as principal investigator and supervised numerous PhD students as well.

As a result, the expertise and skills to provide a high level course in the field is available.

III. RESULTS

The course material has been split into 12 parts, as follows:

1. Overview of wireless communications
2. Fundamentals and technical challenges of wireless communications
3. Wireless channel characterization and models
4. Digital modulation
5. Detection and channel equalization
6. Multiple channel access
7. Routing protocols
8. Standardized wireless systems
9. Communication protocols for wireless sensor networks
10. Localization algorithms and strategies for wireless sensor networks
11. Applications of ad hoc and sensor networks
12. Future of wireless technology and research

The approximatively 500 slides had not been uniformly divided and dedicated to the 12 chapters, but based on the importance of the topics.

The first half of the material deals with the foundations of wireless communication which is then followed by the particular challenges of ad hoc and sensor networks from Chapter 8.

It is important to note that during the course the students also choose a project the goals of which can then be completed on the infrastructure available at the WSN laboratory (software radio, Texas nodes, Xbow Mica2 mote-ok, Android based mobile telephones, Arduino devices). In this way, the students can grow familiar with the standard devices and development kits and become capable of R&D in

the field of wireless communication technologies.

IV. SUMMARY

The course can provide comprehensive foundations combined with up-to-the-minute technological details in the domain of wireless communication technologies to the students. It also provides the knowledge which is needed for the engineers to keep track of the ever changing and evolving technologies and applications.

An Integrated Approach to Linear- and Nonlinear Signal Processing

Digital- and Neural Based Signal Processing & Kiloprocessor Arrays

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***Summary*— The course objective is to give a comprehensive introduction to digital signal processing using the traditional linear- and nonlinear approaches. This objective is very important as the material treated in this course forms the foundation of plenty other subjects. As a result, without a clear-cut and well-presented course on signal processing, the student may miss out on the understanding of further courses in the curriculum. Hence, the course must integrate the basic concepts of linear signal processing in the time- and transformation domain together with the biologically inspired computational paradigms implemented by artificial neural networks and the signal processing algorithms running on kiloprocessor arrays. Besides delving into the theoretical foundations, the course tries to demonstrate each principle by applications in the field of information technologies (e.g. adaptive algorithms for channel equalization and data compression, pattern recognition and data mining examples). In this way, the students can come to grip with basic notions of signal processing via applications as well.**

Keywords: digital signal processing, neural networks and computing

I. INTRODUCTION

The two fundamental areas of signal processing are (i) linear; and (ii) nonlinear signal processing. Treating both of the areas in one course has the advantage of addressing general issues such as (i) representation; (ii) learning; (iii) and generalization together. In this way, the students are not only exposed to the description of signals in time- and transform domains, but to the fundamental issues of signal processing as well. This helps to open up new horizons of understanding not only in linear but also neural based signal processing. This can serve the orientation of students in the info-bionics program who need to get an insight into the signal processing paradigms emerging neural based systems.

The third part of the course deals with kiloprocessor based signal processing which is an important direction of present day signal processing technologies. These technologies make possible to integrate 5 billion transistors in a single chip, which, however poses new challenges to signal processing (taking into account dissipation and signal propagation delays). Thus it is important to highlight how to implement the traditional algorithms on these novel architectures.

The course materials (slides, dictionary, etc.) have been designed to serve this integral approach to signal processing.

II. MATERIALS ALREADY AVAILABLE FOR THE COURSE

Some of the topics touched upon in the course can be found in the following books:

- J.G. Proakis and D.G. Manolakis, Digital Signal Processing, Prentice Hall, 1996;

- S. Haykin, Adaptive filter theory, Prentice Hall, 2001;
- H.P. Hsu, Signals and systems, McGraw Hill, 1995;
- L. O. Chua and T. Roska, Cellular neural networks and visual computing: foundation and applications. Cambridge Univ Pr, 2002;
- S. Haykin, Neural networks: a comprehensive foundation, McGraw Gill, 1999.

However, the references listed above only provide some initial knowledge, but do not provide that comprehensive foundation which is the objective of the course. In our approach the course presents integral foundations which combine the different principles and equip the students with a deeper understanding of the conceptual issues of signal processing. This goal cannot be reached by using international textbooks but needs the background of special expertise of the course instructors.

