

## **Title: "3D data structures and physics-based animation"**

*Course held by Prof. Jacopo Aleotti*

*E-mail reference professor: [jacopo.aleotti@unipr.it](mailto:jacopo.aleotti@unipr.it)*

*4 CFU*

*Semester: second*

Short program:

Part 1) 3D collision detection algorithms. Algorithms for the intersection test between 3D primitives. 3D data structures for collision detection (Bounding Volumes, Bounding Volumes, Hierarchies, Octree, K-d tree, BSP-tree).

Part 2) Physics-based programming. Rigid body dynamics. Introduction to the C++ Bullet Physics library.

## **Title: An introduction to power systems**

*Course held by Prof. Roberto Menozzi*

*E-mail reference professor: [roberto.menozzi@unipr.it](mailto:roberto.menozzi@unipr.it)*

*4 CFU*

*Semester: first*

Short program:

The generation of electric energy; Introduction to power systems; The transmission of electric energy; The utilization of electric energy; Power system control

## **Title: Quantum Computing**

*Course held by Prof. Michele Amoretti*

*E-mail reference professor: [michele.amoretti@unipr.it](mailto:michele.amoretti@unipr.it)*

*3 CFU*

*Semester: second*

Short program:

1. History and perspectives of quantum computing; 2. Linear algebra (a refresher); 3. Postulates of Quantum Mechanics; 4. Quantum bits; 5. Quantum circuit model of computation; 6. Quantum computers; 7. Quantum algorithms; 8. Protocols for quantum cryptography; 9. Quantum Internet

## **Title: Detection over unknown channels**

*Course held by Prof. G. Colavolpe*

*E-mail reference professor: giulio.colavolpe@unipr.it*

*2 CFU*

*Semester: first*

Short program:

First part (overlapped with some lectures of the course Digital Communication, Master degree in Communication Engineering)

Introduction to the problem of sequence detection in the presence of unknown parameters.

Sequence detection in the presence of unknown parameters: channel models, sufficient statistics, optimal strategy in the presence of an unknown stochastic parameter, memory truncation. Examples: noncoherent sequence detection; receivers based on linear prediction.

UMP test. Generalized likelihood. Approach based on estimation. Estimators' classifications. CRB and MCRB. DA estimation. Example: Rife&Boorstyn algorithm and related MCRB. Open-loop estimation of the channel phase: analysis of the ML estimator and comparison with the CRB. Closed-loop estimation of the channel phase: 1st order PLL and its equivalent models. DD estimation. Decision-directed PLL, S-curve of a DD PLL. Per-survivor processing and tentative decisions. NDA estimation: M-th power estimator, Viterbi & Viterbi estimator. Soft-decision-directed estimation. Sufficient statistics for channels with unknown parameters.

Second part (specific for PhD students) (this part requires some basic knowledge on Factor graphs and the sum-product algorithm)

Detection for unknown channels based on graphical models

## **Title: Machine Learning for pattern recognition**

*Course held by Prof. A. Bononi / S. Cagnoni*

*E-mail reference professor: [alberto.bononi@unipr.it](mailto:alberto.bononi@unipr.it)*

*8 CFU*

*Semester: second*

Short program:

Course covers

A. Bononi:

- 1) a review of probability and the Bayesian statistical analysis underlying ML (regression, classification)
- 2) extensions to generalized linear models as a basis to neural networks and other kernel-based methods.
- 3) supervised learning for both regression and classification.

S. Cagnoni:

- 4) some elements of unsupervised learning.
- 5) some programming of ML algorithms based on Weka software.

