UNIVERSIDAD
POLITÉCNICA
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Joint module handbook M.Sc. in Health in Medical Data Analytics

Study Track at UPM

Please note, that all modules presented are just a selection of the elective courses. For more information, please visit the website of the respective university.

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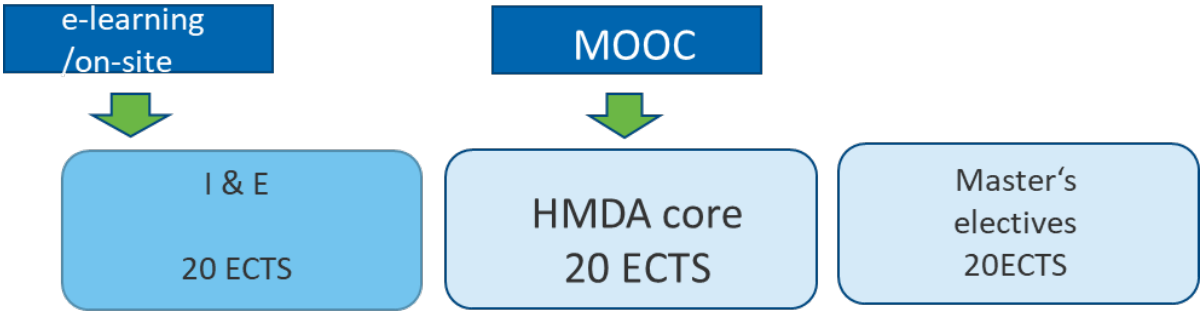
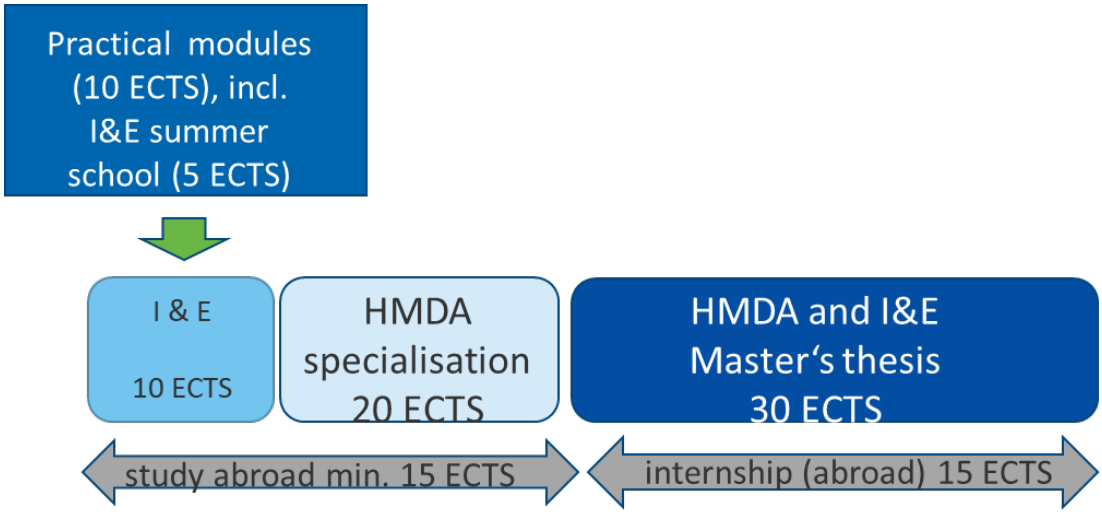
HMDA Alingment

1st year



2nd year



1st year, 1st semester (autumn/winter semester):

Common Core UPM:

Statistical Data Analysis

Responsible lecturer: Arminda Moreno

ECTS: 4.5

Course type and weekly hours: 1hour of lecture + 2 hour of laboratory

Exam type: written exam (3 hours) + group presentation (3 hours)

Contents:

The course is intended to be a non-exhaustive survey of techniques to convert multivariate data into useful information so that good decisions can be made. The perspective is twofold, theorical and applied, covering topics such as: exploratory data analysis, statistical summaries and graphical representations, dimensionality reduction, regression techniques, time series analysis, decision theory and probabilistic graphical models. There will be an emphasis on hands-on application of the theory and methods throughout, with extensive use of R.

Syllabus

1. Descriptive statistics and statistical modelling.
    - 1.1. Aspects of multivariate data. Descriptive statistics. Introduction to R.
    - 1.2. Dimensionality reduction: Principal Component Analysis and biplots.
    - 1.3. Regression models.
    - 1.4. Discrimination analysis and clustering.
2. Time Series.
    - 2.1. Definitions, Applications and Techniques.
    - 2.2. Stationarity and Seasonality.
    - 2.3. Common approaches.
    - 2.4. Box-Jenkins model identification, estimation and validation.
    - 2.5. Forecasting
3. Introduction to Decision Analysis.
    - 3.1. Structure and representation of a decision problem.
    - 3.2. Decision making under certainty and uncertainty.
    - 3.3. Preferences and beliefs modelling.
    - 3.4. Collective decision making.
4. Graphical Models for Decision Making.
    - 4.1. Decision Trees and Influence Diagrams for optimal decisions.
    - 4.2. Bayesian networks for diagnosis and prognosis.
    - 4.3. Sensitivity Analysis for explanation of reasoning.

Learning outcomes and competencies:

- To perform a time series analysis using the proper statistical methodology.
- To build, interpret and conduct diagnostics analysis of regression models.
- To apply the expected utility paradigm to solve decision problems.
- To use multivariate data representation and dimensionality reduction techniques.
- To build, estimate and interpret probabilistic graphical models.

Literature

- Johnson, R.A., Whichern, D.W. (2007) Applied Multivariate Statistical Analysis. Pearson Education
- Rencher, A.C. Methods of Multivariate Analysis.
- Everitt, B.S. and Dunn G. (1997) Applied Multivariate Data Analysis. Arnold.

- Hair, J.F., Black, W.C., Babin, B.J., Anderson R.E. Multivariate Data Analysis.
- Sharma, S (1996). Applied Multivariate Techniques. Wiley.

Keywords: Statistics, regression models, temporal series, PCA descriptive statistics

Machine Learning

Responsible lecturer: Prof. Pedro Larrañaga / Prof. Concha Bielza
ECTC: 4.5 ECTS
Course type and weekly hours: lecture, assessment activity
Exam type: written exam + practical project

Contents:

The amount of data generated in the healthcare sector is growing exponentially, and intelligent systems able to transform this huge quantity of data into knowledge, as represented by mathematical and statistical models, are more than necessary. Machine learning is a part of artificial intelligence that allows to build those models. Machine learning comprises several methods enabling this transformation in such a way that the resulting software systems can provide actionable insights towards optimal decisions. This course covers four groups of techniques: supervised classification, unsupervised classification, probabilistic graphical models and spatial statistics. The course includes theoretical and applied lessons, with specialized software tools used to solve practical problems.