One of the principal research areas of Prof. Dr. Levendovszky János is focusing on adaptive digital signal processing algorithms and on neural based signal processing. He is and has been the principal investigator of numerous international research projects on the field. He has international teaching experience in signal processing giving courses at different universities of USA, South Korea, and Europe.

Dr. Oláh András PhD has developed novel nonlinear signal processing algorithms for digital communication systems.

The new course is based on a 7-year experience of teaching similar subjects and having developed not only lecture series but classroom exercises as well.

III. Results

The course material is divided into 12 parts, given as follows:

1. Introduction and Analog to Digital conversion.
2. Description digital signals and systems in time domain.
3. Description digital signals and systems in transform (Z, DFT) domain.
4. Efficient computation of the transform domain (FFT) and filter design.
5. Adaptive signal processing.
6. Introduction to neural processing (inspiration, history and approaches).
7. Signal processing by a single neuron (linear set separation).
8. Hopfield network, Hopfield net as associative memory and combinatorial optimizer.
9. Cellular Neural Network.
10. Feedforward Neural Networks (generalization, representation, learning, appl.).
11. Principal Component Analysis.
12. Virtual machines: signal processing with multicore systems.

The approximately 1000 slides are not uniformly distributed among the 12 different topics but rather with weighted importance. The linear signal processing part is concluded in Chapter 5. From Chapter 6 the neural based signal processing algorithms are treated followed by the use of kilo-processor arrays.

IV. Summary

The course material presents an integrated approach to linear- and nonlinear signal processing. it guides the student through the different algorithms and signal descriptions through time-domain, z-transform FFT, Hopfield net, Feedforward Neural Networks. It also elaborates on implementing algorithms on kilo-processor arrays. In this way, the students can obtain not only basic concepts but also the necessary skills to implement thee algorithms on MATLAB, on TI DSP development kits or on other platforms.

Basics of Neurobiology

Neurobiology I.

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Keywords **- neurons, glial cells, neurotransmitter and neuromodulator, resting- and action potential, excitation, inhibition, synapse, nucleus, pathway, nerve fiber, forebrain**

I. INTRODUCTION

This subject describes the structure and function of the nervous system by providing the interested audience with sufficient knowledge about the cellular elements, major pathways and the organization rules of the CNS. The lectures introduce first the neurons and glial cells and the tissue built from these elements by explaining their physiology, chemical composition, membrane processes and ultrastructure in sufficient details. This is followed by the demonstration of the major pathways and functional units of the CNS by visualizing their location, spatial orientation and relationship with other units. The techniques employed for the investigation and demonstration of the structural and functional characteristics are summarized also in short presentations.

The formal prerequisite is the subject "Molecular biology".

II. RESULTS

This subject presents 37 different topics in the field of basic neurobiology supplemented with the demonstrations of methodological approaches currently used in neuroscience.

Lectures:

- Introduction (Quo vadis Neurobiology)
- Organization of the nervous system
- The cell
- Cell organelles I.-II.
- Nervous tissue
- The neuron
- Nerve fibers
- Neuroglia
- Nerve endings
- Synaptic communication
- Neurotransmitters I.-II.
- Release of neurotransmitters
- Receptors (Ionotropic, Metabotropic)
- Neurodegeneration
- Development of the nervous system
- Spinal cord
- Internal structure of spinal cord
- Tracts of spinal cord
- Stretch reflex
- Flexor and autonomic reflexes
- Brain stem
- Structure of cerebellum
- Networking of cerebellum
- Organization of the brain stem
- Networking of brain stem
- Cranial nerves
- Diencephalon
- Divisions of the Telencephalon
- Cytoarchitecture of cerebral cortex
- Sensory systems
- Motor systems
- Hippocampal formation
- Olfactory system
- Visual system

Methods in Neurobiology:

- Histology techniques: light microscopic studies
- Applications using fluorescent dyes
- Histology techniques: electron microscopic studies
- Techniques to map neuronal connections
- Molecular biological techniques
- Living experimental models
- Electrophysiological approaches
- Behavioral studies
- Dissection, virtual dissection, imaging techniques

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Organic and Biochemistry

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I. Introduction

Chemistry fuels the engine of life, and, as a science, plays an essential role in all biosciences.

