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STUDY PROGRAMME PROPOSALS FOR UNIVPM STUDENTS THAT WISH TO HAVE A MASTER'S IN BIOMEDICAL ENGINEERING AT CUA

1) The UNIVPM students will go at CUA at the SECOND year and will remain at CUA for 1 year (two semesters)
2) It is supposed that UNIVPM students have attended all the FIRST YEAR courses of the Biomedical Engineering Course at UNIVPM
3) To obtain MS degree at CUA, students are required to take 2 of 3 courses (ENGR 516, ENGR 518 and ENGR 520). ENGR 520 is covered by the 3 math courses UNIVPM students have taken at the Bachelor degree (Math Analysis I, Math Analysis 2, and Geometry). Consequently, UNIVPM students are required to take ENGR 516 or ENGR 518 to satisfy CUA requirement.
4) There is no course held in English language that covers the topics of ENGR 516 or ENGR 518. So UNIVPM students have to choose ENGR 516 or ENGR 518 (as they wish) thus saturating one free-choice course that they have at the second year of the UNIVPM MS course.
5) The remaining free elective course at CUA for its 1-year Master's degree must be covered with BE courses equivalent to Physiological Signal processing and modelling in Cardiology (mandatory for the 2-year Master's degree at UNIVPM)

Possible solution for 10 courses without thesis:

			COURSE ATTENDED AT CUA OR UNIVPM	Equivalence	Syllabus
1	ENGR 516 OR ENGR518	Computational methods for graduate students Experimental Techniques for Graduate Students	CUA	None	ENGR 516. Discretization methods (finite differences, finite volumes, finite elements), stability and convergence; parabolic, hyperbolic, and elliptic PDEs: model equations and numerical solutions method. Numerous programming exercises will be assigned. ENGR518. This course introduces students to the different aspects of experimental research in engineering. The course will cover fundamental issues such as: planning and design of an experimental campaign, data acquisition and signal processing. State-of-the-art experimental techniques in different areas of engineering research will also be presented, with focus on, for instances, modern, non-intrusive measurement methods. The goal is to provide students with the knowledge required to plan, design and conduct an experimental campaign, which they can eventually apply to their own research efforts.
2	BE 500 level	Free Elective for CUA but Mandatory for UNIVPM	CUA		AT UNIVPM: Physiological signal processing and modelling in Cardology is mandatory for UNIVPM students at the second year Could be equivalent with: BE 571: Cardio-pulmonary biomechanics. BE581: Medical Imaging AT UNIVPM: Frontal teaching, 41 hours. Lectures about cardiovascular physiology/pathophysiology underlying cardiovascular signals and images,

					concerning electrical heart function (action potential, pacemaking and conduction, genesis of the electrocardiogram, arrhythmias, ECG lead systems and vectorcardiogram, ECG measurements), mechanical heart function (contraction mechanism, excitation-contraction coupling, pump function) and circulation (physical concepts, arteries / capillaries / veins, neural control, humoral control and autoregulation, exercise and orthostasis, atherosclerosis and infarction, heart failure). Lectures about signal and image processing, concerning electrocardiography (ECG), intravascular and intracardiac pressure measurement, blood pressure and pulse oximetry, coronary angiography, echocardiography, single photon emission computed tomography (SPECT) and positron emission tomography (PET), magnetic resonance imaging (MRI), computed tomography (CT), ECG monitoring, intracardiac electrograms and novel diagnostic and therapeutic procedures. Lectures about modelling and simulation of electrical heart activity (with a focus on the ECGSIM simulation program) and about modelling and simulation of the circulation (with a focus on the APLYSIA simulation program), including introductions to the ECGSIM and APLYSIA simulation and MATLAB programming assignments. Also included: frontal teaching during site-visits of the hospital. Student activities in lab/aula (31 hours). Initial simulation experiments with ECGSIM and with APLYSIA, and first ECG processing experiments with MATLAB. Plenary individual poster presentations of simulation assignments with ECGSIM and with APLYSIA, and of the Matlab solution for the ECG processing assignment (which is the same for all students). Plenary presentations, by teams of 2-3 students, in a journal club setting, of their litterature review assignments regarding the signal and image processing topics (electrocardiography, intravascular and intracardiac pressure measurement, blood pressure and pulse oximetry, coronary angiography, echocardiography, single photon emission computed tomography and positron emission tomography, magnetic resonance imaging, computed tomography, ECG monitoring, intracardiac electrograms, and novel diagnostic and therapeutic procedures); every student takes part in two different presentations on different subjects. AT CUA BE 571 (Cardio-Pulmonary Biomechanics) This course is designed to be a first course covering the broad fields of cardiac and pulmonary biomechanics. The course will review the anatomy and physiology of the human circulatory and respiratory systems, but will mainly focus on engineering approaches to the