Syllabus:

1. Introduction to machine learning

2. Supervised classification
 2.1 Performance evaluation
 2.2 Feature subset selection
 2.3 Non-pobabilistic classifiers: k-nearest neighbors, classification trees, rule induction, support vector machines
 2.4 Probabilistic classifiers: discriminant analysis, logistic regression, Bayesian network classifiers
 2.5 Metaclassifiers
 2.6 Multi-dimensional classifiers

3. Unsupervised classification
 3.1 Non-probabilistic clustering: hierarchical, partitional, subspace clustering, cluster ensembles, evaluation criteria
 3.2 Probabilistic clustering: the EM algorithm, finite mixture models, clustering with Bayesian networks

4. Probabilistic graphical models
 4.1 Bayesian networks: basics, inference, learning, dynamic Bayesian networks
 4.2 Markov networks: basics, inference, learning, conditional random fields

5. Spatial statistics
 5.1 Spatial point processes
 5.2 Complete spatial randomness
 5.3 Goodness-of-fit test via simulation
 5.4 Common models: cluster, regular, Gibbs

Learning outcomes and competencies:

- To be able to identify the appropriate (supervised and unsupervised) classification techniques to solve a given real-world problem

- To learn probabilistic graphical models, perform inferences and interpret the structure, parameters and conditional independences
- To perform a spatial analysis using the proper spatial point process methodology
- To be able to apply machine learning software tools for practical problems

Literature:

- A. Baddeley, E. Rubak, R. Turner (2015) Spatial Point Patterns: Methodology and Applications with R, Chapman and Hall/CRC
- C. Bielza, P. Larrañaga (2019) Data-Driven Computational Neuroscience, Cambridge University Press, to appear
- R. Duda, P.E. Hart, D.G. Stork (2001) Pattern Classification. Wiley
- D. Koller and N. Friedman (2009) Probabilistic Graphical Models: Principles and Techniques. The MIT Press
- K.P. Murphy (2012) Machine Learning: A Probabilistic Perspective. The MIT Press

Keywords: Supervised classification, unsupervised classification, probabilistic graphical models, spatial statistics

Data Processes

Responsible lecturer: Ernestina Menasalvas Ruíz
ECTS: 4.5
Course type and weekly hours: 2 hours: 1h lecture + 1 laboratory
Exam type: 2 hour written test + 2 assignments

Contents:

In this course we will deepen on the importance of data for an organization. In fact, the course is centered on the process of extraction of knowledge from databases as a support for decision making. Data Science project development will be central to the course

This course will be adapted depending on the students' profile, but main goal will be to deepen on the importance of data for an organization and deepen on the development of data science projects.

The course will start with the definition of data science projects and will analyze on the one hand the importance to map business needs to data mining problems and on the other the importance of understanding the data sources in the organization.

We will continue the course with understanding the potential of data analysis in the health domain.

Later students will understand the data value chain and will go deep into the process of knowledge extraction. At this stage CRISP-Dm methodology will be used.

The course will follow on going deeper into the different phases of the process: i) business understanding, ii) data understanding, iii) data preparation, iv) modeling v) evaluation and vi) deployment.

Through all the phases the main emphasis will be on students getting hands on the different steps, techniques, algorithms and tools.

Before finishing the course will cover basic aspects of the GDPR and the implications on the process of knowledge extraction in a company

The course will complement all the lectures with use cases in the health domain

Syllabus

1. Introduction
    - 1.1. Course description.
    - 1.2. Data Science and Data Scientist Skills.
    - 1.3. The Value hidden in data.
2. Data Science in the Health domain
    - 2.1. Data Sources in the health domain.
    - 2.2. Main challenges
3. The process of Knowlegde Discovery in Databases
    - 3.1. CRISP-DM
4. Business Understanding
    - 4.1. Goal of BU.
    - 4.2. Planning of a DataScience project.
5. Data Understanding
    - 5.1. Understanding data.
    - 5.2. Nulls and outlier's detection.
    - 5.3. Correlation analysis
6. Data Preparation
    - 6.1. Preparing data for mining: dealing with problems encountered in understanding, transforming data, discretization, data reduction, agregation.
7. Data mining/data modeling

7.1. Type of problems. Data nature, data problems and possible algorithms.
7.2. Classification, association and clustering

8. Evaluation and Deployment
    8.1. Evaluation of the models.
    8.2. Deployment of the models
9. Ethics
    9.1. GDPR and implications in Data Science

Learning outcomes and competencies:

- The ability to propose a well-founded approach in any domain where big data can play a role.
- The capacity to identify and link the key issues related to the use of big data in the main economic, industrial, societal, and scientific domains

Literature

- Ian Witten, Eibe Frank, Mark Hall, Data Mining: Practical Machine Learning Tools and Techniques, 3nd Edition, Morgan Kaufmann, ISBN 978-0-12-374856-0, 2011.
- Smart Machines: IBM's Watson and the Era of Cognitive Computing. Columbia University Press (October 15, 2013)
- Database Systems: The Complete Book (DS:CB), by Hector Garcia-Molina, Jeff Ullman, and Jennifer Widom
- Healthcare Data Analytics (Chapman & Hall/CRC Data Mining and Knowledge Discovery Series). Chandan K. Reddy, Charu C. Aggarwal.

Keywords: CRISP-DM workflow, data mining, data science, medical data analysis, data lifecycle, preprocessing, evaluation

Electives UPM:

Big Data

Responsible lecturer: Antonio Latorre de la Fuente
ECTS: 6
Course type and weekly hours: 3 hours
Exam type:1 hour written test + 2 practical assignment

Contents:

This course will allow the student to gain the fundamentals for the analytical visualization of large volumes of data. With an eminently practical approach, the technologies and fundamentals necessary to successfully accomplish the whole data analysis process will be presented in the context of Big Data, from the raw data to its visualization, through the models derived from them.

Syllabus

1. Introduction to Big Data
    - 1.1. Architectures and applications
    - 1.2. Data types
    - 1.3. Visual analytics
2. Big Data Ecosystem
3. Big Data Technologies
    - 3.1. Technological Challenges
    - 3.2. Basic solution: gfs + MapReduce
    - 3.3. Hadoop (hdfs + yarn)
    - 3.4. Pig
    - 3.5. Hive
    - 3.6. Beyond MapReduce
        - 3.6.1. Tez
        - 3.6.2. Spark
        - 3.6.3. Flink
4. Spark
    - 4.1. Spark Basics
    - 4.2. Brief Introduction to Scala
    - 4.3. Spark Applications
    - 4.4. Spark SQL
5. Machine Learning with Spark
    - 5.1. Brief review of Machine Learning basics
    - 5.2. Spark MLlib
6. Information Visualization
    - 6.1. Information Visualization Fundamentals
    - 6.2. Data Abstractions
    - 6.3. Tasks Abstractions
    - 6.4. Interaction Techniques and Visual Encoding
    - 6.5. Design Methods
    - 6.6. Visualization Examples Analysis
    - 6.7. Lessons Learnt

Learning outcomes and competencies:

- To learn how scientific computing techniques are applied in a specific field of science or engineering
- To know techniques of visualization and processes of data analysis, and of programming, design and debugging of algorithms, for high performance computing.