The course in Organic and Biochemistry aims at providing a solid molecular basis with emphasis on the interface of chemistry, biology and informatics to satisfy the special requirements of students in Molecular Bionics and Infobionics. It presents key concepts and principles of chemistry, focusing on the structures, structure – reactivity/property/function relationships of main classes of organic and bioorganic compounds, the mechanisms, reaction kinetics and thermodynamics of most important types of organic reactions. Throughout, it illustrates the integral role of chemistry in biosciences, helping students get a multidisciplinary view on the complex living systems.

II. Structure of the course

The organic chemistry part starts with nomenclature of organic compounds, and demonstrates how easy to apply rules for naming complex structures. Next, levels of structural representations, 2D and 3D representation of molecules, with overview on isomerism and chirality are discussed. Chemical bond formation, acidity-basicity and reactivity, basic knowledge on reaction mechanisms, and non-covolent interactions are included to foster understanding of governing principles of organic/enzymatic reactions and non-covalent supramolecular, like receptor-ligand interactions. Main classes of organic compounds, alkanes, alkenes, alkynes and aromatic compounds and those possessing functional groups relevant to biology are briefly described. Carbonyl compounds, representing a particularly important class of compounds for living organisms, are discussed in most details. Some representatives of heterocyclic compounds, occuring in biosystems (e.g. building blocks of DNA), their structure – reactivity relationships and involvement in bio-organic and medicinal chemistry are finally included.

The second part of the course, biochemistry focuses on molecules of the living world including major building blocks of life, such as amino acids, proteins, DNA, RNA, carbohydrates, lipids and vitamins. Basic metabolic pathways of the cell and the body, transducing and storing energy describes classical metabolic pathways like glycolysis, the citric acid cycle, and oxidative phosphorylation. Storage and mobilization of energy in the form of fats and glycogen is discussed. Biosynthesis and breakdown represent an inexhaustible topic of biochemistry. The biochemistry course also discusses the synthesis and breakdown of DNA, RNA and proteins, certain methods of recombinant DNA technology and synthetic biology. Structures of membranes and transports through them and ion channels are shown. As an example for understanding complex biochemical processes at molecular

level, how nerve impulses are generated and transmitted is included in the last part.

III. Conclusions

The course aims to demonstrate the essential contribution of chemistry to biosciences, focusing on basic chemical concepts and the most relevant themes of organic and biochemistry. The fascinating achievements of chemistry in understanding key events and key features of living systems at molecular level will boost confidence of students in learning.

Bioethics

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***Summary* - Bioethics is a cross-discipline, in other words it is researched by scientists working on various fields of science: medical doctors, legal experts, sociologists, philosophers, theologians. The purpose of the book is to provide an introduction into the realm of ethics which calls attention to the responsible behavior in different fields of science, most importantly in connection with human life and the environment. Each chapter deals with various basic values of life, mainly human life, and its context. A special focus is given to the conflict between the implementation of the results of science and the limits of their ethical tolerance. Can everything be allowed, which can be technically realized? In the meanwhile a specialized ethical study is carried out with the assistance of the representatives of the different fields of sciences taking the current medical researches and processes into consideration.**

Keywords - Bioethics, medical research, genetic counselling, organ transplantation, informed consent, cloning, abortion, euthanasia, hospice, contraseption, medical oath, beginning of life, end of life

I. INTRODUCTION

Bioethics is a discipline dealing with the ethical issues of the living world. Nonetheless it is an important question what kind of life it is. Very importantly, it is *human life* that called into being the basic topics of Bioethics. They are known by every well informed person, since its issues are: the beginning and the end of human life, in connection with them the question of abortion, artificial insemination, gene-therapy, organ transplantation, euthanasia, which today present not only medical or ethical concerns.

II. ETHICAL ISSUES

One of the first questions that relativize the value of life is: „Which is more valuable a new precious possession or a new child?" The next questions immediately stem from it: „When does individual human life really begin? Is it allowed to terminate the life of a human embryo, if yes, how long?" Another issue can also be raised: „Can any distinction be made between two human beings according to their physical or mental abilities, or their gender?" It leads to the next important problem: „What should happen to foeti showing signs of any deformation?" „What should happen to female embryos?" It is significant that the termination of male foeti is never an issue, which shows the distorted perception concerning the reduced value of women!