					study of these respective areas of study. Other topic areas will include rheology of blood, mechanics of blood vessels and the airway, steady and unsteady flow models, cardiac and pulmonary bioinstrumentation, cardiac ejection mechanics, mechanics of ventilation, and applications of imaging techniques to study the cardiac and pulmonary systems. BE 481.: Introduction to the physical principles, image reconstruction techniques, and advanced digital processing techniques used in modern medical imaging systems. Introduces common imaging modalities such as ultrasound, x-rays, computer-aided tomography (CAT), magnetic resonance imaging (MRI), and positron emission tomography (PET). Discussion of advanced computer methods for 2-D and 3-D image reconstruction as well as digital signal processing methods used in image recognition and enhancement of medical images. Fundamentals of medical imaging. BE 581: Introduction to the physical principles, image reconstruction techniques, and advanced digital processing techniques used in modern medical imaging systems. Introduces common imaging modalities such as ultrasound, x-rays, computer-aided tomography (CAT), magnetic resonance imaging (MRI), and positron emission tomography (PET). Discussion of advanced computer methods for 2-D and 3-D image reconstruction as well as digital signal processing methods used in image recognition and enhancement of medical images. Fundamentals of medical imaging. Prerequisite: MATH 221.
3		Applied Measurement techniques (I year)	UNIVPM	BE 513 + BE 481	AT UNIVPM: 1. Imaging systems : Ultrasound imaging: Generation and propagation of ultrasound; Interaction with tissues; Ultrasound beam shaping; Probes and imaging modes; Image formation and ultrasound tomography; Eco-Doppler, Color Doppler e Power Doppler. X-ray imaging: Generation and propagation of X-rays; Emission spectra and attenuation coefficient; X-ray tube and X-ray machine; Rotating anode; Focal spot; Generation of the image; X-ray system; Fluoroscopy; Image Intensifier and dynamic radiography; X-ray film, anti-diffusion grid, Pottery-Bucky table; Analogue and digital radiography. X-ray Computed Tomography (CT): Tomographic systems; Mechanical tomography; CT scanners modalities; Axial computed tomography; Reconstruction algorithms; Filtering and artifact removal; Gantry; CT machine generations; System components of a modern multislice CT machine; Sensors and CT numbers. Nuclear Medial Imaging (PET e SPECT): Radio-Isotopes and radiation; Physics of radiation and interaction with tissues; Sensors for radiations: Ionization chambers and