- To be able to process massive data

Literature

- Jiawei Han, Micheline Kamber, Data Mining : Concepts and Techniques, 2nd edition, Morgan Kaufmann, ISBN 1558609016, 2006
- Pang-Ning Tan, Michael Steinbach, Vipin Kumar, Introduction to Data Mining, Pearson Addison Wesley, ISBN: 0321321367, 2005
- Ian Witten and Eibe Frank, Data Mining: Practical Machine Learning Tools and Techniques, 2nd Edition, Morgan Kaufmann, ISBN: 0120884070, 2005.
- Keim, D., Kohlhammer, J., Ellis, G., Mansmann, F. Mastering the information age. Solving problems with visual analytics 2010 Eurographics Association.

Keywords: Big Data arquitectures, visualization, spark

Intelligent Systems

Responsible lecturer: Martín Molina
ECTs: 4,5
Course type and weekly hours: 2h
Exam type: Practical coursework

Contents:
In a wide sense, intelligent systems can be considered as a type of computer systems that implement and integrate artificial intelligence methods to acquire and use knowledge for solving problems with limited resources. This course starts presenting machine learning techniques with a general overview followed by a detailed description of machine learning algorithms for symbolic representations (e.g., decision trees and rules). Then, the course explains basic concepts of knowledge representation and reasoning together with specific methods (e.g., representations for ontologies). Next, the course presents language technologies, including solutions for natural language understanding and natural language generation. Finally, the course presents a unit related to ethics for artificial intelligence. The course combines both a theoretical and a practical presentation and the students have to develop practical exercises related to the main presented concepts and techniques.

Learning Outcomes:
- To know what are the main challenges and achievements in the area of intelligent systems
- To be able to use and apply methods for knowledge acquisition to create manually and automatically knowledge bases using other sources of information (e.g., data sets or text documents).
- To be able to identify areas of application where the techniques of intelligent systems can be used.
- To know the existing techniques about intelligent systems (knowledge acquisition, knowledge representation and reasoning) understanding their scope and limitations.

Syllabus:
1. Introduction
   1.1. Introduction to the course
2. Machine learning
   2.1. Overview of machine learning
   2.2. Evaluating learned models
   2.3. Learning decision trees
   2.4. Learning classification rules: Prism, Ripper
   2.5. Learning association rules: Apriori
   2.6. Learning rules from relational data
   2.7. Learning rules with evolutionary algorithms
3. Knowledge representation
   3.1. Overview of knowledge representation
   3.2. Ontologies
4. Language technologies
   4.1. Natural language understanding
   4.2. Natural language generation
   4.3. Linguistic resources
5. Ethics for artificial intelligence

Keywords: Knowledge discovery, knowledge engineering, ontologies, computational vision

Cloud Computing and big data ecosystems

Responsible lecturer: Marta Patiño Martínez
ECTS: 4.5
Course type and weekly hours: 3 hours
Exam type: written test + 2 practical assignament

Contents:
This course presents architecture for scalable distributed systems and data management systems: map-reduce, bigtable, data streaming, persistent queues.

Syllabus

1. Introduction
2. Big Table
3. Dynamo
4. Data Streaming
5. Persistent Queues
6. Containers. AWS

Learning outcomes and competencies:

- To know the applications and systems based on distributed computing
- To be able to process massive data
- To design and implement highly parallel and / or distributed systems
- To know and design information extraction systems

Literature

- NoSQL Distilled: A Brief Guide to the Emerging World of Polyglot Persistence. P.Sadalage, M. Fowler. 2012
- Big Data Now: Current Perspectives from O'Reilly Radar. O'Reilly. 2011
- Graph Databases. I. Robinson, J. Webber, E.Eifrem. O'Really. 2013

Keywords: Big Data, Internet of Things (IoT), non-structured data, data management technologies, data streaming, big table, big data & cloud ecosystems management, performance evaluation

Open Data and Knowledge Graphs

Responsible lecturer: Oscar Corcho

ECTs: 4,5

Course type and weekly hours:

Exam type:

Contents:

During this course you will learn about the main foundations for the Web of Linked Data and the Semantic Web, including the W3C recommendations that are applicable in this area (RDF, RDF Schema, SPARQL, OWL, CSV on the Web) and methodologies for the generation and publication of Linked Data from multiple heterogeneous data sources and formats. You will also learn about how to create shared agreed vocabularies and ontologies that can give support to such Linked Data generation and publication, and will understand how these principles and approaches have been applied to several domains. You will work on a practical hands-on exercise that will be the basis for your participation in hackatons and other similar events.

Learning Outcomes:

- Develop ontologies that serve as vocabularies for the data available on the Semantic Web and for the Linked Data
- Manage bibliographic sources in the domain, including manuals, online documentation and scientific papers
- Identify and solve those types of real-world problems in which Linked Data and Semantic Web technologies can be successfully applied
- Use different languages, techniques, methods and methodologies that enable the development of ontologies and data for the Semantic Web
- Generate data in the format used in the Semantic Web and in the Web of Linked Data, and to publish them for the use of third parties
- Develop applications that exploit the data available on the Semantic Web and on the Web of Linked Data

Syllabus:

1. Introduction to the Web of Linked (Open) Data
2. Data and knowledge representation and access in the Web of Linked Data
   2.1. RDF and RDF Schema
   2.2. SPARQL
   2.3. OWL
3. Linked Data generation, linking and publication from heterogeneous data sources
   3.1. Methodological guidelines for Linked Data generation
   3.2. RDF generation from relational databases
   3.3. RDF generation from semi-structured data sources
   3.4. RDF generation for statistical data
   3.5. Data linking
   3.6. Linked Data publication
4. Vocabulary selection and development for the Web of Linked Data
   4.1. Methodologies for building vocabularies
   4.2. Existing vocabularies
5. Linked Data applications
   5.1. Linked/Open/Big Data in Government
   5.2. Linked/Open/Big Data in Science
   5.3. Linked/Open/Big Data in Journalism

Keywords: Semantic Web, Linked Data, Ontologies, applications

I&E UPM:

Introduction to innovation and entrepreneurship management

Responsible lecturer: Alberto Tejero (alberto.tejero@upm.es)
ECTS: 6
Course type and weekly hours: 2-3 hours
Exam type: activities during lectures and presentation of group´s work

