EUROPEAN UNIVERSITY FOR CUSTOMISED EDUCATION

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STUDY GUIDE

DECODING LIFE SIGNALS: INNOVATIONS IN BIOMEDICAL ENGINEERING

Organised by

University of the Peloponnese

1. IDENTIFYING DATA.

· **Course Name.**	*Decoding Life Signals: Innovations in Biomedical Engineering*
· **Coordinating University.**	*University of the Peloponnese*
· **Partner Universities Involved.**	-
· **Course Field(s).**	*Biomedical Engineering*
· **Related Study Programme.**	-
· **ISCED Code.**	*0715 - Biomedical engineering.*
· **SDG.**	*SDG 3: Good Health and Well-being* *SDG 4: Quality Education* *SDG 9: Industry, Innovation, and Infrastructure*
· **Study Level.**	*Open for Bachelor (B) and Master (M) students*

· **Number of ECTS credits allocated.**	*5*
· **Mode of Delivery.**	*Online live*
· **Language of Instruction.**	*English*
· **Course Dates.**	*Spring Semester:* *Mid February – Early May 2025* *(12 weeks, approximately 10 hours of commitment / week for the students)*
· **Schedule of the course.**	*The exact schedule will be announced .*
· **Key Words.**	*EEG, ECG, EMG, Signal Processing, Biomedical Engineering*
· **Catchy Phrase.**	*Master the art of decoding the body's signals for a healthier tomorrow*

· **Prerequisites and co-requisites.**	- *Background Knowledge: Some prior knowledge of Python programming and Digital Signal Processing (preferred but not compulsory).* - *Study Levels: Available for Bachelor (B) and Master (M) students.* - *Required Linguistic Skills: English B2*
· **Number of EUNICE students that can attend the Course.**	*30 students*
· **Course inscription procedure(s).**	*Standard EUNICE process*

2. CONTACT DETAILS.	
· **Department.**	*Electrical & Computer Engineering*
· **Name of Lecturer.**	*Athanasios Koutras, Associate Professor*
· **E-mail.**	*koutras@uop.gr*
· **Other Lecturers.**	- *Dr. Nyi Nyi Tun (PhD, Post-doc, Biomedical Engineer)* - *D. Anyfantis (MSc, Engineer, PhD Student on Medical Imaging)* - *Guest lecturers, prestigious figures in biomedical engineering and related fields, including renowned academics and leading industry professionals will be invited.*

3. COURSE CONTENT.

This course offers a unique blend of theoretical knowledge and practical skills, focusing on the fascinating world of biomedical signals such as EEG, ECG, and EMG. Students will dive deep into the science of understanding the human body through its electrical signals, using this information to push forward the boundaries of medical technology.

- *Engage with Real Data: From the very start, students will work with real human data. They'll learn how to access open-source databases, extract meaningful information, and navigate the ethical considerations of working with such data. This hands-on approach ensures that the skills they acquire are not only theoretically sound but also practically applicable.*

- *From Data to Insight: The course covers the entire spectrum of working with biomedical data. Starting with data acquisition, students will learn the techniques for cleaning and preprocessing data to remove noise and artifacts. They'll explore various analysis techniques to uncover patterns within the data, using both traditional statistical methods and cutting-edge machine learning algorithms.*

- *Visualization and Interpretation: Understanding data is one thing; explaining it is another. This course places a strong emphasis on data visualization and interpretation, teaching how to turn complex datasets into clear, compelling visuals that can inform and persuade. The students will learn how to use visualization tools to represent data in ways that are accessible to both technical and non-technical audiences.*

- *Python Programming and Specialized Tools: No prior programming experience? No problem. While some familiarity with Python is beneficial, this course will guide students through using Python specifically for biomedical data analysis. They'll become proficient in specialized open-source software designed for biomedical engineering, such as MNE-Python for EEG data analysis, enabling them to tackle their projects with confidence.*

- *Project-**Based Learning**: The centerpiece of this course is its project-based learning component. Students will have the opportunity to work on exciting projects using data from real-life scenarios. Whether it's designing a brain-computer interface, analyzing sleep patterns, or exploring the neural underpinnings of cognition, these projects will challenge them to apply everything they've learned in a cohesive, impactful way.*

- *Accessibility and Innovation: Recognizing that not every student has access to specialized equipment, this course is designed to be inclusive, relying on open-source databases and software that can be explored with just a computer. For those who have access, the course will offer guidance on how to utilize university lab equipment for data acquisition, providing a richer, more hands-on experience.*

By the end of this course, students will not only have a solid foundation in biomedical signal processing but also the skills to contribute meaningfully to the field of biomedical engineering. They'll leave with a portfolio of projects demonstrating their ability to transform raw data into insights that could one day revolutionize healthcare.

