Besides the courses listed below, SDIA (Scuola di Dottorato di Ingegneria e Architettura) offers some additional common courses for all PhD schools within the framework of the Department of Engineering and Architecture. In particular, the following two courses are offered:

- **Introduzione ai metodi e agli strumenti della Ricerca scientifica**
- **Study skills: English for Academic Purposes**

Please note that some of the following courses will be activated only if a minimum of 3 participants will be reached. You are required to contact the reference professor.

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

Course held by Prof. Jacopo Aleotti

E-mail reference professor: jacopo.aleotti@unipr.it

4 CFU

Semester: first

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

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

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: Statistical bases of Machine Learning

Course held by Prof. A. Bononi

E-mail reference professor: alberto.bononi@unipr.it

4 CFU

Semester: first

Short program:

Course covers

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.

Details can be found at: http://www.tlc.unipr.it/bononi/didattica/ML_PhD/ML_PhD.html

Title: Machine Learning fundamentals and practice

Course held by Prof. S. Cagnoni

E-mail reference professor: stefano.cagnoni@unipr.it

4 CFU

Semester: first

Short program: Course covers

1) elements of supervised and unsupervised Machine Learning methods.
2) practical examples of machine learning applications based on free software like Weka (Java/GUI), Scikitlearn (Python), DEAP (Python) with assignments.
Up to 2 extra CFUs can be obtained by developing a final project.

Title: MATLAB FOR ELECTRONICS

Course held by Prof. Valentina Bianchi

E-mail reference professor: 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 throught 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

3 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

Title: Reliability of Power Electronic Circuits

Course held by guest Prof. Francesco Iannuzzo, Aalborg University, Denmark

E-mail reference professor: fia@et.aau.dk

3 CFU

Semester: Second

Short program:

- Design-for-Reliability in power electronics (2 h)
- Lifetime models for power system components (2 h)
- Simulation workflow for reliability prediction [tutorial] (2 h)
- Gate drivers for power electronics devices (2 h)
- Active gate drivers for wide bandgap devices (2 h)
- Active thermal control of power electronics (2 h)
- Faults in power electronics (2 h)
- Power electronics diagnostics (2 h)
- Condition monitoring (2 h)
- Advanced sensing and logging for power system control and reliability (2 h)
- Counting techniques (2 h)
- Design of advanced sensing and driving circuits for power electronics [tutorial] (2 h)

Title: “Embedded Systems”

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

E-mail reference professor: guido.matrella@unipr.it – 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 om 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

E-mail reference professor: guido.matrella@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

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: Subspace-based identification methods

Course held by Prof. Luca Consolini

E-mail reference professor: 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

Duration: about 20 h (part of Wireless Communications)

Semester: 1st (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