Contents:
Idea generation, technology-based entrepreneurship, marketing and markets, organization and project management, new product and process development, entrepreneurial finance, human resource development

Syllabus

- Innovation processes
    - From the idea to the market: a long and risky way towards innovation
    - Relationship of innovation to research and development:
        - Integrated view within the knowledge triangle paradigm.
    - Nature of knowledge and value of R&D and innovation
        - Agents, Process, Results
        - Strategic Planning of R&D and innovation
        - Evaluation of innovation projects
        - Implicit project management issues
- Organisational structures to support innovation
    - Organization of R&D and innovation
        - Approaches for private and public entities
    - Organisational models to accommodate innovation processes
    - Large, SMEs and spin-off cases
    - Dynamic evolution and growth of start-ups
- Innovation models
    - Types of innovation
        - Technology, organisational, commercial innovation
        - Product, process, service innovation
        - Evolutionary, disruptive innovation
        - Open, closed innovation
    - Technology maturity levels (TRL)
        - Innovation dependence on maturity level
    - Open innovation approaches
        - Rationale
        - Open innovation platforms, services and products
        - Open software
    - IC open innovation model
- Protection of technology
    - Protection schemes
        - Patents vs Industrial secret
        - Other schemes (e.g. semiconductor layout, biotech)
        - The case of software patents (legislation approaches)
    - Filing processes

        - Patent offices (e.g. EPO)
        - The UPM regulation
- Management of innovation projects
    - Life cycles models
    - Identification of milestones
    - Human resources
        - Skills and profiles
        - Management of international teams
    - Type of results
        - Prototypes
        - Proof of concept
        - Pilots and demonstrators
- Understanding market environment
    - Industrial sector analysis
    - SWOT
- Financial support for innovation
    - How much and when money is needed?
        - Rounds (from seed capital to expansion)
    - Sources of funding
        - F&F
        - Risk capital
        - Public funds
    - EU public policies for innovation
        - Innovation in H2020
        - Innovation in the regional policy
- Substantial part of the contents will be based on the interest of students based on case studies, examples and geographical/sectorial specificities of this DS master course.
    - Set of case studies (both successful or not) to discuss them with students. Case studies should cover a number of approaches, countries, etc.
        - Discussions with ICT entrepreneurs.
        - Discussions with IT companies with intrapreneurship programmes.
    - Visit to technology-based incubators: UPM (*actúaupm* in the CAIT), Telefónica (*Wayra*) or the Business Incubator Centre of the ESA (BIC-ESA) in Madrid.

Learning outcomes and competencies:

- To know the main concepts, terminology and main issues related to entrepreneurship and innovation management with focus in the IT sector.
- The capacity to identify and link the key issues related to project innovation management and, specifically on the data science field in open, international and cooperative innovation contexts.
- The ability to propose the right management structure and activities of an innovation project from its conception to the deployment to the outcomes to the market by using a specific management model adapted to the type of project.
- The ability to select the best approach to protect his/her technology depending on the type, maturity level and geographical constraints (through patents, industrial secret, etc.) and to understand their consequences in accessing or commercialising it.
- The capacity to understand the basis for entrepreneurship and the rationale for launching a technology-based company creation from previous R&D activities.

- The capacity to identify different sources for innovation funding and to select the most appropriate one according to the business model and involved technology.
- The knowledge of main European Union (EU) policies and programmes to support research and innovation. The role played by the EIT in the EU landscape.

Literature

- Henry Chesbrough. Open Innovation: The New Imperative for Creating and Profiting from Technology (HBS Press, 2003).
- Henry Chesbrough. Open Services Innovation. Rethinking your business to grow and compete in a new era. Ed. Jossey-Bass. 2011. ISBN 978-0-470-90574-6
- Hippel, Eric von (2013): Open User Innovation. In: Soegaard, Mads and Dam, Rikke Friis (eds.). "The Encyclopedia of Human-Computer Interaction, 2nd Ed.". Aarhus, Denmark: The Interaction Design Foundation. Available online at http://www.interaction-design.org/encyclopedia/open_user_innovation.html
- Osterwalder, A. and Pigneur, Y.: Business model generation. John Wiley & Sons 2010.
- The Innovative and Entrepreneurial University: Higher Education, Innovation & Entrepreneurship in Focus. US Dept. of Commerce. Oct. 2013
- J.P. Murmann. The co-development of industrial sectors and academic disciplines. Science and public policy. Vol. 40 No.2 Apr. 2013.
- Hugo Hollanders and Nordine Es-Sadki.Innovation Union Scoreboard. Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT 2017)

Keywords: Innovation, management, organizational structures, market environments, financial support, entrepreneurs, business

1st year, 2nd semester (spring/summer semester):

Common Core UPM:

Deep Learning

Responsible lecturer: Prof. Martin Molina Gonzalez
ECTS: 3
Course type and weekly hours: lecture, assessment activity
Exam type: written exam + practical project

Contents:

Deep learning has emerged from the connectionist branch of machine learning, aided by the arrival of big data and increased computational power (e. g., parallelization using graphics processing units - GPUs). Deep learning has proved to be significantly better than other approaches to solve problems that cope with large amounts of data as it is required, for example, in computer vision (image or video processing) or speech understanding. This course presents a theoretical and practical view of deep learning. The course presents first the foundations of artificial neural networks with both supervised and unsupervised learning. Then, the course presents different types of deep architectures (e.g., convolutional neural networks) and application domains (e.g., computer vision and natural language processing). To complement the practical view, the course also presents specialized software tools for deep learning and describes how to use them in practical problems.

Syllabus

1. Introduction to deep learning
2. Artificial neural networks
    - 2.1. Foundations
    - 2.2. Learning in artificial neural networks
    - 2.3. Tools
3. Deep learning for computer vision
    - 3.1. Foundations of computer vision
    - 3.2. Convolutional neural networks
    - 3.3. Sample projects
4. Deep learning for natural language processing

Learning outcomes and competencies:

- To know the main challenges and achievements of deep learning
- To be able to identify areas of application where the techniques of deep learning can be used
- To know the existing techniques and software tools about deep learning, understanding their scope and limitations
- To be able to apply machine learning software tools for practical problems related to deep learning

Keywords: Neural Networks, computer vision, NLP, applications

Information retrieval, extraction and integration

Responsible lecturer: David Pérez del Rey
ECTS: 4,5
Course type and weekly hours: 2
Exam type: practical coursework

Contents:

The amount of available data in any area has grown dramatically during the las years. However, this increment did not have a proportional impact in the knowledge available for decision making. There is a need of automatic models to manage the data, taking into account that the majority of the data will never be used by a human being. The course Information Retrieval, Extraction and Integration is focused on the necessary tasks to extract information, models to efficiently retrieve data for further integration. These are critical tasks to provide relevant information for decision making, which complexity increases with the amount of data available. As application areas, we focus on biomedicine, due to the complexity and to the specific requriments.