					scintillating crystals; Pulse Height Analyser (PHA); Uptake·monitoring equipment; Gamma camera; PET e PET/CT systems. 2. Therapeutic equipment: Ablation: Tissue ablation; Electric ablation; radiofrequency ablation; Ultrasound ablation; Lithotriptors, Acoustic intensity and focusing; Cryoablation; Microwave ablation; Chemical ablation Biomedical lasers: Physics and laser proprieties; Configuration and classification of laser sources; Laser and tissue interaction; Safety aspects; Clinical use of lasers Radiotherapy: Biological effects of radiations; Dose and fractioning; internal radiotherapy (brachytherapy); External radiotherapy; Planning and modalities of treatment; High-voltage X-ray machine; Betatron; Cobalt-60 machine; Gamma Knife; linear accelerator; Cyberknife. Endoscopy: Functioning principle; Rigid endoscopes; Flexible endoscopes; Main components and scheme; Ultrasound endoscopic probes. Infusion pumps: Modalities of infusion; gravity-fed infusion systems; Mechanical pumps; peristaltic pumps; Volumetric Pumps; Scheme of a infusion pump and alarm systems; closed-loop control system: the insulin portable pump. Ventilators: Respiratory apparatus; Artificial ventilation, types off ventilators; Negative-Positive ventilators; Control systems in ventilators. Biosensors: Chemical sensors; Blood sensors, electrochemical sensors; pH, PO2 and PCO2 s sensors; Glucose sensors; Optical sensors; Pulse-oxymeters; Clinical laboratory instrumentation; spectrophotometry. Telemedicine: The principle of telemedicine; Sensing and sensor networks in telemedicine; Telecardiology; Teleradiology; Home-monitoring systems. 3. Technical norms and standards for biomedical device: Medical device: definition and standard; General aspects on apparatus safety (electric, optic and radiology) for biomedical instrumentation. AT CUA BE 513 - Biomedical Instrumentation I. Introduces the fundamental principles of biomedical instrumentation and their application to real-world devices. In a combination of laboratory and classroom exercises, students design, construct, and test biomedical instruments from the ground level up. Emphasis on use of computers and digital signal processing techniques in biomedical instruments. BE 481 - Medical Imaging. Introduction to the physical principles, image reconstruction techniques, and advanced digital processing techniques used in modern medical imaging systems. Introduces common imaging modalities such as ultrasound, x-rays,

					computer-aided tomography (CAT), magnetic resonance imaging (MRI), and positron emission tomography (PET). Discussion of advanced computer methods for 2-D and 3-D image reconstruction as well as digital signal processing methods used in image recognition and enhancement of medical images. Fundamentals of medical imaging.
4		Bioimaging and Brain Research (I year)	UNIVPM	BE 521-1 BE 581-2	AT UNIVPM Objectives The course enables students to gain in-depth knowledge about the various existing methods for detecting and mapping human brain function.The first part of the course will provide the necessary background so that the students acquire a clear awareness of the more broader multidisciplinary context of the neuroscience with a clear reference to the aspects of neuroimaging and brain research with particular reference to the magnetic/electrical (EEG/MEG) brain activity and haemodynamic (fMRI) response associated with neuronal activity (EEG- fMRI). Program: Content (lectures, 48 hours) Principles of Human Nervous Systems: Neurons, Neural Circuits, Organization of the Human Central Nervous System and Functional Analysis of Neuronal System. Overview of Complex Brain Functions: The Association Cortices, Memory, Language and Speech. How to detect direct and indirect signals from the brain in a non-invasively way: Electroencephalography (EEG); Magnetoencephalography (MEG); Functional magnetic resonance imaging (fMRI). Multimodal imaging approach: Simultaneous EEG fMRI. Biological and non-biological signal detected by neuroimaging techniques. Neuroimaging signal processing: Event Related Potentials (ERPs), Blind Source Separation (BSS) and Independent Component Analysis (ICA). Brain source localization from EEG/MEG recordings. Functional and Effective Brain connectivity: Granger Causality (GC), Directed Transfer Function (DTF), Partial Directed Coherence (PDC). Laboratory exercises (24 hours) - EEGLAB toolbox: an open source framework for EEG/MEG data analysis. - Brainstorm toolbox: an open source tool for data analysis EEG/MEG particularly oriented in brain source localizations; - Statistical Parametric Mapping (SPM) toolbox: an open source framework for MEG/fMRI data analysis. - Group ICA Of fMRI (GIFT) Toolbox: an open source framework for fMRI data analysis. AT CUA BE 521 - Neural Control of Movement. This course examines the role of the nervous system in the production of voluntary movement in humans. Fundamental concepts and current issues will be incorporated into classroom discussions. Neural structures and pathways involved in motor control and feedback, including the cerebral cortex, basal ganglia,