4. LEARNING OUTCOMES.

Upon successful completion of "Decoding Life Signals: Innovations in Biomedical Engineering," students will be able to:

1. Understand Biomedical Signals: Identify and describe the various types of biomedical signals, including EEG, ECG, and EMG, and their significance in understanding human neurophysiological processes.

2. Data Acquisition and Preparation: Demonstrate proficiency in acquiring biomedical data from open-source databases and through direct recording (where equipment is available), as well as in cleaning and preprocessing this data to remove noise and artifacts, ensuring it is analysis-ready.

3. Comprehensive Data Analysis: Apply a range of analytical techniques to biomedical signals to extract meaningful information. This includes time-domain and frequency-domain analyses, wavelet transforms, and time-frequency analysis.

4. Visualization Skills: Develop and employ sophisticated data visualization techniques to represent biomedical data clearly and effectively, facilitating understanding and communication of complex information to both specialized and non-specialized audiences.

5. Introduction to Machine Learning: Gain foundational knowledge and practical skills in applying machine learning algorithms to biomedical data. Understand how these techniques can uncover patterns within data that are not readily apparent through traditional analysis methods.

6. Project Design and Implementation: Design, implement, and manage projects that tackle real-world problems using biomedical data. This includes formulating a problem statement, selecting appropriate analysis and machine learning techniques, and executing the project to derive insightful conclusions.

7. Interdisciplinary Collaboration: Work effectively in interdisciplinary teams, integrating knowledge for instance from electrical engineering, computer science, and biology to address complex challenges in biomedical engineering.

8. Critical Thinking and Problem-Solving: Develop critical thinking and problem-solving skills, applying theoretical knowledge and practical skills to navigate challenges encountered during the analysis and interpretation of biomedical data.

9. Ethical Considerations: Recognize and navigate the ethical considerations involved in working with human data, ensuring respect for privacy, consent, and the responsible use of data in all aspects of work.

10. Communication Skills: Enhance communication skills, with the ability to explain complex biomedical engineering concepts and data analysis results to a broad audience, including writing clear and comprehensive reports and delivering effective presentations.

5. OBJECTIVES.

"Decoding Life Signals: Innovations in Biomedical Engineering" aims to equip students with the knowledge, skills, and innovative thinking necessary to excel in the interdisciplinary field of biomedical engineering. The course is designed with the following objectives:

1. Foundational Understanding: To provide a solid foundation in the principles and applications of biomedical signal processing, ensuring students have a deep understanding of the types of signals and their relevance to human health.

2. Practical Skills in Data Handling: To develop hands-on skills in the acquisition, cleaning, preprocessing, and analysis of biomedical data from various sources, emphasizing the importance of data quality and preparation for analysis.

3. Analytical Proficiency: To teach students how to apply a variety of analytical methods to biomedical data, including traditional statistical techniques and advanced methods such as wavelet and time-frequency analysis, fostering a versatile analytical mindset.

4. Introduction to Machine Learning: To introduce the concepts and applications of machine *learning in biomedical signal processing, preparing students to use these powerful tools to identify patterns, make predictions, and solve complex problems in healthcare.*

5. Visualization and Communication: To cultivate the ability to visualize data and results effectively, enabling students to communicate complex biomedical information clearly and persuasively to a diverse audience.

6. Project-Based Experience: To provide a project-based learning environment where students can apply their skills to real-world challenges, encouraging innovation and creative problem-solving in designing and implementing projects with real human data.

7. Interdisciplinary Collaboration: To foster an interdisciplinary approach, encouraging collaboration across fields of engineering, computer science, and biology, reflecting the collaborative nature of the biomedical engineering field.

8. Ethical Awareness: To instill an understanding of the ethical considerations in biomedical data handling and research, promoting responsible and respectful practices in the analysis and use of human data.

9. Career Preparedness: To prepare students for successful careers in biomedical engineering and related fields, equipping them with a competitive skill set that includes technical proficiency, innovative thinking, and effective communication.

10. Lifelong Learning: To inspire a commitment to lifelong learning and continuous improvement, preparing students to adapt to and lead in the rapidly evolving field of biomedical engineering.