Syllabus

1. Basic Concepts
   1.1. Introduction
   1.2. Data, Information and Knowledge
   1.3. Data types
2. Extraction and Information Retrieval
   2.1. Information Extraction
   2.2. Information Retrieval Models
   2.3. Natural Language Processing
   2.4. Web Search Engines
   2.5. Non-textual Data
3. Data Integration
   3.1. Integration Architectures
   3.2. Semantic Interoperability
   3.3. Data Provenance
4. Applications in Biomedicine
   4.1. Biomedical Information Systems
   4.2. Clinical interoperability Standards
   4.3. Medical terminology
   4.4. Scientific literature retrieval system

Learning outcomes and competencies:

- The ability to analyze information needs to build an information system
- To understand database and data representation language foundations
- To understand and interact with information retrieval systems
- To understand and interact with data extraction systems
- To understand and interact with integration systems
- To apply information retrieval, data extraction and integration to the biomedical field
- To be able to develop simple information retrieval architectures
- To be able to identify applications of interest where the information retrieval methods can be used.

Literature:

1. Baeza-Yates, Ricardo, and Berthier Ribeiro-Neto. Modern information retrieval. New York: ACM press, 1999.
2. Kimball, Ralph, and Margy Ross. The data warehouse toolkit: the complete guide to dimensional modeling. John Wiley & Sons, 2011.
3. Doan, AnHai, Alon Halevy, and Zachary Ives. Principles of data integration. Elsevier, 2012.
4. Manning CD, Raghavan P, Schütze H. Introduction to Information Retrieval. Cambridge University Press. 2008.
5. Witten IH, Moffat A, Bell TC. Managing Gigabytes: Compressing and Indexing Documents and Images, 2nd Edition. Morgan Kaufmann. 1999.
6. Korfhage, R. Information Storage and Retrieval. Wiley. 1997.
7. Bird S, Klein E, Loper E. Natural Language Processing with Python. O'Reilly 2009.

Keywords: Interoperability, Data Integration, Information retrieval, Text Mining, Non-structured data

Electives UPM:

Graph analysis and social networks

Responsible lecturer: Prof. Javier Bajo Pérez
ECTS: 3
Course type and weekly hours: lecture, assessment activity
Exam type: written exam + practical project

Contents:
Social computing is a general term for an area of computer science that is concerned with the intersection of social behaviour and computational systems. During recent years the Internet introduced a social element where users could network, share interests, publish personal insights and use their computers for more than just doing a job faster, and this has led to the development of social machines where both humans and machines collaborate to solve social problems. This course presents the principal of social computing and focuses on graph and network analysis as well as on the design of social machines.

Syllabus
1. Introduction to social computing
2. Graph Analysis
3. Network Analysis
4. Intelligent Agents and Multi-agent Systems
5. Design of Social Machines

Learning outcomes and competencies:
- To know the main challenges and achievements of social computing
- To be able to identify areas of application where the techniques of social computing can be used
- To know the existing techniques and software tools for graph and network analysis, understanding their scope and limitations
- To be able to design social machines for practical problems related to deep learning

Keywords: social computing, graph analysis, network analysis, multiagent systems

AI and legal/societal/ethical aspects

Responsible lecturer: Víctor Rodríguez Doncel
ECTC: 3
Course type and weekly hours:
Exam type:
Keywords: Data protection, intellectual property, SW licensing, IA and data processing ethics

Contents: Virtually every data science and AI professional will have to cope with legal and ethical issues during his or her professional career. This course provides the student with practical and theoretical tools to address these issues. In particular, the student will be given some general notions on the legal framework in Europe of AI and medical data processing, necessary to avoid breaching the law and necessary to exercise their rights. Specific focus will be made both on 'privacy and data protection', including practical cases around the EU GDPR (General Data Protection Regulation) and Electronic Health Records, and on intellectual property and copyright regulation, including practical examples on data licenses and open data policies.

Syllabus

1. Introduction. Overview of issues raised by medical data analytics
    a. Case studies
2. European legal framework medical data analytics
    a. Privacy and Data Protection: general ideas
    b. Privacy and Data Protection: the GDPR applied to EHR
    c. Intellectual property: general ideas
    d. Intellectual property: data licensing, open data
    e. Medical
3. Ethics of medical data analytics
    a. Autonomy, System Design, Agency, and Liability. Ownership, control, access.
    b. Algorithm bias. Governance, Explainability, and Accountability
    c. Ethical guidelines in EU research programmes

Learning outcomes

- Ability to produce documents assesing the impact of medical data analytics, with consideration of legal, regulatory, privacy, ethics, and human behavior topics.
- Identify recurrently appearing legal issues in the exercise of the medical data analytics profession.
- Enumerate the ethical issues considered by the European Commission in their research programmes and Demonstrate familiarity with relevant examples of medical data analytics systems arising ethical problems.
- Demonstrate knowledge of philosophical issues involved in ethics of AI in practical contexts.

Keywords: Privacy, Data Protection, GDPR, Ethics

I&E UPM:

Entrepreneurship & Business Modelling

Responsible lecturer: Arístides Senra Díaz (aristides.senra@upm.es)
ECTs: 6
Course type and weekly hours: 4
Exam type: continuous evaluation, presentation of a business project and development of a business plan

Contents:
Business modelling and development in phases – (a) idea recognition – (b) concept design – (c) Business modelling and planning – (d) Business plan presentation.

Application of subjects from the I&E Basics course or introduced in the Bus Dev Lab:

- Opportunity recognition
- Creativity techniques, Design thinking
- User-centred product/service design
- Product development, project management
- Business Model Canvas (9 boxes), value creation, value proposition, revenue models
- Alternate business modelling methods
- Methods and tools for customer discovery, customer validation, evidence-based decision making, lean process
- Market analysis, competitors' analysis
- Business ethics, sustainability
- Finance (cash flow management, financial scenarios)
- Other business development planning concepts methods and tools (strategy, organization, marketing, market entry / go-to-market, risk analysis)
- Financing, fund raising
- IP and intellectual assets, IP strategies, patent management
- Technology maturity, TRL, prototyping, Technology transfer
- Pitching and oral communication

Learning Outcomes:

- The ability to identify innovative business ideas inside (intrapreneurship) or outside a pre-existent firm (entrepreneurship).
- The ability to evaluate from professional point of view business opportunities with high growth potential.
- The ability to develop business projects with customer orientation.
- The ability to explain his/her technology-based business ideas to external investors.
- The ability to write non-technical information about the business idea for investors or customers.
- The ability to develop a complete business model by using pre-defined methodologies.
- The ability to understand the necessary steps to create a sustainable technology-based company.
- The ability to get external funds to finance the development.
- The capacity to present media material on Internet about their idea.