					cerebellum, brainstem, spinal cord, muscle, sensory receptors, reflex arcs, and other control circuits will be introduced. The interaction of the motor control system with the environment in functional movements (e.g., reaching, locomotion, and balance) will be examined. Typical development and learning of motor control as well as atypical motor control, in the case of motor disorders, will be discussed. BE 581 Medical Imaging. Introduction to the physical principles, image reconstruction techniques, and advanced digital processing techniques used in modern medical imaging systems. Introduces common imaging modalities such as ultrasound, x-rays, computer-aided tomography (CAT), magnetic resonance imaging (MRI), and positron emission tomography (PET). Discussion of advanced computer methods for 2-D and 3-D image reconstruction as well as digital signal processing methods used in image recognition and enhancement of medical images. Fundamentals of medical imaging.
5		Bioinformatics and Systems Biology (I year)	UNIVPM	BIOL 596	AT UNIVPM Elements of comparative biochemistry. Elements of comparative Molecular Biology. Introduction to Bioinformatics. Functional genomics. Biological Databases and databanks. Name and function of database. Retrieval of data and its description. Gene expression analysis. Pairwise sequence alignments. FASTA and BLAST. Multiple Sequence Alignments. Methods of Gene prediction. Sequence Similarity networks. Comparative genomics. Methods for discovery and characterization of sequence motifs. Phylogenetics and Evolutionary Bioinformatics. Molecular modeling of proteins: from simulation to drug design applications. Introduction to Synthetic and Systems Biology. AT CUA BIOL 596 - Computational Genomics. An introduction to bioinformatics. Topics include structure, fraction, and interrelationships of databases, information retrieval, database homology searching, pairwise alignment methods, gene prediction programs and submission of sequence, prediction of secondary and tertiary protein structure using web-based tools. Lecture and lab.
6		Dynamical Modelling of Movement (I year)	UNIVPM	BE 502	AT UNIVPM Dynamics of a material point a. Some basic concepts (reference frame, mass, linear momentum, angular momentum) b. Newton s first law of inertia c. Newton s second law or Fundamental Principle of Dynamics d. Newton s third law or Action-Reaction law e. Some classical forces (gravitational force, friction force, spring force) II. Work, kinetic energy, kinetic moment and related theorems a. Work and Power b. Kinetic energy and work-

					energy theorem c. Conservative forces and potential energy d. Conservation of total energy e. Angular momentum theorem III. Kinetics of a rigid body a. Introduction b. Mass distribution c. Centre of mass d. Kinetic energy associated to the movement of a solid e. Kinetic vectorial quantities associated to the movement of a solid f. Koenig s theorems for the kinetic energy and the angular momentum g. Kinetics of the specific movement of a solid around a fixed point h. Matrix of the inertia tensor in any direct orthonormal basis i. Application of the Koenig s theorems for kinetic calculations j. Time derivative of the linear and angular momentums k. Application in human movement : Inertial body segment parameters evaluation IV. Rigid multi-body dynamics a. Introduction b. Fundamental Principle of Dynamics c. Kinetic energy theorem d. Energy conservation theorem e. Joint modelling f. Application in human movement i. External forces measurement devices ii. Inverse dynamics method to compute net joint moments V. Lagrange s equations of motion a. Generalized coordinates and kinematical constraints b. Generalized forces and virtual work c. Lagrange s equations of motion VI. Musculoskeletal modelling a. Musculo-skeletal models i. Muscle contraction dynamics model ii. Muscle-tendon dynamics model iii. Skeletal dynamics model b. Prediction of mucle-tendon and joint reaction forces i. Static optimization ii. EMG to force iii. Forward dynamics assisted data tracking The course notes will be available for students in PDF format. New concepts will be regularly applied on exercises, mostly related to human movement. AT CUA BE 502: This course provides students with advanced topics of traditional and contemporary biomechanics. Study will address mechanisms by which experimental and computational biomechanics investigate human and joint dynamics (kinetics and kinematics) and its association to ergonomics, orthopedic and sports biomechanics. Selected topics will include: biological materials, measurement techniques, advanced force system analysis, energy considerations, simulation using musculoskeletal models, optimization of inverse and forward dynamics, and applications of finite element techniques in biomechanics.
7		Models and Control of Biological Systems (I year)	UNIVPM	BE 315 +consortium course in modeling (ENGR 222 + BIOL 518)	AT UNIVPM Linear and non-linear compartmental models and control. Structural identification of linear mathematical models: transfer-matrix method. Structural identification of non-linear mathematical models: Taylor series expansion method. Parameter estimation: least-squares and maximum likelihood methods. Design and analysis of identification experiments. Models of glucose kinetics and of C-peptide secretion