The spread of democratic rights has raised another fundamental question: Who should decide about the life of a patient and the treatment to be applied? The doctor, who knows what needs to be done in the sake of the sick person, or the patient, whose life or health is in danger? "Whose life is it, anyway?" Who should make a decision if the person most concerned cannot make a choice or is not able to express his/her wish? Who should determine the fate of the unconscious patient who that of the embryo? What is the doctor supposed to do in case he/she is to assist a patient who has attempted suicide who wishes to die. Should forced gastric lavage be applied or the patient should be left to die?

Using machines to lengthen life also raises a new question: How long a life has to be, can be lengthened?

The different approaches to the above mentioned concerns determine how individuals, a smaller group of people, a state or even more states prioritize these questions or support financially the different options. How much do they promote gene research, how much money is spent on organ transplantation, artificial insemination, scientific research? What current activities are supported? How much are we trying to influence the future with education, propaganda? How much money do we actually allocate for the treatment of suffering patients, how much for prevention? Is there someone whose life is more important than others'? Do we help tumor patients or we spend our wealth on weapons? Do we notice that by the simple act of money allocation we decide on the life or happiness of individuals, and communities? In the course of the book, which deals with different issues of Bioethics in thirteen chapters, several other questions are addressed.

III. ACKNOWLEDGEMENT

The author would like to express his deep gratitude towards Gyula Gaizler (1922-1996), who was the first pioneer lecturing Bioethics at Pázmány Péter Catholic University and this present book intends to be a continuation of his oeuvre.

Biomedical Imaging

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***Summary* — The course introduces current imaging methods in the medical practice and biomedical research. Modern X-ray, CT, PET, PET-CT, MRI and US equipment, principles of the imaging techniques, analysis and practical issues are also covered by the presentations. There is a special emphasis on the application areas of MRI: 9 of the 21 lectures discuss different aspects of this modality including special topics such as pharmacological and small animal MRI. The other field given special emphasis is ultrasound: an exhaustive introduction from the basics to advanced imaging types covered in nine additional lectures.**

Keywords - Imaging, X-ray, CT, MRI, DTI, phMRI, fMRI, PET, US, Biological Imaging, Radiography, SPECT, Nuclear Medicine, Tomography, Diagnostic ultrasound, Gamma Camera, Clinical Imaging, Functional Imaging, Neuroimaging, MRI Technology, MR physics, MR spectroscopy, Perfusion Weighted Imaging, BOLD Imaging, Clinical fMRI, Pharmaceutical fMRI, Connectivity Mapping, Animal fMRI, fMRI Biomarker, Optogenetic fMRI, Electrical Microstimulation fMRI, Diffusion Weighted MRI, Diffusion Tensor Imaging (DTI), Tractography, Arterial Spin Labeling (ASL), Source Localization

I. INTRODUCTION

A. Highschool background

Detailed knowledge about the subject is not required; however, the course builds upon basic knowledge of functional neuroanatomy and nuclear physics. Competence in biology and linear algebra is assumed. Audience will be given extensive glossary to be able to follow the curriculum.

B. Topics in higher education

Preparing the curriculum we built upon our own slides and the publicly available curricula of universities with long history of neuroimaging often exclusive to functional MRI. We exceed the generally available slides with including other neuroimaging modalities (such as CT and PET) and introducing less mainstream MRI techniques (such as DTI, ASL) and funtional MRI applications (such as clinical fMRI, pharmacological fMRI).

II. RESULTS

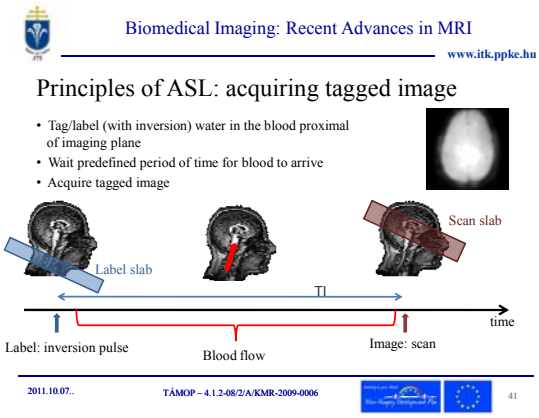
The course is split into 12+9 chapters, including approx. 1000 slides. The biggest emphasis is given to functional MRI, which is detailed in seven chapters, four of which introduces the physics and engineering background, data collection, and basic and advanced analysis techniques, while the other three give numerous examples of application in basic neuroscience, clinical practice, and pharmacology.