Syllabus:

1. Introduction to entrepreneurship fundamentals
    a. Attitude required and analysis methodology from risk investors

    b. Four circles analysis methodology
    c. Idea analysis
    d. Team analysis
    e. Resources from founders
    f. First approach to business model
2. Eleven steps to analyse a business model proposal
    a. Customer analysis
    b. Elevator pitch template
    c. Competitors analysis
    d. Competitive advantage analysis
    e. Team matrix analysis
3. Fast analysis methodology
    a. Environment analysis
    b. Sector analysis. Porter methodology for entrepreneurs
    c. Life cycle
    d. Value chain analysis
    e. DAFO matrix analysis and conclusions for start-ups and new projects launching
4. Marketing and operations
    a. Positioning
    b. MVP and Marketing MIX
    c. MIS and monitoring
    d. Sales projection methodology/ Sales forecast
5. Financial fundamentals
    a. Investment plan/ resources needed
    b. Financing expectations
    c. Negotiation with investors
    d. Profit and loss
    e. Treasury
    f. Balance
    g. Profitability
6. Writing the business plan
    a. Business model generation
    b. Business model canvas generation
    c. Index
    d. Executive summary
    e. Presentation of the business plan
7. Demo Day
    a. How to prepare a presentation for investors
    b. Demo day practice

Keywords: Entrepreneurship, Business planning, Financing

Introduction to Technology watch and competitive intelligence

Responsible lecturer: Javier Segovia
ECTS: 1
Course type and weekly hours: Seminar
Exam type: individual group work

Contents:
This Seminar constitutes the second part of the Basics course. It will be offered during the month of January 2019 by using a blended learning approach with the use of some on-line modules prepared by the UPM.

After presenting the basic elements of innovation management, students will receive detailed information on tools and procedures related to the identification, selection and eventually absorption/adaptation of technologies, which could be useful for the selection of the technologies required to implement their own business projects in the Master Degree.

Syllabus

- Technology evolution
    - Technology maturation
    - Technology roadmaps
    - Technology forecasting
    - Introduction to quantitative approaches in forecasting: econometrics, exponential-smoothing techniques, s-curves, other.
- Technology watch
    - Processes used
    - Internal and external
    - Scouting networks
    - Tools for technology watch
- Technology intelligence
    - Use in decision making
    - Trend-charts
    - Connection to the maintenance of IP portfolio
    - Road mapping of products/services
- Technology transfer
    - Technology absorption
    - Technology transition
- Work on a case study (group activity)
    - Big data in some sectors (e.g. health)

  Visual analytics

Learning outcomes and competencies:

- To provide students with some conceptual and practical tools to understand the evolution of technologies for specific purposes.
- To know how the develop and interpret a technology roadmap in specific technical areas.
- To understand the relationship of technology intelligence to decision making in innovation management.
- The knowledge of the rationale and basic concepts related to technology watch and competitive intelligence.

- The ability to identify the way that information and communications technologies evolve over time.
- The ability to identify the maturity level of a technology.
- The ability to develop and interpret a technology roadmap.
- The ability to use some techniques applied for technology watch and forecasting.
- The ability to understand the relationship of technology watch and competitive intelligence to support decision making in innovation management.
- The ability to identify and to describe the specificities of the market and its technology dependencies.
- The capacity to incorporate technology watch units in a given organization.
- The ability to understand common barriers for technology transfer and absorption in the field of digital services.

Literature

- René Rohrbeck: Harnessing a Network of Experts for Competitive Advantage: Technology Scouting in the ICT Industry. R&D Management, Vol. 40, No. 2 pp. 169-180 http://www3.interscience.wiley.com/journal/123275929/abstract
- Ramona-Mihaela MATEI, Ioan RADU Conceptual Relationship between Information and Communication Technologies and Competitive Intelligence Activities
- Gestión de la I+D+i: Sistema de vigilancia tecnológica e inteligencia competitiva. UNE 166006:2011
- HAMDI Hassen - RAMRAJSINGH Athissingh: Veille et intelligence économique au sein des TPE :vers l'appropriation des outils gratuits
- Big Data: Big today, normal tomorrow ITU-T Technology Watch Report. November 2013 http://www.itu.int/dms_pub/itu-t/oth/23/01/T23010000220001PDFE.pdf

Keywords: technology watch, maturation, roadmaps, technology transfer, visual analytics, big data in health, scouting networks

Launching of digital-based products and services

Responsible lecturer: Francisco Jariego (francisco.jariego@upm.es)
ECTS: 2
Course type and weekly hours: Seminar, 4 hours week
Exam type: activities during lectures + individual work

Contents:
Business modelling and development in phases – (a) idea recognition – (b) concept design – (c) Business modelling and planning – (d) Business plan presentation.

Application of subjects from the I&E Basics course or introduced in the Bus Dev Lab:

- Opportunity recognition
- Creativity techniques, Design thinking
- User-centred product/service design
- Product development, project management
- Business Model Canvas (9 boxes), value creation, value proposition, revenue models
- Alternate business modelling methods
- Methods and tools for customer discovery, customer validation, evidence-based decision making, lean process
- Market analysis, competitors' analysis
- Business ethics, sustainability
- Finance (cash flow management, financial scenarios)
- Other business development planning concepts methods and tools (strategy, organization, marketing, market entry / go-to-market, risk analysis)
- Financing, fund raising
- IP and intellectual assets, IP strategies, patent management
- Technology maturity, TRL, prototyping, Technology transfer
- Pitching and oral communication

Syllabus

- Understanding the sector: towards digital economy
    - Global market
    - Global organisations
    - Mergers and acquisitions: dynamic restructuring
- Structure of the ICT sector
    - Main stakeholders
        - Incumbents and new entrants
        - Actors in value chains
    - Regulation (in the EU) for new products
        - EC competences (EU Treaties)
        - Industrial policies
    - Global markets
        - Indicators from the EU Digital Agenda
- Introduction to the specificities of marketed digital products and services
    - Digital services evolution (versioning, service life cycle).
    - Technology integration and evolution
        - HW/SW embeddedness, open platforms, etc.

    - Services components
- Digital marketing
    - Channels
    - Market surveys
    - The new role of users
- What happens when the product/service is already in the market?
    - Lean approach
    - Metrics and dashboard
    - Different routes to success
- Personal assignments to students
  E.g. practical case on launching an application based on data analysis

Learning outcomes and competencies:

- The ability to define a marketing plan and its international expansion
- The ability to negotiate with other actors in the ICT field the participation in the value chain
- The ability to create a commercial structure
- The criteria to define a pricing strategy
- The knowledge to obtain information on initial users

Keywords: Digital marketing, digital economy, policies

I&E Seminars

Responsible lecturer: Javier Segovia
ECTS: 5
Course type and weekly hours: 3 hours

Contents:
An elective I&E course will be offered covering advanced topics on any of the following: business development, business finance, marketing, innovation management, intellectual property and market research.

