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: Quantum Computing

Course held by Prof. Michele Amoretti

E-mail reference professor: michele.amoretti@unipr.it

18 hours (3 CFU)

Semester: second

Course Description

This course introduces quantum computing from a computer engineering perspective. The focus is on the analysis and design of quantum algorithms, using the most relevant theoretical techniques. Practical experiences are also proposed, introducing the student to software libraries for programming quantum devices and simulating quantum networks.

Short program:

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

Title: Embedded Systems

Course held by Prof. Guido Matrella (guido.matrella@unipr.it) and Prof. Carlo Concari (carlo.concari@unipr.it)

4 CFU =24h

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

Hw/Sw partition of an Embedded System issue will be discussed.

Three different approaches to Embedded System implementation will be described:

1. Fully-SW implementation by using general purpose MicroProcessor;

2. Fully-SW implementation by using specific purpose processors (DSP);

3. Partially-SW implementation exploiting “ad hoc” HW co-processors, by using FPGA.

The fundamentals of compliant firmware design will be provided in order to show the difference between “casual” and professional embedded programming, including the concepts of functional safety, coding standards, and development lifecycle.

Efficient computation will be dealt with through fixed-point arithmetics and numeric approximation.

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

Title: Detection over unknown channels

Course held by Prof. G. Colavolpe

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

2.5 CFU = 16h

Semester: first

Short program:

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.

Detection for unknown channels based on graphical models

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: 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: 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: Elements of thermography and thermal imaging

Course held by Prof. A. Soldati, F. Bozzoli, L. Cattani, G. Chiorboli

E-mail reference professor: alessandro.soldati@unipr.it

2 CFUs: (8 lectures, 2h each)

Semester: first (January – February?)

Short program:

1. Introduction to thermography (Bozzoli/Cattani)
2. Temperature measurement properties and contact sensors (Chiorboli)
3. Principles of thermal imaging (Bozzoli/Cattani)
4. Thermal imagers: calibration, compensation, environmental effects (Soldati)
5. Thermography applications in Power Electronics (Soldati)
6. Thermography applications in Heat Transfer (Bozzoli/Cattani)
7. Postprocessing of radiometric data (Soldati)
8. Hands-on: thermal cameras in action! (Soldati)

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: "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: 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.