6. COURSE ORGANISATION.

UNITS

1.	***Introduction to Biomedical Signals*** - *Overview of biomedical signals (EEG, ECG, EMG)* - *Significance in healthcare and research* - *Ethical considerations in biomedical engineering*
2.	***Data Acquisition and Cleaning*** - *Techniques for collecting biomedical data, including use of open-source databases* - *Cleaning and preprocessing data to remove noise and artifacts* - *Ethical considerations in data handling*
3.	***Analytical Techniques and Machine Learning*** - *Time-domain, frequency-domain, and wavelet analyses* - *Introduction to machine learning algorithms for biomedical data*

	- *Practical applications of machine learning in signal analysis*
4.	***Data Visualization and Communication*** - *Techniques for effective data visualization* - *Communicating complex information to technical and non-technical audiences* - *Tools for creating compelling visualizations of biomedical data*
5.	***Project Design and Implementation*** - *Formulating project ideas and objectives* - *Project management and implementation strategies* - *Team collaboration and interdisciplinary work*
6.	***Hands-on Projects with Real Data*** - *Application of learned skills to real-world biomedical engineering challenges* - *Projects may include designing brain-computer interfaces, analyzing sleep patterns, or studying neural dynamics* - *Use of Python and specialized open-source tools (e.g., MNE-Python)*

LEARNING RESOURCES AND TOOLS.

- *Comprehensive access to online lectures and materials*
- *Guided tutorials on Python programming for biomedical engineering*
- *Open-source software tools tailored for biomedical data analysis*
- *Unique Practical Demonstrations:*

  A distinctive feature of this course is the live demonstration sessions hosted by the University of the Peloponnese. These sessions will provide students with a rare opportunity to witness firsthand the process of biomedical data acquisition using state-of-the-art equipment:

  - *OpenBCI: An open-source platform that will be used to demonstrate the acquisition of EEG signals. OpenBCI is renowned for its versatility and accessibility, making it a valuable tool for understanding brain activity.*
  - *EmotiBit: This wearable biometric sensor will be showcased for capturing EMG signals and other biosignals related to the parasympathetic nervous system, such as GSR (Galvanic Skin Response), heart rate, and SPO2 (blood oxygen saturation).*

PLANNED LEARNING ACTIVITIES AND TEACHING METHODS.

- *Interactive lectures to build foundational knowledge*
- *Hands-on practical sessions for skills development*
- *Group projects to encourage collaboration and real-world application*
- *Regular feedback sessions to guide project development*
- *Access to virtual labs and datasets for remote learning and experimentation*

PROJECT-BASED LEARNING

- *The course heavily emphasizes project-based learning, allowing students to engage with real data and address genuine biomedical challenges.*

- *Projects are designed to enhance student innovation, problem-solving skills, and the ability to work effectively in teams.*
- *Feedback and guidance are provided throughout the project lifecycle, from conception to presentation.*

7. ASSESSMENT METHODS, CRITERIA AND PERIOD.

The assessment for "Decoding Life Signals: Innovations in Biomedical Engineering" is designed to prioritize real-world application of skills and knowledge through project-based learning. The following breakdown further emphasizes the significance of the project work.

Assessment Components:

1. Quizzes (10%)
- Short quizzes to ensure foundational understanding of biomedical signal processing concepts and the application of machine learning techniques.

2. Practical Assignments (10%)
- Targeted assignments to develop and assess individual proficiency in data cleaning, preprocessing, and analysis using specialized software tools. These tasks validate the practical application of theoretical knowledge.

3. Project Proposal (10%)
- A detailed project proposal that outlines the chosen biomedical challenge, objectives, and proposed methodology. This assesses planning and conceptualization skills early in the course.

4. Project Implementation and Report (70%)
The centerpiece of the assessment is the final project, reflecting the course's emphasis on hands-on, project-based learning. This component evaluates:
- The comprehensive application of biomedical signal processing and machine learning techniques to a real-world problem.
- The innovation and creativity in addressing the chosen challenge.
- The effectiveness of data visualization and the clarity of communication in both the written report and the project presentation.

Criteria:
- Mastery of biomedical signal processing and machine learning concepts.
- Technical skill in data analysis and problem-solving.
- Innovation and originality in project design.
- Effectiveness in data visualization and result communication.

- Ability to work collaboratively, as assessed through peer evaluations included in the project component.

Period:
- Quizzes and practical assignments will be distributed throughout the course to maintain engagement and continuous learning.
- The project proposal is due by the end of the first month of the semester, allowing ample time for feedback and revision before proceeding with the project.
- The final project presentation and report submission will take place in the last weeks of the semester, serving as the culmination of the course's learning experience.

Feedback:
- Constructive feedback will be provided for all assessment components, with particular emphasis on the project work, to guide students' learning and improvement. Feedback on the project will include both formative assessments during its development and summative assessments upon completion.