					and kinetics. Model-based characterization of glucose regulation system by indexes of insulin sensitivity and beta-cell responsivity. Relationship between insulin action and secretion. Model-based assessment of hepatic insulin degradation. Applications in clinical and experimental settings. Computer exercises: use of SAAM II Software System for interpretation of insulinemia and glycemia data by models of glucose kinetics. AT CUA BE 315: This course introduces the techniques for analysis and modeling of biological and physiological systems. Students will derive mathematical models of the systems developed in the co-requisite physiology and apply them to generate simulation data. Time and frequency domain issues will be addressed. Students will use computer methods to solve problems in data analysis, system identification, and model validation. Prerequisite ENGR 222, co-requisite BIOL 518.
8	BIOL 418	Physiology	CUA		AT CUA BIOL 418: Vertebrate/human function with emphasis on the cardiovascular system, and on the cellular functions involved with muscle contraction, nerve impulse propagation, renal function, respiration and digestion. Three hours of lecture and three hours of laboratory each week. AT UNIVPM: Human Physiology General principles of Physiology. Concept of homeostasis. Fluid compartments. Cell membrane. Transport mechanisms across membranes. Cell physiology. Resting membrane potential. Action potential: origin and conduction. Synaptic transmission. Central nervous system neurotransmitters.? Functional organization of the vertebrate nervous system. The autonomic nervous system. Muscle physiology. Morphological and functional characteristics of skeletal, cardiac and smooth muscle. Muscle contraction. Mechanical and biochemical aspects. Energy sources for muscle contraction. Motor unit.? Physiology of movement. Definition of reflex. Spinal reflexes: stretch and withdrawal reflexes. Neural substrate for reflex responses. Control of posture and voluntary motor activity. Role of cortical motor areas. Corticospinal and corticobulbar tracts. Role of cerebellum and basal ganglia.?? Sensory physiology. Cutaneous, deep and visceral sensation. Neurophysiology of pain. Neurophysiology of vision. Neurophysiology of hearing and equilibrium. Neurophysiology of taste and smell. Cardiovascular physiology. Electrical activity of the heart. The heart as a pump. General hemodynamic principles. Laminar and turbulent flow. Measurement of arterial blood