Details can be found at: [http://www.tlc.unipr.it/bononi/didattica/ML\\_PhD/ML\\_PhD.html](http://www.tlc.unipr.it/bononi/didattica/ML_PhD/ML_PhD.html)

## **Title: MATLAB FOR ELECTRONICS**

*Course held by Prof. Valentina Bianchi*

*E-mail reference professor: [valentina.bianchi@unipr.it](mailto:valentina.bianchi@unipr.it)*

*4 CFU*

*Semester: first*

Short program:

The course aims to provide students with the knowledge of the main features of the MATLAB/SIMULINK software in order to use it as a support tool to the electronic design through application examples. The students will learn how to use MATLAB and SIMULINK in typical applications of electronics, electrical engineering and signal processing. The students will learn to automatically generate C or VHDL code for Microcontrollers or FPGAs. He/she will learn how to communicate and document the choices made through a well written and documented code. Topics include: 1. Solving Equations 2. Continuous LTI Systems Analysis 3. Digital LTI Systems Analysis 4. FIR and IIR Filters Design 5. FFT 6. Automatic Code Generation 7. Hardware Connection

# **Title: Introduction to Model-Based Design**

*Course held by Prof. Alessandro Soldati*

*E-mail reference professor: [alessandro.soldati@unipr.it](mailto:alessandro.soldati@unipr.it)*

*4 CFU*

*Semester: Second*

Short program:

- Abstraction levels, system partitioning and the V-model
- Unit testing, static code analysis and automatic test-benches and documentation
- Version Control Systems
- Numerical analysis for real-time computation
- Benchmarking of processing units and algorithms
- Data processing in MATLAB for embedded programming
- Optimizers and solvers
- Model-based design and system validation with MIL/SIL/PIL/HIL

# **Title: “Embedded System”**

*Course held by Prof. Guido Matrella and Prof. Carlo Concari*

*E-mail reference professor: [guido.matrella@unipr.it](mailto:guido.matrella@unipr.it) – [carlo.concari@unipr.it](mailto:carlo.concari@unipr.it)*

*4 CFU*

*Semester: second*

Short program:

The aim of the course is to provide to SDIA students, coming from all three different areas of Information (Electronic, Informatics, Telecommunication), an overview of the main high performance Embedded Systems design methodologies.

The crucial issue of the Hw/Sw partition of an Embedded System will be illustrated and how an Embedded System can be implemented using different approaches: 1. Completely by SW, 2. By SW but using specific DSP processors, 3. By SW but using HW circuits “ad hoc” developed on FPGA.

“Programming standards” and “functional safety techniques” will be mentioned.

Examples of HW/SW design activities will be carried out, also using HDL languages and automatic code generation techniques.

# **Title: Optimization using Graphical Models**

*Course held by Prof. M. Locatelli, G. Colavolpe, A. Vannucci, L. Consolini*

*E-mail reference professor: giulio.colavolpe@unipr.it*

*2 CFU*

*Semester: second*

Short program:

*Topic 1: Basics on convex optimization (Locatelli)*

Definitions of convex functions and sets. Brief sketches about complexity and algorithms. Constraint qualifications. Optimality conditions (KKT). Lagrangian duality.

*Topic 2: Bayesian inference and graphical models (Colavolpe)*

Bayesian Networks and Markov Random Fields: Inference in general Graphs.  
Variational Inference techniques in Machine Learning and Artificial Intelligence: Belief Propagation (BP) and Loopy Belief Propagation  
Factor graphs and sum product algorithm: general framework and applications to communications.

*Topic 3: Variational Inference and the Free Energies methods of Physics (Vannucci)*

Approximate Inference and factorized distributions. Variational mixtures of Gaussians. Exponential Family distributions. Variational message passing. Expectation Propagation and its implementation on graphs.

Energy functions and their minimization schemes. Variational average energy and variational entropy; Gibbs and Helmholtz free energies. Stationary conditions for the Bethe free energy and its connections with Loopy belief Propagation. The Mean Field approximation.

*Topic 4: Graphical models for optimization - Trajectory planning and power control (Consolini)*

Speed and trajectory planning problems, dynamic programming. Power control in radio systems. Reduction of previous problems to a standard form and definition of the associated graph. Graph-based solution algorithms.