Literature

- Thomke, Stefan, and Jim Manzi. "The Discipline of Business Experimentation." Harvard Business Review 92, no. 12 (December 2014): 70–79.
- Chapter 7: Testing and Experimenting in Markets in H. M. Neck, C. P. Neck, and E. L Murray, Entrepreneurship: The Practice & Mindset (2017), Sage Publications: Thousand Oaks, CA.

Keywords: Business Finance, Marketing, Business Finance, Innovation management, IP

2nd year, 1st semester (autumn/winter semester):

I&E

I&E Study

Responsible lecturer: Raúl Gutiérrez Sanchis
ECTS: 6
Course type and weekly hours: 3 hours
Exam type: 2 practical assignments (individual and group)

Contents:
Two topics – with related concepts, methods and/or tools – will be covered in the context of a selected innovation or entrepreneurial case:

- One fixed and common topic: Assessing the impact of a technology on an industry, market and/or organization, the support and barriers to its deployment, the influence on a specific goal/agenda (technology transfer, existing industry, new company, etc.).
- One case-dependent topic: pertaining to market / business environment analysis (main forces affecting the business, suppliers, partners, competition, environmental issues), sustainability and social issues, business modeling, go-to-market strategies, etc.

The innovation or entrepreneurial project may be originating from:

- Cases issued from EIT Digital Innovation Action Lines: within Activities, Partners / Business Community projects,
- Cases based on the continuation of students EIT Digital Summer School (or BDLab) project,
- Cases within other innovation or entrepreneurial projects rooted in a real-life environment as may be collected in the university ecosystem.

Learning outcomes and competencies:

- the ability to use knowledge, ideas and technology to create new or significantly improved products, services, processes, policies, new business models or jobs (Innovation skills and competencies)
- the ability of decision-making and leadership, based on a holistic understanding of the contributions of Higher Education, research and business to value creation, in limited sized teams and contexts (Leadership skills and competencies)

Literature

- Thomke, Stefan, and Jim Manzi. "The Discipline of Business Experimentation." Harvard Business Review 92, no. 12 (December 2014): 70–79.
- Chapter 7: Testing and Experimenting in Markets in H. M. Neck, C. P. Neck, and E. L Murray, Entrepreneurship: The Practice & Mindset (2017), Sage Publications: Thousand Oaks, CA.

Keywords: Technology impact, barriers, market analysis, business modelling

I&E Summer School

Responsible lecturer: Various
ECTS: 5
Course type and weekly hours: workshop/laboratory course (150 hours in total, including self-study and preparation of tasks in teams)
Exam type: /

Contents:
The I&E practical training includes the preparation, execution and documentation an pitch of a practical project, which is based on a real use case in the healthcare context. The practical work is carried out in teams a laboratory setting. The infrastructure of the lab gives students the chance to execute their own product ideas or to work on topics from industrial partners.

Learning outcomes and competencies:
Students are able to:

- apply industry standard techniques and team management
- develop, independently and within a team, their problem-solving and creative skills
- implement their ideas as prototypes by applying agile software development methods
- use the results of their projects for the creation of start-ups

Health and Medical Data Analytics specialization (20 ECTS)

Specialization offered by UPM: Analysis of Clinical Data

Data Management and Knowledge in Health

Responsible lecturer: Victor Maojo
ECTC: 4
Course type and weekly hours: lecture (2 hours)
Exam type: 2 individual work group

Contents

This course will address the foundational topics of the area of data and knowledge management for health. The topics will include: (1) Introduction. (2) Data, Information & Knowledge in Biomedicine. (3) Research design for health data management. (4) Decision Making in biomedicine. (5) Biomedical terminologies and vocabularies. (6) Electronic Health Records (EHRs) and Hospital Information Systems (HIS). Surveying Information systems that can be found in Health environment, and, studying most common technologies and standards used in the area. (7) Integration and interoperability for health data and knowledge sources. Classical and semantic methods to integrate heterogeneous clinical information stored in different formats. (8) Bioinformatics applications in biomedicine. Techniques and applications for data sequence processing and analysis. Sequence alignment. At the intersection between biology and medicine, we will focus on new areas such as precision and personalized medicine, including new topics and applications. There will be an emphasis on basic and research concepts, with examples from recent international projects in the area.

Syllabus

1 - Clinical interoperability and integration
2 - Hospital information systems and electronic health records
3 - Artificial Intelligence in biomedicine
4 - Bioinformatics
5 - A Brief Introduction to Biomedical Text Mining

Learning outcomes and competencies:

- Ability to assess the importance of documentary sources, manage them and find information for the development of any research work.
- To be able to use the terminology appropriately and perform public presentations on the topics of the module
- To be able to analyse the state of the art in a given subject, understanding what the main achievements and challenges are, and draw conclusions for one?s own work
- Once the aforementioned points have been understood, students should be able to successfully apply them to the analysis and solution of problems with a complexity proportional to their level of experience

Literature

1. Shortliffe, E. H., & Cimino, J. J. (Eds.). (2013). Biomedical informatics: computer applications in health care and biomedicine. Springer Science & Business Media.
2. Benson, T., & Grieve, G. (2016). Principles of Health Interoperability. Springer.

Keywords:Hospital Information Systems, Clinical Terminologies, Standards, Bioinformatics, Interoperability

E-health: Promoting healthy aging

Responsible lecturer: Elena Villalba
ECTC: 4,5
Course type and weekly hours: lecture (3 hours)
Exam type: individual assignments and team work.

Contents: This course focuses on understanding the necessary models, techniques and architectures that allow the development of interactive systems in the E-health domain. This course covers eHealth, e Inclusion, co-production of health, empowerment, social innovation, social networks, serious games, and participation in society. A final team project closes the course.

Syllabus

1. Active and Health Ageing
    1.1. Course introduction
    1.2. Definition and frameworks
2. Clinical perspective
3. Political perspective
4. Social and personal perspective
5. Intrinsic capacity and frailty
6. Cognitive Decline and Mild Cognitive Impairment
7. Mobile Health
8. Active and Healthy Ageing Project

Competences

- Ability to make connections between the wishes and needs of the consumer or client and what technology can offer
- Ability to analyse the information's needs that arise in an environment and carry out the user-centred design process in all its stages

Learning outcomes

- To evaluate the usability and accessibility of prototypes
- To apply techniques for modelling the context of use
- To understand techniques, technologies and processes that allow to prototype, to develop and to improve digital interactive systems based on various user interface technology platforms
- To understand the needs of specific contexts involving ageing population and its derived disabilities

Literature:

- Bousquet, Jean, et al. "Operational definition of Active and Healthy Ageing (AHA): A conceptual framework." The journal of nutrition, health & aging 19.9 (2015): 955-960.
- Beard et al. (2016). The World Report on ageing and health: a policy framework for healthy ageing. Lancet 2016; 387: 2145-54.
- OMS. Global age-friendly cities: a guide (2017). Disponible en: http://www.who.int/ageing/publications/age_friendly_cities_guide/en/
- Mapping mHealth research: a decade of evolution. Fiordelli, Maddalena, Nicola Diviani, and Peter J. Schulz. Journal of medical Internet research 15.5 (2013).