					pressure.?Capillary exchanges. Blood flow from the major veins to the heart. The regulation of cardiac output and of peripheral circulation.? Respiratory physiology. Respiratory mechanics. Lung volumes. Alveolar ventilation. Alveolar gas exchanges. Blood transport of oxygen and carbon dioxide. Nervous and chemical regulation of respiration.? Renal physiology. Kidney functional anatomy. Glomerular filtration and renal blood flow. Absorptive and secretory functions of renal tubules. Homeostatic mechanisms maintaining osmolality and normal volume and ionic composition of extracellular fluids. Micturition. Gastrointestinal physiology. Motility and secretions. Digestion and absorption of carbohydrates, proteins and fats. Nervous and hormonal control of gastrointestinal functions.
9	BE 521 + BE528	Neural Control of Movement + Rehabilitation Engineering.	CUA		AT CUA BE 521 - Neural Control of Movement. This course examines the role of the nervous system in the production of voluntary movement in humans. Fundamental concepts and current issues will be incorporated into classroom discussions. Neural structures and pathways involved in motor control and feedback, including the cerebral cortex, basal ganglia, cerebellum, brainstem, spinal cord, muscle, sensory receptors, reflex arcs, and other control circuits will be introduced. The interaction of the motor control system with the environment in functional movements (e.g., reaching, locomotion, and balance) will be examined. Typical development and learning of motor control as well as atypical motor control, in the case of motor disorders, will be discussed. BE528 Rehabilitation Engineering. This course explores the principles and practices of rehabilitation engineering and the role of engineers in the delivery of health care to disabled individuals. Discussions of approaches to diagnosis and treatment of disorders involving motor function will be included as will an analysis of the design of devices and systems to aid the disabled. Disabilities as a result of stroke, spinal cord disorders, cerebral palsy and Parkinson's disease will be discussed. Examples of technologies examined include devices aiding mobility, limb prosthetics, robotic aids, functional electrical stimulation, and interfaces to microcomputers. AT UNIVPM: Bioengineering of Motor Rehabilitation Elements of Biomechanics of Movement: Kinematics and Inverse Dynamics. Principles of DSP and stereophotogrammetry for Movement Analysis., Use of dynamometric platforms and of basographic and barographic systems. Motor rehabilitation: ICIDH and ICF classification. Clinical scales for functional evaluation . Surface electromyography. Methods and instrumental

					techniques for the quantitative functional evaluation of movement with particular reference to the control of the orthostatic posture and locomotion. Insights in the methodologies for specific clinical situations (neuropathies, stroke, Parkinson). Theoretical aspects of the functional analysis of locomotion (normality case). Determinants of the gait. Spatiotemporal parameters of gait and gait phases. Laboratory examples and laboratory activities for static and perturbed posture tests, and analysis of locomotion
10	BE 315 + BE 515	Introduction to biomedical systems analysis + Advanced Digital Signal Processing.	CUA		AT CUA BE 315: This course introduces the techniques for analysis and modeling of biological and physiological systems. Students will derive mathematical models of the systems developed in the co-requisite physiology and apply them to generate simulation data. Time and frequency domain issues will be addressed. Students will use computer methods to solve problems in data analysis, system identification, and model validation. EE 515 - Advanced Digital Signal Processing. This course examines the properties of signals and systems, sampling, data acquisition, Discrete-Time Fourier Transform (DTFT), Discrete Fourier Transform (DFT), Z-transform theory, spectral analysis, digital filter design and discrete transforms. Practical applications of digital signal processing will be emphasized with a number of hands on MATLAB Programming exercises. AT UNIVPM: Biomedical Signal and Data Processing Theory. Biomedical signals and classification according to their nature and characteristics. The four fundamental stages of biomedical signal processing (acquisition, transformation, selection of parameters and classification). Examples (electrocardiogram, electromyogram, EEG). Frequency analysis of biomedical signals: from the Fourier series to the continuous and discrete Fourier transforms. Analog/digital conversion and sampling theorem. FFT algorithm. Application examples (Tachogram). Z transform. Input-output relations: difference equations and transfer functions. Numeric filters (FIR and IIR) and their graphics solution. Random variables and their use in clinical decision. Bayes theorem. Clinical test, contingency table, correlation measures (sensitivity and specificity) and positive predictive value (prevalence). ROC curves and definition of a threshold. Coefficient of correlation, regression and least squares method. Stochastic process. Stationarity and ergodicity. Wiener-Kinchin for estimating spectral power. Tutorial. Exercises of practical application of theoretical knowledge. Development of a Matlab project.