Two chapters present less prevalent and hence less known MRI techniques, while the remaining three lectures inform about other neuroimaging modalities: X-ray, CT and PET.

The nine additional lectures are dedicated to ultrasound, encompassing various topics from the phenomenological principles of acoustics on which ultrasound imaging is based to the latest ultrasound-based imaging methods such as sonoelastography and photoacoustic imaging.

III. METHODS

We developed a slide series for the lectures with informative figures pertaining – but not limited – to engineering and physics background of these neuroimaging modalities and schematic illustrations of imaging techniques which make them readily comprehensible (see example below).



Introduction to Biophysics

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***Summary* —This course material is addressed mainly to bachelor and master's degree students in molecular bionics and biology. The material grew out of courses in biophysics and physical biochemistry at Pázmány Péter and Eötvös Loránd Universities in Budapest as well as at UCLA in Los Angeles. The text and figures emphasize those aspects of physics and physical-chemistry which find applications to the life sciences. The approach is interdisciplinary in the sense that principles and methods of physics, chemistry and biology are used to describe the events in a living cell at the level of molecules. An attempt is made to provide conceptual explanations of the models and equations so that students can reinforce quantitative description with qualitative understanding.**

Keywords— molecular biophysics; physical biochemistry; life sciences

I. INTRODUCTION

Biophysics is the discipline of quantitatively describing physical phenomena taking place in biological systems.

Our course focuses on molecular biophysics, mainly the biological macromolecules in aqueous solution. Two chapters are devoted to an important - and from a didactical point of view, the most interesting - macromolecules: proteins, to show how to apply the basic and general concepts of biophysics to biological systems.

Physical approach to molecular life sciences rests on three main conceptual theories:

Quantum mechanics that describes the motions and energies of microscopic particles. In contrast to quantum mechanics **thermo dynamics** deals with macroscopic, directly observable properties, and places strict limitations on the interconversion of different forms energy. Since the interconversion of energy, heat and light is basic to life, thermodynamics is unavoidable to describe living matter. Another important facet of thermodynamics that it allows us to predict equilibrium state having only the properties of substances involved in metabolism.

Statistical mechanics bridges the microscopic realm of quantum mechanics to the macroscopic realm of thermodynamics.

The aim of this curriculum is to demonstrate that scientists must resort to experiments, and quantum and statistical mechanics constitute the framework within which experiment must be interpreted at the level of atoms and molecules.

A. PPREREQUISITES

To be able to follow the course easily, students should have some basic mathematical knowledge. The topics used in this curriculum include one- and multidimensional calculus (functions, derivation, integration), differential equations and vector algebra. Some non-standard, and hence more complicated, elements also appear, but their complete knowledge is not required to fully understand the course.

We also build upon the knowledge of the laws and equations of Newtonian mechanics. The greater part of the course deals with the physics of bimolecular systems, so knowledge of some basic chemical concepts is also required

B. Offered competencies

Through the course, students can learn about methods used to

quantitatively describe some simple phenomena, and several techniques of describing a more complicated process or system starting at the simplest representation of them and advancing to more complicated descriptions by taking progressively more details and conditions into consideration.

II. TOPICS

The course material consists of 10 chapters with 731 slides. Besides text, there are 240 figures and 28 tables.

The first chapter presents the fundamental equations and concepts of phenomenological and statistical thermodynamics. The second and third chapters present both the experimental and theoretical aspects of reaction kinetics. Understanding the current theory of bimolecular kinetics requires basic knowledge of quantum mechanics, so a longer quantum mechanical introduction is incorporated into the third chapter.

From the fourth to sixth chapters, students can become acquainted with the thermodynamics of solutions. The fourth chapter starts with neutral solutions with only two components, and the sixth one discusses the thermodynamics of electrolytes.

The seventh chapter provides an introduction to the topic of molecular interactions, and discusses the binding of one or several small ligands to a biological macromolecule.

The eighth chapter describes the common components and electronic properties of biological membranes.

The last two chapters deal with proteins. Structural features are presented in the ninth chapter and the special function of proteins as enzymes are discussed in the tenth chapter.

III. METHODS

The curriculum emphasizes the rigorous mathematical derivation of different laws. We made an effort to present the derivations in small steps for better clarity while keeping the material sufficiently concise.

The practical applications of concepts and equations are exemplified by experiments to provide qualitative interpretation to models and quantitative descriptions of the phenomena.