OBSERVATIONS.

1. Interdisciplinary Approach: This course operates at the intersection of engineering, biology, and computer science. Students from diverse academic backgrounds are encouraged to enroll, fostering a rich, interdisciplinary learning environment.

2. Equipment and Software: No specific equipment is required for enrollment, making the course accessible to all students. Practical exercises and projects are designed to utilize open-source software and publicly available data sets. However, students with access to biomedical engineering laboratories and equipment at their home universities are encouraged to leverage these resources for their projects, under guidance from their instructors.

3. Collaborative Projects: Students will have the opportunity to work on projects in teams. These teams can be interdisciplinary and may include participants from different universities, promoting international collaboration and networking.

4. Guest Lectures and Industry Insight: The course will feature guest lectures from leading experts in biomedical engineering, data science, and related fields. These sessions aim to provide students with insights into the latest research, industry trends, and career opportunities.

5. Flexible Learning Path: While the course has a defined structure, it also offers flexibility to accommodate students' interests. For instance, project topics can be chosen based on individual interests or career goals, allowing students to tailor their learning experience.

6. Open Source and Community Engagement: Emphasis on the use of open-source tools and *databases underscores the course's commitment to accessible, reproducible science. Students are encouraged to contribute to these communities, whether through code, documentation, or use cases.*

7. Sustainability and Ethical Considerations: Given the course's focus on health-related technologies, discussions will include ethical considerations in biomedical engineering, data privacy, and the sustainability of healthcare innovations.

8. Continuous Feedback Loop: Students will receive continuous feedback throughout the course, not just from instructors but also from peers. This feedback loop is essential for iterative learning and improvement, especially in project work.

9. Certification and Portfolios: Upon completion, students will receive a certification of accomplishment. They are also encouraged to document their project work in a personal portfolio, which can be used for academic or professional advancement.

10. Future Opportunities: Successful completion of this course can open doors to advanced study opportunities, research projects, and internships in the fields of biomedical engineering and data science. Guidance and support for pursuing these opportunities will be provided.

8. BIBLIOGRAPHY AND TEACHING MATERIALS.

Recommended literature and resources will be provided, ensuring availability across EUNICE universities and/or as open-source material.

Bibliography:

1. "Biomedical Signal Processing and Signal Modeling" by Eugene N. Bruce
- A comprehensive text that covers the theory and application of signal processing techniques in the biomedical field.
2. "Signal Processing for Neuroscientists: A Companion Volume: Advanced Topics, Nonlinear Techniques and Multi-Channel Analysis" by Wim van Drongelen
- Focuses on advanced signal processing techniques and their application in neuroscience, ideal for students interested in neural signal analysis.
3. "Machine Learning for Bio-Signal Analysis and Imaging" by S. Ramakrishnan
- This book provides an introduction to machine learning techniques and their applications in the analysis of biomedical signals and images.
4. "Practical Biomedical Signal Analysis Using MATLAB" by Katarzyn J. Blinowska and Jaroslaw Zygierewicz
- Offers practical guidance on analyzing biomedical signals with MATLAB, suitable for students with or without prior programming experience.

Open-Source Tools:

1. MNE-Python (https://mne.tools/stable/index.html)
- An open-source Python package for processing EEG, MEG, and iEEG data. It's great for visualization and analysis of neurophysiological data.
2. BioSPPy (https://biosppy.readthedocs.io/en/stable/)
- A toolbox for biosignal processing written in Python. It supports ECG, EEG, EMG, and other signal types.
3. SciPy and NumPy
- Fundamental packages for scientific computing with Python, providing support for array objects, integration, optimization, and more.
4. Scikit-learn (https://scikit-learn.org/stable/)
- A Python module for machine learning built on top of SciPy. It includes algorithms for classification, regression, clustering, and dimensionality reduction.

Databases:

1. PhysioNet (https://physionet.org/)
- Offers free access to large collections of recorded physiological signals. It is a comprehensive resource for complex physiological signals such as ECG, EEG, and EMG.
2. EEG Database on Kaggle (https://www.kaggle.com/datasets)
- Kaggle hosts various EEG datasets that are suitable for machine learning projects. These datasets can be used for competitions or personal projects.
3. OpenNeuro (https://openneuro.org/)
- A free and open platform for sharing MRI, MEG, EEG, iEEG, and ECoG data. It supports the open science initiative in neuroimaging and neurophysiology.

Additional Resources:

- GitHub Repositories: Many projects and code examples related to biomedical signal processing and machine learning can be found on GitHub. Encourage students to explore and contribute to these projects.