# **Title: Electronics for Internet of Things**

*Course held by Prof. Mora Niccolò*

*E-mail reference professor: niccolo.mora@unipr.it*

*3 CFU*

*Semester: first*

Short program:

Power supply and power profiling of IoT devices;  
Good practices in the design and manufacturing of IoT devices: analysis of specifications, components and PCB production;  
Signal acquisition and conditioning: the analog domain (circuits and architecture review);  
The digital domain: filtering, signal enhancement, data exploration and analysis;

## **Title: ICT for Health and Wellbeing**

*Course held by Prof. Paolo Ciampolini*

*E-mail reference professor: paolo.ciampolini@unipr.it*

*Duration: 8 CFU (recommended part: 4 CFU)*

*Semester: I*

Short program:

Introduction and motivation  
Telemedicine, e-health and m-health  
Biosignals: classification and main features  
Signal acquisition: sensors and acquisition architectures  
Activity and behavioral monitoring  
Data analytics: classification, statistical techniques, machine learning techniques  
Data protection and interoperability: concepts and main standards.  
Healthcare systems organization  
Topical seminars (research, industry).

**Laboratory: teamwork, aimed at multidisciplinary, user-centered design in health and Active and Healthy Ageing use-cases (supported by IBM Research). (4 CFU)**

*(Ph.D. Students may also decide to attend the laboratory part only [boldface], jointly managed by UNIPR and IBM Research, if interested)*

## **Title: Methods of Probabilistic Robotics**

*Course held by Prof. Dario Lodi Rizzini*

*E-mail reference professor: dario.lodirizzini@unipr.it*

*2 CFU*

*Semester: Second*

### Short program:

The goal of this course is to provide an overview of the concepts of probabilistic robotics and of the main localization and mapping methods. Practical demonstrations with software tools used by research community will support the exposition. The main program is organized as follows: definitions and estimation methods, localization and mapping problems, data association, and sensor registration.

#### 1. Representation of Uncertainty

- Motivation and examples
- Probability density functions, function of random variables, normal distribution
- Propagation of uncertainty

#### 2. Bayesian filters

- State estimation for localization and mapping
- ML and MAP criteria
- Parametric filters: Kalman filters, EKF, UKF (hints)
- Derivation of KF
- EKF for localization and SLAM

#### 3. Graphical models

- Full SLAM problem: derivation
- Least-square SLAM
- Models for graphical formulation: landmark-based, pose graph, perturbation operator
- Practical: graphical SLAM backend g2o

#### 4. Localization and Mapping Issues

- Map models: landmarks, occupancy grid maps
- Data association methods: NN, JCBB, correspondence graphs
- Practical: data association

## **Title: Applied Security**

*Course held by Prof. Luca Veltri*

*E-mail reference professor: [luca.veltri@unipr.it](mailto:luca.veltri@unipr.it)*

*3 CFU*

*Semester: Second*

### Short program:

This is a laboratory course that has the objective of providing practical knowledge on the use of security algorithms and protocols for protecting data and communications.

The course is formed by a series of laboratory activities and assignments, consists in both programming and security tool exercises, that will allow the student to learn and improve his/her knowledge on how to use standard security mechanisms.

The following topics will be considered: symmetric cryptography (stream and block ciphers); secure hash functions; password hashing and message authentication code; brute force attacks, asymmetric cryptography (public-key encryption and digital signature); digital certificates; protection of network communications through TLS and VPNs; vulnerability scanning; firewalls.

For the programming exercises, Java with its standard security library will be used as reference programming language; however other languages like C/C++, Python, Go, etc, can be used by the students for their exercises and assignments.

Basic knowledge of cryptography and communication protocols (TCP/IP) is required.

## **Title: Edge Computing & Microservices for the Next Generation of Internet of Things Architectures**

*Course held by Prof. Marco Picone*

*E-mail reference professor: marco.picone@unipr.it*

*3 CFU*

*Semester: First*

Short program:

1. - Internet of Things Overview and (Re)View
  - Introduction
  - Internet of Things Definition & Vision
  - From WSN and M2M to IoT
  - IoT Characteristics
  - IoT Protocol Stack
  - IoT Applications
2. - Do not reinvent the wheel ... Design and Make it Standard !
  - Pub/Sub
  - RESTful
  - CoAP
  - MQTT
3. - IoT Heterogeneity, Interoperability and Web of Things
  - Service and Resource Discovery
  - Protocol Translation and Standardization Solutions
  - Web of Things
  - Digital Twin
  - People & Things Challenges and Opportunity
4. - Edge/Fog Computing: A new Architectural approach for the IoT
  - Edge Computing principles
  - IoT & Edge Computing