- From Personal to Mobile Healthcare: Challenges and Opportunities Villalba-Mora, Elena, Ignacio Peinado, and Leocadio Rodriguez-Mañas. (2016). Emerging Perspectives on the Mobile Content Evolution. IGI Global, 2016. 124-137.

Keywords: Healthcare data and information systems, Internet of Things, Medical Sensors, Mobile Health, Devices, Ethical and Legal Issues, HIS, elderly, frailty, uhealth

Medical time series data mining

Responsible lecturer: Juan Pedro Caraça-Valente
ECTS: 3
Course type and weekly hours: lecture (2 hours)
Exam type: Project and 2-3 small assignments during the course

Contents:

In this course we will focus on Data Mining techniques suited for Time Series data. Time Series are present is almost every area of science and industry, and has a great presence in Medicine. Many medical tests provide time series, like electrocardiograms, electroencephalograms, auditory brainstem responses, isokinetic curves, etc. Data Mining techniques can help the physicians analyze these results, as in many other fields. But Time Series data are a great challenge for traditional data Mining Techniques as attributes are no longer single valued. In this subject we will address the specific problems of Data Mining in Time Series, how some classic techniques have to be adapted for time series data, specific techniques that arise, etc.

Syllabus

1. Introduction to Time Series
    a. Problems of Data Mining in Time Series
    b. Medical Time Series
2. Basic Techniques
    a. Fourier Transform
    b. Euclidean Distance
    c. Segmentation
3. Time Series Distances
4. Dimensionality Reduction on Time Series
5. Time Series Data Mining Techniques
    a. Comparing Time Series
    b. Searching for subseries
    c. Pattern Identification
    d. Event Detection
    e. Temporal Abstraction
6. Evaluation of Data Mining projects in Medicine
7. Applications to Medicine

Learning outcomes and competencies:

- To know how to deal with Time Series data in general and in Medical domains in particular
- To be able to deal with the specific problems of data Mining in Times Series and be able to propose a plan to overcome then
- To know and be able to apply Data Mining Techniques in Time Series data

Keywords: Data Mining, Healthcare data, Time series comparison and search, pattern identification, event detection, Temporal abstraction

Complex Data in Health

Responsible lecturer: Alejandro Rodríguez

ECTC: 4,5

Course type and weekly hours: lecture (2 hours)

Exam type:

Contents:

1. Complex networks
   1.1. Basics of complex networks. Cytoscape for plotting.
   1.2. Physical networks. For instance, connectome, calculate basic topological features, and network randomisation.
   1.3. Functional networks. Reconstructing brain networks with correlation. Difference with causality.
   1.4. Data mining and networks. Optimisation of networks. Using networks in classification tasks.
   1.5. Other topics. MST. Link filtering and prediction. Multi-layer and time-evolving.
2. Disease Networks
   2.1. Human disease networks
   2.2. Human symptom disease networks
   2.3. Disease understanding
   2.4. Approaches and utilities of disease networks
3. Managing complex data
   3.1. Textual health information and its mining
   3.2. Biological databases

Syllabus

Complex networks and network-based analyses

- Reconstruction of physical vs. functional networks
- Analysis of networks and evaluation of topological metrics
- Integrating networks in a data mining process
- Links prediction and filtering

Human disease networks

- Understanding of basic disease components and features
- Understanding of disease similarities and metrics
- New paradigms for disease understanding
- Utility of disease networks

Managing complex data

- Retrieving information from textual sources
- Dealing with complex biomedical data: sources and databases
- Managing complex biomedical information

Learning outcomes and competencies:

- Understanding the basis of complex networks and it's use in health
- Understanding human disease networks: types, uses, challenges
- Dealing with complex biomedical data, including unstructured sources

Keywords: Complex Networks, Human Disease Network, Human Symptoms Disease Network, Complex databases, Biomedical sources, Disease understanding, Textual information, Data structuration

Devices and Biometric Applications for e-Health

Responsible lecturer: Agustín Álvarez

ECTs: 3

Course type and weekly hours: lecture (2 hours)

Exam type: Practical assignment

Contents:

This course will introduce students into the basics of e-health applications from the point of view of device built-in sensors and focused in biometric data analysis useful for patient monitoring. Basic procedures for sensor managing for synchronous and/or asynchronous mode of operation in mobile, wearable and IoT devices will be presented. Finally, application development for different scenarios in the health domain will be reviewed.

Syllabus

1. Introduction: from devices to medical related applications.
2. Biometric signals and e-Health.
   2.1. Signals form common devices (e.g. mobile phones, smart).
   - Voice/speech.
   - Gyroscope/Accelerometer data analysis

   2.2. Medical oriented devices.
   - Glucose scan.
   - ABG reading.
   - Holter monitor.

3. IoT & edge computing for e-Health.
   3.1. Edge computing resources.
   3.2. Cloud platforms for IoT.
4. Mobile application development.
   4.1. Review of main applications.
   4.2. APIs for sensor & dedicated devices.
   4.3. Sensor data acquisition.
   4.4. Data filtering and preparation.
   4.5. User interfaces.

Learning outcomes and competencies:

- To know the applications and systems based on biometric data.
- To be able to deal with unstructured sources as device raw data.
- To know the fundamentals of data extraction and analysis in mobile and wearable computing devices.
- To discover potential new health monitoring applications dealing with IoT and edge computing systems.

Literature

- Mobile Health: Sensors, Analytic Methods, and Applications, James M. Rehg (Editor), Susan A. Murphy (Editor), Springer, 2017, ISBN: 9783319513935
- Handbook of Multisensor Data Fusion: Theory and Practice (2nd Edition), Martin Liggins II, David Hall, James Llinas, CRC Press, 2008, ISBN 9781420053081.
- Data Science for Healthcare. Methodologies and Applications, Consoli, Sergio, Reforgiato Recupero, Diego, Petkovic, Milan (Eds.), Springer, 2019, ISBN: 9783030052485.

Keywords: sensors, IoT, mobile & wearable devices, e-Health applications, patient monitoring.

2nd year, 2st semester (spring/summer semester):

Master Thesis

Supervisor: At least 1 academic supervisor
ECTC: 30
Exam type: written thesis and oral presentation

It is recommended to start looking for a final thesis subject in the second year of study. This way, students have time to take matching study modules to acquire specialized knowledge. Registration is possible for all students, that have completedall mandatory modules andhave acquired at least 75 ECTS credits. From there on, the thesis is limited to 6 months, which correspond to 30 ECTS or 900 hours of work.