- Cloud, Edge and Hybrid Architectures
- The IoT Hub
- 5. - Monolithic vs Microservice oriented Architectures for the IoT
  - Microservices and Service Mesh
  - IoT and Microservices
  - Microservices composition and orchestration in Distributed Environments
- 6. - Make it real ! Tools, Projects and Resources to join the IoT Community
  - Hardware Platform & Operating System
  - Software Libraries
  - IoT Eclipse Foundation Projects
  - Open Source Projects
- 7. - Projects & Evaluation

## **Title: Subspace-based identification methods**

*Course held by Prof. Luca Consolini*

*E-mail reference professor: [luca.consolini@unipr.it](mailto:luca.consolini@unipr.it)*

*2 CFU*

*Semester: second*

Short program:

- 1) Singular value decomposition.
- 2) Elements of realization theory.
- 3) Elements of model reduction.
- 4) Identification of deterministic systems.
- 5) Identification of systems affected by noise.

## **Title: Wireless Communication Channel Models**

*Course held by Prof. Riccardo Raheli*

*E-mail reference professor: [riccardo.raheli@unipr.it](mailto:riccardo.raheli@unipr.it)*

*Duration: about 20 h (part of Wireless Communications)*

*Semester: 1<sup>st</sup> (september-october)*

**Short program:**

1. Channel models (22 h)
  - 1.1 Review of radio propagation (2 h)
  - 1.2 Path loss models (5 h)
    - Free space
    - Flat earth

Empirical models

Ray tracing

1.3 Shadowing model (3 h)

Lognormal distribution

Spatial correlation

Outage probability

1.4 Fading models (11 h)

Rayleigh

Rice

Nakagami

Multipath

1.5 MIMO channel models (1 h)

## **Title: Elements of Electric Drives**

*Course held by Prof. Carlo Concari*

*E-mail reference professor: carlo.concari@unipr.it*

*2 CFU*

*Semester: second*

Short program:

- 1) Structure and components of an electric drive
- 2) Main parameters of electric drives
- 3) DC electric machine: structure and operating principles
- 4) DC electric machine: control

The PhD in Information Technologies provides teaching and research training activities, with a three-year training course, which entails an overall study commitment evaluable in 180 University Training Credits (CFU) and which ends with the presentation of the Doctoral thesis. Recall that 1 CFU corresponds to an average commitment of 25 working hours and that the average year of work of 1500 hours corresponds to 60 CFU. The didactic activities consist of teaching courses and seminars enjoyed by PhD students as students and in didactic training activities.

*Each PhD student should acquire at least 20 CFU within the three years of the PhD course.*

The following types of courses are recognized by the PhD in Information Technologies:

- **Courses organized by the SDIA** (SDIA stands for Scuola di Dottorato in Ingegneria e Architettura, the school which encompasses all PhDs in Engineering and Architecture of the University of Parma).

These courses aim at teaching soft skills. They include an advanced language course and a course which cover different topics such as how to present a patent idea, how to write down a research project, and so on.

- **Advanced doctoral courses (ADC) organized by the PhD in Information Technology**

These are advanced courses related to the specific research topics investigated within the PhD in Information Technologies.

- **External university courses (EUC)**

These are university courses not directly organized by the SDIA or by the PhD in Information Technologies. They allow to acquire advanced knowledge in the scientific fields of interest of the PhD. External university teachings include:

- 1) advanced courses foreseen in the educational offer of the master's degree and second level master's courses at the University of Parma
- 2) advanced courses provided in the educational offer of the master's and second level master's degree courses of other Italian or foreign universities,
- 3) courses from other schools / doctoral courses at the University of Parma or other Italian or foreign universities.

- **Other external courses, short courses (EC)**

Credits can be recognized for

- 1) summer schools and doctoral student schools organized, in Italy or abroad, by research bodies or cultural associations (disciplinary coordination groups, professional associations, ...)
- 2) tutorials, short courses offered at national or international conferences,
- 3) training courses for the use of particularly complex equipment, software, technologies
- 4) managerial training courses provided by public and private bodies
- 5) advanced online courses

*Please, note that each PhD student should acquire at least 6 CFU from SDIA courses and 6 CFU from ADC courses.*